WAR AND AGRICULTURE: THREE DECADES OF CROPLAND LAND COVER CHANGE IN CENTRAL IRAQ

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ABSTRACT

War and institutional changes are important drivers of land use and land cover change, and agricultural regions are the most susceptible to those types of changes. Though agriculture has been a vital component of Iraq's economy, there is limited information on the effects of war, sanctions, and instability on agricultural land use. This research sought to determine if the effects of three decades of war in Iraq are observable in terms of cultivated area using Landsat TM and ETM+ imagery for a single scene near Baghdad. We created multitemporal features of NDVI to determine cultivated area during different periods of conflict and then compared those areas to determine which period experienced the greatest amount of change. The results showed that little change occurred between the Iran-Iraq War, an inter-war period, and initially following the Gulf War; however, cultivated area increased by 68% during the period of UN sanctions.

Keywords: Iraq, War, Sanctions, Agriculture, Landsat

INTRODUCTION

War and institutional changes are important drivers of land use and land cover change, and agricultural regions are the most susceptible to those types of changes (de Beurs and Henebry, 2004; de Beurs and Henebry, 2008). Iraq has a long history of agriculture and war, with the last thirty years almost continuously in conflict (Table 1). However, little has been published about the effects of war, sanctions and political instability on agricultural land use in Iraq, with the exception of Congressional Reports (Schnepf, 2003; Schnepf, 2004). United Nations Food and Agricultural Organization (FAO) and US Foreign Agriculture Service (FAS) statistics are often cited, but these figures are national totals and are often only estimates for many years in Iraq. Even officially reported figures can be incomplete. For example, historical statistics were recently revised to include three northern Kurdish regions that were previously excluded from 1987 to 2007 (US AID, 2008).

Table 1. Periods of Conflict in Iraq since 1980

Iran-Iraq War	September 1980 to August 1988
Gulf War	August 1990 to February 1991
UN Sanctions	August 1990 to May 2003
Iraq War	March 2003 to Present

Satellite image analysis shows improving potential to analyze land use/ land cover change of the agricultural sector, especially where reliable census data are unavailable (Dannenberg and Kuemmerle, 2010). Analyzing land use patterns using satellite images allows the inclusion of a spatial dimension that census based studies lack (Evans et al., 2002; Kuemmerle et al., 2008; Dannenberg and Kuemmerle, 2010). Plus, freely available long image time series have been proven to be effective for monitoring land cover changes caused by conflict and war (de Beurs and Henebry, 2008).

We sought to determine if the effects of three decades of war in Iraq are observable in terms of cultivated area using Landsat TM and ETM+ imagery for a single scene near Baghdad, and to identify which period of conflict experienced the greatest change in cultivated area.

STUDY AREA

Before the development of the oil industry, agriculture was Iraq's primary economic sector (Tripp, 2007). Now the second largest economic sector, agriculture is still the country's largest employer (US AID, 2006). Approximately 78% of Iraq's total surface area is not viable for agricultural use due to the harsh climate and poor soils; the remaining 22% is currently involved in agricultural activities (Schnepf, 2004; UN FAO, 2010). Half of that is marginal and used for seasonal grazing, while the other half, about 4 million ha, is under cultivation (Schnepf, 2004; USDA FAS, 2010). It is estimated that over 9 million ha could be used for crop production (Schnepf, 2004). Rain-fed agriculture is possible in the north, but irrigated agriculture is common in the fertile valleys of the Tigris and Euphrates Rivers (Schnepf, 2004). There is little agricultural activity in the western desert regions (Ahmad, 2002). Cereal production makes up about 70 to 85% of Iraq's cultivated land, two-thirds in the irrigated zones of central Iraq (Schnepf, 2003). Winter crops, like winter wheat and barley, are typically planted between September and November and harvested between May and June, and irrigated summer crops are typically planted between April and May and harvested in August and September (Schnepf, 2003).

Most of Iraq's climate is dry and extremely hot with short, cool winters (Spencer, 2007). Precipitation is low, less than 250 mm annually and rare during the summer months, except in the cooler north (NCDC, 2010). Over 90% of Iraq's precipitation occurs between November and April (Schnepf, 2004). Between May and October, high temperatures and dry winds lead to high evaporation rates (Mahdi, 2000).

Iraq has low crop yields by international standards (US AID, 2006). Many factors are involved. Farmers have had to rely on low quality farm-saved seed as seed improvement programs have repeatedly broken down over the last three decades (US AID, 2006). However, the primary limiting factors are high summer temperatures, water availability, and soil salinity (Schnepf, 2004). The high soil salinity was caused by years of improper irrigation and poor drainage (US AID, 2006). The greatest environmental threats facing Iraq are soil salinization and desertification, both of which can be aggravated by increased agricultural use and abandonment (Beaumont, 1996; Williams, 1999; Zaitchik et al., 2002; Haktanir et al., 2002).

A single Landsat scene was chosen for this research (path 169, row 037). It is centered at approximately 33.1 N and 44.3 E and includes most of Baghdad and a large area to its southwest (Figure 1). According to the MODIS Land Cover Product 2005 (http://daac.ornl.gov), the scene is mostly barren or sparsely vegetated (72%), croplands (11%), water (8%), open shrublands (5%), and urban and built-up (3%). Other land cover types make up approximately one percent of land cover. Irrigated agriculture predominates in this area. This scene was chosen because it has little natural vegetation and has higher temporal coverage than other scenes with similar land covers.

DATA AND METHODS

We chose to use the Landsat family of sensors because it has imagery dating back to the early 1980s and is freely available. Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) have suitable spatial resolution (30m) for our analysis and have been used for decades in this type of research. However, the temporal resolution of Landsat did pose some challenges. Cloud free scenes were not available for months during some years. There were several years in the mid-1990s that did not have a single image of Iraq. Also, with the scan line corrector (SLC) malfunction of Landsat 7, portions of some scenes are excluded (SLC-off images were not used in this research). All of these factors combined to make a season to season or year to year study impractical. Therefore, it was important to use a methodology that could account for years when fields were left fallow, or experienced early or late green-ups or harvests, or suffered from drought conditions, etc.

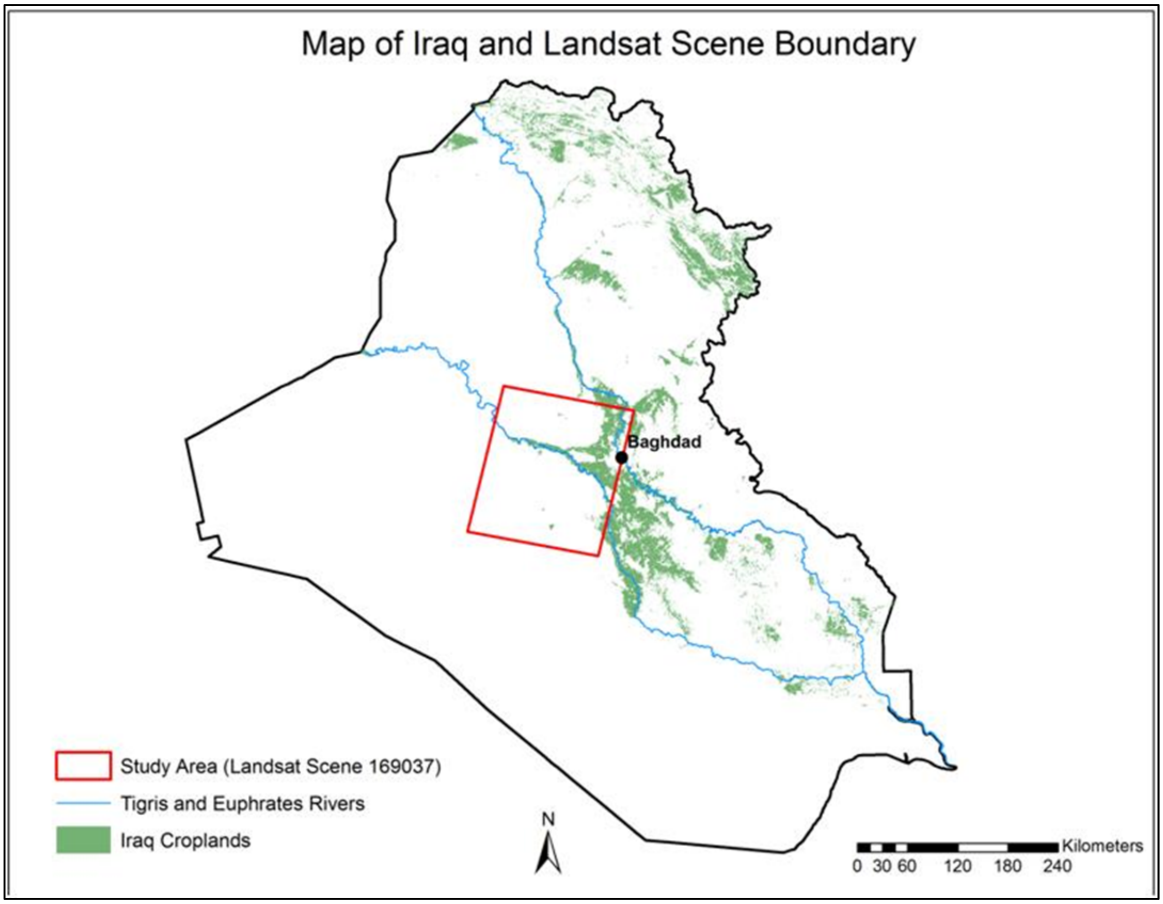

Figure 1. Location of Landsat scene used for this project.

We adopted methods used by Lenney et al. (1996). In these methods, several scenes are collected over many years and seasons and converted into normalized difference vegetation index (NDVI). The NDVI rasters are combined to create one raster layer of maximum NDVI values for each pixel and one raster layer of the range of NDVI values for each pixel. Pixels with both high max NDVI values and a broad range of NDVI values are classified as cultivated with the assumption that at least at one time during that period they were used for agriculture. The final step was to compare the number of pixels identified as cultivated for each period.

To determine which dates of imagery would be most appropriate for our methods, we studied the phenology of the scene using ten years of MODIS NDVI data (2001 through 2010). This multistep process created one thousand random points within the scene using ArcGIS, then reducing that number to only 30 points that could be positively identified as agricultural fields in higher resolution imagery. Next, we extracted MODIS NDVI values to those points for all 230 16-day composites between 2001 and 2010. The values were entered into an Excel spreadsheet that was used to create phenological charts like the one in Figure 2. Based on this curve, images dated between June 25th and August 12th were used as days when the majority of fields would be barren, and images dated between February 18th and April 6th were used for days when they would be "green." A second "green" period spanning late-fall/early-winter was excluded from our analysis because the majority of the available images were cloud-covered. Table 2 lists the dates of imagery used for each period. The phenological charts also allowed us to set thresholds that would define what we would consider high max NDVI values and a broad range of NDVI values. We decided that pixels with greater than 0.4 NDVI would be classified as high, and pixels with greater than a 0.2 range would be classified as having a broad range of NDVI values.

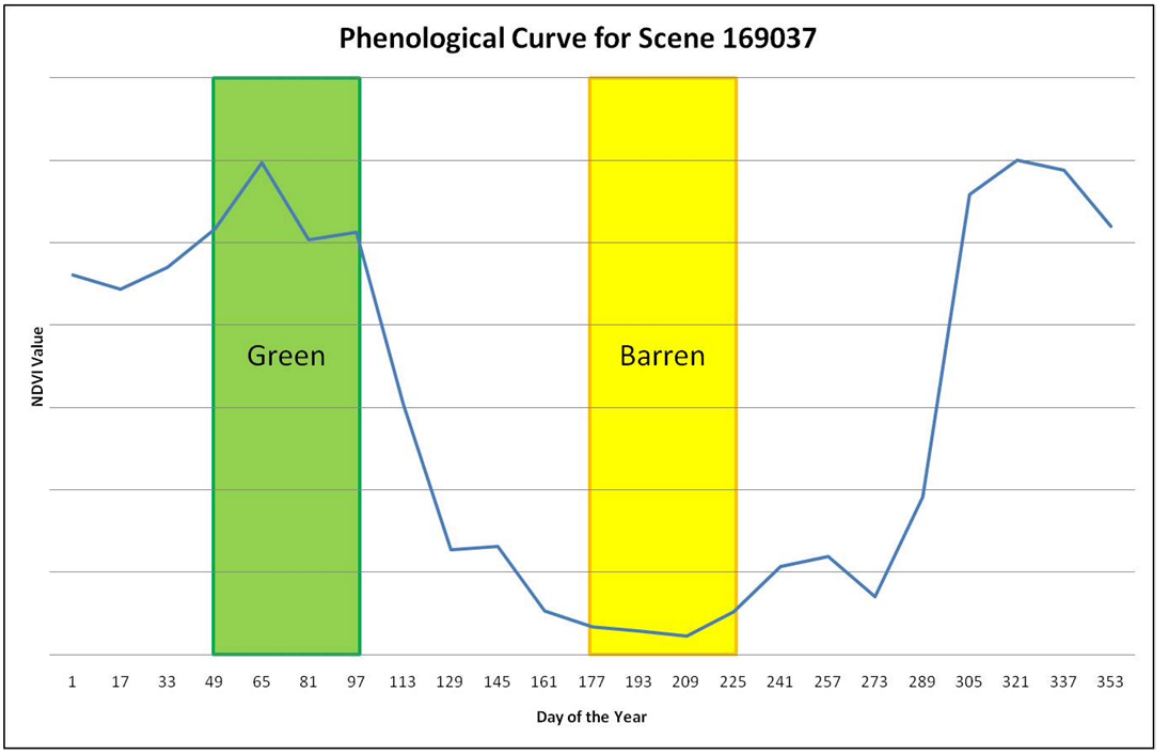

Figure 2. Phenological curve used to select dates of imagery.

Table 2. Landsat Dates

Late Iran-Iraq War	Inter-War Period	Gulf War & Early Sanctions	Late Sanctions
July 17, 1984	July 7, 1989	February 28, 1991	March 5, 1999
March 30, 1985	March 20, 1990	March 7, 1991	July 3, 1999
March 20, 1987	March 28, 1990	July 31, 1992	March 5, 2002
August 11, 1987	July 10, 1990	August 8, 1992	July 11, 2002

We downloaded the Landsat imagery from the Global Visualization Viewer (http://glovis.usgs.gov). The images were preprocessed using the Level 1 Product Generation System and received Level 1T Standard Terrain Correction, which provides systematic radiometric and geometric accuracy by incorporating ground control points while employing a digital elevation model for topographic accuracy. We used the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) to correct each image to directional surface reflectance. In this process, Landsat digital numbers are calibrated to at-sensor radiance and atmospherically corrected to surface reflectance using the 6S approach (Masek et al., 2006). The output also includes a quality assurance layer that was used to mask pixels that were cloud covered or shadowed by clouds.

After the images were processed they were grouped into periods. Within groups, the images were combined using the Mosaic to New Raster tool in ArcGIS. We created a raster layer of Max NDVI using the Maximum Mosaic Method. We created a raster layer of Range of NDVI using the Minimum Mosaic Method and subtracting the output from the Maximum. The Max NDVI raster was reclassified so that pixels with greater than 0.4 NDVI were given a value of 1 and all others a value of 0. The Range NDVI raster was reclassified so that pixels with greater than 0.2 range of NDVI were given a value of 1 and all others a value of 0. The two reclassified layers were multiplied so that only pixels with both a high max and broad range of NDVI would have a value of 1. We multiplied the pixel count by the cell area and converted the result into hectares.

For validation, we created 50 random points that were identified as "cultivated" during the period of Late Sanctions and visually confirmed that all were agricultural fields in higher resolution imagery for that same period. The higher resolution imagery was accessed via the National Geospatial-Intelligence Agency's Web-based Access and Retrieval Portal. Sensors used include Ikonos and Quickbird. This validation method had its limitations though because it was impossible to tell if there was an actual crop growing in the field. Rather, the validation shows that our methods did not classify a pixel as cultivated when it was in fact only open shrubland, urban, water, etc. Therefore, we are confident that our methods were successful in identifying croplands that were cultivated during the period.

RESULTS AND DISCUSSION

Little change occurred between the Iran-Iraq War, an inter-war period, and initially following the Gulf War; however, cultivated area increased by 68% during the period of United Nations (UN) sanctions (Figure 3). The following discussion explains the connection between war and agriculture in Iraq and what led to the extensification of agriculture during the sanctions.

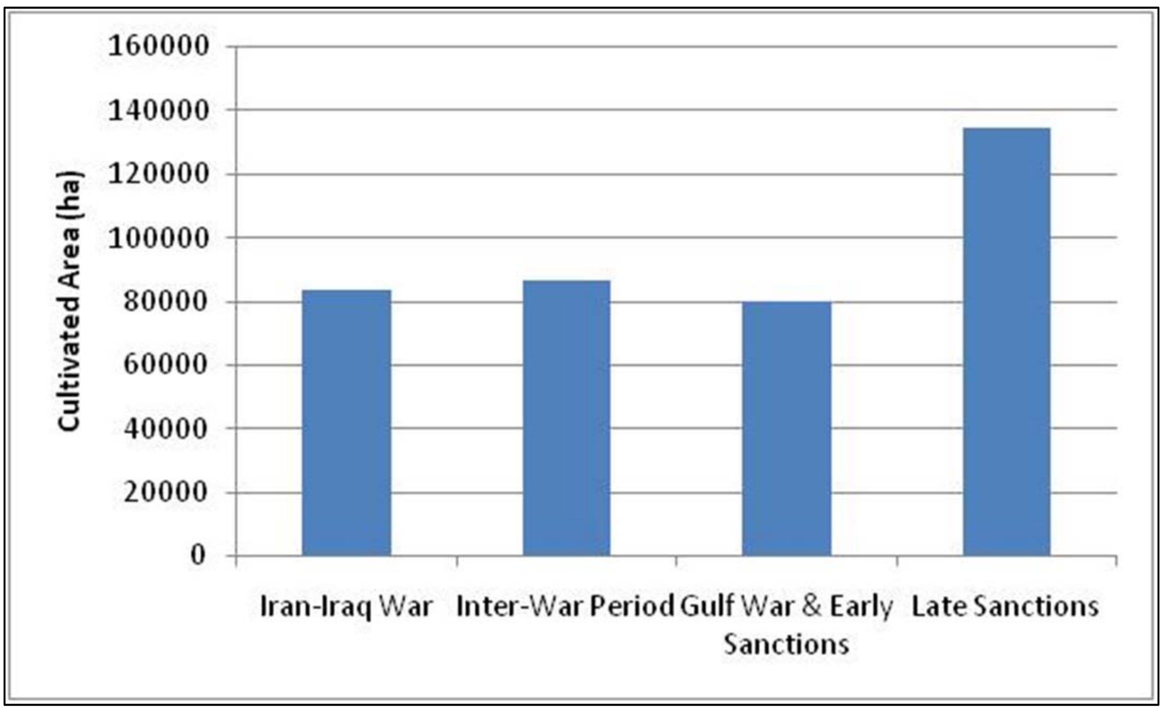

Figure 4. Bar chart showing cultivated area for each period.

In 1979 Saddam Hussein took power as President of the Republic of Iraq. Early in Hussein's reign, his government attempted to return control of Iraq's agricultural sector to private control and investment after years of failing government policies (Springborg, 1986; Schnepf, 2003). Shortly after taking power, Hussein invaded Iraq's eastern neighbor Iran, citing numerous border disputes, though most historians believe that his true motive was to establish Iraq as the dominate power in the region following the Iranian Revolution (Tripp, 2007). The Iran-Iraq War lasted from September 1980 to August 1988, with both countries suffering military invasions from the other. Harvested area and production expanded during the 1980s for most crops, despite the diversion of labor and resources towards the war effort; however, Iraq's reliance on food imports also continued to grow, mostly from the US (Schnepf, 2003; UN FAO, 2010). The economic impact of the Iran-Iraq War was significant, resulting in delays on foreign loans, defaults to foreign contractors, and postponement of development projects, except for those vital for agricultural production (Spencer, 2007).

Iraq's enormous debt following the Iran-Iraq War is often cited as one of the reasons for its invasion of Kuwait in August of 1990 (Tripp, 2007). Not much is written about the time period between the end of the Iran-Iraq War and Iraq's invasion of Kuwait, but it appears that harvested area was not significantly different from that between 1980 and 1988 (UN FAO, 2010; USDA FAS, 2010), indicating perhaps that similar agricultural practices and policies existed. However, that changed in August 1990 when the UN Security Council adopted Resolution 661 imposing comprehensive sanctions against Iraq (Russett et al., 2006). Sanctions failed to compel Hussein to withdraw from Kuwait as he became determined to survive them as he and his regime had survived the Iran-Iraq War (Freedman and Karsh, 1995; Haass, 1997; Tripp, 2007).

The Gulf War was a brief war (August 1990 to February 1991) executed by a multinational force authorized by the UN and led by the US to expel Iraq from Kuwait. The military engagement began with an aerial bombing campaign designed to first attack Iraq's leadership, key production, infrastructure, population, and fielded military forces, in that order (Reynolds, 1995). Within a few short weeks, Iraq suffered extensive damage and destruction of its economic infrastructure, more so than during all eight years of its war with Iran (Tripp, 2007). The bombing destroyed electrical grids, roads and bridges, sewage and water-purification systems, oil refineries, factories and other industries (Spencer, 2007). Schnepf (2003) mentions anecdotal evidence that even Iraq's irrigation infrastructure suffered significant damage. A limited ground campaign followed the aerial bombardment, encountering little resistance, but stopped short of deposing Hussein and his regime.

After he was expelled from Kuwait, Hussein continued to defy UN demands, resulting in continued and even stricter sanctions. Foreign companies were prohibited from investing directly in Iraq. Iraqi oil exports were cutoff, affecting revenues needed to purchase foodstuffs and agricultural inputs (Schnepf, 2003). While food imports were not banned, many agricultural products considered "dual use" were, like fertilizers, agricultural machinery, pesticides, chemicals, and parts that could have been used to repair damaged water-purification systems (Tripp, 2007). In the absence of food imports which the country had become reliant on, there was growing pressure for Iraqis to increase domestic agricultural production. Intensfication—an increase in productivity from increased inputs to land already under cultivation (Wood et al., 2004)—was not possible due to the sanctions. The only alternative was extensification—the horizontal expansion of agriculture into previously non-cultivated lands (Elnagheeb and Bromley, 1994). The Hussein regime became more heavily involved with agricultural production, creating incentives for farmers to expand crop area and punishments (including death) for farmers who failed to deliver their quotas to state collection centers (Schnepf, 2003). Extensification was not enough to support natural needs. The Iraqi people suffered terribly—the monthly death toll from malnutrition-related illnesses averaged 5750 by the mid-1990s (Spencer, 2007). Hussein initially refused the Oil for Food Program resolution in 1991, but in 1996 he agreed to its terms. Despite their ineffectiveness and the civilian casualties attributed to the sanctions, they were renewed every six months until after the US invasion of Iraq in 2003 (Spencer, 2007).

The period of the Iraq War could not be included due to the unavailability of Landsat 5 TM or 7 ETM+ (SLC-on) imagery for the selected scene. Regardless, by 2003, the country's agricultural sector remained plagued by effects of prior wars, sanctions, and political instability (Schnepf, 2004). Iraq's irrigation infrastructure was barely functioning, prime cropland suffered from widespread salinization, and soil fertility had been badly depleted from overexploitation (Schnepf, 2003). The opening "Shock and Awe" aerial bombardment campaign of the Iraq War in March of 2003 greatly resembled the Gulf War, but with greater precision and a near simultaneous ground invasion. The Hussein regime fell quickly. Since that initial campaign, the US has led other countries in sustainment and stability operations in Iraq in an effort to increase political stability while rebuilding continues. Food imports resumed almost immediately, and many aid organizations have been investing in Iraq's agricultural sector (US AID, 2006). Despite its strong agricultural heritage, decades of war, sanctions, and political instability have left the country unable to provide for its domestic market.

CONCLUSION

Our research demonstrated that Landsat TM and ETM+ (SLC-on) imagery can be used to identify and compare changes in agricultural land use in Iraq as an effect of war. Key steps were to identify what dates of imagery would provide the needed information and to use a methodology that could account for early or late green-ups and harvests, years that fields were left fallow, and crop rotations. The results showed that the UN sanctions had a greater impact on the amount of land used for cultivation than the Iran-Iraq War, an interwar period, and initially following the Gulf War.

Agriculture is still Iraq's largest employer and can be effective for "promoting stability through private sector development, poverty reduction, and food security" (US AID, 2006). As the political situation in Iraq stabilizes, it will become increasingly important to monitor changes in land cover and assess agriculture performance and growth, and a baseline study is critical to monitor current conditions and assess future changes (de Beurs and Henebry, 2008). This study provides an important baseline overview for this area.

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