Environmental Impact of Genocide in Guatemala: the Ixil Triangle and the Mexican Border

GSP Working Paper No. 31

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The Research Locations

Research Location 1 of the GSP's study of satellite imagery of the Guatemalan genocide is the area containing the "Ixil Triangle" (Figure 1) situated in the central sector of the Department of El Quiché. The three municipalities of Santa Maria Nebaj, San Gaspar Chajul, and San Juan Cotzal demarcate the triangle's vertices (Figure 4). The municipality of Santa Maria Nebaj represents the Location 1 sub-region of study contained within the Ixil Triangle.

Nebaj: Lat./Lon. Decimal Degrees 15.41 N, 91.15 W

Research Location 2 encompasses an area on the border of Chiapas, Mexico and Guatemala between the Río Salinas and Río Lacaniúm (Figure 1). Characterized by a riverine, low-elevation agricultural district, Location 2 contained border refugee camps, which experienced considerable growth during the period from 1979 to 1986 and increased violence in El Quiché. Location 2 includes the sub-regions Locations 3 and 4 (Figure 13).

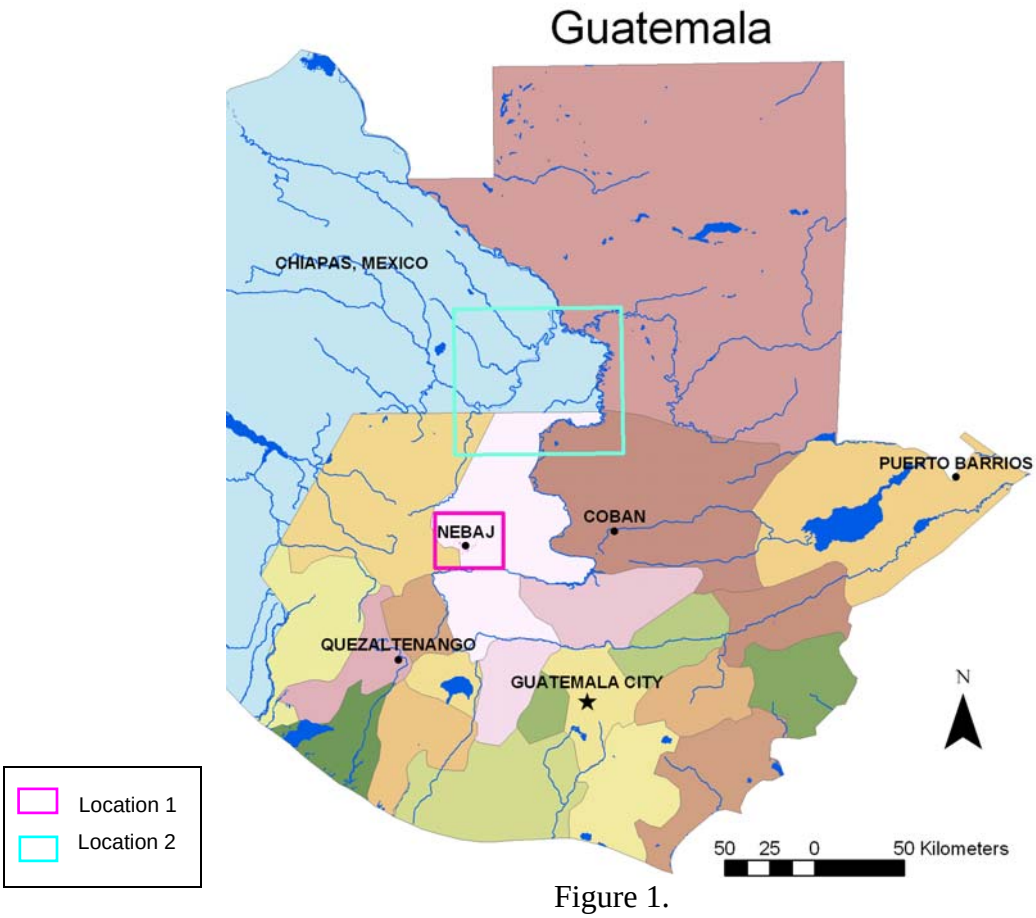

Figure 1.

The Satellite Images*

Coordinate System & Projection:

WRS 1	Path 21	Row 49
WRS 2	Path 20	Row 49
UTM Zones	15N, 16N	WGS 1984

Satellite Images:

Landsat MSS	Acquisition Date: February 6, 1979
Landsat MSS	Acquisition Date: March 13, 1986
Landsat TM	Acquisition Date: March 13, 1986
Landsat ETM+	Acquisition Date: January 23, 2000

The spatial resolution for the Landsat MSS images is 57 m, and Landsat TM and ETM+ images 30 m. For the ETM+ images, by using the panchromatic band, the spatial resolution can be reduced to 15 m for viewing purposes only.

*For more information about GIS (Geographical Information Systems), Remote Sensing, and Satellite Images, see "An Introduction to Remote Sensing & GIS," http://www.yale.edu/gsp/gis_files/remote_sensing_intro.pdf.

Introduction

Location 1 of the GSP's study of satellite imagery of the Guatemalan genocide is the area containing the "Ixil Triangle," in the central sector of the Department of El Quiché. Guatemala's Maya Indians population is primarily concentrated here and in other parts of the country's mountainous northwest, while Ladinos occupy the lower and more agriculturally productive south and east portions of Guatemala. The three municipalities of Santa Maria Nebaj, San Gaspar Chajul, and San Juan Cotzal demarcate the triangle's vertices (Figure 4). The central sector of El Quiché is the historical home of Guatemala's Ixil Indians, a relatively isolated, ruggedly mountainous region. Between 1977 and 1986, the El Quiché's population was approximately 80 to 100 percent Mayan. During the government-sponsored Guatemalan genocide from 1981-83, El Quiché experienced some of the highest frequencies and magnitudes of killings. The data contained in Figure 2 were collected and archived by the American Association for the Advancement of Science (AAAS) and the International Center for Human Rights Research (CIIDH). These data document over 40,000 killings and disappearances in Guatemala between 1960 and 1996. These graphs use a subset of this data spanning the ten-year period of 1977 to 1986. Other estimates of numbers of overall killings and disappearances range from 80,000 to 400,000.[1]

Implementation of President Efrain Ríos Montt's "scorched earth" strategy brought the violence to a peak in 1982-1983. During this period, the military systematically destroyed virtually all of the rural settlements surrounding the municipalities of Santa Maria Nebaj, San Gaspar Chajul, and San Juan Cotzal. In late 1983, the army launched its program of Development Pole villages. A development pole was a decentralized regional development zone. Villages, previously located on hillsides with each house surrounded by its own varied-sized lot, are now laid out in a concentrated, rectilinear grid pattern.[1]

[1] Manz, Beatriz, *Refugees of a Hidden War: The Aftermath of Counterinsurgency in Guatemala*. Albany, NY: State University of New York Press, 1988.

These "Model Villages" were an important part of its "guns and beans" (*fusiles y frijoles*) counterinsurgency program. Villagers displaced by the violence and still surviving in the area of their former residences were forced to live in concentrated model villages.[2] Changes to the countryside included: the consolidation of a well-- distributed population living in small settlements spread throughout a heavily-wooded countryside accessible primarily by small footpaths, into a few, tightly-controlled, more urban centers. Roads were built and well-maintained allowing greater mobility for government and military vehicles. The heavily-wooded areas along the roadsides disappeared. Finally, overuse of available land, erosion, and continued deforestation further lowered agricultural production and sped up environmental deterioration.[3] In the municipality of Nebaj, eleven villages and ninety-one hamlets have been reduced to approximately eight settlements or model villages. Acul, Tzalbal, Pulay, Ojo de Agua, Salquil Grande, San Felipe Chenlá, and Bichibalá all form part of the Ixil Triangle development pole.

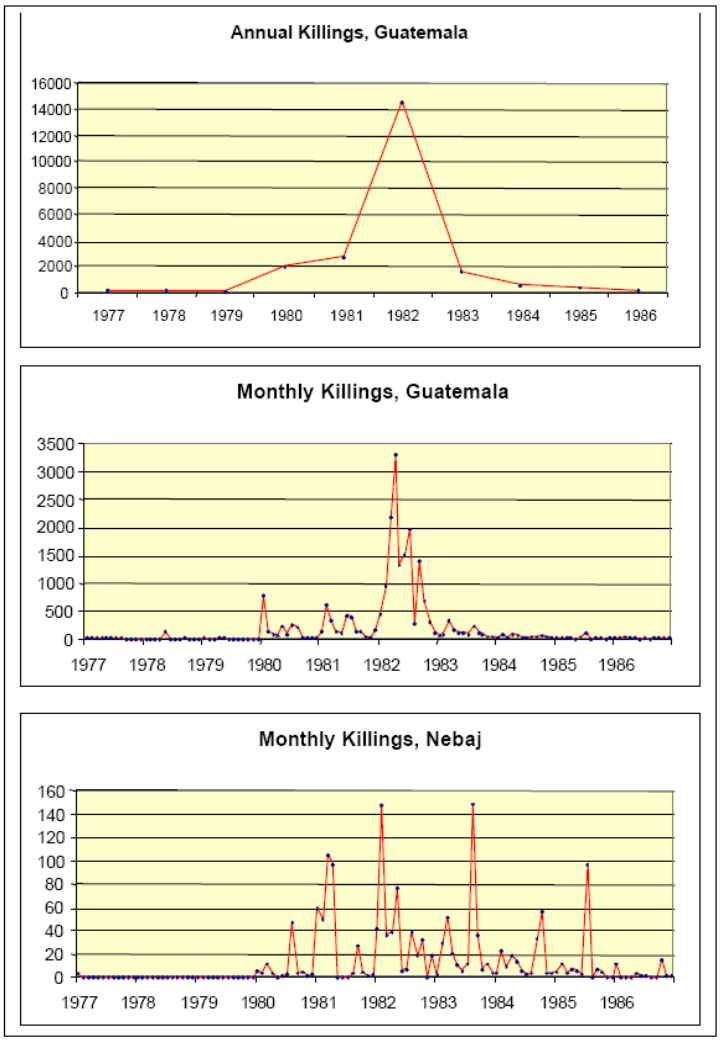

Figure 2. Time Series Graphs: Annual, Monthly, and Monthly for Nebaj[4]

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[2] Manz, Beatriz, *Refugees of a Hidden War: The Aftermath of Counterinsurgency in Guatemala*. Albany, NY: State University of New York Press, 1988.

[3] Ibid.

[4] Gulden, Timothy, R., *Spatial and Temporal Patterns in Civil Violence: Guatemala 1977-1986*. Center on Social and Economic Dynamics, Working Paper No. 26, February 2002.

The Research Questions & Applications

The primary research task for Location 1 was to find evidence of scorched-earth burnings of houses and crops, and the creation and congestion of model villages in and around the central municipalities, and along the roads leading to these more urban loci. For the Guatemalan case, the basic remote sensing analysis approach was change detection, i.e. before, during, and after image comparisons of the locations. Temporal change detection of the study area involved assembling four Landsat satellite images with the following acquisition dates: February 6, 1979; March 13, 1986; and January 23, 2000. One standard remote sensing application for detecting temporal change in land cover, especially vegetation, is the *Normalized Difference Vegetation Index* (NDVI).

The NDVI application is a remote sensing application, which involves a ratio formula between the visual red and near-infrared (NIR) electromagnetic (EM) bands (Landsat MSS Bands 2 and 3, and Landsat TM Bands 3 and 4 respectively). This ratio application helps to distinguish healthy and stronger vegetation reflectivity from other materials with similar reflective qualities in those same EM band wavelength groups. NDVI applications are useful because two images can be processed into a false color composite, which allows for visual temporal change detection in vegetation coverage. Moreover, by applying standardized thresholds to multiple NDVI manipulated images, multiple classification training regions can be created and supervised computer generated classifications of multiple images executed. From these resulting images, area summary reports are calculated. These spread sheets provide empirical data enabling a more accurate assessment of change in area of the corresponding land-cover training regions for a research location.

For Location 2, a more simple visual analysis of two Landsat MSS images acquired on February 6, 1979 and March 13, 1986 was undertaken. Change detection of two sub-regions (Locations 3 and 4) contained within the Location 2 macro area, an area documented to have experienced an increase in Guatemalan refugee communities in Mexico, revealed distinguishable landscape change and features in the locations of these communities between 1979 and 1986.

When utilizing satellite images to assess most types of land cover change detection, primarily those involving change in vegetation coverage, image acquisition dates and any possible, especially dramatic, variations in climate must be considered. For better control and accuracy in these analyses, comparing images acquired during the same month or season is advisable. However, due to the uncertain availability of satellite images corresponding to particular dates and locations, this is not always possible. Furthermore, annual and seasonal climate data are not always available for the region or temporal period being researched. For this research, changes in average rainfall, temperature, etc. must be inferred using more macro regional and global data.

For Guatemala, the dry season occurs from October to March and the rainy season from April to September.[5] The primary agricultural growing season occurs during the dry season. However, there is cultivation of a variety of crops throughout the year. All six satellite images used in this research were acquired between the months of January and March, during the dry season. Therefore, seasonal influences on vegetation change during the study period are negligible. Because it was not possible to get precipitation

[5] http://www.pecad.fas.usda.gov/cropexplorer/index.cfm

data specifically for Guatemala during the 21-year study period, a standardized graph charting annual global precipitation was utilized (Figure 3). According to the graph, the change in annual precipitation between 1979 and 1986, and 1986 and 2000 is notable and must be considered. Between 1979 and 1986, global rainfall decreased by 40 mm, and again increased by just over 40 mm by 2000. However, the extent of this decrease in annual rainfall in Guatemala is unknown; and, furthermore, this decrease is not sustained for a prolonged period of time to constitute drought conditions. According to NOAA's Palmer Drought Index, annual average rainfall ranging between –1.0 to –1.9 inches (-25.4 to -48.26 mm) below average is considered "Abnormally Dry" but not drought conditions.

Moreover, 1986 and 1987 were El Niño years, which means there would have been increased rainfall in the regions from the southern U. S. to Peru. Therefore, although the research findings conclude a substantial deforestation of Location 1 between 1979 and 1986, this possible annual decrease in rainfall probably had minimal-to-no influence on this observed decrease in vegetation. Rather, the primary causes for this change in vegetation can be positively attributed to human activity and the cumulative direct, or indirect, influences of these activities on the environment. Firstly, the areas of most deforestation on the image occur in the concentrated study area; secondly, there is eyewitness documentation that corroborates this destruction; and thirdly, there is not a strong return to pre-1986 conditions in 2000.

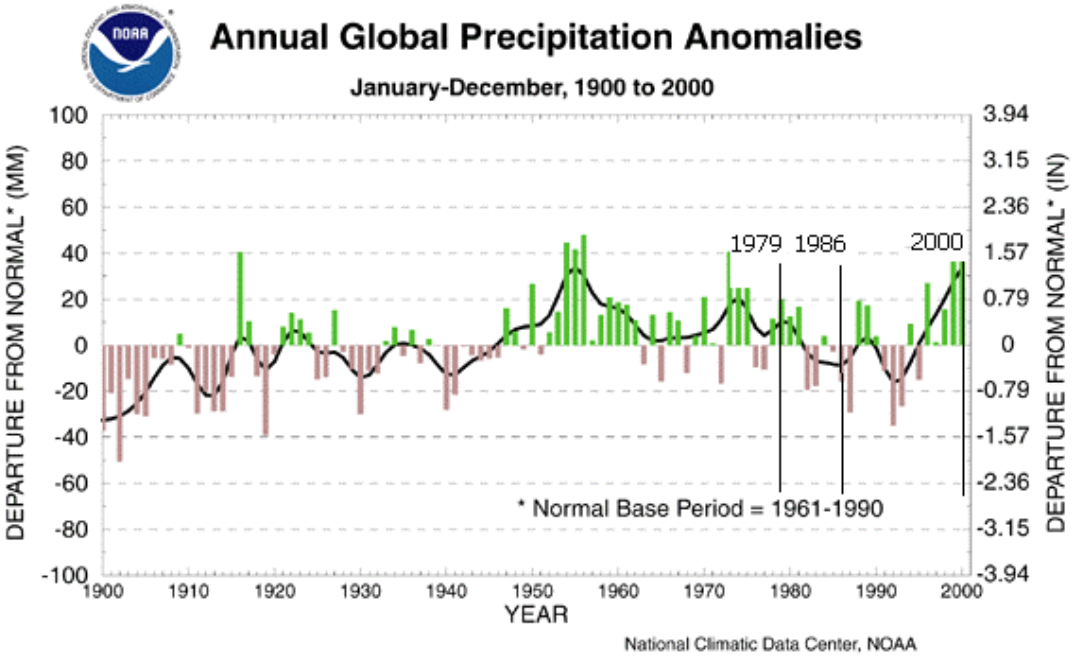

Figure 3. Annual Global Precipitation Anomalies

The Findings

Location 1: The Ixil Triangle

The following image (Figure 4) is a 1986 RGB 321 real color scene of the Ixil Triangle and the macro region of Department of El Quiché. It includes the locations of many of the documented "Model Villages." Corresponding data on these loci can be viewed in Table 1. The roads connecting and forming the Pole Villages from Nebaj to Salquil and San Gaspar Chajul, as well as other loci, are quite distinguishable.

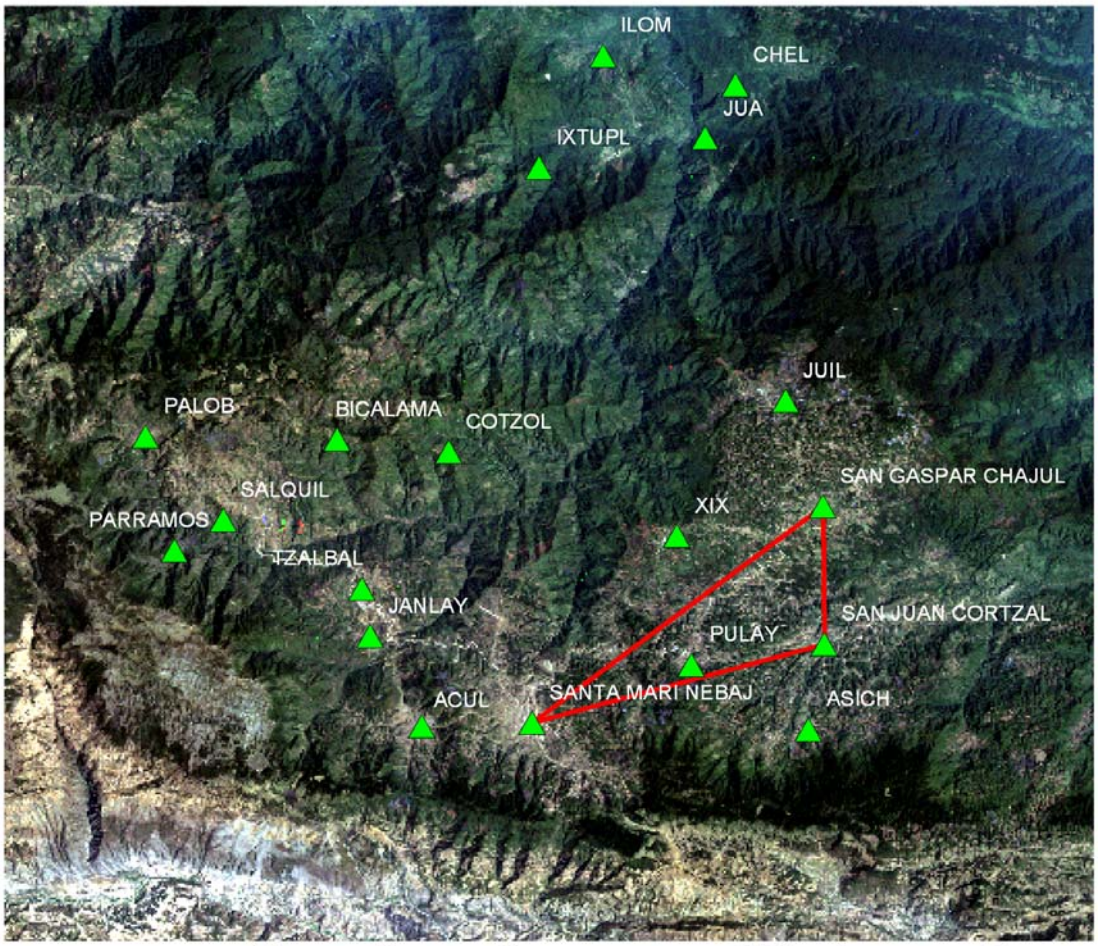

Figure 4.

- The 1986 Landsat TM image is prepared as an RGB 321 real color visual representation.

Villages and towns of known acts of genocide and household displacement between 1980-1986
The Ixil Triangle

Numbers of Families/Households Displaced to Development Pole Cities
(Model Villages) by Location (see Figure 4)

Location	No. of Households Displaced
Acul	450
Asich	40
Biclamá	250
Chel	250
Chichel	56*
Cotzol	80
Ilom	450
Ixtupil	54
Janlay	83
Juil	123
Palob	160
Parramos	125
Pulay	140
Salquil	500
Tzalbal	315
Xix	79

*Location not shown on Figure 4.

Table 1.[6]

The most revealing visual change to the landscape between 1979 and 1986 can be viewed in a Landsat 1979 TM/1986 ETM+ false color composite (Figure 5), which demonstrates the extent and devastation of President Efrain Ríos Montt's "scorched earth" strategy and the military's systematic destruction of the rural settlements surrounding the municipalities of Santa Maria Nebaj, San Gaspar Chajul, and San Juan Cotzal. In this image, red represents areas vegetated in 1979 but not in 1986; green represents areas vegetated in 1986 but not in 1979; and yellow represents areas of relatively no change.

In late 1983, the army launched its program of Development Pole villages. In the sub-region of Nebaj & Acul, a closer look at a 1986 TM RGB 342 image (Figure 6) clearly demarcates some of these same scattered red blotch anomalies (Figure 5) as darker purple. In a comparison, these anomalies are no longer present on a 2000 ETM+ RGB 342 image of the same location (Figure 7). This recovery of vegetation from 1986 to 2000 is actually slightly deceiving. Eyewitness documentation describes an area in the late 1980's and 1990's still under the strict control of the government and military. The landscape descriptions include a return of some agricultural vegetation but not of the forests: the heavily-wooded areas along the roadsides are gone; and overuse of available land, erosion, and continued deforestation continue to lower agricultural production and speed environmental deterioration.[7]

A reliable method often used to quantify intense changes to a landscape is by comparing NDVI supervised classifications and their accompanying area summary reports. For the purposes of this study, three supervised class regions were designated

[6] Manz, Beatriz, *Refugees of a Hidden War: The Aftermath of Counterinsurgency in Guatemala*. Albany, NY: State University of New York Press, 1988.
[7] Ibid.

representing: “heavy vegetation” (heavily-wooded areas); “medium vegetation” (agriculture, mixed vegetation, and disbursed vegetation); and “light to no vegetation” (open ground, exposed soil, urban areas, roads, and perimeter vegetation) in the false colors representation red, salmon, and turquoise respectively. The results can be viewed in Figures 8 to 13 and the accompanying area summary reports (Tables 2 and 3).

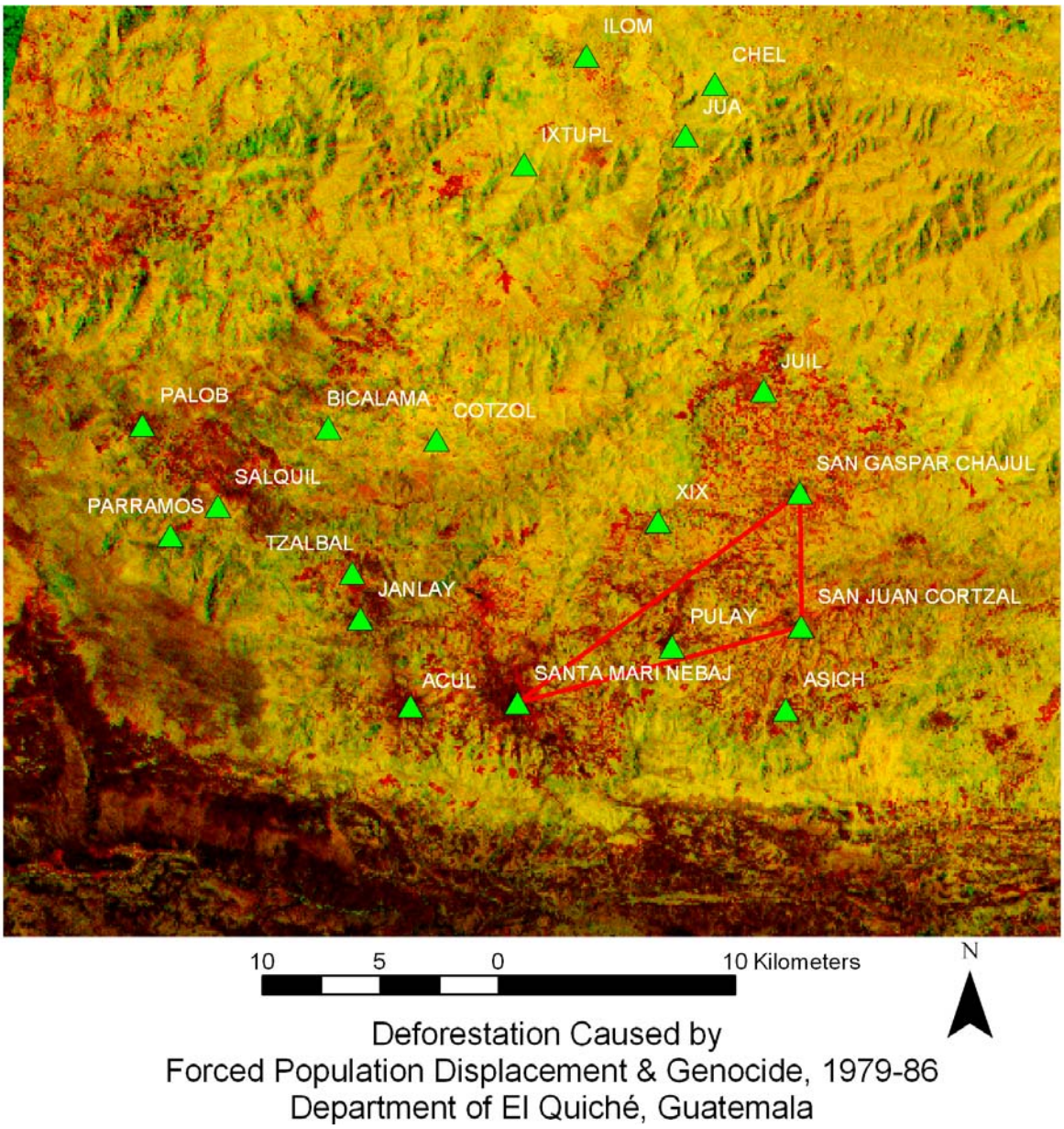

Figure 5.

- A Landsat 1979 TM/1986 TM false color composite representing NDVI change in vegetation.
- Red represents areas vegetated in 1979 but not in 1986.
- Green represents areas vegetated in 1986 but not in 1979.
- Yellow represents areas or relatively no change.

Villages and towns of known acts of genocide and household displacement between 1980-1986
The Ixil Triangle

Location 1: Nebaj & Acul
03/13/1986
Landsat TM RGB 342

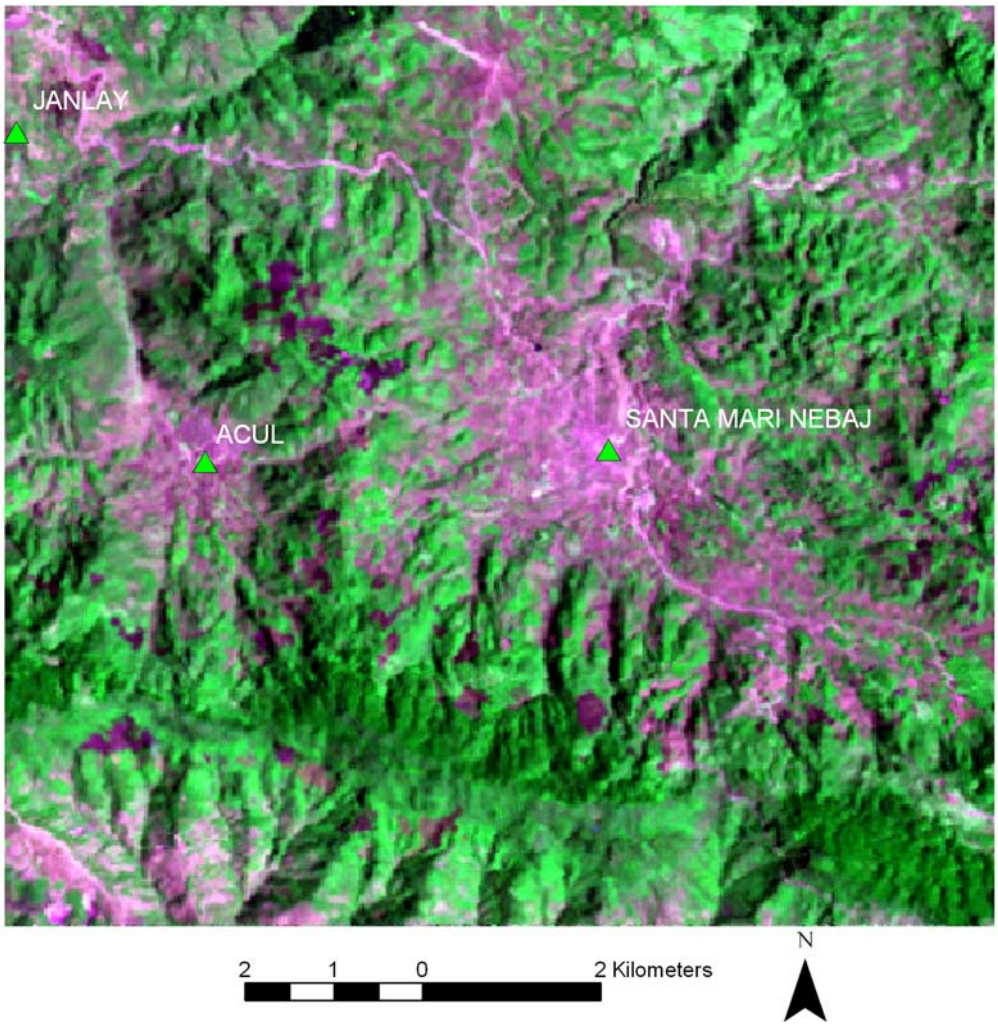

Figure 6.

- A 1986 Landsat TM false color composite representation of bands 4, 3, and 2 in an RGB 342 application.
- Green represents areas of heavy vegetation.
- Light violet to white represents areas of decreasing to no vegetation.
- Dark violet (purple) represents areas of cleared vegetation possibly due to the scorched earth policy implemented in the mid-1980's.

Location 1: Nebaj & Acul
12/12/2000
Landsat ETM+ RGB 342

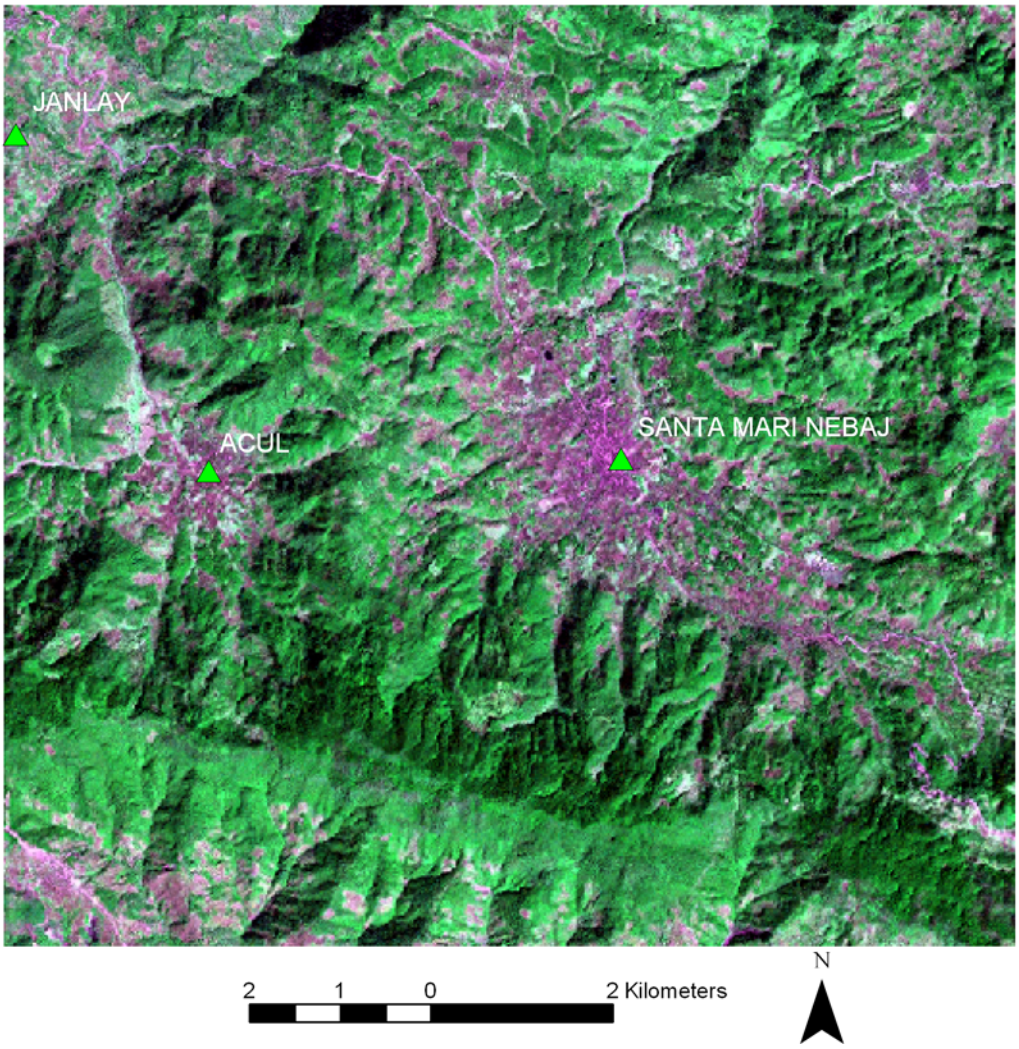

Figure 7.

- A 2000 Landsat ETM+ false color composite representation of bands 4, 3, and 2 in an RGB 342 application with 15 m spatial resolution.
- Green represents areas of heavy vegetation.
- Violet to white represents areas of decreasing to no vegetation.

Nebaj & Acul
Landsat MSS 1979
NDVI Supervised Classification

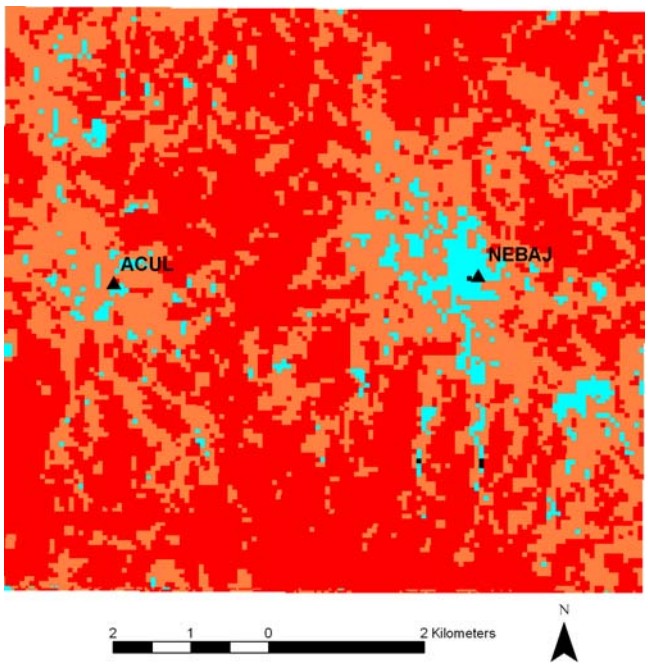

Figure 8.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “light to no vegetation.”

Nebaj & Acul
Landsat TM 1986
NDVI Supervised Classification

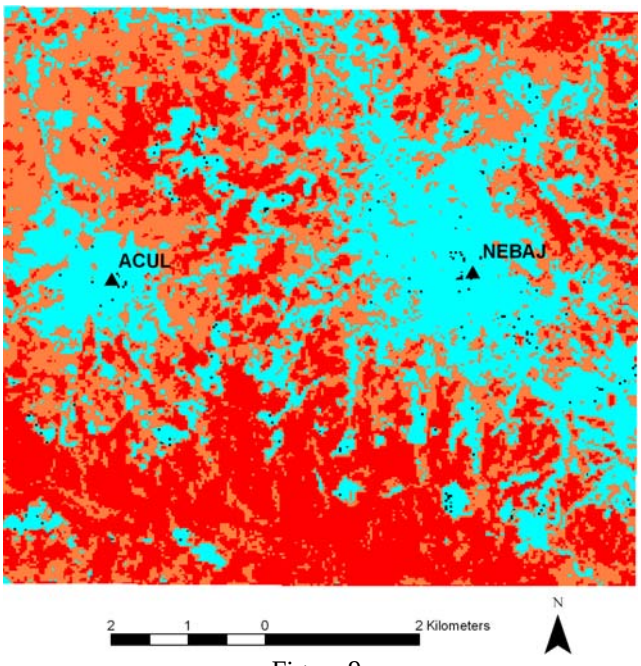

Figure 9.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “light to no vegetation.”

Nebaj & Acul
Landsat ETM+ 2000
NDVI Supervised Classification

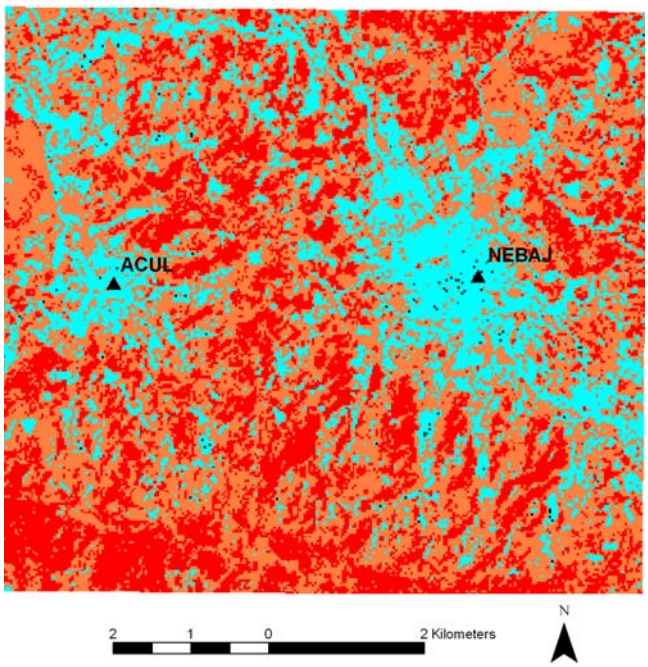

Figure 10.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “light to no vegetation.”

Nebaj & Acul Region Summary Reports (Figures 8, 9 & 10)

Area Summary Report for 02/06/1979 MSS NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	3520.127	35.201	8698.423	13.591
Medium Vegetation	2223.105	22.231	5493.413	8.583
Light to No Vegetation	236.738	2.367	584.992	0.914
All	5981.409	59.814	14780.385	23.094

Area Summary Report for 03/13/1986 MSS NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	1984.002	19.840	4902.576	7.660
Medium Vegetation	2240.186	22.402	5535.619	8.649
Light to No Vegetation	1742.357	17.424	4305.459	6.727
All	5981.409	59.814	14780.385	23.094

Area Summary Report for 01/23/2000 MSS NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	1758.440	17.584	4345.200	6.789
Medium Vegetation	2906.312	29.063	7181.653	11.221
Light to No Vegetation	1308.210	13.082	3232.657	5.051
All	5981.409	59.814	14780.385	23.094

Table 2.

In the same format, an even more dramatic change of the Location 1 macro region can be observed between 1979 and 1986, and 1986 and 2000 (Figures 11, 12, and 13). The NDVI false color classification images and accompanying summary reports (Table 3) strongly corroborate the documented descriptions of land cover changes in the following chronological interpretation: a pre-1980, heavily-wooded, and rural landscape is dramatically changed during a process of population relocation and genocide policies carried out by the Guatemalan military (most accelerated from 1983 to 1986) and the local resistance to these aggressions. By 1986, the concentrations of populations and growth of model villages, and the artifacts of destroyed rural hamlets and agricultural lots under a scorched earth policy are definitively reflected in both the Location 1 sub- and macro-region summary reports, as well as visually represented in the accompanying images. These data demonstrate a dramatic reduction of "heavy vegetation" from 622 km^2 in 1979 to 436 km^2 in 1986, accompanied by an equally dramatic increase in the "light to no vegetation" class from 148 km^2 to 277 km^2 respectively (Table 2). The most dramatic change occurred around the larger municipalities. In percent of total area classified, these two categories constitute a change of 16 percent reduction in "heavy vegetation" and an increase of 11 percent in "light to no vegetation" between 1979 and 1986.

This same percent of total change is even more apparent in the Nebaj/Acul sub-region. In this location, for the same two categories, there is a 25 percent decrease of "heavy vegetation" and an equal increase in "light to no" vegetation. Moreover, although by 2000 the "light to no vegetation" class is more dispersed accompanied by an increase of medium vegetation (Figure 10), there is no overall recovery to the pre-1986 environmental conditions—conditions that were probably changing as early as 1980. Although after 1986 there was a decrease in government sponsored genocide type activities, the military remained openly active and present in the area continuing to implement the relocation and Model Village policies.[8]

This continued military presence is reflected in the 2000 increase in total area of "medium vegetation" (from 447 km^2 in 1986 to 561 km^2 in 2000) but a negligible change in "light to no vegetation" (an increase of 11 km^2), and a continued decrease in the amount of "heavy vegetation" (a decrease of 125 km^2). In conclusion, the temporal and spatial changes to the physical landscape (observed on the prepared satellite images and

[8] Manz, Beatriz, *Refugees of a Hidden War: The Aftermath of Counterinsurgency in Guatemala*. Albany, NY: State University of New York Press, 1988.

documented by the accompanying empirical data presented in this report) strongly support and are a direct result of the published accounts describing the events that occurred in the Department of El Quiché during the period from 1979 to 2000.

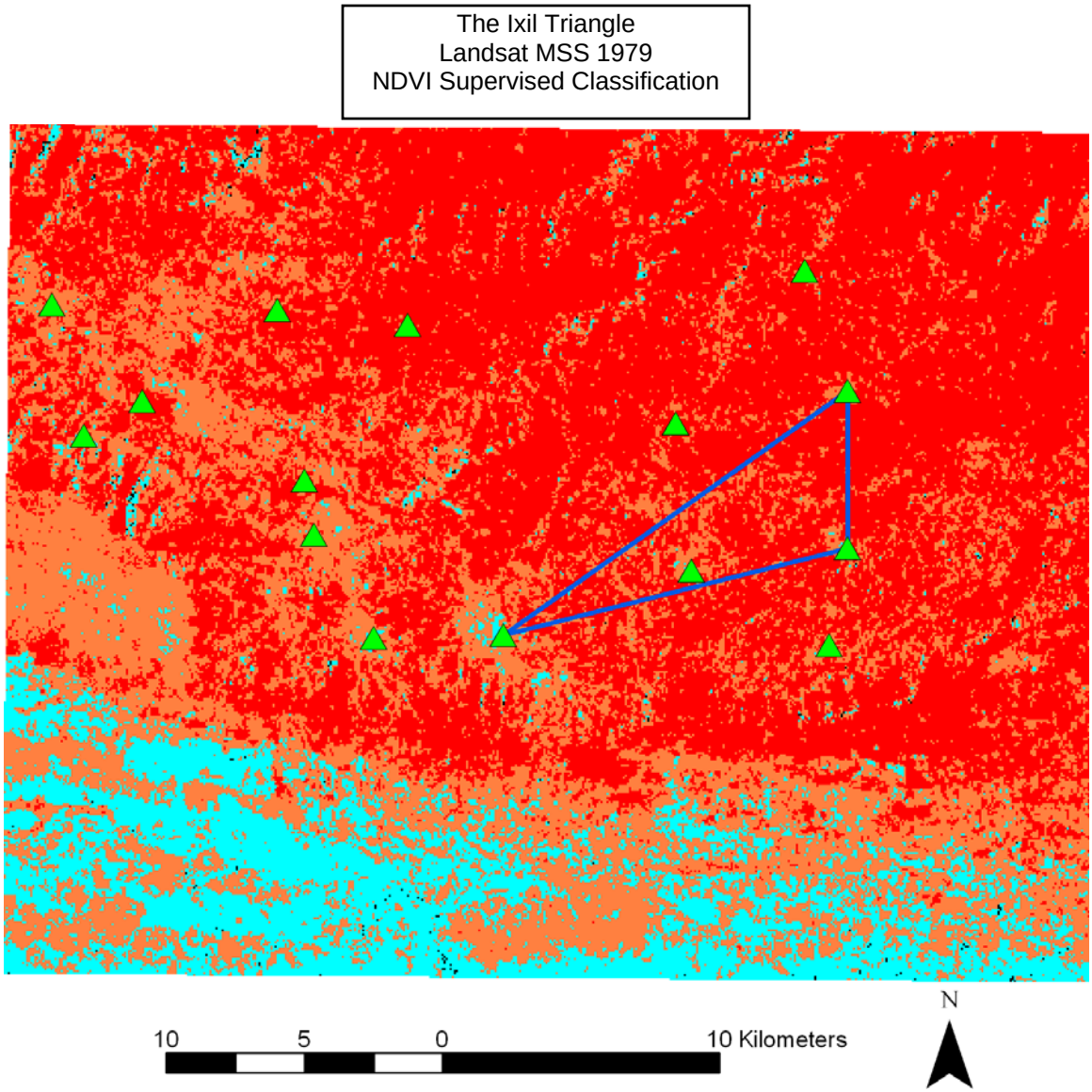

Figure 11.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “low to no vegetation.”
- The blue triangle represents the Ixil Triangle.
- The green pyramids represent villages and towns of known acts of genocide and household displacement between 1980-1986 (Table 1).

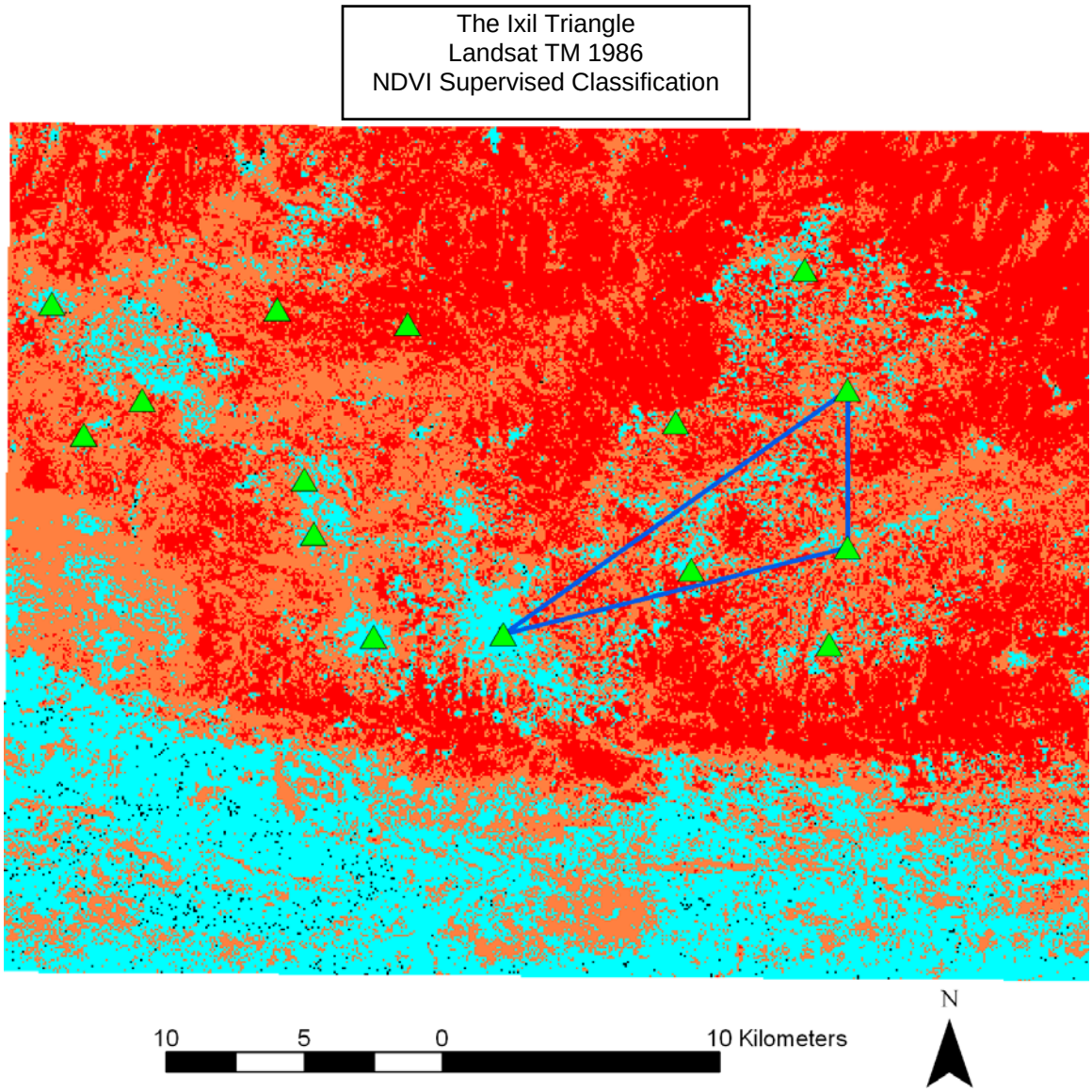

Figure 12.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “low to no vegetation.”
- The blue triangle represents the Ixil Triangle.
- The green pyramids represent villages and towns of known acts of genocide and household displacement between 1980-1986 (Table 1).

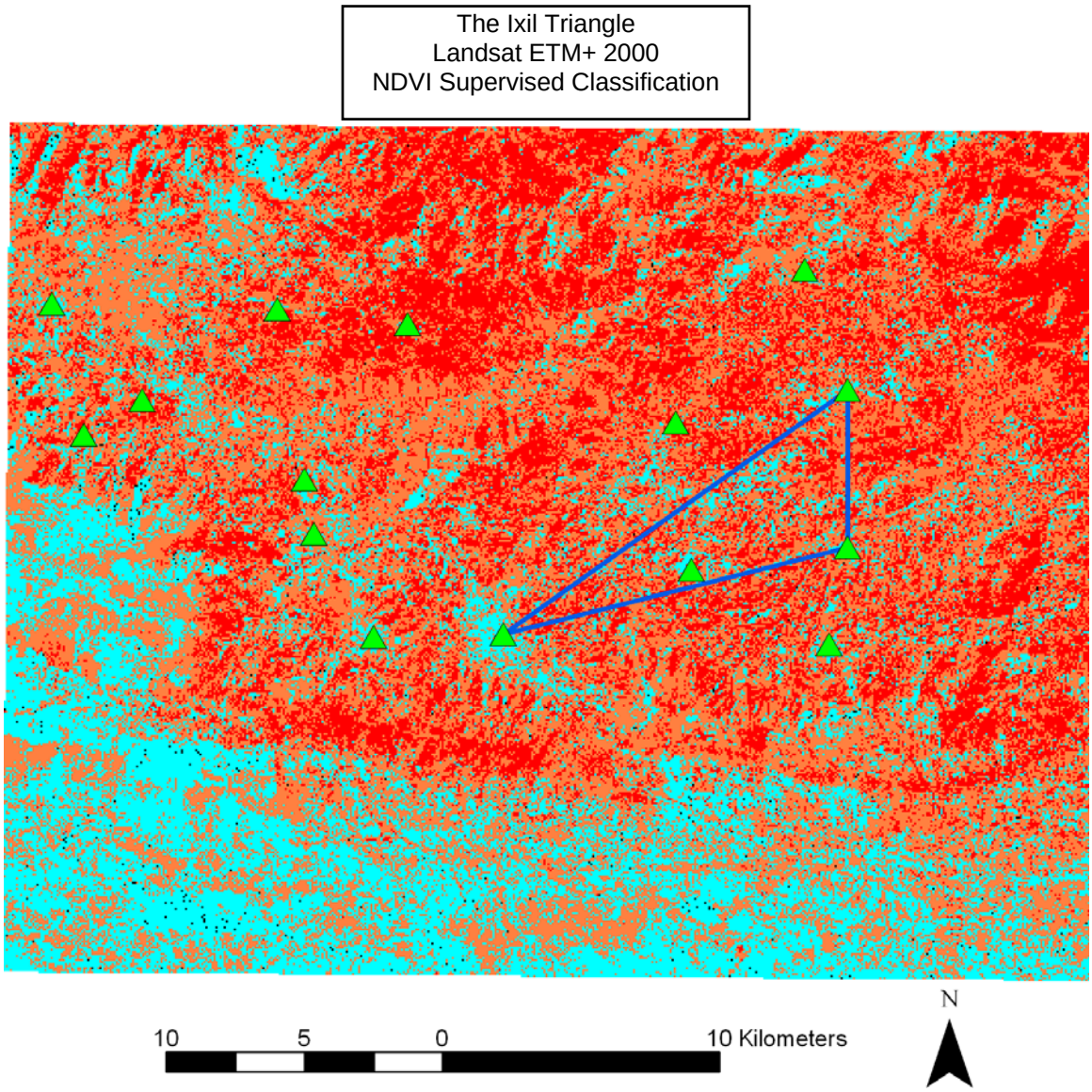

Figure 13.

- Red represents areas of “heavy vegetation,” salmon represents areas of “medium vegetation,” and turquoise represents areas of “low to no vegetation.”
- The blue triangle represents the Ixil Triangle.
- The green pyramids represent villages and towns of known acts of genocide and household displacement between 1980-1986 (Table 1).

The Ixil Triangle & Macro-Region Summary Reports (Figures 11, 12 & 13)

Area Summary Report for 02/06/1979 MSS NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	62221.352	622.214	153752.320	240.238
Medium Vegetation	39331.703	393.317	97190.761	151.861
Light to No Vegetation	14774.210	147.745	36508.612	57.054
All	116454.341	1164.543	287764.965	449.633

Area Summary Report for 03/13/1986 TM NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	43592.198	435.922	107718.675	168.310
Medium Vegetation	44659.870	446.599	110356.949	172.433
Light to No Vegetation	27720.560	277.206	68499.002	107.030
All	116347.795	1163.478	287501.685	449.221

Area Summary Report for 01/23/2000 ETM NDVI Classified

Class/Region	Hectares	Sq. Km	Acres	Sq. Miles
Heavy Vegetation	31092.032	310.920	76830.089	120.047
Medium Vegetation	56128.914	561.289	138697.578	216.715
Light to No Vegetation	28875.709	288.757	71353.436	111.490
All	116347.795	1163.478	287501.685	449.221

Table 3.

Location 2: The Guatemalan/Mexican Border

The image analyses of the Guatemalan/Mexican border, including research sub-regions Locations 3 and 4 (Figure 14), were based on more simple visual change detection. The interest in these locations on the border of Mexico and Guatemala is concerned with the increase of refugee camps and towns, as well as border activity, along the Río Salinas and Río Lacaniúm. Events that are cotemporaneous with the 1980-1986 increase in violence and government sponsored genocide activities in the Department of El Quiché.

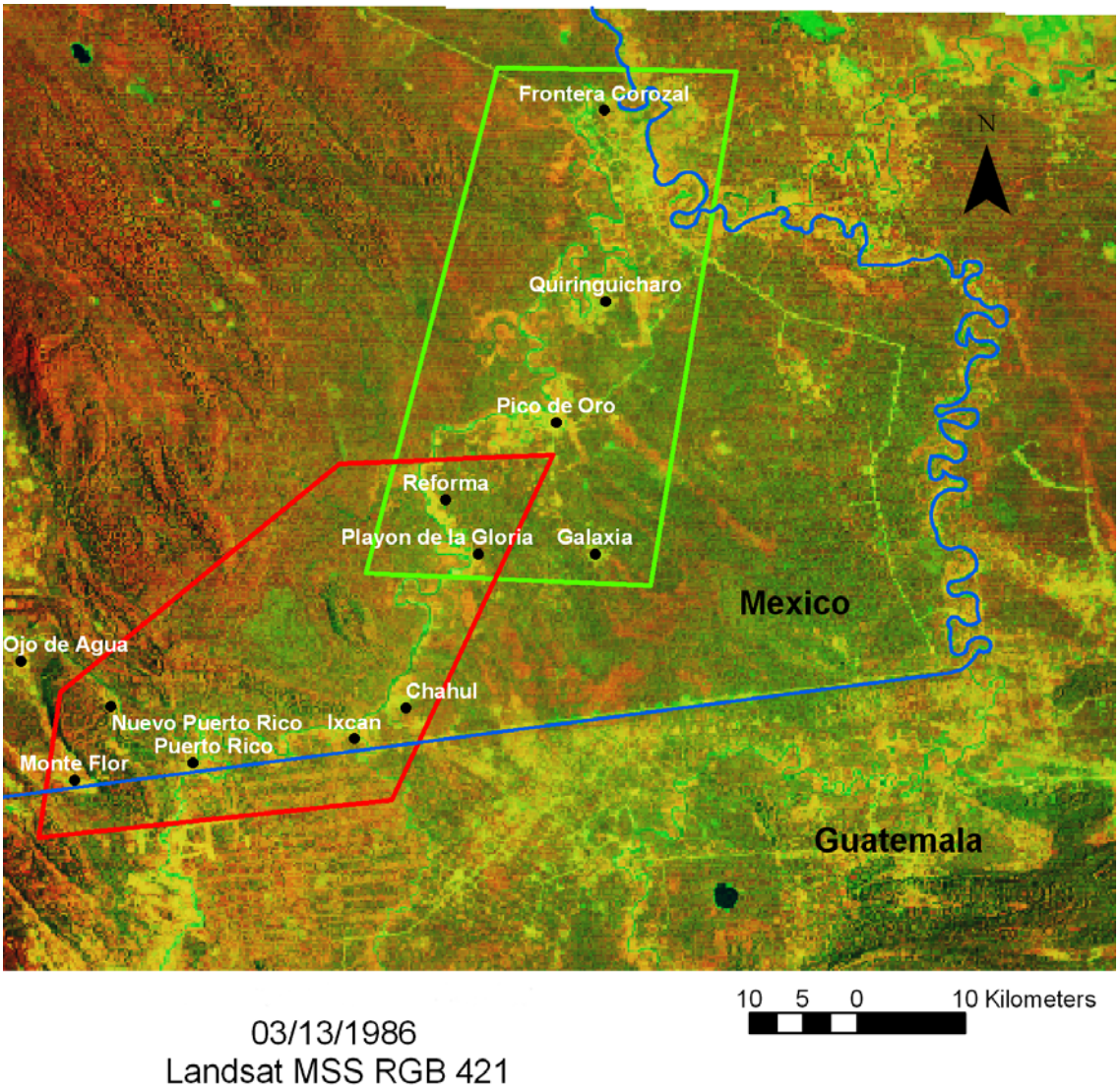

Figure 14.

- The international border is shown in blue.
- Locations of Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- The red polygon represents location 3.
- The green polygon represents location 4.
- Dark green represents heavy vegetation; rusty orange represents medium to light vegetation; yellow/lime green represents bare soil; and lime green represents water and roads.

At Locations 3 and 4, the primary changes between 1979 and 1986 are the clearly visual increases of the light to no vegetation areas surrounding the centers of known refugee camps and towns[9] (Figures 15, 16, 17, and 18) as described by the image captions of Figures 17 and 18. In all the areas marked by these refugee camps and towns, there is

[9] Manz, Beatriz, *Refugees of a Hidden War: The Aftermath of Counterinsurgency in Guatemala*. Albany, NY: State University of New York Press, 1988.

a discernable increase of center-to-periphery growth resulting in a decrease of surrounding vegetation. This type of center-to-periphery growth is usually evidence of increased human activity and/or population. The evidence of increased activity and population in the 2, 3, and 4 border locations corroborates with sources documenting a large migration of Guatemalans fleeing into this region during the 1980-1986 violence.[10]

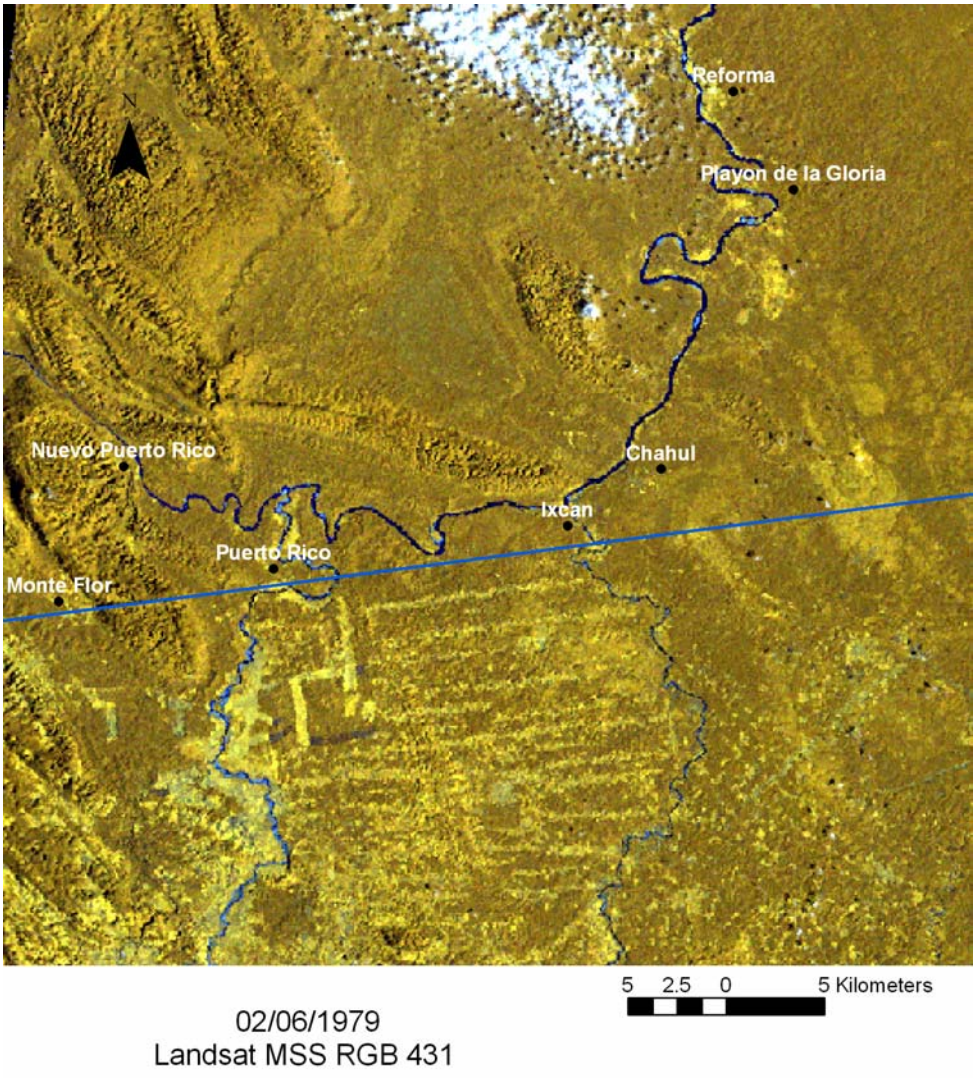

Figure 15.

Location 3
- The international border is shown in blue.
- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Darker yellow ochre represents vegetation; lighter yellow ochre represents more bare soil; the white streaks are clouds; and the blue/black features represent water.

[10] Ibid.

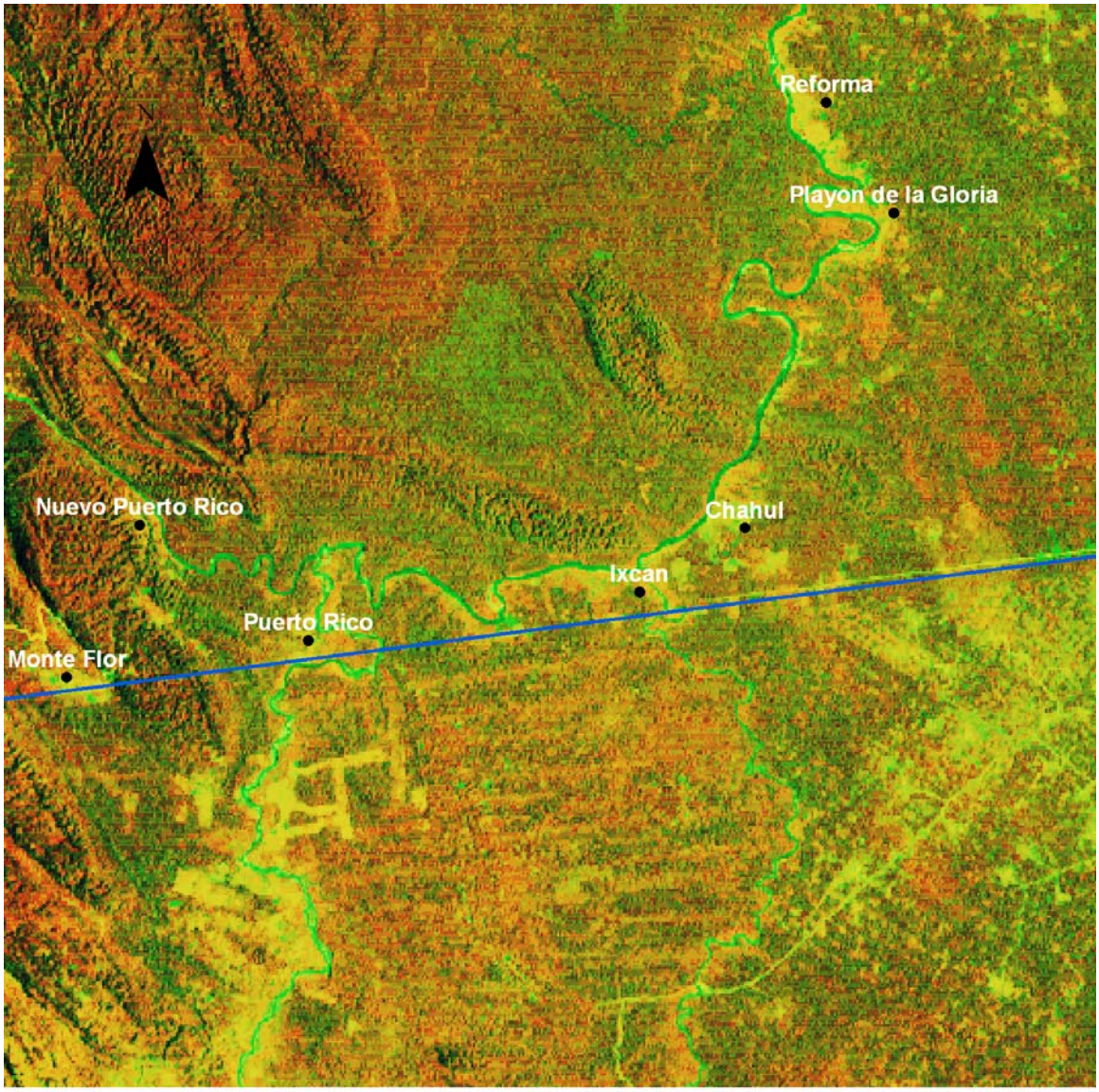

Figure 16.

Location 3

- The international border is shown in blue.
- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Dark green represents heavy vegetation; rusty orange represents medium to light vegetation; yellow/lime green represents bare soil; and lime green represents water and roads.

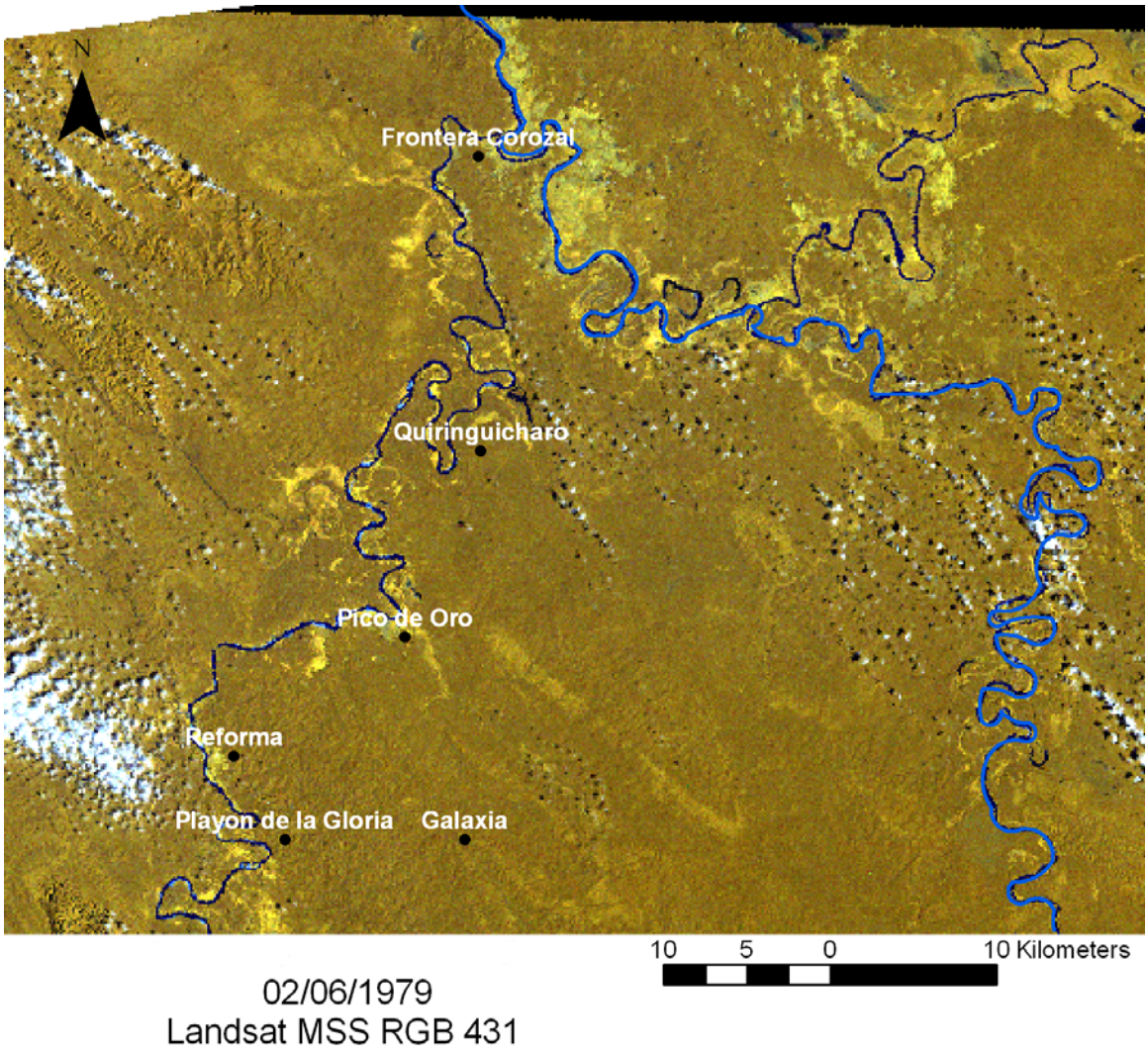

Figure 17.

Location 4

- The international border is shown in blue.
- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Darker yellow ochre represents vegetation; lighter yellow ochre represents more bare soil; the white streaks are clouds; and the blue/black features represent water.

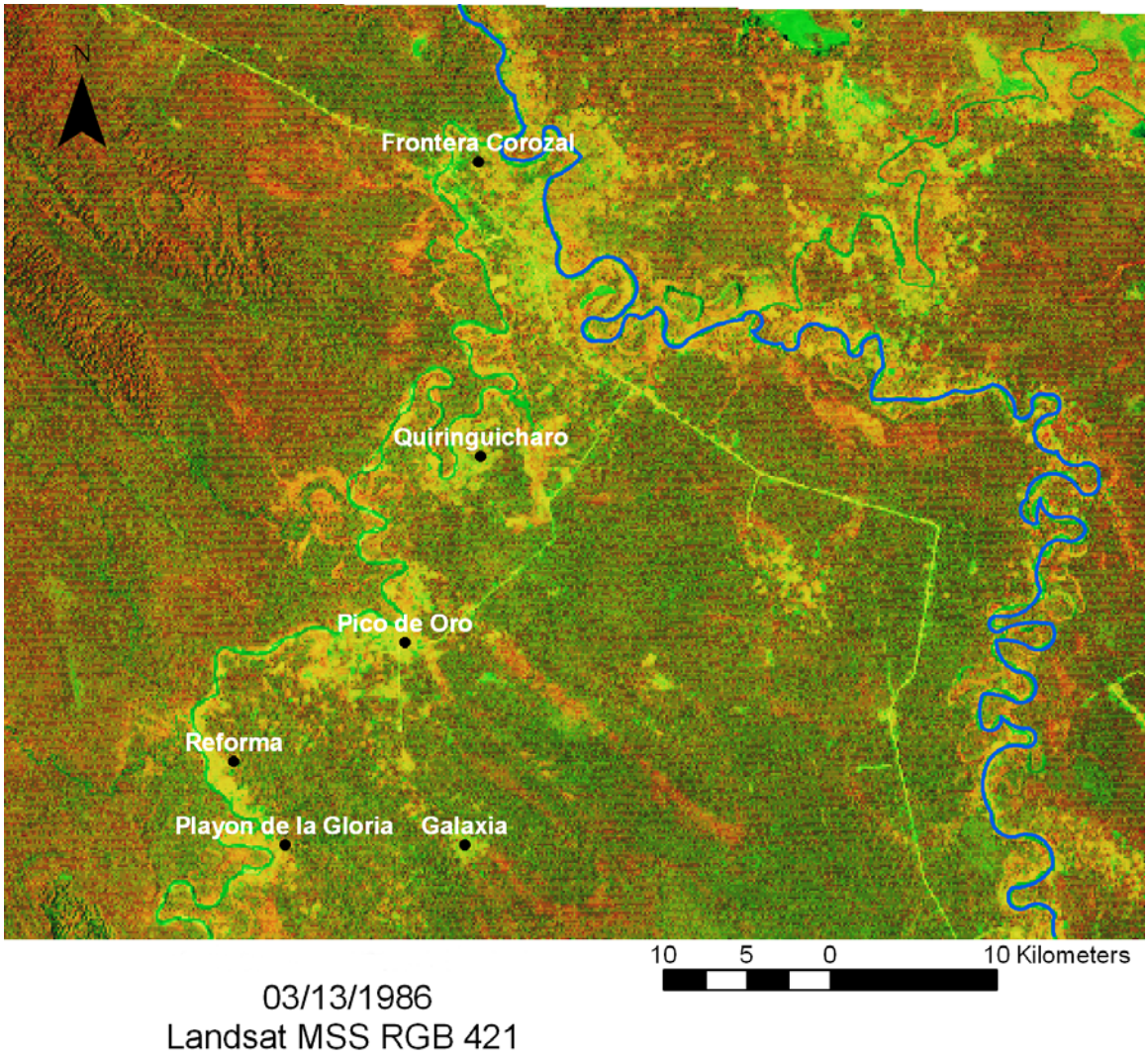

Figure 18.

Location 4
- The international border is shown in blue.
- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Dark green represents heavy vegetation; rusty orange represents medium to light vegetation; yellow/lime green represents bare soil; and lime green represents water and roads.

The other discernable change to the landscape is the appearance of an international border road in the 1986 image, which is not present in 1979 (Figures 19 and 20). The appearance of this road probably reflects an increase of both Guatemalan and Mexican military related border activities. Just over the border in Guatemala, these obvious changes to the landscape are further accentuated (Figure 21 and 22) and support evidence of a Guatemalan military build-up in this border region and possible Guatemalan military insurgencies into Mexico, which instigated a Mexican reaction. There is presently no post-1986 image available to observe what change has occurred in this research Location 1I since 1986.

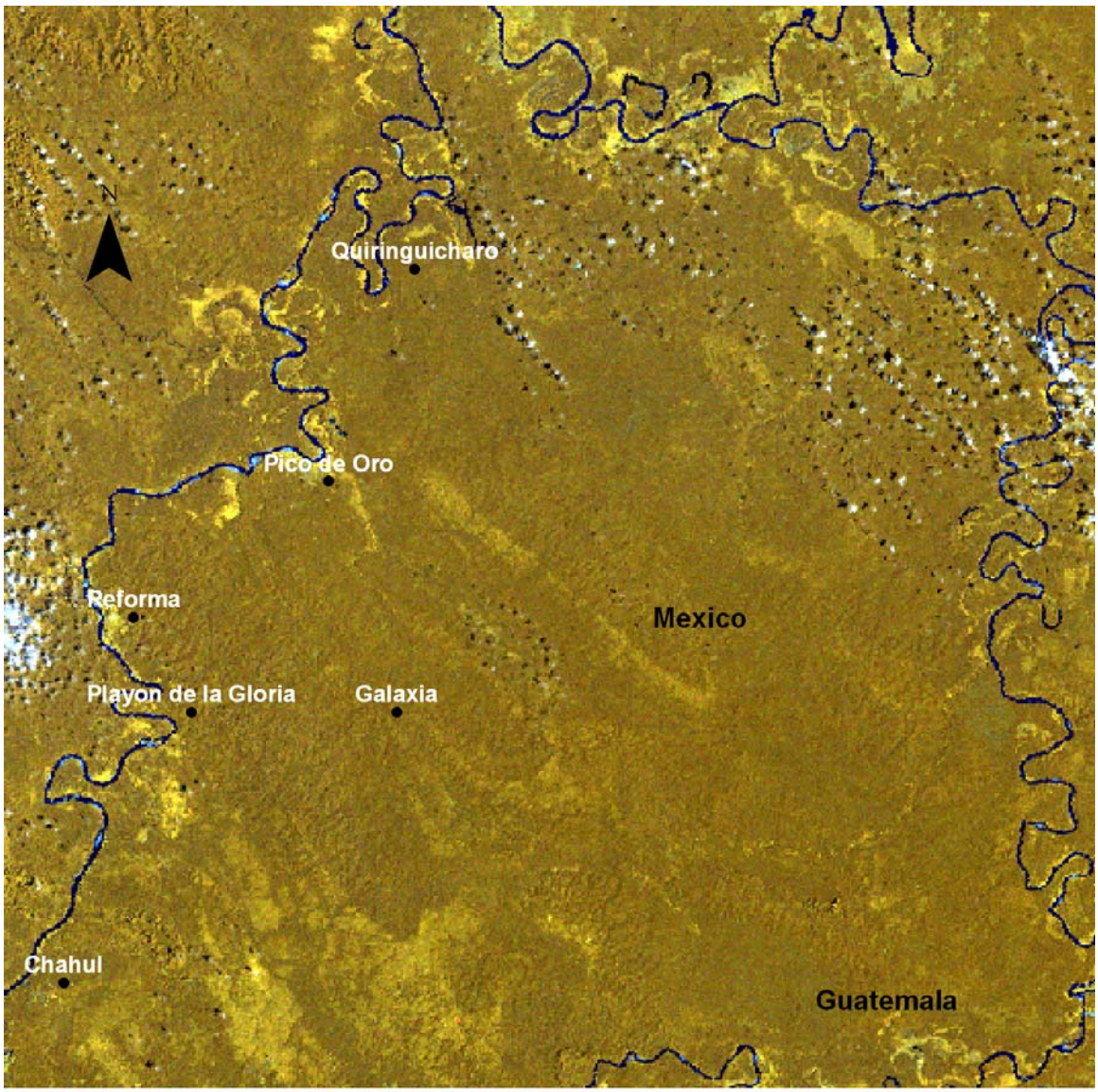

Figure 19.

- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Darker yellow ochre represents vegetation; lighter yellow ochre represents more bare soil; the white streaks are clouds; and the blue/black features represent water.

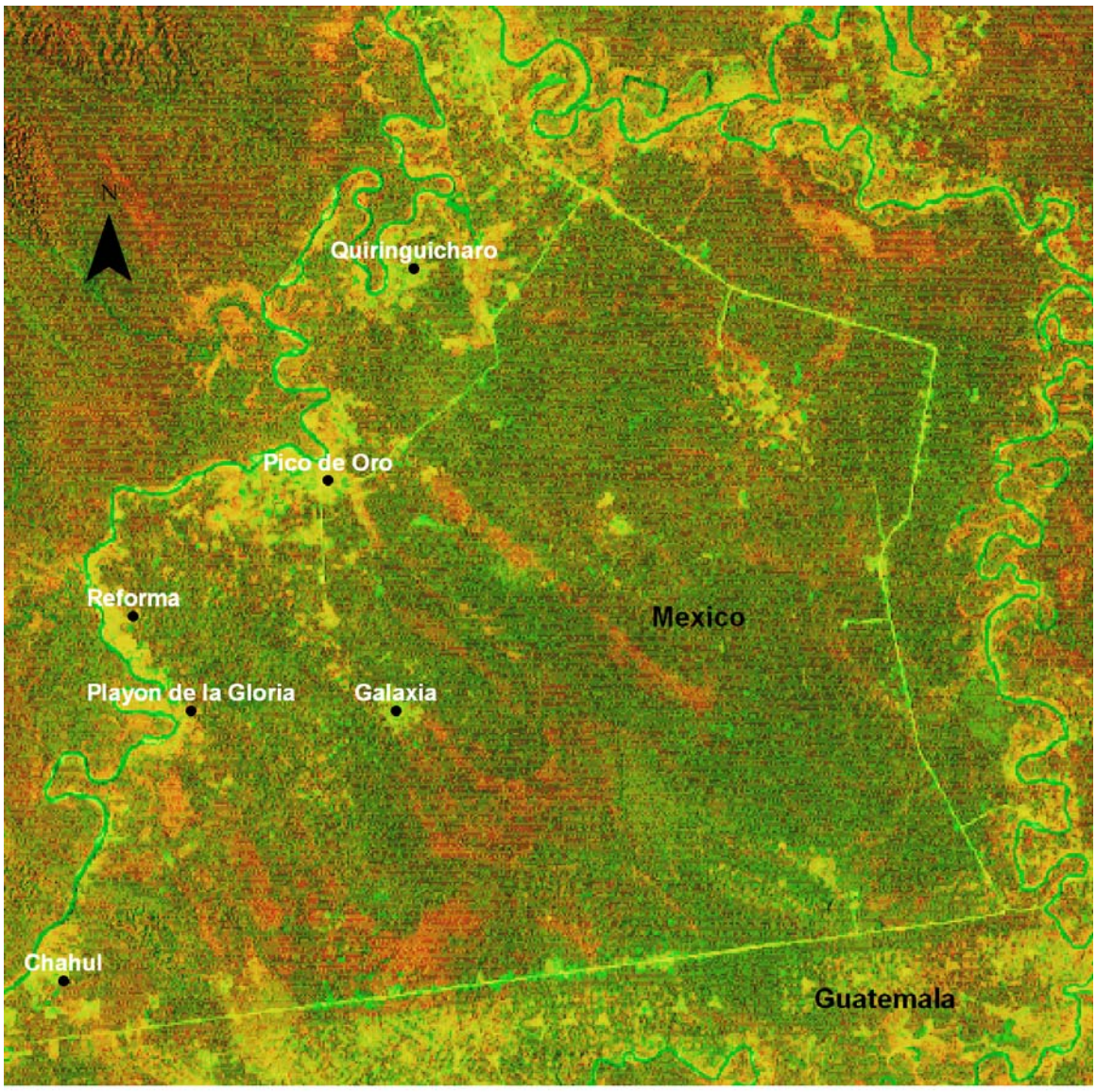

Figure 20.

- Guatemalan refugee camps and towns in Chiapas, Mexico, 1980-1986.
- Dark green represents heavy vegetation; rusty orange represents medium to light vegetation; yellow/lime green represents bare soil; and lime green represents water and roads.

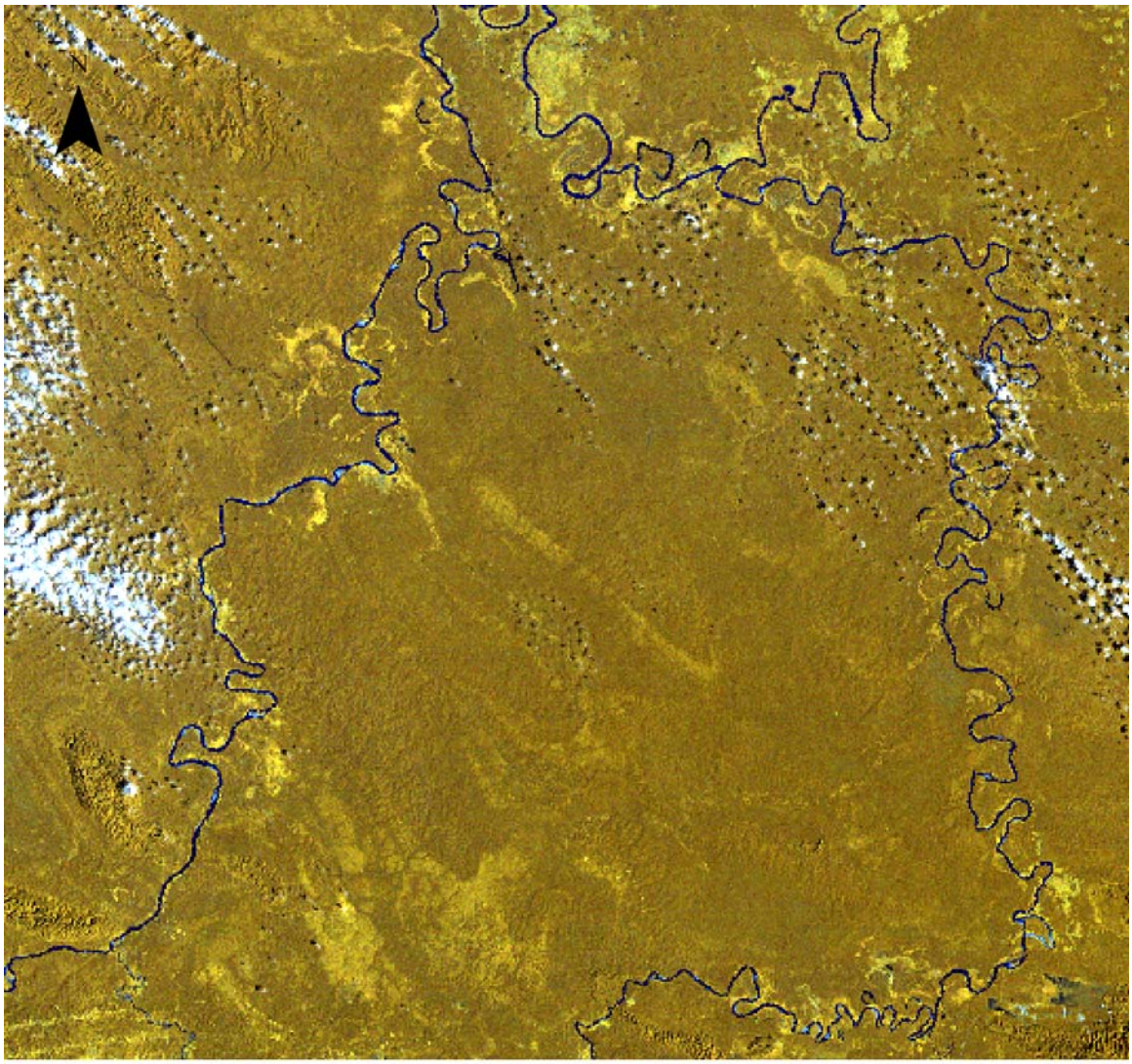

Figure 21.

- The international border is shown in blue.
- Darker yellow ochre represents vegetation; lighter yellow ochre represents more bare soil; the white streaks are clouds; and the blue/black features represent water.

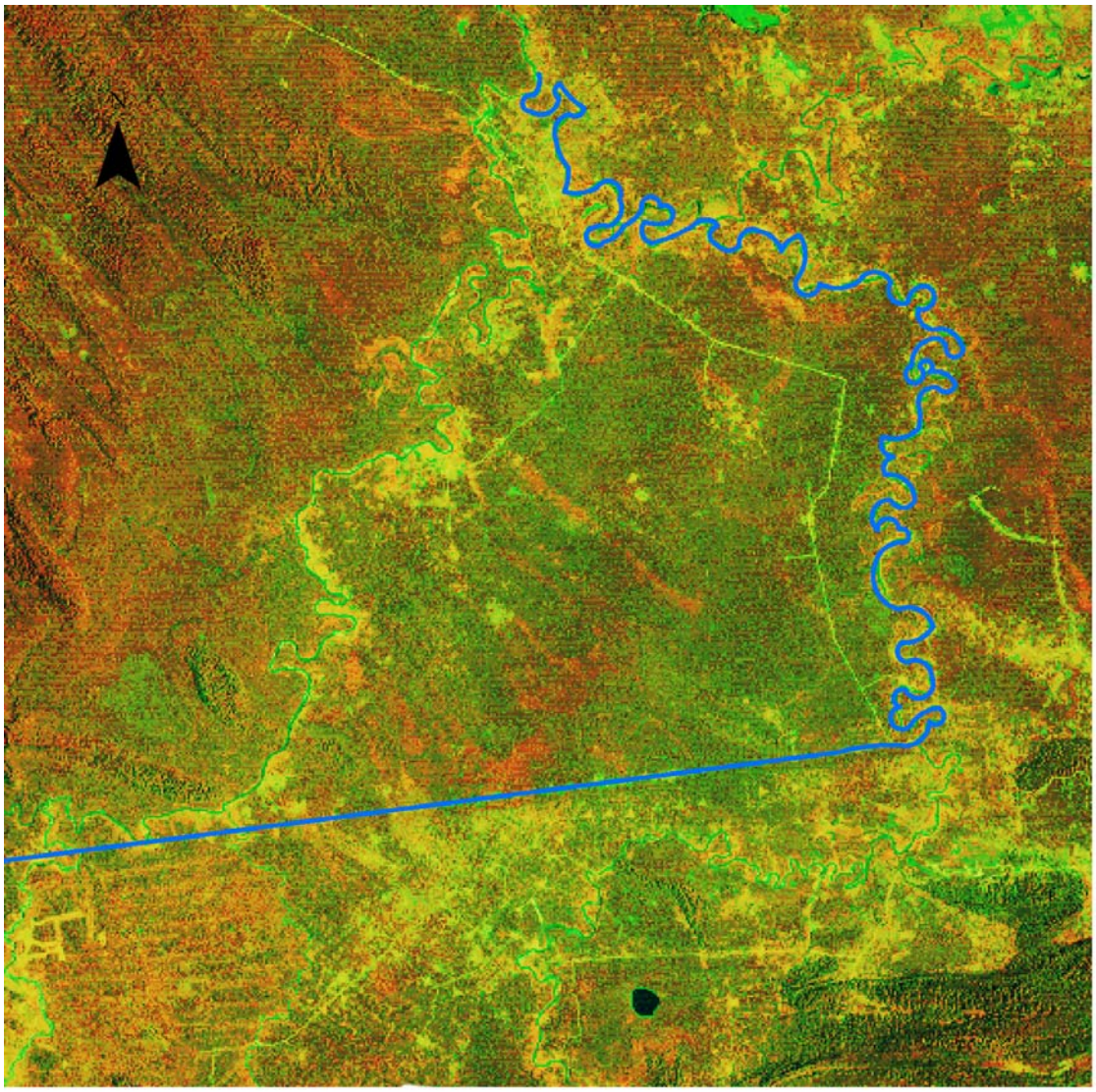

Figure 22.

- The international border is shown in blue.
- Dark green represents heavy vegetation; rusty orange represents medium to light vegetation; yellow/lime green represents bare soil; and lime green represents water and roads.