With the impact of globalization and changes in the forces and relations of production, risks are no longer posed in isolation from each other. The intrinsic character of global threats and their low frequency of occurrence pose certain challenges in the operationalization of risk events. In a similar vein, the basic differences between the global risks themselves require analysts to approach each threat using a strategy that combines common methodology with analysis that is unique to each condition. The main intent of this book is to return to the principle that we can understand global crises not just on the basis of knowing what occurred prior to the incident that we are interested in, but also that we can understand the social, economic, political, and physical contexts in which crises occur. We consider the temporal as well as spatial factors that precede, interact with, and follow the incident's occurrence. This book equips the reader with the skills for responding to conceptual and methodological differences, challenges, and novelties of the data analysis process, and demonstrates effective ways to apply mapping techniques and risk terrain modeling methods to transnational data.

We use the outbreaks of governmental internal armed conflict to demonstrate an application of risk terrain modeling (RTM) for spatial risk assessment at both the national and sub-national levels on a global extent. RTM can give actionable meaning to the relationships that exist between place-based indicators and damaging outcomes. Planners can use RTM methods to develop strategic models to forecast where problems are likely to emerge and to engage in steps that might reduce risks in the future and, potentially, avert crises altogether.

In the first part of this book, we review the risk terrain modeling approach to spatial risk assessment and present a short overview of the theoretical underpinnings of globalization theory. In the second part we detail the technical steps of RTM for analysts to follow using ArcGIS software. In the third and final part, we present ideas about how RTM can be used for strategic and tactical decision-making.

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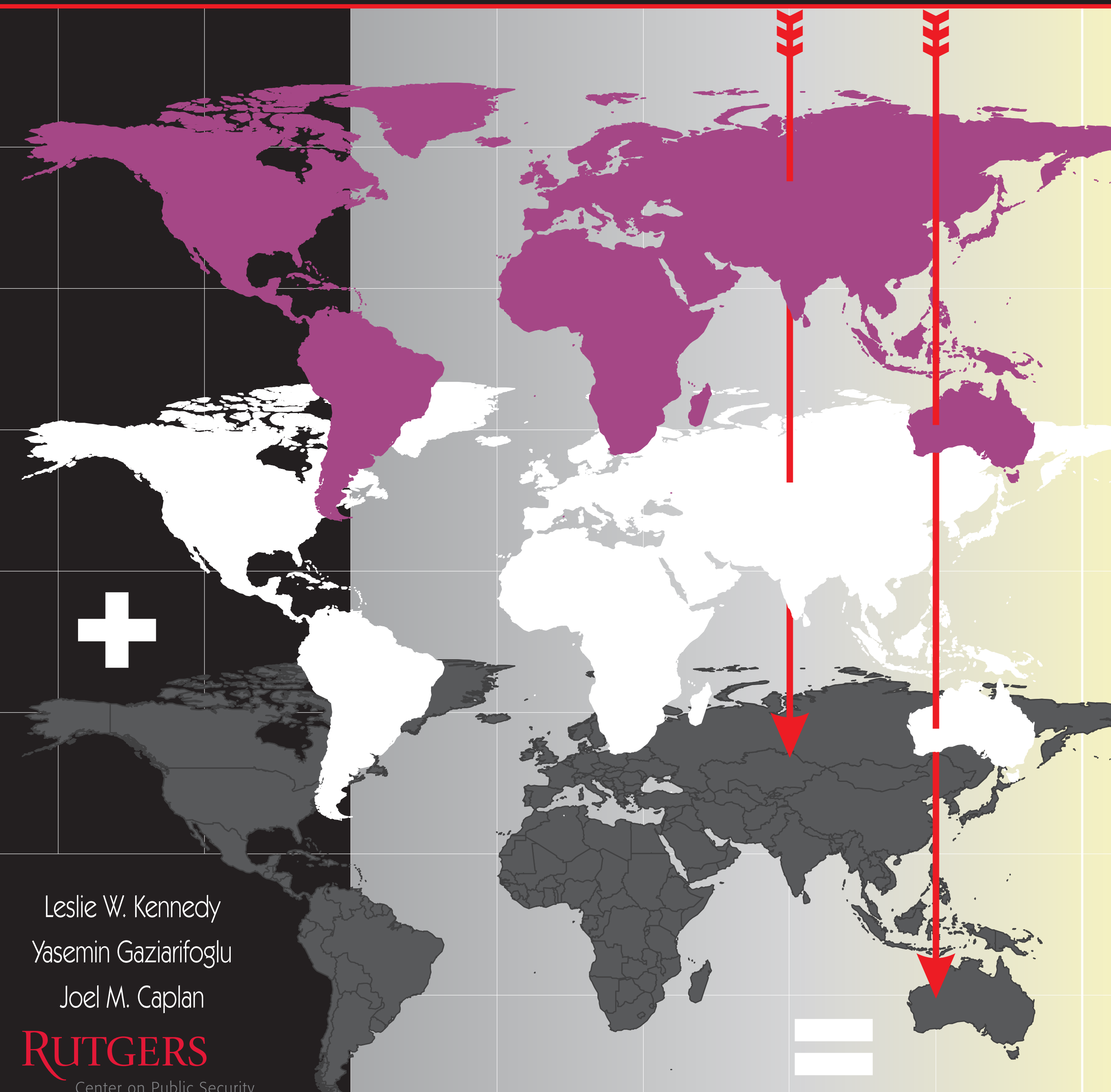
KENNEDY GAZIARIFOGLU & CAPLAN

ANALYZING AND VISUALIZING WORLDWIDE SPATIAL DATA

ANALYZING AND VISUALIZING WORLDWIDE SPATIAL DATA

AN APPLICATION OF RISK TERRAIN MODELING



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Analyzing and Visualizing Worldwide Spatial Data: An Application of Risk Terrain Modeling

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Preface

Just think about the very beginning of civilizations. Since the earliest and simplest analyses and management of risks exercised by the priests of Mesopotamia in 3200 B.C., forecasting the damaging effects of hazards has undergone many structural shifts with the development of numerical systems, probability, game theory and cost-benefit analysis. Yet, the very same problems of anticipating hunger, drought, famine and conquest dominated the early societies as a byproduct of increased production, population, and settlement (McDaniels and Small 2004). We have had some notable successes in responding to hazards. Remember the certification of global eradication of smallpox in 1979[i], which changed human history by making no discrimination against its target group, including kings and queens. But new challenges continuously emerge on our global menu of threats including cyber crime, electromagnetic fields, climate change, space weather, and loss of biodiversity[ii].

Understanding the initiation, persistence or desistance of these global threats requires analysis of the "why" and "how" dimensions of the problem. At this point, as one might expect, some critical concerns appear in how one should address these dimensions. For instance, in terms of interest, what should we define as the indicators of a threat? Or, on a measurement level, how do we analyze those indicators? Is it better to look solely at individual risk factors, to cumulatively combine them as if they have equal weights, or to weight them according to their relative importance? Contextually, how should we define the place and time of the analysis? Which one is better as a study extent: A country, region, city or a neighborhood? Or, temporally, what is the ideal time frame to analyze a threat? Five years, a year, seasons, months; maybe even smaller spatial and temporal segments?

To answer these methodological questions it is necessary to understand the nature of risk, in general, and the nature of "global risk", in particular. Risk is a continuous dynamic value that increases or decreases intensity and clusters or dissipates in different places over time. Valuations of risk are tied to geography and risk values are the measure of a place's potential for an event of some sort to occur. So, for example, the occurrence of a disease outbreak or a disaster has a calculable risk that connects to the geography of the place in which these occur. Geographic, or place-based, risk is determined by a nexus of certain factors and it changes as the characteristics and interactions of those factors are considered. Drawing from an example in meteorology, individual factors that are incorporated into weather forecasting do not necessarily produce rain, thunderstorms, or hurricanes by themselves. It is only when they intersect in space and time that they have the greatest potential to yield a particular outcome, e.g. a storm. Other times, only one or a few factors may be required to interact at the same geography and at certain times for a particular event to occur.

Understanding the spatial-temporal interaction effects of certain factors, or correlates, of major global events is key to assessing and valuing risk. Risk Terrain Modeling (RTM) was developed by Joel M. Caplan and Leslie W. Kennedy at Rutgers University School of Criminal Justice in recognition that a method was needed to simultaneously apply multiple empirical research findings to practice. In 2010, "Risk Terrain Modeling Manual: Theoretical Framework and Technical Steps of Spatial Risk Assessment" was published to primarily demonstrate effective ways to apply RTM to crime analysis and police operations. The need for writing this manual on global threats is rooted in four main contingencies.

First, due to the systemic and conflating nature of global threats, the coexistence of individual risk factors creates a greater effect than the cumulative sum of their effects. With the impact of globalization and changes in the means, modes and relations of production, risks are no longer posed in isolation from each other[iii]. Second, the intrinsic character of global threats, such as, financial crisis, political instability, or corruption, and their low frequency of occurrence (i.e. adverse regime changes, oil price strikes, and other financial crises), pose certain challenges in the operationalization of risk events. Third, and in a similar vein, the intrinsic differences between the global risks themselves, again regarding the elusiveness and frequency of threats, require the researcher to approach each threat using a strategy that combines common methodology with analysis that is unique to each condition. Fourth, the spatial and temporal data collection differences for risk factors, such as the frequency of the collection of data (longer time intervals vs. shorter time intervals) or the geographical availability of the data (national vs. sub-national), requires the researcher to follow a flexible approach. Also, the trivial significance of the variations in data collection (fixed vs. dynamic data) may require the researchers to be innovative in addressing these differences.

Taking these contingencies into consideration, the main intent of this manual is to return to the principle that we can understand global crises not just on the basis of knowing what occurred prior to the incident that we are interested in but also that we can understand the social, economic, political, and physical contexts in which crises occur. This approach supports efforts that examine crises in terms of events, that is, to consider the temporal as well as spatial factors that precede, interact with, and follow the incident's occurrence. And while doing that, this manual aims to equip the reader with the skills for responding to conceptual and methodological differences, challenges, and novelties of the data analysis process, demonstrating effective ways to apply GIS techniques to transnational data. Through this process, analysts can identify risk terrains that give actionable meaning to the relationships that exist between place-based indicators and damaging outcomes. Planners can use this approach to develop strategic models to forecast where problems are likely to emerge and to engage in steps that might reduce risks in the future and, potentially, avert crises altogether.

This manual is presented in three parts. In the first part, we review the Risk Terrain Modeling approach and present a short overview of the theoretical underpinnings of globalization theory, addressing the social and environmental factors that contribute to social and economic problems. In the second part we detail the technical steps for analysts to follow in using ArcGIS software to develop risk terrain maps. In the third and final part, we present ideas about how RTM can be used for strategic and tactical decision-making.

Part 1

Introduction to Risk Terrain Modeling for Global Spatial Risk Assessment

Chapter 1

Risk Terrain Modeling Overview

Risks, Terrain, and Modeling

Risk suggests the likelihood of an event occurring given what is known about the correlates of that event and it can be quantified with negative, low or high ordinal values. Using risk as a metric, it is possible to model how risk evolves spatially and temporally, accounting for the different stages of the crime event. Modeling broadly refers to the abstraction of the real world at certain places. Specifically within the context of risk terrain modeling, it refers to the acts of attributing the presence, absence, or intensity of qualities of the real world to places within a terrain, and combining multiple terrains together using map algebra (Tomlin 1994) to produce a single composite map where the newly derived value of each place represents the aggregated or synthesized qualities of those places. A terrain is a grid of the study area made up of equally sized cells that represent a continuous surface of places where values of risk exist.

Risk Terrain Modeling[iv], then, is an approach to risk assessment that standardizes risk factors to common geographic units over a continuous surface. Separate map layers representing the presence, absence, or intensity of each risk factor at every place throughout a terrain is created in a geographic information system (GIS), and then all map layers are combined to produce a composite "risk terrain" map with attribute values that account for all risk factors at every place throughout the geography. Risk terrain maps assist in strategic decision-making and tactical action by showing where conditions are ideal for events to occur in the future. RTM combines actuarial risk prediction with environmental criminology to assign risk values to places according to their particular attributes.

Risk assessment is not an arbitrary process but is guided by principles that agencies follow to provide consistent guidance to their efforts. Often confounding this effort, however, are the lack of good data and analytical techniques that support believable forecasts of hazardous outcomes. The agencies that have had success in dealing with these uncertainties in predictions have worked hard to improve data collection and coordinate forecasting efforts; the best examples of this can be demonstrated by the work of the world health organizations (see Kennedy et al. 2011, for a review of the approaches taken by agencies addressing different problem areas in developing risk assessment and response mechanisms). Advancing from these successes in data collection requires conceptually sound analytical procedures that can be used to identify and manage hazards before they become crises. In the next chapters, we present a model that outlines steps that can be used in applying a spatial analytical approach using RTM to the study of hazards. We use the outbreaks of governmental internal armed conflict, a problem that has been previously studied in the work of Buhaug and Rød (2006) in Africa, as a way of demonstrating the risk assessment technique both at a national and sub-national level on a global extent.

In previous work using RTM for crime analysis, the applications were applied using readily available raster data that defined places by standard-sized cells. The raster maps provide the facility to easily combine locational attributes on a grid over a geographic surface. Raster data are used to represent terrains in RTM. In the study of global hazards, we face a data challenge in using raster maps, as so much information is missing or aggregated to a level that makes the use of cell data ineffective. For example, dividing up large regions of a country like counties into smaller grids in which all of the information is the same is not very useful. This does not mean that we cannot convert vector maps of this sort to a raster format for risk terrain modeling, it just means that until we get better micro-level data (a challenge that analyses presented in this manual, and related research, embarks on overcoming), we will need to be aware of the limitations that this presents to our analysis.

The technical approach to RTM is straightforward: identify, through meta-analysis or other empirical methods, literature review, professional experience, and practitioner knowledge all factors that are related to a particular outcome for which risk is being assessed. Then, connect each factor to a common geography. Essentially, RTM assigns a (weighted or un-weighted) value signifying the presence, absence or intensity of each risk factor at every place throughout a given location. Each factor is represented by a separate terrain (risk map layer) of the same geography. When all map layers are combined in a GIS, they produce a risk terrain map—where every place throughout the geography is assigned a composite risk value that accounts for all factors associated with the particular outcome. The higher the risk value the greater the likelihood of an event occurring at that location. Risk terrain modeling of crimes produces maps that show places with the greatest risk or likelihood of becoming spots for an event of interest to occur in the future[v], not just because statistics show that reported incidents occurred there yesterday, but because the social and environmental conditions are suitable for them to occur there tomorrow.

Risk terrain modeling assumes a step that is basic to the development of geographic information systems in asserting that certain places can acquire attributes that, when combined in prescribed ways, create contexts in which certain outcomes are made more likely. A risk terrain map provides a composite picture of the underlying conditions throughout a neighborhood, community, city or region. The ways in which these conditions combine is an important aspect for setting up the "meaning" that a risk terrain model will carry. The setting (or terrain) is not necessarily static but it is recognizable and sustainable. Its characteristics emerge over time and connect the structure of an environment to the activities that occur at these locations. For example, the combined attributes of an open air marketplace denotes particular types of activities will take place at this locations. These attributes combined can be used to anticipate the types of behavior that we would expect, reducing the uncertainty in our forecasts about what would transpire there. In this way, environmental attributes are used as a means of assigning risk (or likelihood) that certain events will happen at a particular place. These events may be benign (e.g. buying and selling of goods) or they may take on a more sinister character where a combination of certain types of factors creates a context in which the risk of hazardous events can occur, such as pick-pocketing or theft. The advantage of RTM at the global scale is that it provides a picture of a landscape in terms of factors that contribute to negative events, such as crime or terrorism. RTM suggests the formation of places that share characteristics that are not pre-defined by the attributes of the people who live or travel there.

RTM considers outcome variables as less deterministic and more a function of a dynamic interaction that occurs at places. Place-based attributes are not necessarily constant over time, but the ways in which they interact can be studied to reveal consistent patterns of interaction. The computation of these patterns is a key component of RTM, with the added ability to weight the relative importance of different factors at different places and how they influence behaviors and events. The attributes themselves do not create events; they simply point to locations where, if the conditions are right, the risk of certain outcomes occurring will go up. This might be influenced by factors outside of the context that we are studying, such as, the general level of social control that exists across places. But, this, too, can be added as a quality of space to be considered in a risk terrain model. We cannot simply assume, though, that because a location is high in risk according to a risk terrain model that specific consequences will always ensue (any more than we can assume that a location that is a high risk for disease will experience an outbreak, as a matter of course). Important in considering place-based risk is the extent to which we are likely to find that these locations are susceptible or exposed to conditions that promote and/or enable certain behavior.

Forecasting applications undertaken to date are diverse, some more explicitly embracing theory than others and some relying on more complex statistical techniques. From our point of view, an important consideration for the development of forecasting models is the ability of analysts to replicate the approach using existing and commonly available GIS tools. Also, the approach should enhance analysts' ability to inform strategic decision-making. To be clear, forecasting is not the same as predicting. Forecasting is more advantageous to practitioners because it does not rely on an incident to actually occur, or for the event to occur at an exact location. Predictions are determinist in that an event is assumed to happen unless proper actions are taken; any occurrence of the predicted event connotes a failure of the agency practitioners who were tasked with prevention, while any absence of the predicted event connotes either an adequate practitioner response or a failed predictive model. Unfortunately, the only true measure of success of a predictive model is for the event to occur, which is generally not in the public's or responsible practitioners' best interest. This is why most agency responses are measured as failures when negative events occur or when crises cannot be properly managed. Prevention activities performed in response to predictions always have the burden of proving that those activities were the direct result of the non-event—while assuming that the event would absolutely have occurred otherwise.

While prediction methods focus on the presence or absence of an event, forecasts based on risk assessments using RTM focus on the conditions of the environment where an event could occur. The unit of analysis is the geography, not the event. As a case in point, a particular geography's risk of an event occurring there will be high when conditions at that location are ideal for it to occur. The identification of risky areas permits practitioners to intervene and allocate resources to reduce risk at the unit of analysis that they are operationally conditioned for—the geography. The impact of interventions to reduce risk (and avert negative events) can be evaluated by regularly re-assessing risk and then measuring changes in risk values among different risk terrain maps at micro or macro levels using inferential statistics. For example, when evaluating the impact of an intervention that was taken in response to an assessed risk, subsequent risk terrain maps might be expected to show certain results, such as, an overall reduction in risk values throughout the intervention area; a fragmentation or shift of high-risk clusters; or, an equalization of risk throughout the study area—with a decreased intensity of high-risk clusters and a slightly increased or constant intensity of risk at cooler spots. In this way, the risk assessment model and the interventions performed by public safety practitioners to reduce risk can be appropriately and mutually exclusively credited with success or failure.

Risk Positions and Global Threats

At the turn of the 21st century, many social theorists suggested that we were entering a new era: the risk society. For Beck (1992), this meant that the former basis upon which social groupings were made, primarily (access to) resources, would be replaced by the democratizing effect associated with the threats faced in today's world. Rather than class position or access to goods determining one's social position, Beck theorized that vulnerability to threat (exposure to 'bads') would become the basis upon which classifications would be made. Vulnerability would replace wealth as the 'glue' holding particular groups together (and others apart). While it is clearly not the case that wealth has become irrelevant in today's society, since obviously those with greater wealth are better able to buy protections required in the face of adversity, vulnerability to particular types of threats facilitates a form of cohesion or collective agreement among parties that may have been unlikely in the absence of these hazards.

What does this mean with respect to risk positions among nations? It means that there are differences in vulnerability among nations that are not going to 'go away' in the face of threats, such as, terrorism or natural disasters. Clearly it is unrealistic and naive to suggest that less wealthy countries are able to protect themselves with the same effectiveness as more wealthy countries. In particular, poor countries in

Africa are not as able to protect themselves against terrorism in the same way that wealthy European nations might. At the same time, the threat of terrorism is not equal among nations – it is likely that poorer countries will simply be seen as less attractive targets and therefore may be less vulnerable to terrorist threat. With regard to vulnerability to terrorist threat, economic prosperity – often the 'trump card' in the face of other forms of threat – may be a type of lightning rod to which terrorists are attracted. What is typically perceived as strength may become, in the context of terrorism, a source of vulnerability. The idea that nations are not equally vulnerable to terrorist threat is part of an ongoing discussion within the United States. In the U.S., less populated states have made the claim that they are entitled to as much federal protection from terrorism as the more populated states. This demand is made in the face of information that terrorist strikes are far more likely to occur in areas characterized by significant infrastructure capacity – something that is not a feature of smaller and less populated states. This illustrates that nations, not unlike particular states within the U.S., vary in terms of their risk positions. Each nation has certain characteristics that combine in various ways with exposure to particular threats, resulting in specific, and unequal, vulnerabilities (Cerny 2000).

The global accessibility of communications, along with historical relationships among countries, serves to create a dynamic in the 21st century that has never been seen before. Unlike events of any other century, at play today is unparalleled access to data and, subsequently, influence. The impact of such access plays into the concept of 'scale' as discussed by Sjoberg (2008). Sjoberg notes, "…according to political geographers, states, regions, and other scales do not exist a priori, but exist because of and dependent on human physical and social organization."(p.478). The specific impacts of physical and social organization and how these may be brought to bear on risk positions suggests that any one factor that we might consider, such as economic resources, must be considered in the context of other factors that might serve to balance or tip the scales of international relations in one particular direction or another. The notion of 'scaling risk position' might be effectively applied to countries that have less access to particular resources and how it is that they frame the threats that they face. For example, states that perceive themselves as facing dissimilar losses in the face of threat are likely to define their responses to terrorism much differently as their physical and social organization will derive from different historical roots.

Risk is directly tied to security. Securitization is the action of taking steps to respond to threats. Security concerns revolve, as Buzan et al. (1995) point out, around interdependencies – the relationships that individuals, groups, collectives, or governments establish across regions and across sectors. Caballero-Antony (2006) explores the relationship between securitization and public goods in a review of the response to the SARS epidemic in South East Asia. In looking at the infectious disease problem solely in terms of threat, she says, governments are limited in their responses and have trouble finding the resources to control these types of outbreaks. If they combine an approach that includes securitization with the additional resources provided by public and private agencies that provide assistance in public health problems but not enforcement, the likelihood of success is much greater. This approach considers the importance of moving beyond considering security as simply something to be achieved through response to threats to an approach that considers how we might integrate threat analysis with an understanding of vulnerabilities and consequences.

Developing Composite Measures in Global Risk Assessment

Risk assessment is conventionally defined as a "methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend" (UN/ISDR 2004, 26). Using the idea of "risk conflation", we can see a transition towards a more holistic risk assessment and decision-making approach (see Figure 1) where identification and prioritization of risks is based on the assumption that "risks are rapidly transmitted across geographical and systemic boundaries" (World Economic Forum 2006, 6).

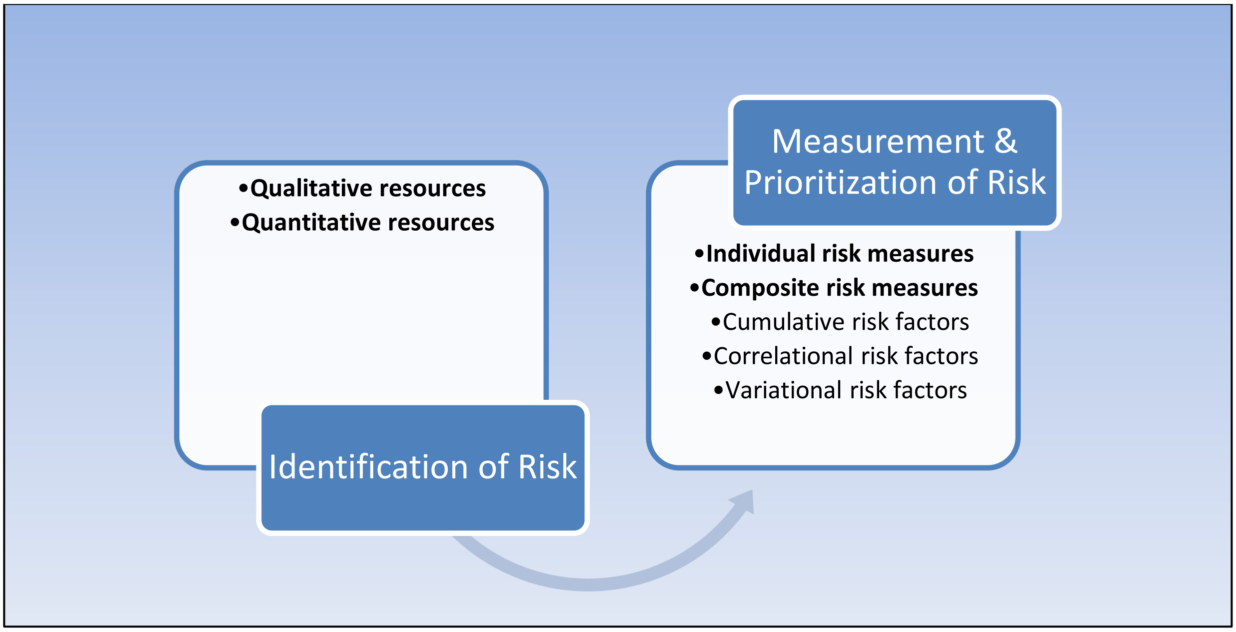


Figure 1. Evolution of Risk Assessment and Primary Decision Making (**Source**: Kennedy et al. 2011)

Identification of the Risk

As Kennedy et al. (2011) point out, in any risk management practice, before any counter-measure is implemented, a risk analysis should be performed. All risk assessment and decision-making processes, whether from an individualistic or holistic approach, start with the identification of the threat or hazard focusing on the source of the problem or the "problem" itself. This identification is established through data collection from various resources; therefore, the nature of risk identification can be qualitative and/or quantitative.

Prioritization of Risk

The main aim of risk prioritization is to rank order the risks identified for risk mitigation as resources for risk mitigation are limited. Similar to the risk identification phase, prioritization of risks can be qualitative and/or quantitative in nature. However, unlike the risk identification phase, contemporary risk prioritization procedures have started to show an evolution towards a holistic approach in response to the increasing connectivity between risks and increasing homogeneity of risk across the globe.

Individual measures

In this very first stage, risk prioritization is established through a process in which the probability of the risk event and the consequence of the relevant risk's occurrence are used to create a risk factor. Accordingly, this risk prioritization application may be seen as an elimination process in which relative importance and impact of each risk is calculated *to exclude the irrelevant factors from a pool of risks*. In this simple stage of risk prioritization, the interactions between risks are not taken into consideration. An example for this type may be a simple supply chain risk assessment and evaluation process in which the risk in the extended supply chain is identified through prioritization among different types of risks, such as, supply risks, operational risks, demand risks, security risks, macro risks, etc. Assuming a supply chain is vulnerable to many threats, the highest vulnerabilities in the supply chain are identified (Manuj and Mentzer 2008).

Composite measures

This stage constitutes a big leap in risk assessment and risk prioritization as we start to move along categories of composite measures, the existence of a relationship between risks and the strength of the relationships are gradually more and more elaborated. This characteristic is pivotal in 21st century risk assessments as the systemic nature of risk requires an ongoing and iterative risk assessment procedure.

Cumulative calculation of risks

The basic difference of this category from our first individual measures category is *its acceptance of the relationships between different risks*. Therefore, in this category every new condition is assigned the same risk factor and by adding up the ratings of different risk indicators, the final composite risk is calculated. The classification of the risk ranges is often subjective, where risk analysts and experts identify the thresholds for certain risk categories (such as low risk, moderate risk and high risk). An example for this type of composite measure is the Failed States Index[vi] in which countries are ranked on their global security levels (such as critical, in danger, borderline, stable, and most stable) according to the total scores of 12 indicators in the index (each indicator is assigned a value between 0-10, accordingly the total score is the sum of the 12 indicators and is on a scale of 0-120). Although this index is highly influential, as it attracts attention to the additive effect of risks (rather than the individual effect of each risk), the index does not reflect the direction and strength of relationships between different indicators. With regard to the scoring system, a score of 60 (or any other score) in this scale neither indicates the weight of indicators nor an existence of a relationship between indicators.

Identification of the relationship between risks

Overcoming the limitations that develop from the inability to detect relationships between different risk indicators, some organizations have proposed new risk assessment models in which the relationships of risks are elaborated. The World Economic Forum's Risk Correlation Matrix provides an index in which the interconnectedness of different risks is assessed in terms of correlations. Their correlation matrix shows the strength of the macro correlations perceived by the experts of the relevant global risk report. Although this example represents a further step in risk assessment with regards to the emphasis on the interconnectedness of risks through a correlation analysis in which *existence of a relationship and the strength of relationships are taken into consideration*, we still cannot understand the dynamics of the relationship between risks and causal relationships (World Economic Forum 2008).

The nature of relationship between risks

Although the correlation analysis of risks through matrixes revolutionizes the way risk assessment is performed, the methodology still lacks some essential components for identifying the *dynamics of relationships* between risks. The Global Risk Network's Risk Interconnection Maps (World Economic Forum 2010) and the United Nation's Global Pulse Projects[vii] are more recent examples of a more sophisticated risk assessment approach which point out the complexity and interconnectedness of risks in the 21st century. The main aim of Global Pulse as indicated on the UN website is "to harness new data and emerging technologies to detect--in real-time--when populations are changing their collective behavior in response to crises". In a similar vein, Global Risk Network tries to establish the same aim through identify the changing dynamics of the relationships between different risk events with the ideas of experts from different fields.

In this century where the interconnectivity between risks increases in parallel to globalization, it is not feasible to manage global risks with an "individual" and "silo" approach (World Economic Forum, 2007).

Accordingly, in the same way we do not have the luxury to deal with the risk events independent of other individuals, organizations, or countries, we do not have the luxury to evaluate them on an individual basis. This necessity of a systemic risk approach is reflected in the risk assessment phase of risk management through a more holistic risk identification and prioritization process exemplified by the composite measures of risks that takes the strength and nature of relationships between various factors into consideration.

As Kennedy, et al. (2011) point out, relationships between risks increase the odds of systemic risks. The interconnectivity which is seen as the main driving force of global prosperity also acts as a driving force for increased vulnerability to global threats.[viii] Furthermore this interconnection may damage different global networks in a way that the cumulative risk events outsize the individual contribution of each risk event. So how does this interconnected nature of risks reflect itself in the 21st century risk assessment methodology? As a rule of thumb, whether a specialist or an ordinary citizen, nearly everyone has the tendency to fear the most unanticipated events.[ix] Accordingly, for effective management of globalization, the uncertainty of global risks must be decreased to the maximum extent. Additionally, for sustaining credibility of risk assessment efforts, the scientific risk methodology should also account for the probability of "perfect storms," where *"cumulative risk events cause damage far in excess of the sum of each individual risk event"*.[x] This is particularly true as current risk assessment and decision-making practices have started to shift towards systemic methodologies where ideal risk assessment and decision-making is seen dynamically. It is important that the direction, the strength, and the nature of relationships between risks are analyzed.

Van Brunschot and Kennedy (2007) suggest that in any approach to threats, be they crime, terror, or natural disaster, it is important to understand the basis upon which individuals and agencies seek to balance resources against risk. This risk balance can vary according to where we are in relationship to the threat. Are we trying to reduce the threat from becoming reality, are we managing the actual incident, or are we taking steps to recover and prevent future acts? All of these considerations are set into the context of how much we are willing to do to protect ourselves. This risk balance is important in determining not only what we need to do relative to crime/terror detection but also what we consider normal and safe.

What are the models of integration used in data centers to manage and apply these intelligence sources to responding to threats? How are these models differentiated by the experience in different nations that have addressed local/national security threats? In considering these questions, it is easy to promote intelligence building based on data in search of patterns uninformed by some underlying model or logic. That is not to say that data dredging is an arbitrary activity; rather, it can operate at a tactical or responsive level instead of being guided by a larger model which explains relationships, guides inquiry based on problem solving strategies, and so on.

The patterns of warning signals can be tabulated and used to anticipate consequences and, if possible, avoid the incident all together. We see in the efforts to develop indices of failed states, sentinels for health hazards, warning devices for disasters, and stress indicators for financial markets that a great deal of effort is involved in developing early warning systems that will help prepare for and mitigate the effects of these global threats. Examples of early warning systems include Humanitarian Early Warning System of the UN Office for the Coordination of Humanitarian Affairs (OCHA), Forum on Early Warning and Early Response (FEWER), Early Recognition and Analysis of Tensions (FAST), Famine Early Warning System Network (FEWSNET), and International Crisis Group's Crisis Watch (Toomey and Kennedy 2011). A difficulty that occurs with these is that they are often not very dynamic or complete. The predictions that are made are often out of context and involve very "linear" explanations. Risk terrain modeling provides a means by which we can overcome this static nature of warning systems by "…helping solve certain resourcing issues, due to the lack of expensive specialist software/hardware required for it to function; enabling early warning systems to generate easily accessed and easily understood warnings through the use of GIS maps; improving risk assessment capabilities by increasing flexibility and facilitating integrated threat analyses, and by allowing for the inclusion of various different correlates and sources of information; and most importantly, explaining not only what threats are likely to occur in a certain area, but also to elaborate on the differential vulnerabilities of people within the area being studied" (Toomey and Kennedy, 2011, 11-12).

The forecasting of damaging outcomes can also be radically affected by the rapidity with which they evolve into crises. When we turn attention to the incident, we are generally confronted with a situation that, if not properly anticipated, turns quickly into a disaster. Crisis mapping has addressed the need to better react to incidents and mobilize the efforts needed to reduce the disastrous consequences of poor plans and inadequate resources. According to Patrick Meier, Director of Crisis Mapping at Ushahidi and co-founder of the International Network of Crisis Mappers, crisis mapping involves three basic steps[xi] : information collection, visualization and analysis. As Meier states it, there can be many ways of data collection ranging from traditional surveys to crowd-sourcing reports via SMS or parsing social media data on the web. Regarding the visualization and analysis he states that it is all about providing maximum insight into the dynamic nature of data through easily comprehensible and often times free and/or open source geographical information systems. Lastly he emphasizes the "on the fly" nature of the data (i.e. real time) and points out the necessity of a crisis mapping platform that will enable users to easily explore and test different scenarios. As Toomey and Kennedy state (2011, 11), crisis mapping can be supplemented and improved upon when coordinated with an effective RTM strategy in the following ways:

- Regarding visualization and resourcing, "The usefulness of RTM comes partially from the added value it can provide for a relatively insignificant cost." Although some commercial geographical information systems might be preferred by the users, free and/or open source tools such as GeoDa or GRASS GIS may also be utilized. Additionally with the free Risk Terrain Modeling Manual for Crime Analysis and this manual, the user can easily equip himself with the required skill set to perform RTM.
- With regard to the dynamic nature of risk indicators, RTM allows the user to easily manipulate the risk data in a model and test scenarios with multiple inputs (surveys, SMS, social media data etc.) at any temporal (year, month, weeks, days, hours) and spatial (national, sub-national) level.

Conclusion

Risk terrain modeling offers an approach to global risk assessment that combines the already well-developed theorizing about the causes of global risks and their occurrence with a spatial analysis technique that provides a basis upon which to provide forecasts of vulnerability to outbreaks of damaging events. The RTM approach provides a framework that can accommodate different scales of analysis, as well as cope with the various correlates that need to be considered across hazards and locations. The advantage of a place-based strategy is that, with the increased advent of geo-referenced data and the spread of social media that has location identifiers, the analysis of risk becomes more precise and the forecasts more reliable. In the next chapter, we demonstrate how risk assessment has evolved and the role that it plays in modern views of global threats.

Part 2

Steps and Techniques of Risk Terrain Modeling

Chapter 2

Getting Started with RTM for Global Risk Assessment

Introduction

This manual is intended to guide ArcGIS users with basic mapping skills and basic knowledge of vector and raster data through the technical and conceptual steps of risk terrain modeling (RTM). In this part of the manual, RTM is explained for the purpose of risk assessment and forecasting; though, the RTM approach can also be used for other purposes, such as for resource allocation or to evaluate the effects of past activities or interventions. Mapping and analysis steps were performed using ArcGIS Desktop 9.3.

What You Will Need to Begin

- ArcGIS (or similar GIS software; you can get a free trial version at www.esri.com)
- Spatial Analyst Extension (or other raster processing tools)
- Risk Terrain Modeling Toolset for ArcToolbox (download for free at www.riskterrainmodeling.com)
- Spatial Data

Software

ArcGIS is a scalable system of GIS software produced by Environmental Systems Research Institute (Esri). It contains three different products: ArcView, ArcEditor, and ArcInfo. Risk Terrain Modeling can be done with any of these products, but it does require the Spatial Analyst Extension. Note that ArcGIS is designed to run on a Microsoft Windows operating system. But with tools such as Parallels (www.parallels.com) or Boot Camp (part of MAC OS X Snow Leopard; www.apple.com), Intel-based Macintosh computer users can run ArcGIS products. (Just use an external mouse or learn how to “right-click” on a MAC). If you do not already own ArcGIS Desktop, you may download a free trial copy at www.esri.com. If you are a student with a valid ID card, you might also consider purchasing the software at the discounted educational rate.

Spatial Analyst Extension

The Spatial Analyst Extension is specifically intended for the processing of grids (raster data) in ArcGIS. You will need the Spatial Analyst Extension and requisite tools to make risk terrain maps and work with raster data. Before you start working with raster data, you should define your study area by setting the "processing extent" to be the same as the entire study area layer.

RTM Toolset and ArcToolbox

[From ArcMap or ArcCatalog, click the "ArcToolbox" button]. The ArcToolbox window is where you find, manage, and execute geoprocessing tools. Tools are (and must be) stored in Toolboxes, which are sorted alphabetically. The exact number of tools and toolboxes available depends on what extensions you have installed. The toolboxes you see in ArcToolbox are analogous to shortcuts in Windows Explorer or layers within ArcMap. If you remove a toolbox from ArcToolbox, you are simply removing it from the list and not actually deleting it on disk. BUT, if you delete a tool in a toolbox, the tool will be permanently deleted from the disk.

Opening Tools: [From the ArcToolbox window, double-click the tool].

Adding the RTM Toolset to ArcToolbox: First download the Toolset and save it to your computer's hard drive. [From the ArcToolbox window, right-click on the ArcToolbox > Add Toolbox > navigate to the folder with the toolset, select it > Click the "Open" button].

Spatial Data (Shapefiles, Vector and Raster Data)

Data are essential to GIS and base maps are the foundation. Essentially, base maps are your reference layers for orienting and analyzing your primary data. Typically, they comprise a geographic backdrop such as a country boundary. You want to obtain "shapefiles" if possible, which are the most compatible forms of data for use in a GIS. If shapefiles are not already available that is OK, you can create them. But, the data—whether it is your own or from another agency—must have a geographic reference such as street addresses or XY coordinates that can be used to link it to a map.

Esri, the maker of ArcGIS created the shapefile format in order to represent vector GIS data. Other GIS programs will use shapefiles, but geographic files from other GIS programs must be converted to shapefiles before ArcGIS applications can read them. As with other formats of geographic data, shapefiles link information about the location and shape of the map features to their attributes. Vector is a common format for GIS data used in the social sciences. It uses points, lines, and polygons to represent map features. Vector data is excellent for representing discrete objects such as parcels, streets, and administrative boundaries. The vector format is not as good for representing things that vary continuously over space, such as temperature, elevation, or risk. Raster data use grids made up of regularly-sized cells to represent spatially continuous data. Each cell is assigned real world coordinates and one attribute value (such as risk value). The user defines the cell size, allowing for very fine or course raster surfaces. Raster grid cells are like pixels on a TV or computer screen. Whereas vector shapefiles are oriented toward the depiction and analysis of discrete objects in space (represented as points, lines, or polygons), raster grids are oriented more toward the qualities of space itself. When raster layers have the same size cells, their values can be added, subtracted, multiplied, divided and queried using map algebra and the Raster Calculator in ArcGIS's Spatial Analyst Extension.

A Really Brief Overview of the Steps of RTM

STEP 1: Select an outcome event
STEP 2: Choose a study area
STEP 3: Choose a time period
STEP 4: Obtain base maps
STEP 5: Identify aggravating and mitigating risk factors related to the outcome event
STEP 6: Select particular risk factors to include in the risk terrain model
STEP 7: Operationalize risk factors to risk map layers
STEP 8: Weight risk map layers
STEP 9: Combine risk map layers to create a composite map
STEP 10: Finalize the risk terrain map to communicate meaningful information

Every effort should be made to maximize validity and reliability of your risk terrain model. The discussions that follow each step in the coming chapters are intended to provide some guidance as you consider these methodological issues, and to explain the conceptual and technical purpose of each step in relation to all subsequent steps in the risk terrain modeling process. It is recommended that your first risk terrain map be done using binary valued risk map layers (see Step 7) and an equal-weights risk terrain model (see Step 9). This is the easiest risk terrain map to produce and it is best for practicing the technical and conceptual aspects of risk terrain modeling. If this "basic" map proves useful and/or is found to have statistically significant predictive validity, then it may be considered a good estimate of your risk terrain model's potential. You can then revise your model, apply weights, or incorporate other more advanced techniques to improve your risk terrain maps as needed.

While examining the nature of global threats in relation to certain geographies, two main methods seem to dominate the research literature: 1) When the risk events are rare (i.e. political instability in the form of "regime change"; natural disasters etc.) and/or the risk data are available only on an aggregate level, national level geographic data is used to proxy for individual social-economical and political characteristics; 2) When the risk events are frequent (i.e. armed conflicts, terrorist attacks) and/or when the risk data are available on a disaggregated level, sub-national level data is used to reflect the local differences. In Chapter 3 a risk terrain model is developed to illustrate how RTM can be tailored to forecast governmental internal armed conflict incidents with national geographical level risk factors. In Chapter 4, another risk terrain model is developed to illustrate how RTM can be tailored to forecast governmental internal armed conflict incidents with sub-national geographical level risk factors.

Chapter 3

A Stepwise Example of RTM Using National Level Geographic Data

Step 1: Select an Outcome Event of Particular Interest

→ Governmental Internal Armed Conflict Incidents

If you are interested in assessing the risk of more than one event or type of global threat, then you will get the most reliable results if you repeat the steps presented here to produce separate risk terrain models for every event (or, at least one risk terrain model for groups of events with similar underlying risk factors). For example, if you are interested in the causes of armed conflict and transnational crime, although some overlaps might be possible, the causes of armed conflicts will most likely differ from the causes of transnational crime, so you would not generally combine these events together to identify mutual risk factors. More generally, it would not be reasonable to use a risk terrain map of transnational crime to forecast the locations of armed conflicts because the risk factors for each differ.

Governmental internal armed conflict incidents are selected as the outcome event for this demonstration. The armed conflict data have been acquired from UCDP/PRIO Armed Conflict Dataset[xii]. Uppsala Conflict Data Program (UCDP) defines armed conflict as: "a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths" (UCDP/PRIO 2009, 1). This dataset defines two types of internal armed conflict (UCDP/PRIO 2009, 7) both of which were included in our analysis:

1. Armed conflict which occurs between the government of a state and one or more internal opposition group(s) without intervention from other states;
2. Armed conflict which occurs between the government of a state and one or more internal opposition group(s) with intervention from other states (secondary parties) on one or both sides.

In this demonstration, the armed conflict incidents have been identified as "governmental" depending on the description of the opposition parties involved in the armed conflict and cross checking of the ideologies of these parties from the START TOPs (Terrorist Organization Profiles) database[xiii].

Step 2: Choose a Study Area

→ Nation States, Worldwide

Risk terrain modeling can be applied to any extent—small or large. Conceivably, if you want to assess the risk of finding a needle in a haystack, your study area could be the haystack; or, if you want to assess the risk of maritime piracy on the Earth's oceans, your extent could be the entire globe. The only real limit to the study area you select is your ability to obtain data for all of it.

When deciding upon a study area, you should consider at least three things. First, select an area for which the information provided by the risk terrain will be meaningful for operational management. Second, make sure that your risk factors data and all base maps will cover the entire study area that you select, and that your outcome event data (i.e. armed conflict incidents) are collected/recorded in a manner that covers the entire area. Finally, be careful not to select a study area that is too large for, or unrepresentative of, the outcome event since this can produce both visually and statistically deceptive results. Since the aim of this study is to show how RTM can be utilized with national level data, the entire globe has been selected as the study extent.

Step 3: Choose a Time Period

→ Risk factors current in 1996 will be used to predict the governmental internal armed conflict incidents observed between 1997 and 2005.

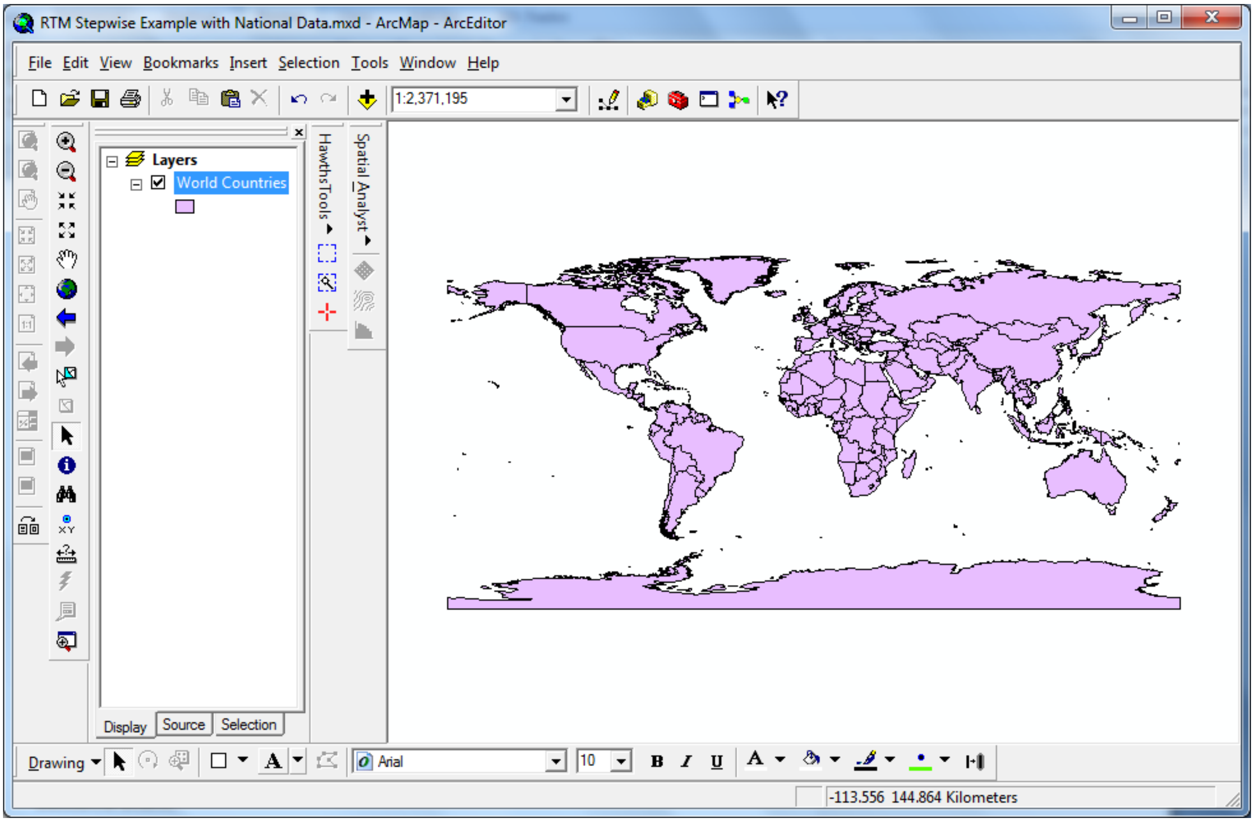
The time period should be meaningful for your data and considerate of how the information communicated by the risk terrain map will be used for decision-making (i.e. long-term, short-term). You should be able to reasonably justify that the qualities of the study area during time period 1 are (or will be) relevant during the subsequent time period that you are trying to model. As an extreme example, it is probably not reasonable to use a risk terrain map that was produced with data from one week during the summer in 2010 to forecast risky locations during the entire 2011 calendar year because, for many reasons, a summer week is not representative of happenings throughout an entire year. This example raises the issue of seasonality. The time period that you choose may depend on seasons. For instance, maritime terrorism exemplifies how seasonality could affect time periods used for RTM because empirical research suggests that the frequency of maritime pirate attacks changes according to weather conditions. There are fewer pirate attacks during monsoon season, for example. So, if you wanted to create a risk terrain map of global maritime piracy for an entire calendar year, you may have to create separate risk terrain maps using data from each of the seasons to produce each map, respectively. In effect, this would "control" for seasonality. The "Monsoon Season Risk Terrain Map" using risk factors from the 2010 monsoon season might be used to forecast risky locations of maritime pirate attacks during the 2011 monsoon season. But, this map would not yield as reliable or valid measures of risky places during a season with calmer waters.

Basically, the time period is important for interpreting risk terrain maps in a valid, meaningful, and actionable way. In this demonstration, risk factors from 1996 will be used to create the risk terrain maps. According to Barton et al. (2008), nation level indicators are important factors for anticipating instability *in long-term*. To test the validity of this assumption the predictive validity of the risk terrain model produced by the 1996's predictor variables will be used to predict the governmental internal armed conflict incidents for the consecutive nine years from 1997 thru 2005.

Step 4: Obtain Base Maps of your Study Area

→ The polygon shapefile of world countries.

At least some base maps that you may need are readily available for free in GIS compatible formats via some public and private organizations[xiv]. To maximize the validity and reliability of your risk terrain model, use base maps that are most representative of the time period that you are creating risk terrain maps for. If you are using risk terrain modeling to evaluate a completed intervention, then you might require older maps (e.g. new roads are added all the time). If you are producing risk terrain maps to identify future risky places, then you probably want to use the most current data and base maps. The polygon shapefile used in this demonstration (see below) represents generalized boundaries for the countries of the world as they existed in January, 2007.



Step 5: Identify Aggravating and Mitigating Risk Factors Related to the Outcome Event

→ Governance indicators; Country size; Neighbor conflict; Rough terrain; GDP per capita

The product of this step should be a comprehensive list of risk factors that are related to the outcome event in your study area. Fortunately, empirical research has already identified a variety of independent variables significantly correlated to a variety of global threat outcomes. Risk terrain modeling enables the analyst to simultaneously apply all of these empirical findings to practice. Your scholarly prowess, access to empirical literature, and innovativeness are key components of how comprehensively you can identify all factors that are related to the threat for which risk is being assessed. Some suggestions are: meta-analysis or other empirical methods, literature review, professional experience, and practitioner knowledge.

Ideally, you want to identify every single aggravating and mitigating factor. Practically, though, this is not feasible, and that is OK. At the very least, make a reasonable effort to identify as many factors that you believe to be related to the outcome event in your particular study area. Different threats will likely have different risk factors; or, different risk factors might be identified for the same type of threat in completely different settings. If you have access to a college or university library, search the catalog and electronic journal databases for books and articles related to your outcome event and that suggest risk factors relevant to your study area. You can also search Google Scholar (http://scholar.google.com), which indexes scholarly literature across many disciplines and sources (and it is free!). Another option is to look at reports and documents from reputable research centers, such as, the World Bank (http://data.worldbank.org), the Center for Systemic Peace (http://www.systemicpeace.org), the United Nations (http://data.un.org), Global Risk Data Platform (http://preview.grid.unep.ch), and CIA (http://www.cia.gov/library/publications/the-world-factbook). Presentation abstracts and professional conference proceedings are another useful source of general information about the outcome event. You might also join World Economic Forum's (www.forumblog.net) electronic discussion list to exchange ideas on the highlights. There are many sources of reliable information about risk factors related to many types of outcome events—too many to list all of them here. Consult those that are most accessible and useful to you (suggestions can be found in publications at www.rutgerscps.org).

In this demonstration, most of the cross-national studies of armed conflict are influenced by the work of Fearon and Laitin, Collier and Hoffler, and Hegre and Sambanis, who mostly focus on proxy measures of economic indicators. Fearon and Laitin (2003), Collier and Hoffler (2004) and Hegre and Sambanis (2006) conclude that in country level analysis among all correlates, **country size** is one of the most robust positive indicators of civil wars; large countries have more frequent conflict than small countries (Raleigh and Hegre 2009). According to the Human Security Centre (2004), low **GDP per capita income** strongly correlates with conflict. According to Pinherio (1996), **governance indicators** are robust predictors of political stability. Pinherio suggests that with the decrease in the perceived level of rule of law, regulatory quality, voice and accountability and the increase in the perceived level of corruption, the political stability is expected to be weakened. Conflict also has an international element. According to macro-level studies by Esty et al. (1998a) and Esty et al. (1998b), countries with **neighbor conflict** have an increased risk of experiencing internal conflict (Human Security Center, 2004). Goldstone et al. (2010) suggest that having four or more bordering states with major armed civil or ethnic conflict increases the risk of political instability. **Environmental conditions** are also significant predictors of conflicts. Hegre (2003) supports this argument by finding mountainous countries to have a higher risk of war than other countries as they provide rebels with natural sanctuaries. In a similar vein Fearon and Laitin (2003) suggest that environmental conditions favoring insurgents are significant predictors of civil wars **(**Blattman and Miguel 2006). According to Buhaug and Rød (2006), rough terrains are estimated by the average share of forest and mountain areas.

Step 6: Select Particular Risk Factors to Include in the Model

→ Governance, neighbor conflict, rough terrain

Chances are that your ability to use every risk factor from the list that you compiled in Step 5 will be limited by the availability or quality of data. Sometimes, this is due to the nature of your jurisdiction. For example, research may suggest that the locations of regime changes are correlated with the incident locations of future armed conflicts. But, if a country has not experienced a regime change so far, this does not mean that risk factor is irrelevant and should be excluded from your risk terrain model of armed conflicts, only that it needs to be judged in terms of relative likelihood of occurring and influencing the dependent variable. Other times, you might be forced to exclude a risk factor from the model because of missing data. Risk terrain modeling is dependent upon the availability of valid data from reliable sources. More risk factors do not always produce better models. Just because your literature review identified five factors to be correlated with the outcome event, for instance, including all five factors in the risk terrain model might not yield a risk terrain map with the best predictive validity. The model may still be meaningful and could serve your operational needs, but improvements to the model might come from including only the "most correlated" factors and excluding all others. This phenomenon of "less can be more" in RTM has been proved empirically by Kennedy, Caplan and Piza (2011)[xv] in their work with risk terrain modeling in Newark, NJ.

Two methods for deciding which factors to include and which ones, if any, to exclude, are discussed below. Both options have strengths and weaknesses.

Ad-hoc Method of Risk Factor Selection

If it makes sense to include all of the risk factors that you identified in Step 5, then do it. If your knowledge of the study area, personal experience, and/or data limitations reasonably justifies the inclusion of only some of the many risk factors that you identified, then use only those factors. Or, through an iterative process of trial and error, you might realize the best model after producing a risk terrain map, testing it for predictive validity, and then comparing it to subsequent risk terrain maps produced with different combinations of risk factors. These are all ad-hoc methods for creating risk terrain models. The ad-hoc method should be supported (at a minimum) with a reasonable and articulated justification for why certain factors were included in your risk terrain model. Your goal should be to maximize the credibility, validity and reliability of the risk terrain maps that will ultimately be produced by the combination of risk factors that you select. The ad-hoc method is based solely on the assumption that findings from various sources about what to include in your risk terrain model are valid and applicable to your study area. There is no statistical verification. This method is advantageous because it allows for expedient risk terrain map production that is grounded in existing theory, empirical research, and/or professional experience. But, it lacks the statistical support that your model is in fact the best of many alternatives in your particular study area. The ad-hoc method is likely to be an appropriate option for risk terrain modeling by many risk analysts in many settings.

Empirical Method of Risk Factor Selection

The empirical method requires an extra step of statistical analysis and a dataset of outcome event locations. This extra step empirically tests the place-based correlation of each risk factor (that you identified in Step 5) on the outcome event. This permits the use of only the most significantly correlated risk factors in your risk terrain model. The downside to the empirical method is the time required to complete it and the need for outcome events (which you might not have; though, you can use outcome event data from the same time period as the risk factor data. (The outcome events do not have to be "future" events). The advantage of the empirical method is that it helps to maximize the reliability and validity of your risk terrain model by permitting the inclusion of only the most relevant risk factors.

For this demonstration, the empirical method was used to decide which risk factors to include in the risk terrain model. Five separate chi square tests were utilized to identify the variables most significantly correlated with the outcome event. As shown below, Governance ($p<.001$), Neighbor Conflict ($p<.001$) and Rough Terrain ($p\leq.01$) risk factors are significantly correlated with the presence of governmental internal armed conflict between 1997 and 2005. Accordingly, out of the five risk factors identified in Step 5, only these three statistically significant variables will be included in the risk terrain model.

Pearson Chi-Square Test Results for the 1997-2005 Armed Conflict Incidents

Risk Factor	Sig. (2-sided)
Country Size	.280
Governance	.000
Rough Terrain	.008
GDP per Capita	1.000
Neighbor Conflict	.000

Step 7: Select Particular Risk Factors to Include in the Model

The operationalization of national-level data is relatively easier than the operationalization of sub-national data because the risk values are attributed to the state polygons rather than smaller units of analysis. Accordingly, every risk factor's spatial influence may be added together on one map by simply recording each operationalized risk factor as a separate column in the attribute table of the study area shapefile.

Whether you are working with national or sub-national level data, the process of operationalizing each risk factor to a risk map layer should be done so that it reasonably and meaningfully represents the spatial influence of the risk factor on the outcome event at each place (i.e. unit of analysis) throughout the study area. Regardless of how risk factors are operationalized, you must standardize the values for every risk factor so that the numerical value of "high risk" for one risk factor is (relatively) equal to the numerical value of "high risk" for all other risk factors. For example, if you are giving binary values to one risk factor (0=Not high risk, 1=High risk), the other risk factor should be given the same binary values (0=Not high risk, 1=High risk). If, for instance, you are using infant mortality and GDP per capita as risk factors in your analysis of a global threat, the nations with values below or above your risk threshold (depending on how you operationalize "high risk" for these factors) should be given the same risk value schema: "0=Not high risk, 1=High risk". Otherwise you will not be able to add the risk values together in a meaningful way to create a composite risk map.

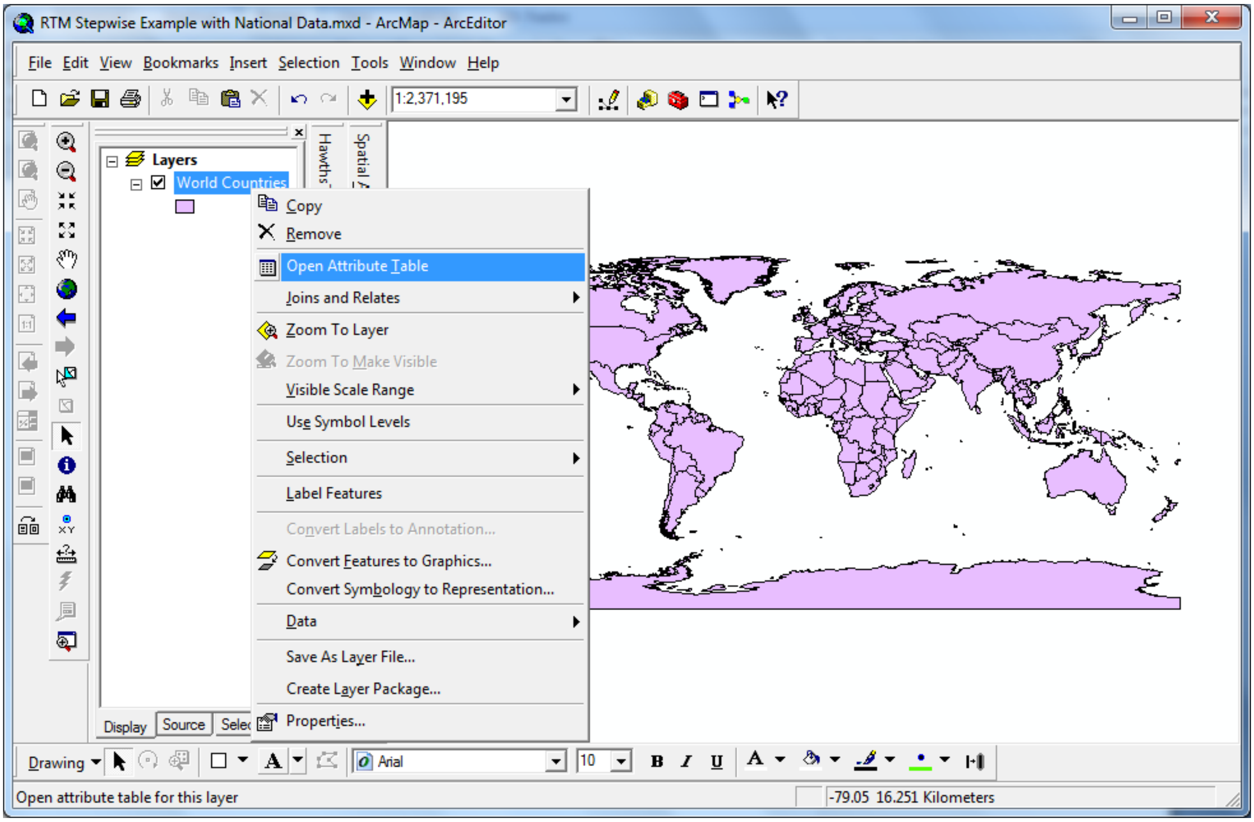
In this demonstration, the three risk factors identified and selected in Steps 5 and 6 will be operationalized and attributed to the study area shapefile as follows:

Operationalizing Governance

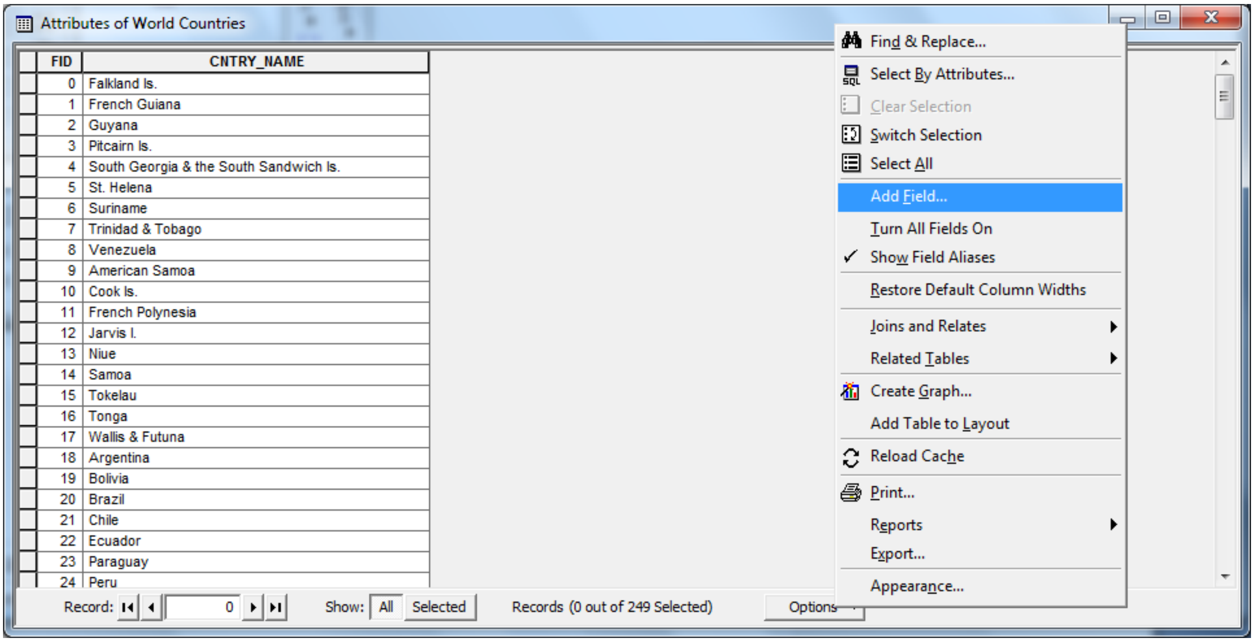
Governance indicators have been identified as a robust predictor of political instability. For this demonstration, the 1996 data of governance indicators were acquired from The World Bank's World Governance Indicators dataset. In this dataset governance is defined as "the traditions and institutions by which authority in a country is exercised" (Kaufmann et al., 2010, 4). In this index, six dimensions of governance are used: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and Control of Corruption. This index calculates each country's percentile rank for each of the 6 components (being in lower percentiles shows that the country has a lower quality for the specific governance indicator, for instance a country within the 25th-50th percentile for corruption is considered to have a better governance than a country within the 0th-25th percentile for corruption).

The spatial influence of the "governance" risk factor was operationalized as "Countries within the first quartile (0th to 25th percentile) of any of the governance rank will increase the risk of those countries having governmental internal armed conflicts". To calculate the cumulative risk value for the 6 governance indicators; initially, countries were coded as "1" or "0" to identify which countries fell into the 1st quartile in the country governance rankings. Countries in the first quartile were coded as "1", whereas countries in the "25th - 100th" percentile were coded as "0". Countries with missing data were coded as "999". Following that, the initial 6 scores (1 or 0) were added up to get a cumulative governance risk score. Therefore each country was assigned a cumulative governance risk value between 0 and 6. The cumulative governance risk value for each country was added to the attribute table of the world countries shapefile by the following procedure:

First, by right clicking the shapefile, the attribute table of world countries was opened.



By right clicking the options tab, a new field was added for the cumulative governance risk value using the "Add Field" function.



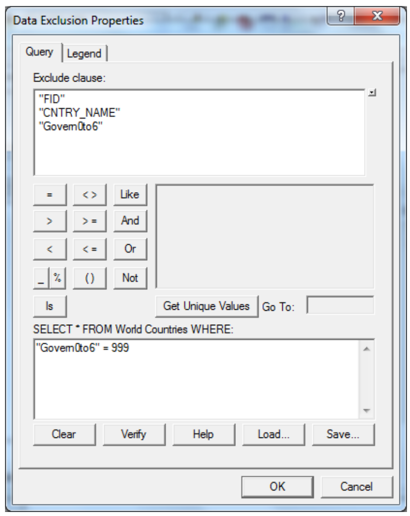
TIP: Do not use punctuation such as ?,&,$,#,@,*,!,~ or spaces in your field name and keep your field name to 10 or fewer characters. From the dropdown menu, choose the type of field. Short Integer: numeric, no decimal place, up to 19 characters. Long Integer: numeric, no decimal place, up to 19 characters. Float: numeric, with decimal place, (default is one place before decimal and 11 after). Double: numeric, with decimal place (default is 7 places before the decimal and 11 after). Text: numbers or letters, specify length (default = 50 characters). Date: can include time and date. Blob: up to four characters. Finally, determine the scale (number of places) and precision (number of places to the right of the decimal point), or accept the defaults by leaving them 0.

After adding the new field (Govern0to6), the cumulative governance risk value is manually added to the attribute table of the world countries shapefile.

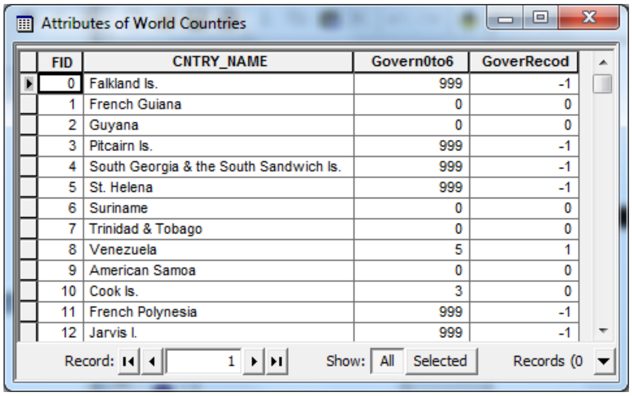
TIP: To manually add data to a new field, first click the "Start Editing" tab in the Editor toolbar's drop-down menu. Once you finish editing, save your edits by clicking "Save Edits" tab and then click "Stop Editing" tab on the same toolbar.

Countries' cumulative governance risk value was classified into 2 groups according to standard deviational breaks using the symbology tab in the layer properties. "High risk" countries were deemed the countries with cumulative governance values greater than +1.5 SD (or top 15%), whereas "Not high risk" countries were deemed the countries with cumulative governance values less than or equal to +1.5 SD. The reason standard deviation was used as a classification scheme in this particular example is because it is not affected by positively skewed distributions or outliers, and it is statistically meaningful. Countries with missing data were excluded from the classification.

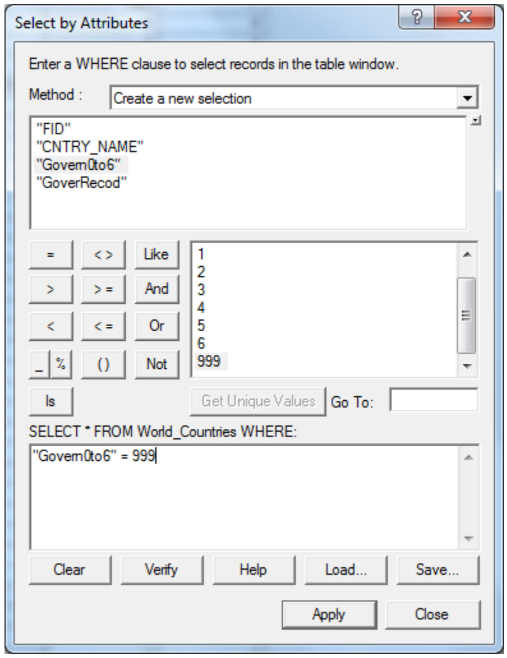
TIP: To change the classification scheme, you can access layer properties by either double-clicking on the relevant map layer or right-clicking on the map layer, then clicking the "Properties" tab. You can use different colors—or different shades of the same color—to represent different values to create choropleth maps. From "Layer Properties," click on the "Symbology" tab. On the left side of the screen, click on "Quantities" and "Graduated Color." Choose the field with the values you wish to use. Use the "Classes" dropdown menu and the options in "Classify" to change the number of categories or method for breaking values into categories. When you want to exclude certain values from your classification, click the exclusion tab in the Classification window. To exclude a certain value you have to write a query that is compatible with your coding.

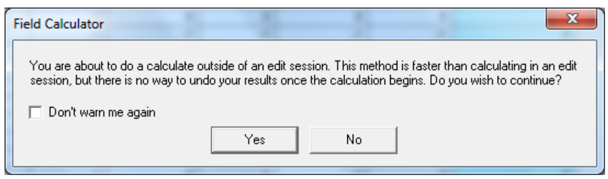


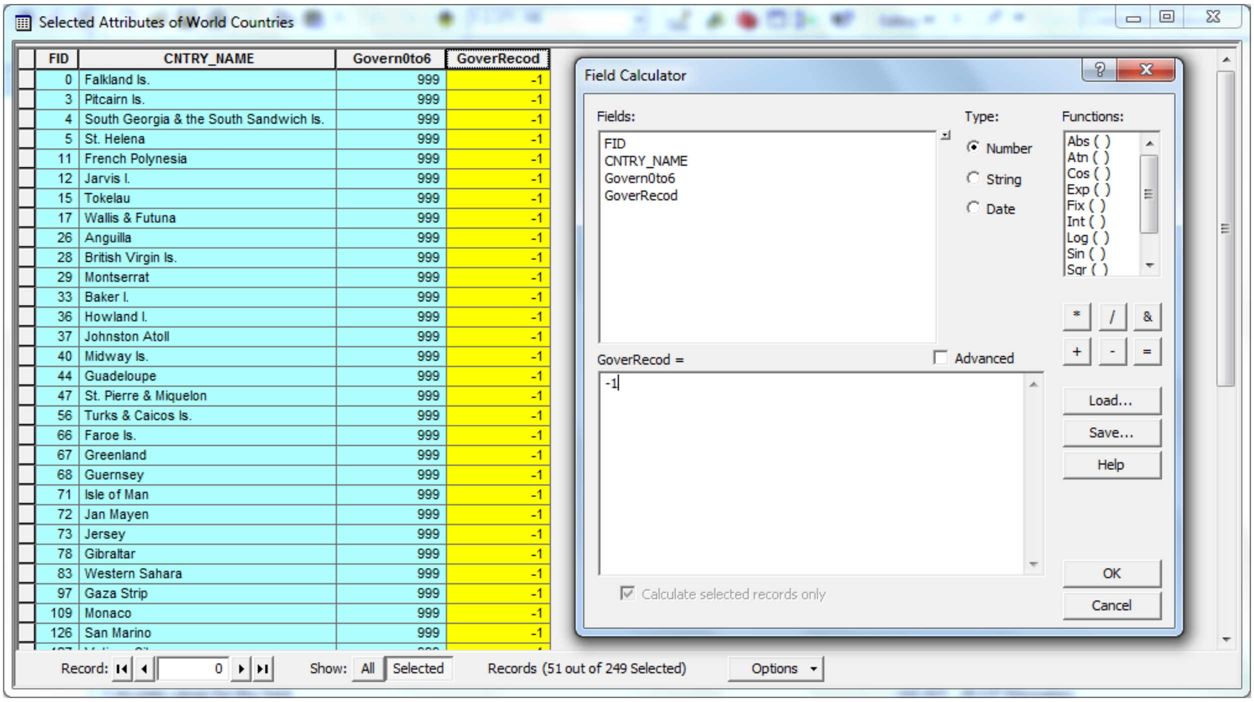
By adding a new column (GoverRecod) to the attribute table, countries with a governance value which was +1.5 SD of the mean or higher (values 5 and above) were coded as "High risk (1)" and countries with a governance value less than or equal to +1.5 SD of the mean (values 0-4) were coded as "Not high risk (0)" for the final governance risk value. The countries with missing/incomplete data were coded as "-1".



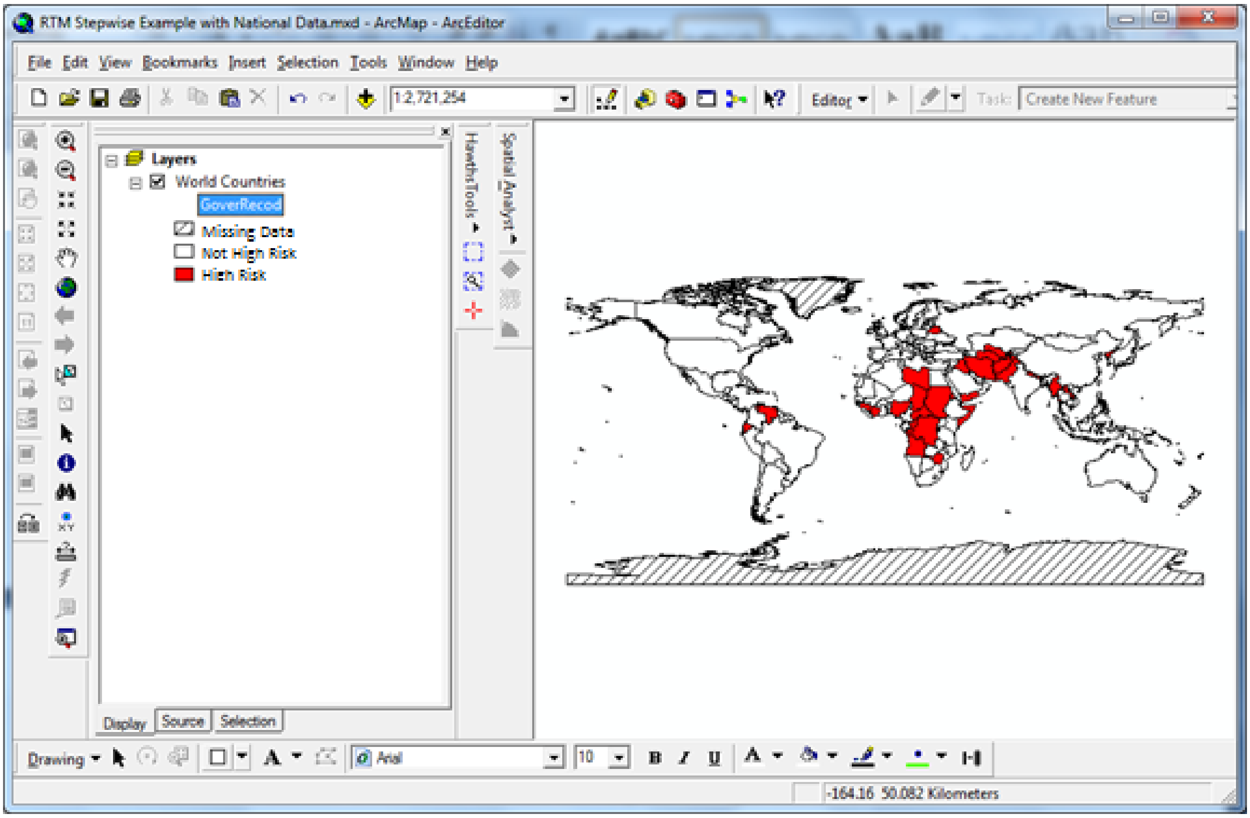
TIP: Please note that when you have the cut points for standard deviational breaks; rather than manually entering the new scores (0, 1 and -1) you can use select by attributes and field calculator functions to enter the new values for cases. Here, for example, after adding the new field of "GoverRecod"; by right clicking the "Govern0to6" field in attribute table and then selecting the "Select by attributes function" you can select the countries with missing data/countries with a governance score between 0-4 or 5-6 and then by right clicking your new field "GoverRecod", you can calculate the field for only selected cases. Please remember that by choosing different options from the drop-down menu of select by attributes such as "Create a new selection", "Add to current selection" or "Remove from current selection", you can easily change which values to include in the reclassification (See below for an example for how to code missing data in 2 easy steps). To access the "Field Calculator" function: on the attribute table of your shapefile, right click on the field name of the column you want to work on. Once you click the "Field Calculator", the system will warn you about doing a calculation outside an edit session. Click "Yes" and continue.







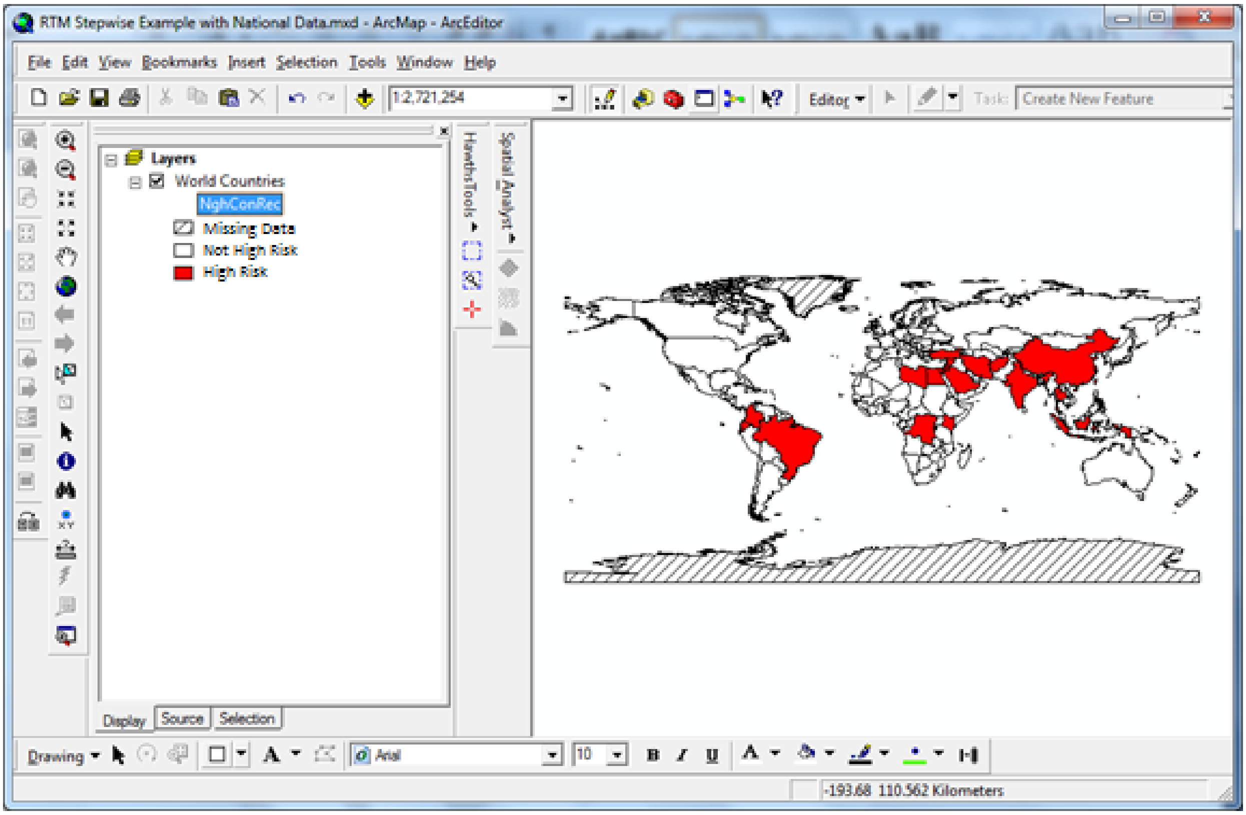
As shown in the following map, after symbolizing the recoded governance values using the symbology function, 33 countries have been identified as high risk countries with regard to governance: Afghanistan, Angola, Belarus, Burundi, Central African Republic, Chad , Comoros, Congo, Democratic Republic of the Congo, Ecuador, Equatorial Guinea, Eritrea, Guinea, Haiti, Iran, Iraq, Ivory Coast, Laos, Libya, Myanmar, Nepal, Nigeria, North Korea, Pakistan, Somalia, Sudan, Tajikistan, Togo, Turkmenistan, Uzbekistan, Venezuela, Yemen, Zimbabwe.



TIP: To symbolize the recoded risk values, double click on your risk layer, click symbology tab, and choose unique values under "Categories". By clicking the "add all values" tab, you can add all values in your recode schema and change the symbology of the values by double clicking on the rectangle shape next to the value headings.

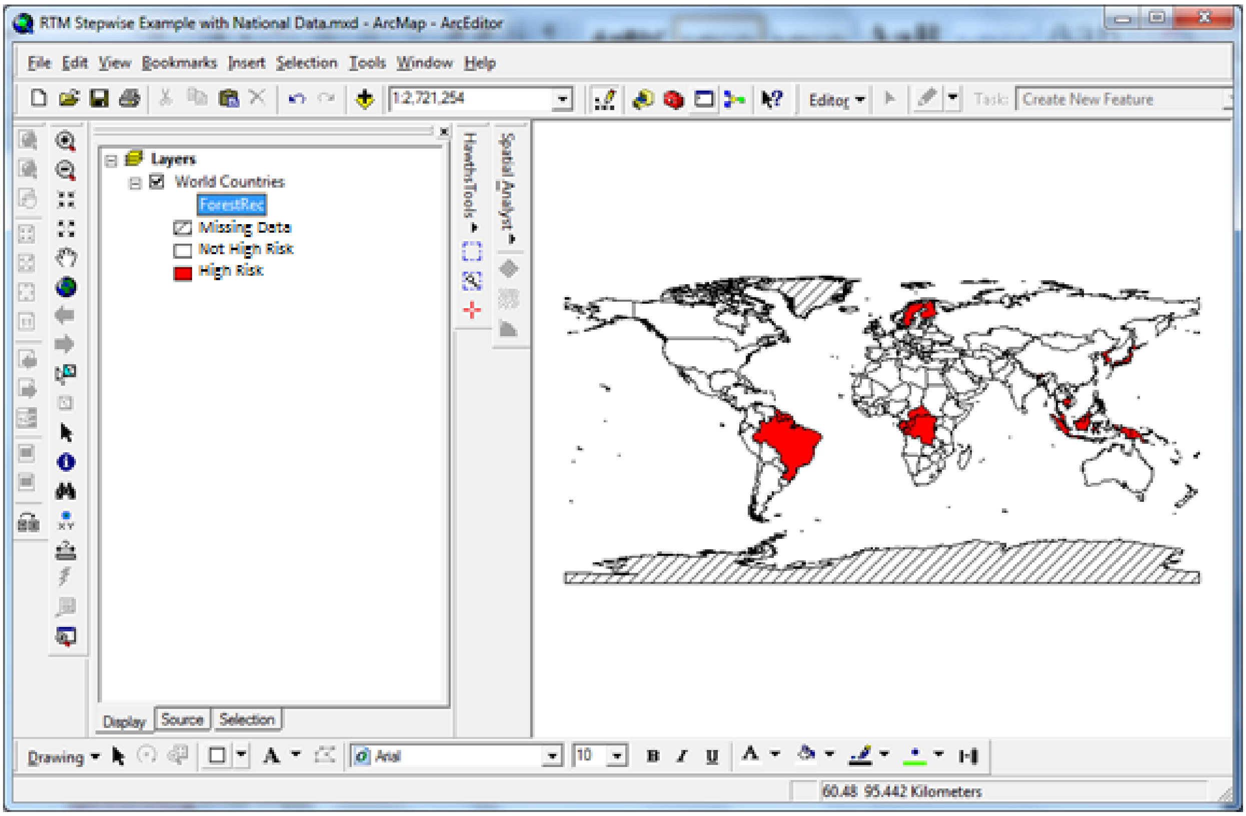
Operationalizing Neighbor Conflict

Countries' armed conflict data have been acquired from UCDP/PRIO Armed Conflict Dataset. Unlike the outcome event (which was only governmental internal armed conflict incidents), all armed conflict incidents of 1996 were included in the neighbor conflict variable. The spatial influence of the "neighbor conflict" risk factor was operationalized as "Countries with more neighbor conflict will increase the risk of those countries having governmental internal armed conflicts". Following the same procedures in the previous operationalization section after creating a new column (NghConNo) for neighbor conflict on the attribute table of the world countries shapefile, the number of neighbor countries with armed conflict for each country has been manually entered. Countries with missing data were coded as "999" (mean number of neighbor countries with armed conflict= 0.88, SD= 1.1, max=7). By adding a new column (NghConRec) to the attribute table, countries with a neighbor conflict value which was +1.5 SD of the mean were coded as "High risk (1)" and countries with a neighbor conflict value less than or equal to +1.5 SD of the mean were coded as "Not high risk (0)". The countries with missing/incomplete data were coded as "-1". After this analysis, as can be seen in the following map, 19 countries were identified as high risk countries with regard to neighbor conflict: Afghanistan, Brazil, China, Colombia, Democratic Republic of the Congo, Cyprus, Ecuador, Egypt, Georgia, India, Indonesia, Iran, Jordan, Kenya, Libya, Saudi Arabia, Syria, Thailand and Turkey.



Operationalizing Rough Terrain

Rough terrain data was acquired from CIA World Factbook 1996[xvi]. For instructional purposes, here, rough terrain has been operationalized as countries' forest area percentages. Readers interested in armed conflict analysis might re-conceptualize this indicator utilizing mountainous area or other natural terrain patterns. Following the same procedures in the initial operationalization section, after creating a new column (ForestPerc) for rough terrain on the attribute table of our world countries shapefile, the forest percentage for each country has been manually entered. Countries with missing data were coded as "999" (mean= 26%, SD= 23%, max=97%). By adding a new column (ForestRec) to the attribute table, countries with a forest percentage which was +1.5 SD of the mean were coded as "High risk (1)" and countries with a forest percentage less than or equal to +1.5 SD of the mean were coded as "Not high risk (0)". The countries with missing/incomplete data were coded as "-1". After this analysis, as can be seen in the following map, 23 countries were identified as high risk countries with regard to rough terrain: American Samoa, Bhutan, Brazil, Brunei, Cambodia, Central African Republic, Congo, Democratic Republic of Congo, Fiji, Finland, French Guiana, Gabon, Guyana, Indonesia, Japan, Malaysia, North Korea, Papua New Guinea, Sao Tome and Principe, Solomon Islands, South Korea, Suriname and Sweden.



Operationalizing Armed Conflict

Armed conflict has been operationalized as the governmental internal armed conflicts between the government of a state and one or more internal opposition group(s) without intervention from other states or internationalized internal armed conflict between the government of a state and one or more internal opposition group(s) with intervention from other states (secondary parties) on one or both sides. National level indicators are believed to be *long term predictors* of armed conflict; to test this hypothesis for each country, armed conflict incidents between 1997 and 2005 have been coded as a new variable (Gov97_05) following the same procedures in the initial operationalization section.

STEP 8: Risk Map Layer Weighting

There are two types of weighting that can be done in risk terrain modeling. The first is somewhat inherent in the task of Step 7—when you operationalize every risk factor according to a standard index, such as 0 or 1. In this way, the influence of the risk factor is "weighed" around the geography. The second type of weighting weighs the risk map layers relative to one another so that the most "important" risk factor affects the risk terrain map more so than the other risk factors. Risk terrain models are considered "weighted" when the risk map layers are weighted relative to one another. Risk terrain models are considered "un-weighted" when risk map layers are operationalized according to a standard index (which is a must, as discussed above in Step 7) and when the influence of each risk map layer on the outcome event is considered to be equal, so relative weights are not assigned. To weight risk map layers in a risk terrain model with some statistical rigor, we recommend using the following weighting procedure.

Weighting the Risk Factors

While working with national level data; to weight risk map layers in a risk terrain model with some statistical rigor, we recommend calculating standardized coefficients for each of the significant risk factors (e.g. for Governance, Neighbor Conflict and Rough Terrain). To do this, first you should identify how many of your units (countries) fall into the respective risk category (High Risk). In this case study, 33 countries have been identified as high risk countries with regard to governance, 19 countries have been identified as high risk countries with regard to neighbor conflict and 23 countries have been identified as high risk countries with regard to rough terrain. Then, for each risk factor, you should identify how many governmental internal armed conflict incidents have been observed in the high risk countries for the designated time period (e.g., between 1997 and 2005). Between 1997 and 2005:

- 61 governmental internal armed conflict incidents have been observed in 33 high risk countries with regard to governance,
- 27 governmental internal armed conflict incidents have been observed in 19 high risk countries with regard to neighbor conflict, and
- 8 governmental internal armed conflict incidents have been observed in 23 high risk countries with regard to rough terrain.

After identifying number of risk units (countries) and the count of outcome events (number of observed governmental internal armed conflicts between 1997 and 2005) for each risk factor, you should divide the count of outcome events by the number of high risk units to get each risk factor's relative spatial influence (RSI). In this case:

→ For governance risk map layer: 61/33: 1.85

→ For neighbor conflict risk map layer: 27/19 = 1.42

→ For rough terrain risk map layer: 8/23 = 0.34

After calculating the RSI of each indicator, calculate the risk factor's weight by dividing the RSI value of each risk map layer by the smallest RSI (i.e., here, the smallest RSI is 0.34):

→ The standardized coefficient for Governance: 1.85/0.34= **<u>5.44</u>**

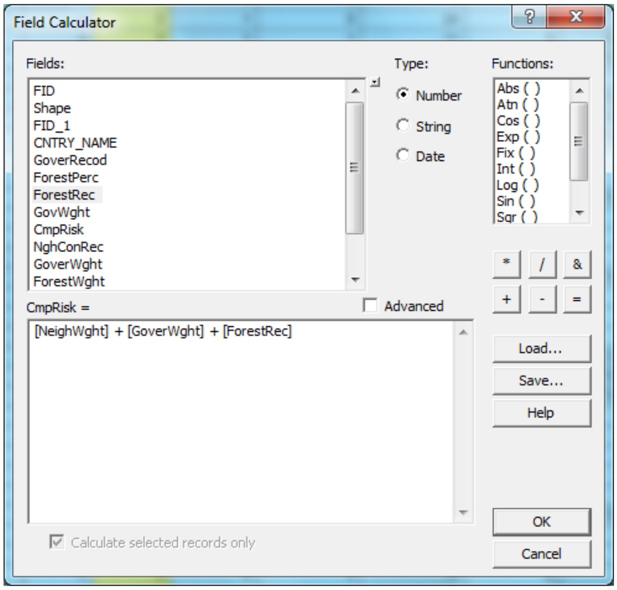
→ The standard coefficient for Neighbor Conflict: 1.42/0.34= **<u>4.17</u>**

→ The standard coefficient for Rough Terrain: 0.34/0.34=**<u>1</u>**

After calculating the standardized coefficients for the risk map layers; following the same procedures in the initial operationalization section, you should create new columns in the attribute table of your study area map to apply the relevant standardized coefficients to the previously calculated risk values (0 and 1). To calculate the new risk values you can use the Field Calculator function in ArcGIS. Once you create a new column for each risk factor (in our case since Rough Terrain [forest percentage] is the baseline risk factor, two weight columns were created, namely; GoverWght and NeighWght), calculate the new risk value by multiplying the previous binary risk values (GoverRecod, NghConRec) with the relevant standardized coefficient, excluding the cases with missing data.

STEP 9: Combine Risk Values to Form a Composite Map

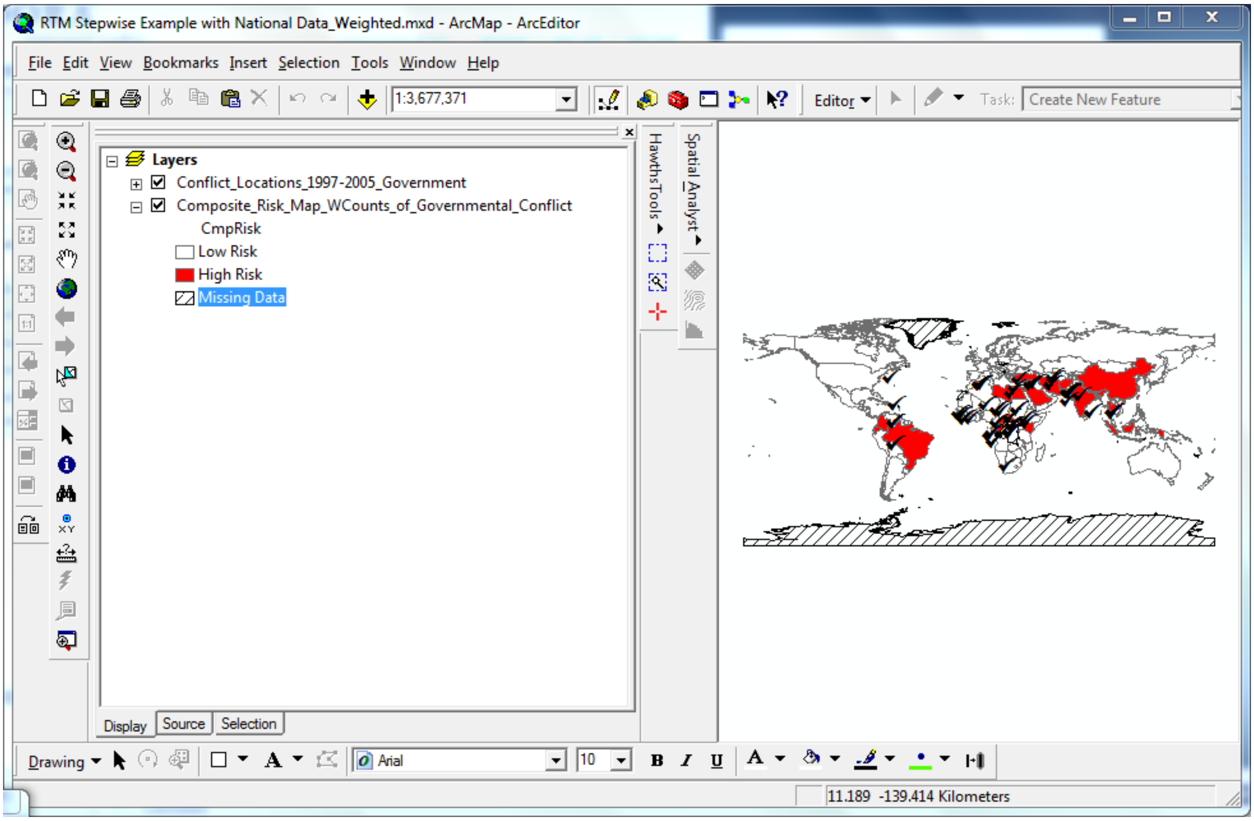
To combine the risk values of the 3 factors (namely; GoverWght, ForestRec and NeighWght); a new field (CmpRisk) was added to the World Countries' attribute table using the "Add Field" function. Once the new field was added to the attribute table of the World Countries shapefile, the composite risk value was calculated using the "Field Calculator" function.



IMPORTANT: While adding the risk values, remember to exclude the countries with missing data.

STEP 10: Finalize the Risk Terrain Map to Communicate Meaningful Information

The resulting composite risk value (from Step 9) should be symbolized to clearly communicate information about the study area for purposes of strategic decision-making and/or tactical action. To symbolize the composite risk value, the symbology function was activated by double clicking the world shapefile layer > Properties > "Symbology" tab. Using the graduated colors in Categories section, the Composite Risk Value (range: 0-8.63; mean=1.09; sd=1.89) was symbolized. As can be seen in the map below, the countries that fell into the top 15% with regard to armed conflict risk (risk value >+1.5 SD) have been symbolized in the shades of red, whereas the countries with a risk value ≤+1.5 SD have been symbolized with hollow background and the country polygons with missing data were symbolized with a 10% simple hatch. Twenty two countries are identified as high risk with regard to their weighted composite risk values: Afghanistan, Brazil, Central African Republic, China, Colombia, Congo, Democratic Republic of the Congo, Cyprus, Ecuador, Egypt, Georgia, India, Indonesia, Iran, Jordan, Kenya, Libya, North Korea, Saudi Arabia, Syria, Thailand, Turkey. Among those 22 countries identified as high risk, nine (namely **Afghanistan, Colombia, Central African Republic, Congo, Democratic Republic of the Congo, Egypt, India, Iran and Turkey)** had experienced at least one governmental internal armed conflict between 1997 and 2005. Among 119 governmental armed conflicts between 1997 and 2005, this risk terrain model with national level risk data successfully forecast 32 conflicts (27%) in 22 countries (11% of all independent countries) deemed to be high risk.



Statistically Validating Your Risk Terrain Model

Testing the predictive validity of your risk terrain model gives it empirical credibility and allows for the estimation of future events with a certain degree of confidence. The drawback is that it requires outcome event data. You could assume that your model is valid (which the technical steps above should help to make it so), and then validate your model after it has been applied to practice and the subsequent time period has ended. Or, you could produce a risk terrain map using data from two periods back to test your model's predictive validity with current outcome event data and then, if found to be valid, replicate the risk terrain model using current risk factor data to forecast the subsequent time period. The procedure for testing a risk terrain model's validity can also be used to compare which time period a model is best able to forecast. For example, existing research has shown that risk terrain models from January through June can forecast locations of hazards during July through December with statistical validity. However, your tests might show that, in fact, the "January through June" model is a stronger predictor of locations of outcome events during the same time period the following year. That is, for instance, "January through June 2010" could be a better predictor of "January through June 2011" than "July through December 2010". Or, you might find that time periods work best when they are in weekly, monthly, quarterly, yearly, etc. intervals. The best model will likely differ across different settings, extents, and jurisdictions. We recommend using regression analysis to test the validity of your risk terrain model or alternatively using a chi-square difference test (using the "null" or constant-only model) to compare the fit of the model with and without the predictor(s). There are many ways in which to do these, and there are many tools to use, including software like EpiInfo (http://wwwn.cdc.gov/epiinfo). It is beyond the scope of this manual to direct you to one particular method since there are many legitimate methods and because it requires at least an intermediate level of statistical knowledge that is somewhat specific to the method used. For this demonstration, the statistical validity of the risk terrain model was tested using logistic regression analysis. Logistic regression analysis allowed us to measure the extent to which the 1996 risk terrain model with national risk indicators explained the patterns of governmental armed conflict incidents between 1997 and 2005 (Ind. Var. = "Composite Risk Value" [0-8.63]; Dep. Var. = "Presence of Any Governmental Internal Armed Conflict" [Yes or No]). As shown in Table 1, the odds ratio suggests that for every increased unit of risk, a future armed conflict is 1.55 times more likely to occur ($p<0.001$).

Table 1: Logistic Regression for Risk Value on Armed Conflict:: 1996 Risk Terrain

		B	S.E.	Sig.	Exp(B)
	Risk Value	0.439	0.096	0.000	1.551
	Constant	-2.386	0.285	0.000	0.092
-2LL: 148.865; Nagelkerke R square: .189					

Chapter 4

A Stepwise Example of RTM Using Sub-National Level Geographic Data

In Chapter 3, RTM risk values were attributed to *vector polygons* of countries. In this chapter, a risk terrain model will be created through *raster mapping* (rather than vector mapping), with a focus on sub-national data. Refer to Chapter 2 for detailed information on shapefiles, vector data, raster data.

STEP 1: Select an Outcome Event of Particular Interest

→ Governmental Internal Armed Conflict Incidents

If you have not read the previous chapter, refer to Step 1 in Chapter 3 for the description and source of the Armed Conflict data.

STEP 2: Choose a Study Area

→ Global scale

For instructions on how to select your study extent please refer to Step 2 in Chapter 3.

STEP 3: Choose a Time Period

→ Risk factors of 1996 will be used to predict the governmental internal armed conflict incidents observed between 1997 and 2005.

For instructions on how to select your time period please refer to Step 3 in Chapter 3.

STEP 4: Obtain Base Maps of Your Study Area

→ The polygon shapefile of the world countries (world countries in 2007)

For instructions on which base maps you should obtain and how to obtain them please refer to Step 4 in Chapter 3.

STEP 5: Identify Aggravating and Mitigating Risk Factors Related to the Outcome Event

→ Proximity to capital, diamond reserves, petrol reserves, border, rough terrain; density of population, minority language, roads

As exemplified in the previous chapter, most of the popular indicators of conflict, in general, and internal armed conflict, in particular, utilize factors *that vary geographically within states*. Accordingly, analyses conducted using country level aggregate data to explain local armed conflict incidents fall victim to the phenomenon of "ecological fallacy". Especially in the case of spatial analysis of risk, the ecological fallacy might be specifically defined as the Modifiable Areal Unit Problem (MAUP), where aggregate levels of data are used to forecast incidents that have specific micro-level locations. In recent armed conflict literature, some authors have started using different sets of sub-national conflict predictors, utilizing Geographical Information Systems, to describe the nature of armed conflict incidents and to produce more reliable datasets by creating raster cell-level risk values to overcome MAUP concerns and, additionally, test for the spatial autocorrelation of risk indicators. According to the recent specific studies of armed conflict with sub-national level data, the probability of armed conflict at a specific location is expected to be *dependent on*:

1. **Military factors:**
   a. **The location of conflict relative to the capital** (Buhaug and Gates 2002; Buhaug and Rød 2006; Hegre and Raleigh 2006; Rød and Buhaug 2008): As rebel groups might be safer in distance to governmental institutions; or from a different perspective, opposition groups might specifically prefer to create conflict around the capital if the opposition is against government.
   b. **The location of conflict relative to the border** (Buhaug and Gates 2002; Buhaug and Rød 2006; Rød and Buhaug 2008): As neighbor countries might provide safer zones for rebels and this might give a tactical advantage for military superior opposition.
   c. **The factor of local road density (**Buhaug and Rød, 2006)**:** Since remote regions are harder to reach by government forces they are thought to be ideal for organizing a rebellion.
   d. **The factor of distance to/local extent of rough terrain** (Buhaug and Gates 2002; Buhaug and Rød 2006; Hegre and Raleigh 2006; Hegre and Sambanis 2006; Rød and Buhaug 2008): Mountainous

and forested terrain is believed to provide shelter for rebels. Additionally, forests are considered to provide funds and food for rebels (Rustad et al. 2008).

e. **The factor of population density** (Collier and Hoffler 2004; Buhaug and Rød 2006): A dispersed population is believed to inhibit government capability and thus facilitate rebellion.

2. **The factor of local dominance of a minority language (**Buhaug and Rød 2006, 319): According to Rokkan and Urwin (1983) "language and other cultural distinctions are prone to be amplified by political and rebel leaders".
3. **The location of conflict relative to the valuable resource deposits** (Le Billon 2001, Buhaug and Rød, 2006, 320): As ''the spatial distribution and lootability of resources are crucial with regard to the opportunities of belligerents to seize or retain control over resource revenues".

STEP 6: Select Particular Risk Factors to Include in the Model

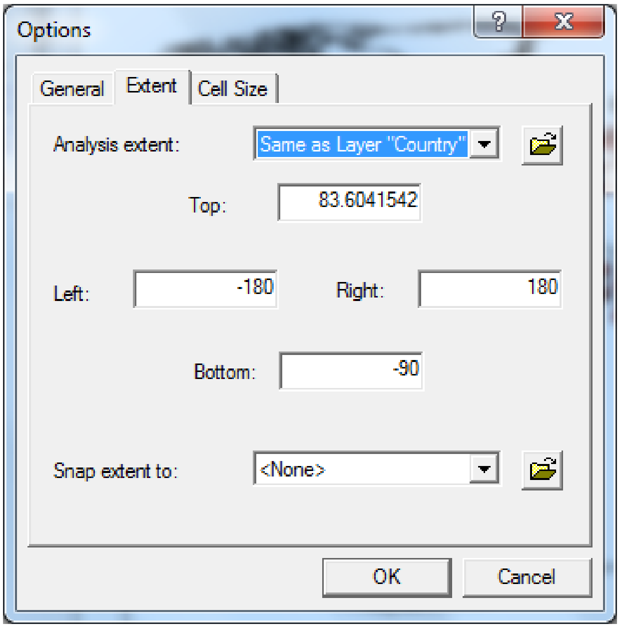
→ Proximity to capital, diamond reserves, petrol reserves, rough terrain

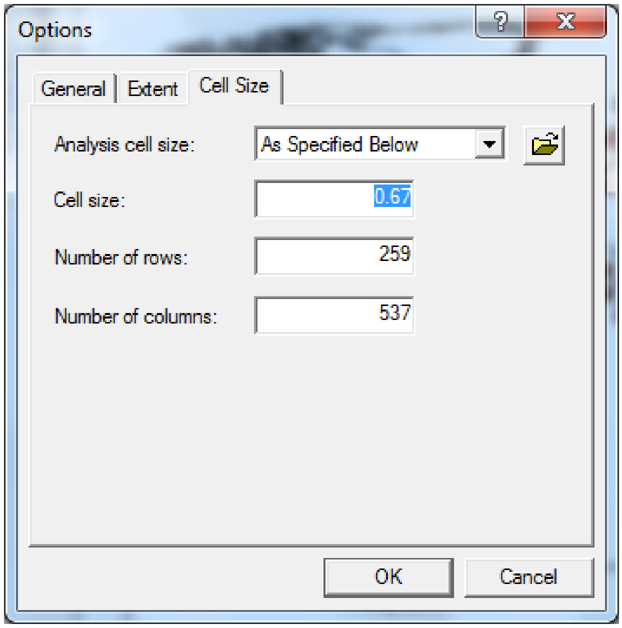
Among the eight risk factors initially identified in Step 5, four risk factors (i.e., proximity to capitals, proximity to diamond reserves, proximity to petrol reserves, and proximity to rough terrain) have been selected using the ad-hoc method because the locations of these factors were readily and publically available as either geocoded shafefiles or XML format (with X and Y coordinates). *For detailed information on the ad-hoc method of factor selection please refer to Step 6 in Chapter 3.*

STEP 7: Operationalize Risk Factors to Risk Map Layers

⚠ **IMPORTANT:** All shapefiles included in this model have been projected with the Mercator projected coordinate system and the linear unit has been chosen as 150 km (which means 1 map unit represents 150 km). Since different projections might preserve distance, shape, direction or area; the projection you choose should depend on what you want to preserve most in your analysis. To permanently change the projection of a shapefile; open ArcCatalog, right click on the shapefile, and click Properties. In the XY Coordinate System you can edit the projected or geographic coordinate system from "Select" and you can edit the properties of the currently selected coordinate system from the "Modify" tab.

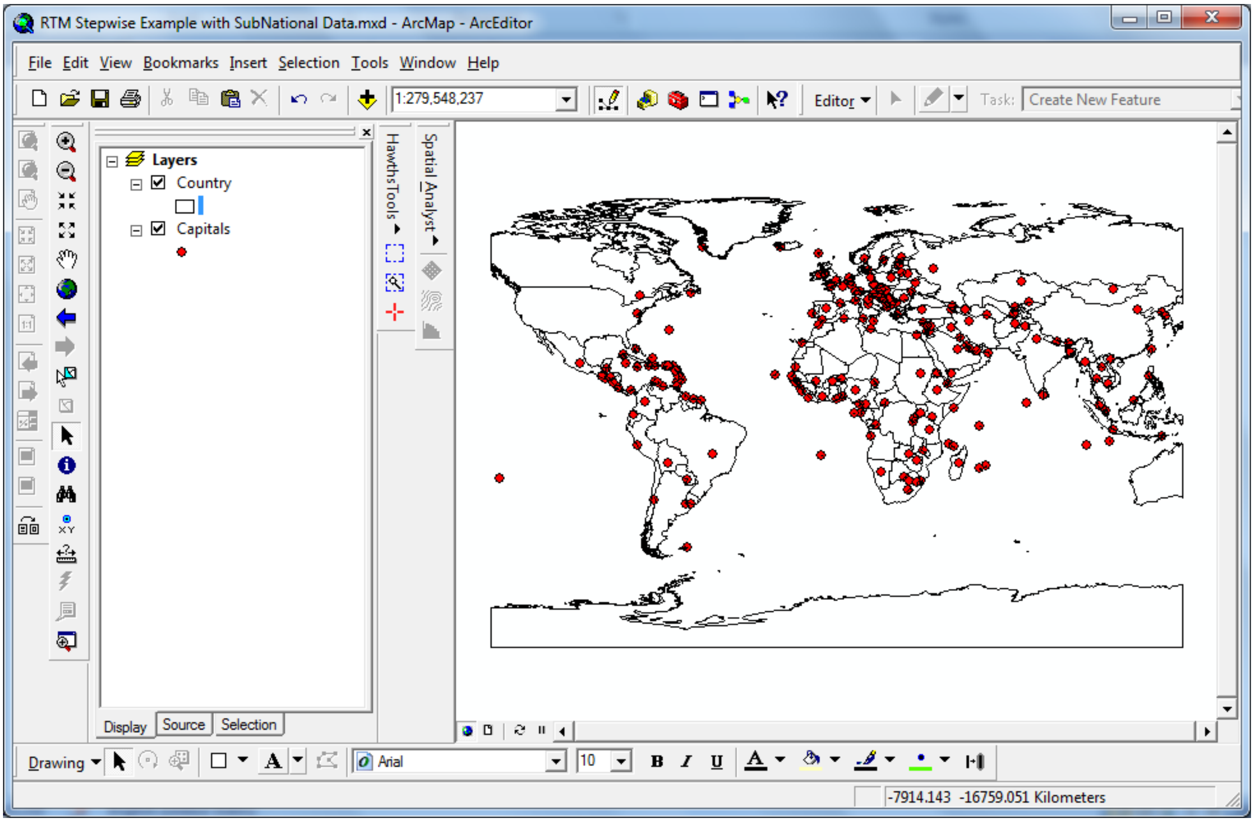
Before doing any density or distance calculation make sure to set the analysis extent as the same as your basemap (in our case; Countries) from Spatial Analyst/Options/Extent. (To set extent in ArcGIS 10, see http://www.rutgerscps.org/docs/RTMArcGIS10Changes.pdf). Additionally, you can select a meaningful cell size for your raster cells. On Spatial Analyst/Options/Cell Size window you can set the cell size for your analysis. For our analysis 100 km x 100 km grid cells were chosen in reference to Buhaug and Rød's study (2006) where this resolution was chosen to analyze the correlates of civil wars in Africa. As can be seen in the screenshot below since at the beginning the linear unit has been edited as "150 km", the output cell size has been chosen as "0.67" which equals to 100 km in a 150 km unit scale (100/150 = .67).



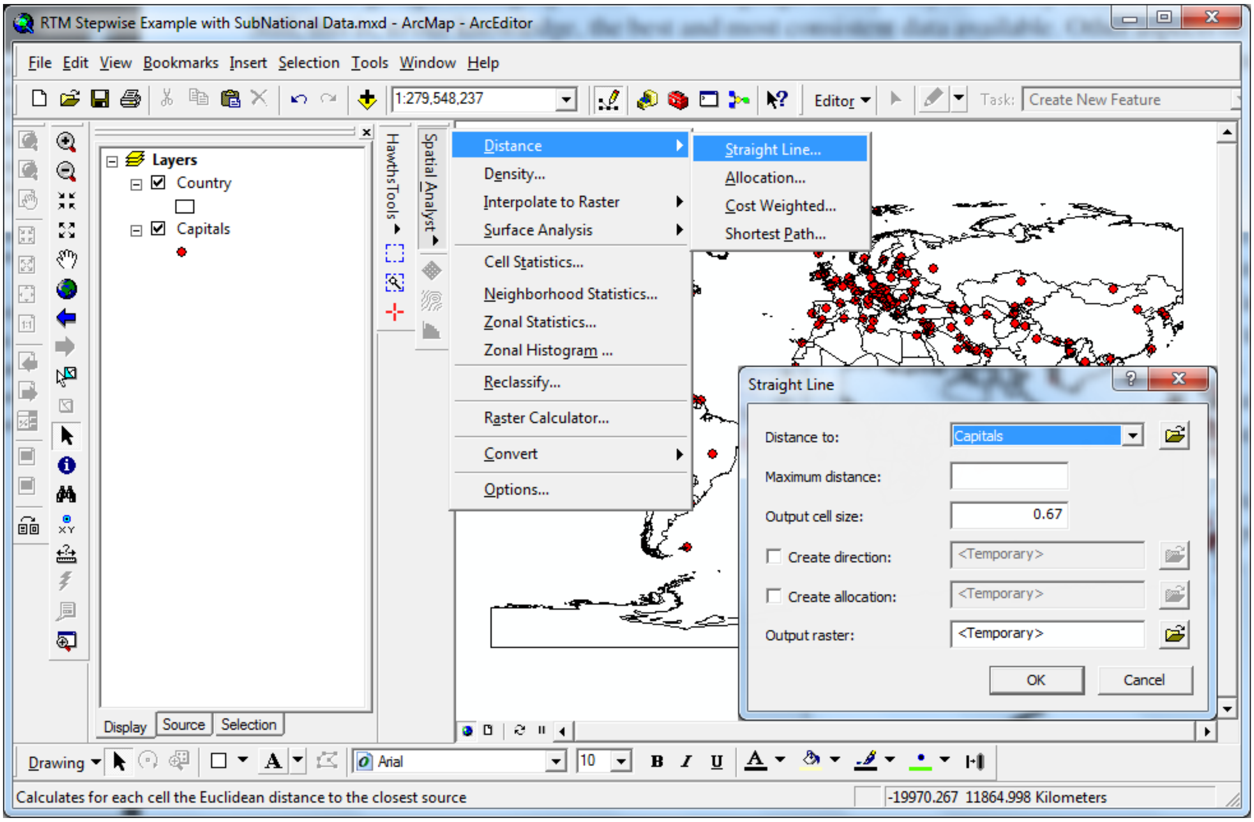


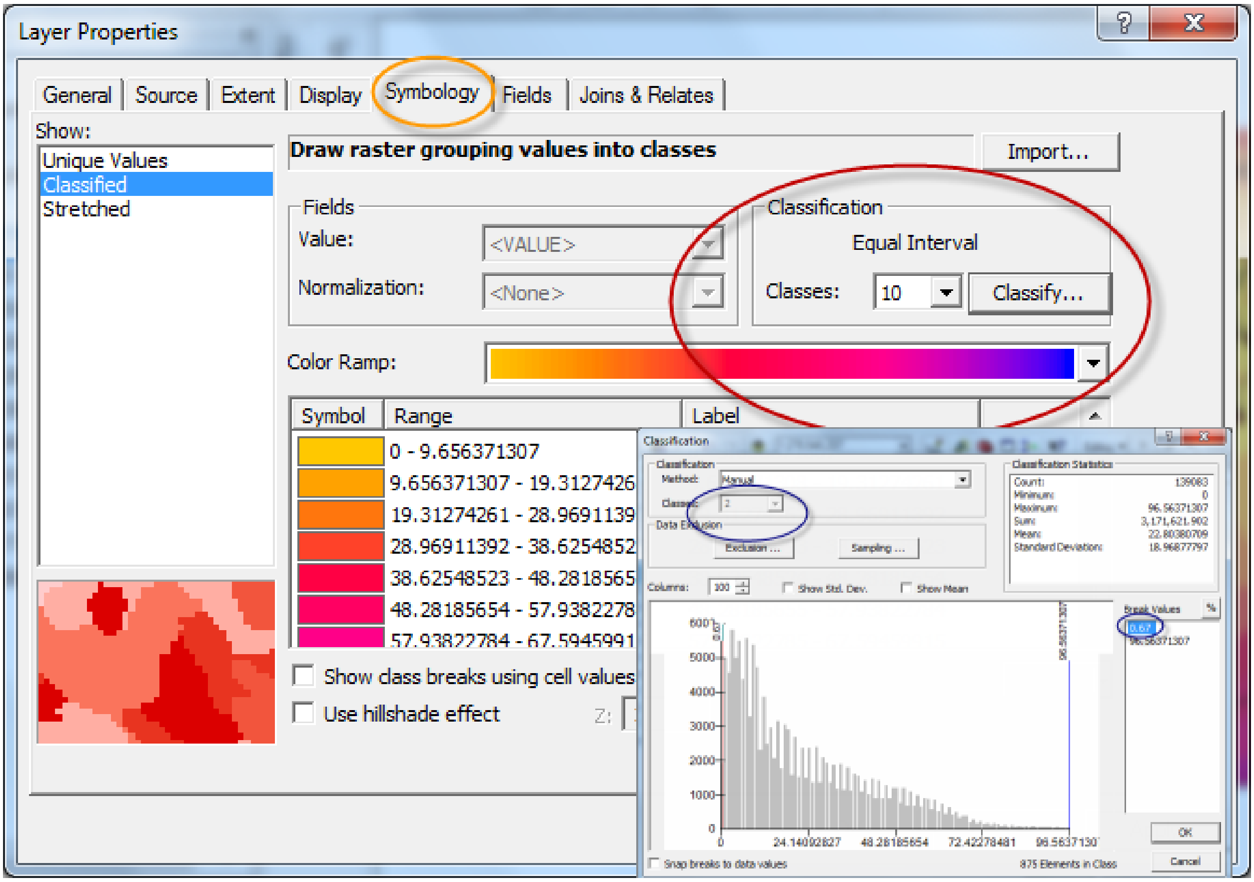
Operationalizing Proximity to Capitals

First, the X and Y coordinates of capitals were geocoded to the World Countries shapefile to create point features representing the locations of country capitals.



The spatial influence of the "capitals" risk factor was operationalized as "distances less than 100 km from the capital pose the greatest risk of governmental internal armed conflict". So a straight line distance map was created and the 100 km threshold was set by using the classified scheme in symbology--setting classes to "2". To access the "Symbology" tab: double click (or right click) on the map layer you are working with, select Properties, and then click Symbology. You can change the number of classes and break values from the "Classified" Scheme in symbology by clicking the "Classify" button under classification.




Layer Properties
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48.28185654 - 57.9382278
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Show class breaks using cell values
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Manual
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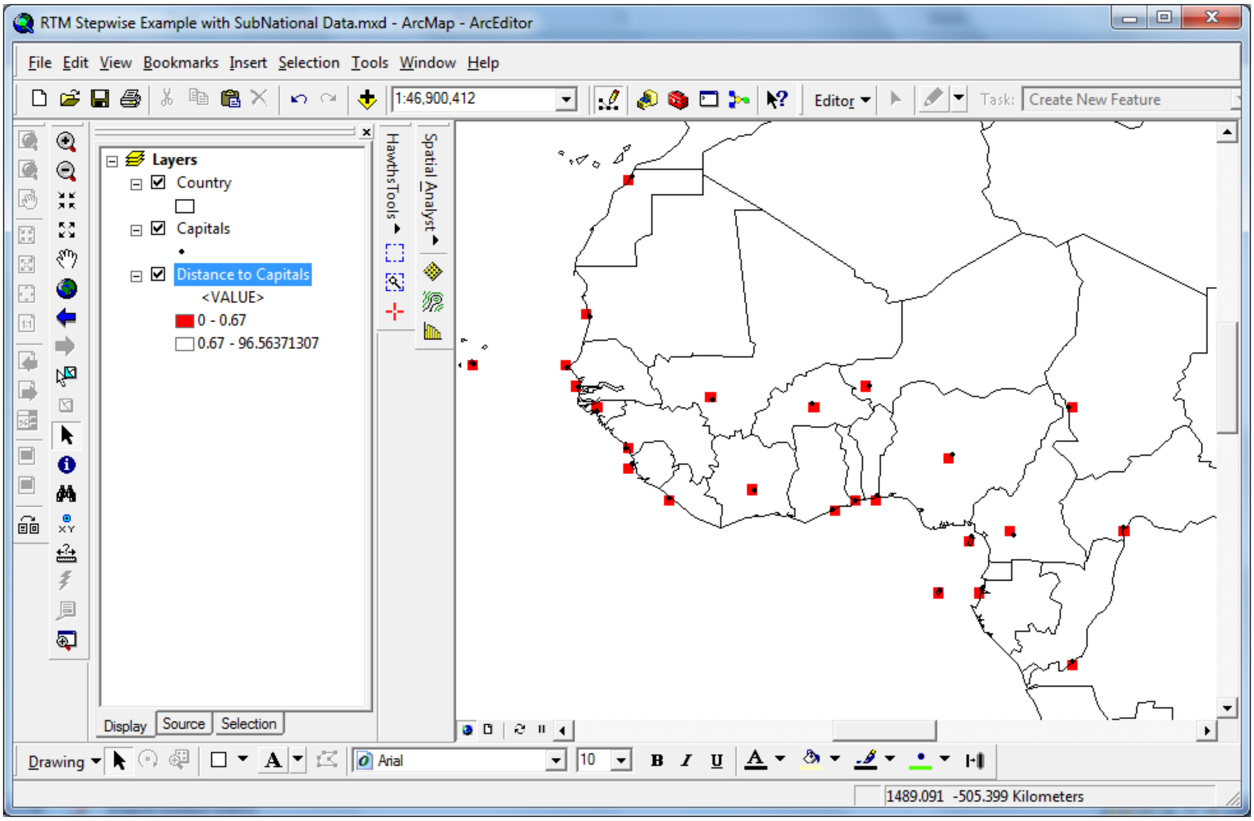
RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
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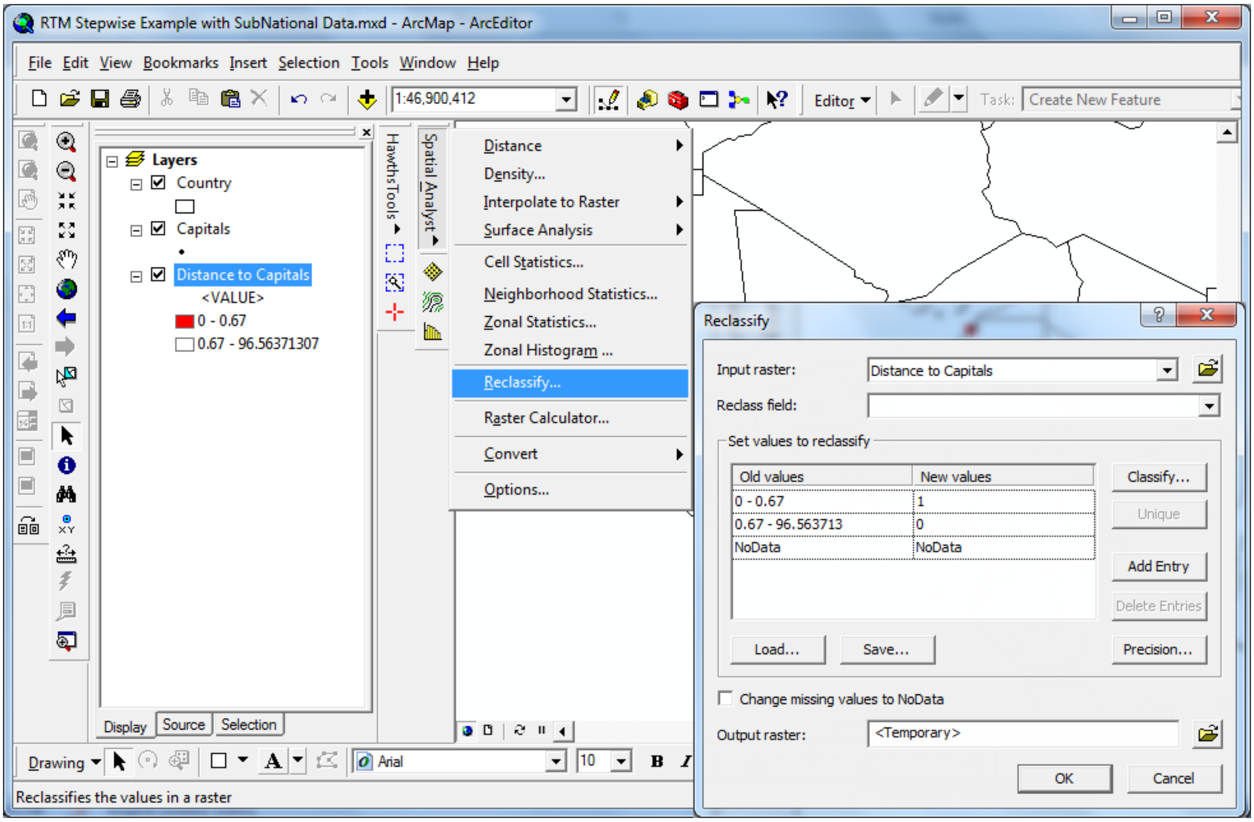
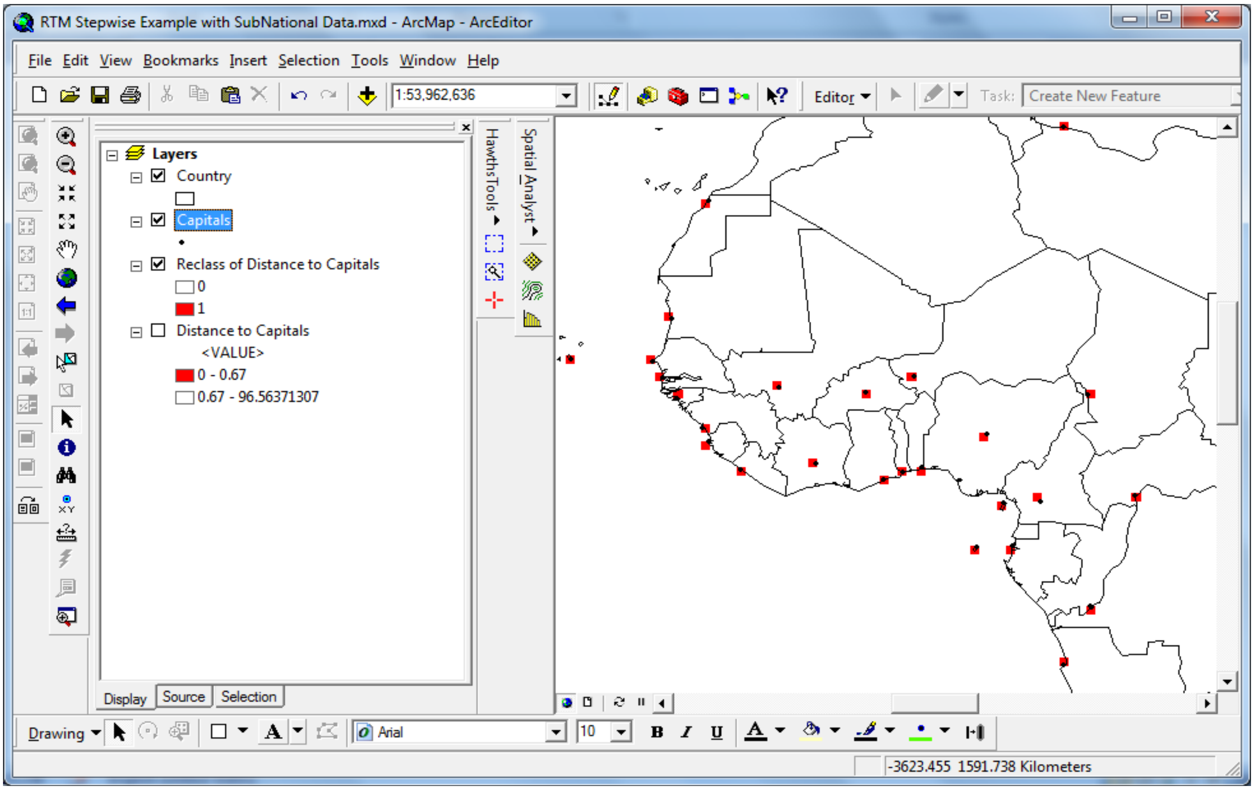
After symbolizing the features, use the "Reclassify" function in Spatial Analyst to permanently set:

- places ≤100 km distance to the capitals were deemed high risk and given a risk value of "1"
- places >100 km distance to the capitals were deemed not high risk and given a risk value of "0"




RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
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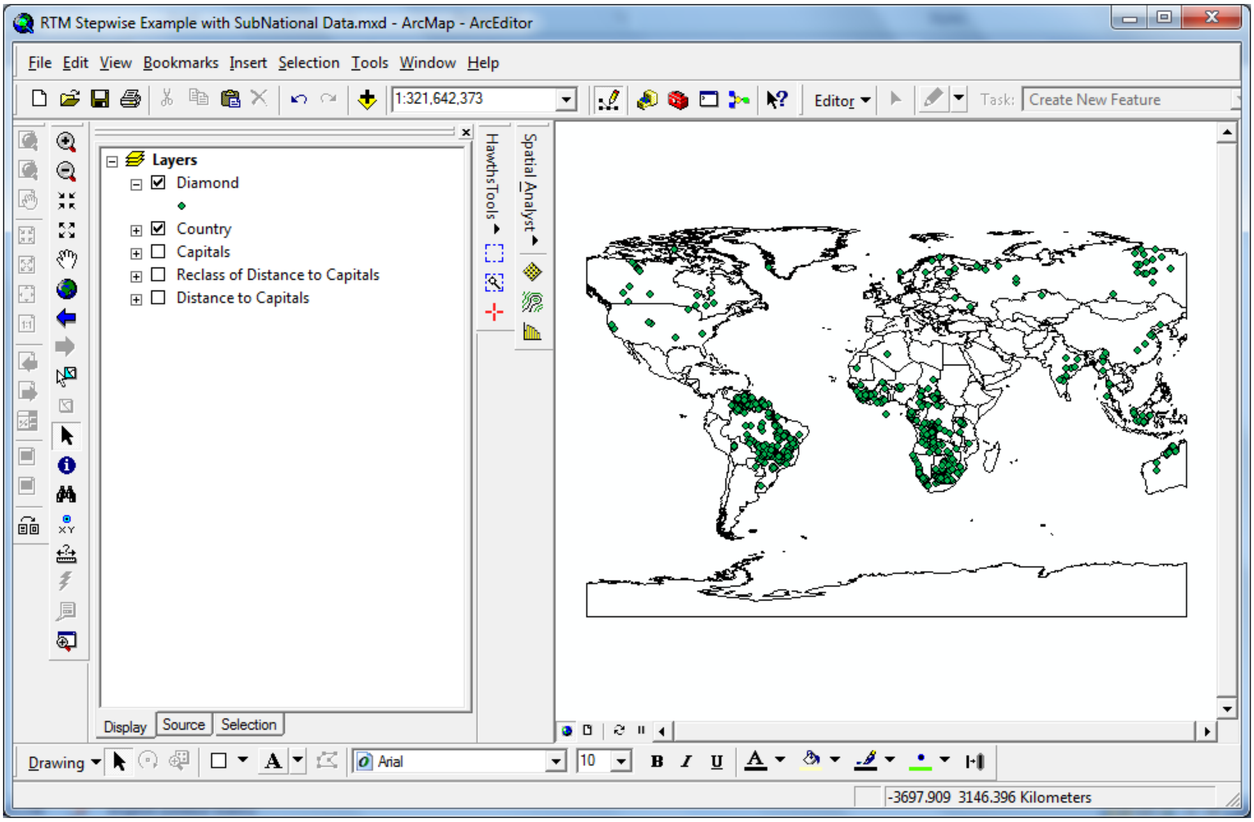
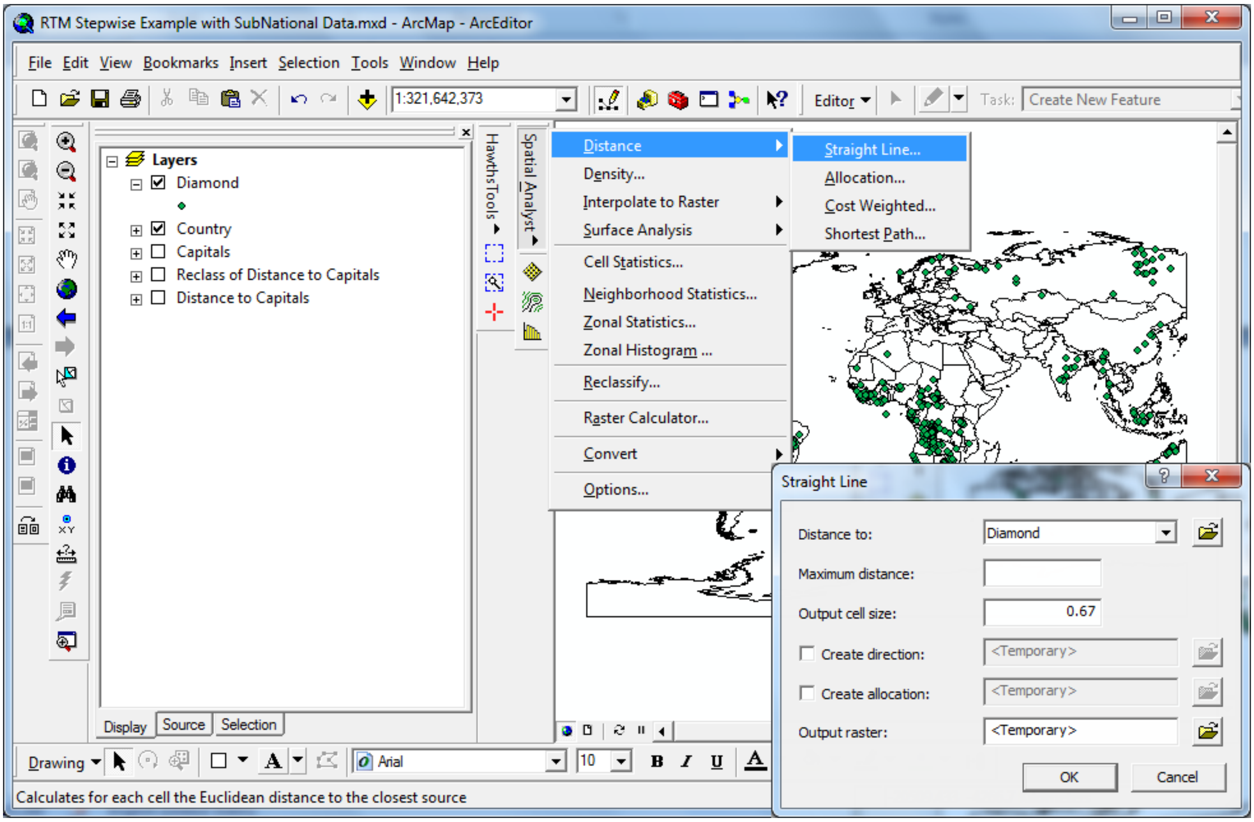
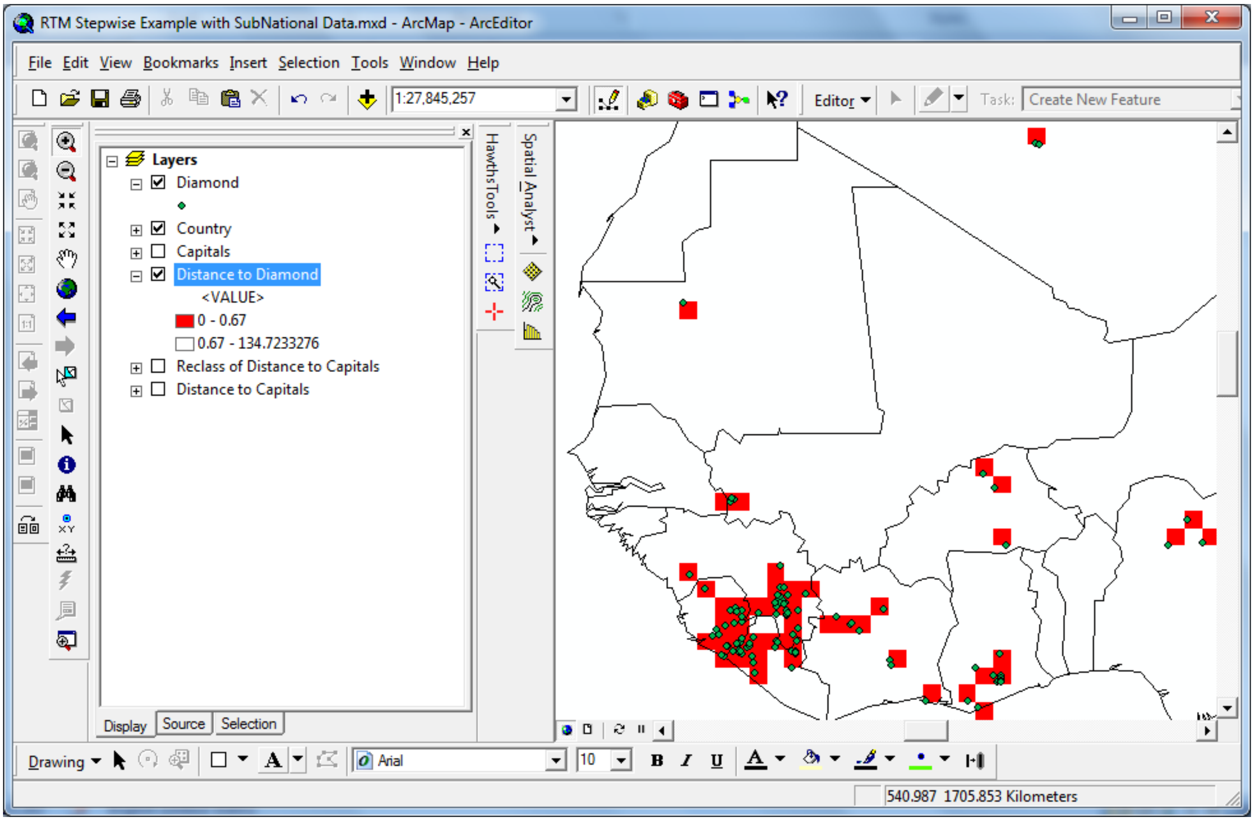
Operationalizing Proximity to Diamond Reserves

The shapefile representing the point features of diamond reserves was acquired from the Geographical and Resource Datasets of Centre for the Study of Civil War (CSCW)[xvii].



The spatial influence of the "diamond reserves" risk factor was operationalized as "distances less than 100 km from a diamond reserve poses the greatest risk of governmental internal armed conflict". Since there was no prior study indicating the statistically significant distance threshold for the relationship between diamond reserves and armed conflict, again 100 km was selected as a "pilot threshold".




RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
1:27,845,257
Editor
Task: Create New Feature
Layers
Diamond
Country
Capitals
Distance to Diamond
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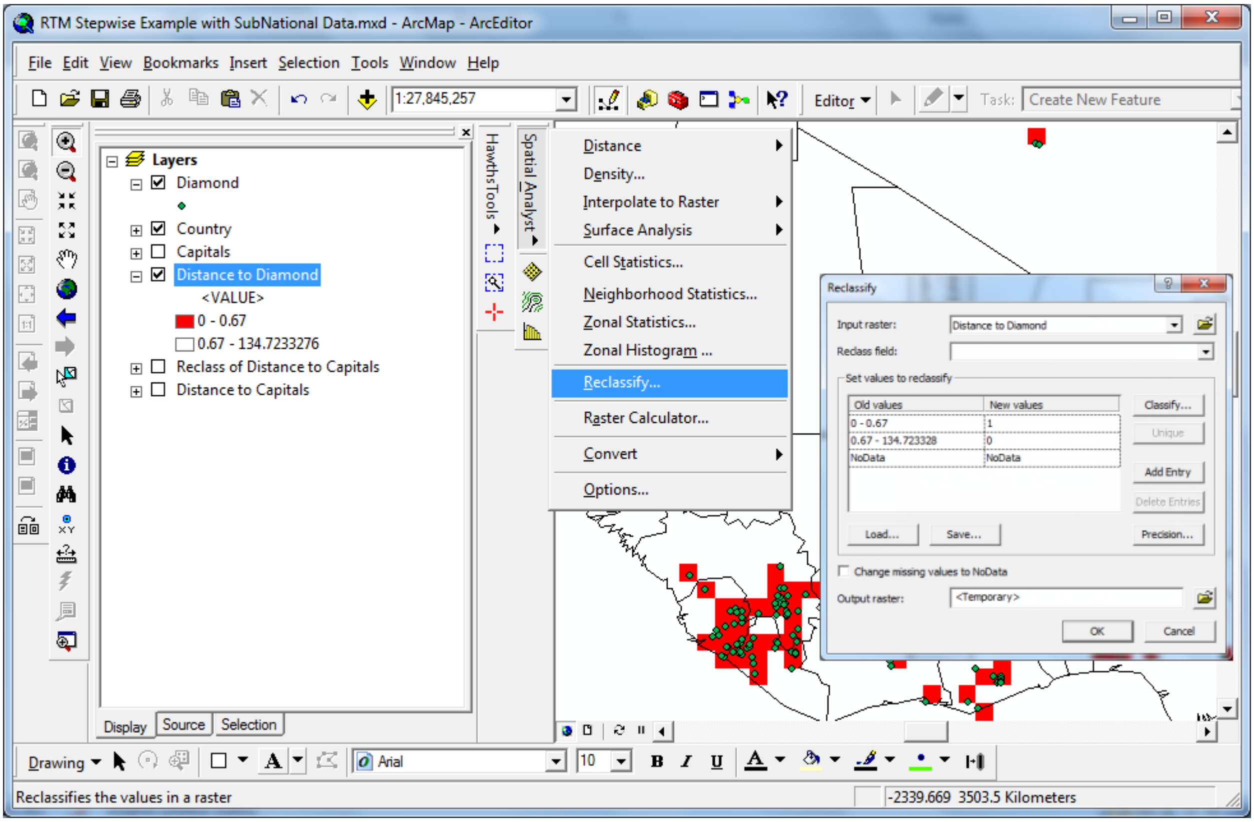
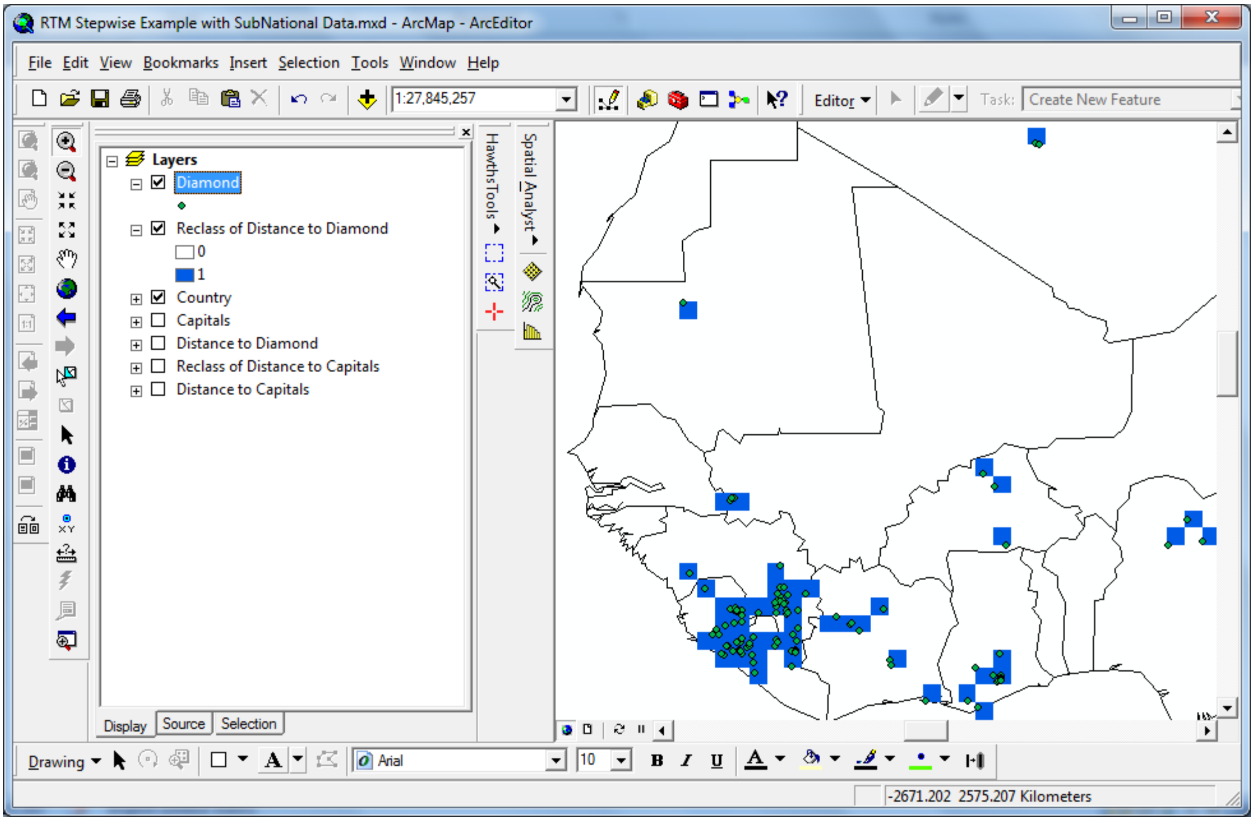
0 - 0.67
0.67 - 134.7233276
Reclass of Distance to Capitals
Distance to Capitals
HawthsTools
Spatial Analyst
Display
Source
Selection
Drawing
Arial
10
540.987 1705.853 Kilometers

Next, use the "Reclassify" function in Spatial Analyst to permanently set:

- places ≤100 km distance to the diamond reserves were deemed high risk and given a risk value of "1"
- places >100 km distance to the diamond reserves were deemed not high risk and given a risk value of "0"

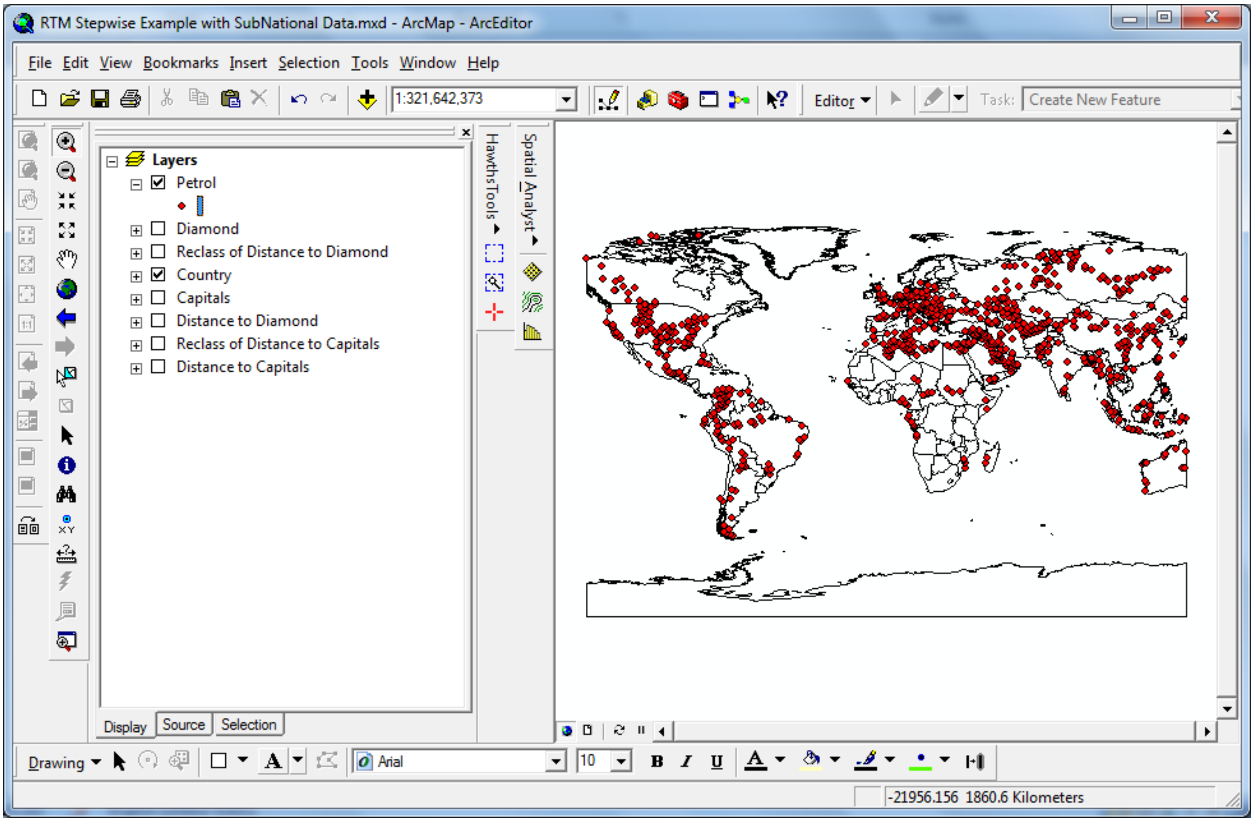




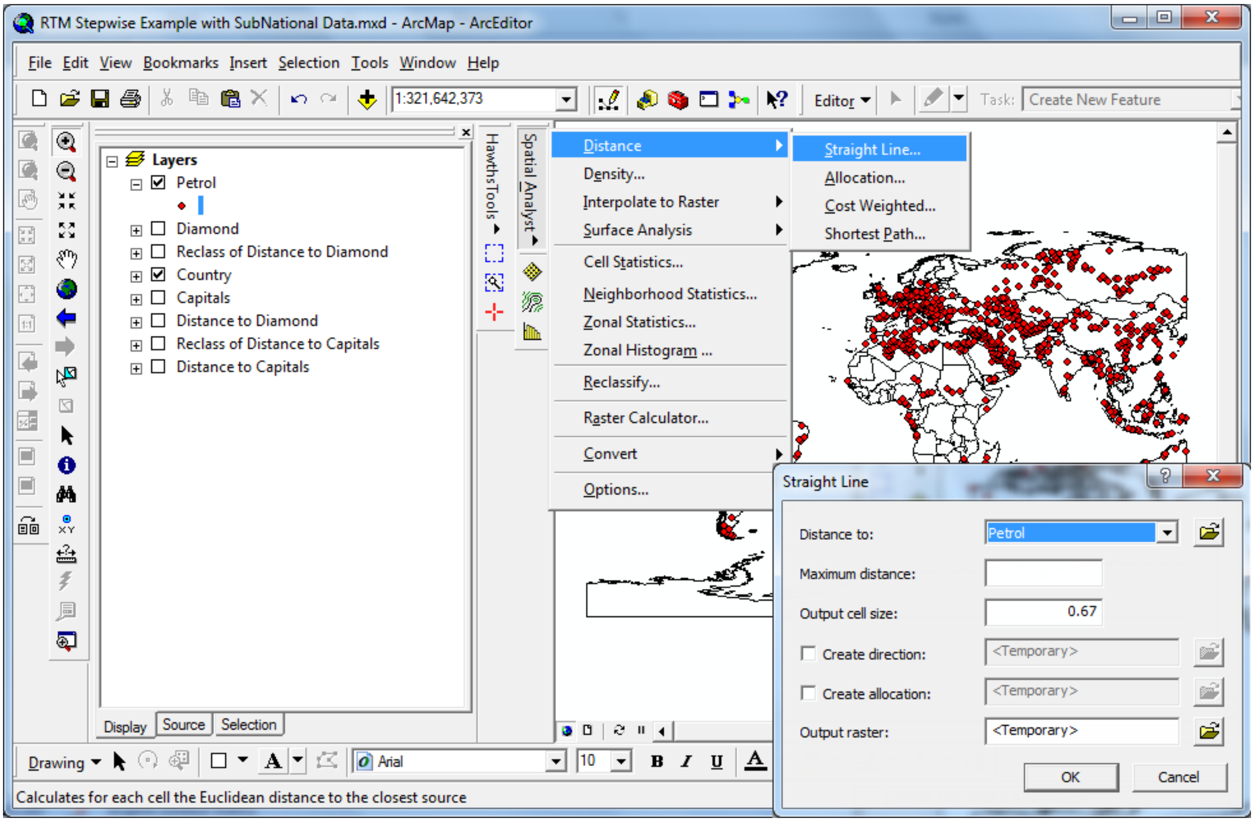
RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
1:27,845,257
Editor
Task: Create New Feature
Layers
Diamond
Reclass of Distance to Diamond
0
1
Country
Capitals
Distance to Diamond
Reclass of Distance to Capitals
Distance to Capitals
Display Source Selection
HawthsTools
Spatial Analyst
Drawing
Arial
10
-2671.202 2575.207 Kilometers

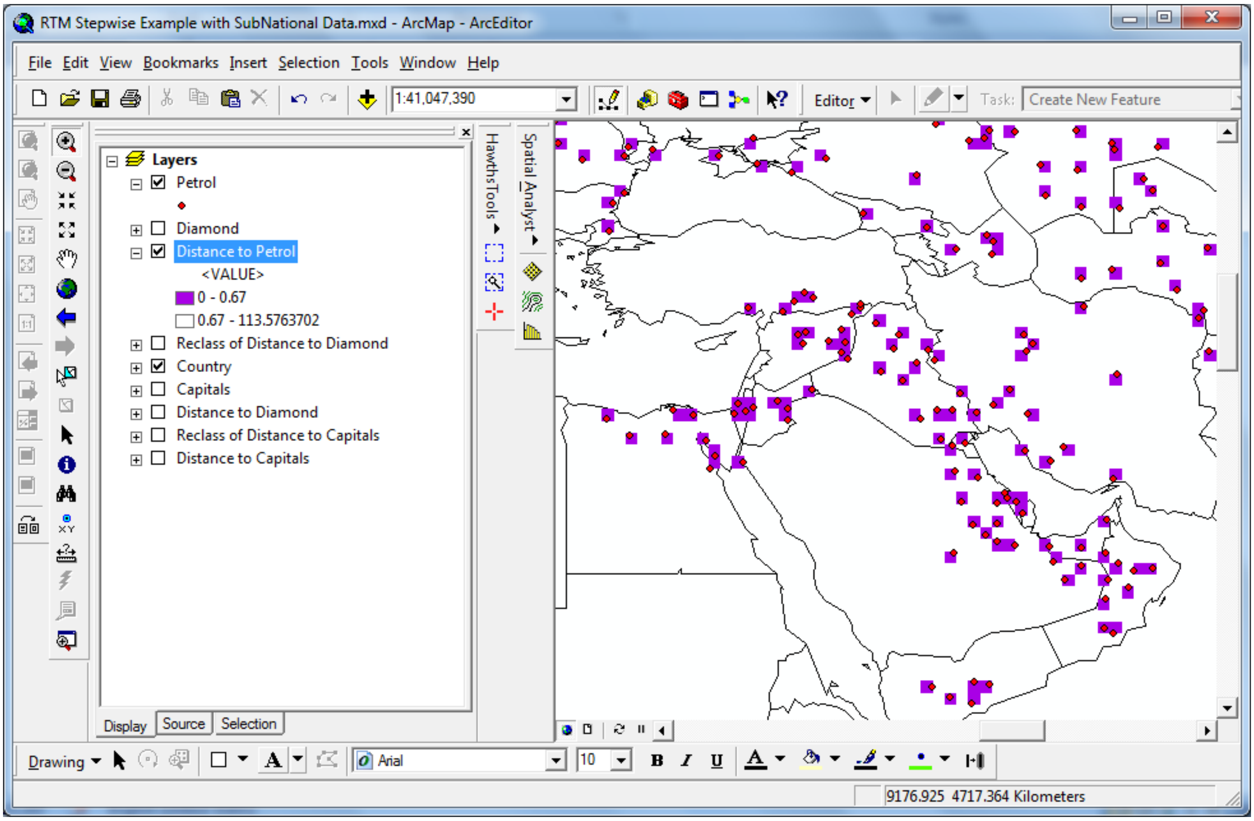
Operationalizing Proximity to Petroleum Deposits

The shapefile representing the point features of petroleum deposits was acquired from the Geographical and Resource Datasets of Centre for the Study of Civil War (CSCW)[xviii].



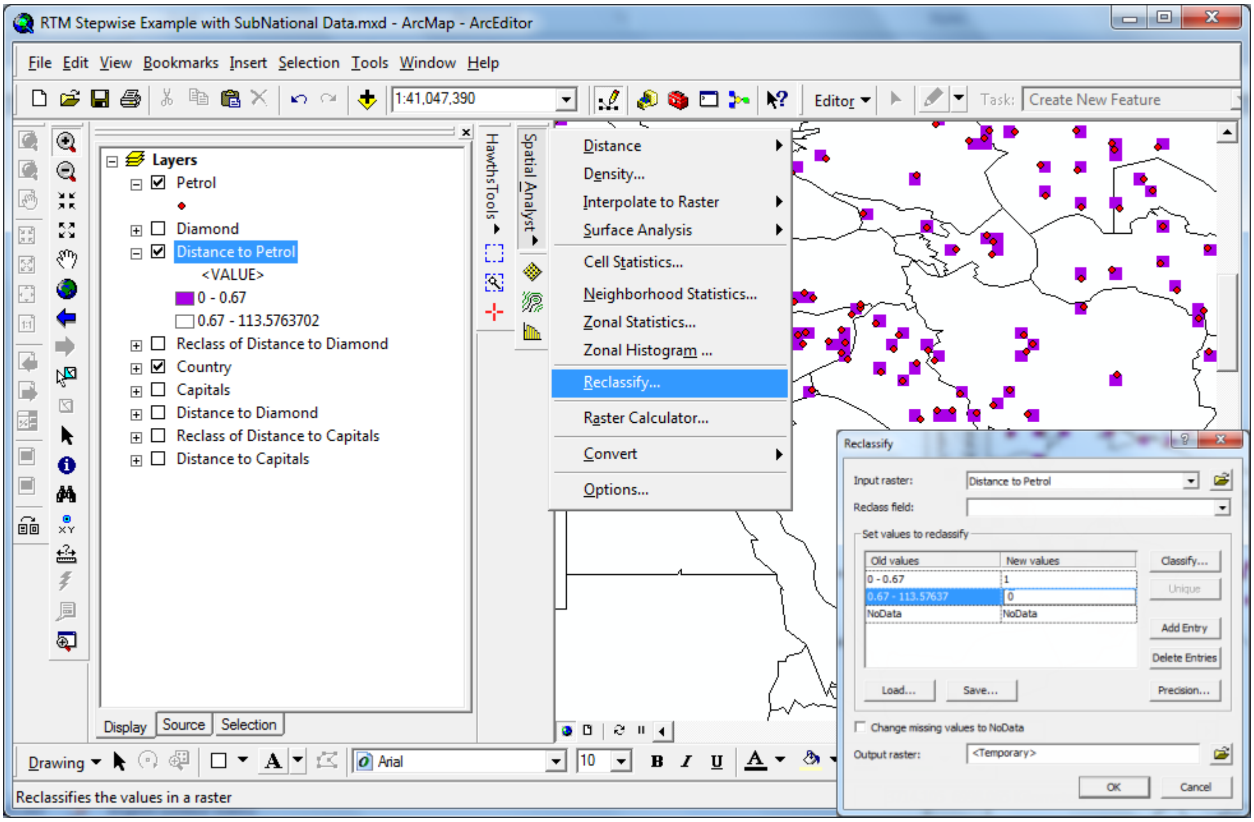
The spatial influence of the “petroleum deposits” risk factor was operationalized as “<u>distances less than 100 km</u> from a petroleum deposit poses the greatest risk of governmental internal armed conflict”. Since there was no prior study indicating the statistically significant distance threshold for the relationship between petroleum deposits reserves and armed conflict, 100 km was selected as a “pilot threshold”.

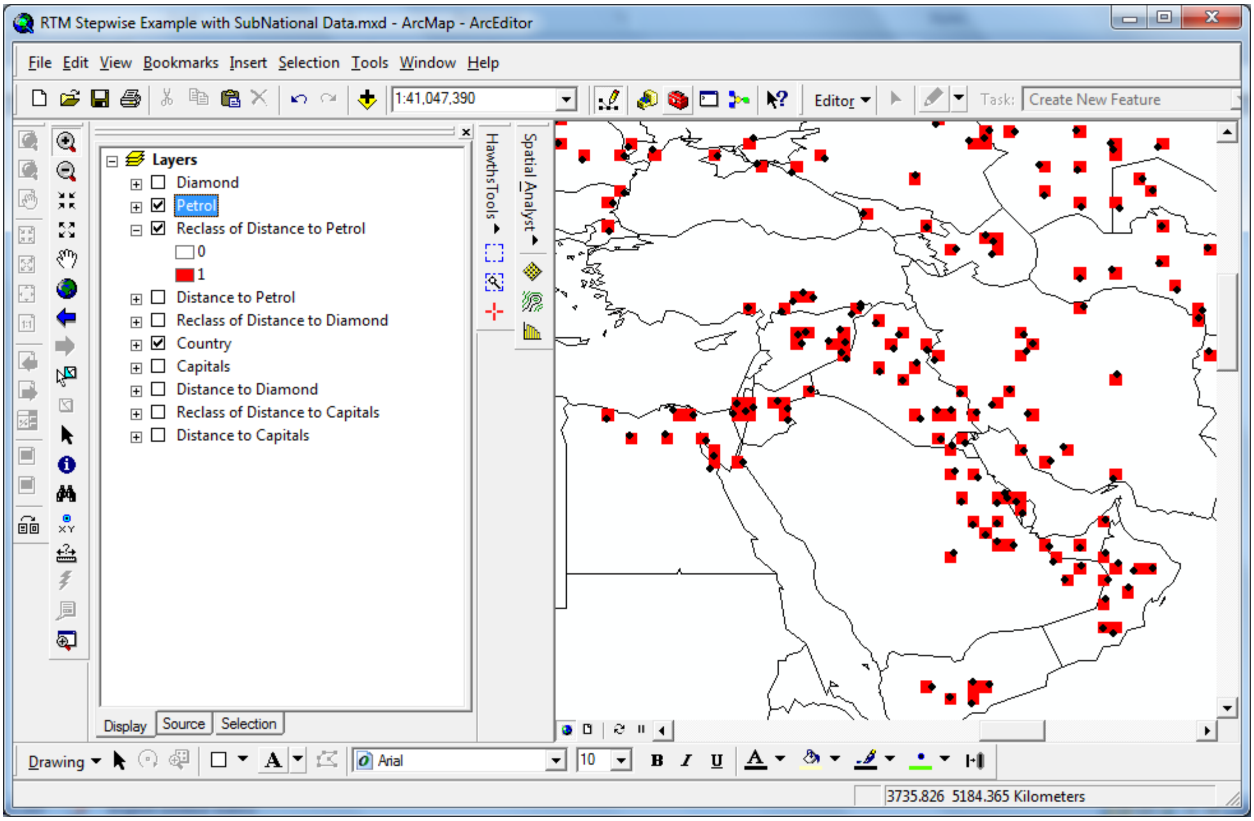



RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
1:41,047,390
Editor
Task: Create New Feature
Layers
Petrol
Diamond
Distance to Petrol
<VALUE>
0 - 0.67
0.67 - 113.5763702
Reclass of Distance to Diamond
Country
Capitals
Distance to Diamond
Reclass of Distance to Capitals
Distance to Capitals
Display
Source
Selection
HawthsTools
Spatial Analyst
Drawing
Arial
10
9176.925 4717.364 Kilometers

Next, use the “Reclassify” function in Spatial Analyst to permanently set:

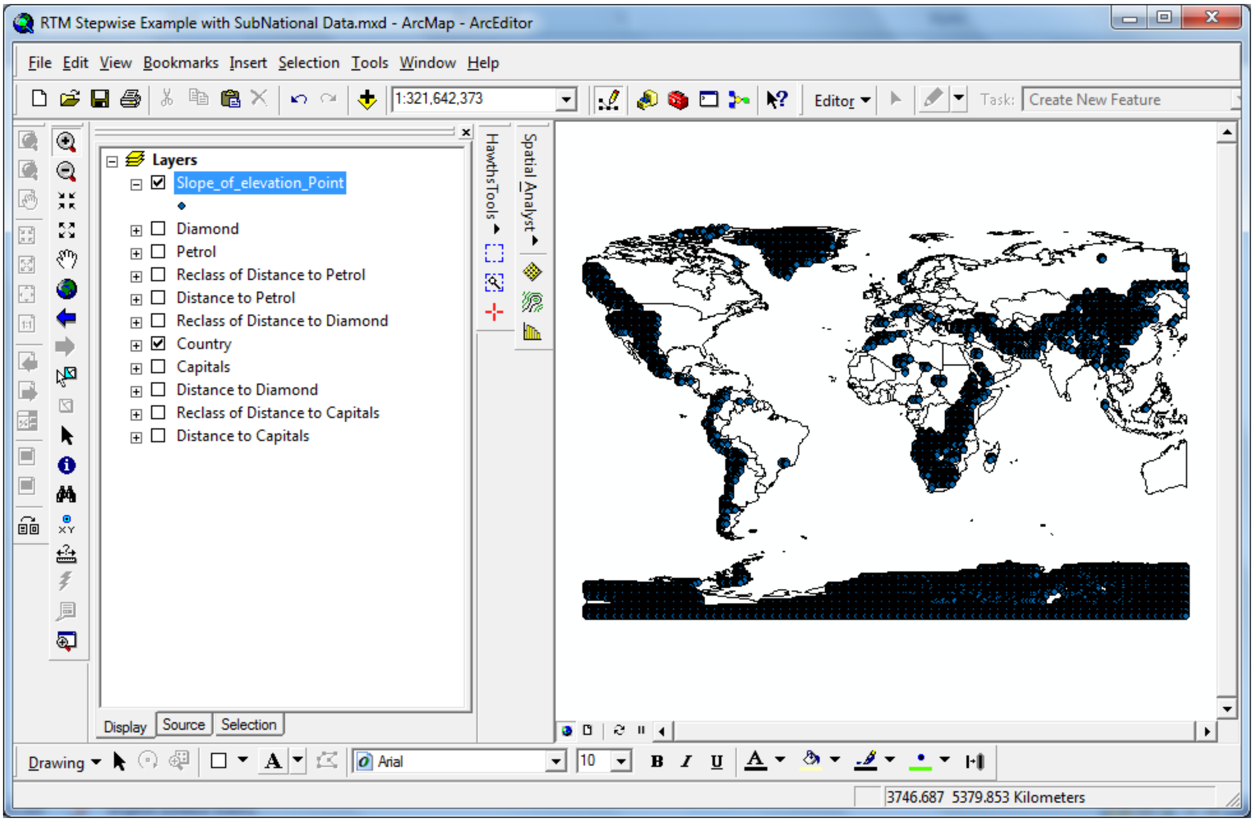
- places ≤100 km distance to the petroleum deposits and deemed high risk a risk value of “1”
- places >100 km distance to the petroleum deposits and deemed not high risk and given a risk value of “0”



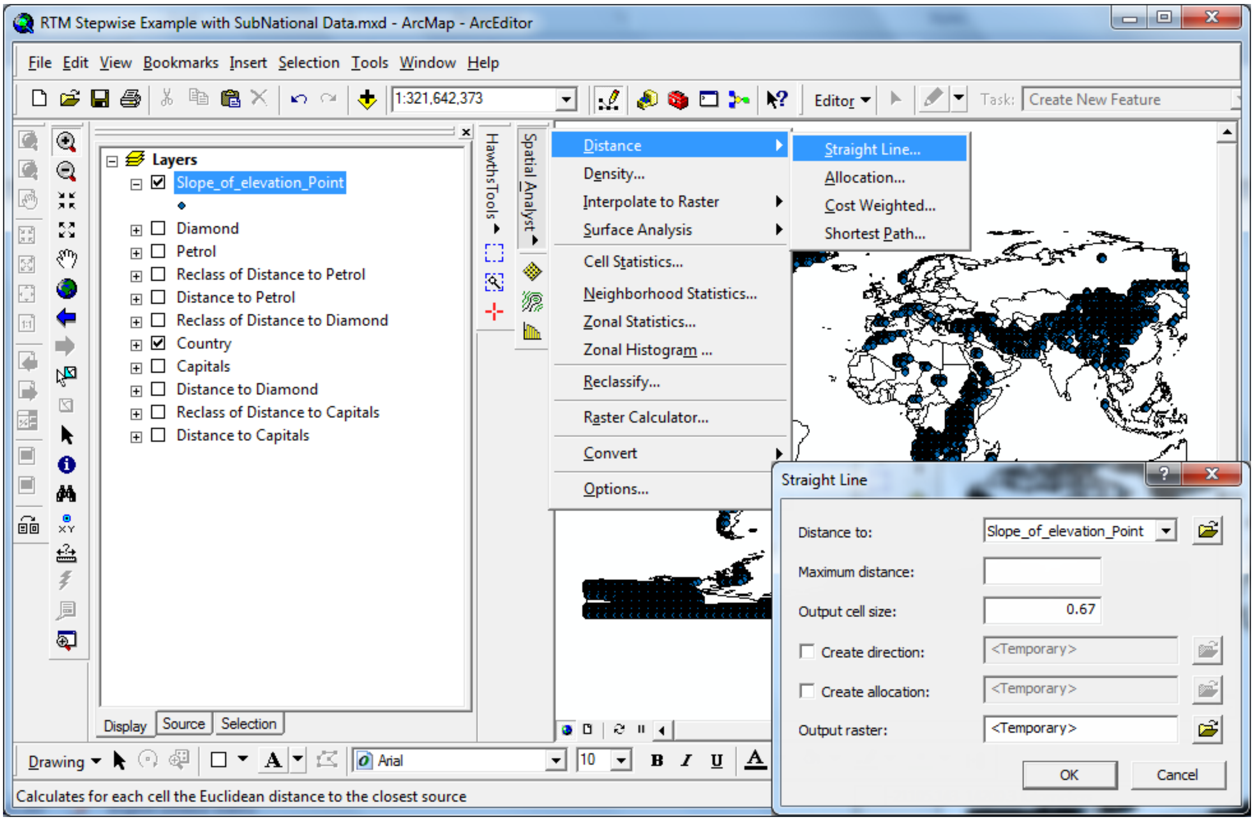

RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
1:41,047,390
Editor
Task: Create New Feature
Layers
Diamond
Petrol
Reclass of Distance to Petrol
0
1
Distance to Petrol
Reclass of Distance to Diamond
Country
Capitals
Distance to Diamond
Reclass of Distance to Capitals
Distance to Capitals
HawthsTools
Spatial Analyst
Display
Source
Selection
Drawing
Arial
10
3735.826 5184.365 Kilometers

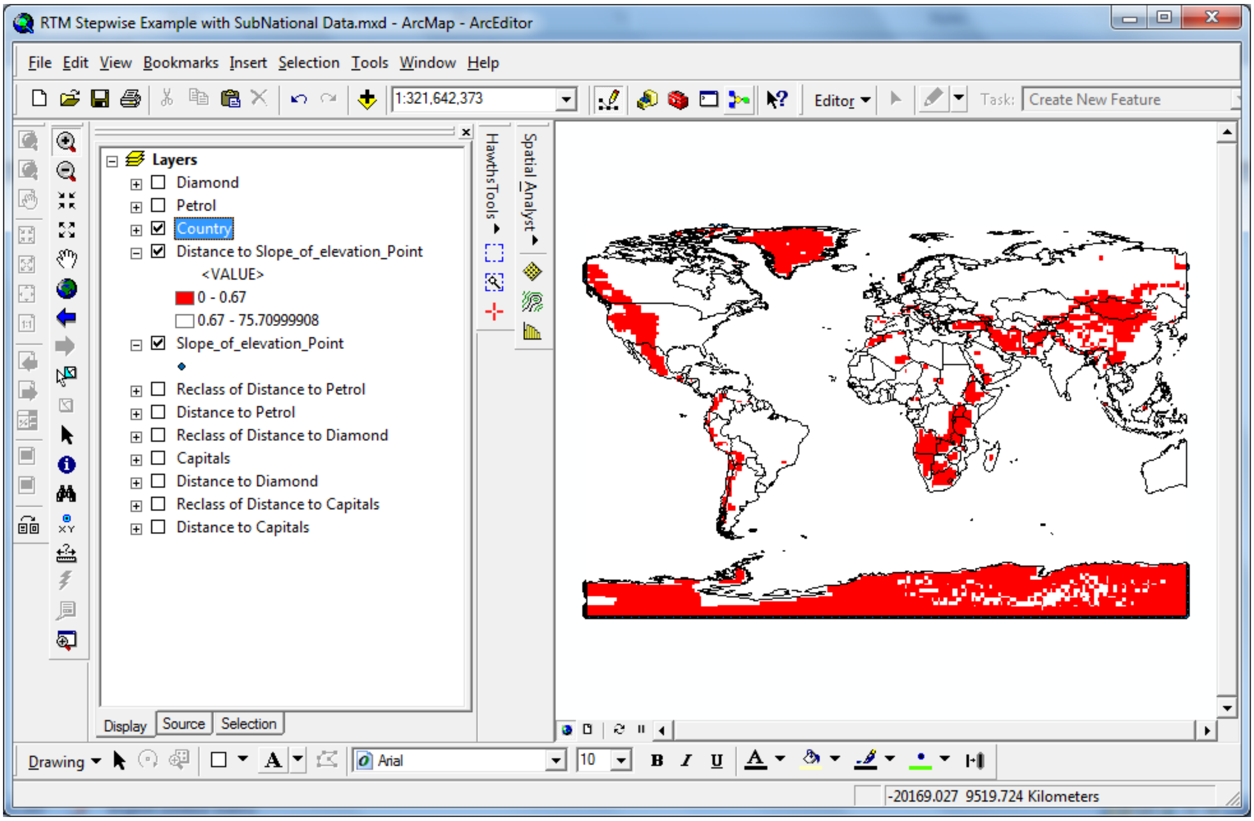
Operationalizing Proximity to Rough Terrain

The rough terrain risk factor is limited to mountainous areas. The shapefile representing the world elevation was acquired from the European Environment Agency.[xix] Mountainous areas are operationalized as areas with an altitude more than 1000 m and a slope of 5 degrees.[xx]



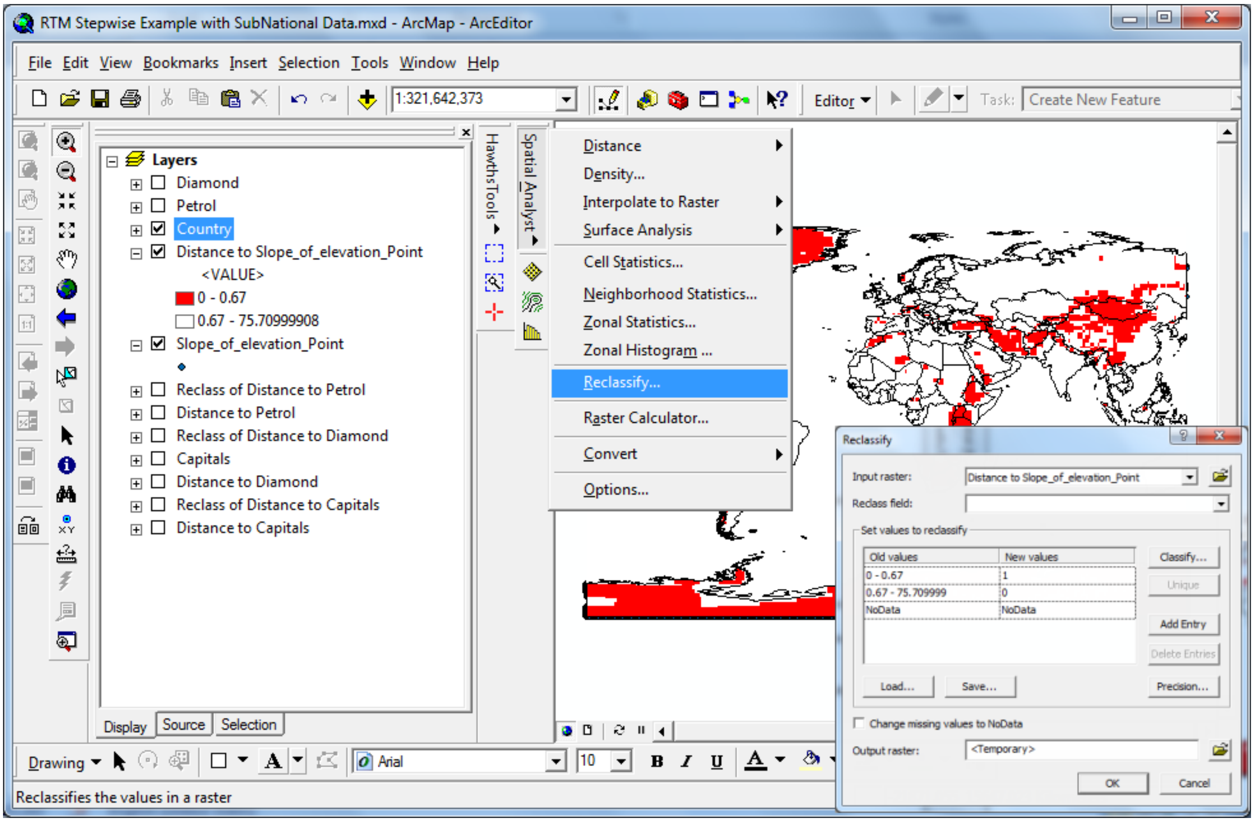
The spatial influence of the "rough terrain" risk factor was operationalized as "distance less than 100 km from a mountainous place poses the greatest risk of governmental internal armed conflict".

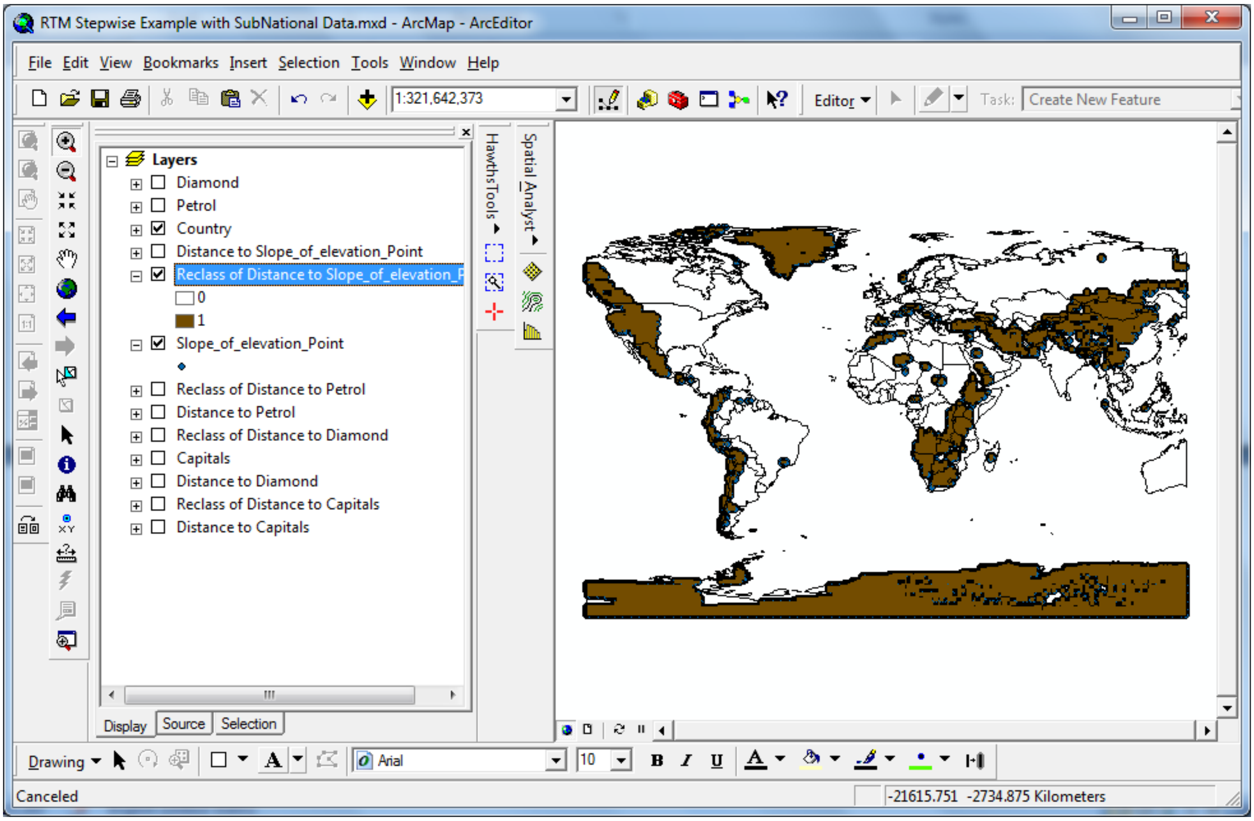



RTM Stepwise Example with SubNational Data.mxd - ArcMap - ArcEditor
File Edit View Bookmarks Insert Selection Tools Window Help
1:321,642,373
Editor
Task: Create New Feature
Layers
Diamond
Petrol
Country
Distance to Slope_of_elevation_Point
<VALUE>
0 - 0.67
0.67 - 75.70999908
Slope_of_elevation_Point
Reclass of Distance to Petrol
Distance to Petrol
Reclass of Distance to Diamond
Capitals
Distance to Diamond
Reclass of Distance to Capitals
Distance to Capitals
Display
Source
Selection
HawthsTools
Spatial Analyst
Drawing
Arial
10
-20169.027 9519.724 Kilometers

Next, use the “Reclassify” function in Spatial Analyst to permanently set:

- places ≤100 km distance to the mountainous places and deemed high risk a value of “1”
- places >100 km distance to the mountainous places and deemed not high risk and given a risk value of “0”





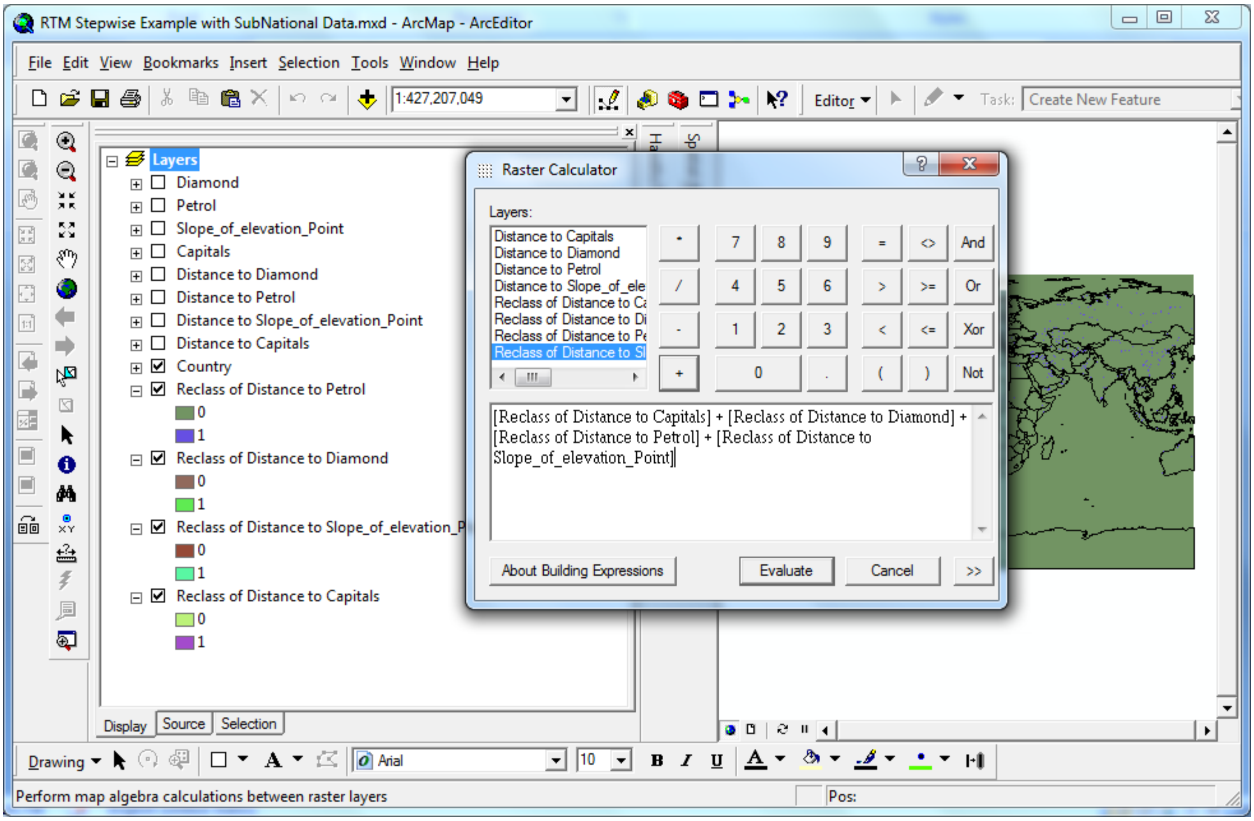
STEP 8: Inter Risk Map Layer Weighting

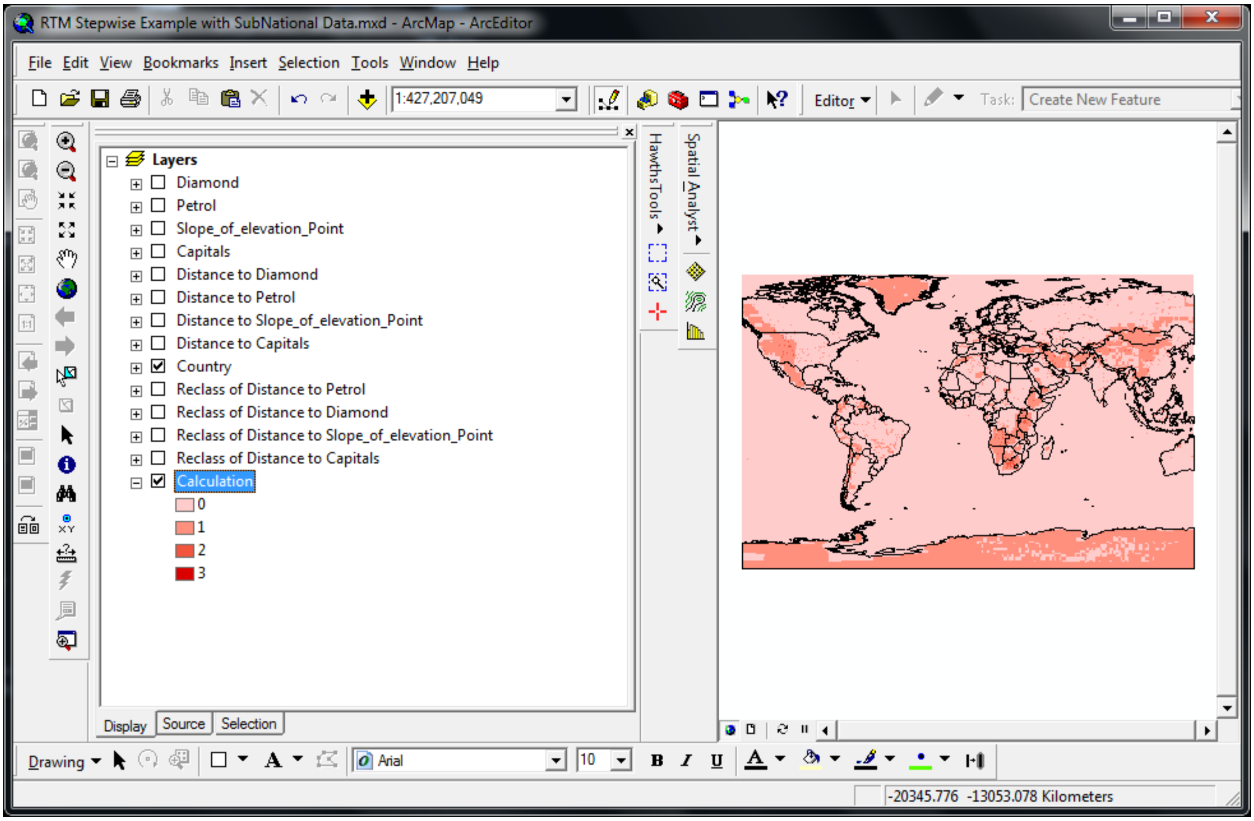
In this demonstration, all risk map layers will carry equal weights to produce an un-weighted risk terrain model. So, for example, being over 100 km distance to a petroleum deposit poses the same risk of having governmental internal armed conflict as being over 100 km distance to a diamond reserve.

STEP 9: Combine Risk Values to Form a Composite Map

The Raster Calculator in the Spatial Analyst Extension is used to combine all risk factors (i.e., proximity to diamond reserves, proximity to petroleum deposits, proximity to capitals, and proximity to rough terrain): From the "Spatial Analyst" toolbar, click "Spatial Analyst" > Raster Calculator. The "Raster Calculator" operation creates a new raster map whereby the value of each cell is computed by applying map algebra to the value of the cells on one or more existing (raster) risk map layers. The "Raster Calculator" dialog box provides for building algebra-like expressions that will produce new maps.

Variables (i.e., risk values) are inserted into the expression box either by typing, by double-clicking on the layer names in the "Layers" section, or by using the buttons. Once an expression has been fully specified, click the "Evaluate" button to generate a new raster map (Your risk terrain map!)





STEP 10: Finalize the Risk Terrain Map to Communicate Meaningful Information

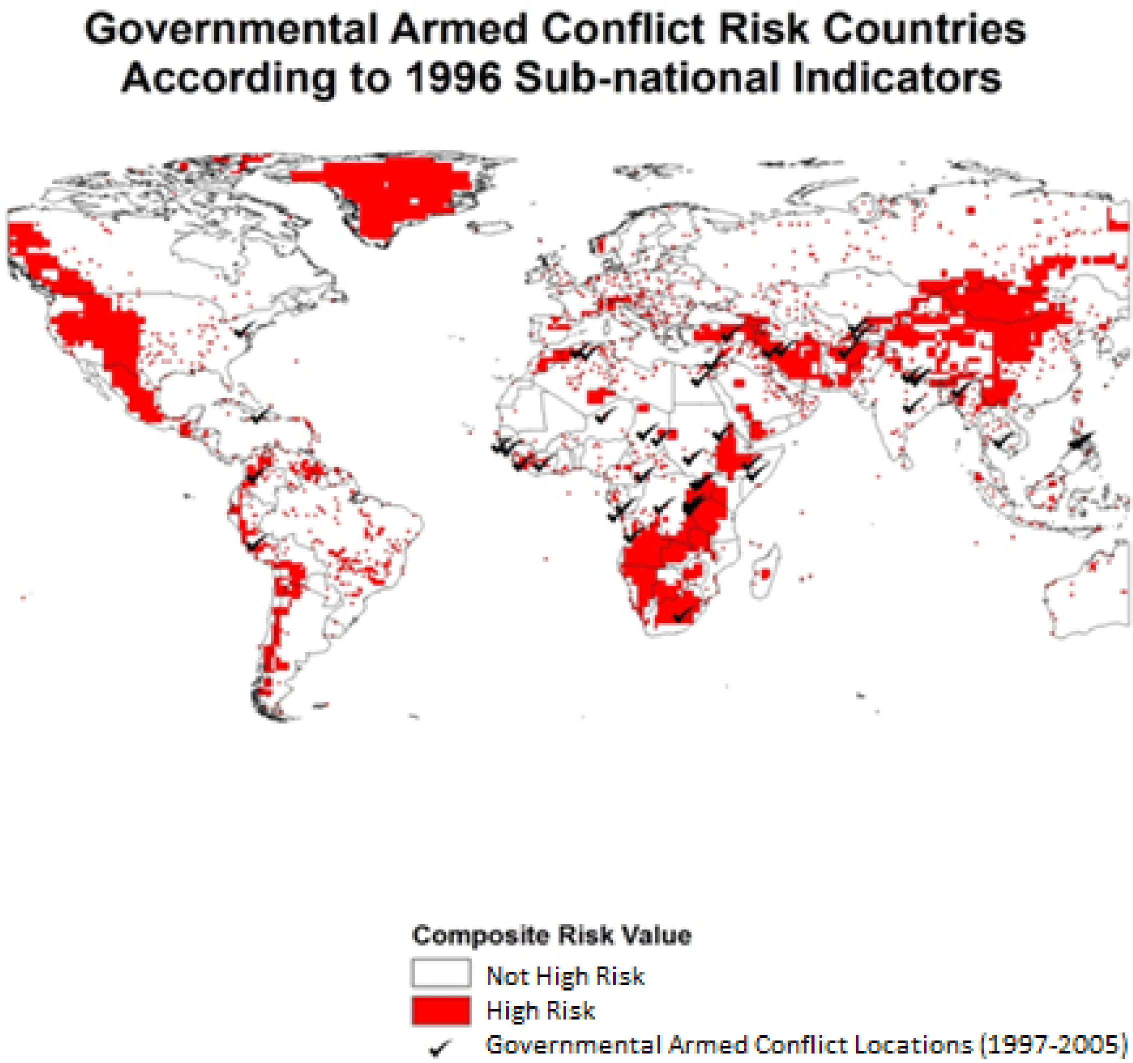
The resulting composite map from the "Raster Calculator" operation (in Step 9) is your risk terrain map. Symbolize this map in a meaningful way so that it clearly communicates information about the study area for purposes of strategic decision making and/or tactical action [From ArcMap's Table of Contents, right-click the (risk terrain map's) layer > Properties > "Symbology" tab]. Symbolizing raster map layers differs slightly from vector maps. When trying to change the symbology, you may get a message that says "Unique histogram does not exist. Do you want to compute unique values?" Click "Yes". In the "Layer Properties" dialog box, under the "Symbology" tab, click the "Classify" button under the "Classified" scheme (on the left). Standard Deviation is a good option for showing variation in raster values, especially risk terrain maps. Your choice of symbology and classification schemes might imply areas that some people would call "hotspots" or clusters of high-risk upon visual inspection alone.

However, this terminology should be used cautiously. The (often) arbitrary choice of colors and classification ranges, or the classification method (e.g. Equal Interval, Natural Breaks, Standard Deviation) could substantially change a map's appearance. For this reason, a cluster of high-risk places defined upon visual inspection is much different than a "statistically significant" cluster.

To be statistically significant, a group of cells must have high values and be surrounded by other cells with high values. Similarly, clusters of low-risk places consist of cells with low values surrounded by other cells with low values. This pattern must occur beyond random chance. The "Hotspot Analysis" tool in ArcGIS calculates the Getis-Ord Gi* statistic (Z score) for each feature in a dataset. The larger the statistically significant positive Z score is, the more intense the clustering of high values. The smaller the statistically significant negative Z score is, the more intense the clustering of low values. You can use the "Hotspot Analysis" tool to create a final map that shows clusters of places in your study area that are high-risk or low-risk. Or the "Cluster and Outlier Analysis" tool in ArcGIS might be preferred because it can identify clusters of places with values similar in magnitude as well as features that are spatial outliers. For example, whereas the resultant Z score from the Getis-Ord Gi* statistic can only tell where features with either high or low values cluster spatially surrounded by other similarly-valued features, the "Cluster and Outlier Analysis" tool can distinguish between statistically significant clusters of high values surrounded by high values (HH), low values surrounded by low values (LL), high values surrounded by low values (HL), and low values surrounded by high values (LH). (Note that you must convert the risk terrain map into a grid of vector polygons in order to use the hotspot or cluster analysis tools. Use the "Convert Raster Layer to Vector Polygon Grid" Tool in the RTM Toolbox [available at www.rutgerscps.org/grtm.htm] to perform the vector conversion in a way that maintains each cell's composite risk value). For both of these aforementioned cluster or hotspot analysis tools, the field containing the composite risk values is your analysis field.

To clip the risk terrain map (e.g., to your country's borders) you need to use a raster clipping tool. This can be found in ArcToolbox under Data Management Tools > Raster > Raster Processing. You can also find vector and raster clipping tools by searching for keyword "clip" in the Search tab of ArcToolbox. Double-clicking on the tool in the results area opens it directly.

In this demonstrative model, the Unweighted Composite Risk Value (range: 0-3; mean=0.16; SD=0.37) was symbolized using the symbology tab. As can be seen in the following map, the countries that fell into the top 15% with regard to armed conflict risk (risk value >+1.5 SD) have been symbolized in shades of red, whereas the countries with a risk value ≤+1.5 SD have been symbolized with hollow background. In the finalized risk terrain map Antarctica has been excluded from the study extent as it has no permanent residents. Fifteen percent of the study extent has been identified as high risk with regard to governmental armed conflict risk, and these high risk cells accounted for 69 governmental armed conflict incidents (i.e. 15% of the study area deemed highest risk accounted for 57% of all governmental internal armed conflict incident locations).



Statistically Validating Your Risk Terrain Model

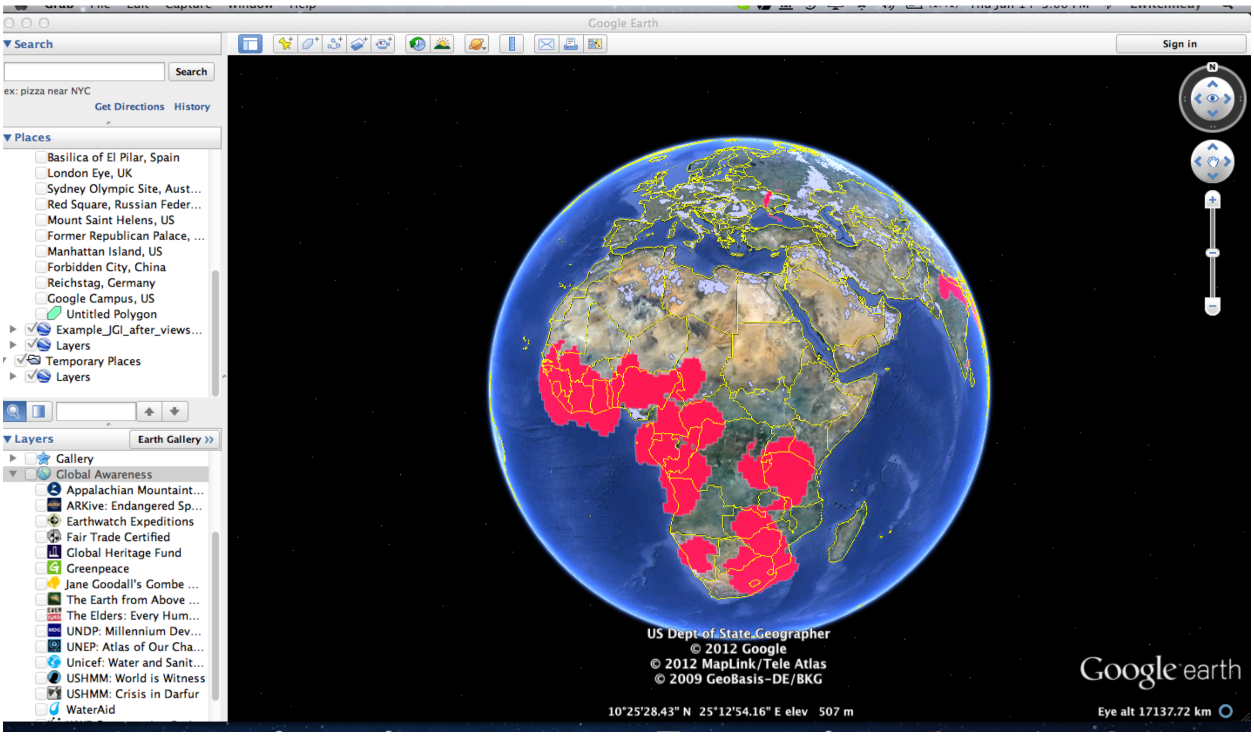
We recommend using regression analysis to test the validity of your risk terrain model. There are many ways in which to do this, including a Logistic Regression or Ordinary Least Squares Regression; and there are many tools to use, including external software like EpiInfo (http://wwwn.cdc.gov/epiinfo) or GeoDa (http://geodacenter.asu.edu), or the "Ordinary Least Square" or "Geographically Weighted Regression" tools in ArcMap. It is beyond the scope of this manual to direct you to one particular method since there are many legitimate methods, and because it requires at least an intermediate level of statistical knowledge that is somewhat specific to the method used. Here, we will discuss the steps that would be required to prepare the risk terrain map and outcome event data for statistical testing. We will also discuss some important considerations that should be had when performing the tests.

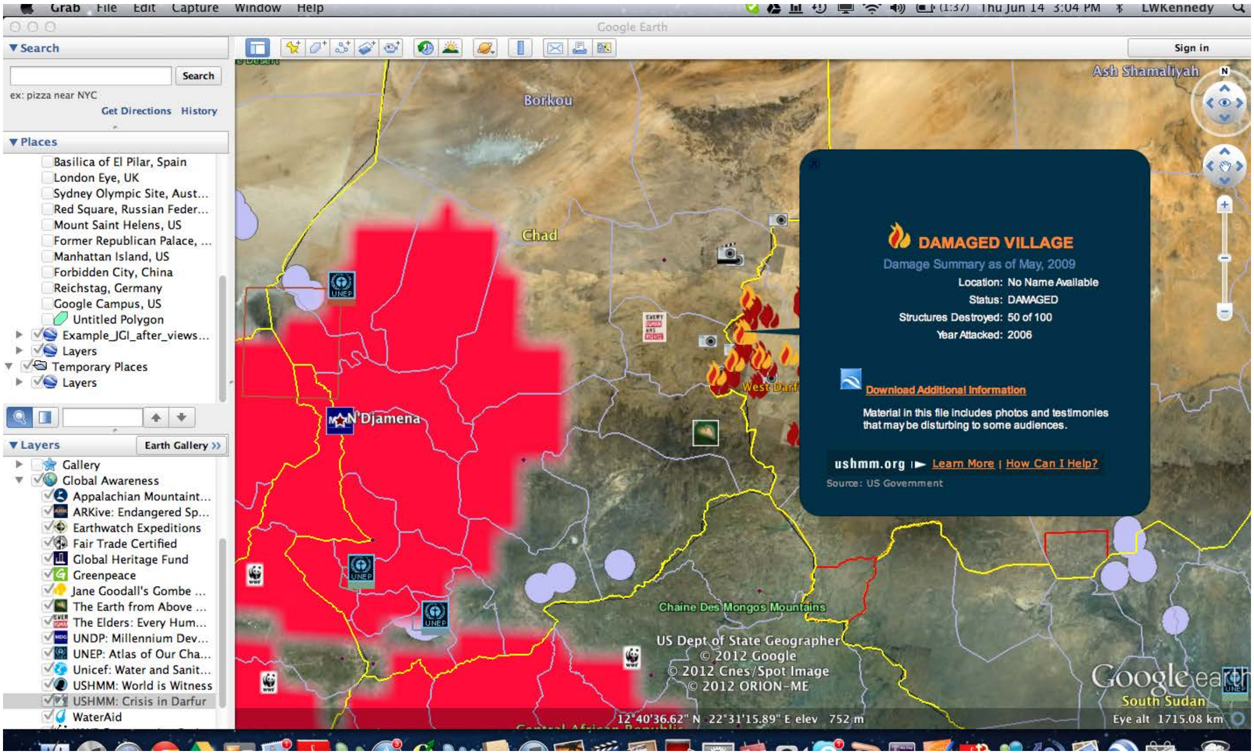
Ultimately, you will need an attributes table of the risk terrain map of your study area with at least two variables: (1) composite risk value of each cell and (2) count of outcome events (e.g. governmental internal armed conflict incidents) for each cell. Raster data do not permit more than one attribute value per cell, so you need to convert your (raster) risk terrain map to a vector grid of polygons. You can do this using the "Convert Raster Layer to Vector Polygon Grid" tool in the RTM Toolbox in a way that maintains the integrity of each cell (you need each raster cell to be a unique polygon feature in the vectorized risk terrain map). With a vector risk terrain map, you may use a "Spatial Join" to get a count of armed conflict incidents located in each cell.

Keep in mind that spatial autocorrelation might exist for your outcome event, which would need to be controlled for in a regression model. Distributions among geographical units, such as grid cells, are usually not independent, meaning that values found in a particular cell are likely to be influenced by corresponding values in nearby cells. Moran's I measures this autocorrelation, with values approaching 1 when geographical units are situated near other similar geographical units, and approaching –1 when geographical units are situated near dissimilar geographical units. A Moran's I value of 0 indicates the absence of autocorrelation, or independence, among geographical units. GeoDa, a freestanding software application, can be used to calculate Moran's I values for each risk terrain with a Queen Contiguity Weight matrix. ArcMap also has a "Spatial Autocorrelation (Moran's I)" tool that can be used. If spatial autocorrelation is found to be statistically significant, calculate a spatial lag variable for each cell (via tools in GeoDa or in ArcMap) and include that variable in your regression model as a control.

Visualizing Risk Maps in Google Earth

The maps that are created with RTM provide informative renditions of spatial risk. However, their value can be enhanced through a visualization process that employs readily accessible internet tools, in particular, Google Earth. ArcGIS can convert layers or shapefiles into .kml files that can be saved and easily imported into Google Earth. These maps can then be combined with other information that is stored on the Google Earth site that may pertain to the crisis being studied. For example, there are publicly available layers provided by Google and populated by agencies that are interested in global issues. In the case of armed conflict, Google Earth has a layer called "crisis in Darfur", that can be loaded and then compared to the RTM maps imported from ArcGIS. For an explanation of how to convert shapefiles to .kml, go to http://www.rutgerscps.org/docs/MapLayerToGoogleEarth_Tutorial.pdf.




Grab File Edit Capture Window Help
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LWKennedy
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Search
ex: pizza near NYC
Get Directions History
Places
Basilica of El Pilar, Spain
London Eye, UK
Sydney Olympic Site, Aust...
Red Square, Russian Feder...
Mount Saint Helens, US
Former Republican Palace, ...
Manhattan Island, US
Forbidden City, China
Reichstag, Germany
Google Campus, US
Untitled Polygon
Example_JGI_after_views...
Layers
Temporary Places
Layers
Layers
Earth Gallery
Gallery
Global Awareness
Appalachian Mountaint...
ARKive: Endangered Sp...
Earthwatch Expeditions
Fair Trade Certified
Global Heritage Fund
Greenpeace
Jane Goodall's Gombe ...
The Earth from Above ...
The Elders: Every Hum...
UNDP: Millennium Dev...
UNEP: Atlas of Our Cha...
Unicef: Water and Sanit...
USHMM: World is Witness
USHMM: Crisis in Darfur
WaterAid
Sign in
Borkou
Ash Shamaliyah
Chad
N'Djamena
West Darfur
Chaine Des Mongos Mountains
DAMAGED VILLAGE
Damage Summary as of May, 2009
Location: No Name Available
Status: DAMAGED
Structures Destroyed: 50 of 100
Year Attacked: 2006
Download Additional Information
Material in this file includes photos and testimonies that may be disturbing to some audiences.
ushmm.org Learn More | How Can I Help?
Source: US Government
US Dept of State Geographer
© 2012 Google
© 2012 Cnes/Spot Image
© 2012 ORION-ME
South Sudan
12°40'36.62" N 22°31'15.89" E elev 752 m
Eye alt 1715.08 km

Part 3

Applications of Risk Terrain Modeling for Global Spatial Risk Assessment

Chapter 5

Decision-Making and Global Risk Assessment

Conflict incidents with the rest of global threats are one of the main concerns of the global agenda. Conflict incidents; whether in Egypt, Libya, Turkey, Mexico or Afghanistan, affect the rest of the nations. With the effects of globalization and the changes in the means and modes of production, risks no longer pose themselves in isolation from each other. Accordingly, the systemic and conflating nature of risks makes a problem even in the farthest country, the problem of every nation. Therefore creating robust predictive models for armed conflict should be in the agenda of every country. Even leaving the topic of armed conflict aside, RTM has much to offer current risk management practices, because it brings together the tools of scalable and flexible prediction and statistical testing; acts as a mind-provoking research tool; and offers responses to conceptual and methodological differences, challenges and novelties of the data analysis process. Kennedy et al. (2011) discuss how risk priorities can be incorporated into decision-making through the overt steps taken by agencies to account for local differences and to manage data sources in a way that facilitates forward looking planning. As they point out, in ideal risk assessment processes, authorities (UN/ISDR 2004, 63):

- identify the risk factors, vulnerabilities and capabilities,
- estimate the risk level,
- evaluate the risks,
- perform the socio-economic cost-benefit analyses,
- establish priorities,
- establish acceptable levels of risks,
- elaborate on the scenarios and measures, and
- agree on how to respond. (Kennedy et al. 2011)

But this is not always the way things work, as in many countries there are few local organizations with adequate resources or capacity for continuous analysis and assessment of threats and vulnerabilities to threats. Further, although in many countries there are different organizations with different sets of risk data, such information may not be accessible across different parties for security reasons or due to power relations. These problems may be exacerbated by the fact that production and communication of risk data may not be the first priority of many organizations.

There is more, as Kennedy, et al. (2011), point out;

From an ownership and governance perspective:

- Although we foresee cooperation on the local, regional, national and international level, it's often hard to identify the actors (governments, public and private organizations and, individuals) who will take the responsibility of the risks (World Economic Forum 2008).
- In most circumstances any government, business or international institution is incapable of addressing these risks independently (World Economic Forum 2006).
- For the emergence of a global risk management paradigm, there is an increasing need for long-term dedication from the political sphere but this becomes unlikely due to pressures of electoral cycles and executive tenures (World Economic Forum 2010). In most instances governments are expected to guarantee zero-loss, where zero risk is impossible to reach (Wooldridge 2001).

From a perception perspective:

- Every nation's definition and prioritization of risks is different. Accordingly some governments are relatively more risk-averse.
- In most situations it's not possible to find management and mitigation strategies which will satisfy the needs and requirements of every stakeholder (involved in the risk assessment process). There will always be parties profiting or suffering more from a specific response (World Economic Forum 2008)." (Kennedy et al. 2011)

Kennedy et al. (2011) also point to an extensive literature on risk and risk management dealing with a range of topics including the study of terrorism (Cummins and Lewis 2003; Viscusi and Zeckhauser 2003). The risk assessment process is oriented to the description and evaluation of the risk at hand. It is important to gather as much information as possible, in order to move to the second stage: decision-making. As Kennedy et al. (2011) summarize, "We know now the scope and characteristics of the problem: what resources do we have to address it? How do we plan to allocate them? How are these decisions taken and who is responsible for them?" The institution or organization responsible for deciding how to face the threat receives the information from the local level. As Kennedy, et al. (2011) suggest, the questions that need to be addressed are the following:

- a. Who is in charge of evaluating the risk at this level and making decisions? How is that authority established? (centralized vs. diffuse leadership)
- b. What is the risk assessment that has been received from the local level? Has the risk been reassessed at a higher level? With what result?
- c. What are the priorities?
- d. What are the available resources? How can they be allocated effectively?
- e. Once the decisions about how to face the threat are made, how are they communicated? To whom? How is that established?
- f. Is monitoring foreseen as a source of data for constant decision-making? Are there protocols of re-examination of decisions according to new information in place?"

Decision-making should involve risk management. Kennedy et al. (2011) suggest that this include all specific actions addressed to the avoidance of the risk (prevention and preparedness), as well as everything that is done to manage the consequences after the event has happened (adaptation and mitigation). Some of the important questions in this area are the following:

- a. Once the decisions are communicated to the institutions or individuals responsible to carry them out, is further communication to lower levels required? How is this done? Are protocols designed with that goal?
- b. Are the specific responsibilities of each level (national, regional, local) established? How?
- c. Are data gathered about the effective implementation of the measures adopted? (monitoring) How? Who is responsible to do that? Is that information passed on to the authorities? How?
- d. How is the effectiveness of the measures established? By whom? Is this communicated to higher authorities? How?" (Kennedy et al. 2011).

With the help of RTM, the imperatives of decision-making and risk management at the global scale can be more directly and effectively addressed.

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Endnotes

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[xii] http://www.prio.no/CSCW/Datasets/Armed-Conflict/UCDP-PRIO/
[xiii] http://www.start.umd.edu/start/data_collections/tops/terrorist_organizations_by_ideology.asp
[xiv] Links to some organizations and companies providing free country shapefiles are provided below:
http://www.aprsworld.net/gisdata/world/
http://www.mapcruzin.com/free-world-country-arcgis-maps-shapefiles.htm
http://www.esri.com/data/free-data/index.html
http://www.diva-gis.org/gData
http://geomatics.nlr.nl/unsdi/srv/en/main.home
http://www.bluemarblegeo.com/products/worldmapdata.php?op=download
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[xvi] http://www.umsl.edu/services/govdocs/wofact96/
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