# Predators or Protectors?
# Analyzing Liberia's Rebels Using Satellite Data

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**Abstract**

This paper uses satellite imagery to measure local food production during Liberia's civil war, 1989-2003. Contrary to media reports of rampant abuse and the predictions of existing theories, I show that the NPFL rebels provided enough security for civilians to maintain farming at pre-war levels, while other rebels triggered significant declines in food production due to their predation. I propose a new theory of rebel group behavior that focuses on the motives of external patrons who provide resources to rebel leaders. When patrons benefit from disciplined groups, they provide financing to qualified leaders, who then use these resources to encourage cooperation among their troops. Other patrons, seeking to manipulate the group, support low quality leaders and withhold resources that could strengthen leader control. The theory predicts food production to follow a spatial pattern based on distance to rebel bases and lootable resources and finds support in the data.

## 1 Introduction

In this paper I use satellite imagery to measure the effects of rebel group behavior on local food production during Liberia's civil war, 1989-2003, as one aspect of civilian abuse. When

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rebel groups are highly predatory, civilians struggle to gain access to food and other essentials, resulting in high levels of displacement, malnutrition, and disease. These indirect costs of war, caused by insecurity, are ultimately more damaging than the fighting (Ghobarath, Huth, and Russett 2003).

I show, contrary to reports of rampant abuse from media outlets and humanitarian organizations, that the rebel National Patriotic Front of Liberia (NPFL), led by the infamous Charles Taylor, provided enough security for civilians to maintain food production at pre-war levels. Other Liberian rebel groups, such as Liberians United for Reconciliation and Democracy (LURD) and the Liberia Peace Council (LPC), triggered dramatic declines in farming and threatened civilian food security due to their predatory behavior.

This finding is puzzling for existing theories of rebel group behavior, which focus on access to resources, ethnic composition, or territorial stability. Jeremy Weinstein (2007) argues that groups with access to valuable resources are flooded with opportunistic recruits and provide less security than resource-poor groups. According to this theory, the NPFL rebels, who generated hundreds of millions of dollars through resource extraction, are expected to provide less security than the LURD or LPC, which had little access to these resources. Macartan Humphreys and Jeremy Weinstein (2006) argue that ethnically homogeneous groups are better able to police their members and thus commit less civilian abuse than diverse groups. But in Liberia, the ethnically homogenous LPC rebels terrorized civilians and failed to provide the same level of security as the ethnically diverse NPFL. Theories of territorial stability argue that unstable areas provide fewer returns to taxation than looting (Olson 1993) and encourage rebels to use mass violence to deter civilians from collaborating with the government (Kalyvas 2006). Consistent with these theories I show that unstable areas in Liberia suffered the greatest declines in crop land. But these theories

cannot explain the acute insecurity that characterized even the most stable parts of LURD territory.

Contrary to these theories, I argue that rebel group behavior is driven by the motives of external patrons, which shape the rebel leader's ability to offer incentives to group members. Some external actors such as diaspora communities and corporations benefit from disciplined rebel groups with strong leaders. These actors are motivated to provide ample financial and military resources to qualified leaders who are trusted by their troops. These leaders, in turn, use the patron's resources to provide on-the-spot cash payments and make credible promises to encourage cooperation and enforce discipline among rebel members. Other patrons, motivated by a desire to manipulate the rebel group for policy ends, have incentives to support weak leaders and withhold financial resources that could strengthen leader control. Unable to offer cash incentives or credible future rewards, these leaders allow their troops to loot locals in exchange for a minimal level of loyalty.

External patrons have access to the financial resources, military supplies, and logistics necessary for large-scale rebellion. Without external support, few rebel groups emerge from obscurity.[1] The importance of external support gives patrons great influence in shaping the incentives of rebel leaders and their followers. Without access to credit markets or bank loans, rebel groups rely on external patrons for financing and other vital supplies. In some cases, the patron even decides which individual is selected as leader, thereby influencing the leader's quality and credibility. The type of partnerships available to a rebel group depends

[1]Statistics on state support for insurgencies provides some indication of the importance of external patrons. RAND's (2001) survey of insurgent movements finds that 44 of the 74 rebel groups (59.5%) active during 1991-2000 received state support that was crucial for their survival. According to the EACD dataset, over 44% of the 331 non-state armed groups that were active during 1945-2003 (excluding coups) received military assistance from a foreign government (Cunningham et al 2009). These figures ignore the role of corporations, arms dealers, diaspora communities, and other external supporters of rebellion. The percentage of rebel groups relying on external patrons for crucial support is likely to be much higher.

on factors beyond the group's control, such as natural resources and international politics. The international dimensions of civil war, through their effects on rebel group organization, shape the humanitarian situation on the ground.

Consistent with the Liberian case study, this theory predicts that the NPFL rebels provided security to civilians due to Charles Taylor's partnerships with foreign corporations that demanded security and his ability to offer cash incentives to his troops. The LURD and LPC rebels are predicted to be predatory because the leaders were appointed by external patrons seeking to influence the groups' activities and the leaders lacked the ability to create incentives for their troops. Through remote sensing methods, I show that Liberia's NPFL rebels provided enough security to maintain farming at pre-war levels in many areas, while the LURD rebels triggered declines in crop land of up to 66% and the LPC rebels triggered declines of over 18%.

This theory of external patrons and commander incentives also predicts a spatial pattern to security in conflict zones. When a rebel leader is able to offer cash incentives to enforce discipline, the effectiveness of these incentives depends on the ability to monitor troop behavior. Rebel members will be more disciplined and provide more security near the rebel headquarters, under the watchful eye of the leader. By contrast, if the leader cannot offer cash incentives, monitoring is ineffective and rebel members prey on civilians. The most intense looting will occur near rebel bases, where the highest concentrations of armed men are located. For all groups, valuable lootable resources raise the opportunity costs of following the leader's orders and result in less security for civilians.

Through various methods, I show that the NPFL provided more security closer to their major bases, while the other rebels were more prone to predation near their bases, likely due to the leaders' inability to control their troops. Holding constant other factors, if a farmer

100km away relocated to the the NPFL headquarters, his crop area would increase 259%. By contrast, a farmer relocating to LURD headquarters from 100km away would experience a catastrophic 97% decline in crop area. For all groups, lootable resources are associated with less security for civilians.

To overcome the identification problem caused by the endogenous selection of rebel bases, I examine changes over time in food production near Buchanan, a major port in Liberia's southeast. Buchanan was the secondary headquarters of the NPFL from 1990 until 1994, when the town became the secondary headquarters of the LPC rebels. As predicted, food production benefitted from proximity to Buchanan during NPFL rule, and suffered from this proximity after the town fell to the LPC. By holding geographic factors constant, this shift in security isolates the effect of rebel behavior from potential omitted variables.

The civil war literature in the past decade has shifted from theoretically-informed case studies (e.g. Wood 2003) to cross-national econometric models (e.g. Fearon and Laitin 2003) to within-country spatial analyses (Humphreys and Weinstein 2006; Bohara et al 2006; Hegre et al 2009; Kalyvas and Kocher 2009). Continued progress in the field, however, is constrained by a lack of reliable, micro-level data. Studies of civil war tend to rely on media reports, post-conflict surveys, or other data that can result in misleading or improper inferences (Kalyvas 2008). Remote sensing offers an opportunity to overcome some of these limitations, providing objective, verifiable data on events of profound humanitarian significance. This paper is the first to apply remote sensing methods to the study of rebel group behavior and builds on a growing literature that uses remote sensing to study political phenomena (e.g. Min 2009).

The paper proceeds as follows. Section 2 describes the key features of Liberia's rebel groups, drawing on extensive fieldwork and interviews with rebel members, and shows how the motives of external patrons shaped the credibility of the rebel leaders and their ability

to offer incentives to their troops. Section 3 describes the methods for generating data on crop area in Liberia. Section 4 examines group-level differences in local food production, and Section 5 analyzes spatial variation within group territories. Section 6 looks at changes over time as an identification strategy for isolating the effects of rebel group behavior. Section 7 concludes.

# 2 Liberia's Rebel Organizations

On Christmas Eve, 1989, some 100 rebels crossed into Liberia from Côte d'Ivoire and captured the border town of Butuo. The soldiers aimed to overthrow the military dictatorship of Samuel Doe and were led by Charles Taylor, a former government official backed by Libya, Burkina Faso, and Côte d'Ivoire. The National Patriotic Front of Liberia (NPFL), as the group was called, rapidly advanced across Liberia, gaining momentum as new recruits swelled its ranks and government forces collapsed. Six months after the invasion began, Charles Taylor's NPFL controlled more than 80% of Liberia, including Liberia's second-largest port, Buchanan, and all of Liberia's iron ore and timber resources. Nearly all of NPFL's top commanders shared ethnic ties and had previous military experience. But below the top level of the organization, the NPFL's units were ethnically diverse.[2]

Even before invading Liberia, Charles Taylor established relationships with leading Ivorian, French, and Lebanese business people (Ellis: 1999: 89). By late 1990, various corporations were engaged in large-scale resource extraction in Taylor's "Greater Liberia". The Liberian Minerals Company (LIMINCO) reportedly paid Charles Taylor $10 million per month for the opportunity to extract and export iron ore from NPFL territory (Reno 1998:

[2]James Pugel's (2007) survey of ex-combatants provides some indication of this diversity.

100).[3] Another mining operation in Nimba County netted Taylor about $80,000 per month (Ellis 1999: 164; Reno 1998: 100). During 1992 alone, logging firms removed an estimated 200,000 cubic meters of hardwood, valued at $20 million, from NPFL territory (Reno 1998: 97). From late 1990 through 1993, Charles Taylor generated revenues estimated at $75-250 million per year.[4]

From his headquarters in Gbarnga, Charles Taylor ordered his troops to protect civilians and encourage market activity. Taylor often gave stern speeches to his commanders and warned against harassing civilians (C26).[5] Civilians held the key not only to NPFL's food supply, but also to Taylor's revenue and legitimacy. Foreign firms depended on the NPFL to provide security for their operations and could justify their dealings with Taylor only if Taylor maintained the appearance of a responsible leader (Reno 1998: 102). A large civilian population in NPFL territory also gave Taylor more leverage during peace negotiations. Media reports described the brutality of NPFL fighters during the group's assaults, but also noted the security and order that prevailed in Taylor's headquarters (e.g. Ellis 1999).

Other rebel groups emerged in the 1992-93 period to challenge the NPFL's dominance of the Liberian countryside. Most of these rebel groups received support from the West African peacekeeping mission (ECOMOG) in exchange for coordinating their military activities with the peacekeeping forces. One of these groups, the Liberia Peace Council, was composed almost exclusively of ethnic Krahn members, and most of the commanders had

[3]This figure, which is also cited by Liberia's Truth and Reconciliation Commission (TRC 2009: Vol. III, Title III, par. 83) and Pham (2004: 122), derives from a report by the Economist Intelligence Unit in 1992. The reliability of this figure is questionable, but the estimate remains the best available.

[4]The lower estimate of $75 million per year comes from congressional testimony from William H. Twaddell, Acting Assistant Secretary of State for African Affairs and is quoted in Ellis (1999: 90-1). Scholar Will Reno (1998: 99) surveys the available secondary sources to produce the high estimate of $200-250 million per year.

[5]Interviews are cited by letter and number. See the Appendix for a description of each informant cited.

previous military experience in Liberia's armed forces (C42). Led by George Boley, an exile with connections to ECOMOG but virtually unknown by his troops, the group failed to develop partnerships with timber corporations, despite its control of Liberia's richest timber areas. To purchase ammunition from the peacekeepers, the group looted machinery and engaged in ad hoc trade in rubber and gold (C42; Ellis 1999: 167; Reno 1998: 105). Although relatively small in size, the LPC quickly gained a reputation for terrorizing civilians in its territory (TRC 2009).

Unlike the other rebel leaders, Charles Taylor provided cash payments to his top commanders as reward for following orders. Payments of $10-25,000 in cash were not unusual (C19). Commanders could also keep any revenue they earned through taxing civilians, although they were expected to share these funds with their soldiers. NPFL commanders who abused civilians and failed to control their soldiers were removed from stable areas and either punished or transferred to the frontline, where looting was less damaging to the group (B43, C08, C24, C39). Top NPFL commanders could also expect to benefit after the war. When Charles Taylor was elected president in 1997, two of his top four commanders received high-level positions in the Liberian armed forces; the other two commanders received lucrative commercial contracts (C15, C24). Many lower-level NPFL members also received positions in the civil service (C26, C27).

Soon after Taylor took office as president, Liberian exiles in Guinea and Sierra Leone began seeking support to overthrow his repressive, although democratically elected, regime. Guinean President Lansana Conté became sympathetic to the exiled Liberians' goals and provided them with limited weapons and ammunition. Prominent Liberians, including lawyers and respected dissidents, competed with each other to lead the nascent rebel organization, but were eventually forced to accept Sekou Conneh—a former used car salesman with no

political or military experience—as their chairman. Conneh was married to the spiritual advisor of the Guinean president, and President Conté insisted on Conneh as leader if the group hoped to receive any military assistance. After several false-starts, LURD expanded beyond its headquarters in Voinjama in 2002 and captured much of northern Liberia. Similar to NPFL and LPC, the top commanders in LURD had experience in Liberia's armed forces during the 1980s. Although the leadership and top commanders were mostly ethnic Mandingo and Krahn, LURD units were ethnically diverse (Pugel 2007).

LURD captured areas rich in timber, rubber, and other resources, but failed to form any partnerships with foreign corporations. Timber companies were skeptical of LURD's ability to provide security and, almost immediately after LURD's invasion, a series of incidents in which LURD soldiers looted property and machinery forced all companies to cease operations in LURD areas (UNSC 2003a: 13). LURD territory also included diamond fields, and LURD soldiers immediately went to work shoveling gravel and sifting for diamonds. Diamond revenue would have provided LURD with greater autonomy from Guinea, but the LURD leadership could not gain control over the diamond trade (UNSC 2001: 34). Worried that diamond mining would distract their troops from fighting, senior LURD officials issued a ban on mining in LURD territory, but this did little to discourage the motley crew of soldiers and civilians in the diamond fields (B48, C30, C32; ICG 2002: 7; Brabazon 2003).

With no money or food provided by the organization, LURD soldiers and commanders preyed on civilians. LURD members stripped buildings of their zinc roofs and electrical wiring, and looted anything of value. Large tracts of the countryside were depopulated as civilians fled to more secure areas. Facing severe food shortages, the LURD leadership in Voinjama attempted in mid-2001 to provide security for civilians, but failed to stem the predatory behavior of the troops (ICG 2002: 9-10)

A high level of distrust characterized the LURD organization, and top commanders knew that Sekou Conneh's promises were not credible. In advance of LURD's invasion of Monrovia in June 2003, Sekou Conneh ordered the Guinean military to arrest the group's top commander, Prince Seo, because Conneh feared the commander would become too powerful if he entered the capital city (C2). Indeed, high-level LURD members plotted to remove Conneh from power as soon as the group no longer depended on Guinean support (C29, C30, C34). After Charles Taylor was forced from power, Sekou Conneh filled LURD's positions in the transitional government with family relatives and cronies; none of LURD's top commanders received positions in the post-war government.

## 2.1 Discussion

The behavior of Liberia's rebels illustrates the importance of external patrons and the leader's ability to offer incentives to the troops. Charles Taylor rose to power through his charisma, international connections, and family ties to top commanders. International corporations found in Taylor a capable business partner and rewarded him with hundreds of millions of dollars in cash and military supplies. Although NPFL soldiers committed brutal acts against civilians in certain parts of the country, Charles Taylor demanded that civilians be protected in his "Greater Liberia" and rewarded commanders for implementing these orders with cash and future opportunities. Without his external allies, Taylor would not have been able to create the incentives necessary for security to prevail in NPFL territory.

In contrast to Taylor, George Boley and Sekou Conneh became leaders despite their lack of leadership qualities or personal connections to their troops. Both men were appointed by external patrons hoping to manipulate the groups for their own ends. ECOMOG hoped to use the LPC to attack NPFL positions when needed, while Guinea used LURD to destabilize

Taylor's regime. To maintain their influence, these patrons withheld resources that would have strengthened leader control. George Boley couldn't provide necessary weapons or food, so his troops stole from civilians and traded rubber and gold for ammunition from the peacekeepers. Likewise, Sekou Conneh could offer nothing to his followers but opportunities for looting. The predation among LURD forces was so intense that the LURD leadership itself faced food shortages in its headquarters at Voinjama.

The predatory behavior of LPC and LURD cannot be explained by the quality of the group members. LPC soldiers shared ethnic and family ties, and the initial LURD members included lawyers and respected dissidents. Both groups relied on skilled commanders who had years of experience in Liberia's armed forces. With different leaders and more resources, these groups could have become disciplined fighting forces. But their external patrons had other plans. By appointing unknown leaders and providing few resources, ECOMOG and Guinea assured their influence over the group's activities, despite the costs to civilians.

# 3 Remote Sensing and Local Food Production

The Liberian conflict produced countless stories of atrocities, but few data exist that can provide a systematic picture of rebel behavior. Satellite imagery collected during the conflict, however, can shed light on the situation on the ground. Crop land is a suitable proxy for civilian security because the incentive to clear crop land depends on the rebel group's recent behavior towards civilians, as well as expectations of the group's future behavior. Crop land declines in areas that have been depopulated by violence and predation. Among the population that remains, a farmer will not spend the energy to clear land if he expects his crops to be looted upon harvest—or if he might be killed or displaced in the meantime.

In Liberia, civilians in insecure areas abandoned their farms and sought shelter in refugee camps or hid in the surrounding forest and survived on foraged foods such as bush yam. During stable times, Liberian farmers clear approximately the same amount of land each year, limited by their physical ability to clear forest.[6] Total crop area is determined by the number of farmers able and willing to clear land in a given area at a particular time. Over the course of the war, therefore, a decline in crop land in $t_1$ indicates that the area is less secure than it was in $t_0$.

Analyzing crop area in a country such as Liberia presents certain challenges. First, the majority of Liberians outside the capital city depend on small-scale, subsistence agriculture which can be difficult to identify in a satellite image. Second, Liberia experiences nearly constant cloud cover, which makes it possible to obtain satellite images only during the brief dry season, January-March. Third, crop land can be difficult to distinguish from the surrounding vegetation, or from cleared areas such as villages, roads, and sports fields.

Fortunately these challenges can be overcome. Two satellite programs, LANDSAT and SPOT, provide images with 20-30m resolution—sufficient for identifying the small fields. Further, the dry season, when all cloud-free images are collected, is the time when farmers slash and burn the areas they intend to plant, making the cleared crop land easily identifiable against the surrounding vegetation. Because land is cleared before the first rains of the season, crop area measurements are insensitive to annual variation in rainfall or other climatic events. Finally, new land is cleared each year in an eight-year fallow cycle. Layering multiple satellite images highlights changes in land use and allows the shifting crops to be easily distinguishable from stationary villages and other non-agricultural areas.

[6]Liberia is characterized by low population density and large tracts of uncultivated land. According to interviews with farmers, land use is constrained by the labor required to clear forest for new crop fields, not by limitations on the supply of land or the ability to purchase new land.

To measure changes in crop area in NPFL territory, I compare four LANDSAT images from January 1991 to four images of the same region from January 1986, before the start of the war. The coverage area includes neighboring agricultural areas in Guinea and Sierra Leone, which provide a comparison. LURD territory is covered by three LANDSAT images from March 2003, which are compared to three corresponding images from February 2001, before the first major rebel offensive. These images cover all of LURD territory, as well as large tracts of government territory and neighboring areas of Guinea and Sierra Leone. Figure 1 depicts the coverage area. Very few satellite images are available for Liberia during 1992-2000, but four SPOT images, two from January 1993 and two from January 1995, can be combined with the LANDSAT images to provide additional information on a small but significant area of Liberia, depicted in Figure 2. This area was partially captured in 1994 by the LPC rebels and provides an identification strategy to isolate the effects of rebel behavior by examining changes over time.

For each image, a certain number of pixels are classified manually by the researcher.[7] These training pixels provide the input necessary for computer software such as ENVI to categorize the remaining pixels in the image based on maximum likelihood estimators. The resulting classified image is then adjusted iteratively until no major errors can be determined through inspection (CI 2006). Specific types of land cover can be difficult to identify in satellite imagery. To confirm my ability to distinguish important land categories, I visited various locations in Liberia to collect ground truth information and interviewed farmers on their land use practices. The final result is a simple raster dataset that allows for crop area measurements in a GIS.

[7] A typical image might contain 12-30 classes, including, for example, "forest", "dark forest", "river", "road", and so on.

Assessing the accuracy of classification images is a vital part of land-use research and the subject of a large literature in the earth sciences (for an overview see Foody 2002 and Stehman and Czaplewski 1998). I selected a random sample of pixels from the classified image and then compared them manually to the original images (Hess and Bay 1997). For this project, 600 randomly-selected pixels were manually assessed for each pair of LANDSAT images and 300 random pixels were assessed for each pair of smaller SPOT images, stratified between crop and non-crop areas.

LANDSAT pixels identified as crop land were 81-97% likely to reflect true crop land, depending on the image, with an average accuracy of 88.7%; pixels classified as non-crop were 95-99.25% likely to reflect true non-crop areas, with an average accuracy of 98%. Among SPOT images, pixels classified as crop land were 72-96% likely to reflect true crop land, with an average accuracy of 86.4%; pixels classified as non-crop were 98-99.5% likely to reflect true non-crop areas, with an average accuracy of 98.6%.

These error matrices were then used to estimate crop areas, standard errors, and statistical significance using bootstrap simulations with 100,000 samples. This process provides an estimate of measurement error for the image as a whole, which is then used to estimate crop area at lower levels of aggregation, such as the village level. This extrapolation is not ideal, since errors may be spatially concentrated in the image, but provides a better estimate than the raw measurements, which have known biases. Error propagation caused by these issues continues to pose a fundamental challenge to spatial analyses (Haining 2003: 126).

# 4 Group-Level Comparisons

Group-level comparisons are a useful starting point for a quantitative look at the competing theories. Theories of adverse selection predict that groups with access to economic resources are dominated by opportunistic members who are more likely to abuse civilians. In Liberia, only the NPFL had access to any significant economic resources, though all of the rebel groups offered looting opportunities. Adverse selection, therefore, predicts that the LURD and LPC provided at least as much security for civilians as the NPFL rebels, if not more. Theories of ethnic composition would expect higher levels of security from the homogeneous LPC rebels and lower levels of security from the ethnically diverse NPFL and LURD rebels. Theories of territorial stability expect higher security in stable areas than in unstable areas for all groups. By contrast, the theory of external patrons and commander incentives, proposed here, predicts that the NPFL provided more security than either LURD or LPC, due to Charles Taylor's access to financial resources and credible promises. Figure 3 summarizes these predictions.

Between 1986 and 1991, crop area is estimated to have increased 4.8% in the NPFL areas covered by the study area. This difference, however, is not statistically significant ($p = 0.35$) when compared to the null hypothesis of no change in crop area.[8] Crop area in neighboring regions of Guinea grew by 7.9% during this period ($p = 0.34$), while crop area in neighboring regions of Sierra Leone decreased 16.1% ($p = 0.09$).

The situation in LURD areas between 2001 and 2003 was dramatically different. Crop area decreased by 37.1%, which is significant at $p = 0.028$. Neighboring regions of Guinea, where LURD forces were also active, decreased by 39.5% ($p = 0.000$), while neighboring

[8]The significance values are best interpreted as the probability that the difference in crop area is purely the result of measurement error.

government-controlled areas of Liberia decreased by 34.6% ($p = 0.016$). Crop area in neighboring regions in Sierra Leone—where a decade-long civil war ended in 2002—increased by 120.9% ($p = 0.000$) during this period. Figure 1 depicts these changes in crop area.

Crop area declined more in LURD territory than in NPFL territory, but these data do not necessarily imply that LURD was more abusive than NPFL. The declines in LURD territory could be caused by larger, systemic forces that were also responsible for the large declines in neighboring government areas and in Guinea. Rather than LURD abuse, the declines in crop area could be caused by instability and fighting. Indeed, unstable government areas that were attacked by LURD and other armed groups, such as Nimba County, experienced 45.8% declines in crop area ($p = 0.008$). Crop land in unstable LURD areas, such as the region around Zorzor, declined by 65.7% ($p = 0.0004$).

A comparison of stable areas, however, reveals significant differences between LURD and government forces. Crop area in relatively stable government-controlled areas such as Bong County declined by only 6.2% during this period ($p = 0.33$). In contrast, even the most stable LURD areas around Voinjama declined by 53.6% ($p = 0.076$). In LURD territory, the lowest declines in crop area were in extremely remote areas, only accessible by foot and relatively protected from looting. These trends suggest that the behavior of LURD forces contributed to the decline in food production in the group's territory.

Although fewer data are available for the LPC rebels, some comparisons can be made. The study area depicted in Figure 2 was controlled by the NPFL until 1994, when the LPC captured part of the region. Between 1991 and 1995, crop area declined 18.3% in LPC areas ($p = 0.40$) while neighboring NPFL areas benefitted from an increase of 17.2% ($p = 0.26$). Due to the poor quality of the images, however, this difference could potentially be explained by measurement error ($p = 0.28$).

These group-level comparisons contradict theories of adverse selection and ethnic composition, which predict greater security from LURD and LPC. The data are consistent with theories of territorial stability, but the large declines in stable LURD areas suggests other factors are also important for explaining patterns of security during conflict. The results are in line with the theory of external patrons and commander incentives, but any number of potential theories could offer an explanation for the lower declines in crop area in NPFL territory. Examining variation within group territories provides greater confidence that rebel behavior is driven by the incentives provided by the rebel leader.

# 5 Within-Group Spatial Variation

To measure within-group variation, crop area is aggregated at the village level by constructing Thiessen polygons around villages identified during the 2008 census.[9] Figure 4 depicts the percent change in crop area in NPFL and LURD territories. For the analysis, the dependent variable is the log ratio of crop area in $t_1$ to crop area in $t_0$ for each village, multiplied by 1,000 to scale the coefficients.

The theory of external patrons and commander incentives has several spatial implications. Rebel leaders who receive financing from external patrons are able to provide incentives and control their subordinates, but this control depends on effective monitoring. Security, therefore, will be higher near the rebel headquarters and possibly in the vicinity of other rebel bases. By contrast, when leaders cannot offer incentives to their subordinates, security is *lower* near rebel bases due to the higher concentration of predatory rebels. For all groups,

[9]Very small settlements were combined with larger neighbors to ensure that all villages are separated by at least 500 meters. Village locations did not change significantly in Liberia between the pre- and post-war periods, so the data do not suffer from selection bias due to destroyed or newly-formed settlements.

security is lower in areas that contain lootable resources such as rubber, and in unstable areas.

The theory does not specify how the leader's monitoring abilities depend on distance or other geographic factors. As a first-cut towards assessing this spatial implication, imagine that a rebel group's territory can be divided into two zones, a "close" zone where effective monitoring and control is possible and a "far" zone beyond the view of the rebel leader. When rebel leaders can offer incentives and exercise control, we expect to see smaller declines in crop area in the close zone than in the far zone. For groups in which the leader cannot offer incentives, monitoring is ineffective and we expect larger declines in crop area in the close zone than in the far zone. At the most basic level, the close zone can be defined by a cutoff distance from the rebel headquarters. For example, if the cutoff point is 30km, all villages within 30km of the rebel headquarters are considered "close" and all villages beyond 30km are considered "far".[10] This relationship can be estimated with an OLS model:

$$y_i = \beta C_i + \gamma \boldsymbol{x}_i + \epsilon_i$$

The dependent variable is the log ratio of crop area in $t_1$ to crop area in $t_0$ for village $i$, multiplied by 1,000. $C_i$ is a binary variable that equals 1 if village $i$ is in the "close" zone and $\boldsymbol{x}_i$ is a vector of control variables. To keep the analysis simple, only two controls are used: (1) the number of battles within 30km since $t_0$, coded from the ACLED dataset (Raleigh and Hegre 2005); and (2) percent crop area at $t_0$ (logged) in village $i$, which accounts for local, idiosyncratic differences in agriculture.

By systematically varying the cutoff distance for villages in the close zone, it is possible

[10]It is also possible to define a "middle" zone of villages that can be excluded from the analysis to buffer against the spatial dependence between villages. This approach yields similar results.

to measure the region over which monitoring is effective. For the theory to be plausible, we should see positive values of $\beta$ for villages close to Gbarnga during NPFL rule, and negative values for villages close to Voinjama during LURD rule. Figure 5 plots the values of $\beta$ with 95% confidence intervals for cutoff values ranging from 10km to 200km, at 10km intervals. As predicted, a significant positive effect is demonstrated for close villages in NPFL territory over a range of cutoff values (20km-170km). A strong negative effect is observed for villages close to Voinjama in LURD territory over a similar range (30km - 200km). Being close to rebel headquarters was beneficial for civilians during NPFL rule, but detrimental during LURD rule.

## 5.1 Spatial Model

Other factors might affect civilian security and changes in crop area. For example, monitoring might be more effective near a major road, or civilians might be more likely to abandon their farms if they are near an international border or humanitarian aid operations. The theory also predicts higher levels of abuse in areas that contain lootable resources, as well as in unstable areas. Perhaps more importantly, changes in crop area exhibit strong spatial dependence: if one village is attacked, people in neighboring villages are more likely to flee. To account for these influences, a spatial model is necessary.

A simultaneous autoregressive model (SAR) accounts for spatial dependence by using a regression on values from other areas in the vicinity of village $i$ (Bivand et al 2008). The spatial error model takes the following form:

$$\mathrm{Y} = \mathrm{X}\beta + \lambda \mathrm{W}\xi + \epsilon$$

where W is a matrix of spatial dependence and $\xi$ is the spatial component of the errors (Ward and Gleditsch 2008). To account for spatial dependence, I construct a neighbor matrix in which village $i$ is considered to neighbor all villages within 15km.[11] The influence of each neighbor on village $i$ is assumed to be equal, but I relax this assumption with alternate spatial weights in the robustness tests.

The dependent variable remains the log ratio of crop area times 1,000, but the key independent variable is now the distance to rebel headquarters (in km). To account for how the effectiveness of control changes over distance, I model this variable as a polynomial. I also include the distance to the rebels' second largest bases—Buchanan for NPFL and Tubmanburg for LURD—although neither of these bases was fully established at the time the satellite images were taken. To account for the effects of lootable resources, villages are coded for whether they contain diamonds or rubber. The information on diamond locations comes from DIADATA (Gilmore et al 2005), and the location of rubber plantations was derived from the satellite images. A non-lootable resource, timber, is also included. The locations of both active and potential timber areas are coded based on information from Conservation International. Figure 6 depicts the distribution of these resources.

To examine the effects of ethnic social networks on rebel behavior, I code villages that are predominately ethnic Gio or Mandingo. These villages are most likely to share social and family ties with NPFL and LURD members, respectively. The coding is based on linguistic characteristics of village names,[12] as well as the 2008 Liberian census and survey data from Lofa County, where all Mandingo villages are located (Fearon et al 2009).

[11]The 15km cutoff because ensures that all villages are connected to at least one neighbor, a requirement of spatial models, and is substantively significant because the distance corresponds to a half-day's walk across difficult terrain.

[12]Nearly all Gio villages end in -ay, while Mandingo village names usually end in -du or -dou.

Distance to the capital city Monrovia and distance to the nearest land border are included to control for the cost of displacement among civilians. Civilians might be more inclined to abandon their farmland if they can easily access the refugee camps of neighboring countries or reach the capital city, the only location where humanitarian aid organizations operated during the war. Distance to a major road is included to control for ease of access. Locations near major roads might be easier for rebel groups to monitor—or to loot. This variable is coded from a road network dataset compiled by the Liberian Institute of Statistics and Geo-information Services.

Battles within 30km of village $i$ since $t_0$, the date of the first image, measures the effect of instability on crop area and is coded from the ACLED data. Figure 7 depicts the locations of battles during January 1990 to January 1991 and during February 2001 to March 2003. For the LURD rebels, a dummy variable indicates villages that were already under LURD control in February 2001, when the first satellite image was taken, coded based on U.N. security council reports as well as field interviews with LURD commanders.

The number of households (logged) in a village was derived from a 2005 United Nations study that provides rough estimates of the number of housing structures in a given location. By focusing on structures, both destroyed and intact, the study includes data on villages that were depopulated during the war. In this way, the data mitigate the endogeneity problem of insecurity-related population movement. Finally the percent crop area at $t_0$ and a measure of village area (in pixels, logged) is included to account for unique village characteristics not related to the conflict. To limit the effects of measurement error caused by noise in the satellite images, I exclude villages with 20 pixels or less of crop land in either image (pixels measure 30m by 30m). These villages are essentially non-agricultural locations.[13] Figure 8

[13]This restriction excludes 11% of villages in the NPFL sample and 38% of villages in LURD territory.

presents descriptive statistics of the variables.

## 5.2 Results

The same model was run for both NPFL and LURD areas (except for the *LURD 2001* and *Gio* variables), and Figure 9 presents the results side-by-side. As predicted, when villages are closer to the NPFL headquarters at Gbarnga (smaller distance) they experience lower declines in crop area. The effect is large and substantive. Holding constant other factors, if a farmer 100km away relocates to the the NPFL headquarters, his crop area is expected to increase 259%. An opposite and significant effect is observed in LURD territory: a farmer relocating to LURD headquarters from 100km away experiences a catastrophic 97% decline in crop area. Proximity to LURD's secondary headquarters in Tubmanburg also corresponds to significant declines in crop area, as does proximity to a major road in LURD areas. No significant effect was observed for NPFL's secondary headquarters in Buchanan.

In terms of lootable resources, no significant effect is observed for diamonds, but diamond mining remained small-scale throughout the conflict. The presence of rubber has a strong negative effect in NPFL territory and a significant, although smaller, negative effect in LURD territory. In NPFL territory, being in a rubber area corresponds to a 25% decline in crop area; in LURD territory the decline is 9%. These effects possibly reflect the black market trade in rubber, especially during the early years of the war, in which rebel soldiers and civilians sold rubber to Nigerian peacekeepers (C09). A truckload of rubber could fetch $300 on the black market (Ellis 1999: 167). The effects of ethnic links to villages and nearby battles are not significant in the model, although the coefficients are in the predicted

Running the regressions without this restriction does not substantively affect results, but does introduce spatial autocorrelation caused by the measurement error.

directions. The high value of $\lambda$ indicates that spatial autocorrelation exists between the observations, but a Moran's I test on the residuals reveals that the spatial model reduced the autocorrelation to the point where it is no longer significant.

## 5.3 Robustness

Spatial models depend on assumptions regarding the structure of the spatial dependence. Examining the results under a variety of spatial weights and specifications provides some insight into the robustness of the results. In addition to the 15km neighbor matrix, I constructed matrices that weight neighbors according to the inverse distance between them and the inverse distance squared. These weights imply that villages farther apart have less influence on each other. Each of these weights, including the basic neighbor matrix, was also extended to the 30km range.

The effects of proximity to rebel bases and rubber areas in NPFL territory remain as predicted, and their statistical significance increases under these alternative specifications. The effect of battles remains negative and becomes statistically significant, but the increased significance could be explained by the spatial autocorrelation that remains in the model under these alternative spatial weights. In LURD territory, distance to rebel headquarters remains significant in the predicted direction for all weights matrices. Rubber and battles are significant and negative in the basic 30km neighbor matrix, but lose their significance in models using the distance-based weights.

A major challenge of spatial analysis is the Modifiable Areal Unit problem (Haining 2003). Statistical results may be sensitive to how the variables are spatially aggregated (Kalyvas 2008). To address this issue, I aggregate crop area at the level of clans, the smallest administrative unit in the Liberian government, as an alternative to the village-level

analysis.[14] Distance to Rebel Headquarters remains statistically significant in the predicted direction for NPFL territory, as does the presence of rubber plantations. In the LURD model, the coefficient for distance to headquarters loses statistical significance but retains the predicted sign. The presence of rubber is negative and statistically significant at the clan level in LURD territory.

# 6 Changes Over Time and the Endogeneity of Rebel Bases

Additional information can be gained by examining changes in crop area over time in the smaller study area depicted in Figure 2. SPOT images from 1993 and 1995 allow for a comparison of crop area in NPFL territory during 1991, 1993, and 1995 and within LPC territory during 1995.[15] This framework provides a comparison of security in NPFL versus LPC territory and addresses, to some extent, the endogenous location of rebel bases. Instead of organizational challenges, security in rebel territory might be driven by the strategic decision to site rebel bases in particular areas, or other omitted variables related to geography. The NPFL's secondary headquarters was located in Buchanan until the town fell to the LPC rebels in 1994. By measuring the changes in crop area near Buchanan before and after this change in authority, omitted variables related to the location of Buchanan are eliminated and the effect of rebel behavior on local food production can be identified.

[14]There are 832 clans in Liberia. Village-level household figures were replaced by the number of households in each clan, according to the 2008 census conducted by the Liberian government. Several variables, including distance to capital and distance to secondary base, had to be removed to prevent singularity.

[15]These observations could be combined into a panel model by adding a time component to the spatial weights matrix, but this specification would require additional assumptions that are difficult to justify on theoretical grounds.

Figure 10 depicts the results of the analysis. The first three columns apply to NPFL territory while the final column describes the situation in LPC territory. The geographically-compact nature of the study area and its demographic characteristics allow several control variables to be dropped.[16] The NPFL was in the process of reorganizing its forces in January 1991, depicted in the first column. The effect of distance to Buchanan, its secondary base, has the expected sign but fails to reach statistical significance. In January 1993, however, after the NPFL's presence was firmly established, there is a strong, positive effect on crop area near the Buchanan base. This effect disappears in January 1995, in the third column, which is expected since the NPFL lost control of Buchanan to the LPC in 1994. Civilian abuse is higher in the rubber areas in 1991 and 1995, but the coefficient switches signs in 1993, which is puzzling. Being closer to a main road is beneficial for civilians in NPFL territory during 1993 and 1995, which could imply better monitoring and control of rebel forces near the highway.

The estimates for the LPC also support the theory's predictions. Greater declines in crop area occurred closer to the LPC's secondary base in Buchanan.[17] Greater declines also occurred closer to the main roads in LPC territory, which could indicate a greater opportunity for looting. Thus even though the LPC was ethnically homogeneous, the group exhibits the characteristics of a predatory organization, as predicted. For both groups, battles had a negative effect on civilians, but the coefficient only reaches statistical significance in 1993. The changing levels of security in NPFL versus LPC territory reveal that the results cannot be explained by omitted variables related to the strategic selection of rebel bases or

[16]In addition, the model relaxes the restriction of villages with less than 20 pixels in both time periods to include villages that contain more than 20 pixels of crop land in *either* $t_0$ or $t_1$. Again, the results are not substantively affected when this restriction is dropped.

[17]The rebels were headquartered in Greenville, Sinoe County.

any geographical characteristics of the area. Rather, group behavior explains the level of security provided to civilians.

# 7 Conclusion

I argue that external patrons shape the behavior of rebel groups by choosing which leaders to support and how much support to provide. These resources, and the quality of the rebel leader, determine the leader's ability to provide cash incentives and make credible promises to the troops. Timber and iron corporations benefitted from Charles Taylor's extensive foreign contacts and his family ties with skilled military commanders. The money supplied by these corporations allowed Taylor to provide cash incentives to his troops, and increased his motivation to provide security for civilians. Other patrons, motivated by a desire to manipulate the rebel group to achieve policy goals, have incentives to support weak leaders and withhold money and other resources that could strengthen leader control. The government of Guinea and the ECOMOG peacekeepers supported weak leaders who were willing to follow orders in exchange for weapons and ammunition. Sekou Conneh and George Boley, leaders of LURD and LPC, respectively, were distrusted by their troops and were unable to provide any cash incentives. With little control over their forces, LURD and LPC members looted and preyed upon civilians, most intensively near the rebels' headquarters. Civilian security was sacrificed for the patron's policy goals.

Even when leaders can offer cash incentives, their ability to enforce discipline depends on monitoring and the presence of lootable resources. These incentives imply a spatial pattern to abuse, which finds support in the data. In NPFL territory, local food production benefited from proximity to the rebel headquarters and suffered from the presence of rubber,

part of the black market trade in looted goods. Identifying rebel behavior as the cause of these patterns can be accomplished by examining territory that changed hands between rebel groups. While food production benefitted from proximity to Buchanan during NPFL rule, it suffered after the town fell to the LPC rebels. This shift in security cannot be explained by the endogenous choice of rebel bases or other geographic factors. The Liberian case demonstrates the potential of remote sensing to generate objective and verifiable micro-level data on the behavior of political actors. With more development, remotely sensing can become an integral part of the civil war research program and help create a bridge between micro-level theories and cross-national patterns of political violence.

# A Interviews Cited

| ID | Description | Faction(s) | Location | Date |
|---|---|---|---|---|
| B43 | Soldier | NPFL | Monrovia | 21 Aug 2007 |
| B48 | Civilian | NPFL, ULIMO, LURD | Lofa Bridge, Cape Mt | 23 Aug 2007 |
| C02 | Senior Commander | ULIMO/J, LURD | Monrovia | 4 May 2009 |
| - | - | - | (via telephone) | 8 May 2009 |
| - | - | - | - | 20 Jun 2009 |
| - | - | - | - | 13 Aug 2009 |
| C08 | Sr. Political Official | NPFL, NPFL-CRC | Monrovia | 13 May 2009 |
| C15 | Senior Commander | NPFL | Monrovia | 27 May 2009 |
| C19 | Commander | INPFL, NPFL | Monrovia | 1 Jun 2009 |
| C24 | Senior Commander | NPFL, AFL | Monrovia | 15 Jun 2009 |
| C26 | Senior Commander | NPFL | 15 Gate | 18 Jun 2009 |
| C27 | Commander | NPFL | 15 Gate | 18 Jun 2009 |
| C29 | Sr. Political Official | MODEL | Monrovia | 30 Jun 2009 |
| C30 | Commander | LURD | Monrovia | 2 Jul 2009 |
| C32 | Sr. Political Official | MODEL | Monrovia | 4 Jul 2009 |
| C34 | Commander | ULIMO/J, LURD | Monrovia | 8 Jul 2009 |
| C39 | Sr. Political Official | NPFL | Monrovia | 14 Jul 2009 |
| C42 | Commander | LPC | Monrovia | 13 Aug 2009 |
| - | - | - | (via telephone) | 14 Aug 2009 |

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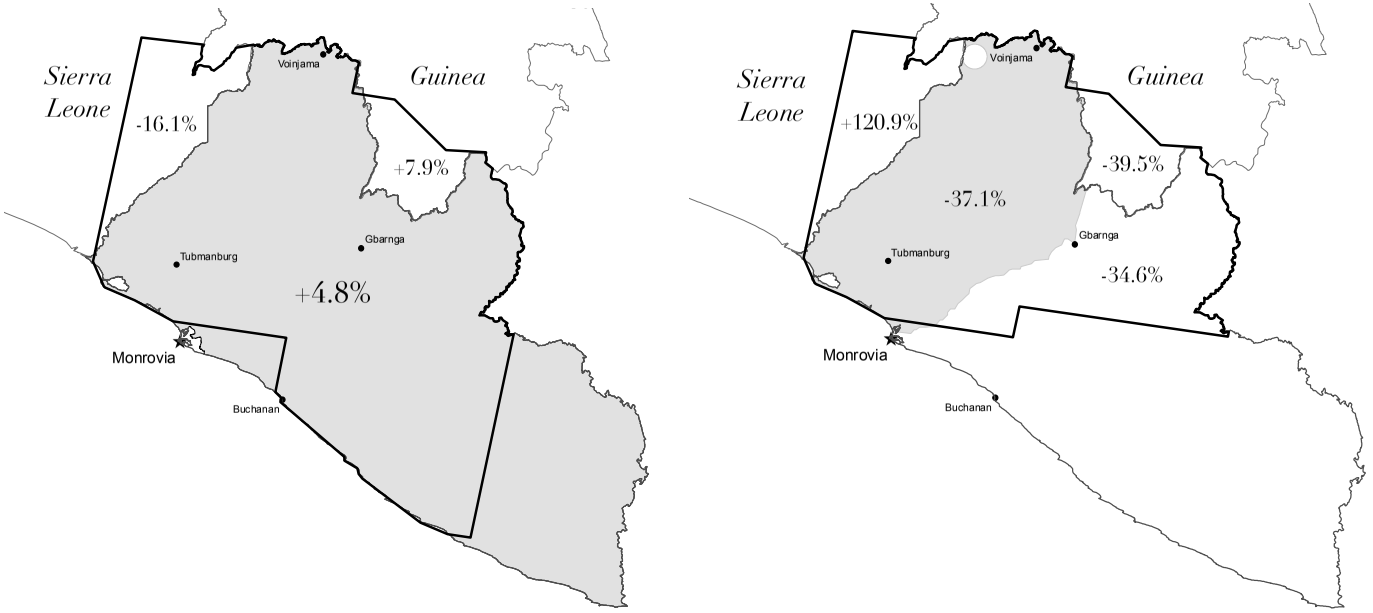



Figure 1: Change in crop area in NPFL and LURD territories (shaded) and neighboring regions of Sierra Leone and Guinea. Bold lines indicate the study areas.

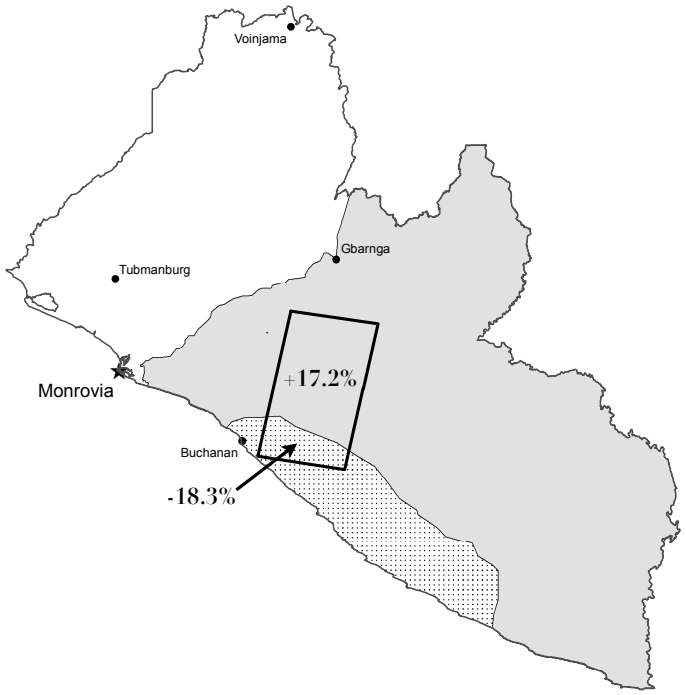



Figure 2: Change in crop area, 1991 v. 1995, in territory that remained under NPFL control (shaded) and territory captured by LPC (dotted). Study area depicted by bold line.

| Theory | Civilian Security |
|---|---|
| Adverse Selection | LURD $\approx$ LPC $\geq$ NPFL |
| Ethnic Composition | LPC $>$ LURD $\approx$ NPFL |
| Territorial Stability | Stable Areas $>$ Unstable Areas |
| External Patrons and Commander Incentives | NPFL $>$ LURD $\approx$ LPC |

Figure 3: Competing predictions of rebel behavior in Liberia.

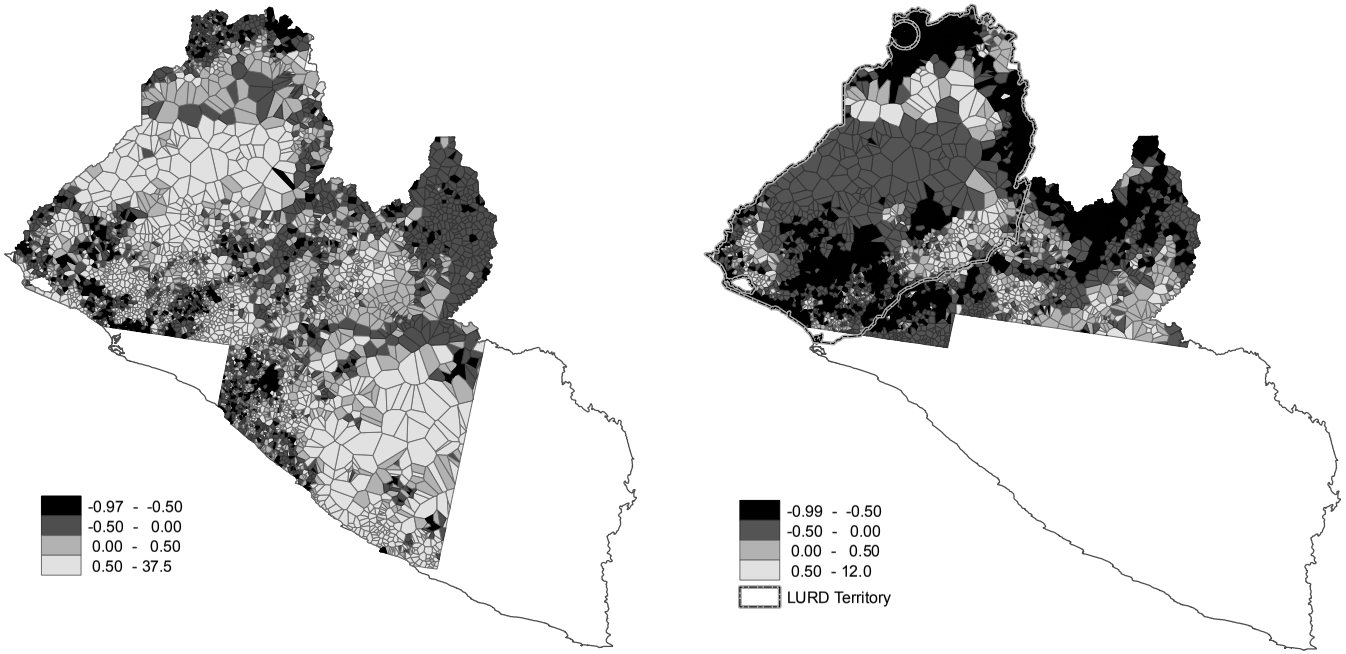
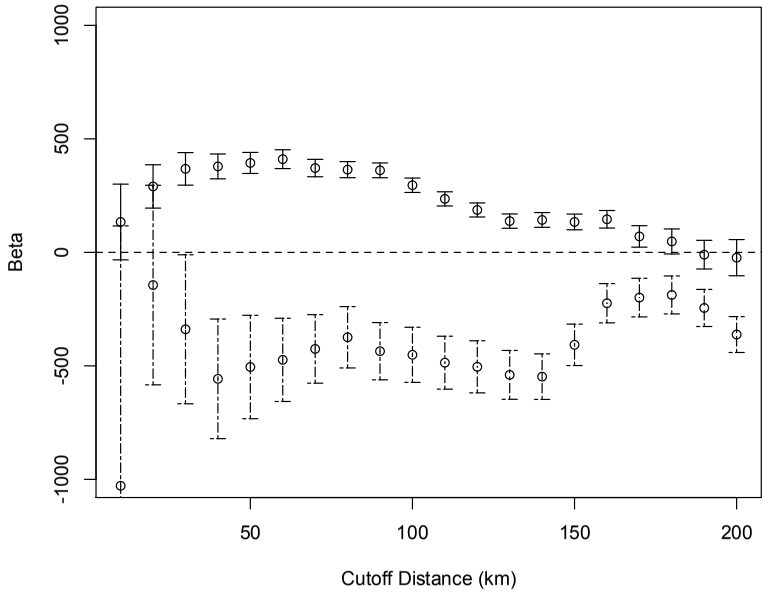



Figure 4: Percent change in crop area at village level in NPFL and LURD territories.




| | NPFL | | LURD | |
|---|---|---|---|---|
| Cutoff Distance (km) | $\beta$ | S.E. | $\beta$ | S.E. |
| 10 | 134 | 85.1 | -1028 | 584 |
| 20 | 290 | 48.9 | -144 | 224 |
| 30 | 368 | 36.6 | -339 | 167 |
| 40 | 379 | 27.9 | -557 | 134 |
| 50 | 394 | 23.7 | -505 | 116 |
| 60 | 411 | 21.2 | -474 | 93.5 |
| 70 | 371 | 19.6 | -425 | 77.0 |
| 80 | 364 | 18.1 | -374 | 68.9 |
| 90 | 361 | 16.6 | -435 | 64.4 |
| 100 | 296 | 16.2 | -451 | 62.0 |
| 110 | 236 | 15.9 | -486 | 59.5 |
| 120 | 187 | 15.8 | -504 | 58.5 |
| 130 | 138 | 16.1 | -540 | 54.8 |
| 140 | 143 | 16.6 | -547 | 51.2 |
| 150 | 134 | 17.7 | -407 | 46.5 |
| 160 | 146 | 19.7 | -224 | 44.1 |
| 170 | 70.3 | 24.1 | -199 | 43.4 |
| 180 | 48.1 | 28.1 | -188 | 42.7 |
| 190 | -10.1 | 32.2 | -245 | 41.7 |
| 200 | -23.4 | 40.7 | -362 | 40.3 |

Figure 5: The effect of proximity to rebel headquarters for villages in NPFL territory (solid lines) v. villages in LURD territory (dashed lines), with 95% confidence intervals. Positive values of $\beta$ correspond to lower declines in crop area. The dependent variable is the log ratio of crop area, multiplied by 1,000.

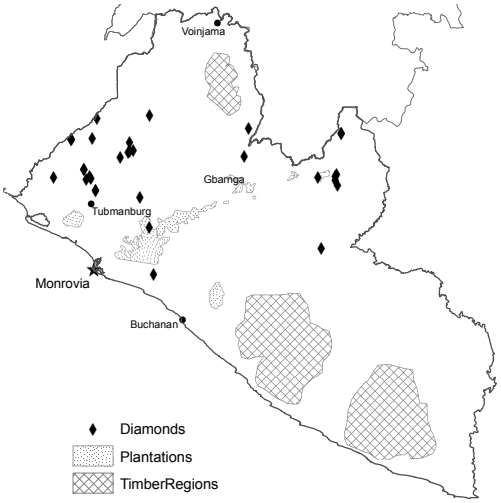



Figure 6: Natural resources in Liberia. Source: DIADATA, Conservation International, satellite imagery analysis.

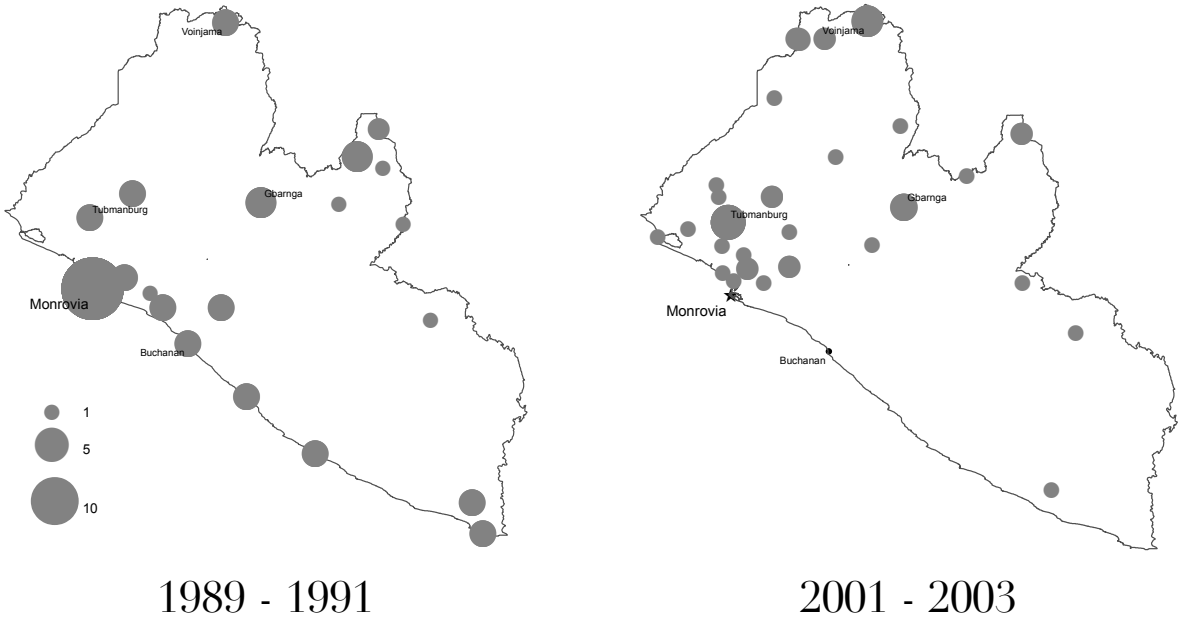



Figure 7: Number and location of battles. Source: ACLED.

| | NPFL | | | | LURD | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Min | Mean | Max | St.Dev. | Min | Mean | Max | St.Dev. |
| DV | -2449 | 44.42 | 3055 | 659.8 | -2932 | -366.2 | 2053 | 710.0 |
| Dist. Rebel HQ | 0.45 | 112.3 | 246.9 | 50.0 | 3.5 | 190.2 | 257.7 | 50.8 |
| Dist. 2nd Base | 3.9 | 132.0 | 294.9 | 68.9 | 3.3 | 66.1 | 220.2 | 43.5 |
| Diamonds | 0 | 5.4e-3 | 1 | 7.3e-2 | 0 | 7.7e-3 | 1 | 8.8e-2 |
| Rubber | 0 | 8.4e-2 | 1 | 0.28 | 0 | 0.10 | 1 | 0.30 |
| Timber | 0 | 3.0e-2 | 1 | 0.17 | 0 | 1.1e-2 | 1 | 0.10 |
| Mandingo | 0 | 1.2e-2 | 1 | 0.11 | 0 | 3.9e-3 | 1 | 6.2e-2 |
| LURD 2001 | - | - | - | - | 0 | 1.2e-2 | 1 | 0.11 |
| Dist. Capital | 14.2 | 141.8 | 290.5 | 70.3 | 14.9 | 89.9 | 271.7 | 52.6 |
| Dist. Border | 0.10 | 73.3 | 172.6 | 49.5 | 0.10 | 62.5 | 122.8 | 33.8 |
| Dist. Road | 0.0 | 7.9 | 50.3 | 8.1 | 0.0 | 7.4 | 39.4 | 6.6 |
| Battles within 30km | 0 | 2.1 | 21 | 3.4 | 0 | 3.5 | 11 | 3.1 |
| Village Households | 1 | 63.2 | 5241 | 174.9 | 1 | 62.2 | 2051 | 128.9 |
| % Crop Area $t_0$ | 2.6e-3 | 4.3e-2 | 0.23 | 3.0e-2 | 3.6e-3 | 3.7e-2 | 0.28 | 2.5e-2 |
| Village Area | 7.4e5 | 1.5e7 | 1.5e8 | 2.5e7 | 1.1e6 | 1.5e7 | 3.3e8 | 2.6e7 |

Figure 8: Descriptive statistics.

| | NPFL 1986 v. 1991 | LURD 2001 v. 2003 |
|---|---|---|
| | Estimate (S.E.) | Estimate (S.E.) |
| Dist. to Rebel Headquarters | -12.8*** | 57.0** |
| | (3.35) | (19.6) |
| Dist. Rebel HQ$^2$ | 0.033* | -0.205*** |
| | (0.013) | (0.044) |
| Dist. to Rebel Secondary Base | 2.04 | 19.7** |
| | (3.81) | (7.58) |
| Dist. 2nd Base$^2$ | 0.006 | -0.047 |
| | (0.010) | (0.100) |
| Diamonds | -68.7 | 94.4 |
| | (78.8) | (133) |
| Rubber | -289*** | -93.0* |
| | (30.9) | (56.0) |
| Timber | 52.5 | 191 |
| | (61.0) | (216) |
| Gio | 15.2 | - |
| | (50.7) | - |
| Mandingo | -35.7 | 130 |
| | (65.2) | (427) |
| LURD 2001 | - | 175 |
| | - | (271) |
| Distance to Capital | -4.37 | -52.9*** |
| | (3.03) | (11.4) |
| Dist. Capital$^2$ | -0.001 | -0.161 |
| | (0.010) | (0.104) |
| Distance to Border | 5.10 | 24.0* |
| | (3.11) | (13.3) |
| Dist. Border$^2$ | -0.036* | -0.139* |
| | (0.020) | (0.0.075) |
| Distance to Road | 2.35 | 22.1*** |
| | (2.74) | (6.22) |
| Dist. Road$^2$ | -0.249* | -0.961** |
| | (0.108) | (0.298) |
| Battles within 30km since $t_0$ | -4.29 | -2.55 |
| | (2.83) | (7.23) |
| Village Households (log) | 4.13 | -0.933 |
| | (4.69) | (10.4) |
| % Crop Area $t_0$ (log) | -839*** | -804*** |
| | (12.5) | (30.1) |
| Village Polygon Area (log) | -79.2*** | -138*** |
| | (9.24) | (19.6) |
| (Intercept) | -516 | -3061 |
| | (502) | (3478) |
| $\lambda$ | 0.888 | 0.967 |
| LR Test Value | 1059.2 | 253.7 |
| p-value | <2.22e-16 | <2.22e-16 |
| Moran's I Std. Deviate | 0.8851 | 0.6885 |
| p-value | 0.1880 | 0.2456 |
| N | 4430 | 1293 |
| *** $p < 0.001$; **$p < 0.01$; | * $p < 0.1$ | |

Figure 9: Spatial model of changes in crop area for NPFL (1986 v. 1991) and LURD (2001 v. 2003). The dependent variable is the log ratio of crop area, multiplied by 1,000.

| | NPFL 1991 | NPFL 1993 | NPFL 1995 | LPC 1993v. 1995 |
|---|---|---|---|---|
| | Estimate (S.E.) | Estimate (S.E.) | Estimate (S.E.) | Estimate (S.E.) |
| Dist. to Rebel Secondary Base | -7.94 | -29.0*** | -5.60 | 45.9* |
| | (7.69) | (8.53) | (18.6) | (18.6) |
| Dist. 2nd Base$^2$ | 0.100* | 0.147* | 0.181 | -0.487* |
| | (0.059) | (0.063) | (0.125) | (0.282) |
| Rubber | -248** | 237* | -333*** | -169 |
| | (93.9) | (107) | (96.2) | (181) |
| Timber | 103 | -92.4 | 257 | -126 |
| | (103) | (118) | (184) | (172) |
| Distance to Road | -11.4 | -52.4*** | -25.8* | 34.1* |
| | (8.94) | (8.76) | (10.3) | (19.4) |
| Dist. Road$^2$ | 0.223 | 2.33*** | 0.916* | -0.976 |
| | (0.447) | (0.434) | (0.520) | (1.13) |
| Battles within 30km since prev. | - | -55.6** | -13.4 | -45.2 |
| | - | (17.7) | (35.0) | (63.2) |
| Village Households (log) | 0.736 | 8.01 | -1.74 | -5.25 |
| | (12.5) | (12.4) | (15.7) | (19.8) |
| % Crop Area Previous (log) | -536*** | -898*** | -896*** | -480*** |
| | (40.4) | (35.9) | (48.4) | (51.2) |
| Village Polygon Area (log) | -131*** | -80.0** | -87.5** | 20.6 |
| | (25.9) | (26.1) | (28.5) | (41.6) |
| (Intercept) | 64.4 | -1205** | -2414** | -3212*** |
| | (403) | (446) | (874) | (733) |
| $\lambda$ | 0.736 | 0.795 | 0.948 | 0.826 |
| LR Test Value | 20.9 | 36.3 | 80.7 | 9.60 |
| p-value | 4.9e-6 | 1.7e-9 | ¡2.22e-16 | 1.9e-3 |
| Moran's I Std. Deviate | -0.836 | 0.420 | 1.66 | 1.32 |
| p-value | 0.798 | 0.337 | 0.0483 | 0.0929 |
| N | 615 | 436 | 409 | 258 |
| | *** $p < 0.001$; | ** $p < 0.01$; | * $p < 0.1$ | |

Figure 10: Change over time in a section of NPFL territory and spatial variation within a section of LPC territory. The dependent variable is the log ratio of crop area, multiplied by 1,000.