

A System Dynamics Approach to Analyzing Violence, Death, and Displacement in Darfur

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This paper presents a System Dynamics approach to analyzing the violence and widespread death and population displacement in Darfur, Sudan, as observed since 2003. We lay a foundation for using simulation to investigate the underlying structure and effects of violence; model analysis indicates that the dynamics may be driven more by the population at risk than by aggressor intent. This model can aid in future policy analysis and establishes a foundation for using System Dynamics to understand the structure and pattern of genocide. We present several challenges to analyzing the Darfur crisis including observability, information delays, and the choice of metrics. Finally, we discuss modeling results and options for intervention and propose several policy questions and areas for future research.

Keywords: Darfur, Sudan, Violence, Refugees, Population Displacement, Policy, Genocide

Our research focuses on the dynamics of the mass killing and displacement of the people of Darfur, in the Western region of Sudan, since 2003.

In Darfur, violence has led to an estimated 450,000 deaths and 2.5 million displacements, including refugees fleeing to Chad and internally displaced persons (IDPs) in settlement camps within Darfur. The affected populations are facing widespread disease and starvation, and many humanitarian organizations have been unable to serve in the region due to the ongoing violence, lack of security, and lack of access. In many cases, the Sudanese government limits the form of international aid. Additionally, since the peace agreement in May, the under-staffed and under-funded African Union (AU) Forces have been unable to stabilize the violence and IDP crisis. Sudan refuses to allow additional help from United Nations (UN) troops.

The observed patterns of violence – mass killings, destruction of land, physical abuse, and forced displacement – that have evolved since the conflict began in February 2003 demonstrate the dynamic nature of this problem; it has gone through periods of acceleration and deceleration, indicating dynamic behavior. We note many citations from literature on the causal rela-

tionships between the actions of resistance groups, militias, and their effect on humanitarian aid. Policy is influenced by international awareness of the crisis and actions carried out affect the resistance and militia groups, as well as the Sudanese government. These causal relationships create a highly complex and dynamic environment where the coupling of problems demands careful evaluation of policy. This paper presents a method for explicitly analyzing the internal dynamics of the Darfur crisis. In addition, it presents an analytical tool that helps us develop an endogenous explanation for the crisis, serves as a method for deciding the case of genocide, and acts as a test-bench for simulating the effectiveness of future policy options.

Background of Darfur

Geography

Darfur is the largest region of Sudan, situated in the West, and is about the size of France. Darfur borders Chad, the Central African Republic (CAR), and Libya. Only 15 percent (six million) of Sudan's population lives in Darfur. Sudan is the largest country in Africa and is approximately one quarter the size of the United States. Water, a critical resource in Sudan and throughout Africa, is channeled by the Nile River and its tributaries. This covers an area of about 2.5 million square kilometers with a population of nearly 40 million, primarily living in urban centers. Sudan's political stability is of great international interest because of the number of countries it borders: Egypt in the North; Eritrea, Ethiopia, and the Red Sea in the East; Uganda, Kenya, and the Democratic Republic of Congo in the South; and Chad, the CAR, and Libya in the West. Sudan is rich in petroleum and has small reserves of other minerals such as iron ore, copper, zinc, tungsten, gold, and silver (World Bank, 2005).

Ethnography

For political strategies and expediency, the Darfurian identities have been polarized into "Arab" and "African". The Government of Sudan (GoS) has exploited these categorizations for its own benefit (De Waal, 2004b). Despite this categorization, however, it is rarely possible to tell, on the basis of skin color, to which group a person of Darfur belongs. Understanding this subtlety is essential to analyzing the crisis, since preconceived notions shape the way the dynamics are studied, beginning with selection of variables. There are between 40 and 90 ethnic groups in Darfur (Flint & De Waal, 2005). Most groups have been in the area for centuries and all are Muslims of one sect or another, mainly Sufi or Madhi. Until the Darfur conflict, the different groups mixed freely and intermingled, uniting in marriage and family groups, and forming pastoral, farming groups and semi-nomadic herding groups. These nomadic groups occupied well-defined areas and followed established courses (De Waal, 2005).

Political/Military Conflict

During the last few decades, several factors contributed to the violence in Darfur. Widespread use of the land and environmental factors have resulted in desertification. The Sahara desert is gradually expanding into the Sahel region, shrinking water supplies and reducing available land for herding and even less arable land for farming. In the wake of the drought and famine of 1984-1985, a series of local conflicts erupted. Though the people of Darfur already lived in a resource-poor region, the herding groups were set against the farmers in a struggle for diminishing resources. No government intervention occurred to alleviate the conflict, and as a result, both sides armed themselves.

The GoS marginalized the region of Darfur, ignoring the basic infrastructure, health and educational needs of its people. Additionally, Darfur was not included in the negotiations and subsequent peace agreement that ended Sudan's long civil war in the South. "Cognizant of the fact they had been left out of the peace process whose results would not help them, and frustrated by government inaction on past land conflicts and persistent complaints for being marginalized by the GoS, including loss of their jobs to Arabs, sections of non-Arab Darfurians launched attacks on several army positions" (Nasong'o & Murunga, 2005). The GoS, fearing that an armed rebellion would inspire resistance groups in other parts of the country, began the campaign against Darfur. The Sudanese military began aerial bombings and the GoS armed a paramilitary group called the Junjaweed. The Junjaweed were needed because the majority of the armed forces were from Darfur (Nasong'o & Murunga, 2005); the capital city, Khartoum, feared that the forces would refuse to fight family and friends if they were sent to Darfur. Encouraging the ideology of Arab supremacy (Arabization) established among some of the Bedouin groups by Libyan President Muammar Gaddafi during the 1980s, the GoS recruited and armed the Junjaweed, who "stole, burned, mutilated, killed and raped – subjecting tiny communities to unimaginable horrors" (De Waal, 2004). The Junjaweed, often with full army support, eradicated whole villages and destroyed wells and fields so that they could not be used again.

The government policy was not just one of counterinsurgency but to destroy a way of life. The Junjaweed and the Sudanese military either stole or destroyed all food and animals. Anything of value was either removed or burned. Villages, including schools, clinics and markets were decimated. Wells were polluted – often with dead bodies – and fields were burned and salted. With over two million people displaced, the GoS then began blocking humanitarian aid efforts. The Junjaweed blockaded displacement camps and prevented delivery of aid. In Khartoum, supplies would not be released to agencies. On the few roads that exist in Darfur, roadblocks and hijackings occurred regularly.

Since February 2003, an estimated 450,000 people have died and over two million have been displaced. What is being labeled as a conflict between "Arabs" and "Africans" to the international community is an attempt to obfuscate by the central Sudanese government. The GoS has attempted "to suppress a rebellion motivated by a demand for basic human rights and regional autonomy" (Howard-Hassman). The Junjaweed, together with the Sudanese military, have continued to systematically commit acts of mass murder, rape, torture and mutilation in Darfur (State Department, 2004).

Genocide

The United Nation's (UN) Convention on Genocide of 1948 (signed by over 100 nations in 1951) defines genocide as a punishable crime. Article Two of the Convention defines genocide as "any of the following acts committed with the intent to destroy, in whole or in part, a national, ethnic, racial or religious group, as such:

- Killing members of the group
- Causing serious bodily or mental harm to members of the group
- Deliberately inflicting on the group conditions of life calculated to bring about its physical destruction in whole or in part
- Imposing measures intended to prevent births within the group
- Forcibly transferring children of the group to another group (United Nations, 1948)

Article Three of the Convention continues on to specify that in addition to the act of genocide itself, conspiracy, direct and public incitement, and the attempt to commit genocide, as well as complicity in genocide are equally punishable acts. Beyond punishing the perpetrators of such a crime, the convention also imposes the general duty on the signatories “to prevent and punish” those who commit genocide.

Model Structure

Modeling Goals

Our analysis is directed towards the UN and international community in service to the people of Darfur. The UN has a vested interest in the Darfur crisis because of their ability and obligation to respond to the crisis, as the Sudanese government has been largely ineffectual. In addition, a UN recognition of genocide leads to additional obligations for UN members. Therefore, the objective of our modeling and analysis is to provide insight for the UN and international community on the effectiveness of alternative policies.

In this paper we focus on the goal of restoring peace to Darfur by ending and preventing future violence-related deaths (both direct and indirect), and displacement (both refugees and IDPs). This goal is measured by tracking the deceleration, stabilization, and eventual decrease in displacements and deaths due to disease, starvation, and violence. Future works will address subsequent goals: insuring that all the people of Darfur are geographically, socially and economically reintegrated into Darfur society; and, opening the political space necessary for reconciliation and creating opportunities for interchange with the UN, AU, and neighboring countries (e.g. Chad and the Central African Republic).

Objective

Our objective is to present a System Dynamics approach to analyzing the crisis in Darfur from February 2003 to the present (April 2007). We describe a simulation model and key causal relationships and feedback structures to analyze the trends of displacement and deaths due to violence. We explore the following seven questions:

1. What are the primary dynamics that might drive excess mortality and displacement?
2. What are the current dominant feedback loops?
3. What are possible effects on neighboring countries?
4. What are the linkages between structure and behavior in cases of genocide?
5. What are the opportunities for intervention?
6. How is policy effectiveness measured?
7. How is model success determined?

Model Formulation

Our research focuses on observed events, phenomena, and time-series data from February 2003 to present. We focus on the following main stock variables which form the basis for future policy and action (see Appendix A for the complete list of included and excluded variables):

- Non-displaced people of Darfur
- Displaced people of Darfur in transit
- Displaced people of Darfur in settlement camps
- Deaths in Darfur due to direct violence

- Deaths in Darfur due indirectly to violence and displacement (starvation and disease) and lack of aid
- Militias and Sudanese military
- Resistance groups

Exogenous model variables consist of the fractional rates, time delays, and constants that govern the flow processes between stocks.

Figure 1 illustrates how the people of Darfur transition through various phases. Initially, all people of Darfur begin at home. Conflict then causes people to join resistance groups and militias, causes displacement, and results in death due to violence. Because people in transit are more susceptible to attacks, we disaggregate the process of displacement into two stocks: “in-transit” and “at displacement camps”. This also allows us to capture the dynamics of multiple-displacement. Death can occur from all states. Militias, military, and resistance groups grow due to both voluntary and involuntary recruitment. Our simulation model is shown in Appendix B and model equations are documented in Appendix C.

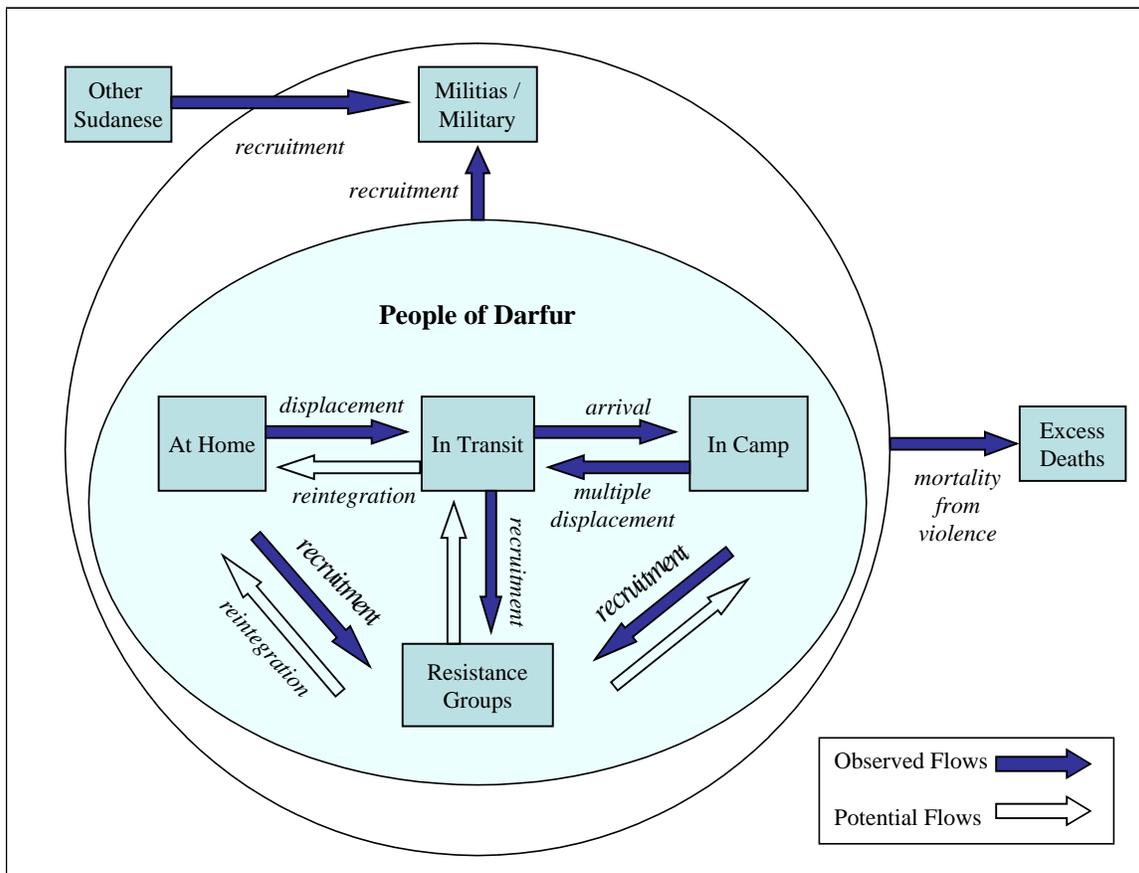


Figure 1. Simplified Stock and Flow Diagram for Genocide and Displacement in Darfur

The model of the Darfur crisis consists of six key components:

1. Militias and Military
2. Resistance Groups
3. The Process of Killing
4. The Process of Displacement

- 5. Displacement Camps and Multiple Displacement
- 6. Disease, Starvation and Aid

Militias and Military

Militia and military violence are abstracted as a single concept since both groups inflict violence against resistance groups and the people of Darfur. Sources describe coordinated attacks between the GoS and the Junjaweed where the Government attacks first with bombs, and the Junjaweed follow with attacks by horseback and camelback (Patrick, 2005). One factor that increases the number of militia and military aggressors is the process of involuntarily recruiting children into armed groups (Office of UN Deputy, 2006).

Militia and military growth is modeled as a Bass Diffusion process, shown in Figure 2. The first important assumption is that aggressors recruit new aggressors, both voluntarily and involuntarily. Societal pressures contribute to voluntary recruitment (diffusion element), and as noted above, there is evidence of involuntary recruitment of children (forcing function element). This structure gives rise to S-Shaped growth of militia/military membership, as seen in Figure 3, where growth accelerates initially as potential members are plentiful, and then decelerates to equilibrium as the stock of potential members drain. Figure 4 shows the predicted behavior using the model's current parameters and initial conditions, where initial aggressors and a high involuntary recruitment rate dominate the Aggressor's goal-seeking feedback loop throughout the time horizon.

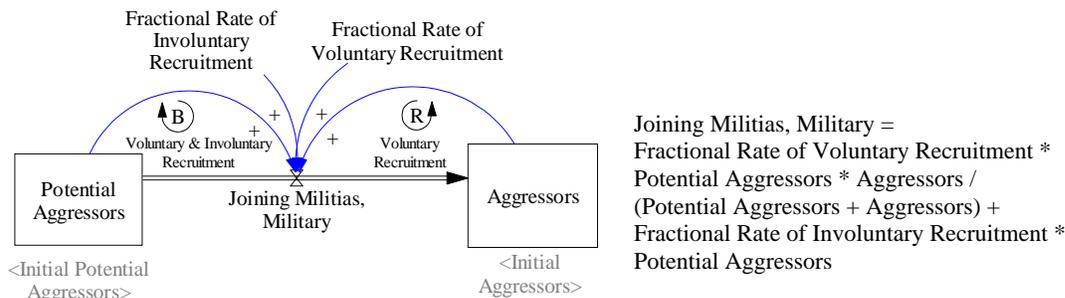


Figure 2. Structure of Militia and Military Growth

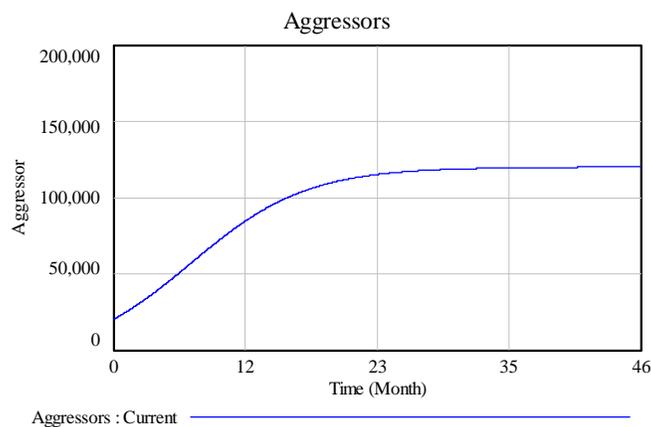


Figure 3. Aggressors vs. Time, S-Shaped Growth

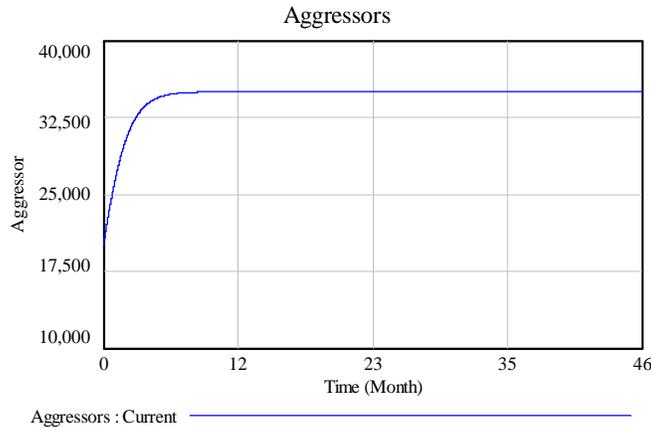


Figure 4. Aggressors vs. Time, Goal Seeking Growth

Resistance Groups

Since resistance groups in Darfur took up arms in February 2003, the Sudanese government has recruited and supplied militia forces in a sweeping campaign of attack against the civilian population of Darfur (Leaning, 2004). Boys affected by the violence become ripe for recruitment into these resistance groups (Reeves, 2006).

The growth of resistance group involvement is modeled as a first-order process as shown in Figure 5, governed by a fractional recruitment rate. This is a balancing feedback loop where the number of new recruits is a function of the potential new recruit population. The growth shown in Figure 6 is slightly damped due to additional draining of the stock “Darfurians At Home” from death and displacement. The recruitment process can be expanded into an SI or Bass Diffusion process, similar to the previous structure for militia membership growth.

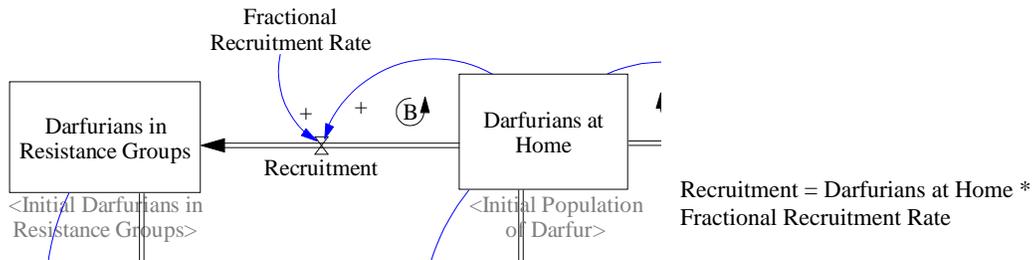


Figure 5. Structure of Resistance Group Growth

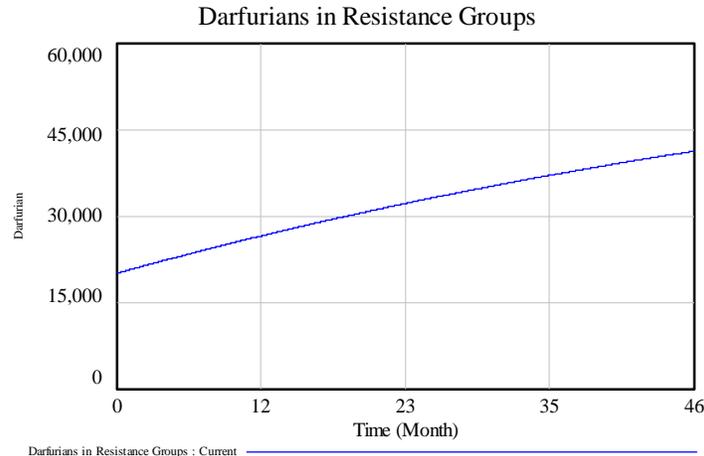


Figure 6. Resistance Groups vs. Time, First-Order Process

The Process of Killing

The militias target civilians sharing the same ethnicity as the resistance groups in Darfur in an effort to stem alleged support for enemy groups (Office of UN Deputy, 2006). Militias also directly target young men and boys (Patrick, 2005). Groups that have been attacked (sedentary farming communities) self-identify as not being aligned with groups that support militia groups whereas self-identified Arab-communities are relatively untouched by the Junjaweed and government forces (Patrick, 2005). The GoS has restricted access to Darfur over the past three years, making it difficult for UN teams to estimate excess death due to violence. In 2005, however, the death rate was estimated at roughly 10,000 per month (Udombana, 2005).

The killing and displacement processes are identical in structure (compare Figures 7 and 9). Both depend on the number of militia or military members and the frequency at which they attack the villages, as well as the size of the susceptible population. Both have the basic structure necessary for S-shaped growth. The first part of the process is dominated by a reinforcing loop due to the growth of aggressors and the large population at risk. The process then shifts loop dominance to a balancing behavior due to the draining of the susceptible population due to displacement and killing.

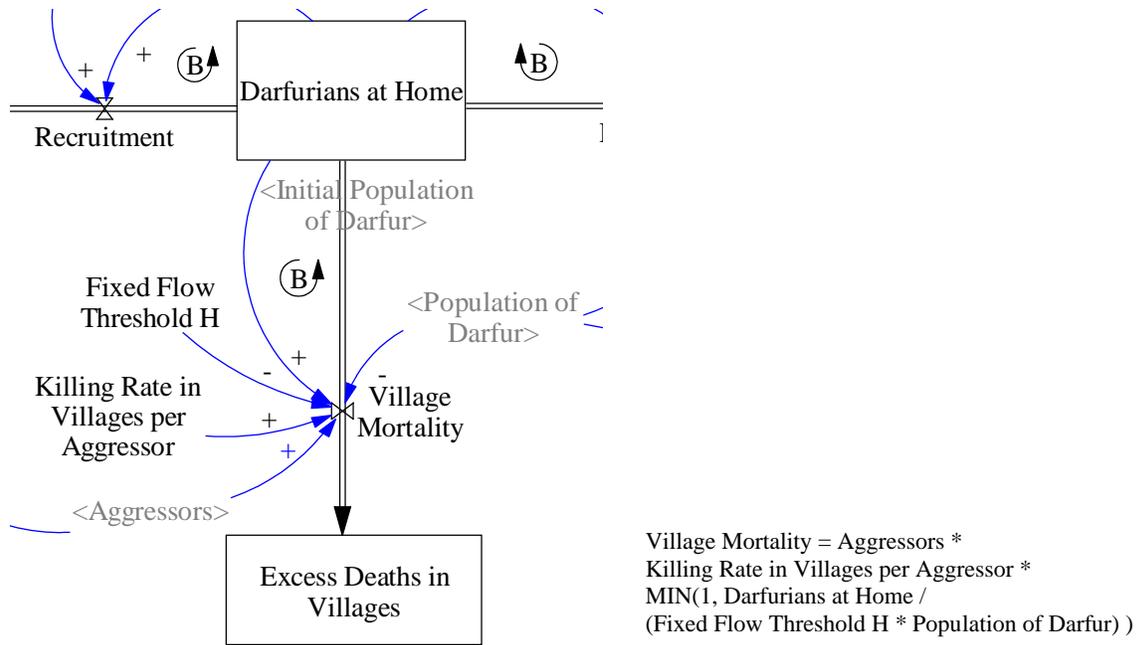


Figure 7. Structure of Killing

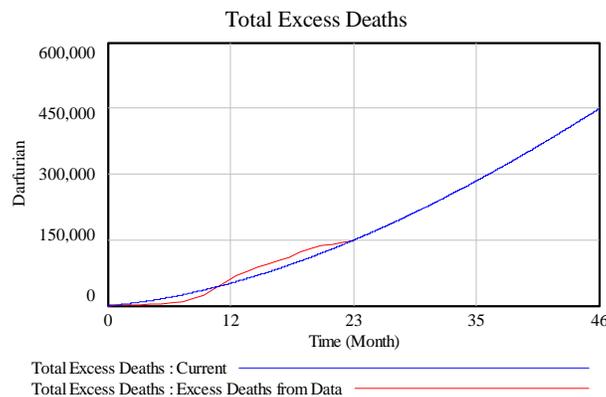


Figure 8. Total Excess Deaths vs. Time: Model Behavior and Reference Mode Data (Bureau of Intelligence and Research, 2005)

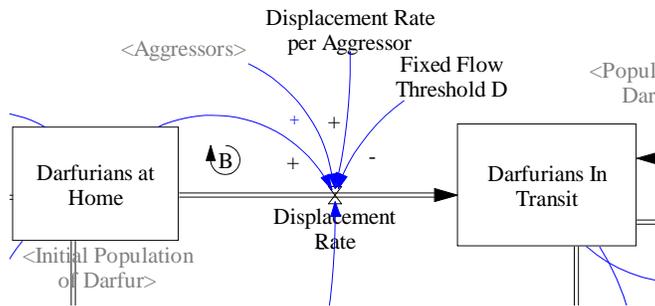
The time-series data shown in Figure 8 starts at the beginning of the conflict and ends two years into the conflict. The data represents excess deaths in Darfur beyond typical mortality rates for the region. The initial population of Darfur in February 2003 was six million. As of 2005, 180,000 to 350,000 have been killed, 300,000 fled to Chad, and there were two million IDPs in Darfur, with greater than three million who were conflict-affected (about half the population of Darfur) (Patrick, 2005).

Currently, the model does not reflect AU forces. Another aspect excluded is the violence within the Southern Liberation Army (SLA), which adds to the abuses suffered by civilians (Office of UN Deputy, 2006).

The Process of Displacement

Intensified fighting and insecurity has led to large population displacements, even when the planting season encourages a return to the farmlands (Office of UN Deputy, 2006). Large movements of populations are recorded after military and militias clash with SLA forces (Office of UN Deputy, 2006). Furthermore, an increase in abuse and violations against civilians has been compounded by their lack of protection (Office of UN Deputy, 2006). Villages are looted and burned, resources are stolen, wells are poisoned, land and fields are destroyed, women are raped, and populations are displaced into inhospitable IDP camps (Patrick, 2005).

The process of displacement uses the same structure presented previously for killing, as indicated when comparing Figures 7 and 9. Displacement moves populations from home to in-transit.



$$\text{Displacement Rate} = \text{Aggressors} * \text{Displacement Rate per Aggressor} * \text{MIN}(1, \text{Darfurians at Home} / (\text{Fixed Flow Threshold D} * \text{Population of Darfur}))$$

Figure 9. Structure of Displacement Process

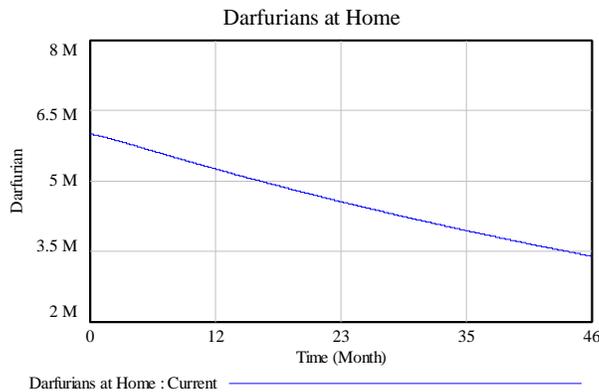


Figure 10. Darfurians at Home vs. Time

The model behavior in Figure 10 is consistent with current projections of IDPs and refugees.

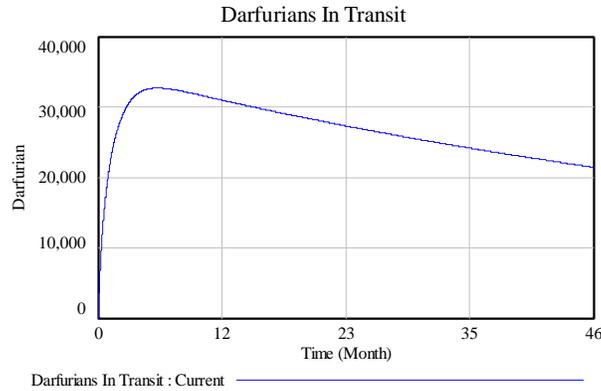


Figure 11. Darfurians In Transit vs. Time

We explored modeling killing and displacement as a constant process, a first-order process, or a constant process that transitions into first-order. Systematic acts of violence driven primarily by aggressor size and capability may produce a constant rate of killing and displacement. If violent acts are more random and, in addition to aggressor capability, are also driven by the available population at risk, a first-order process is appropriate. A population that is drained at a constant rate may eventually shift to a first-order flow once the susceptible population reaches some fraction. In order to evaluate these processes, our model allows us to change structure where killing and displacement are constant through some fraction of the initial population, and then shifts into a first-order process.

Displacement Camps and Multiple Displacement

IDPs continue to be targeted by the militias due to their extreme vulnerability, and many have been displaced multiple times (Office of UN Deputy, 2006). In addition, distributions of food and non-food items have been low due to insecurity, lack of funding, and inaccessibility which also forces large numbers of IDPs to flee the camps. (Office of UN Deputy, 2006) It is difficult to estimate the number of IDPs because headcounts are not conducted every month, resulting in a time lapse between displacement and registration. This, together with continuous movements which are not easily tracked, results in significant delays before IDPs appear in statistics (Office of UN Deputy, 2006).

We model camp arrivals as a first-order process with an average travel time, as shown in Figure 12, while also noting that people in transit are susceptible to attacks. The process of modeling multiple-displacement is similar to the process for displacement. In our current model, multiple displacement is caused by external violence. We have not yet analyzed factors of over-capacity, lack of aid, and intra-IDP fighting (Office of UN Deputy, 2006). We estimate that the average time to reach displacement camp is two weeks, although it is difficult to estimate this parameter accurately due to the lack of data and variability.

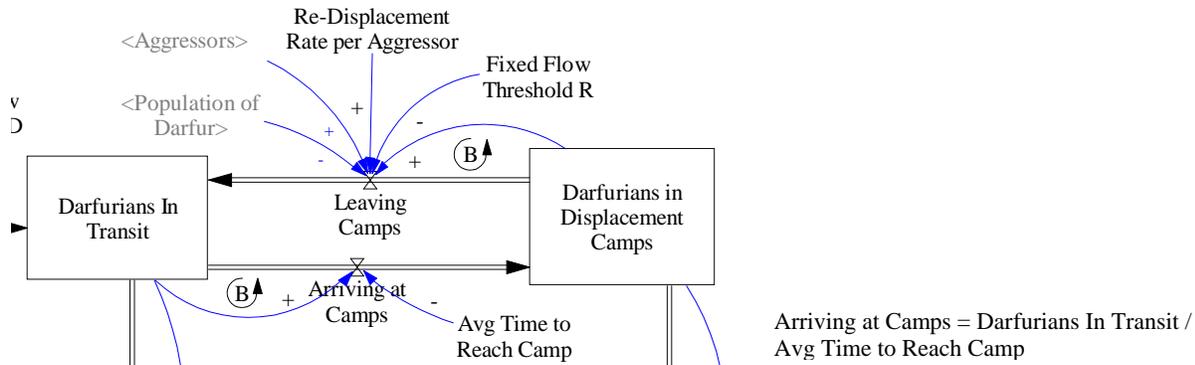


Figure 12. Structure of IDPs and Multiple-Displacement.

Figure 13 displays time-series data for the number of IDPs starting one year into the conflict through mid-2006. The model structures are not adequate for capturing the rise, overshoot, and settling behavior, while still satisfying reasonable death estimates in the same simulation run. The model reproduces the rise and fall with certain parameter settings; however, it is not possible with the current structure to simultaneously track both IDP and death reference modes.

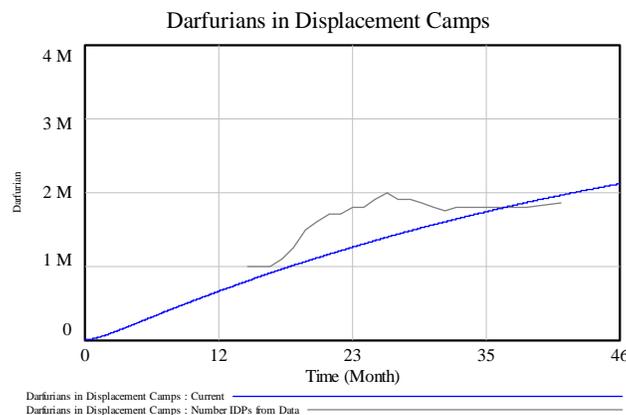


Figure 13. Darfurians in Displacement Camps vs. Time: Model Behavior and Reference Mode Data (Office of UN Deputy, 2006).

Disease, Starvation, and Aid

Many challenges prevent the adequate administering of aid to IDPs, resulting in deaths due to disease and starvation. Humanitarian access in Darfur is affected by the degree of insecurity, denial of access, and the continued harassment of humanitarian organizations and workers (Office of UN Deputy, 2006). In addition, intra-SLA fighting causes humanitarian organizations to withdraw (Office of UN Deputy, 2006). Funding shortages result in ration cuts (Office of UN Deputy, 2006). It is difficult to find consistent, comprehensive estimates of mortality that distinguish disease- from starvation-related deaths.

Starvation affects members of a homogenous population independently and equally, and at a very high level of abstraction is modeled as a first-order process, as shown in Figure 14. Disease however has the added element of diffusion through contagious infected populations and requires an SI or SIR structure at minimum. Although we did not implement this structure, it is a natural extension to our model. Figure 15 shows the simulated trajectory of excess deaths at camps.

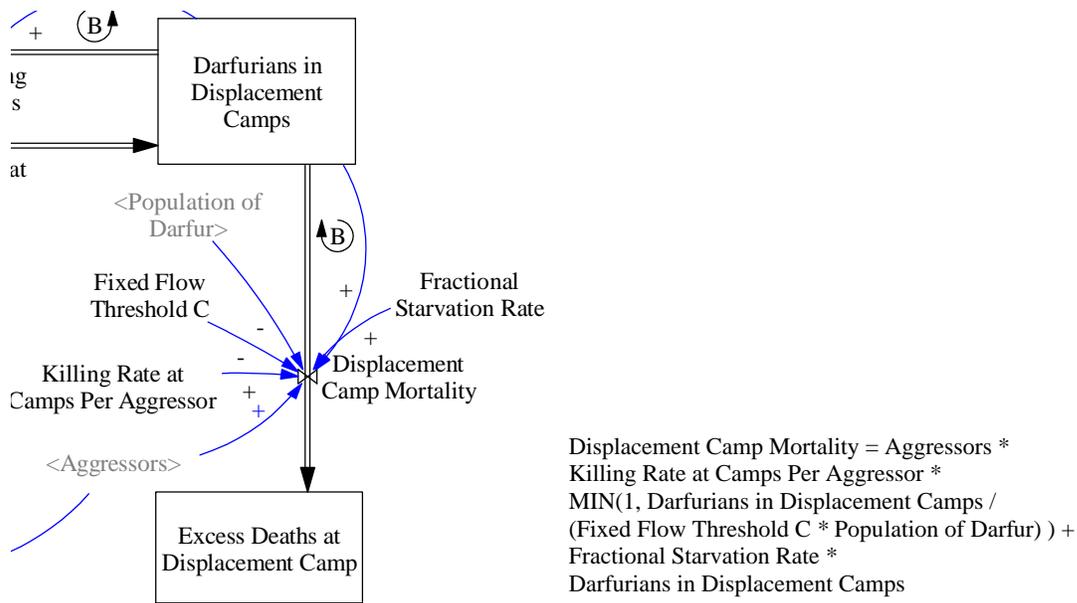


Figure 14. Structure of Displacement Camp Mortality

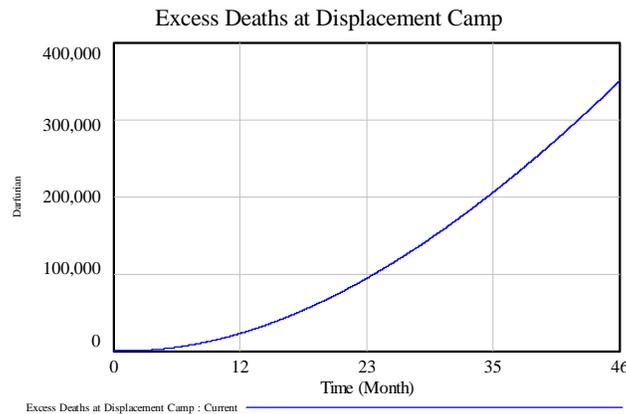


Figure 15. Excess Deaths at Displacement Camp vs. Time

Displaced population is not a useful metric for evaluating policy effectiveness. An increase in displaced persons obviously is not desirable when the client’s goal is to decrease displacement.

On the other hand, a decrease in the displaced population does not necessarily indicate successful re-integration into society; it could indicate an increase in mortality or that more IDPs are in transit.

Validation and Testing

Structural Assessment

All stocks represent human populations, and therefore never go negative. In our model this is assured by using first-order material delays or hybrid first-order, constant flow processes which never drain stocks below zero. Stocks are only drained into other stocks or ultimately

death. The stocks represent a collectively exhaustive, mutually exclusive set of states under our level of disaggregation. Limits to growth for each of the stocks is captured by the fact that stocks receive no more than the total of the stocks that flow into them. That is, there are no open sources or sinks in our stock flow diagram. The sum of all the “people of Darfur” stocks (including death), therefore, is equal to the initial number of people of Darfur at home (six million). This verifies flow conservation.

Behavior Reproduction

We compared simulation results against time-series data for death and displacement; however, because the majority of data collected is inconsistent or incomplete, we have only rough estimates. Behavior reproduction tests demonstrate that with the basic structures employed, we match qualitative trends; however, systematic bias remains indicating that missing feedback loops are not yet captured.

Model Limitations

The model does not include economic or political factors, policy, or the dynamics of AU Forces. After calibrating to past behavior, the next step is to incorporate observation feedback that informs or influences policy. We are currently researching the dynamics of conflict between militia and military members and resistance groups. Our current model focuses more on the effects of violence than the cause.

Model Suitability

This model is suitable for evaluating the effects of systematic or random acts of violence against the people of Darfur and for understanding flow processes between states. We use the model to test dynamic hypotheses derived from reports and literature on the crisis, and whether they are capable of producing observed behavior. The model is a basic stock-flow structure, expandable to incorporate and test feedback links that affect death and displacement. The model can be expanded to incorporate policy levers based on observation of the crisis.

Results

In response to the seven questions we explored throughout our analysis, we have summarized our results and insights based on model exploration, testing, and sensitivity analysis.

1. The dynamics of mortality and displacement are driven primarily by two feedback loops: the reinforcing loop that increases violence (growth in militia/military population and violent acts), and the balancing loop of the susceptible population at risk. Our model currently does not model the dynamics of AU troop protection, or military and humanitarian resource depletion, which may also contribute to the dynamics.
2. The dominant feedback loop currently driving displacement and mortality is the balancing loop associated with the depletion of the population at risk, as opposed to the reinforcing loop of increasing militia and military population. This is why even in the absence of AU or peacekeeping forces, the model predicts a deceleration in the number of deaths and displacements. When compared to observed data, we also see that currently the number deaths and new IDPs are decelerating or holding constant, despite the ineffec-

tiveness of AU presence. The depletion of the stock of people at risk is slowing down the displacement and death rates, making it difficult to judge the individual impact of current efforts and future intervention based on death and displacement statistics alone.

3. One possible effect on Sudan's neighboring countries is that an abundance of new people at risk (a fresh stock) could again accelerate the current crisis, if left unabated.
4. Important linkages between structure and behavior in the case of genocide may be found in the flow process of displacement and killing. A systematic process may be more likely to produce a constant flow of death and displacement, not as sensitive to the susceptible population at risk until a large portion of the population has been removed. More random acts of violence would resemble a first-order flow response. In our model for Darfur, we can test for systematic or random violence by changing the point where displacement and killing shifts from a constant flow to a first-order process. Initial simulation runs are inconclusive due to incomplete reference mode data sets.
5. Options for intervention fall into three categories: reducing vulnerability of the population at risk (e.g. deploying additional peacekeeping forces); reducing the means of violent incidents (e.g. affecting military resource supply or military/militia recruitment), and reducing will for violent incidents (e.g. peace treaties, additional resources, political or economic incentives).
6. Policy effectiveness can be measured in part by tracking additional displacements and excess deaths due to disease, starvation, and violence. As we have shown, however, we must also measure re-integration and gain more insight into what happens to people during transit and re-displacement.
7. In order to use the model to design effective policy, we must first show that it is consistent with data on displacement and deaths provided by the UN (UNICEF, OCHA and WHO), USAID, CARE, and Doctors Without Borders. Then we must identify possible lever points for intervention. Model success requires identifying high-leverage opportunities to introduce balancing loops that would both stabilize the crisis and lead to an environment conducive to reintegration efforts. Success of the model also requires the ability to gain insight on why certain policies would be ineffective.

Implications and Next Steps

Even with the UN's definition of genocide, detection in Darfur is complex. Our approach is to study the conflict in Darfur as a system and investigate the dynamics. System Dynamics allows a unique approach to investigate, compare, and contrast patterns of violence that arise from different roots. Genocidal acts intentionally target national, ethnic, racial, or religious groups in whole or in part. This creates a causal-loop structure distinct from other violent political actions that can be tested through simulation. Policy designed to address genocide must consider the effects of mass death and displacement on future generations. The loss of nearly half a million people and the displacement of half the population of Darfur will have profound effects on reintegration and future economic and social policy.

In modeling the crisis in Darfur and designing effective policy, two challenges arise. First, there is a lack of data for people in transit, and it is difficult to obtain accurate excess mortality rates. Also, the significant delay time between camp arrival and camp registration leads to misestimates of the current crisis, making it difficult to assess the effectiveness and consequences of policy.

Our model has focused on the social and military domains, and the effects of violence. Future work will expand the baseline model to incorporate political, economic, religious, and geographic factors that influence conflict and violence. In developing the conflict model, we will consider the effects of military and humanitarian resource availability, accessibility, peacekeeping efforts, and AU troop protection.

Our goal is to use the model to evaluate alternative policies and their effectiveness, projecting several years into the future, with the goal of answering the following policy-related questions:

- Can/should the UN declare genocide in Sudan (Patrick, 2005)? If so, what actions follow?
- Should the international community impose targeted sanctions against Sudan and Sudanese nationals accused of war crimes in Darfur (BBC News, 2006)? What type of sanctions (economic, travel) (Patrick, 2005)?
- What is the most effective deployment of peacekeeping troops (who, where, when, and how many)?
- Should a protection force be commissioned, in addition to the AU, to counter all aspects of violence with a full mandate to protect civilians at risk (Patrick, 2005)?
- What is an adequate mission deployment and how do we define its mandate (Pendergast, 2007)?
- What is the most effective use of aid workers (who, where, when, how many, and what type of aid)?
- Should new or revised peace agreements be enacted? How (Kristof, 2006)?

To answer these questions, several aspects of the crisis entail further investigation and data mining. The dynamics of voluntary recruitment into both resistance forces and militias require research and validation. Additional information is needed to calibrate the fractional recruitment rates of children, the initial number of potential militia and military members, and the initial number of actual militia and military members in February 2003. Also, the time from when boys are affected by violence and when they are susceptible to recruitment needs to be analyzed. Further work is necessary to study the dynamics of how AU forces affect resistance groups, militias, and the GoS, and the protection they provide to IDPs and humanitarian aid workers. More research is needed to study displacement rate and its relationship to military, militia, and at-risk population size. Another area of concern is the anti-DPA sentiment in IDP camps: this has led to attacks on AU personnel and assets, forcing the AU to reduce its presence in a number of IDP camps, and subsequently increasing camp vulnerability to outside attack (Office of UN Deputy, 2006). Lastly, we seek current data that tracks population movements, death at displacement camps and the phenomena of multiple displacement.

References

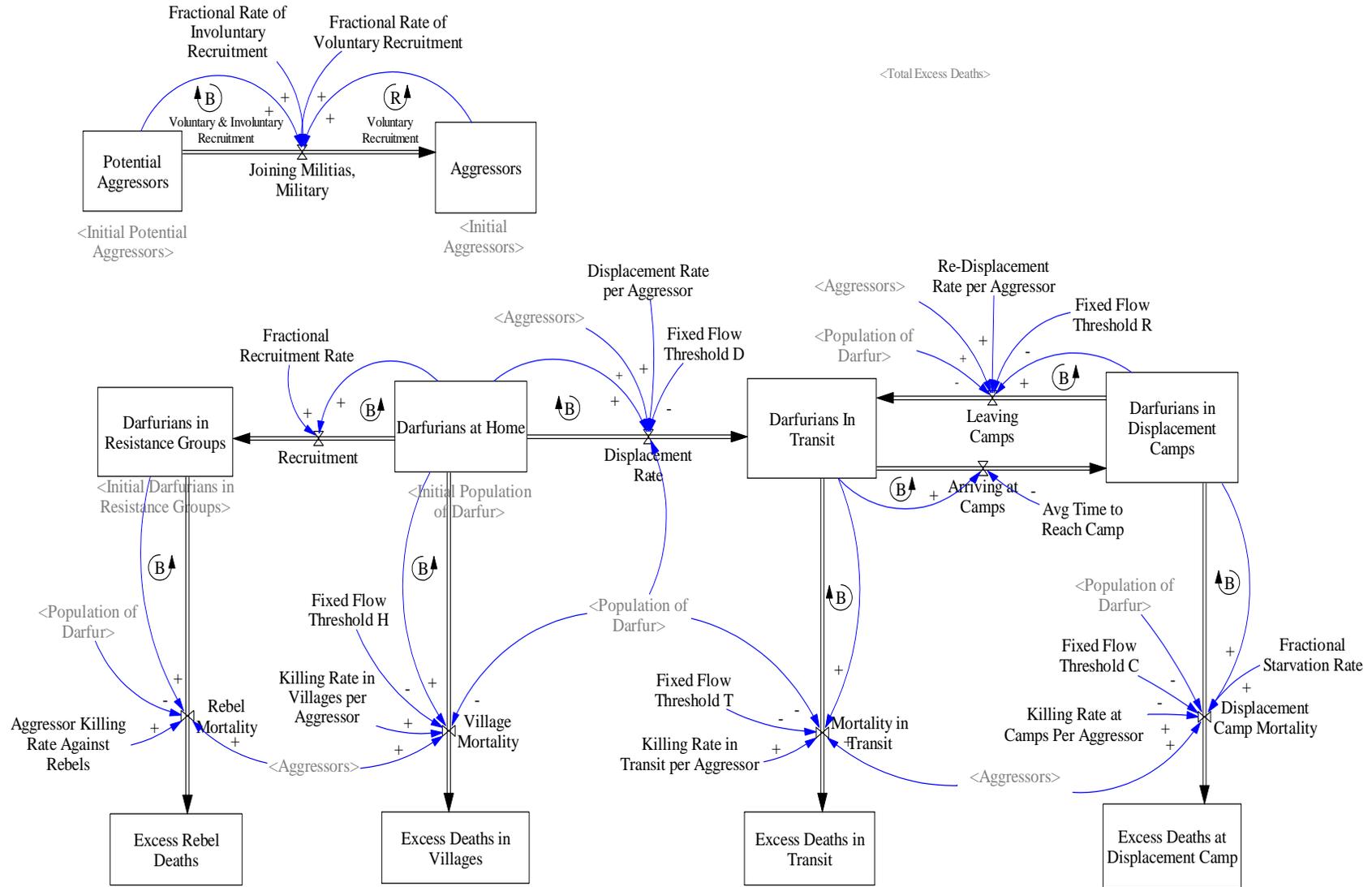
- British Broadcasting Company News. 2006. Q&A: Sudan's Darfur conflict. British Broadcasting Company, <http://news.bbc.co.uk/2/hi/africa/3496731.stm> (accessed 9/13/2006)
- De Waal, A. 2005. Briefing: Darfur, Sudan: Prospects for peace. *African Affairs*, 104, no.414:127-135.
- De Waal, A. 2004a. Counter-insurgency on the cheap. *London Review of Books*, no.15 (August 5).
- De Waal, A. 2004b. Who are the Darfurians? Arab and African identities, violence and external engagement. *Justice Africa*.
- Edkins, J. 2005. Mass starvations and limitations of famine theorizing. *International Development Society Bulletin*, 33, no.4: 12-18.
- Eighth report of the Secretary General to the Security Council. 2006. *Darfur: Whose responsibility to protect? no.(October 26)*. Human Rights: New York.
- Flint, J. & De Waal, A. 2005. *Darfur: A short history of a long war*. Zed Books: London and New York.
- Howard-Hassman, R.E. 2005. Genocide and state-induced famine: global ethics and western responsibility for mass atrocities in Africa. *Perspectives on Global Development and Technology*, 4, no.3-4: 487-516.
- Kristof, N. 2006. China and Sudan, blood and oil. *The New York Times*, National edition, April 23, Sec. 1:15.
- Kristof, N. 2006. When genocide worsens. *The New York Times*, National edition, July 9, Sec1:13.
- Leaning, J. 2004. Diagnosing genocide – the case for Darfur. *New England Journal of Medicine*, 351, no.8:735-739.
- Nasong'o, S. W. & Murunga, G.R., 2005. Lack of consensus on constitutive fundamentals: Roots of the Sudanese civil war and prospects for settlement. *African and Asian Studies*, 4, 1-2: 51-82.
- Office of UN Deputy Special Representative of the UN Secretary-General for Sudan, UN Resident and Humanitarian Coordinator 2006, July 1. *Darfur Humanitarian Profile No. 24*. New York: United Nations.
- Patrick, E. 2005. Intent to destroy: the genocidal impact of forced migration in Darfur, Sudan. *Journal of Refugee Studies*, 18, 411 – 427.

- Pendergast, J. 2007. The answer to Darfur: How to resolve the world's hottest war. *Enough: The Project to Abolish Genocide and Mass Atrocities*. International Crisis Group
- Reeves, E. 2006. Darfur, eastern Chad face unconstrained human destruction. *Sudan Tribune*, November 27.
- Reeves, E. 2006. The future of Darfur: Next causality, *The New Republic*. May 15, 234: 18-20.
- The Res Publica, 2006. *The Darfur resistance: who they are, what they want, and what they need to help create a new Sudan*. Retrieved from <http://www.therespublica.com>. (accessed October 10, 2006).
- Timiraos, N. 2006,. Sudan - divestment activists get act together. *The Wall Street Journal* National Edition, July 19, Sec. C1.
- Udombana, N. J. 2005. When neutrality is a sin: the Darfur crisis and the crisis of humanitarian intervention in Sudan. *Human Rights Quarterly*, 27: 1149-1199.
- United Nations, 1948. *Convention on the Prevention and Punishment of Genocide*, Created on August 16, 1994 / Last edited on January 27, 1997.
<http://www.hrweb.org/legal/genocide.html> (accessed on 12/16/2006).
- The World Bank, 2006. *Sudan-Country Brief*. Retrieved from <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/SUDANE> . (accessed on 11/10/2006).

APPENDIX A: Simulation Model Boundary Chart

	Endogenous Variables	Exogenous Variables	Excluded Variables
Affects Model Behavior	X	X	
Behavior Affected By Model	X		
	<p><u>Stocks:</u> People of Darfur ...</p> <ul style="list-style-type: none"> • In Home Villages • In Resistance Groups • In Transit from/to Displacement Camps • In Displacement Camps • Dead (Excess Deaths Due to Violence, Disease, Starvation) • Potential Militia or Military Members (Potential Aggressors) • Militia or Military Members (Aggressors) <p><u>Flows:</u></p> <ul style="list-style-type: none"> • Recruitment into Resistance Groups • Joining Militias, Military • Mortality (People of Darfur) • Displacement • Arriving at Camps • Leaving Camps 	<ul style="list-style-type: none"> • Initial Conditions for All Stocks <p><u>Auxiliary Variables:</u></p> <p>Fractional Rates:</p> <ul style="list-style-type: none"> • Resistance Recruitment • Militia Involuntary Recruitment • Militia Voluntary Recruitment • Killing Rate Against Resistance Groups (Per Aggressor) • Killing Rate in Villages (Per Aggressor) • Killing Rate in Transit (Per Aggressor) • Killing Rate at Camps (Per Aggressor) • Displacement Rate (Per Aggressor) • Re-Displacement Rate (Per Aggressor) • Starvation/Disease Death Rate • Average Time to Reach Camp 	<ul style="list-style-type: none"> • Weather, Seasons, and Acts of Nature • Domestic Issues in Neighboring Countries • Media Observation • Economic Variables (e.g. Oil Revenues and Distributions, Economic Sanctions, Foreign Investment, Divestment) • Peace Treaties • Politics Between UN, Sudan, and US • Military Supplies • AU Forces • UN Forces • Births • Non-Violence Related Deaths

APPENDIX B: Simulation Model Stock Flow Diagram



APPENDIX C: Simulation Model Equations

(01) Aggressor Killing Rate Against Rebels=
0.001

Units: Darfurian/(Month*Aggressor) [0,0.05,0.001]

Exogenous Parameter: Rebels killed per month per aggressor (by aggressors).

(02) Aggressors= INTEG (
"Joining Militias, Military",
Initial Aggressors)

Units: Aggressor [0,?]

Stock: Aggressors represent the militia and military population.

(03) Arriving at Camps=
Darfurians In Transit/Avg Time to Reach Camp

Units: Darfurian/Month [0,?]

Flow: First-order flow from Darfurians in transit to displacement camps, dictated by average time to reach camps.

(04) Avg Time to Reach Camp=
0.5

Units: Month [0,12]

Exogenous Parameter: Average time for Darfurians to reach camp once displaced, or average time in transit during multiple-displacement.

(05) Darfurians at Home= INTEG (
-Displacement Rate-Recruitment-Village Mortality,
Initial Population of Darfur)

Units: Darfurian [0,?]

Stock: People of Darfur all originate at home, and leave "home" via recruitment into rebel groups, death, and displacement.

(06) Darfurians in Displacement Camps= INTEG (
Arriving at Camps-Displacement Camp Mortality-Leaving Camps,
0)

Units: Darfurian [0,?]

Stock: Population of displacement camps.

(07) Darfurians in Resistance Groups= INTEG (
+Recruitment-Rebel Mortality,
Initial Darfurians in Resistance Groups)

Units: Darfurian [0,?]

Stock: Population of rebels.

(08) Darfurians In Transit= INTEG (
+Displacement Rate+Leaving Camps-Arriving at Camps-Mortality in Transit,

0)

Units: Darfurian [0,?]

Stock: People of Darfur in a state of transition between home and camp.

(09) Displacement Camp Mortality=
Aggressors*Killing Rate at Camps Per Aggressor*MIN(1, Darfurians in
Displacement Camps
/(Fixed Flow Threshold C*Population of Darfur
))+Fractional Starvation Rate*Darfurians in Displacement Camps
Units: Darfurian/Month

Flow: Camp mortality includes direct killing and disease/starvation. Direct killing follows either a first-order flow based on the aggressor and the camp population, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the initial camp population where the mortality shifts from constant to first-order process. Starvation is a first order flow dictated by the fractional starvation rate of the camp population.

(10) Displacement Rate=
Aggressors*Displacement Rate per Aggressor*MIN(1,Darfurians at
Home/(Fixed Flow Threshold D
*Population of Darfur))
Units: Darfurian/Month

Flow: Displacement moves population from home to in transit. The process follows either a first-order flow based on the aggressor and the susceptible population at home, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the initial home population where displacement shifts from a constant to first-order process.

Acts of violence include looting and burning villages, stealing resources, poisoning wells, destroying land and fields, raping women, directly killing young men and boys, and forcing displacement into inhospitable IDP camps (Patrick, 2005).

(11) Displacement Rate per Aggressor=
2
Units: Darfurian/(Month*Aggressor) [0,?,0.001]

Exogenous Parameter: People of Darfur displaced per month per aggressor (by aggressors).

(12) Excess Deaths at Displacement Camp= INTEG (
Displacement Camp Mortality,
0)
Units: Darfurian [0,?]

Stock: Counts total excess deaths in displacement camps.

(13) Excess Deaths in Transit= INTEG (

Mortality in Transit,
0)
Units: Darfurian [0,?]

Stock: Counts total excess deaths of those who are in transit.

(14) Excess Deaths in Villages= INTEG (
Village Mortality,
0)
Units: Darfurian [0,?]

Stock: Counts total excess deaths of people of Darfur at home, in vil-
lages.

(15) Excess Rebel Deaths= INTEG (
Rebel Mortality,
0)
Units: Darfurian [0,?]

Stock: Counts total excess deaths of rebels.

(16) FINAL TIME = 46
Units: Month
The final time for the simulation.

(17) Fixed Flow Threshold C=
1
Units: Dmnl [0.01,1]

(18) Fixed Flow Threshold D=
1
Units: Dmnl [0.01,1]

(19) Fixed Flow Threshold H=
1
Units: Dmnl [0.01,1]

(20) Fixed Flow Threshold R=
1
Units: Dmnl [0.01,1]

(21) Fixed Flow Threshold T=
1
Units: Dmnl [0.01,1]

(22) Fractional Rate of Involuntary Recruitment=
0.04
Units: 1/Month [0,0.1,0.01]

Exogenous Parameter: Fraction of potential aggressors that are involuntar-
ily recruited each month.

(23) Fractional Rate of Voluntary Recruitment=
0.7624
Units: 1/Month [0,?]

Exogenous Parameter: Fraction of potential aggressors that are voluntarily recruited each month.

(24) Fractional Recruitment Rate=
0.0001
Units: 1/Month [0,0.001,0.0001]

Exogenous Parameter: Fraction of people of Darfur at home that are recruited into resistance groups each month.

(25) Fractional Starvation Rate=
0.005
Units: 1/Month [0,0.1,0.005]

Exogenous Parameter: Fraction of people in displacement camps that starve each month.

(26) Initial Aggressors=
20000
Units: Aggressor [0,?]

(27) Initial Darfurians in Resistance Groups=
20000
Units: Darfurian [0,?]

(28) Initial Population of Darfur=
6e+006
Units: Darfurian [0,?]

(29) Initial Potential Aggressors=
15000
Units: Aggressor [0,?]

(30) INITIAL TIME = 0
Units: Month
The initial time for the simulation.

(31) "Joining Militias, Military"=
Fractional Rate of Voluntary Recruitment*Potential Aggressors*Aggressors/
(Potential Aggressors + Aggressors) + Fractional Rate of Involuntary Recruitment
*Potential Aggressors
Units: Aggressor/Month [0,?]

Flow: Moves people from potential aggressors to aggressors. Process follows a Bass-diffusion process where two forces contribute: voluntary joining and involuntary joining.

(32) Killing Rate at Camps Per Aggressor=
0.24
Units: Darfurian/(Month*Aggressor) [0,0.5,0.01]

Exogenous Parameter: Number of people of Darfur in camps that are killed per aggressor (by aggressors), per month.

(33) Killing Rate in Transit per Aggressor=

0.001

Units: Darfurian/(Month*Aggressor) [0,0.05,0.001]

Exogenous Parameter: Number of people of Darfur in transit that are killed per aggressor (by aggressors), per month.

(34) Killing Rate in Villages per Aggressor=
0.08

Units: Darfurian/(Month*Aggressor) [0,0.5,0.01]

Exogenous Parameter: Number of people of Darfur at home in villages that are killed per aggressor (by aggressors), per month.

(35) Leaving Camps=

Aggressors*"Re-Displacement Rate per Aggressor"*MIN(1, Darfurians in
Displacement Camps
/(Fixed Flow Threshold R*Population of Darfur
))

Units: Darfurian/Month

Flow: In this model, people leave camps due to aggressor violence. The process follows either a first-order flow based on the aggressor and the camp population, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the initial camp population where the process shifts from a constant to first-order process.

(36) Mortality in Transit=

Aggressors*Killing Rate in Transit per Aggressor*MIN(1, Darfurians In
Transit
/(Fixed Flow Threshold T*Population of Darfur
))

Units: Darfurian/Month

Flow: Mortality is due to direct killing (aggressor violence). The process follows either a first-order flow based on the aggressor and the susceptible population, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the initial susceptible population where mortality shifts from a constant to first-order process.

(37) Population of Darfur=

Darfurians at Home+Darfurians in Displacement Camps+Darfurians in Re-
sistance Groups
+Darfurians In Transit

Units: Darfurian [0,?]

Auxiliary Variable: Sum does not include militia/military population.

(38) Potential Aggressors= INTEG (

- "Joining Militias, Military",
Initial Potential Aggressors)

Units: Aggressor [0,?]

Stock: Population of people who can potentially be recruited into militias or the military.

(39) "Re-Displacement Rate per Aggressor"=
0
Units: Darfurian/(Month*Aggressor) [0,?]

Exogenous Parameter: Number of people of Darfur in camps that are re-displaced per aggressor (due to aggressor violence), per month.

(40) Rebel Mortality=
Aggressors*Aggressor Killing Rate Against Rebels*Darfurians in Resistance Groups
/Population of Darfur
Units: Darfurian/Month

Flow: Mortality is due to direct killing by aggressors. The process follows either a first-order flow based on the aggressor and the rebel population, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the rebel population where mortality shifts from a constant to first-order process.

(41) Recruitment=
Darfurians at Home*Fractional Recruitment Rate
Units: Darfurian/Month [0,?]

Flow: Moves population of Darfur at home to resistance groups. A first-order process determined by a fractional recruitment rate.

(42) SAVEPER =
TIME STEP
Units: Month [0,?]
The frequency with which output is stored.

(43) TIME STEP = 0.0078125
Units: Month [0,?]
The time step for the simulation.

(44) Total Excess Deaths=
Excess Deaths in Villages + Excess Deaths in Transit + Excess Deaths at Displacement Camp
+Excess Rebel Deaths
Units: Darfurian [0,?]

(45) Village Mortality=
Aggressors*Killing Rate in Villages per Aggressor*MIN(1, Darfurians at Home
/(Fixed Flow Threshold H*Population of Darfur
))
Units: Darfurian/Month

Flow: Mortality is due to aggressor violence (direct killing). The process follows either a first-order flow based on the aggressor population and the population at home, or a constant flow based on the aggressor population alone, or a hybrid of the two. A hybrid is dictated

by the "Fixed Flow Threshold" ranging from 0 to 1 which represents the fraction of the initial home population where mortality shifts from a constant to first-order process.

Acts of violence include looting and burning villages, stealing resources, poisoning wells, destroying land and fields, raping women, directly killing young men and boys, and forcing displacement into inhospitable IDP camps (Patrick, 2005).