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REMOTE SENSING TENDENCIES IN THE ASSESSMENT OF AREAS DAMAGED BY ARMED CONFLICTS

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Abstract

War and armed conflicts have been shown to contribute directly to decreased landscape values and environmental degradation, especially in developing and tropical countries. This paper presents a methodic review approach designed to analyze the relationship between drivers and remote sensing methods in areas affected by armed conflicts. The document seeks beyond showing and comparing a series of cases where the various remote sensing methods have been used, seeks to find trends, patterns of repetition or non-repetition, points of convergence and divergence taking into account variables such as area, scale, satellite sensors used, and geographic conditions to determine the relationship between causes and consequences of the conflict with the remote sensing methods. We collected data from international peer-reviewed journals that are indexed using scientific search engines as Scopus and Science Direct. We analyzed 43 research papers from 1998 to 2019 time-lapse that used satellite imagery and aerial photos in 21 countries of 4 continents to assess environmental effects caused by armed conflicts. Quantitative analysis of the trends identified within these areas contributed to an understanding of the reasons behind these conflicts.

Key words: *armed conflict, deforestation, forest cover, land use change, remote sensing.*

INTRODUCTION

Principles for remote sensing of violent conflict

The utilization of remote-sensing analysis to study violent conflict has increased considerably over the last 10 years and the trend shows that is going to keep growing steadily (Witmer, 2015). This recent increase has been driven, in part, by the conflicts in the Sub-Saharan region, Latin-American region and the higher availability of ultra-fine resolution satellite imagery (Butsic et al., 2015; Leiterera et al., 2018; Gorsevski et al., 2012; Rincon-Ruiz et al., 2013; Potapov et al., 2012; Sanchez-Cuervo & Aide, 2013; Murad and Pearse, 2018).

Originally remote sensing methods including aerial photos analysis in armed conflict areas were used for military purposes because the military field has been for a long-time source of innovation and has had enough financial resources to invest in remote sensing technology researching (Corson and Palka, 2004). Improvements in the remote sensing technology and satellite imagery have increased the effectiveness of armies and the accuracy of military operations (Witmer, 2015).

The difficulty of access to an area during wartime combined with no clear spatial or temporal definition for the extent of conflict makes an accurate and timely assessment of the impacts extremely challenging (Butsic et al., 2015).

Because of these limitations, information derived from satellite remote sensing data can provide insight into how conflict directly affects the physical environment during wartime and indirectly leads to changes in human populations and land use activity that drive the observed land cover modifications.

The impacts of armed conflicts on ecosystems are complex and difficult to assess due to restricted access to affected areas during the war, making satellite remote sensing a useful tool for studying the direct and indirect effects of conflicts on the landscape (Murad & Pearse, 2018; Hoffmann et al., 2018). Since World War II, 80% of armed conflicts occurred directly at biodiversity hotspots, most of which are tropical forest regions (Hanson et al., 2009). Due to this high spatial correlation and the need for increased conservation efforts, the

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relationship between war and the environment needs to be further examined (Ordway, 2015).

Sensors and Satellite Imagery.

Remote sensing technology is based on the detection of electromagnetic energy reflected or emitted from a surface without making physical contact with it.

There are two types of remote sensing approaches; passive is based on solar radiation reflected or emitted from a surface, while active remote sensing generates radiation impulses and detects the reflected signal. Most conflict-related research uses passive technology mounted on a satellite platform (Witmer, 2015).

There are also two types of images available; the free online images (e.g. Google Earth), these images have the disadvantage that they only provide information in the visible range, without multispectral data in the infrared range. These images can be very useful, for example, as ground reference data used to confirm conflict-related land abandonment and to corroborate the effects of war.

Resolution is a key consideration in the use of remote sensing. Spatial, spectral and temporal resolutions are perhaps the most relevant, but radiometric resolution also affects what can be detected.

Table 1 lists the sensors commonly used to study the effects of violent conflict. The sensors are grouped by spatial resolution using the category jumps found in the SAGE Remote Sensing Manual (Warner, Nellis and Foody, 2009), where the very fine spatial resolution images are ≤ 1 m, fine 1-10 m, moderate 10-250 m, and coarse > 250 m (Table 1).

Direct and Indirect Drivers

Armed conflict and post-conflict development may interact with land use and land cover activities to influence the modification of the landscape and severity of forest deterioration. Land use has contributed to the recent overwhelming decline in biodiversity through habitat fragmentation, modification and loss, leading to degradation of ecosystems and environmental services (Ordway, 2015; Nackoney et al., 2014; Qamer 2012 et al., 2005; van Etten et al., 2008). The growing body of literature addressing various direct and indirect impacts of armed conflict on the environment has raised a number of hypotheses (Black, 1994; Jarret, 2003; Machlis and Hanson, 2008; McNeely, 2003; Omar et al., 2009).

Table 1. Characteristics of commonly used sensors (Source: Witmer, 2015)

Sensor	Spatial resolution (m)	Swath width (km)	Spectral bands	No. Studies
Very fine spatial resolution (≤ 1 m)				
QuickBird	0.6	30	Pan	3
World View	0.5	18	Pan	2
IKONOS	0.8	11	Pan	3
GeoEye	0.5	10	Pan	1
Fine spatial resolution (1-10 m)				
GeoEye	1.6	10	4	1
QuickBird	2.4	30	4	3
SPOT	2.5	60	Pan	4
IKONOS	3.2	11	4	3
IRS LISS 4	6	25.70	5	0
Moderate spatial resolution (10-250 m)				
SPOT	10, 20	60	4	4
IRS LISS 3	6, 23, 70	70,140	5	1
Landsat 8 OLI	15, 30		11	6
Landsat 6-7 ETM +	15, 30		8	19
Landsat 4-5 TM	30	185	7	20
Landsat 1-5 MSS	60, 120		4	3
Coarse spatial resolution (> 250 m)				
MODIS	250, 500, 1000	2330	36	4
AVHRR	1100, 4400	2500	5.6	1
DMSP-OLS	2700	3000	2	

Studies have shown that conflict and war can drive deforestation or promote forest recovery (Alvarez, 2003; Biswas and Tortajadaquiroz, 1996; Dávalos, 2001; Hecht and Saatchi, 2007; Lodhi et al., 1998; McNeely, 2003) (Figure 1).

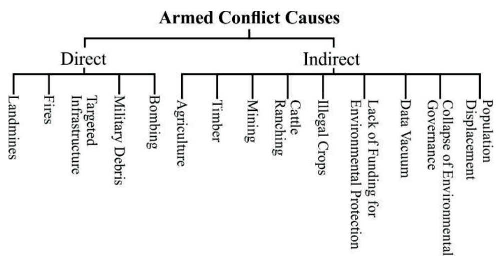

Figure 1. Causes on environment based on Jha, 2014

Direct impacts are all events that are physically related to direct military action of confrontation and that frequently arise in the immediate or short term (bombings, direct armed confrontations, military structure), while indirect impacts are those that are generally linked to many factors not necessarily military triggered by the armed conflict and only manifest themselves completely in the medium or long term (Jha, 2014; Partow, 2008). Some examples of direct impacts include the deliberate destruction of natural resources, environmental pollution from the bombing of industrial sites and military debris and demolition wastes from military infrastructure.
On the other hand, indirect effects include the environmental footprint of displaced populations, deforestation due to new colonization areas, the possible creation of illegal crops and illegal mining, the collapse in the implementation of environmental regulations and the information vacuum, as well as the lack of funds for environmental protection. Another additional problem is that any war destroys buildings and infrastructure that must be rebuilt and consume large resources and increase extensions (Jha, 2014; Solomon et al., 2018) (Figure 2).

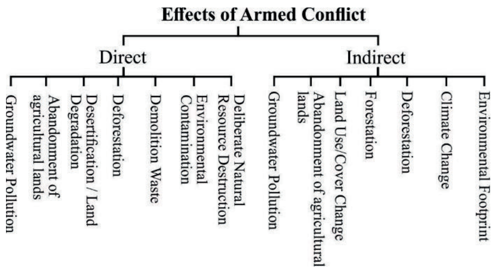

Figure 2. Effects of conflict on environment based on Jha, 2014

Besides and complementing the aforementioned Witmer states that the effects can be categorized into four groups, sorted by the time for which each effect normally requires to be visible. For example, physical damage induced by bomb or fire detonations is often a very immediate impact, which occurs in minutes or hours. Other effects such as environmental damage (hours to days), population forced and unforced movement (days to months) and changing land cover/use (months to years) take more time to materialize. Although there is some overlap between the different effects of the conflict between direct and indirect, this categorization generates a useful way of approaching research (Figure 3).

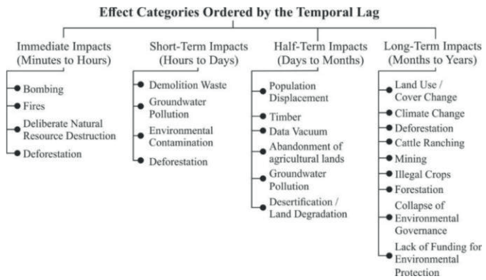

Figure 3. Effects ordered by temporal lag (Source: Witmer, 2015)

Aim

The aim of this paper is to offer an overview of the most important trends in the usage of remote sensing methods as a media of environment affectations assessment in conflict areas. Our study aims to demonstrate the specific correlation between armed conflicts (causes) and environment (consequences) using state-of-the-art remote sensing technology to provide conditioned geo-spatial environmental information. More specifically, this paper presents an integrative and transferable approach for the quantification, systematic comparison, and an evaluation of the remote sensing methods used in areas affected by armed conflicts.
Therefore, this approach not only produces a spatial delimitation and prioritization of armed conflict based on context-specific landscape values, but it also characterizes the underlying drivers of conflict based on the qualitative understanding of affectation indicators. We demonstrate the utility of satellite-based remote sensing techniques for monitoring difficult hard access zones and examining the different links during wartime and post-conflict periods observing modification, repetition and difference patterns in the environment.
The questions motivating this review are:
- How is the relationship between armed conflict causes (indirect and direct drivers) and environmental consequences using remote sensing analysis?

- Which are the direct and indirect consequences that can be analyzed by remote sensing methods?
- Which is the connection between the drivers and satellite imagery sensors and spatial resolution?
- What might the future hold for the remote sensing of armed conflict?

MATERIALS AND METHODS

We reviewed papers published in international peer-reviewed journals that are indexed using Scientific Search Engines as Scopus and Science Direct from 1998 to 2019 (Figure 4).

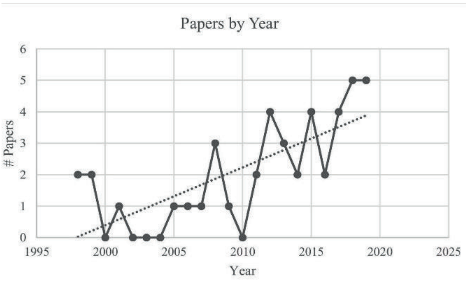

Figure 4. Papers by year

We searched the terms "Remote sensing + Armed Conflict", "Land Use Changes + Armed Conflict" and "Deforestation + Armed Conflict", finding 2554 papers related, after we made a filtered search based on the parameters of indicators (Sensors, Scale, Causes, Consequences, etc.) we depured and analyzed 114 papers deeper, after the second review, we chose 43 documents that fulfilled with all or almost all the information required for the review. The documents retrieved from the various searches were read, evaluated and synthesized in the write-up.
We collected data from 43 research papers that used satellite imagery and aerial photos. We searched data of study area size, armed conflict causes and consequences, types of causes (direct or indirect), forest cover affectation (increase or decrease), time-lapse, data set source (satellite sensor), spatial resolution, conflict period and site focus.
Quantitative analysis of the parameters identified within these areas contributed to an understanding of the reasons behind these affectations and their correlations. The resulting inventory mapping comprises statistics charts, patterns, trends, and findings on the remote sensing and its relationship with armed conflict.
The target of this paper is to review the environmental impacts of armed conflict in the world and where have been studied using remote sensing methods. We found that at least in 21 countries of 4 continents this methods have been used (Afghanistan, Belgium, Bosnia & Herzegovina, Cambodia, Colombia, El Salvador, Kuwait, Liberia, Myanmar, Nicaragua, Pakistan, Republic Democratic of Congo, Rwanda, Sierra Leona, South Sudan, Sri Lanka, Syria, Thailand, Turkey, Uganda, Zambia) (Figures 5 and 6). This was done in the context of a comprehensive review, the process of collecting, appraising, and then synthesizing data from a large number of sources.
The main method for selecting the literature was cumulating research findings across different studies on the same issue which, in our case, was "remote sensing of environmental impacts of armed conflict".

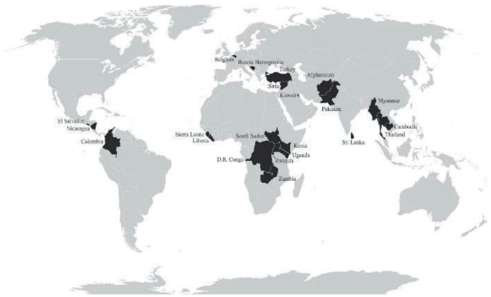

Figure 5. Papers location by country

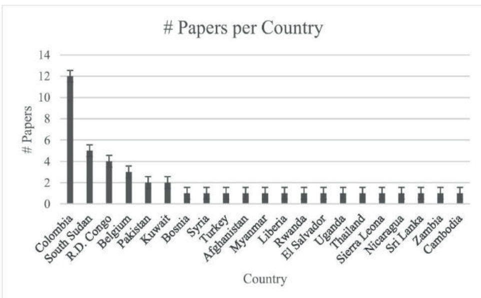

Figure 6. Distribution by country

RESULTS AND DISCUSSION

Geographical results.

The research geographically covered worldwide papers without distinction of latitudes or spatial conditioning, within the search it was found that most of the papers that used remote sensing to analyze the environmental effects in areas affected by armed conflicts, are in areas near the Equatorial line, which in turn are the most highly biodiverse areas of the planet, countries like the Democratic Republic of Congo, South Sudan, and Colombia concentrate almost half of the papers; 21 of the 43 analyzed. Thirteen papers are scattered in small quantities (1 to 3 papers per country) in other tropical areas near the equator, especially in Southeast Asia (Myanmar, Cambodia, Sri Lanka and Thailand), in Sub-Saharan Africa (Rwanda, Liberia, Sierra Leone, Uganda) and in Central America (Nicaragua and El Salvador). On the other hand, nine papers are geographically located in Europe (Bosnia Herzegovina and Belgium) and Western Asia (Syria, Turkey, Afghanistan, and Pakistan), areas where on average the forest cover is lower and the arid, semi-arid or grassland areas are predominant. An exception is made for two research, one in the case of Belgium papers that refer to remote sensing methods using aerial photographs to analyze effects on the landscape during the First World War (Gheyle et al., 2018; Note et al., 2018). And the second is the analysis of the conflict intensity in Arab countries especially in Syria during the Arab revolution (Levin et al., 2018). Some works use remote sensing images to assess the ecological and wildlife consequences of the conflict or to identify populations at risk of conflict, but these lines of research are beyond the scope of this review and therefore were not considered for this investigation.

The outcome yielded by the research were obtained by cross-checking the data between geographical location and the causes of the impact on the environment. These indicate that regarding to direct causes (Bombing, Direct Confrontation/Military Infrastructure and Landmines) the papers that focused on the bombings (10) are spatially located in countries mostly outside the intertropical area such as Belgium and Kuwait (5) and to a lesser extent (3) in Bosnia, Syria and Turkish Kurdistan and few (2) in tropical areas such as Sierra Leone and Cambodia. The papers of direct confrontation and/or military infrastructure (9) were carried out more spread in countries of diverse regions as Colombia and Congo (3) and equally and jointly in Kuwait, Syria, Turkey, Sierra Leone, Cambodia, and Liberia. In terms of the use of remote sensing to analyze the use of landmines and their impact on the environment, there were only two documents on this subject in Sri Lanka and Bosnia-Herzegovina each. In terms of the geographical location of the papers that through satellite image analysis studied the indirect causes, it was found that most of the forced migration was analyzed in African countries (11), Colombia and Central America (4), Southeast Asia (2), Pakistan (2) and Bosnia (1), being the indirect cause, most analyzed. Concerning unforced migration, three documents were found in Africa and one more in Sri Lanka. Mining as an indirect cause has been studied in Colombia (3), Congo (2) and Liberia (1) times. Illicit crops as an indirect cause have been studied by remote sensing mainly in Colombia (5) and to a lesser extent in Afghanistan and Myanmar with one study each. Agriculture as a direct cause has been strongly studied in Colombia (5) and in one study each in Pakistan and Afghanistan, as well as livestock has been an indirect cause of study in Colombia (5) and Afghanistan (1). Finally, logging (2) and fires (1) have only been studied in Colombia through the use of remote sensing (Figure 7).

Subsequently, the literature review found that the geographical location of the papers that through satellite image analysis studied the consequences of the armed conflict on the environment are distributed as follows: deforestation mostly in Colombia (11), Central America (2), Sub-Saharan Africa (12) especially in South Sudan (4) and Congo (3), in Southeast Asia (3) comprising Myanmar, Sri Lanka and Cambodia with one paper each, East Asia; Pakistan (2), Turkey and Afghanistan 1 each, being the most studied consequence (32).

Regarding afforestation as a consequence, only South Sudan (1) and Uganda (1) were analyzed. Desertification and land degradation were studied in South Sudan (2), Liberia (1) and Uganda (1). In terms of land-use change, 24 related documents were found in total, distributed as follows: Colombia (8), Congo (3), South Sudan (2), Liberia (1), Zambia (1), Myanmar (1), Thailand (1), Sri Lanka (1), Pakistan (1), Kuwait (2), Turkey (1), Afghanistan (1) and Bosnia-Herzegovina (1). Mine craters were studied only in Congo (1) and Belgium (2). Regarding military infrastructure as a consequence, they were also studied only in Congo (1) and Belgium (1). The abandonment of agricultural lands was analyzed scattered in Africa (2) Western Asia (2) and Europe (1). Finally, water pollution has been studied only in southern Sudan and Kuwait (1) each, through the use of remote sensing methods (Figure 8).

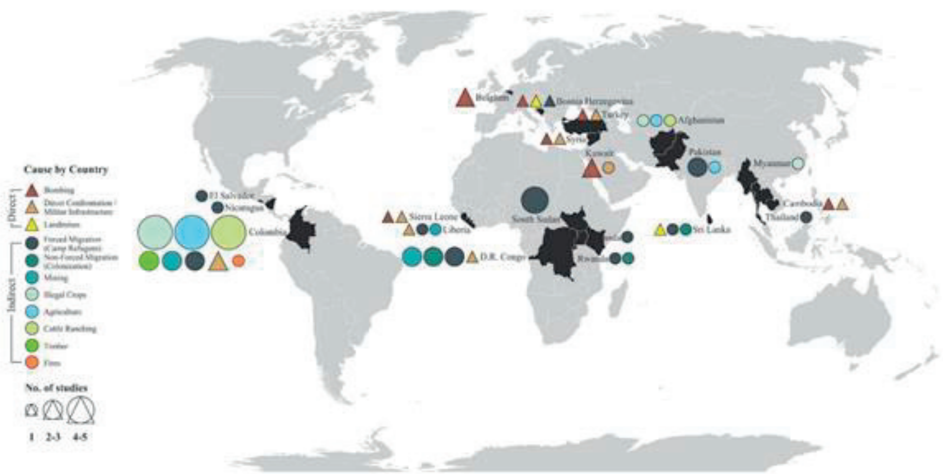

Figure 7. Armed conflict causes analyzed using remote sensing by countries

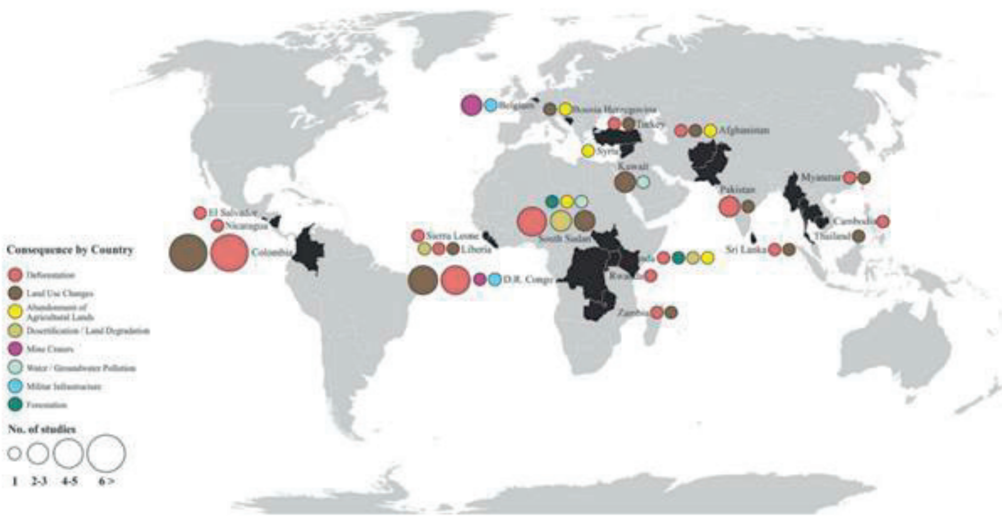

Figure 8. Armed conflict consequences analyzed using remote sensing by countries

Satellite Imagery Results.
Based on the SAGE Remote Sensing Manual classification, we found that 14 papers used Very fine spatial resolution (≤ 1 m) and/or Fine spatial resolution (1-10 m), including SPOT-5 (4), QuickBird (3), IKONOS (3), WorldView-2 (2), GeoEye (1) and ALOS (1) sensors.
Regarding Moderate spatial resolution (10-250 m) we found that is the most times used for Remote Sensing analysis (53), segmented by Landsat 1-5 MSS (3), Landsat 4-5 TM (20), Landsat 7 ETM+ (19), Landsat 8 OLI (6), ASTER (2), Google Earth VHR (1), Sentinel-2 (1) and IRS - LISS-III (1) sensors. Finally, in terms of Coarse spatial resolution (> 250 m), 6 papers used these kinds of sensors; Modis (4), VIIRS (1) and AVHRR (1). It is important to clarify that several papers used more than one sensor to complement the gaps of information that the use of a single sensor can offer, this results in each paper can use satellite images of more than one sensor and makes the statistical study more complex to analyze. It is also important to clarify that aerial photos, Viewit, and RapidEye sensors are not categorized within the SAGE table (Figure 9).

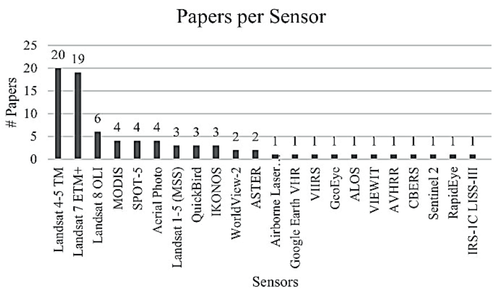

Figure 9. Papers per sensor

Sensors and Causes
In the table of the relation between the analysis of causes generated by armed conflicts and the crossing of data from satellite sensors, we could find that the use of remote sensing is almost five times less for the analysis of direct causes (29) compared to the use of indirect causes (118). In detail and regarding to direct causes (Bombing, Direct Confrontation / Military Infrastructure and Landmines) the Landsat 4-5 TM and Landsat 7 ETM+ moderate spatial resolution sensors are the most commonly used, in five papers for the case of bombing and direct confrontation, it is also worth noting the use of aerial photos for the analysis of bombings (3), ALOS (1) and QuickBird (1).
For the analysis of confrontation and/or military infrastructure, sensors such as Landsat 8 OLI (1), VIIRS (1) were used.
Finally, and to a considerably lesser extent for the analysis of landmines, high-resolution sensors such as QuickBird (1) and moderate resolution Landsat 4-5 TM (1) and Landsat 7 ETM+ (1) were used.
With respect to the indirect causes analyzed by remote sensing, it was found that forced migration was the one that used the most sensors (38), mainly moderate resolution sensors; Landsat 4-5 TM (11), Landsat 7 ETM+ (9), Landsat 8 OLI (3), Landsat 1-5 MMS (2), Google Earth VHR (1). The very high and high-resolution sensors SPOT-5 (2), QuickBird (2) and World View-2 (3). For the analysis of unforced migration, the most used sensors were Landsat 4-5 TM (3) and Landsat 7 ETM+ (4).
For mining moderate and low-resolution sensors were used as Landsat 4-5 TM (2), Landsat 7 ETM+ (6), Landsat 8 OLI (3), ASTER (1), Sentinel-2 (1), CBERS (1) and RapidEye (1). When analyzing illicit crops, the use of very high and high-resolution sensors such as SPOT-5 (1), QuickBird (1), IKONOS (1), GeoEye (1) and ALOS (1) was more noticeable.
Moderate-resolution sensors were also very relevant for the monitoring of illicit crops Landsat 4-5 TM (2), Landsat 7 ETM+ (3), Landsat 8 OLI (1), ASTER (1).
The causes of affectation such as agriculture and livestock were analyzed mainly by Landsat 1-5 MSS (2) Landsat 4-5 TM (7), Landsat 7 ETM+ (10), Landsat 8 OLI (5), ASTER (2), by high resolution sensors; SPOT-5 (1) and GeoEye (2) and by uncategorized sensors such as CBERS (2) and RapidEye (2) times.
Finally, the Landsat 4-5 TM (3) and Landsat 7 ETM+ (3) sensors were used to analyze logging and fires (Table 2).

Table 2. Cause vs Sensor

Cause vs Sensor		Direct			Indirect								
		Bombing	Direct	Landmines	Forced	Non-Forced	Mining	Illegal Crops	Agriculture	Cattle Ranching	Timber	Fires	**Total**
Very fine (≤1m) and Fine (1 - 10m)	SPOT-5				**2**			**1**	**1**				4
	Quick Bird	**1**		**1**	**2**			**1**					5
	IKONOS							**1**					1
	World View-2				**3**	**1**							4
	GeoEye							**1**	**1**	**1**			3
	ALOS							**1**					1
Moderate (10–250 m)	Landsat 1-5 (MSS)				**2**				**1**	**1**	**1**		5
	Landsat 4-5 TM	**5**	**5**	**1**	**11**	**3**	**2**	**2**	**4**	**3**	**2**	**1**	39
	Landsat 7 ETM+	**3**	**4**	**1**	**9**	**4**	**6**	**3**	**6**	**4**	**2**	**1**	43
	Landsat 8 OLI		**1**		**3**	**1**	**3**	**1**	**3**	**2**			14
	ASTER						**1**	**1**	**1**	**1**			4
	Google Earth VHR				**1**	**1**							2
	Sentinel 2						**1**		**1**	**1**			3
Coarse (>250	MODIS				**3**								3
	VIIRS	**1**	**1**										2
	AVHRR				**1**								1
No Category	Aerial Photo	**3**	**1**		**1**								5
	CBERS						**1**		**1**	**1**			3
	Rapid Eye						**1**		**1**	**1**			3
	Airborne Laser Scanning (ALS)	**1**											1
	ESDA							**1**					1
	Total	14	12	3	38	10	15	13	20	15	5	2	

Consequences and sensors.

Crossing the analysis of the consequences of armed conflicts on the environment with the use of satellite sensor data, we could find that the use of remote sensing is strongly focused on the analysis of deforestation (63) and changes in land use (49). In detail and concerning deforestation very fine and fine sensors were used: SPOT-5 (1), QuickBird (2), IKONOS (1), WorldView-2 (1), GeoEye (1) and ALOS (1).

The use of moderate resolution sensors was the highest (42) segmented by; Landsat 1-5 MSS (3) Landsat 4-5 TM (16), Landsat 7 ETM+ (16), Landsat 8 OLI (4), ASTER (2) and Sentinel-2 (1). Low resolution and non-categorized sensors were used in a small proportion to analyze deforestation, MODIS (3), AVHRR (1), Aerial Photos (1), CBERS (1), RapidEye (1), ESDA (1), ViewIt (1) and IRS 1C LISS (1). As for the effects of land-use changes, very fine and fine sensors were used: SPOT-5 (3), QuickBird (2), IKONOS (1), WorldView-2 (2), GeoEye (1) and ALOS (1). The use of moderate resolution sensors was the highest (31) segmented by; Landsat 4-5 TM (11), Landsat 7 ETM+ (10), Landsat 8 OLI (6), ASTER (2), Google Earth VHR (1) and Sentinel-2 (1).

Low resolution and non-categorized sensors were used, but in a small proportion to analyze changes in land use, MODIS (2), AVHRR (1), CBERS (1), RapidEye (1), ESDA (1), ViewIt (1) and IRS 1C LISS (1). As for the other consequences of the armed conflict on the environment, we find that they have been considerably less studied from remote sensing approaches.

In the case of Afforestation, Desertification and Land Degradation, Landsat 4-5 TM (3), Landsat 7 ETM+ (3), MODIS (2), QuickBird (1) were used. For mine craters and military infrastructure, Landsat Landsat 4-5 TM (2), Landsat 7 ETM+ (2) and ALS (1) were the only ones used.

Abandonment of agricultural land is the third most analyzed using various types of sensors such as; Landsat 4-5 TM (3), Landsat 7 ETM+ (2), MODIS (2), QuickBird (1), GeoEye (1) and VIIRS (1) (Table 3).

Table 3. Consequence vs Sensor

Consequence vs Sensor		Deforestation	Forestation	Desertification / Land	Land Use Changes	Mine Craters	Militar Infrastructure	Abandonment of	Groundwater Pollution	**Total**
Very fine (≤1m) and Fine (1 -	SPOT-5	**4**			**3**					7
	QuickBird	**2**		**1**	**2**			**1**	**1**	7
	IKONOS	**1**			**1**					2
	WorldView-2	**1**			**2**					3
	GeoEye	**1**			**1**			**1**		3
	ALOS	**1**			**1**					2
Moderate (10–250 m)	Landsat 1-5 (MSS)	**3**								3
	Landsat 4-5 TM	**16**	**1**	**2**	**11**	**1**	**1**	**3**	**1**	36
	Landsat 7 ETM+	**16**	**1**	**2**	**10**	**1**	**1**	**2**		33
	Landsat 8 OLI	**4**		**1**	**6**					11
	ASTER	**2**			**2**					4
	Google Earth VHR				**1**					1
	Sentinel 2	**1**			**1**					2
Coarse (>250	MODIS	**3**	**1**	**1**	**2**			**1**		8
	VIIRS							**1**		1
	AVHRR	**1**			**1**					2
No Category	Aerial Photo	**2**	**1**	**1**		**1**	**1**	**1**		7
	CBERS	**1**			**1**					2
	RapidEye	**1**			**1**					2
	Airborne Laser Scanning (ALS)					**1**				1
	ESDA	**1**			**1**					2
	VIEWIT	**1**			**1**					2
	IRS 1C LISS	**1**			**1**					2
	Total	63	4	8	49	4	3	10	2	

Relationship between Causes and Consequences

The study showed that the relationship between the causes and consequences of armed conflicts in the environment is complex and varies depending on the social and geographical context of each conflict. In spite of the above, we found some differentiated patterns of repetition. From the investigative approach of remote sensing to analyze each cause and its relationship with the environmental effects generated, we can clearly distinguish that with regarding the direct causes (34) they are three times less than with indirect causes (92). Segmenting the direct causes one by one, the direct confrontation (17) is the one that generates more consequences in the environment; deforestation (7), changes in the use of the soil (5) and only in one paper each in degradation of the soil, craters of mines, abandonment of agricultural lands and groundwater pollution. Another important direct cause is the bombing, which has been mentioned as a cause of deforestation (3), changes in land use (4), mine craters (2), abandonment of agricultural lands (2) and groundwater pollution (1). The use of landmines was found to cause deforestation (1), changes in land use (2) and abandonment of agricultural lands (1) times. In terms of indirect causes that are most often present, it is evident that forced migration is the most recurrent cause at the time of generating effects on the environment; deforestation (16), afforestation (1), desertification (1), changes in land use (11), abandonment of agricultural lands (2) and groundwater pollution (1). Non-forced migration is linked exclusively to deforestation (4) and changes in land use (2). Mining is found as one of the biggest causes of deforestation (5), desertification (1), changes in land use (5) and mine craters (1). Illicit crops are another important cause of changes in the environment distributed as follows: deforestation (7), changes in land use (4) and abandonment of agricultural lands (1). Agriculture and livestock are shown as indirect causes of deforestation (6), (6) and changes in land use (5), (4). Finally, logging and fires are the lowest cause of deforestation (3), (1) generated from armed conflicts and tackled from remote sensing (Tables 4 and 5).

Table 4. Cause vs Consequence

Cause vs Consequence	Direct			Indirect								
	Bombing	Direct Confrontation	Landmines	Forced Migration	Non-Forced Migration	Mining	Illegal Crops	Agriculture	Cattle Ranching	Timber	Fires	**Total**
Deforestation	**3**	**7**	**1**	**16**	**4**	**5**	**7**	**6**	**6**	**3**	**1**	59
Forestation				**1**								1
Desertification / Land Degradation		**1**		**3**		**1**						5
Land Use Changes	**4**	**5**	**2**	**11**	**2**	**5**	**4**	**5**	**4**	**1**		43
Mine Craters	**2**	**1**				**1**						4
Militar Infrastructure	**1**	**1**				**1**						3
Abandonment of agricultural lands	**2**	**1**	**1**	**2**			**1**		**1**			8
Groundwater Pollution	**1**	**1**		**1**								3
Total	13	17	4	34	6	13	12	11	11	4	1	

Table 5. Type of Cause vs Consequence

Type of Cause vs Consequence	Direct	Indirect	Both	**Total**
Deforestation	**2**	**24**	**5**	31
Forestation		**1**		1
Desertification/Land Degradation		**3**		3
Land Use Changes	**3**	**17**	**4**	24
Mine Craters	**2**		**1**	3
Militar Infrastructure	**1**		**1**	2
Abandonment of agricultural lands	**1**	**2**	**1**	4
Groundwater Pollution	**1**	**1**		2
Total	10	48	12	

CONCLUSIONS

The paper covers general aspects of conflict-environment from the remote sensing approach and demonstrated that conflict has extensive negative impacts and just a few positives. The impacts of conflict on environments are diverse and complex, increase mainly deforestation and land-use changes. In social terms and general human well-being, the causes and effects of conflict can be difficult to separate. This can lead to a cycle of conflict in which the detrimental effects of conflict create the conditions for increased violence. Many of these effects (e.g. reduced living standards, hunger, disruption of the economy and the education system) are difficult, if not impossible, to measure through remote sensing images. Thus, while the physical causes and effects of conflicts can easily be intertwined, the studies included here focus on the environmental effects of conflicts. On the other hand, through research we were able to verify that changes in coverage over large areas are more common to detect and quantify through the use of remote sensing methods, mainly consequences such as deforestation, land-use changes and abandonment of agricultural lands, contrasting with changes in coverage in smaller areas and shorter permanence time as military infrastructure, land degradation, craters and groundwater pollution. This is mainly due to the resolution of the available sensors, to the electromagnetic refraction contrast, and to the fact that these effects also require in situ verification, since in these cases the use of remote sensing is not sufficient to produce conclusive results.

Regarding the location of remote sensing studies of causes of armed conflicts, it can be inferred that most of these studies are in intertropical areas, and especially in sub-Saharan Africa and Colombia. The papers of direct causes such as bombings and direct confrontation are distributed mainly in Europe and western Asia since due to the specific conditions of the conflicts in these zones, bombings are more frequent. On the contrary, in the tropical zones of Latin America, Africa, and Southeast Asia, the greatest cause of affectation are indirect causes such as forced and unforced migration, illicit crops, mining, agriculture, and livestock. This can be explained because migrant populations are larger in these zones and require large resources to both moves and settle. In the case of Colombia and Afghanistan, illicit crops are a major factor in deforestation and land-use change. The conclusions on the geographical location of the studies analyzing the consequences of armed conflicts are that deforestation and land-use change are the most predominant effects in tropical areas because their forest cover is greater and often these conflicts occur in nature reserves or rural areas with little or low population especially in the case of Colombia and Central America forcing people to colonize forest areas, while in areas such as western Asia and Europe, the effects are more measured in changes in land use, abandonment of arable land, craters and military infrastructure as deforestation is not predominant in these areas.

The research allowed us to conclude that the relationship between sensors, causes and consequences shows marked trends of which are the most used sensors and why. The trend is that the Landsat 4-5 TM and Landsat 7 ETM+ sensors are by far the most used to analyze all kinds of causes and consequences in all the countries analyzed. This is due to several reasons among which can be found in the good relationship between resolution, number of bands, price, versatility in bands and availability of images. Very high and high-resolution sensors such as SPOT-5, QuickBird, WorldView2, and IKONOS are especially used to monitor indirect causes such as forced migration and illicit crops and consequences such as deforestation and land-use changes. It is due these studies require higher resolution, more constant monitoring but at the same time, the acquisition of these images is more expensive. Finally, we can conclude that low-resolution sensors such as MODIS, VIIRS, and AVHRR were used in very few studies, mainly MODIS to calculate deforestation, land-use changes and abandonment of agricultural lands due to forced migration or bombing. Its low use is because it does not have sufficient resolution, although its acquisition costs are low or free, also an important reason is that several of these satellites have ceased to function and have ceased commercial use in recent years. Given the recent and current peace processes in most of the armed conflicts, it would be especially interesting to continue tracking deforestation, land-use changes and other consequences in those countries. Tracking of year-to-year changes using high-resolution data would be especially useful for correlating specific economic and political conditions with landscape, land use, and deforestation rates and distributions.

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