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EXPLORING SPATIAL DYNAMICS OF CIVIL CONFLICTS IN VIRTUAL AFRICA: A NEW RESEARCH DESIGN

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Abstract

This article offers a unique approach to analyzing spatial dynamics of civil conflicts and the accompanying process of state territorial integration/ disintegration: crucial phenomena that have been defying vigorous theoretical treatment. Based on the combined use of multi-agent simulation (MAS) and a geographic information system (GIS), these dynamics are simulated in virtually constructed sovereign states that reflect the defining characteristics of the existing ones. These 'realistic virtual states' then provide a reliable environment for conducting policy as well as theoretical analyses of conflicts in a highly context-sensitive manner. Focusing on the countries in Northeast Africa, this article illuminates the promising potential of the proposed approach with two sets of illustrative simulations. The first aims to reproduce the diverse historical dynamics of conflicts actually observed in the region. The second conducts hypothetical policy experiments in virtual Sudan, which investigate the effectiveness of several policy options in bringing peace to the country.

I. Introduction

The sovereign state is a territorial entity. Therefore, an armed conflict on its soil is essentially a spatial phenomenon. Whether in Afghanistan, in Somalia, or in Syria, the occurrence and the intensity of civil conflict can vary greatly across the territory of the state concerned: some localities suffer more from the violence than others do. The dynamics of each conflict are also spatial in nature: a conflict intensifies as it expands on the territorial space, and wanes with spatial recession.

All of these aspects of civil conflict——spatial variability and spatial dynamics——seem quite obvious. Yet, for an equally obvious reason, grasping them has posed considerable challenges to researchers: it is intellectually intractable. Generally speaking, understanding spatially bounded phenomena, which most often consist of a countless number of mutually connected local interactions, demands far more complicated, and a far larger amount of, logical

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reasoning than non-spatial ones typically require. Furthermore, it also requires a considerable capacity for information processing, as one has to deal with spatially disaggregated empirical data, which comprise a far larger amount of information than, say, cross-national conflict datasets typically contain. These intellectual requirements render the development of spatially explicit theory of civil conflict a simply daunting task. In fact, until quite recently, excluding several notable exceptions (e.g., Doreian and Hummon 1976, chap. 7), the spatial aspects of conflict had largely remained beyond the theoretical reach of the relevant literature (see the next section).

Hence, the challenges are enormous. On the other hand, overcoming these challenges could bring considerable benefits. Not only would it enable a much fuller as well as a more accurate understanding of civil conflicts. It would also allow researchers to shed light on a closely related——in a sense more fundamental——process: integration and disintegration of state territorial rule. How do the sovereign states, sometimes violently, organize themselves, or fail to do so, on their own territories? How do new political entities, which, on rare occasions, even successfully attain formal statehood, appear and disappear on parts of those territories? Vigorous theoretical treatment of these questions would make a substantial contribution to another body of research on 'state weakness', 'state failure', or 'state collapse', which has so far been characterized by the notorious lack of theories and models beyond a confusing array of classificatory labels (e.g., Migdal 1988; Rotberg 2004; Zartman 1995).

In short, some fresh approach to civil conflict, especially to its spatial dimensions, is both necessary and helpful. This motivates the present article. It articulates a research design for analyzing spatial dynamics of civil conflict and state disintegration that at the same time overcomes the intellectual difficulties mentioned above. The design builds on a distinctive research platform: 'realistic virtual states', which are constructed virtually but reflect some of the defining characteristics of the corresponding sovereign states that exist in the actual world. On the territories of these virtual states, various spatial dynamics of conflicts are simulated with the accompanying processes of state integration and disintegration. Specifically, the article focuses on several virtual states that approximate the actual states in Northeast Africa (Eritrea, Ethiopia, Kenya, Somalia, and the Sudan), a region where violent processes of state integration and disintegration have continuously been observed over the past half-century.

Methodologically, the platform is aided by the integrative application of multi-agent simulation (MAS) and a geographic information system (GIS), each of which has shown notable development and application in the past two decades. MAS offers a way to explicitly model complex interactions among a plenty of autonomous——but often spatially bounded——agents; GIS provides a powerful package for dealing with a variety of geo-spatial data. These two computer-based techniques, in combination, make the explicit treatment of spatial phenomena highly feasible and largely tractable (e.g., Gimblet 2002).

The proposed platform of virtual states can support a broad range of theoretical, empirical and even policy investigations into civil conflicts while maintaining close touch with reality. The present article aims to illuminate this potential. As such, the emphasis here is on drawing a broad picture of the alternative research method and practice made possible by MAS and GIS, rather than focusing on specific issues of contention in the existing literature. The article is organized as follows. The next section critically discusses the existing conflict literature with a particular focus on the recent trend toward 'disaggregation' of civil conflicts. Given the limitations of the literature, the following section posits an alternative research design and describes its major components: the MAS model of a virtual state and the GIS data of the Northeast African countries. Then follow two sections that illustrate simulations conducted in the 'virtual Northeast African states'. The first set of simulations aims to reproduce, and thus understand, the diverse spatial dynamics of civil conflicts and state disintegration historically observed in Northeast Africa. The second set is more policy-oriented: it investigates the effectiveness of several policy options, including the partition of territory, in bringing peace to virtual Sudan and its component regions.

II. Emerging Trend in Civil War Literature

'Disaggregation' is a recent major twist in the civil war literature that has been characterized by constant theoretical and empirical contestations (Cederman and Gleditsch 2009). The most conspicuous development in this regard is the more explicit treatment of space and geography in analyses of civil conflicts (Buhaug and Gates 2002; Buhaug and Rød 2006; Toft 2003; Cunningham and Weidmann 2010). As was indicated above, these elements had not received sufficient consideration in preceding studies, which mostly focused on the non-spatial dimensions of conflicts, such as their 'onset', 'duration' and 'termination'. This situation has been rapidly changing, most notably in the following two aspects.

The first aspect concerns empirical data and analysis. One common source of controversy in the past literature would be the lack of empirical association between certain country-level variables and civil conflicts. For instance, in major large-N analyses, the empirical relevance of the descriptive narratives that focus on ethnic fractionalization/polarization and socio-economic inequality has often been questioned because of the statistical insignificance of the proxies employed such as the Ethno-Linguistic Fractionalization index (ELF) and the national GINI coefficient (Collier and Hoeffler 2004; Fearon and Laitin 2003; Hegre et al. 2003. See also Cederman and Girardin 2007; Fearon et al. 2007). These indexes are calculated and aggregated at the national level, leaving sub-national differences seriously disregarded. But the dubiousness, if not absurdity, of building arguments upon aggregated factors alone becomes quite obvious, when one considers the simple fact that conflict events and their possible co-variates are not uniformly distributed over the state territory.

In this light, several recent works have re-examined the existing findings in more spatially disaggregated settings, and succeeded in 're-establishing' the causal relationships that were not fully captured in the previous analyses. Relying on GIS datasets, these works rescale units of analyses down to the sub-national level. For example, by conducting cross-sectional analysis of conflict events at the level of sub-national administrative regions, Cunningham and Weidmann (2010) revealed the strong influence of a particular local configuration of ethnic groups on conflict incidence in the given region. Similarly, Østby et al. (2009) obtained results indicating the significance of interregional as well as intraregional socio-economic inequality in promoting conflicts in the administrative regions of 22 African countries; while Hegre et al. (2009), adopting a uniformly imposed grid-cell rather than an administrative region as the basic data unit, investigated the spatial aspects of the Liberian civil war and confirmed the effect of similar socio-economic factors. Together with accompanying endeavors for spatial data collection such as the GREG ('Geo-Referencing of Ethnic Groups') project (Weidmann et al. 2010), these studies have indeed brought renewed vigor to the civil war literature.

However, disaggregating a conflict implies more than mapping its constituent events onto spatial tracts; a civil conflict is not a mere collection of local armed clashes. While each clash between a government and insurgents might occur within a limited space, it often has consequences that stretch well beyond the locality concerned, interacting with events in the surrounding localities and causing diverse macro-dynamics of state integration and disintegration in the process. Accordingly, understanding a civil conflict in its totality requires some logical link between the local competitions taking place in various localities of the given state on the one hand and the resulting macro-dynamics affecting that state's integrity in a certain direction on the other hand. In this respect, the works discussed above are of little help. In face of spatial data, most of these works have simply adopted the same type of statistical procedures as their predecessors', without offering any logic that accounts for the complex spatial interactions involved in conflicts.

Given this situation, the second aspect of the trend toward disaggregation is important since it is more about constructing causal logic. For the past decade or so, there have been an increasing number of theoretical models that analyze civil conflicts in a spatially as well as temporally disaggregated manner (e.g., Cederman 1997; 2008; Lustick et al. 2004; Weidmann 2006; Weidman et al. 2006). Employing the computational method of MAS due to the sheer amount of interactions involved, these models variously simulate the dynamic processes of armed conflicts and the accompanying group formation on a virtual space. For example, on a space with a simple cultural makeup, Cederman (1997, chap.8) focused on the collective identity formation emerging from local interactions among spatially distributed communities that face repression by the central government. He later made a quite elaborate spatial model of a civil war, deriving insights about the impact of geographical and cultural factors on its incidence (Cederman 2008).

These models considerably deviate from the dominant modeling approach in the civil war literature, which heavily relies on traditional tools and concepts that were developed for analyzing inter-state relations such as 'security dilemma' and 'credible commitment' (Posen 1993; Snyder and Jervice 1999; Walter 1997; 1999). In the latter approach, the spatial dimension is totally omitted. So is the temporal dimension. Moreover, as is clearly seen in the game theoretic modeling, the groups in conflict are exogenously given, and treated as monolithic and constant (e.g., Fearon 1998; 2004). All of these seriously constrain the prospects for capturing the processes of state integration and disintegration accompanying civil conflicts, which almost always involve dynamic elements of group formation and dissolution. In contrast, the new approach, which utilizes the technique of MAS, more or less overcomes these limitations: it is spatially explicit, dynamic, and treats mutually conflicting groups as endogenously emerging from interactions among 'agents' such as communities and individuals. There is no doubt that these aspects constitute significant theoretical advancement.

The emerging theoretical trend is not without its own problems, however. The most important problem is that many of its contributions disaggregate conflicts in highly abstract and stylized spatial settings. In other words, the spatial configurations of geographical and cultural features in a virtual world are abstractly, and often even randomly, determined without giving much consideration to the corresponding reality. Sometimes justified by referring to the so-called KISS ('keep it simple, stupid!') principle (Axelrod 1997, 4-5), this tendency can be quite problematic, especially in dealing with spatial phenomena including civil conflicts. The reason is clear: a civil conflict consists of a series of local interactions taking place over the state territory, and local interactions almost by definition show strong dependence on the configurations of the space on which they occur. This means that spatial properties detached from reality may render the whole exercise irrelevant, at least in terms of the empirical relevance of the model concerned. Thus, in this aspect of disaggregation, quite contrary to the first one, the lack of empirical elements poses a serious obstacle to understanding conflicts.

Obviously, the path toward a better grasp of spatial dynamics of civil conflict seems to lie in much tighter integration of empirical data and theoretical logics. Several of the latest studies, including the present one, have thus been pursuing this promising path (Bhavnani and Choi 2012; Cederman and Girardin 2006; Lim et al. 2007; Weidmann and Salehyan 2013). Following what Lustick and Miodownik (2009) call a 'Virtualizations' strand of research designs for conducting MAS, this tiny body of researchers, with the aid of GIS, tries to reflect strong empirical elements on the geo-spatial makeups of their respective virtual worlds. Weidmann and Salehyan (2013), for example, built their MAS model of ethnic violence on several layers of GIS data that describe the ethnic compositions as well as the locations of sectarian clashes in Baghdad after the Iraq War. Prominently, this 'Virtual Baghdad' model, while illuminating dynamic causal relationships between ethnic segregation and violence, has attained a certain level of congruency between simulated and actual spatial distributions of conflict events.

Unfortunately, however, their model, together with similar ones dealing with ethnic violence in other places (Bhavnani and Choi 2012; Lim et al. 2007), faces significant limitations. In terms of the research interests set forth in this article, the most serious one is that they largely treat each ethnic clash as a basically localized, discrete event. In contrast, overall structure of political division such as that between Sunnis and Shias, which is supposed to connect these local events, is exogenously given in most cases, and not subject to vigorous treatment in any way. This compromises the utilities of these models as tools for exploring macro-dynamics of state territorial integrity: something that makes civil conflict the relevant subject to many political scientists. Additionally, these studies suffer from a potential problem of case-sensitivity. Most of them exclusively focus on a single case, avoiding extensive application of their respective models beyond that[1].

III. Constructing Virtual Africa

All of the above critical reflections on the civil war literature condition the specifics of the research platform offered here: a platform that enables spatially explicit analysis of civil conflicts and state territorial rule in multiple empirical cases. It consists of the following combination of a MAS model and GIS datasets.

1 Lim et al. (2007) applied their model to two cases (former Yugoslavia and India), but not necessarily in a strictly comparable manner (see Weidmann and Toft 2010, 173-174; Harmon et al. 2010, 184).

A. MAS Model[2]

The proposed model of civil conflict builds on a virtually constructed state, which captures several basic components of statehood supposedly held by the existing sovereign states. This virtual state, first of all, has its territory represented as a two-dimensional space. Over this space, numerous virtual inhabitants are settled. They are differentiated from each other according to several socio-cultural traits (ethnicity, religion, etc.), and all of them are placed under the rule of a government at first. In addition to the inhabitants and the central government, the model assumes existence of a large number of latent insurgent organizations, whose aim is to subvert the rule of the government by force. Then, competition among the government and these insurgents for the exclusive rule over the territory and its inhabitants take place in various localities, driving the macro-state of territorial integrity of the virtual state in diverse directions.

1. Agents

Two types of agents, namely *PopCell* (Population Cell) and *Ruler* (Ruling Entity), are defined along the line of the above setting.

The model assumes a grid structure on the territory of a given state, and a *PopCell* agent represents each piece of the territory thus demarcated with the inhabitants living on it. In the simulations reported in the following sections, the territory of each virtual state is gridded at a resolution of 30 arc-minutes (approximately 55km at the equator).

A *PopCell* is characterized by three variables: *State*, *Traits* and *Resources*.

State specifies which of the competing organizations governs the *PopCell* concerned. It assumes a specific integer value that identifies one of the *Ruler* agents.

Traits describe the socio-cultural traits of the inhabitants on the cell. Following earlier MAS models (Axelrod 1997, chap.3; Cederman 1997, chap.8), this model represents these traits as a vector of strings consisting of several dimensions. Each dimension corresponds to a specific category of the inhabitants' traits. For example, in the context of 'virtual Ethiopia' that will be introduced later, the vector ("02", "93", "02") denotes inhabitants who are ethnically Tigrinyan ("02"), religiously Christians ("93"), and regionally Eritreans ("02").

Finally, *Resources* denote the amount of human and material resources that exist on the cell.

Of these three variables, *State* is a time-variant endogenous variable, while *Traits* and *Resources* are assumed to be time-invariant, their values being derived from empirical data in the way that will be shown later. Needless to say, the latter's assumptions of time-invariance are purely theoretical without denying the empirical variability of human traits and the quantity of resources. Macro-dynamics of conflict spread/recession and the accompanying territorial integration/disintegration in a virtual state are generated by time-series changes in the

2 This model is implemented on *artisoc* (*art*ificial *soc*iety), a general-purpose simulator developed and updated by Kozo Keikaku Engineering Inc. (KKE). Its freeware version, *artisoc player*, is available from KKE's web site (http://mas.kke.co.jp/, in Japanese). For a comprehensive introduction to *artisoc*, see Yamakage (2009). The model itself can be obtained from http://citrus.c.u-tokyo.ac.jp/vs/eng/.

overall configuration of *State*s of *PopCell*s across its territory.

The other type of agents is the *Ruler*. This agent represents either the government or insurgent organizations, the former being defined here as the *Ruler* that holds the capital of the virtual state. The *Ruler*'s main function is to forcibly exclude other competing *Ruler*s from gaining control of the state, and to expand and preserve its exclusive rule over the territory.

The defining characteristics of a *Ruler* are described by two kinds of variables: *Traits* and *Mobilization Factors*.

Traits display the *Ruler*'s political stance vis-à-vis inhabitants in terms of the former's alignment with the latter's socio-cultural traits. This variable is also represented in the form of a multi-dimensional string-vector, and, following Cederman (1997, chap.8), is allowed to take a value ("*") indicative of a political 'wildcard' that represents indifference toward the inhabitants' traits. Turning back to the above example, a vector ("02","*","02") describes a *Ruler* that is ethnically and regionally committed to Tigrinyans ("02" in the first element) and Eritreans ("02" in the last) respectively, while being religiously neutral (denoted as "*").

Mobilization Factors control the *Ruler*'s access to human and material resources both inside and outside the virtual state. This variable consists of two real numbers. The first element, *Mobilization Level*, stipulates the fraction of a *PopCell*'s *Resources* to be collected by the *Ruler* within each period of time. The second, *External Resources*, specifies the amount of resources that accrues to this *Ruler* irrespective of the number of *PopCell*s it possesses.

All the variables of *Ruler*s are time-invariant and exogenously determined, albeit in differentiated manners. With regard to *Traits*, the values assigned to the *Initial Government*, that is, the *Ruler* that is the government at the start of the simulation, are specified on the basis of crude empirical characterization of the corresponding government in reality. Otherwise, the *Traits*' values are randomly generated for each *Ruler* at the beginning, and held constant thereafter[3]. On the other hand, *Mobilization Factors*, as will be shown in the next section, are assigned values according to some drastic assumptions that make things tractable.

2. Interactions

The simulation proceeds as illustrated in Figure 1. Each run starts with the formation of the initial state. This is done by setting the *State* variables of all the *PopCell*s to the same value that is indicative of the *Initial Government*, thus placing the whole territory under the unitary rule of the government. The *Ruler*s other than the *Initial Government* are randomly scattered over the territory, without any *PopCell* to rule over yet. After forming the initial state, the model is run for a specified number of 'periods'. Each period consists of two phases, where the following behavioral rules are applied in turn[4].

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3 More specifically, each insurgent *Ruler* is set to infiltrate the virtual state from a predetermined point on the territory. Its *Traits* are then formed by randomly determining whether or not it is committed to each socio-cultural element that constitutes the Traits of the *PopCell* located on that point.

4 See Sakamoto (2011, chap.2) for more formal and complete specification.

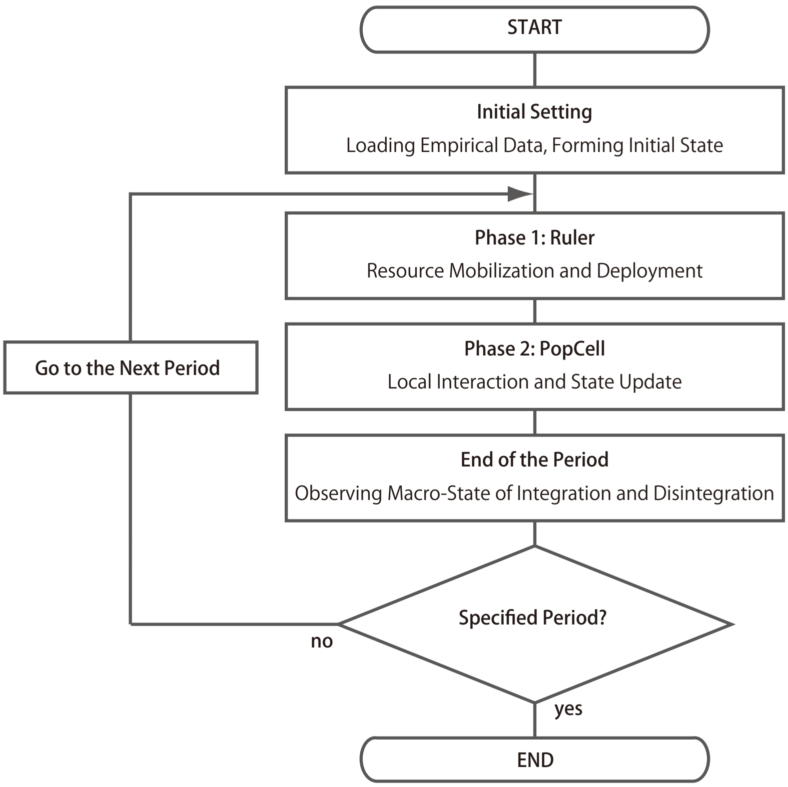

FIGURE 1. The Flow of a Simulation Run

Every *Ruler* is exclusively concerned with monopolizing the territorial rule in the virtual state. For this purpose, each *Ruler* mobilizes the human and material resources of the *PopCell*s under its rule, and spreads these resources——thus makes its presence felt——across the space.

The rules for the first phase describe how this happens. A *Ruler* mobilizes human and material resources from two sources: the *PopCells* under its rule (if the *Ruler* holds any *PopCell*), and an unspecified source that is external to the virtual state. The resources collected from the former are the sum of specific fractions of the Resources of the *PopCells* concerned, the size of these fractions being controlled by the *Mobilization Level* of the governing *Ruler*. To these resources, those from the latter source, the amount of which is exogenously determined in accordance with the *External Resources* of the *Ruler*, are added. Subsequently, the *Ruler* deploys the collected resources across the entire space that it controls. This is formalized as allocation of the resources to each *PopCell* in proportion to the ‘weight’, or importance that the governing *Ruler* attaches to the *PopCell* in question. As a plausible rule, a populous ‘frontline’ *PopCell* that adjoins another *Ruler*’s territory tends to receive more weight from its governing *Ruler*[5].

The rules for the second phase depict the response of each *PopCell* to the preceding changes in the spatial configuration of *Ruler*s' presence. Here, all the *PopCell*s simultaneously update their affiliations with *Ruler*s on the basis of locally defined interactions, generating a renewed macro-state of territorial integration and disintegration. To be more specific, each *PopCell* stochastically determines its *State* variable in a way that, while allowing for a certain amount of contingency, basically reflects the following pair of logics[6].

Logic 1: Other things being equal, a *PopCell* tends to come under the rule of the adjacent *Ruler* that deploys the most resources to the neighborhood where it is located.

Logic 2: Other things being equal, a *PopCell* tends to come under the rule of the adjacent *Ruler* whose *Traits* are the most inclined toward its own *Traits* [7].

In the model, a *PopCell*'s 'neighborhood' is defined as a Neumann neighborhood that includes the cell itself and the four adjacent *PopCell*s that lie above, below, left and right. On the other hand, a *PopCell*'s 'adjacent *Ruler*' is defined as a *Ruler* that governs at least one *PopCell* in the neighborhood of the cell in question; or a 'latent' *Ruler* that happened to be

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5 More specifically, a *PopCell*'s weight is proportional to the product of the logarithm of its local population count multiplied by a certain inflator. The latter amplifies the effect of the former if the *PopCell* in question adjoins at least one *PopCell* under the rule of a *Ruler* other than its current *Ruler*.

6 In its formal representation, this stochastic rule follows the dominant spatial modeling approach typically found in stochastic mechanics. The basic idea is to define the 'potential' for a *PopCell*'s affiliation with each *Ruler* to be replaced with affiliation with another *Ruler*. The functional form of this potential satisfies both Logic 1 and Logic 2. Thus, for each *PopCell* i and for each *Ruler* k, if k is i's adjacent *Ruler* (see the main text), a local potential function $H_i(k)$ is defined as $H_i(k) = -Aff(i,k) - cR_i(k)$, where *Aff* denotes affinity between the *Traits* of i and k, $R_i(k)$ specifies a total amount of k's available *Resources* in i's neighborhood, and c, called *Coercion Effect* here, is a non-negative parameter scaling the potential of the second term in relation to the first. Otherwise, $H_i(k)$ is a sufficiently large constant, which effectively blocks i's state transition to k. By using a specific probability function that monotonically decreases with the potential thus defined, the probability of the *PopCell* being under the rule of each *Ruler* during each period can be calculated. On some grounds derived from information theory, this function takes the form of the Gibbs distribution, that is, $P_i(k) = \frac{1}{Z_i}\exp\left(-\varepsilon^{-1}H_i(k)\right)$ $\left(Z_i = \sum_{l\in\Psi}\exp\left(-\varepsilon^{-1}H_i(l)\right)\right)$, where ε controls the amount of stochastic noise and Ψ is a set of all the *Rulers*.

7 Affinity between the *Traits* of two kinds of agents is quantified almost the same way as Cederman (1997, 192) calculated his 'fit' value between a communal identity and a transcommunal identity.

placed on the cell at the start of the simulation but has not held it yet[8].

In short, Logic 1 represents military competition among *Ruler*s over the forced occupation of a *PopCell*; while Logic 2 reflects political competition among *Ruler*s to win over the hearts and minds of its inhabitants. The former drives the *State* of a *PopCell* in one direction in which the locally superior *Ruler*, in terms of the amount of resources deployed to the neighborhood, is likely to prevail on the cell. The latter drives the *State* of a *PopCell* in another direction in which the most preferred *Ruler*, in terms of the affinity between the Traits of two kinds of agents, is likely to dominate. As countless accounts of civil conflicts have revealed (e.g., Johnson 2003; Kurimoto 1994; Pool 2001; Young 1997), such interplay of forces, which often have conflicting directions, has almost always been observed in actual conflicts. The model places these essential politico-military interactions at the core of its micro-level logics.

B. GIS Data

Along the line shared by some of the latest research reviewed in the previous section (e.g., Weidmann and Salehyan 2013), the present study pursues the tight correspondence between virtual and actual worlds. In the context of the model introduced above, this can be achieved by assigning values that are based upon relevant empirical data to the variables of each agent in a virtual state. Specifically, this study relies on GIS data on several Northeast African countries: Ethiopia (before the independence of Eritrea in 1993), Kenya, Somalia, and the Sudan (before the independence of South Sudan in 2011). The following introduces two kinds of spatial datasets. Applying GIS data-processing methods to these datasets yields the spatial distributions of *Resources* and *Traits* of *PopCell*s in virtual states that strongly reflect the actual spatial makeups of those countries.

1. Resource Distribution

Every country has its own spatial configuration of human and material resources. Here, such a configuration is crudely approximated by employing spatial data on the population distribution of a country as well as non-spatial aggregated data of the country's Gross National Income (GNI); *Resources* variable of each *PopCell* is assigned a specific value that is the product of the total number of people living on the corresponding patch of territory and the annual per capita income derived from the country's GNI.

With regard to the sources of demographic data, the present study employs the Center for International Earth Science Information Network (CIESIN)'s *Gridded Population of the World version 3* (GPWv3) because of the clarity and simplicity of its mapping method (CIESIN et al. 2004). GPWv3 allocates the estimated world population to a series of geo-referenced grids at

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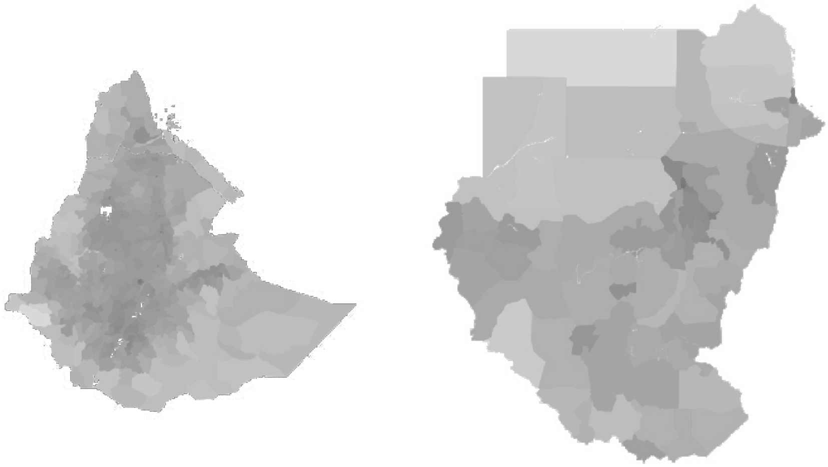
8 Logic 1 above should be interpreted in a slightly different manner for the case of a latent *Ruler*, since such a *Ruler* does not possess any *PopCell* to deploy its resources to. Specifically, the military capability of a latent *Ruler* is evaluated in terms of a total amount of resources available to itself, which in this case exclusively consist of its *External Resources*.

a resolution of 2.5 arc-minutes (approximately 5km at the equator)[9]. Figure 2 illustrates the estimated 1990 population distributions of Ethiopia and the Sudan. The gray scale shades display different sizes of local population on each cell as measured by its logged population count. The annual GNI of each country was acquired from the World Bank's African Development Indicators (World Bank 2005).



Ethiopia-Eritrea Sudan

FIGURE 2. Population Distribution in Etiopia and the Sudan

2. Trait Distributions

With the notable exception of the GREG project that deals with the worldwide distribution of ethnic groups (Weidmann et al. 2010), there have been few comprehensive GIS datasets mapping socio-cultural traits that characterize human beings. Due to the paucity of available data, empirical spatial data on these traits have been gathered from various non-digital sources including paper maps, and have subsequently been integrated in a digitized form on a GIS platform. The endeavor is ongoing, and the data products themselves are still in need of constant improvement, especially with regard to their spatial precision[10]. Never-

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9 The geodetic system employed in GPWv3 is WGS84.This model is also applied to the other spatial data introduced below.

10 The latest version of the GIS dataset is available by request to the author. More accessible 'Virtual State Viewer', which is built on *artisoc* (see footnote 2), can also be downloaded from http://citrus.c.u-tokyo.ac.jp/vs/eng/. The latter shows the detailed spatial composition of the virtual states, on which the former's empirical data are directly reflected.

theless, these GIS data have sufficient quality and accuracy for certain purposes, including that of this study; a relatively large area of each *PopCell* in virtual states (30 min. x 30 min.) allows utilizing these data in the determination of the *PopCell*'s *Traits* without seriously compromising the reliability of the data.

The problem is which kinds of traits are relevant to analysis of civil conflicts. Focusing on the countries in Northeast Africa, at least three categories of traits have been conspicuous for their political and social importance: ethnicity, religion, and region.

The first category consists of traits that have been variously labeled as 'ethnicity', 'nation', 'nationality' and 'tribe' in the region. Construction of the spatial dataset in this category owes much to the existing linguistic distribution maps, such as those found in *Atlas of the World's Languages* (Asher and Moseley 1993). These maps were scanned, geo-referenced and then structured in the form of a vector-type GIS dataset, in which each data object represented as a polygon describes the spread of the corresponding ethnic group. Other relevant encyclopedias were also consulted for the purpose of examining and adjusting the classification of ethnic groups, although such adjustment remained minimal (Ayabe 2000; Skutsch 2004; Yaken 1999).

The GIS data regarding the second category, religion, were derived directly from those of the first. This is because a sizable proportion of the ethnic groups in the region retain their own systems of faith. These so-called 'traditional' religions exist side by side with the 'universal' religions, the latter including various denominations of Christianity and Islam, which also have a substantial number of followers in the region. Based on information obtained from the above-mentioned encyclopedias, the religion(s) that the members of each ethnic group are considered to believe in was specified, and the corresponding polygon object describing its spread was derived from the polygons in the first dataset.

As to the third category of traits, which captures the regional divides (e.g. 'North-South' division) observed in the region, the traits were approximated by the classification based on administrative units[11]. Such data were sought from several sources. For example, one of the principal regional divides in pre-1993 Ethiopia, between Eritrea in the north and the remaining part of the country, is directly reflected on the current border between the two separate sovereign states. Accordingly, its data were obtained from the spatial dataset on state boundaries provided as a supplement to the CIESIN's GPWv3 (CIESIN et al. 2004). In addition, the CIESIN provides detailed spatial information on the sub-national administrative units of each country in a PDF format. This information was utilized to generate spatial data on the north-south divide of the Sudan's territory. Finally, a similar division in Somalia was captured by the boundary between two colonial entities: Italian Somalia and British Somaliland. Digitizing and geo-referencing a paper map from the colonial period yielded GIS data on that division (Lewis 1998).

Sometimes, however, these three categories are too broad to differentiate peoples and characterize various political inclinations of ruling entities. Indeed, in the northeastern part of Africa, narrower kin and/or territorial subgroups not only have local importance, but also often have nation-wide political impact. In order to deal with these realities, the database of trait distributions has additional layers of information on sub-classes of each trait. The case in

11 In fact, as Clapham (1996, 49) emphasizes, administrative divides have often assumed independent political importance in sub-Sahara Africa.

point here is the Somali lineage structure, whose spatial configuration was replicated in the dataset of ethnicity distribution from the detailed paper map that Lewis included in his work (Lewis 1998)[12].

Through somewhat complicated procedure of data conversion and interpolation applied to the above spatial datasets, the three-dimensional vector representation of *Traits* of each *PopCell* can be obtained (Sakamoto 2011, chap.3). Figure 3 displays examples of trait distributions in each dimension.

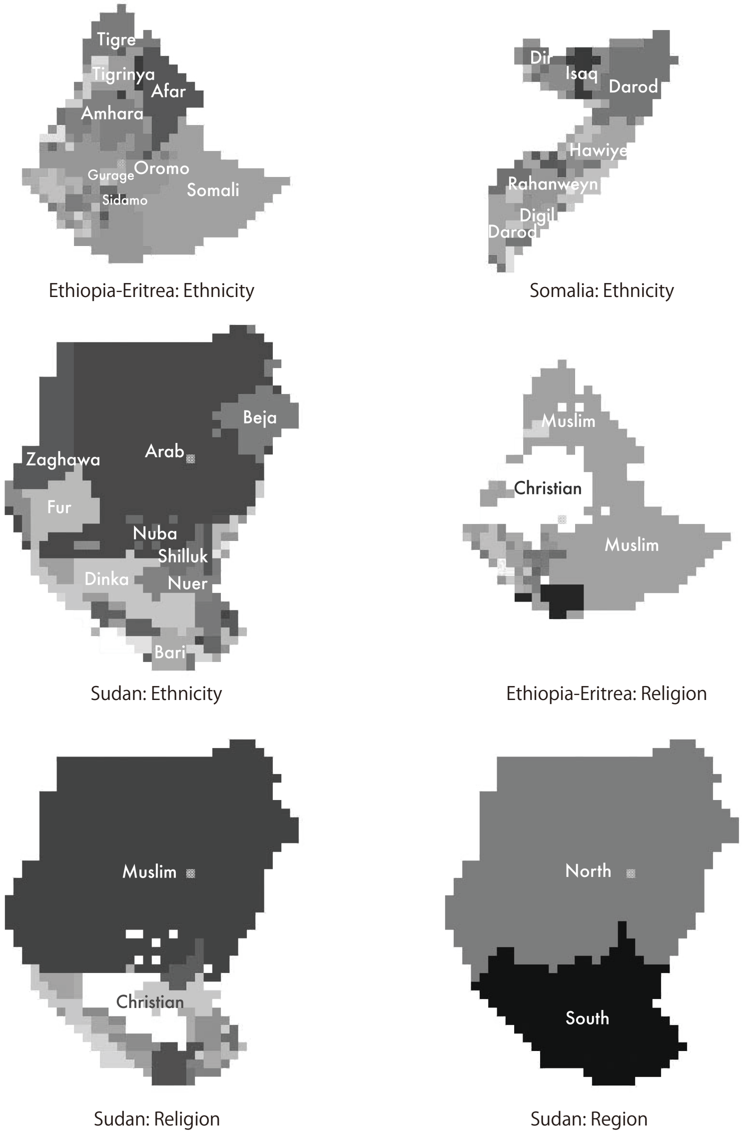

FIGURE 3. Examples of Traits Distributions in the Virtual States

12 In this case, a given trait is converted to an extended form of a string vector such that a string “18-03-01”, for example, denotes inhabitants who belong to the Ogadeni clan (“01”) of the Darod clan-family (“03”) of the Somali ethnicity (“18”).

IV. Understanding Observed and Unobserved Dynamics

The research platform just described allows researchers to tackle a variety of hitherto formidable questions on civil conflict, especially those about its spatial aspects as well as the accompanying dynamics of state territorial order. One set of such questions pertains to understanding: how does civil conflict spread and recede across the territory of a sovereign state; how, in the process, does the state in question integrate and disintegrate on its territory; and why do all these things happen? The following suggests a possible approach to handling these questions on the proposed platform, which is illustrated with brief reports on the simulations conducted in'Virtual Northeast Africa'.

A. Target Countries and Governments

The intractability of spatial dynamics of civil conflict can be made clear from yet another angle: by showing their sheer diversity in reality. One can obtain a glimpse of this diversity in Table.1. The table summarizes the typical dynamics of conflict and territorial rule historically observed in the four countries in Northeast Africa while a particular government was in power in each country[13]. It also shows the GNI per capita of each country as well as empirical characterization of each government's inclination toward the traits of inhabitants (in order of ethnicity, religion, and region)[14]. Each dimension of the *Traits* of the corresponding *Initial Government* is determined according to the latter. Besides the data sources mentioned in the previous section, these pieces of information were derived from an extensive examination of the preceding case studies (e.g., Brons 2001; Gebru Tareke 1996; Johnson 2003; Kimenyi and Njuguna 2005; Lewis 2002; Markakis 1990; Pool 2001; Widner 1992).

Focusing on the last column of this table reveals a varying degree of deviation from the ideal of sovereign statehood that civil conflicts can bring to the existing states. On one hand, there are states like Kenya where armed conflicts, if they happen at all, lack a significant level of spatial expansion and temporal duration; and some semblance of territorial integrity is maintained as a result. On the other hand, that integrity can variously be eroded, starting from sustained but mostly localized conflicts of the sort that Imperial Ethiopia had faced in northern Eritrea and other places until it finally collapsed from the center in the 1974 revolution. The Sudan has been suffering from a still heightened level of conflict since its independence, especially in its south where the widespread expansion of insurgency, often accompanied by its own internal division, led to the effective division of the country's territorial rule. Somalia from the late 1980s offers the most extreme case of state collapse. There, a rapid succession of conflicts from the north eventually engulfed the whole country, leaving behind the serious disintegration of territorial rule among competing factions.

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13 Sakamoto (2011, chap.4) offers more extensive coverage of periods.

14 *Traits* in virtual Kenya do not include the regional dimension because of the relative lack, in its counterpart in reality, of the politicization independently based on administrative groupings. However, some historical examples, including the secessionist rebellion in the northeastern part of the country in the early 1960s (Markakis 1990, 182-191), might suggest otherwise.

These contrasting dynamics are admittedly crude as description; probably inevitably so given the general lack of spatial data describing precise conditions of territorial order in each sovereign state. Yet, the differences among these patterns are marked enough to treat the four cases as a representative set of samples that indicates the broad spectrum of actual conditions of civil conflict and territorial rule. As such, they offer a useful starting point to test the effectiveness of the platform of virtual states for capturing and explicating the complex reality.

	Government	Traits of the Government (Ethnicity/ Religion/Reion)	GNI per capita (1990)	Observed Pattern of Conflict and Territorial Rule
Ethiopia	Haile Selassie (1930-1974)	Amhara ("03") / Christian ("93") / Ethiopia ("01")	$168.94	Local Infiltration: sustained conflict in Eritrea; sporadic uprisings in the Southeast
Kenya	Daniel arap Moi (1978-2002)	Kalenjin ("53") / Indifferent ("*")	$343.92	Unitary Rule: sporadic clashes that are contained and localized
Somalia	Siad Barre (1969-1991)	Somali-Darod-Marehan ("18-03-02") / Indifferent ("*") / South ("01")	$116.58	Total Disintegration: nation-wide civil war among multiple factions; government collapse; ensuing relative tranquility in the North
Sudan	Successive Governments (1956-)	Arab ("01") / Muslim ("01") / North ("01")	$499.49	Division of Rule: North-South civil war; frequent conflicts in the South; uprisings in the North

Table.1 Target Countries and Governments

B. Simulations and Their Results

The virtual states are different from each other because each one is constructed from a particular set of empirical data, namely, the GIS datasets and other non-spatial data introduced above. The other aspects are set to be identical across all the virtual states, as Table.2 depicts[15].

15 The parameters in the Table are measured against a scale that defines one unit of *Resources* as a value-added equivalent to 20 million US dollars on an annual basis.

The Number of Periods	500
The Number of Rulers (including the Initial Government)	100
Mobilization Level	1.0 for all the Rulers
External Resources	0.0 for all the Rulers
Coercion Effect	0.2
Sensitivity to Frontline	2
The Amount of Stochastic Noise	0.2

Table.2 Common Parameters of the Virtual States

Of the common parameters appearing in the Table, *Coercion Effect*, Sensitivity to Frontline, and Stochastic Noise have some functions in the formal specification of the model (see footnote 5 and 6), and each requires a brief mention. *Coercion Effect* controls the relative importance of military competition among *Ruler*s (Logic 1) as compared to political competition (Logic 2) in the determination of each *PopCell*'s *State*. *Sensitivity to Frontline* controls the amount of weight that each *Ruler* assigns to a *PopCell* located on the 'frontline' in the former's resource deployment. Lastly, *Stochastic Noise* specifies the extent to which each *PopCell*'s update of its own *State* is influenced by contingent factors.

Table 2 also shows that the *Mobilization Level*s of *Ruler*s are set to the same level while their *External Resources* are set to zero. Such assumptions about *Mobilization Factors* make subsequent simulations manageable. Moreover, the model's formal specification allows *Mobilization Level*s to be set to 1.0 without losing generality.

Given the parameters specified in the Table, and starting from the initial state where all the *PopCell*s are placed under the rule of a single *Initial Government*, the virtual states exhibit diverse spatial dynamics of armed conflicts and the accompanying territorial integration/disintegration. Some of these dynamics are realistic in the sense that the emergent spatial configurations are similar to the actual patterns of conflict observed in the corresponding real states. The four panels in Figure 4 depict examples of such configurations, each of which was sampled after 500 periods of simulation. In the figure, the *PopCell*s colored black are those that remain under the rule of the *Initial Government* after 500 periods. For example, the panel of virtual Sudan shows the typical north-south divide between the *Initial Government* based in the nort and a single insurgent *Ruler* that has emerged in the south. In virtual Somalia, on the other hand, the government's territory has completely disappeared amid the extreme disintegration of territorial rule. These simulated spatial patterns of conflict are consistent with the descriptions in Table 1, albeit in a somewhat exaggerated fashion.

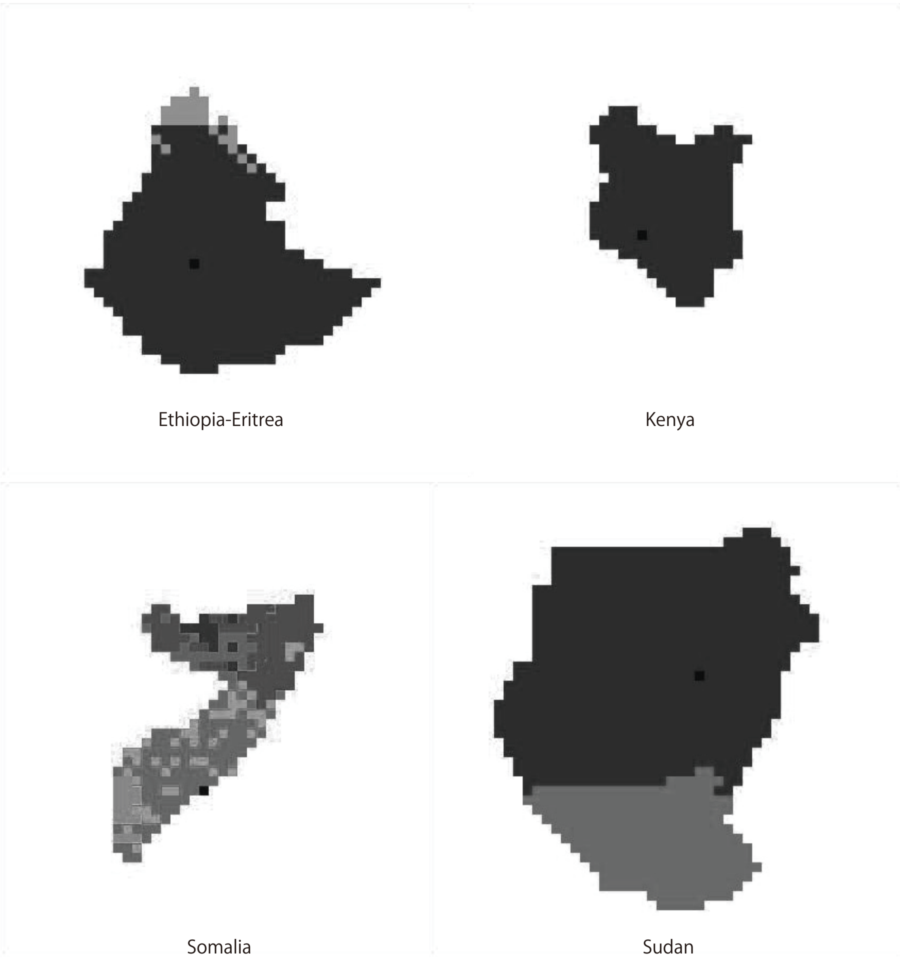

FIGURE 4. Spatial Patterns of Conflicts in the Virtual States

At the same time, however, the simulations generated other alternative scenarios with different spatial dynamics of conflict. This is not unusual given the highly stochastic nature of the model, which in turn demands a statistical treatment of the results. Figure 5 exhibits the simulation results of each virtual state in the form of frequency distribution of a certain summarizing index. This index, the *Disintegration Index* (*DI*), measures the amount of entropy that the given macro-state entails. Its value is non-negative, and increases as the territorial rule in a virtual state becomes more fragmented[16]. The frequency distribution was obtained from 20 simulation runs in each of the virtual states, and *DI* was sampled after 500 time periods in each run. In the figure, the dark-bordered areas correspond to the runs in which the *Initial Government* somehow survived the entire periods; while the light-bordered areas correspond

16 More specifically, *DI* is defined as $DI=-\Sigma ter(k)\log_2 \mathrm{ter}(k)$, where *ter*(*k*) denotes the ratio of a total area of *PopCell*s under the rule of *Ruler k* relative to that of the whole territory. The summation is taken over all *k*.

to those in which it disappeared from the scene prior to the end of the run. The lighter shade of colors indicates more disintegrative territorial order as measured by *DI*. The text labels in the graphs summarize the typical patterns found in the areas around them. These labels also reveal that some of the virtual states often show conflict dynamics considerably different from those observed in history.

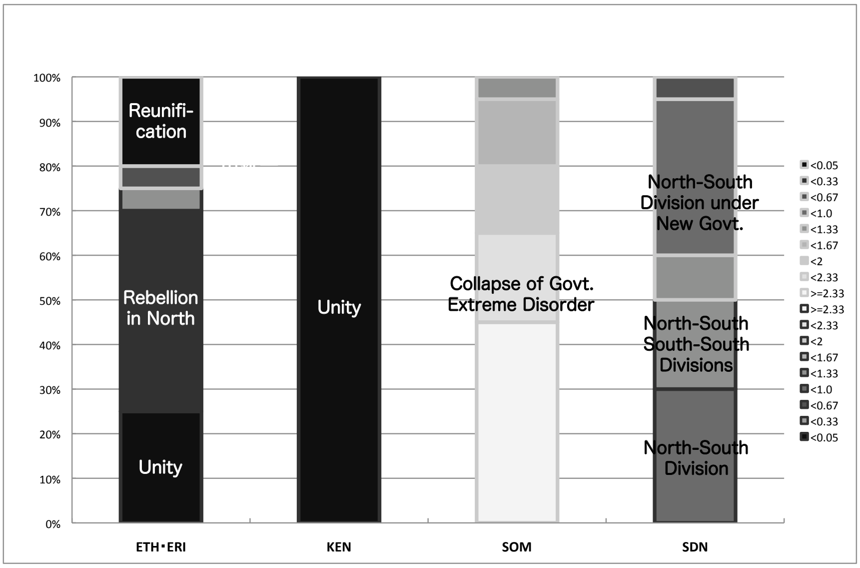

FIGURE 5. Long-Term Patterns of Conflicts in the Virtual States

The following is a brief account of each virtual state's dynamics drawn from these results.

1. Ethiopia (Haile Selassie)

The imperial government in virtual Ethiopia cannot avoid some form of rebellion in Eritrea in the north. Such a rebellion most often has a particular type of insurgent at its core, the *Ruler* whose *Traits* include Islam ("01") in its religions dimension and Eritrea ("02") in its regional dimension, reflecting the traits of the most excluded segment of the population concentrating in lowland Eritrea. Like the historical Eritrean insurrection, however, without mobilization of the large Christian population in highland Eritrea, these characteristics of the insurgents pose a certain limit to their long-term prospect for survival and expansion. Indeed, as the area of 'Unity' in the corresponding graph in Figure 5 indicates, the *Initial Government* was often successful in suppressing all of these rebellions during the 500 periods, thus maintaining the territorial integrity at the end of each run.

Moreover, rebellions were observed in other parts of the country as well, at least in the short term. One of the regions that witnessed their frequent occurrence is the southeast. This region has a vast stretch of a single locally dominant ethnic group, Somalis ("18"). This makes the coordination and expansion of insurgent activities relatively easy tasks. However, due to the thinly stretched demographic pattern, the region does not have enough resources to sustain the challenges to the *Initial Government*, which makes most of their struggles quite short-lived.

Although these rebellions in the north and southeast did not directly threaten the *Initial Government*'s survival, they sometimes did so indirectly. As such rebellions force the government to deploy a larger fraction of its resources to the regions where the rebellions take place, they help induce potential insurgent *Ruler*s to emerge in other parts of the country. The most serious threat to the *Initial Government* in this regard comes from the populous area right around the capital, where ethnic Oromos ("16") are concentrated. In the simulations, this large and historically excluded group often exhibited the ability to sustain powerful insurgents, which occasionally overwhelmed the government and other competing organizations, thus bringing about the alternative 'Reunification' scenario found in Figure 5.

2. Kenya (Daniel arap Moi)

Among the four states, virtual Kenya shows the most robust tendency toward territorial unity. Conflicts there remained at most sporadic and localized. In fact, a large part of the territory of this state has a settlement pattern in which a number of different ethnic and religious groups coexist in a hugely mixed manner, making it hard for potential insurgents to organize and sustain a large-scale rebellion. Moreover, virtual Kenya has a relatively wealthy population that is mostly concentrated within a compact space, giving a substantial advantage to the *Initial Government* that can access their resources from the outset. Therefore, without denying the fact that territorial unity by no means implies an absence of bloodshed as the history of Kenya tells, it can be said that virtual Kenya is endowed with spatial configurations that are the least vulnerable to disintegration.

3. Somalia (Siad Barre)

As easily read from Figure 5, virtual Somalia, quite similarly to actual Somalia, is prone to face extreme disintegration of rule, and the government cannot expect even its survival in the long run. The extreme fragility of virtual Somalia in comparison with the other states can be explained by two factors. One is the severe material and demographic constraint that the state faces: any *Ruler* has to stretch its mobilized resources, a small quantity in itself, thinly over the vast territory. The other is the narrow extension of the *Initial Government*'s strongholds, i.e., Marehan ("18-03-02"), which prompts spontaneous emergence of insurgent *Ruler*s in many parts of the country.

As to long-term dynamics, the model generated substantial variation in results, including the prolonged division of rule among a large number of narrowly based fiefdoms. On the other hand, the model was largely unable to reproduce the formation of relatively large territorial entities observed in the north of the country: Somaliland and Puntland.

4. Sudan (Successive Governments)

As Figure 5 illustrates, virtual Sudan showed a strong tendency toward some form of north-south division. Broadly speaking, two typical patterns can be recognized here. One, which corresponds to the pattern observed in the first civil war (early 1960s-1972), is characterized by serious competition among southern insurgent movements along ethno-religious lines in addition to the north-south divide. This reflects a particular spatial configuration of the south where several locally dominant groups such as Dinka ("33") and Nuer ("35"), all alienated from the government in the north, are settled in their own homelands in a largely segregated manner. The other pattern, in contrast, overcomes the additional division in the south, and captures a certain degree of unity attained by SPLA during the second civil war (1983-2005).

Apart from the south, the government of virtual Sudan can face challengers in the north. The disastrous conflict in Darfur, for example, has its counterpart in virtual Sudan, although the latter never matched up with the former in its intensity and duration. Rather, more serious prospects for the *Initial Government* lies in its total collapse from the center, which is induced by emergence of insurgents based on the government's own stronghold among the Arab ("01") and Muslim ("01") population. Observed in as many as 50% of the simulation runs, these prospects become probable in the situation of a relative vacuum around the capital where most of the government's resources are devoted to the vastly stretched frontline in the south. It is instructive that, even in this alternative scenario of a full-scale civil war, which engulfs the northern as well as southern parts of the country, virtual Sudan demonstrates a persistent tendency toward north-south divide.

It should be noted that these juxtapositions of observed and unobserved patterns of conflict in the four virtual states are conditional on the parameter values given in Table 2. Manipulating each of the parameters across a broad range of values allows one not only to examine the robustness of the conflict patterns described above, but also to explore additional scenarios of war and peace that are yet to be seen in each virtual state. Although reporting such simulations exhaustively is simply beyond the space available, one example, which is illustrated in Figure 6, would be helpful for grasping the overall image. This graph plots successive histograms of the distribution of *DI*s among 20 simulations run in virtual Sudan as a function of the amount of the *Initial Government*'s *External Resources*. It is essentially an extension of the rightmost histogram in Figure 5: this histogram corresponds with the leftmost side of the graph in Figure 6 where *External Resources* = 0.0. The latter graph reveals that in the context of virtual Sudan, an increase in the amount of External Resources, a clear advantage to the *Initial Government*, does not necessarily translate into more integrative territorial rule. Rather, virtual Sudan demonstrates considerable resistance to change in this variable. While the relative frequency of each conflict pattern does in fact show dependence on its value (e.g., the decreasing occurrence of the 'south-south division' with increase in *External Resources*), the overall tendency toward the north-south division remains quite strong throughout.

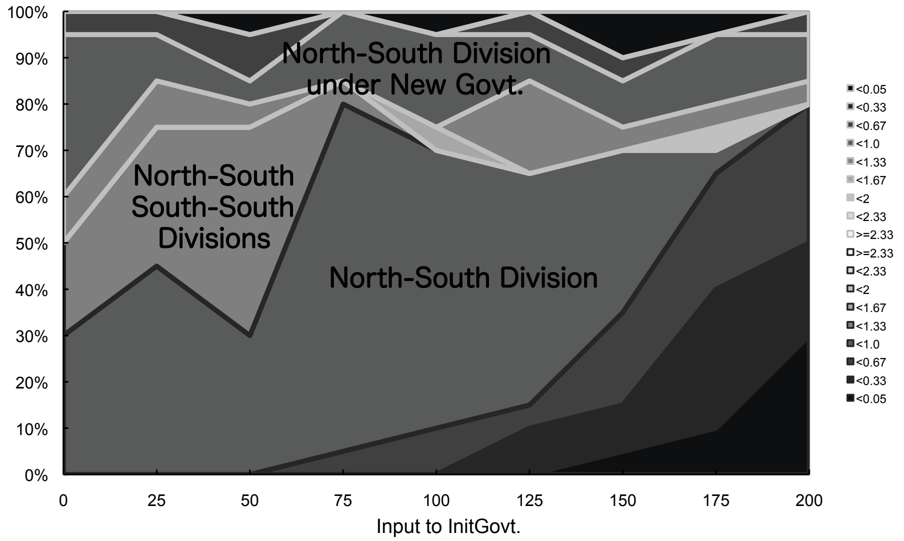

FIGURE 6. External Resources and Conflict Patterns in Virtual Sudan

C. Toward Richer Understanding of Conflicts

Illustrative and selective as they are, the above simulations suggest a certain degree of empirical relevance of the platform presented here. Given sufficient correspondence to actual sovereign states through empirical data, the virtual states generate diverse spatial dynamics of conflict that reflect some of the defining characteristics of the observed processes along with a variety of alternative dynamics. Obviously, there are still numerous aspects of reality that the model has been unable to capture (e.g., the formation of relatively peaceful areas like Somaliland in war-torn Somalia). Overall, the results obtained so far are nonetheless encouraging ones.

Different behaviors of the virtual states, observed as well as unobserved ones, are essentially generated through the model's application to a limited combination of mostly spatial datasets. Thus, the implication here is the importance of several dimensions of the state's spatial configuration for understanding civil conflicts. These include the spatial structure of political inclusion and exclusion; and the spatial distribution of human and material resources. As is indicated in the preceding analysis, the spatiotemporal dynamics of civil conflict and territorial rule show dependence on these factors in a largely non-obvious manner, defying easy reductionism: the simulated diversity can never be attributed to differences in one variable, say ethnicity distribution, alone. Although only extensive experiments and systematic comparisons conducted across diverse virtual states, of which those reported above constitute only a tiny part, would enable one to explicate the whole picture of this complex causality, the basic tool and procedure supporting such arduous endeavors are already in place.

V. Experimenting Policies

Given the virtual states that can more or less approximate observed dynamics of conflict, it is quite natural——almost irresistible——to ask another set of questions: how can spatial expansion of civil conflict effectively be prevented or managed across the territory of a sovereign state; how, in the process, can the unity and stability of the state in question be attained or sustained on its territory; and which policy means are effective in bringing about all these things? In fact, the proposed platform enables one to almost seamlessly proceed in this direction of policy analysis.

A. Three Options for Peace in the Sudan

The following offers a brief illustration of hypothetical policy experiments conducted in virtual Sudan, which has a persistent tendency toward the north-south divide as much as the actual one. Specifically, it focuses on three policy options that have historical as well as theoretical importance, and examines their respective effectiveness in bringing lasting peace to this country. The three options are as follows.

1. Pluralism

In view of the highly ethnocentric character of the successive governments in Khartoum, this policy prescribes an alternative of erecting a pluralistic government at the center: a government that embraces the coexistence of diverse peoples regardless of their ethnic, religious and regional backgrounds. In the context of virtual Sudan, the effectiveness of this option can be examined by changing the *Traits* of the *Initial Government* from highly inclined (“01”,“01”,”01”) to totally indifferent (“*”,”*”,”*”).

2. Autonomy

This option cedes a certain degree of political autonomy to the south under some form of regional governance. The historical precedents can be found in the institutional schemes stipulated in the Addis Ababa Agreement in March 1972 and the Comprehensive Peace Agreement (CPA) in January 2005.

Formalizing these schemes demands substantial extension of the model with various possibilities for their specification. The following, somewhat crude extension should be treated as the first step toward a more comprehensive treatment of the issue (see Sakamoto 2011, chap.6 for more complete specification):

(1) Allowing the *Initial Government* to have a dual-layered structure that consists of the ‘central government’ and the ‘regional government’ in the south.

(2) Introducing a new parameter, the *Degree of Decentralization* (*DD*), which assumes a value on [0,1], and which controls the degree of autonomy of the regional government in its relation with the central government.

(3) Extending the rule of the *Initial Government*'s resource mobilization in such a way that, of the resources mobilized in the south, the regional government takes the fraction specified by *DD*, and the central government takes the rest.

(4) Extending the rule of the *Initial Government*'s resource deployment in such a way that the regional government can deploy its resources only to the *PopCell*s located in the south while the central government can deploy its resources to anywhere under the control of the *Initial Government*.

(5) Extending the rule that calculates an affinity of a *PopCell*'s Traits with those of the *Initial Government* in such a way that its value for the *PopCell*s located in the south essentially consists of a *DD*-weighted sum of an affinity with the regional government and that with the central government.

(6) Allowing the regional government, along with its accompanying *PopCell*s in the south, to break away from the central government if the total amount of the former's mobilized resources exceeds that of the latter's.

The distinction between the 'north' and the 'south' here is identical with that in the regional dimension of *PopCell*s' Traits in virtual Sudan. Considering the situation in post-CPA Sudan, the central government inherits the *Traits* ("01","01","01") from the *Initial Government* in the preceding simulations; while the regional government's *Traits* is set to ("*","*","02").

3. Secession

From the perspective of the people of the south, the secession of their land from the northern half of the country represents the most advanced form of self-determination. They finally opted for this path, leading to the birth of the new state, South Sudan, in July 2011.

This policy option, historically much debated, can be easily examined in virtual Sudan: by splitting the virtual state into two parts along a specific border. This border is again derived from the data that was employed to differentiate regional traits of *PopCell*s in virtual Sudan[17]. Assuming the continued dominance of the current leadership in each part, the *Traits* of the two *Initial Governments* in two separate virtual states, namely, virtual North Sudan and virtual South Sudan, are set to ("01","01") and ("*","*") respectively, excluding the regional dimension of *Traits*.

B. Simulations and Their Results

Given the nascent nature of this study (see Conclusion), any policy implication should be drawn with some caveats on its real-world applicability. Still, policy experiments such as those illustrated here are very instructive: they sometimes reveal unanticipated consequences of various policies within a realistic environment where no one actually suffers or dies because of the negative effects of the given policy intervention.

The graphs in Figure 7 summarize the effects of the three policy options depicted above on the long-term behavior of the model. Except for the specific changes made for introducing

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17 The data attaches the heavily contested area of Abyei to the north.

each policy, the simulations were conducted in exactly the same setting as the previous ones (see Table.1 and 2). Each graph plots the frequency distributions of *DI*s sampled after 500 periods for different values of a control variable. The control variable in the first and the third graphs is the External Resources of the *Initial Government* while that in the second is *DD*. Each graph merits a brief account.

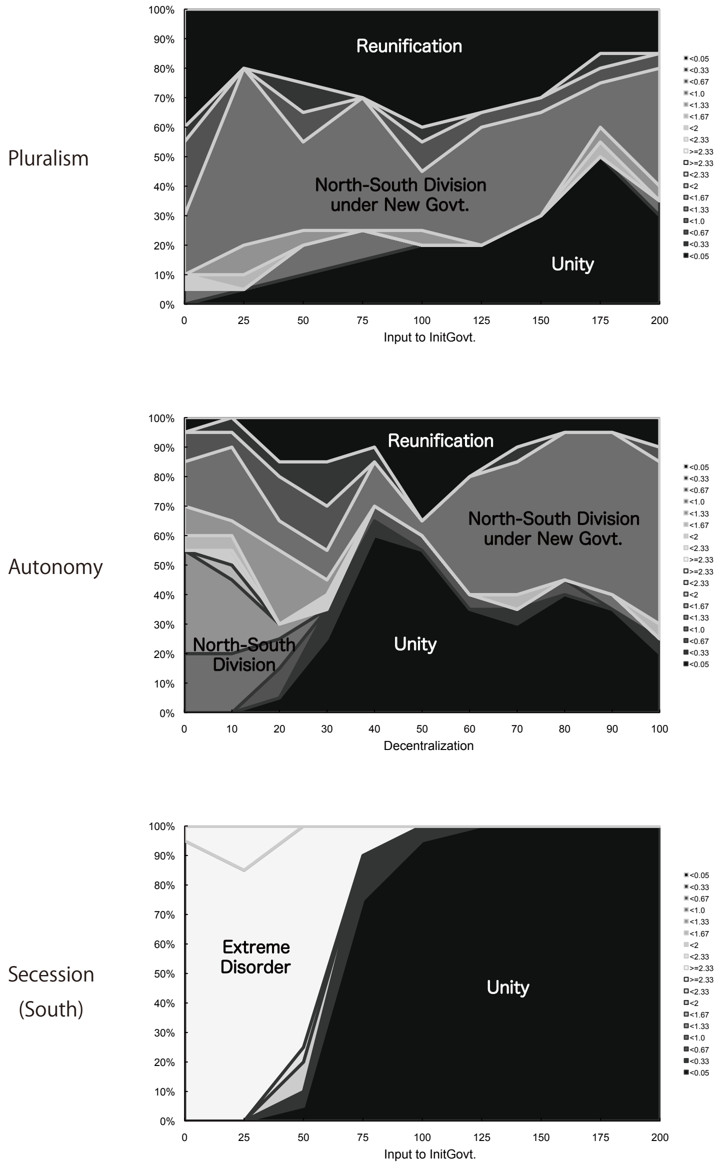

FIGURE 7. Policy Interventions and Conflict Patterns in Virtual Sudan

1. Pluralism

In virtual Sudan, pluralism does not contribute to the improvement in prospects for lasting peace. On the contrary, unless a considerable amount of *External Resources* is available, the pluralistic *Initial Government* cannot expect its own survival in the long run. Moreover, the most likely scenario after its collapse is exactly what it intended to avoid: a lasting civil war along the north-south division. This grim picture suggests the significance of the state's spatial configurations from another angle. The northern part of virtual Sudan has a vast area occupied by populous and mostly homogenous inhabitants, namely, the Arab/Muslim population. There, the pluralistic government cannot compete with a more exclusive *Ruler* that is deeply inclined to the Arab ("01") and Muslim ("01") traits. Since the latter *Ruler* has nothing to share with the southern population, with its rise in the north, the persistent pattern of the north-south conflict simply comes back.

2. Autonomy

Some form of decentralized arrangement in the south is likely to considerably alter the dynamics of virtual Sudan. While the corresponding graph in Figure 7 still shows the persistent pattern of the north-south civil war, it also suggests a notable change: the autonomy in the south can bring rare unity to virtual Sudan within a certain range of *DD*. Such a scenario is the most probable around *DD*=0.4, indicating that this level of decentralization ensures an appropriate mix of the *Initial Government*'s legitimacy and presence in the south.

3. Secession

The last graph in Figure 7 shows grim prospects for virtual South Sudan after the secession. In fact, as two panels in Figure 8 illustrate, the partition of virtual Sudan brings starkly contrasted scenarios to its former constituent parts. While virtual North Sudan maintains its territorial unity with less difficulty, its counterpart in the south is likely to be plagued with fierce conflicts among multiple *Ruler*s, which bring about serious disintegration of territorial rule. As the previous simulations demonstrate, the unity of the south is always precarious. Left with the sparsely populated and vastly stretched area that offers few resources, the government there finds substantial difficulty in consolidating this unity.

At the same time, the graph in Figure 7 also suggests that the situation is not totally hopeless. With a fair amount of *External Resources*, the government in the south can cope with the predicament. In the context of the actual Sudan, various sources of *External Resources* are conceivable for the south, including possible revenues from the oil fields scattered around the north-south border. Given this interpretation, it can be said that oil, which is one of the major issues yet to be settled between the north and the south, has direct implications for the peace and unity of the new country.

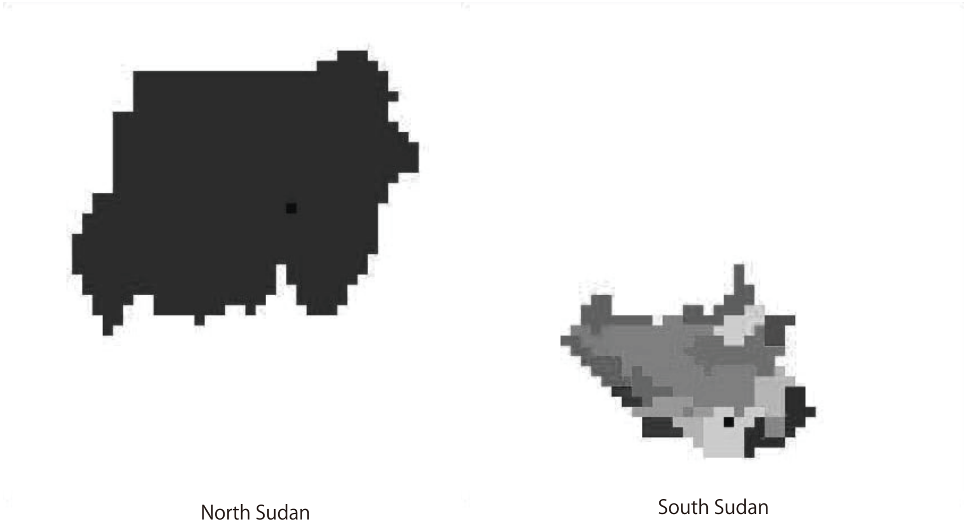

FIGURE 8. Spatial Patterns of Conflicts in Virtual North Sudan and South Sudan

VI. Conclusion

By employing MAS and GIS in a fully integrative manner, this study has offered a promising alternative for analysis of civil conflicts. First of all, it provided the research platform of virtual states, which makes the difficult intellectual task of capturing spatial dynamics of conflict largely manageable, and, in so doing, broadens the theoretical focus of conflict research to include the crucial process of state territorial integration and disintegration. Second, through the incorporation of various empirical data on the existing states within a common framework, this platform also enables researchers to explore spatial dynamics of conflicts in a highly contextual manner, without being bogged down in excessively idiosyncratic and unstructured arguments. Third, the research design built on this platform opened up the prospects for deeply integrated endeavors to theoretically understand as well as practically manage conflicts, which could significantly blur the traditional distinction between academic and policy fields of research.

This fresh approach to civil conflict received an encouraging initial boost from a considerable extent of congruence between the simulated spatial dynamics of conflict and their real-world counterparts. As is indicated above, however, the congruence is far from being complete. In order to achieve a better fit with reality in a broader range of cases, constant update both of the theoretical model and the empirical data is necessary. For example, the MAS model can be improved and extended substantially in several aspects, including, most notably, the explicit incorporation of trans-boundary influences exercised by neighboring countries and other external actors. Likewise, in addition to the efforts made to improve the quality of the GIS data, continuous efforts are needed to expand the data sample far beyond Northeast Africa. As is reported elsewhere (Sakamoto 2013), some of these endeavors have already been underway.

In addition to the problems about the research platform itself, there is also a crucial methodological challenge: its empirical validation. Specifically, the generated spatial dynamics of conflicts in different virtual states have to be subjected to more vigorous, preferably more quantitative, examination than the one offered here, which remains a somewhat sketchy comparison drawn with descriptive accounts of reality. This is a potentially serious but not insurmountable challenge since it is, in the end, largely a matter of data availability. In this respect, the ever-growing supply of relevant GIS data in recent years is quite encouraging. For example, there are now several GIS datasets on the location and scope of various conflict events (e.g., Raleigh et al. 2010). These data have enabled researchers such as Weidmann and Salehyan (2013) to employ sophisticated quantitative methods for validation as well as calibration of their respective MAS models. The comparative development is awaited here, especially in collection of the spatial data explicitly describing diverse conditions of territorial integration and disintegration that the sovereign states have actually displayed.

Overcoming these and other challenges would make it possible to analyze a larger number of civil conflicts in a more accurate and extensive manner. Researchers would also be able to draw more definitive conclusions regarding the effectiveness of various policies by examining the condition of virtual states prior and posterior to the implementation of these policies. It is hoped that the platform of virtual states offered here will not only become a useful academic tool for understanding and explaining conflicts, but also a strong practical tool for pursuing sustainable peace in many war-torn and war-prone societies in the world. The present study at least indicates that this is not an infeasible objective.

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