The application of Geographical Information Systems to armed violent conflict resolution and peacebuilding: a literature review

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Abstract

Many conventional approaches to resolving armed violent conflicts, including negotiations, peace talks, and stabilization, have been adopted, especially in Asia and Africa, but sustainable peace is still illusive in some of these areas. Most of these approaches emphasize the economic and political aspects of peace negotiations and tend to ignore the spatial component. There are several innovative technologies, such as smart cell phones, the internet, Global Position Systems (GPS), and satellite data for mapping armed violent conflict resolution. However, GIS has been recognized as an invaluable tool, a decision support system, and has the potential to assist in conflict resolution. This paper aims to review literature on the application of GIS in the prevention of armed violent conflict, its resolution, post-conflict reconstruction, and peacebuilding. The literature review reveals that while GIS continues to be applied in armed violent conflict resolution and peacebuilding, several challenges remain, including amongst others, its availability, its acceptance by conflicting parties, its accessibility, the accuracy of its data, and the expertise of GIS personnel undertaking the data analysis and integration of data from different sources. A suggested area of further study includes either the application of remote sensing to violent conflict resolution or an integrated application of GIS and Remote Sensing to armed conflict resolution.

1. Introduction

Worldwide, several forms of armed violent conflicts, including armed robberies, civil wars, terrorism, and armed rebellions, are occurring (Asal and Shkolnik, 2021; Colera, 2018; Omeje and Hepner, 2013; Wood, 2000; and Elwell, 2009). Some of these conflicts are supported by external powers for various reasons, including political, religious and economic (Lang, 2009; SIDA report, 2004). Many efforts have been made over the past decades to address these conflicts through conventional approaches, notably, the United Nations peace negotiations, peacekeeping operations (PKO), peace conferences and peace talks, but

sustainable peace remains a challenge and elusive, especially in some parts of Asia and Africa (Bjorkdahl and Buckley, 2016). There are several innovative technologies such smart cell phones, the internet, Global Position Systems (GPS) and satellite data that could be used to map armed violent conflict resolution (Mancini, 2013; Stauffacher, 2011), however, GIS has been identified as a valuable tool in conflict resolution and peacebuilding (Tooch, 2005; Ayeni, 1997). Several authors have researched the applications of GIS in armed violent conflict resolution and peacebuilding (Manchini, 2013; Hardy, 2012; Wood, 2000; Longley *et al.*, 1999). However, the question remains: To what extent can GIS serve as a decision support system in armed violent conflict resolution? This paper aims to review the literature on the application of GIS in armed violent conflict resolution and peace building. Challenges are examined, with their significance highlighted in the successful applications of GIS to armed violent conflict resolution and peacebuilding. The structure of this paper includes a contextualization of armed violent conflicts, the contested nature of GIS, GIS capabilities and applications to armed violent conflict prevention, resolution, post-conflict reconstruction, and the existing challenges.

2. Contextualization of Armed Violent Conflict

The concept of 'conflict' itself is complex and even more difficult to explain when it deteriorates into violence (Elwell, 2009; Galtung, 1969). The word 'conflict' comes from the Latin term, 'conflictus', which means "collision or clash" (Elwell, 2009: 55). According to Galtung (1969), not all conflicts result in armed violence, killings, and bloodshed. It is, therefore, any author's challenge to determine why some societies, especially in the Developed Countries, live for decades without major outbreaks of armed violent conflict, while many other African, South African and Asian countries experience prolonged civil wars and armed rebel violence.

Several authors and experts in conflict resolution and peacebuilding have long been in a quest for solutions to questions related to armed violent conflict. They have attempted to analyse and define 'conflict' from different perspectives (Mine, 2013). Understanding a conflict from various points of view, notably the definition, types, causes, actors, and dynamics is a good start to shed light on conflict resolution (Gatlung, 1959). Violent conflict dates back to ancient/traditional societies and was related to individuals and communities disputing or fighting for access to land rights, naturalization, citizenship, or the extension of their administrative boundaries (Mhandara, 2020; Pottier, 2002; Shyaka, 2006). While such conflicts still exist in contemporary societies, they have become more complex, involving various global and local actors. Acknowledgement of this complexity is captured in the comments of Dr. Weisi Guo, one of the Syrian conflict resolution specialists and one of the

world's leading data scientists, who said, "You have to zoom out a bit and think about the global flux" to resolve some contemporary local level conflict challenges (Colera, 2018:5).

Given the complexity related to these conflicts and the term 'conflict' itself, some authors have provided definitions that are easy to understand at different levels of conflict. For, example, Elwell (2009:56) defines conflict as "a struggle between opponents over values and claims to scarce status, power, and resources". Whilst this definition contains a fundamental and generalised knowledge of conflict, it has been critiqued for being narrow, with little attention paid to the role of causal mechanisms and the societal level (Soytong and Perera, 2014; Beber and Blattman, 2009). Other authors have interrogated the type of society where political violence occurs or what groups (intergroup or intersociety/nations) are most involved or likely to use violent repertoires (Balcells and Justino, 2014; Kalyvas and Kocher 2007; Goodwin, 2001). Such detailed knowledge assists in understanding the nature and persistence of conflict in some societies.

Violent conflicts are characterised by three main stages, namely the pre-conflict, conflict, and post-conflict (Table 1). Each respective stage has an intervention method that includes strategies for proactive prevention, resolution, and peacebuilding.

Table 3.1: Characteristics of Violent Conflicts (Source: The Researcher, 2019)

Features	**(1) Pre-conflict**	**(2) Conflict/Violence**	**(3) Post-conflict reconstruction**
General characteristics	The conflict is not yet highly visible, and neither are the forms of violence. This phase can display conflict behaviour and manifestations of it	Communications between the conflicting sides have completely broken down. The violence is at its most intense, and people on all sides are being killed.	When the violence has ended, and an agreement has been reached, the tension decreases and relationships can be re-established between the conflicting parties.
Intervention methods	Pro-active Prevention	Resolution (amongst others, conflict talks and negotiations, peace-making and keeping and stabilization)	Peace building (post-conflict reconstruction)

According to Mine (2013:2), "violent conflicts are not inevitable". The question is why conventional PKO approaches to violent conflict resolution partially work or do not work at all. Jett (2001) argues that most of these PKO approaches are economically and politically oriented and thus fail because of inadequate planning, staff incompetence, and an inability to act rapidly, with little attention to related geospatial aspects and a lack of careful rethinking of their spatial relationships, all of which play a vital role in peace talks or conflict resolution engagements (Bjorkdahl and Buckley, 2016; Cedric, 2002). The GIS responses to these challenges act as a tool for collecting, analysing and managing spatial and attribute data that can aid in armed conflict resolution (Baker, 2015).

3. Geographical Information System (GIS) – A Contested Concept

Goodchild (2000) defines a GIS as a computing application that allows the user to create, store, manipulate, visualize, and analyse geographic information. This technology has the capability to map locations on the earth's surface (Aung, 2021; Heywood, 2006; Goodchild, 2000; Wright, 1997), allowing users to display, visualize and query data in order to understand their spatial relationships and patterns. Typically, GIS users deal with 'geographical or spatial data'- "where things are, or perhaps where they were or will be" (Huisman and Rolf, 2009:27).

GIS is currently used all over the world for a wide range of purposes and applications; but remains a contested concept (Huisman and Rolf, 2009; Heywood, 2006; Wright, 1997). A pertinent question is to know what sets GIS apart from other information technology systems, such as smart phones or the Global Positioning System (GPS). Many authors argue that what makes GIS technology unique is its capability to handle both spatial and attribute data (Huisman and Rolf, 2009; Yoffe and Fiske, 2001; Martin, 1996 and Grimshaw, 1950) and its ability to create "visual representations and make explicit the implicit features of data" (Wright, Goodchild and Proctor (2004:352).

However, there are endless debates on whether GIS is a science, a tool, or a set of interrelated techniques (Campbell and Masser, 2020; Wright *et al*., 1997). When viewed as a series of interrelated techniques, such as data capture, storage, querying, analysis, and presentation of results (Yao and Hei, 2018; Ballatore *et al*., 2013; Raleigh, *et al* 2010; Huisman & Rolf, 2009; Heywood, 2006; Pickles, 1997), the challenge is that the absence of one or more of these steps could result in it being classified as something else (Bierman *et al*., 2016; Martin, 1996; Grimshaw, 1950).

Authors who argue that GIS is a tool maintain that it is merely a computer system to organise and manage spatial data (Campbell and Masser, 2020; Longley *et al.,* 1999; Allen & Massey, 1995 and Goodchild, 1992), or a toolbox with useful commands to manage and organise spatial data (Bierman, et al., 2016; Kulldorff, 2007; Goodchild, 1992). Contrary to these perceptions, some authors argue that GIS is a science or an applied science with its own unique and logically coherent knowledge system (Wei and Yao, 2018; Prakash, 1998; Martin, 1996 and Grimshaw, 1950).

Perhaps a better compromise would be to consider GIS as both a tool and a science (Bierman *et al*., 2016; Pickles, 1997 and Weght, 1997) that can be applied to different disciplines and areas. This compromise and integrated perception are corroborated by its increasing use by researchers in many disciplines, amongst which are geology, archaeology, the environmental sciences, resource management, biodiversity management, town planning,

and transportation. Thus, we can describe the GIS process as an approach used by different disciplines (the physical and human sciences) for integrating, synthetising and modelling data for its application in the real world (Jihong, 2014, Gimblett, 2002; Wood, 2000; Longley et al., 1999 and Martin, 1996). The understanding of these concepts of GIS sheds light on its application to address issues related to violent conflict resolution.

4. GIS Capabilities and Armed Violent Conflict Resolution

In the domain of peacebuilding, GIS has the technological capabilities to facilitate decision-making in conflict resolution talks (Tooch, 2005; Wright, Goodchild, and Proctor; 2004). GIS on its own cannot resolve any conflict (Wood, 2000; Prakash, 1998; Martin, 1996 and Prakash, 1998) but rather, it is a decision support system, aiding different parties in a conflict to reach an agreement informed by spatial data that has been collected, transformed, and analysed (Hardy, 2012; Goodchild, 2004; Bouchardy, 2000).

One of the most valuable capabilities of GIS technology is the ability to create a geo-database or a geographical database on a GIS platform. The term 'geo-database' derives from a 'database', which according to Musa (2016:47) is "a collection of one or more data files or tables stored in a structured manner, such that the interrelationships which exist between items or sets of data can be utilized by the Database Management System (DBMS) software for manipulation and retrieval purposes". Such a geo-database provides an integrated platform for further geospatial analysis, including spatial data overlays, spatial data queries, buffer zone creation (Campbell and Masser, 2020; Mossa *et al*., 2019; Conley, 2005; Prakash, 1998; Martin, 1996), and the spatial display of issues and/or resources related to conflict. For example, GIS overlays, including remotely sensed imagery, digital terrain models, and other digital data layers allow for the spatial visualization of the area in dispute. They can identify the types of resources at stake or the populations that might be affected by the conflict. Other GIS capabilities that apply to violent conflict analyses include proximity analysis, digital mappings and the multi-criterial analysis of causative factors to determine risks and vulnerabilities, and hotspot analysis using kernel density tools to determine areas characterized by the recurrence of violence (Humanitarian Tracker Project, 2014; Hegre, H 2011; Mossin, 2007). Such analyses can inform decisions on conflict prevention, mitigation, and resolution (Sugumaran and Degroote. 2011).

The capabilities of GIS, as outlined in the previous paragraph, harmonize with those expounded by Grimshaw (1993: 206), who pointed out that GIS enables policy or decision-makers to explore the geographical dimension of data, providing an opportunity to determine the best possible solution to a problem, typically by evaluating and modelling various alternatives (Humanitarian Tracker Project (2014); De Groote, 2011; McCall, 2003 and Gimblett, 2002). Since most or almost all violent conflicts occur in geographic space, GIS

provides a geospatial platform for such data exploration aimed at conflict prevention planning, peace talks and/or post-conflict reconstruction (Halls, 2008).

5. The Application of Geographical Information Systems to Armed Violent Conflict Prevention

Conflict prevention is a "set of instruments or measures used to prevent or solve disputes before they have developed into active conflicts" (Swanstram and Weissmann, 2005:5). There is a belief that GIS could assist in achieving better solutions to armed violent conflicts before they erupt (Humanitarian Tracker Project, 2014; Pauw, 2012; Bouchardy, 2000) and spread into neighbouring areas. For example, GIS can be used to monitor and control violent conflict activities through prediction models and provide the right information for preventing the spread of conflict. These functionalities and capabilities of GIS enable all sides in a conflict to have an improved picture of different aspects related to the conflict, thus informing peace talks and stakeholders' decisions (Longley *et al.*, 1999).

An example of a GIS application to armed violent conflict prevention is the case of Kyrgyzstan, a Central Asian state bordering China (Manchini, 2013; Mossin, 2007; Bisig, 2002). Since the collapse of the Soviet Union, it has been host to persistent low-level violence and is suffering from a multiplicity of challenges that are traditionally associated with conflict. These challenges range from sky-high unemployment rates to widespread poverty, a strain on local natural water sources, inter-ethnic tensions, and geopolitically volatile neighbourhoods (Humanitarian Tracker Project, 2014 and Mossin, 2007). GIS has been used to "develop a dataset for conflict vulnerability assessment, generating practical applications to assist in identifying areas where future conflicts might break out and to predict the appropriateness of future aid allocation" (Mossin, 2007:1). More importantly, several variables, including the areas of ethnic boundaries, competition for natural resources, the population's susceptibility to violence (based on young unemployed and unmarried men indicators), and terrorism hotspots were analysed, with conflict vulnerability and aid distribution maps subsequently being developed (Mossin, 2007).

The areas vulnerable to inter-ethnic conflicts were predicted through the calculation of Euclidean distance in GIS terms. Areas closer to an inter-ethnic boundary were classified as being more vulnerable to ethnic conflict (Mossin, 2007; Bisig, 2002). The Euclidian distance was also used as a tool to determine the water proximity of an area to Kyrgyzstan's main rivers and lakes (Humanitarian Tracker Project, 2014; Mossin, 2007), the area then being reclassified as more vulnerable to ethnic conflict. Whether an area is prone to resource competition was also established. The two criteria on which this decision was based were proximity to natural resources and density of population in that area (natural resources in this context were defined as water resources, including rivers, lakes, and arable land).The

population density was mapped showing people's access to natural resources, with the areas with greater access to natural resources being those with water proximity and arable land combined (Dawwas, 2014; Mossin, 2007; Bisig, 2002).

An area would be considered to have a relatively large population susceptible to violence in terms of three census data categories, notably, the percentage of young, unemployed, and unmarried persons, the percentage of different ethnic groups, and the percentage of scarce natural resources in the region (Mossin, 2007). As regards terrorist hotspots, the areas at risk of renewed violence were identified using the kernel density tool on the Global Terrorism Dataset for Kyrgyzstan for the period 1991-2011 (Humanitarian Tracker Project, 2014; Mossin, 2007). It was assumed that areas that had previously experienced violence would be more prone to future violence (Mossin, 2007; Bouchardy, 2000).

To develop a conflict vulnerability map in Kyrgyzstan, four indicators were aggregated, applying the following mathematical relationship: (Proximity to ethnic boundaries x Access to natural resources) + (Population at risk + Previous terrorism hot spots) (Mossin, 2007:8). In addition, an aid distribution map was developed. It was based on international aid distribution data for June 2011 that had been compiled by the United Nations Office of the Coordination of Humanitarian Affairs (UN OCHA) and on the location of all ongoing international aid activities in Kyrgyzstan. The map was created by dividing the number of aid projects in a region with the total number of people in that region. Thereafter, the map was rasterized and reclassified to create the population-at-risk dataset. Finally, "areas currently underserved in terms of aid, while scoring high on a conflict vulnerability index, were found by subtracting the areas found vulnerable to ethnic conflict from those featuring on the aid distribution map" (Mossin, 2007:8).

6. The Application of Geographical Information Systems to Armed Violent Conflict Resolution

GIS has been emerging as an important data source for decision-making in conflict resolution. The eminent case is Israel *versus* Palestine's persistent armed violent conflicts, where GIS problem-solving capabilities have been used in conflict-related negotiations (Wallach, 2011; Mossin, 2007; Tooch, 2005). The Israeli-Palestinian conflict is one of the most complex and persistent disputes in the world and it is linked to decades of repeated violence and stalled peace talks on territories such as Gaza, Jerusalem, and the West Bank (Silverbrand, 2008; Tooch, 2005).

The main issues causing the conflicts were and continue to be the expansion of Israel's settlements, border demarcations between the two opposing groups, access to natural resources (mainly the Jordan water basin rights), management of Jerusalem City, and other

crucial aspects of the prolonged dispute between the two groups (Baker, 2015; Wallach, 2011; Tooch, 2005). In this case, GIS was instrumental in groundwater and water quality assessments and watershed and surface water management programmes, all of which were thereafter used by peace-making experts to resolve the water management conflict between the two parties (Gvirtzman, 2012 and Tooch, 2005).

Another prominent example of GIS applications in armed conflict resolution includes the use of digital mapping technology in the Dayton Peace Accords between the Bosnian, Serb, Croat, and Muslim ethnic factions in the former country of Yugoslavia (Johnson, 1999). Besides diplomatic negotiations, digital mapping, including various aspects of the conflict over, amongst others, boundaries, battlefields, and topographical data, contributed to successful peace negotiations.

7. The Application of Geographical Information Systems to Armed Violent Conflict and to Post-conflict Reconstruction

Post-conflict reconstruction is necessary and is a multi-disciplinary process, related not only to the planning and physical reconstruction of services, infrastructure, and buildings, but also to the reconstruction of civil society (Barakat, 2018; Halls, 2008; Smith, 2001; Ayeni, 1997 and Yaakup, 1994). In most cases, the post-war recovery involves people displaced from their homes or their countries and seeking a return to or integration into normal life (Halls, 2008).

There are various case studies where the application of GIS was successfully used in post-conflict reconstruction (Halls, 2008). Some examples include the use of GIS for territorial negotiations in Bosnia (Wood, 2000), better aid allocations in Kyrgyzstan (Mossin, 2013), and in the Kosovo post-war reconstruction by the United Nations High Commission for Refugees (UNHCR), in partnership with other Kosovo Albanian organizations for decision-making and emergency response (Halls, 2008; Wentz, 2002; Hetherington, 2000). GIS models were created and database support was used to map areas in need of reconstruction. The Kosovo post-war reconstruction has been an especially successful example since the use and sharing of GIS data have been so obviously apparent in providing a model for organizations in search of standards for all parties involved in a conflict to agree upon (Hetherington, 2000; Lenz, 2002). The new system for regional reconstruction provided prospects for sub regional and regional integration, promoting collaboration, peaceful negotiations, and trust among the different conflict groups living together (Hetherinngton, 2000). This approach also provided an open opportunity for inter-regional local and foreign investment, facilitating industrialization and regional peace.

8. The Application of GIS to Armed Violent Conflict Resolution and Peacebuilding – a Synthesis and Challenges

The evidence reviewed in this paper suggests that GIS offers considerable scope for application to violent conflict prevention, resolution, and post-conflict peacebuilding. While some authors such as Grimshaw (1950) and Pickles (1997) argued that GIS is a science, with its own unique, logically coherent knowledge system, others such as Hetherington (2000) and Halls (2008) believe that GIS remains a tool. A consensus to this debate has been that GIS is both a tool and a science (Ballatore et al., 2013; Arnstein, 1969), with its interpretation depending on the perspective of the user (Bjorkdahl and Buckley, 2016; Heywood, et al., 2006; Bouchardy, 2005).

There is also an assumption, implicit in this paper, that GIS data can be used to inform action in operational and strategic planning, and to inform the way in which conflicts are managed in the interests of the community (Sieber, 2006; Bouchardy, 2005; Carver, 2001). However, the extent to which geo-information is incorporated into decision-making depends on whether all parties agree with the data and the results of the GIS (Bjorkdahl and Buckley, 2016; Heywood, et al., 2006). If the parties in a conflict do not mutually agree on the information provided by the GIS, the use of GIS could have some negative impacts on the process of negotiation (Bjorkdahl and Buckley, 2016), creating distrust and further stalling the peace process. In such a scenario of distrust, the solution would come from an independent, neutral GIS body, which would provide unbiased data to support the conflict resolution process (Heywood *et al*., 2006). It is therefore imperative that the use of GIS in conflict resolution should not only gain the mutual support of opposing parties but also draw from the expertise and the integration of other approaches that are involved in conflict resolution.

In addition to these general challenges related to GIS applications in armed violent conflict resolution, availability, access, and the accuracy of spatial data are issues in Developing Countries (Mennecke and West, 2001). While governments in many Developed Countries have found GIS to be a critical tool in resource management, regional planning, and economic development (Bocco and Sanchez, 1995), GIS in many Developing Countries is hampered by deficiencies and inaccuracies in spatial and demographic data, political factors, and management issues (Mennecke & West, 1998). For instance, politically, Bocco and Sanchez (1995) have pointed out that while some boundaries follow physical features such as coastlines, rivers, and so on, others are arbitrary or have their roots in historical events and can be disputed. Maps drawn by one country or region showing political or administrative boundaries could differ from those drawn by the opposing parties, thus requiring consensus (Baker, 2015; Wood, 2000). Some solutions to these challenges include the creation of geo-databases for armed violent conflict by national government GIS departments and non-

governmental organizations that could provide accurate spatial data to assist conflict resolution practitioners and policymakers in making decisions on conflict resolution and peacebuilding (Hetherington, 2000; Soytong, and Perera, 2014). The establishment of such geo-databases should be complemented by the training of GIS experts within organizations and institutions to manage the geo-databases (Weber, 2004).

Further to the challenges discussed in the preceding paragraphs (the nature of GIS, its availability, its acceptance by conflicting parties, its accessibility, and its accuracy), Gerland (1996) identified a variety of integration problems, including data from different sources with different standards, missing positional and reference information, as well as different geographical projections and transformations (Gerland, 1996). These issues are relevant and require trained GIS personnel for the successful application of GIS to conflict resolution (Spittaels, 2021; Weber, 2004).

9. Conclusion

This paper has reviewed the applications of GIS to conflict resolution and peacebuilding, scrutinizing the claims made for and against GIS applications in the prevention of violent conflict, its resolution, and in post-conflict reconstruction. There are many successful results of GIS applications in armed violent conflicts, viz. Kyrgyzstan, the persistent civil war between Israel and Palestine, and the Kosovo post-war reconstruction. While GIS continues to be applied in armed violent conflict resolution, and peacebuilding, it cannot resolve any conflict on its own. The whole process requires the mutual collaboration of the parties involved in the conflict. Several challenges accompany the application of GIS to armed violent conflict resolution and peacebuilding, including amongst others, its availability, its acceptance by conflicting parties, its accessibility, its accuracy of data, and the expertise of the GIS personnel undertaking the data analysis and integration of data from different sources. Knowledge of these challenges is important for all stakeholders in a peace process and researchers undertaking studies related to GIS applications in violent conflict resolution. A suggested area of further study includes either the application of remote sensing to armed violent conflict resolution or an integrated application of GIS and Remote Sensing to armed violent conflict resolution.

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