

Remote Sensing for International Security

Subjects: **Sociology**

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Remote sensing technology has seen a massive rise in popularity over the last two decades, becoming an integral part of our lives. Space-based satellite technologies facilitated access to the in-accessible terrains, helped humanitarian teams, support complex emergencies, and contributed to monitoring and verifying conflict zones. The scoping phase of this review investigated the utility of the role of remote sensing application to complement international peace and security activities owing to their ability to provide objective near real-time insights at the ground level.

conflict resources monitoring

disease control and prevention

human rights

genocide tracking

human rights violation

geopolitics

1. Introduction

Assuring the individual and collective well-being are the quintessential goals of any society. Different civilizations and societies develop certain principles and ethos that are binding as rules and regulations to their citizens. In return, the state (through its administrative machinery) strives to ensure its residents safety and welfare as a social contract ^[1]. The technology-oriented industrial revolution propelled the advent of the nation-state system and democratic thought. The Government's mandate and tools to deliver its functions continue evolving with time, demography, and technological innovations. The knowledge frontiers explore more scientific methods with considerable precision and accuracy to testify and ensure compliance with rules ^[2]. In the initial years, the power to master the earth's natural resources was the fundamental principle for economic expansion ^[3]. However, this uncontrolled growth became the reason for conflict (strategic control over oil and key mineral resources) among participating powers ^[4].

The rise of a scientific-industrial-military complex before and during the Cold War era had a lasting effect on the peace and tranquility of certain resource-rich and strategic regions. Although the techno-economic prowess aided development, the armed conflicts affected individual and community rights. For centuries, military commanders have sought out positions with a high elevation, such as mountains and ridges, to gain visual information about their enemies' locations and movements ^[5]. The First World War is widely regarded as the turning point in history that led to the wide popularity of many advanced techniques and weaponry systems. In particular, remote sensing gained prominence due to the application of high-altitude airplanes for aerial reconnaissance ^[6]. The aerial photographs were specifically used to locate enemy trenches and hidden positions, troop movements, supply routes, and depots, as well as to verify the effectiveness of artillery attacks against the enemy ^{[7][8]}.

The development of the man-made satellite was considered one of the largest technological breakthroughs in the military field [9]. The Cold War and Post-Cold War phase saw a vast expansion in such satellite deployments for international peace and security [10]. The United States Air Force's CORONA satellite program operated during the Cold War and collected over 800,000 aerial images of the Union of Soviet Social Republics (USSR), the People's Republic of China (PRC), and other countries and regions. As the platforms for remote sensing applications advanced by leaps and bounds, the sensors themselves also improved drastically. Initially, the CORONA satellite was only able to capture images from orbit with a spatial resolution up to roughly 12 m [11]. However, the spatial resolution of satellite images has shown drastic improvement to below one meter in recent years [12]. Multi spatio-temporal satellite data with local to global data acquisition can be applied in international peace and security in conflict zones. Several applications are shown in Figure 1.



Figure 1. Applications of remote sensing for international peace and security.

In particular for military and conflict management, the application of remote sensing was initially limited to the technologically advanced nations, like the United States of America (USA) and the former USSR, as well as other countries with significant defense budgets. Satellite data have been used by the forces to identify terrains, rivers, ridges, populated areas, strategic installations, communication networks, etc. [13][14]. With time and technical advancements, remote sensing has also made significant contributions for less developed countries, such as Vietnam, Indonesia, Thailand, India, Cambodia, etc. The type of information accessible from remote sensing for peace and security depends on the sensor's specific properties and platform. Recently, with the availability of high spatio-temporal data, remote sensing technology was actively used in the detection of genocide in Darfur and human and drug trafficking in Afghanistan [15][16]. In addition to the applications in military purposes, aerial and satellite remote sensing have been significantly utilized for international peace through their role in preventing resource conflicts [17], disease control and prevention [18], human rights protection [19], and tracking genocide [20].

Earth observation satellites and communication technologies offer precise and accurate means for remote monitoring of conflict zones. Some of the worst forms of human rights violations have been deeply rooted in either war zones (in resource-rich regions) or regions lacking basic resources like water and food [21]. It can be difficult to monitor these dangerous zones using ground information. However, remote sensing techniques can help to monitor such remote and dangerous zones without physical contact. Remote sensing has also been used for verifying international laws, treaties, and resolutions, e.g., for monitoring oil pollution sources [22], exploring

renewable energy resources [23]. The technological development and rise in using sensors have led to the surge in remote sensing companies, aiding in the usage of data for the larger social and environmental safety. Geospatial techniques can provide useful information for the implementation of The United Nations Sustainable Development Goals (SDGs#16, i.e., to promote peaceful and inclusive societies for sustainable development, and provide access to justice for all and build effective, accountable and inclusive institutions at all levels) [24][25].

Several approaches of remote sensing for military and civilian applications have been investigated [26]. These studies displayed remote sensing's utility for international peace and security both from a macro-perspective and micro-perspective, respectively. At the macro-level, the application of Geographical Information System (GIS) techniques in identifying the role of historical precedents in territorial disputes has shown valid results. For instance, in the European context, the application of GIS helped in finding the relationship between historical boundaries and conflicts [27]. For instance, studying the micro-level effect on issues like migration led to violent situations in the Goma City (the Democratic Republic of Congo) [28] and city-level consequences of Arab Spring in Jordan [29][30]. Furthermore, along with GIS techniques, other scientific tools like big data have been utilized to understand the intensity of such conflicts [31]. Remote sensing can also assist in understanding the issues emanating due to state classifications like ethnic fractionalization [32]. This, in return, can aid in the consolidation of socio-cultural theoretical frameworks of other humanities disciplines.

2. Discussion

Remote sensing applications have come a long way, ever since the testing of the *Transit* (1960), which is the United States Navy's first military navigation satellite. The defense applications have expanded leaps and bounds from intelligence gathering, positioning, and navigation to communications. This technique has become essential in many aspects of international peace and security [33][34]. The costs of using satellite and other imagery data are very high, and, therefore, such techniques are not accessible to all actors playing a role in peacemaking and peacebuilding processes.

Applications of remote sensing techniques have been improved with the advancement of sensor technology and processing algorithms over time. Table 1 shows the major case studies related to remote sensing applications in peace and security in the last two decades. Landsat data has played a vital role and is popular among most of the major case studies presented in Table 1 because of free access since 2008. There were fewer case studies before 2010 and most of these studies used conventional visual image interpretation techniques using common satellite data. The number of published papers increased after 2010 and used advanced image processing algorithms with advanced sensors. Machine learning algorithms have recently become popular to process satellite data with better resolutions. The use of advanced sensor data with advanced spatio-temporal strengths can provide more accurate information about incidents. This information can help to develop an early warning system to prevent conflicts. However, there is still a need to establish a standard methodology and code of ethics [96] to use these scientific data as a source for international cooperation and international courts of law.

For the operations of law enforcement agencies, the satellite data can be used as a piece of credible evidence in a court of law. However, since there is a paucity of legal criteria for interpretation and admissibility of remote sensing imaging, the legality of its use as uncontested evidence requires refinements in country-specific bye-laws. As indicated, the issues of measurement validity and selection biases require assessment through a multidisciplinary lens. Where the local and standard definitions, classifications, and constructs regarding socio-cultural and historical aspects need to be a combiner. This will strengthen the capacity of legal institutions to respond to human rights violations and bring perpetrators to justice. Furthermore, the field of remote sensing technology must look beyond the courts and tribunals by educating members from other disciplines like sociologists, demographers, and members from law enforcement and judicial agencies, such as judges, prosecutors, and paralegal professions. The value of satellite imaging for human rights and its use as evidence in legal proceedings need to be strengthened across the multidisciplinary dimensions.

Much of the research on remote sensing and its applications in counter-terrorism initiatives are based on data that was mainly derived by the experts in the field. Several computer algorithms are available, which determine what objects are present in satellite imagery. Effective data interpretation is very important in such cases where information is dynamic and dependent on many variables. Still, information gathered through remote sensing can increase transparency in the cases of counter-terrorism. However, many measures should be taken to understand and contextualize data as well as ensure its protection because of the sensitivity of the remote sensing-based information. The existing literature indicates a paucity of papers in which a deeper contextual analysis based on the socio-economic and historical data is conducted.

The use of visual images post facto as evidence of genocide, population displacement, environmental damage, the supplementation of the results with eyewitness and independent reports, and the versatility of the use of data are all examples of how important remote sensing has become in the domain of global peace and security. Though it is not novel for use as military means, it has only recently been incorporated into other areas, such as quantifying conflict zones. More research is needed regarding how to use remote sensing imagery as an early warning tool for conflict prevention. The credibility of remote sensing information and its application in court or by policymakers is still a grey region. In the field of peace and security, the need for strong communication between scientific applications and policymakers is crucial. The *Eyes on Pakistan* project is one of the successful examples of how remote sensing data documenting human rights violations have been used and publicized through an open-source platform accessible to public and government officials [35].

Table 1. Major case studies associated with applications of remote sensing data in peace and security.

No.	Authors	Publication Year	Study Area	Remote Sensing Sensors	Methodologies
1	Koch and El-Baz, [36]	1998	Kuwait	Landsat, SPOT	Visual image interpretation

2	Bjorgo [37]	2000	Thailand	Russian KVR-1000 sensor	Visual image interpretation
3	Giada et al. [38]	2003	Tanzania	IKONOS	Supervised, unsupervised image classification
4	Schimmer R. [39]	2006	East Timor	Landsat	Visual image interpretation
5	Schimmer R. [40]	2008	Darfur, Sudan	MODIS, SPOT-vegetation, Climate data	Temporal change in vegetation phenology
6	Prins [41]	2008	Darfur, Sudan	Landsat ETM+	Normalized burn ratio (NBR)
7	Anderson et al. [42]	2008	Rift Valley province, Kenya	MODIS	Active fire detection
8	Madden et al., [43]	2009	Uganda	Landsat, Google Earth	Visual interpretation
9	Schoepfer et al. [44]	2010	The Democratic Republic of the Congo	Rapideye, Geoeye-1	Object-based image classification
10	Gorsevski et al. [45]	2012	South Sudan and Uganda border	Landsat, MODIS, Aerial photographs	Image classification, TCA, disturbance index (DI), NDVI

11	Hagenlocher et al. [46]	2012	Northern Darfur, Sudan	QuickBird	LULC, Object-based image analysis (OBIA)
12	Marx and Loboda [47]	2013	Darfur, Sudan	Landsat	Reflectance, TCA
13	Jiang et al. [48]	2017	Yemen	NPP-VIIRS	Theil-Sen Median Trend Method, Nighttime Light Indexes
14	Casana et al. [49]	2017	Southern Turkey, Syria, and Northern Iraq	High-resolution satellite (DigitalGlobe)	Image interpretation
15	Pech et al. [28]	2017	Goma city, the Democratic Republic of the Congo	Landsat, Worldview-2, topographic maps	Image processing and visual interpretation
16	Sawalhah et al. [50]	2018	Jordan	Landsat 8	Maximum likelihood classification
17	Levin et al. [31]	2018	Arab countries	VIIRS, Flickr photos	Temporal trends in monthly time-series
18	Quinn et al. [51]	2018	NA	NA	Machine learning
19	Hassan et al. [52]	2018	Bangladesh	Sentinel-2A and Sentinel-2B	Random forest classification
20	Marx et al. [53]	2019	Rakhine, Myanmar	PlanetScope	Pixel-based value extraction

21	Levin et al. [54]	2019	World heritage sites	VIIRS, MODIS, Global Terrorism Database	Statistical analysis
22	Prem et al. [55]	2020	Colombia	Landsat	Empirical model
23	Shantnawi et al. [30]	2020	North Jordan	Landsat	Supervised classification and change analysis

Remote sensing techniques have been instrumental in supporting international treaties, monitoring crises, and predicting natural catastrophes. Various United Nations, governmental, and non-governmental organizations have shown a substantial interest in remote sensing technologies for international peace and security. The main purpose of these organizations is to provide scientific information toward international peace and security. The cooperation between various space agencies can provide useful information to decision-makers, helping to establish global peace and security. For an example, the “International Charter Space and Major Disasters” platform provides satellite-based information for relief during humanitarian disasters. Satellite data are made available for rapid response to reduce disaster losses and damages. Advanced near real-time geospatial data can provide useful information to control the conflicts if combined with mobile data [\[56\]](#). Big data initiatives can be helpful in conflict prevention and uncovering the relationship between conflict dynamics and development goals [\[57\]](#).

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