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War Impacts Studies Using Remote Sensing

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Abstract-*Since 1960, remote sensing satellite imagery reconnaissance has played a significant role in military operations by providing information concerning enemy missiles, troop deployments and military positioning using photographic images from lighter-than-air balloons to aircraft platforms and finally satellite remote sensing imagery with little attention given to broader war impacts. However, besides the war-related uses of such technology, many academic researchers have taken pains to use such advanced technology for examining war impacts. This paper highlights the applications of this technology for detecting war impacts.*
Keywords: *Satellite Imagery, Remote Sensing, War Impacts*

I. INTRODUCTION

A. *Remote sensing technology*

The term "remote sensing," was first used in the United States in 1950 by Ms. Evelyn Pruitt of the U.S. Office of Naval Research. Remote Sensing (RS) is now commonly used to describe the science and art of obtaining information about an object, area, or phenomenon under investigation by a device that records the spectral properties of surface materials on the earth without actually coming into contact [1-2]. Basically, two types of remote sensing instruments are available: passive and active. Passive instruments detect the natural energy that is reflected or emitted from the observed scene whereas active instruments provide their own energy(electromagnetic radiation) to illuminate the object or scene.

Remote sensing from airborne and space-borne platforms provide a huge amount of valuable data about our earth's surface including aerial photographs, satellite images, spatial data set and other data [3]. The increased availability of mid- to fine-resolution satellite imagery since the early 1990s, offers repetitive data that vary among themselves in terms of spatial, radiometric, spectral, temporal resolution and its synoptic view [4]. Also, the digital format makes their data suitable for many computer image processing softwares. All these properties have made remotesense data the main source for various remote sensing applications [5-6-7].

B. *Remote Sensing Applications*

Remote sensing satellite imagery has provided the scientific community with an excellent opportunity to uncover the causes and consequences of land use/land cover changes when compared to the corresponding patterns of human activity [8]. Previous studies have used remote sensing data in many applications, notably in agricultural crop rotation [9], deforestation assessment [10], yield assessment [11], coastal zone changes [12-13], land degradation detection [14], vegetation mapping [15], urban change detection [16] snow cover changes [17], vegetation changes [18-19], burned area mapping [20] and other applications. Recent advances in remote sensing and spatial analysis techniques have availed researchers of powerful tools for studying war impacts.

II. REMOTE SENSING RULE IN STUDYING THE CONFLICTS

Remote sensing satellite imagery has long been utilized to improve the effectiveness of military operations. Since 1960, satellite reconnaissance has played a significant role in providing information concerning enemy missiles, troop deployments and military positioning using photographic images from lighter-than-air balloons to aircraft platforms and finally satellite remote sensing imagery with little attention given to broader war impacts [21]. However, besides the war-related uses of such technology, many academic researchers have taken pains to use such advanced technology for examining war impacts [22].

The uses of satellite imagery in war's impact studies received much public attention during the 1991 Gulf War between Iraq and Kuwait, due to extensive interest in the war's environmental consequences spurred by the massive impacts resulting from vehicle movements, hundreds of oil well fires, and numerous oil lakes [23-24-25]. Since then, numerous researchers have utilized satellite imagery to show war impacts, initially concentrated on the immediate impacts of violence and military action by monitoring villages, urban infrastructure, housing, and urban built environment [26-27]. On the other hand, the mass displacement of local residents; re-vegetation of agricultural areas and construction of new service roads as a result of war lead to changes in land use and land cover which can be detected easily using remote sensing devices [28].

Numerous published studies used a remote sensing approach to examine the effects of war on land cover changes, but primarily paying attention to changes in vegetation health, abandoned agricultural land, agricultural land loss, vegetation land changes, and forest cover [29-30-31-32-33-34-35-36-37-38-39-40-41-42-43]. Among the studies that utilized remote sensing data to analyze the war's effects by monitoring land cover changes are Suthakar and Bui (2008)applied post-classification method and GeographicalInformationSystems to monitor land use/land cover changes in the Jaffna Peninsula, northern Sri Lanka over the two decades from 1984 to early 2004. Over this period, the Jaffna Peninsula has been impacted severely by armed conflict. Results indicate that the land use/land cover pattern has been very dynamic since the early 1980s, showing a remarkable decrease in agricultural land use and concomitant increase in non-agricultural land use. The ethnic conflict and its consequences, particularly large-scale population migrations, have been the main driving force for such land use/land cover [44]. Witmer in 2008, applied Landsat Thematic Mapper data and Quickbird imagery to study the effects of war on land use/land cover change in northeast Bosnia. Three change detection methods,namely; the multivariate alteration detection transformation, simple algebraic differencing, and supervised classificationtechniques were evaluated for their effectiveness in detecting LULC changes. The results of these analyses show that wars have a negative effect on abandoned agricultural land [36]. Maathuis in 2003, made a study of land cover changes and identified construction of service roads along minefields, vegetation removal from minefield perimeters, and vegetation regeneration of mined agricultural areas and mapped minefields using remotely sensed data in Zimbabwe [28].

In terms of assessing the war's damage caused to the environment, remote sensing data have shown the ability in detecting and indicating the impact of war on the environment For example, Veerabuthiran in 2011 used the LIDAR data for detection of biological warfare agents and toxic gases in the atmosphere [58]. Reuveny in 2010showed in his study the effects of warfare on the environment [59].

Recently, remote sensing satellite imageries have received attention from the Human Rights Watch organization and thus led to the highlighting of other new applications of satellite imagery on war impacts. In a unique study conducted by Witmer and O'Loughlin, thenighttime light imagery from the Defense Meteorological Satellite Program (DMSP) Operational Line-scan System (DMSP-OLS) satellite data were used to detect the effects of war in the Caucasus region of Russia and Georgia. The results showed that conflict-related events such as large fires that burn for weeks and large refugee movements are possible to detect, even with the relatively coarse spatial resolution (2.7 km) of the DMSP-OLS imagery [30]. Fine resolution satellite imagery such as IKONOS panchromatic (1m) and JERS (5-10m) has been used to count refugee tents to estimate populations at risk [45] and locate hidden water sources to site refugee camps for Sudanese in eastern Chad [46]. The Quickbird imagery (60cm resolution) from 2002 and 2006 was used to document the repressive actions of the Zimbabwean government in the destruction of dwellings [47].

Furthermore, WorldView-1 and Formosat-2 satellite imagery (http://unosat.web.cern.ch/unosat/)showed burning and destroyed homes after the August 2008 fighting during the ethnic cleansing of ethnic Georgian villages in South Ossetia. The humanitarian use of satellite data is for finding displaced persons fleeing conflict zones and relocating them to large refugee camps, where international assistance can be more easily administered and accessed. For this purpose, remote sensing, which has been increasingly used to monitor the spatial extent of these camps for more efficient aid management, population estimates, and impacts to adjacent forests [43-48-49].

III. WAR IMPACT STUDIES IN IRAQ

During the last thirty years of the 20th century, Iraq in particular has been deeply and disproportionately affected by several conflicts, from the Iran-Iraq War,, the Gulf War and the initial campaign of Operation Iraqi Freedom (OIF), to economic warfare in the form of comprehensive United Nations (UN) sanctions, to the long-term occupation and reconstruction of OIF, and post invasion [56]. In spite of these many wars that Iraq has been involved in, very few researches have been carried out to demonstrate the capacity of remote sensing in showing the effects of these wars. The Gulf War between Iraq and Kuwait, was one of the first large scale environmental disasters that was closely monitored by remote sensing technology such as multiple sensors from relatively coarse AVHRR imagery to finer spatial resolution Landsat and SPOT data, which were used to map, evaluate, and monitor changes dealing with urban development, vegetation, coastal wetlands, and sand sheet surface differences and to document the effects of the 1991 Gulf War in terms of oil lakes, oil spills, burning oil wells and military vehicle movements [23-24-39-50-51-52]. Further analyses were also used to identify the distribution of burning wells in different oilfields and produced estimates of flow rates and emissions of gaseous pollutants and particulates by incorporating the different spatial and temporal resolutions of AVHRR, Meteosat, Landsat Thematic Mapper, and SPOT data [50-54].

Remote sensing satellites were used to document the war's impact on the environment in Iraq. Multi-spectral imagery of Landsat and IKONOS was applied by UNEP in 2003 to show the effects of the oil trench fires on the environment around Baghdad in March 2003 at the start of the second US-Iraq conflict [60]. Xian in 2006 introduced in his study, the ability of two kinds of meteorological satellite data, geostationary orbit

satellite and polar orbit satellite (FY-1C/LDPT) data and the Metosate-5 images to analyze the huge dust storm that happened in the middle of the Arabian Peninsula from 25-27 March 2003, in the course of the Iraq war, which shows that weather condition is one of the important parameters in Modern warfare [54]. Koch in 1998, used multi-source and multi-scale data derived from satellite images, land form/surface maps, and field observations to identify and characterize changes in the desert surface of Kuwait resulting from military activities during and after the Gulf War of 1991 by applying geographic information system (GIS) techniques. These changes produce alterations to the surface sediment and morphological features that lead to environmental degradation [55].

Besides this, remote sensing data also offer unrivaled utility in detection, monitoring and quantifying the changes in land use and land cover in Iraq. Gibson in 2012 used time-series Landsat TM and ETM+ imagery to create multi-temporal normalized difference vegetation index (NDVI) data to identify and quantify changes in agricultural land use and compare cultivated area and abandoned land as an effect of war in central Iraq during four conflicts (Iran-Iraq War from 1980 to 1988, Gulf War from 1990 to 1991, UN Sanctions from 1990 to 2003, and Operation Iraqi Freedom from 2003 to 2011) [56]. UNEP (2010) used decision tree analysis to classify multi-temporal Landsat TM and ETM+ imagery to monitor the cultivated area in central Iraq, during three decades of war. Brasington in 2002 applied satellite imagery as well to document the effects of war on the Mesopotamian Marshlands in the southern part of Iraq [61].Also, the effect of war on land vegetative cover in Saudi Arabia was studied due to the second Gulf War [57].

IV. CONCLUSION

Remote sensing technology will continue to be an important resource for a growing body of research using remote sensing imagery to study war and its effects and observing its effect on land cover in current and future conflict and war regions. However, from the previous studies, remote sensing instruments are still surprisingly limited to study war and conflict impacts and still the ability of satellite imagery for detecting war impacts such as: bullet-pocked walls, abandoned buildings and individual mines are limited and difficult due to spatial, spectral and temporal characteristics of the data. Further studies are neededto look at new applications of remote sensing in war impacts studies.

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