

# **Identification of Potential Hydrocarbon Target Areas in the Colombian Vaupés-Amazonas and Caguán-Putumayo Basins by Means of Satellite and Hyperspectral Airborne Data and Field Validation\***

**José F. Osorno<sup>1</sup>, David Schonwandt<sup>2</sup>, Talía C. Berg<sup>2</sup>, and Guillermo E. Re Kühl<sup>2</sup>**

Search and Discovery Article #10531 (2013)

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## **Abstract**

Hytec Alto Americas S.A. was contracted by the Colombian Hydrocarbon National Agency (ANH) to conduct a remote sensing study in the Vaupés-Amazonas and Caguán-Putumayo basins in southern Colombia, over an area of approximately 280,000 km<sup>2</sup>. The objective was to detect hydrocarbon prospective areas using satellite, airborne and field remote sensing technology. The rationale behind the application of this technology is that the migration of lightweight hydrocarbons to the ground surface can generate local anomalies which are characterized by reducing conditions that facilitate the development of a variety of chemical and mineralogical changes and can be detected through remote sensing techniques.

The initial phase involved the selection and acquisition of all the ASTER, LandSat 7 ETM+, LandSat 5 TM, LandSat 4, MODIS, SRTM, and PALSAR imagery over the entire study area. RADARSAT images were also acquired over selected areas. Preprocessing and processing techniques were applied to the acquired data. The most significant indexes applied during this project were the Stressed Vegetation Index and the Bleaching Index. These analyses allowed the identification of 156 anomalies that were categorized according to the weight of their spectral and structural characteristics. Oil seeps indicated in regional databases were also taken into account for the targeting process.

Almost half of those satellite spectral anomalies were directly or indirectly field validated by means of a hyperspectral helicopter and field survey program. A total of 1,200 spectral bands were registered along the flight lines. Geochemical sampling was also performed in selected places. The prospective hydrocarbon targets identified cover approximately 45,000 km<sup>2</sup>, which represents the 16% of the entire area. The final weighting process of the targeted anomalies after field validation indicates that 12% of them showed strong characteristics as indicators of potential occurrences of hydrocarbon accumulations.

# Identification of Potential Hydrocarbon Target Areas in the Colombian Vaupés- Amazonas and Caguán– Putumayo Basins

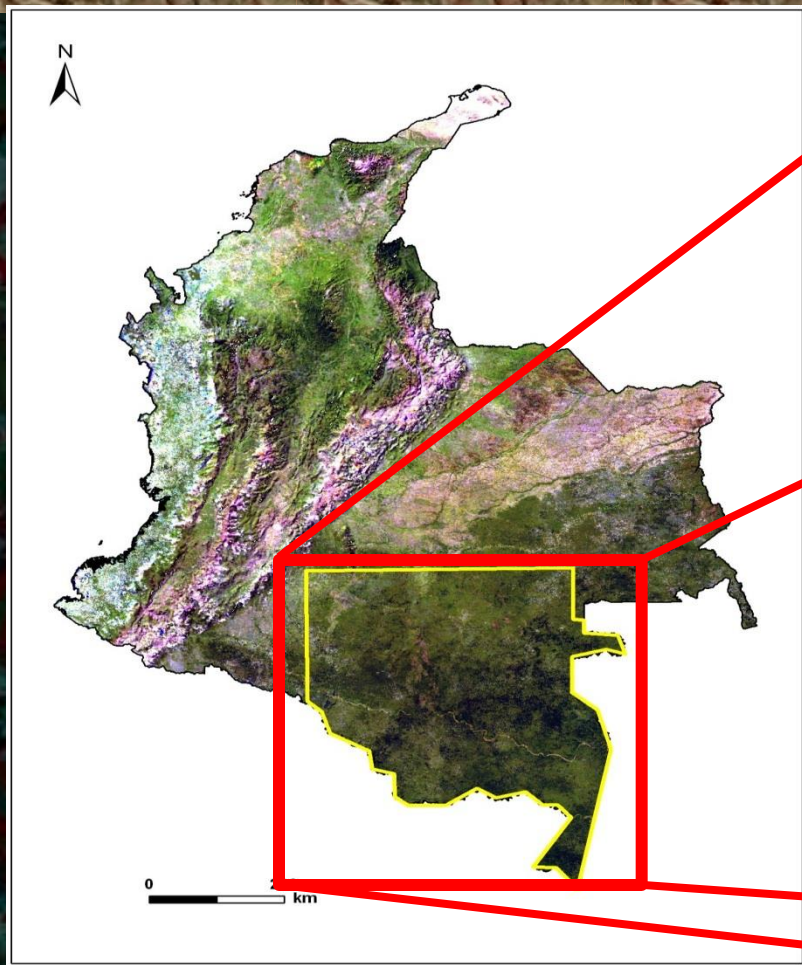
By means of Satellite Data  
and Hyperspectral Airborne  
and Field Validation

**OSORNO, J.F.<sup>1</sup>, SCHONWANDT, D.<sup>2</sup>, BERG, T.<sup>2</sup> AND RE KÜHL, G.<sup>2</sup>**  
**(1) ANH- AGENCIA NACIONAL DE HIDROCARBUROS**  
**(2) HYTEC ALTO AMERICAS**



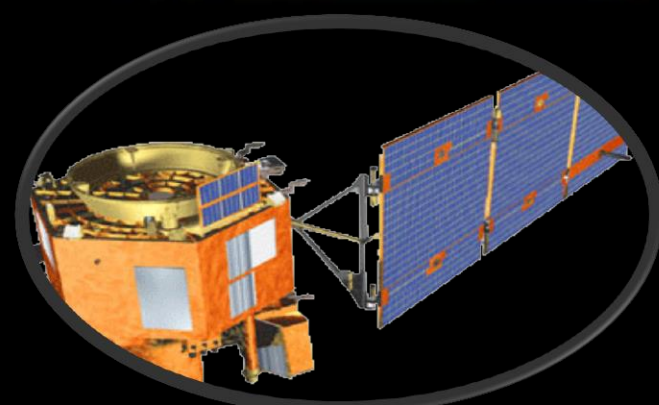
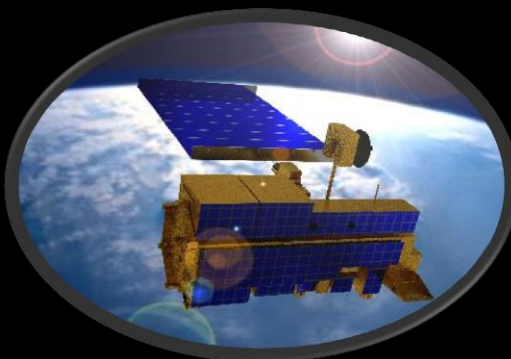
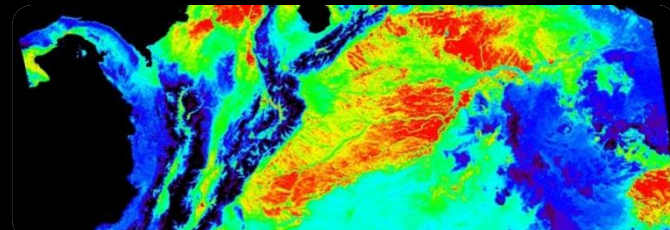
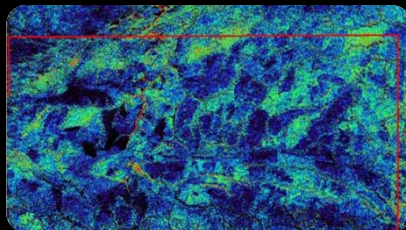
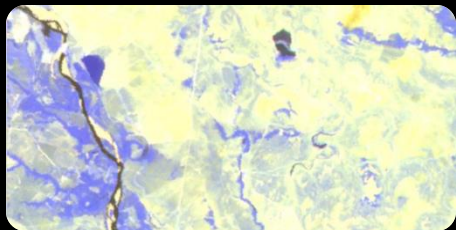


# PROJECT AREA





## ✓ Phase 1. Imagery Selection & Acquisition



### LANDSAT

**Spectral Region:** VNIR, SWIR, TIR  
(0.45 – 12  $\mu\text{m}$ )  
**Spectral Range:** 8 Bands  
**Spatial Resolution:** 15 / 30 m

### ASTER

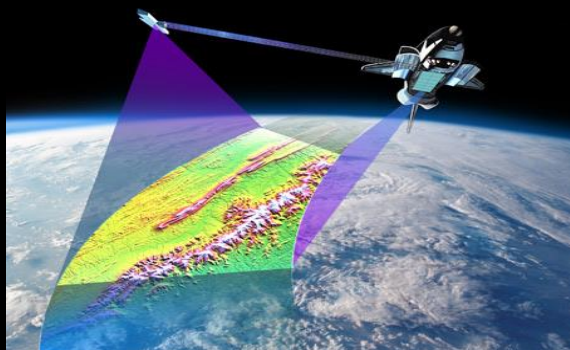
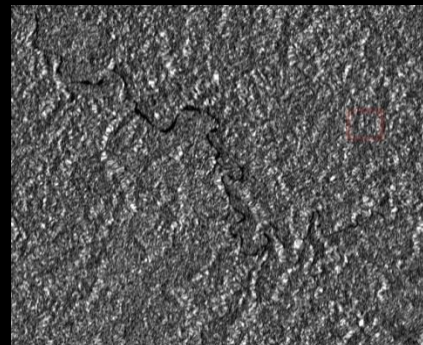
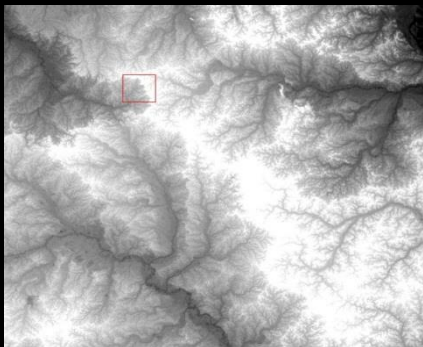
**Spectral Region :** VNIR, SWIR, TIR  
(0.52 – 11.65  $\mu\text{m}$ )  
**Spectral Range :** 14 Bands  
**Spatial Resolution :** 15 / 30 / 90 m

### MODIS

**Spectral Region :** VNIR, SWIR, TIR  
(0.459 – 2.145  $\mu\text{m}$ )  
**Spectral Range :** 36 Bands  
**Spatial Resolution :** 250 / 500 / 1,000 m



# ✓ Phase 1. Imagery Selection & Adquisition



## SRTM

System:	SIR-C
Frequency:	5.2 GHz
Wavelength:	5.8 cm
Resolution:	30 m

## PALSAR

Polarization:	HH o VV
Incidence Angle:	18 a 43
L Banda :	1270 MHz

# ✓ Phase 1. Imagery Selection & Acquisition

## Selection & Acquisition of Satellite Data

**Product Search**

DPH Search | Search Area | [Reset](#) | [Search Exec](#)

For an inventory search, the minimum search criteria are Geographic Information plus at least one of the following: Sensor, Parameter. Search DefaultID is only ASTLIA.  
Roughly parameter maybe spend long time to search.

Select range: ☒ ASTER ODS ☐ EODS

Search Type: ☐ Directory ☒ Inventory

ASTER / Inventory | ASTER / Directory | EOSDS / Inventory

Sensor:

Instrument Mode:

ASTER sAR ID:

Cloud Coverage: ☒ Yes ☐ No

Day/Night:

Orsatles with Browse only: ☐ Yes ☒ No

Number of Orsatles returned per Dataset:

Date/Time: ☒ Continuous Time Range ☐ Annually Repeating Time Period

Continuous Time Range

Start Date/Time	End Date/Time
YYYY MM DD hh mm ss	YYYY MM DD hh mm ss
2011 7 27 9 11 0	2012 1 27 9 11 0

SWIR acquired after April 2007 may be saturated because of increase of SWIR detector's temperature. Please check a browse image.

☐ Inventory Search by designated Orsatle ID.

Search Parameters, Date/Time and Search Area are ignored.

Please input use Orsatle ID per one row.

Copy & Paste are possible by Ctrl+C & Ctrl+V keys.

When ID other LIA was input LIA is searched with the shooting date and time.

**ERSDAC**  
Earth Remote Sensing Data Analysis Center



## ✓ Phase 1. Imagery Selection & Acquisition

### Selection & Acquisition of Satellite Data

PLATFORM	EVALUATED	ACQUIRED	SOURCES
LandSat 4	1.200	13	ESDI / USGS
LandSat 5	2.300	71	
LandSat 7 ETM+	3.000	116	
SRTM	43	43	
ASTER	500	144	ERSDAC.OR.JP
MOD09A1	3.000	176	
MOD011A2	3.000	176	
PALSAR	50	28	
<b>TOTAL</b>	<b>13,000</b>	<b>767</b>	

## ✓ Phase 2. Data Processing

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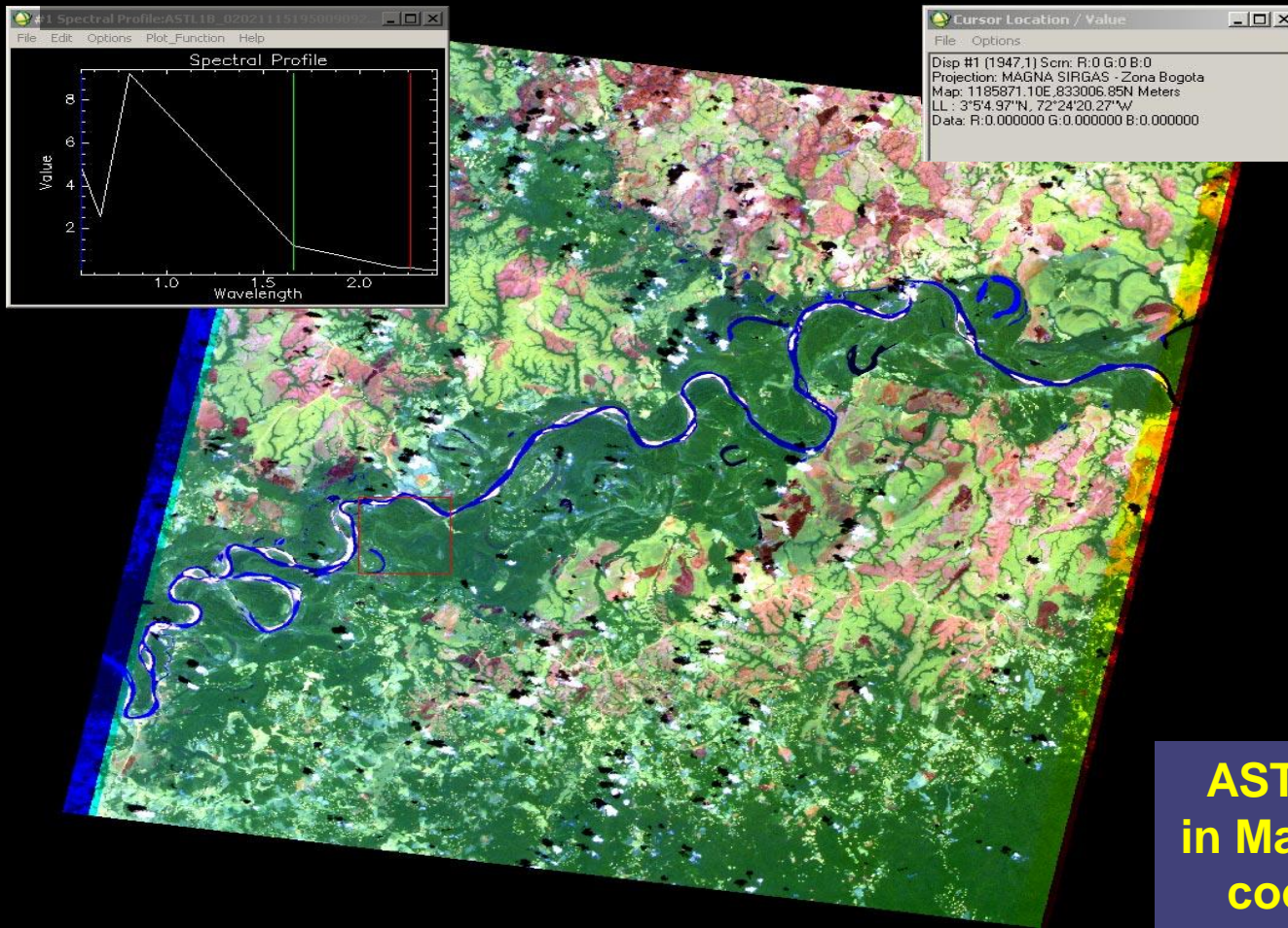
### Data Pre-Processing

- Geometric Adjustments
- Orthorectification
- Georeferencing (MAGNA SIRGAS)
- Spatial Enhancement
- Radiometric Calibration
- Atmospheric Correction (Reflectance)
- Emissivity Calculation
- Digital Mosaicking



## ✓ Phase 2. Data Processing

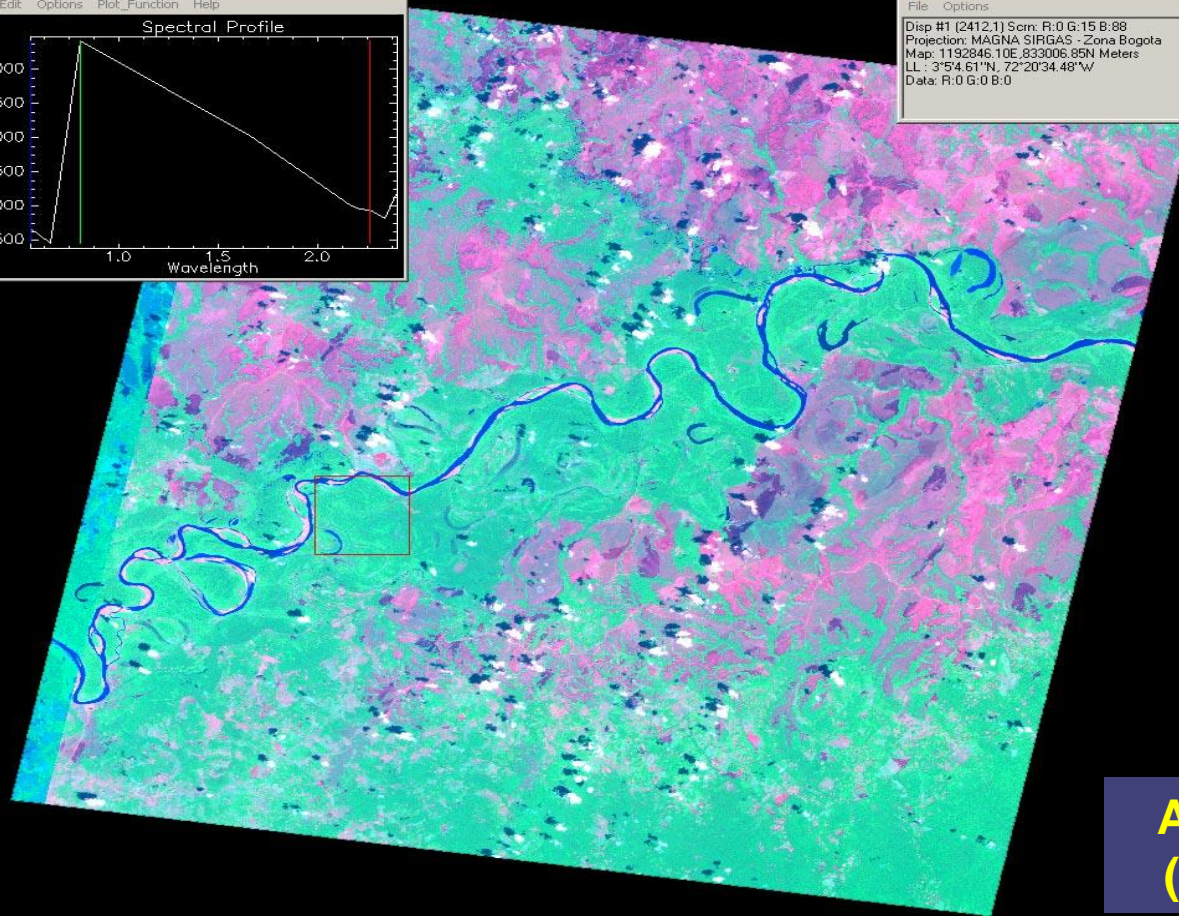
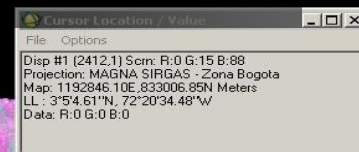
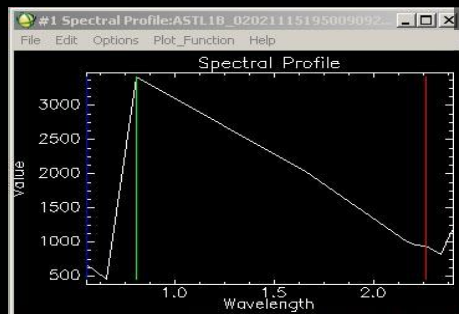
### Georeferencing



**ASTER Image  
in Magna Sirgas  
coordinates**

## ✓ Phase 2. Data Processing

### Atmospheric Correction

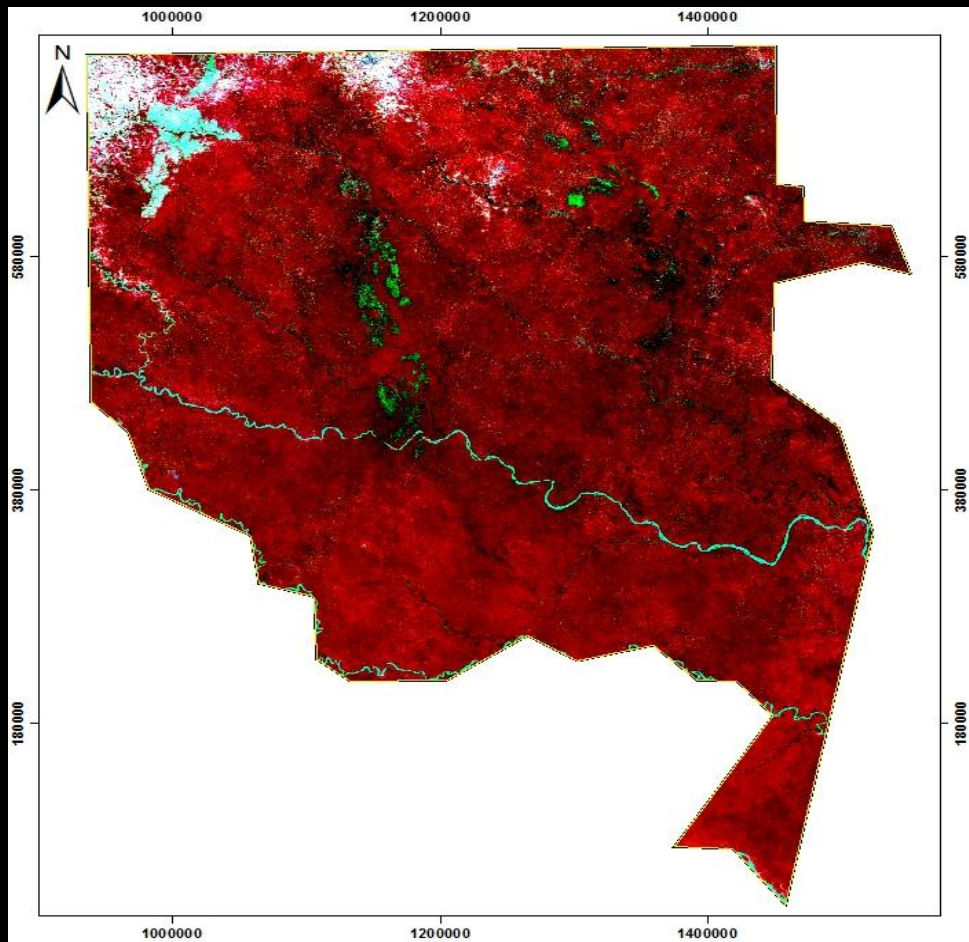


**ASTER Image  
(Reflectance)**



## ✓ Phase 2. Data Processing

### Mosaicking



**MODIS Mosaic  
R2 G4 B1**

## ✓ Phase 2. Data Processing

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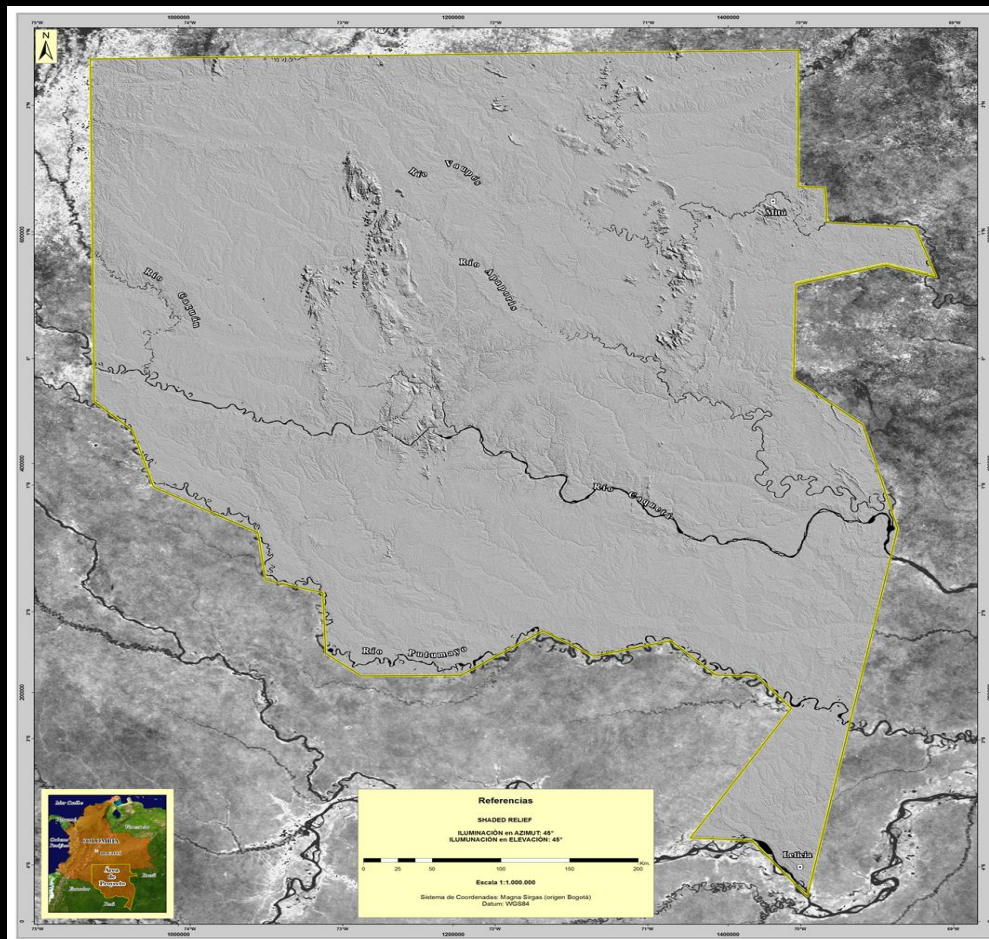
### Data Processing

- **Geological & Geobotanical Enhancements**
- **Band Ratioing**
- **Principal Components Analysis (PCAs)**
- **Structural Filtering**
- **Drainage Basins Analysis**
- **Vegetation Indexes**
  - Cellular Density (PCDR)
  - Pigmentation (PPR)
  - Photosynthetic Vigor (PVR)
  - Normalized Vegetation Index (NDVI)
  - Others
- **Mineral & Soil Indexes**
- **Thermal Products**
- **Relative Thermal Inertia**



## ✓ Phase 2. Data Processing

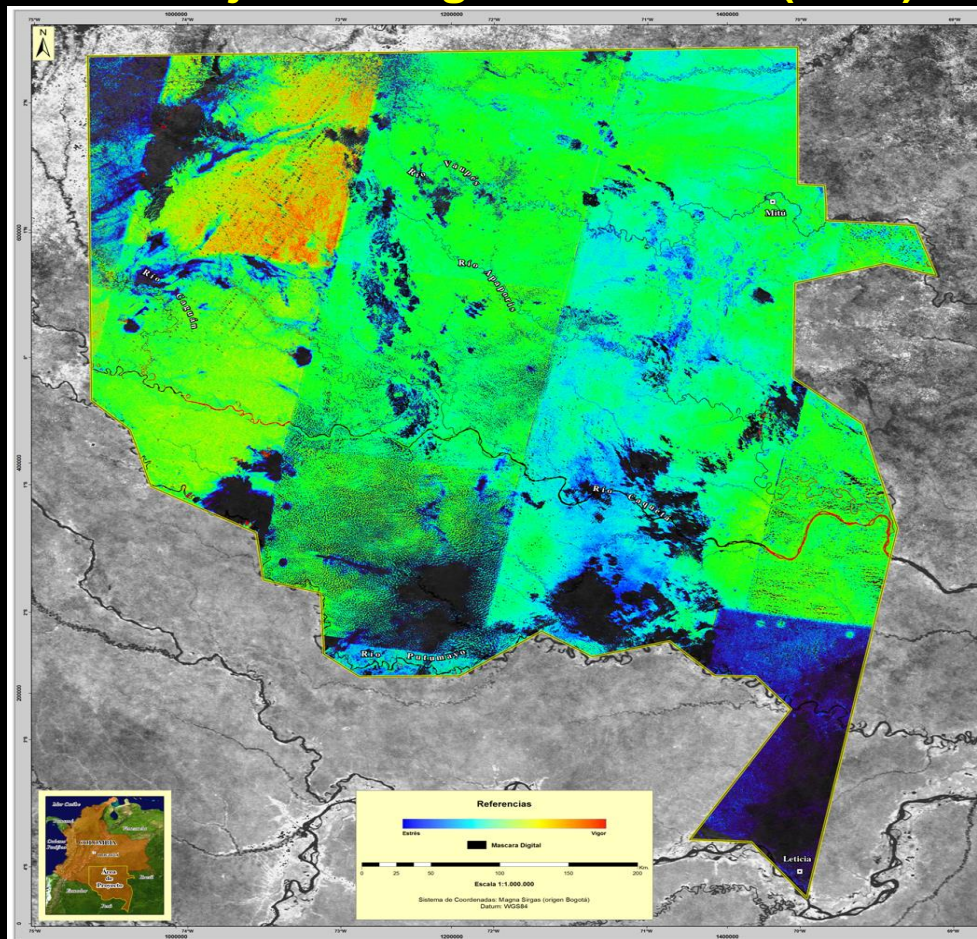
### Shaded Relief



**SRTM Mosaic  
C BAND**

## ✓ Phase 2. Data Processing

### Soil Adjusted Vegetation Index (SAVI)

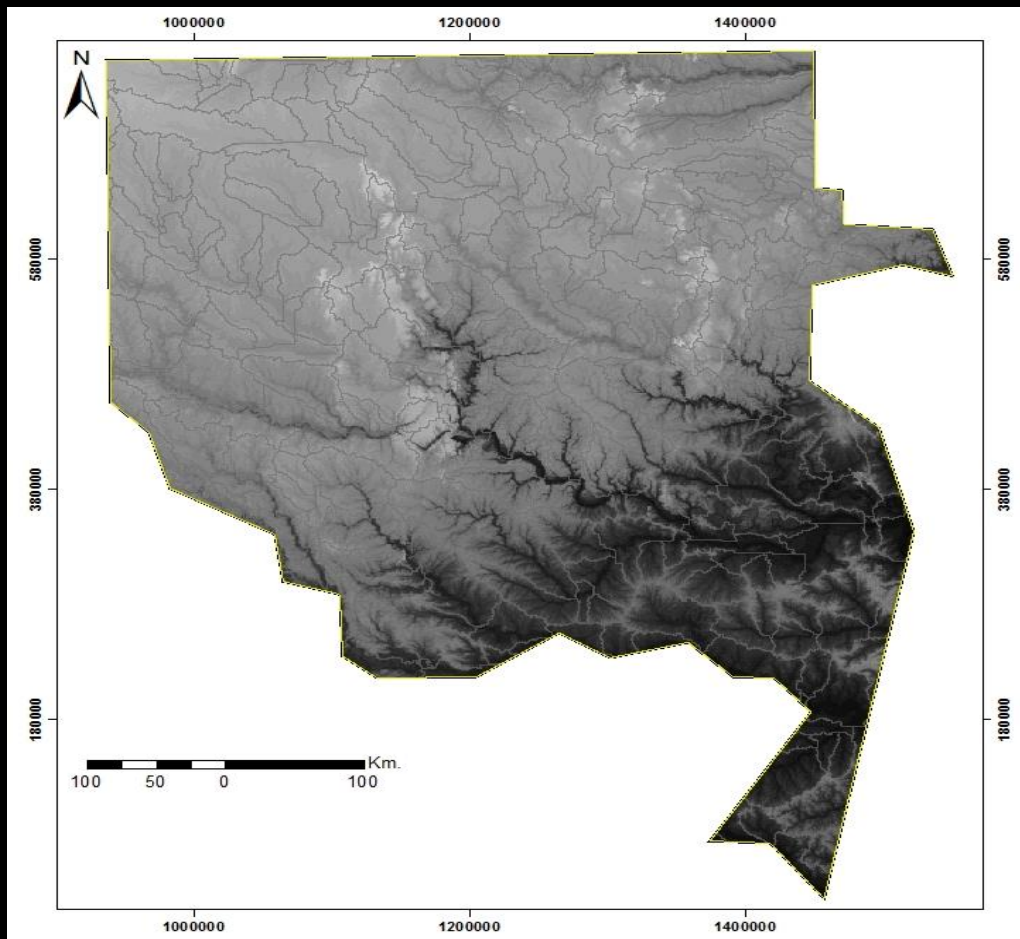


**LandSat 7 ETM+  
Mosaic**



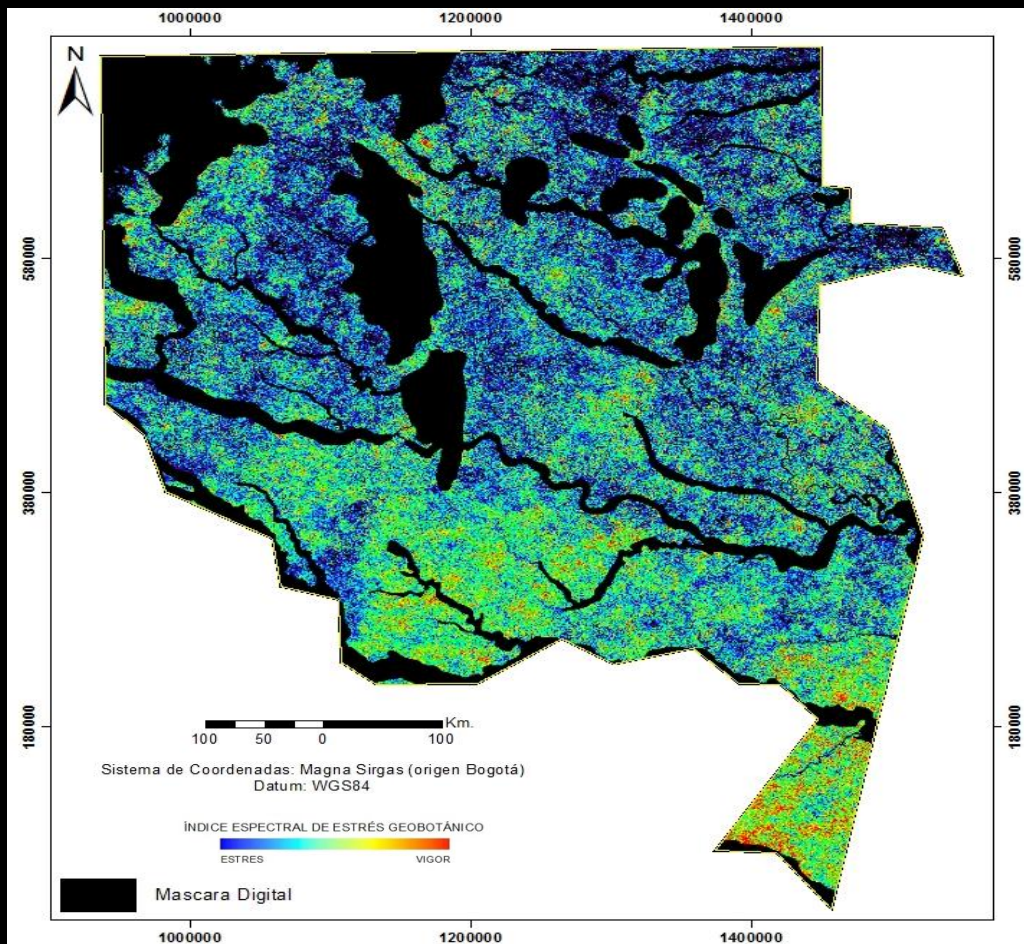
## ✓ Phase 2. Data Processing

### Drainage Basins Analysis



## ✓ Phase 2. Data Processing

### Stressed Vegetation Index

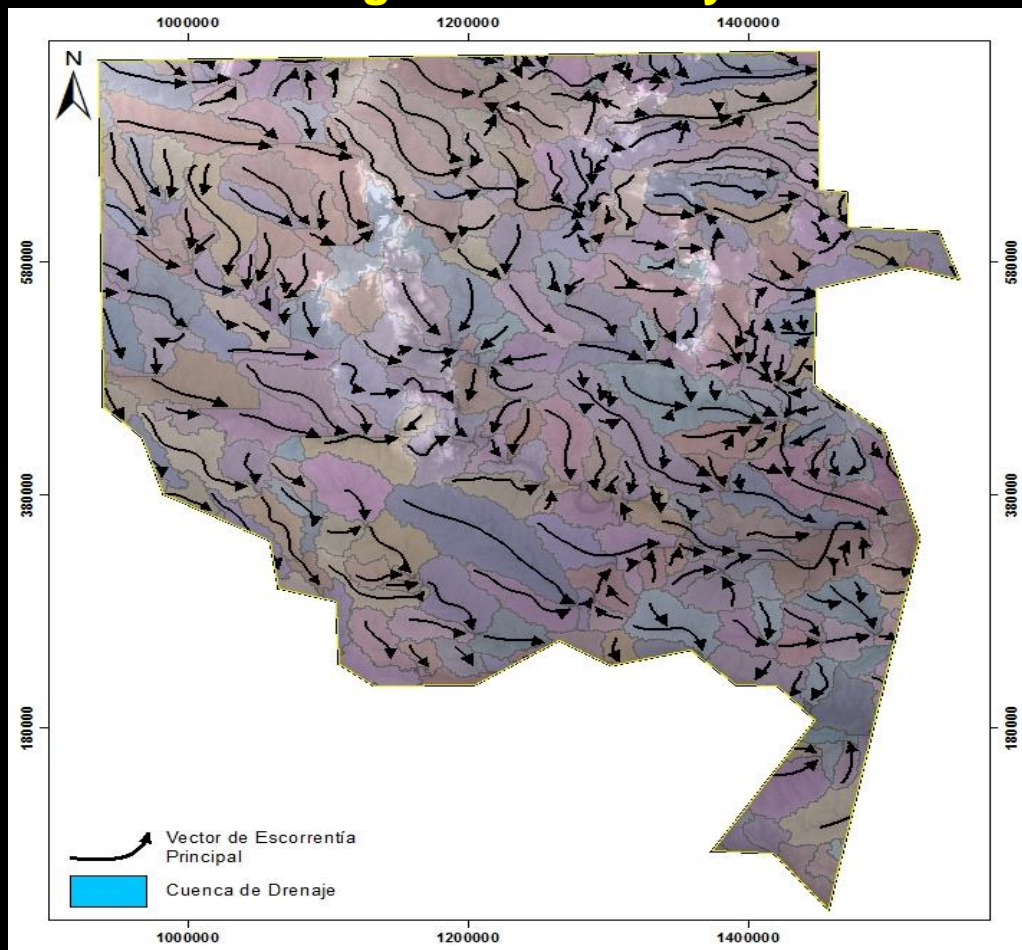


**MODIS 09A1  
Mosaic**



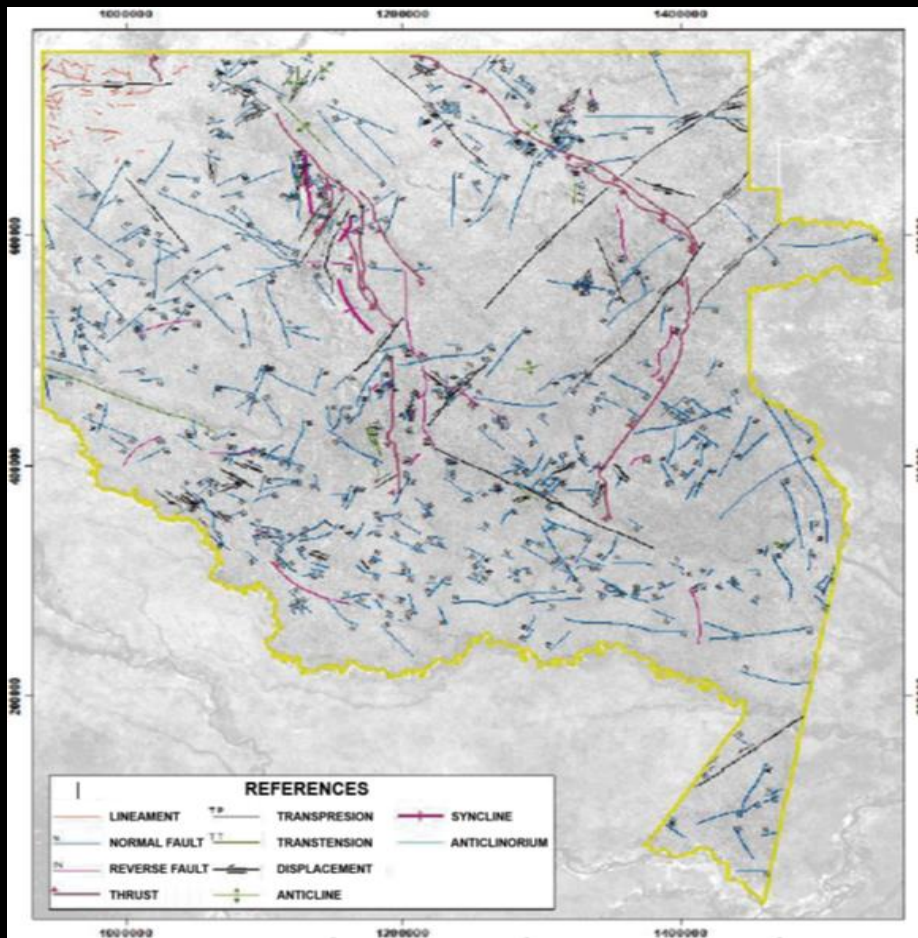
## ✓ Phase 3. Data Interpretation

### Drainage Basins Analysis



## ✓ Phase 3. Data Interpretation

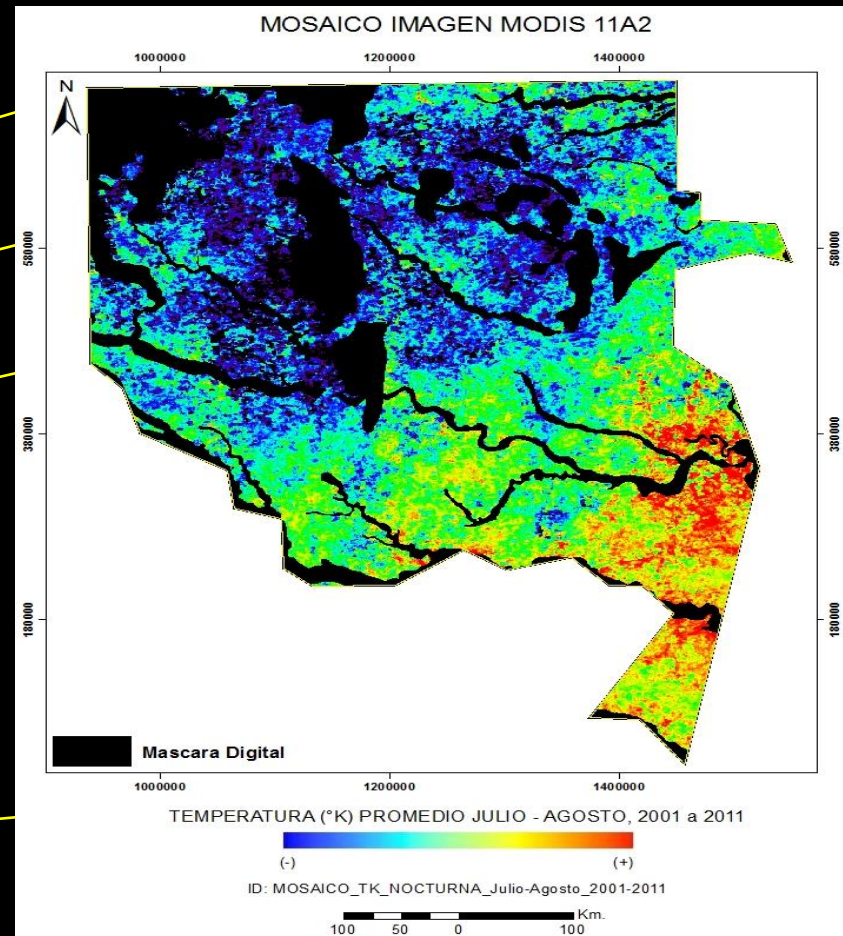
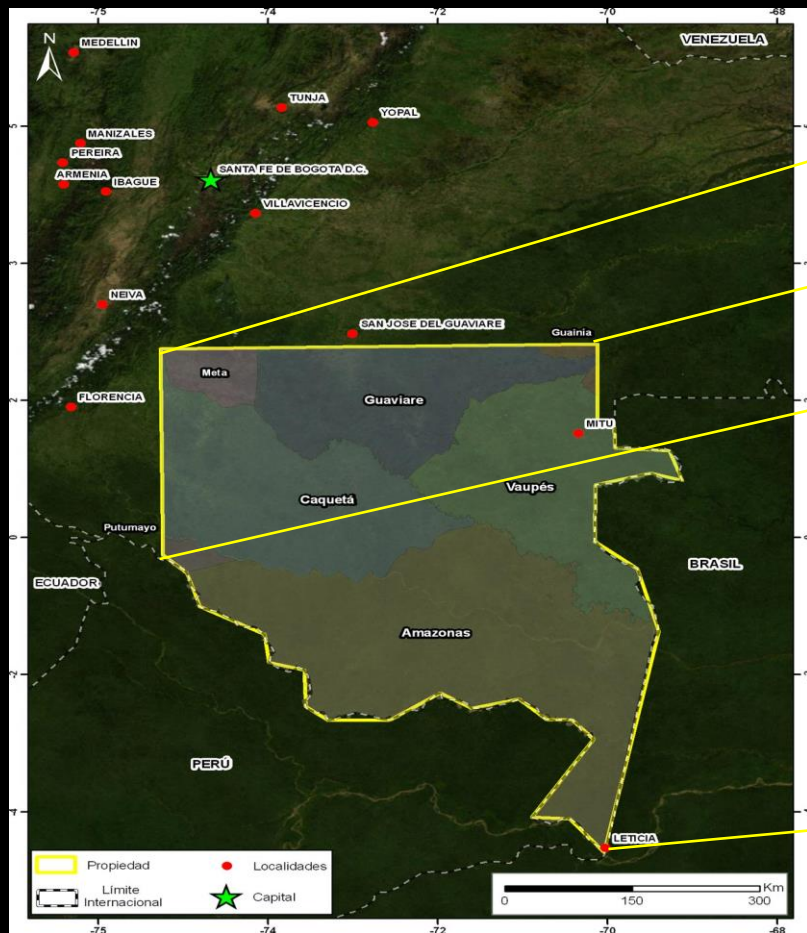
### Structural Analysis





## ✓ Phase 3. Data Interpretation




















### Thermal Anomalies

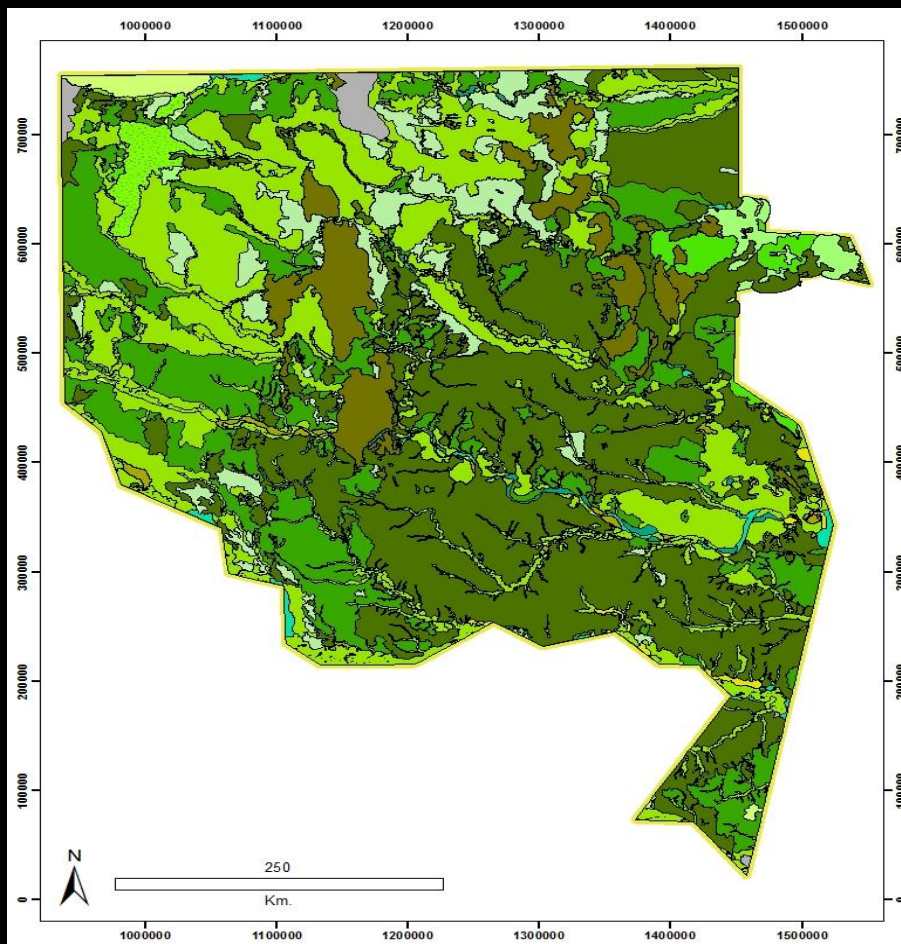


## ✓ Phase 3. Data Interpretation

### Vegetation - Type Spatial Distribution

#### Main Vegetation Types

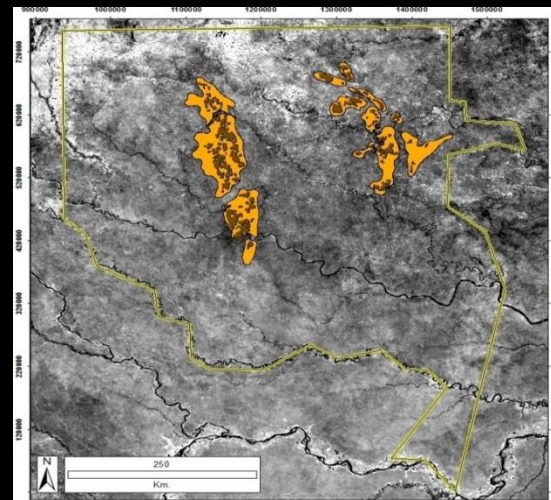
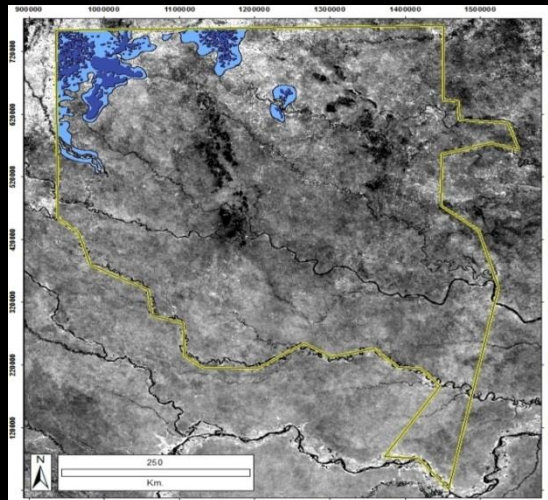
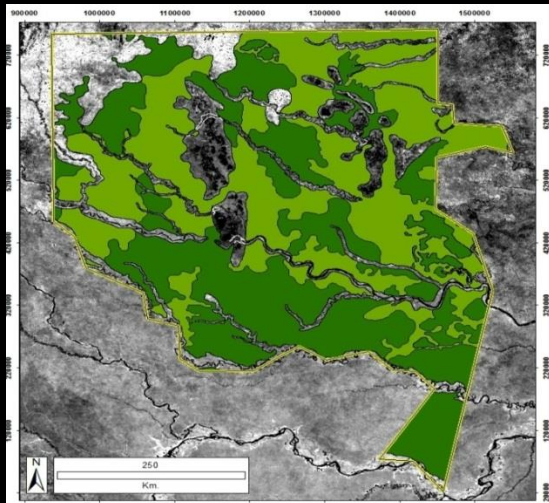
-  Bosque Alto
-  Bosque Alto-Denso de superficies disectadas
-  Bosque alto de Sabana
-  Bosque Bajo
-  Bosque Bajo de superficie de erosión plana
-  Bosque Bajo de terrazas y superficies disectadas
-  Bosque bajo de Sabana
-  Bosque de Colinas altas
-  Bosque de Terraza Baja
-  Bosque de diques naturales
-  Bosque de Vega Inundable
-  Bosque de Vega Baja permanentemente inundado
-  Sabana Arbustiva
-  Sabana Arbustiva de Superficie Disectada
-  Sabana de Gramíneas
-  Vega Alta
-  Vega Baja
-  Vega Baja/Vega Alta
-  Área con influencia humana





## ✓ Phase 3. Data Interpretation

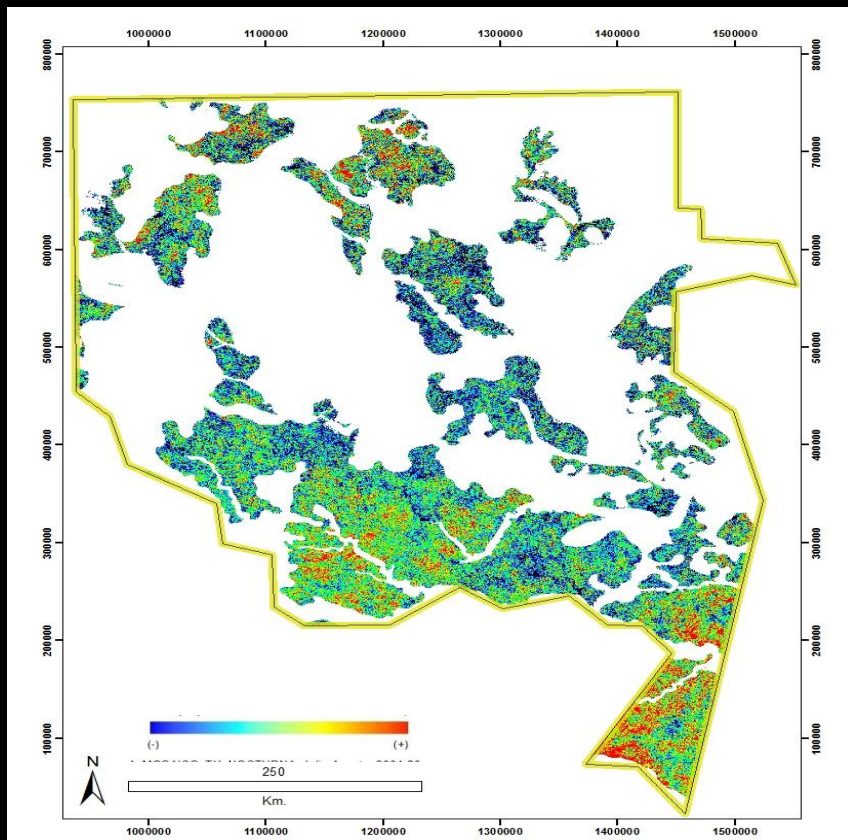
### Spectral Domains and Regions Recognition



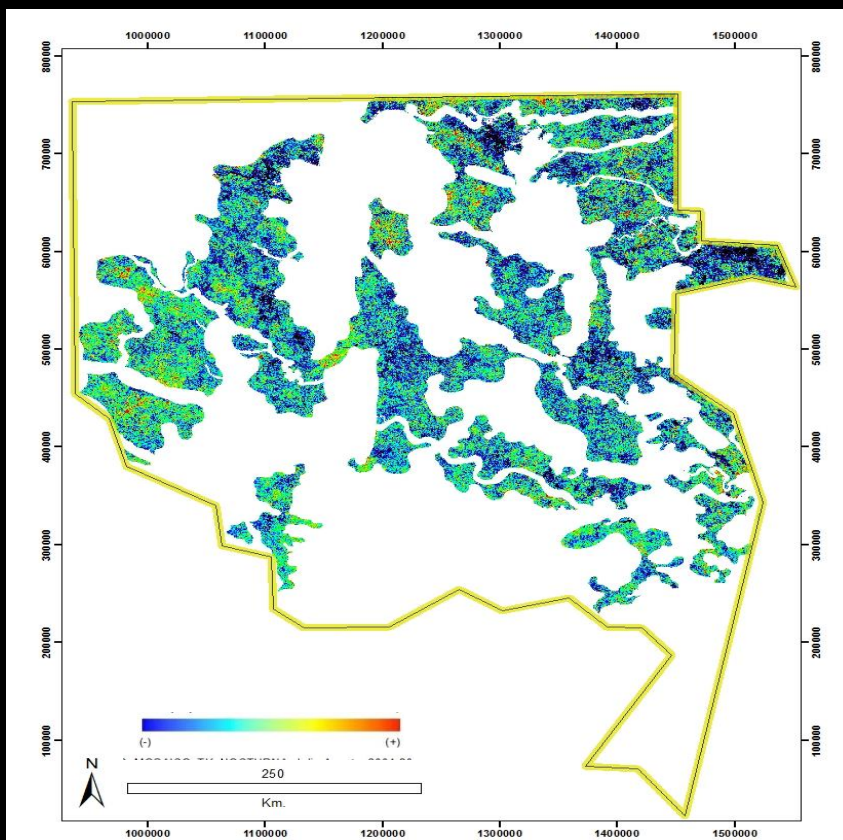
	SUP. Km2	DOMINIO	REGIÓN	SUP. Km2	SUB T. %	TOTAL %
AREA DEL PROYECTO	279.387,00	VEGETACIÓN Densa	ALTA REFLECTANCIA	107.736,00	38,6	76,7
			BAJA REFLECTANCIA	108.587,00	38,2	
		VEGETACIÓN ANTROPIZADA	PREDOMINIO DE SUELO	6.008,00	2,2	6,5
			PREDOMINIO DE VEGETACIÓN	12.029,00	4,3	
		VEGETACIÓN RALA	PREDOMINIO DE AFLORAMIENTO	3.795,00	1,4	9,6
			PREDOMINIO DE VEGETACIÓN	23.134,00	8,3	
		INFLUENCIA DE CAUCES - ZONAS NO CLASIFICADAS		20.078,00		

## ✓ Phase 3. Data Interpretation

### Stressed Vegetation Index



**Dense Vegetation Domain  
High Reflectance Region**



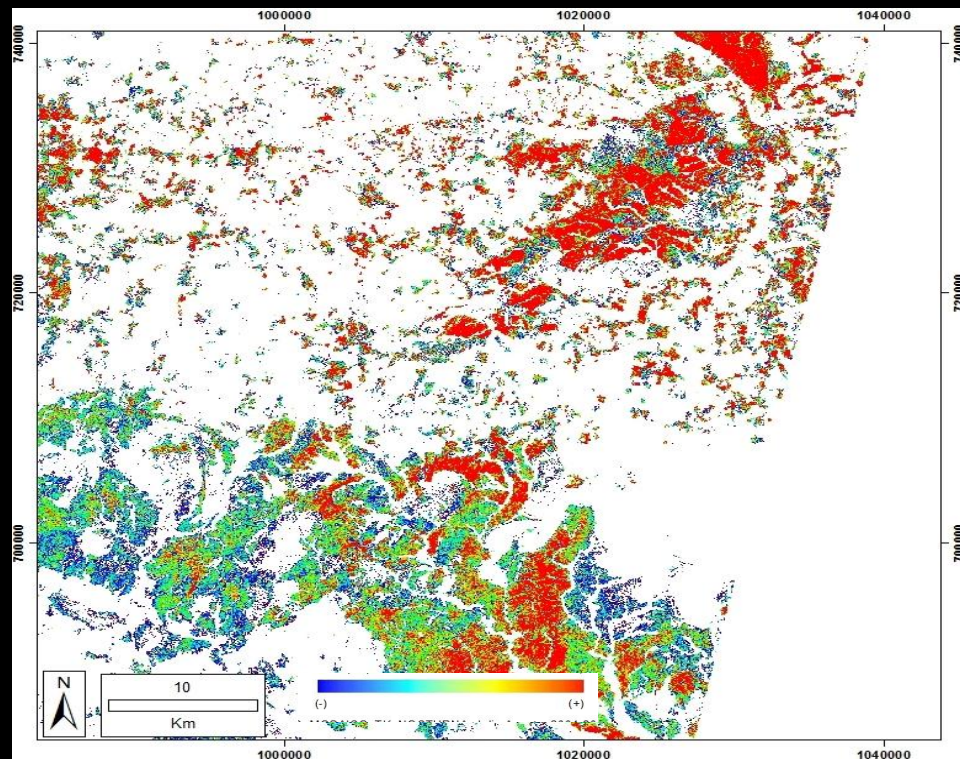
**Dense Vegetation Domain  
Low Reflectance Region**



## ✓ Phase 3. Data Interpretation

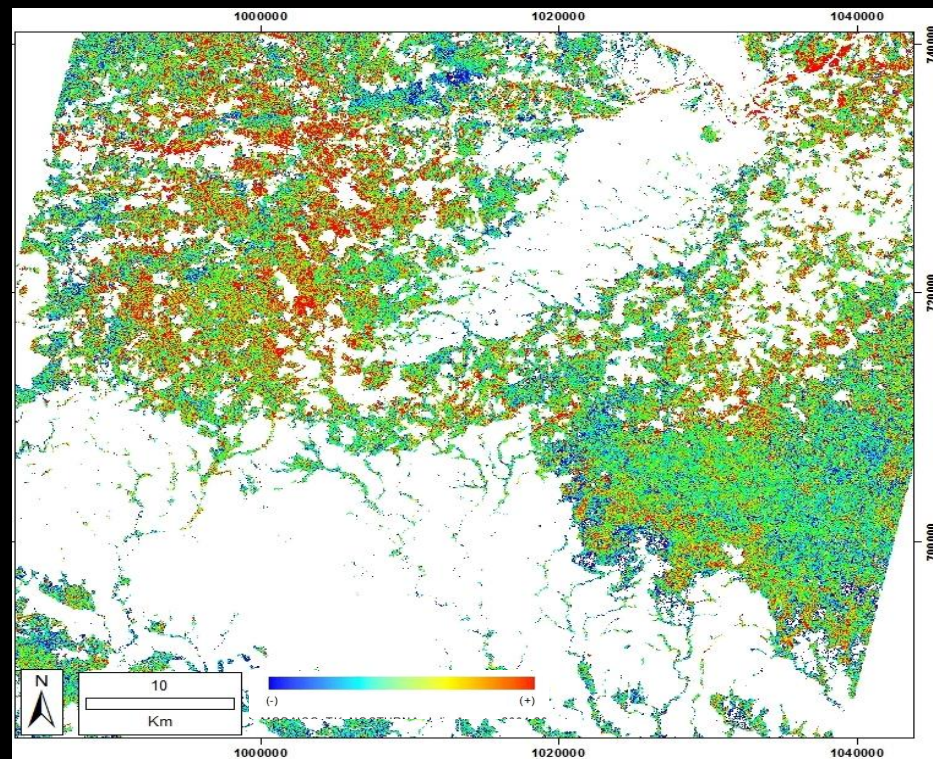
### SPECTRAL INDEXES

#### Bleaching Index



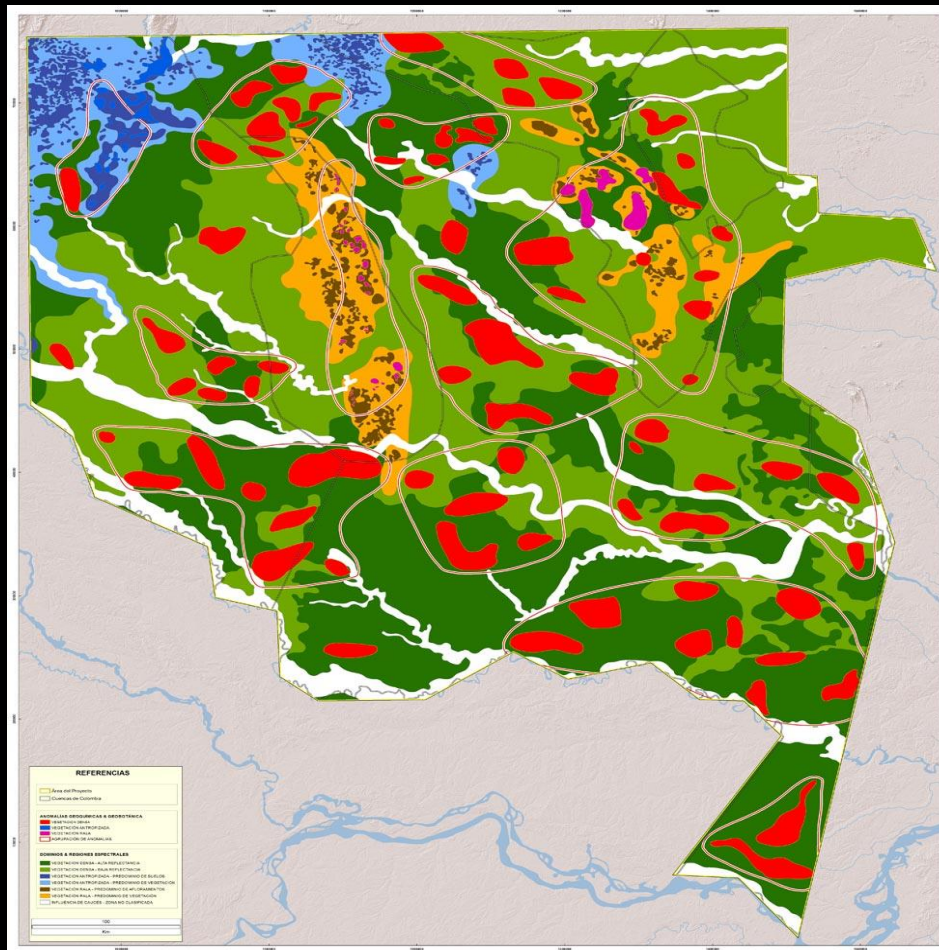
**Antropic Vegetation Domain**  
**Soil Dominated Region**

#### Stressed Vegetation Index



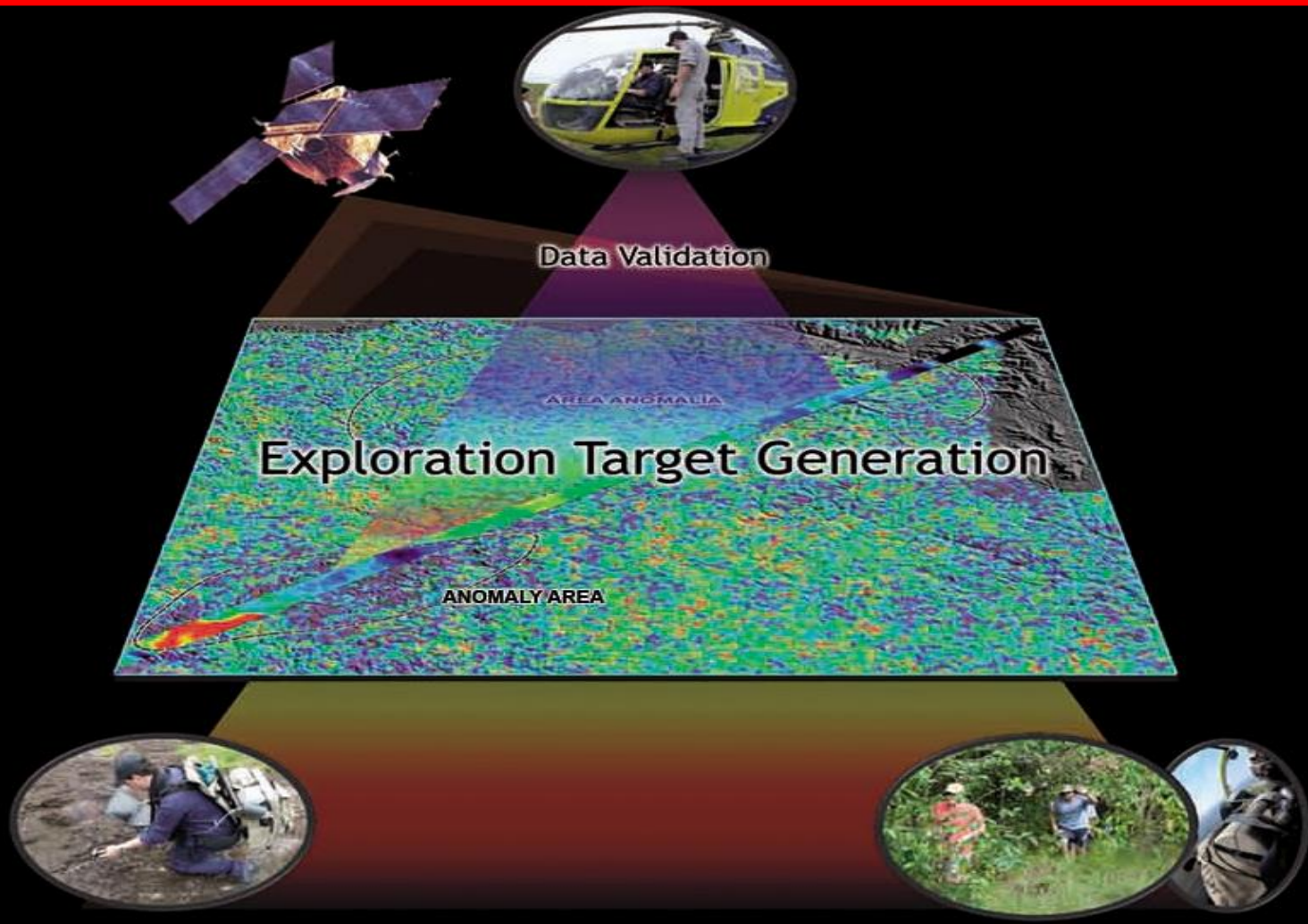
**Antropic Vegetation Domain**  
**Vegetation Dominated Region**





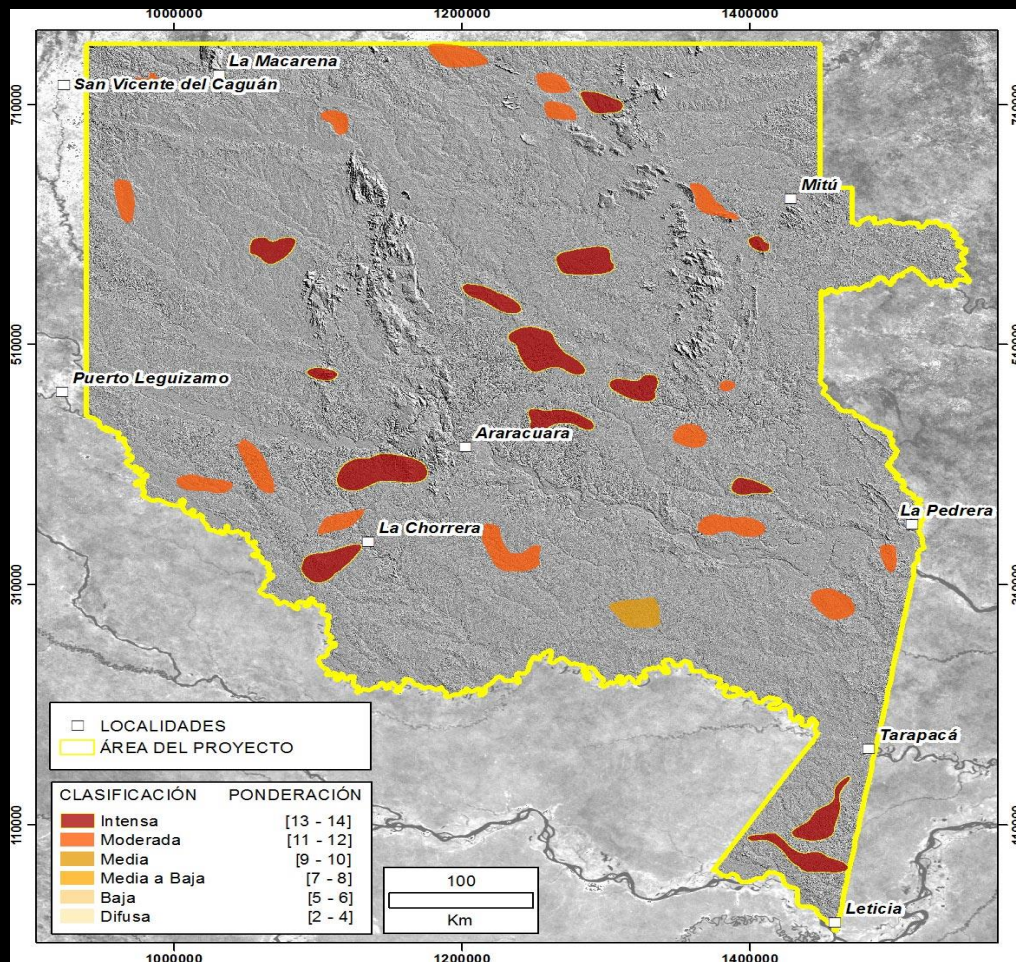


## ✓ Phase 4. Airborne & Field Hyperspectral Validation



# ✓ Phase 4. Airborne & Field Hyperspectral Validation

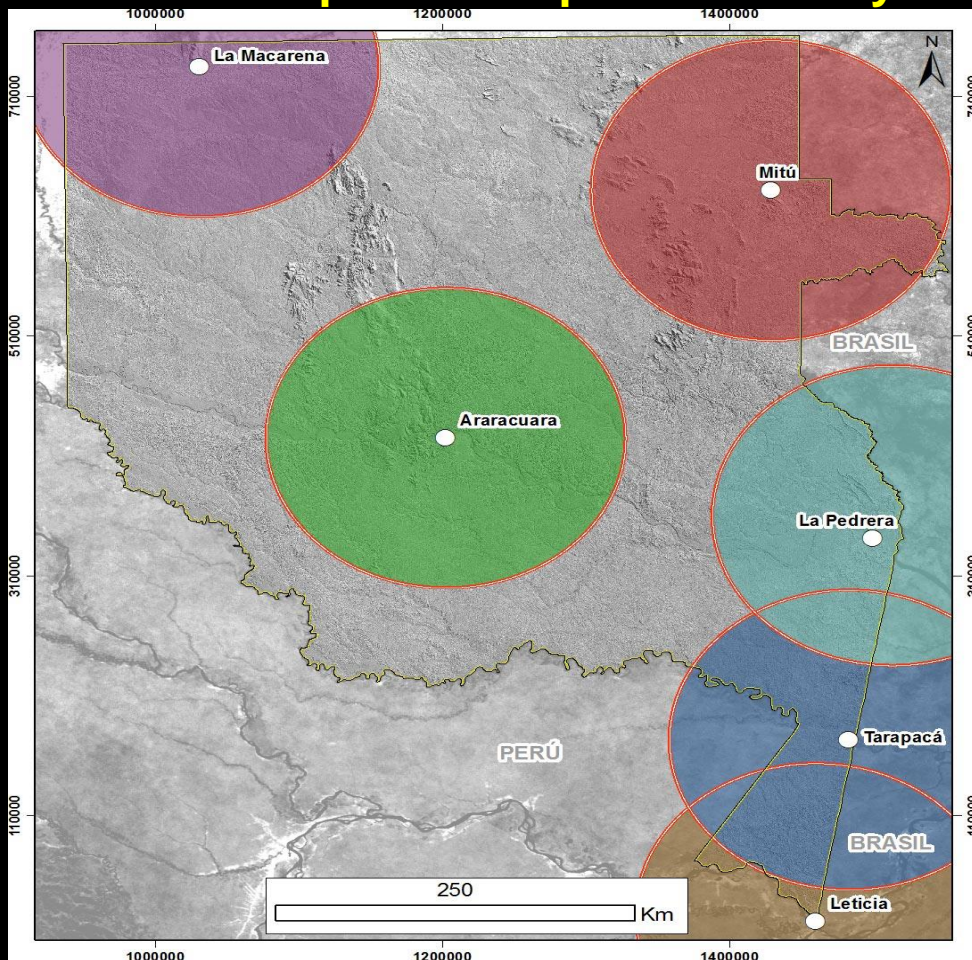
## Selection of Areas of Interest for Field Validation





## ✓ Phase 4. Airborne & Field Hyperspectral Validation

### Base Camps / Helicopter Autonomy





## ✓ Phase 4. Airborne & Field Hyperspectral Validation

### Airborne & Field Hyperspectral Survey



## ✓ Phase 4. Airborne & Field Hyperspectral Validation

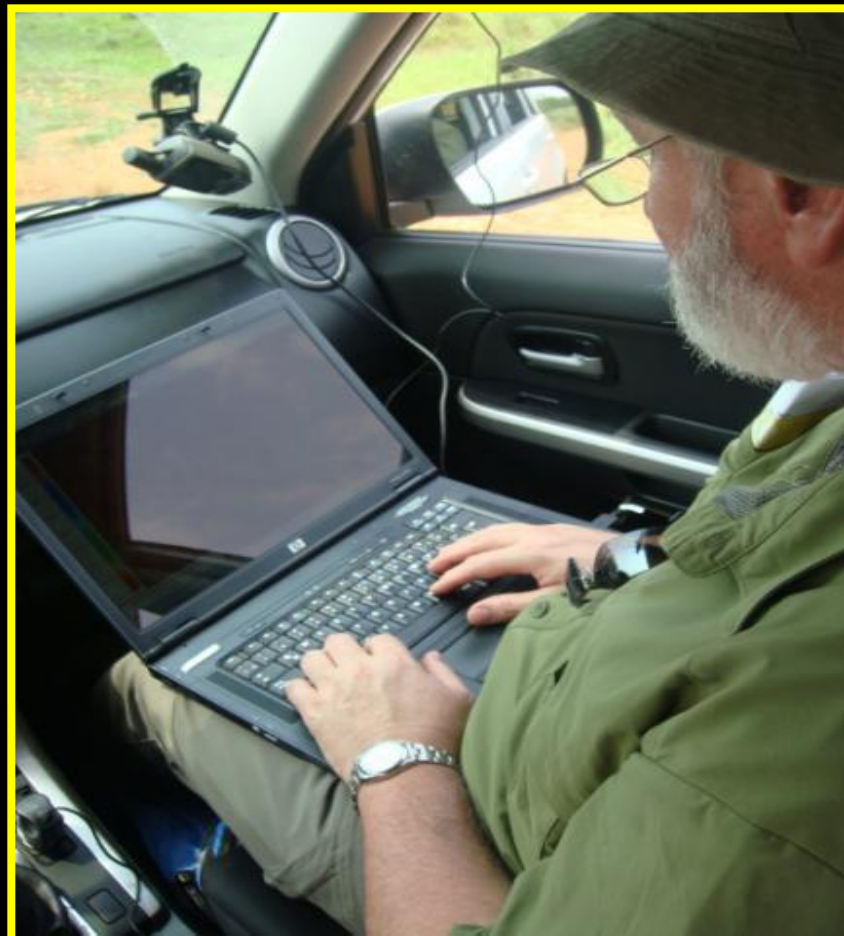
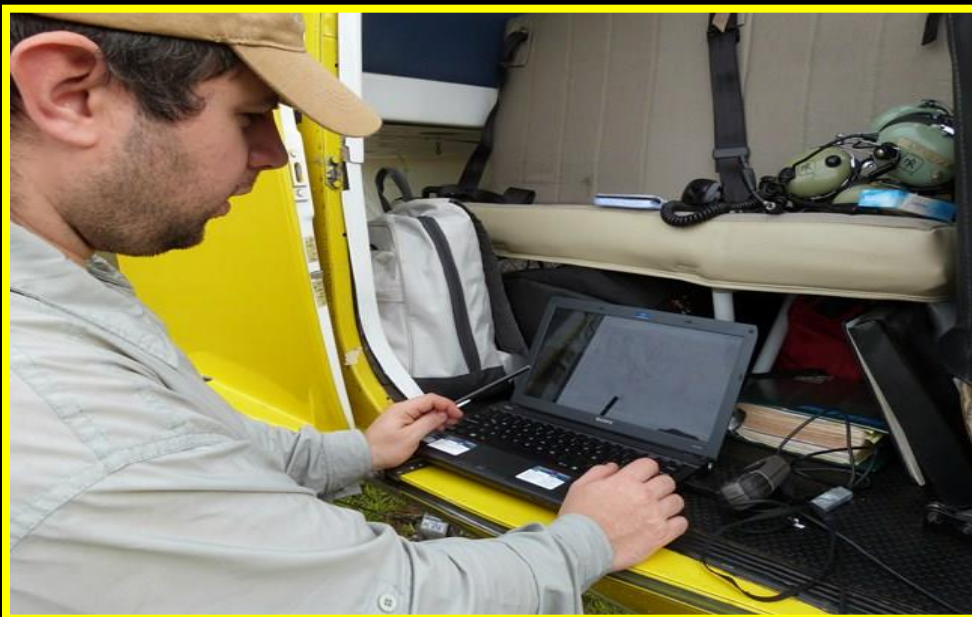
### Airborne & Field Hyperspectral Survey





## ✓ Phase 4. Airborne & Field Hyperspectral Validation

### Airborne & Field Hyperspectral Survey

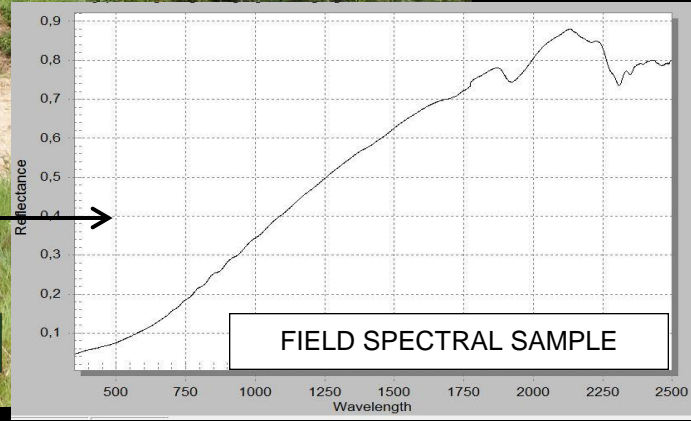
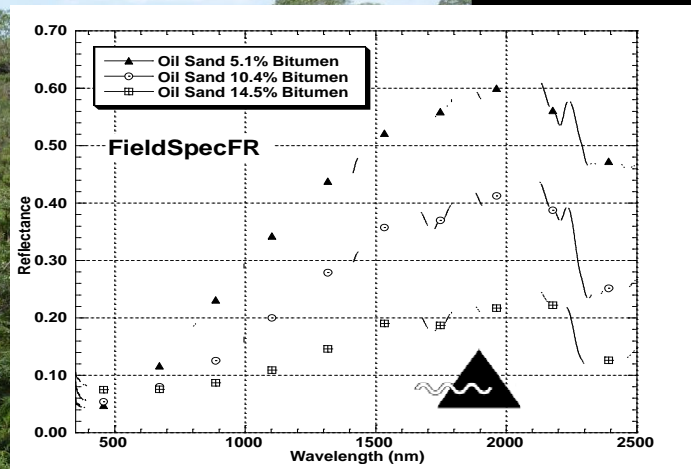


# ✓ Phase 4. Airborne & Field Hyperspectral Validation

## Airborne & Field Hyperspectral Survey



**Oil- Seep Recognition**





## ✓ Phase 4. Airborne & Field Hyperspectral Validation

### Airborne & Field Hyperspectral Survey





## ✓ Phase 4. Airborne & Field Hyperspectral Validation

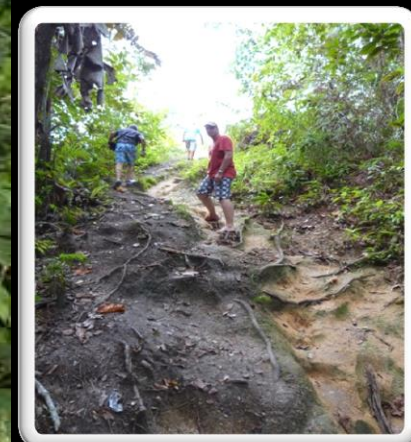
### Airborne & Field Hyperspectral Survey





## ✓ Phase 4. Field Validation

### Geochemical Survey





## ✓ Phase 4. Field Validation

### Geochemical Survey

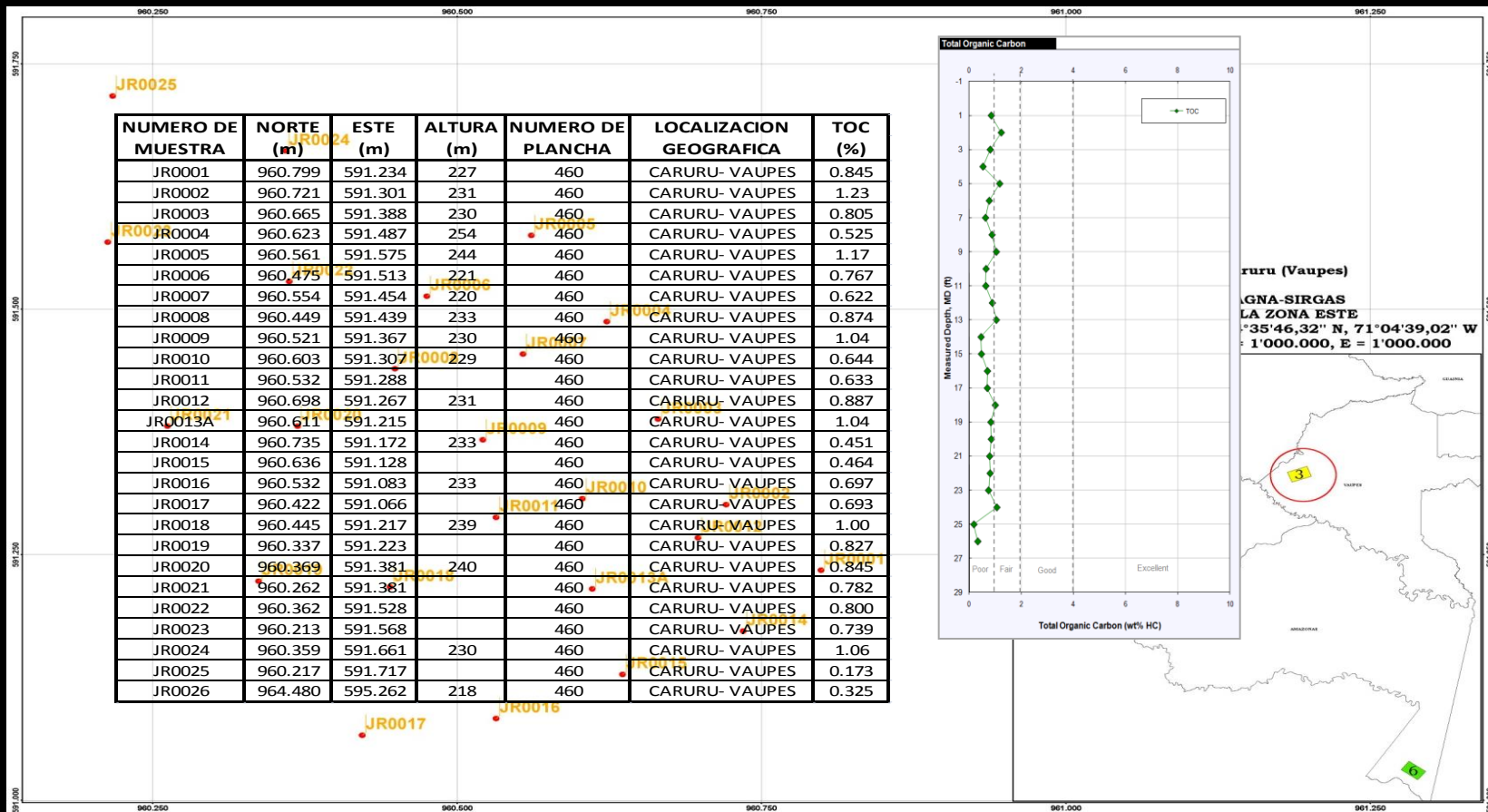
#### ❖ DETERMINATION OF HYDROCARBON PRESENCE AND CONTENT IN SOILS

- Total Organic Content (% TOC)
- Pyrolysis *Rock Eval*
  - Types of Organic Mater
  - Degree of Thermal Evolution
  - Hydrocarbon Generator Potential



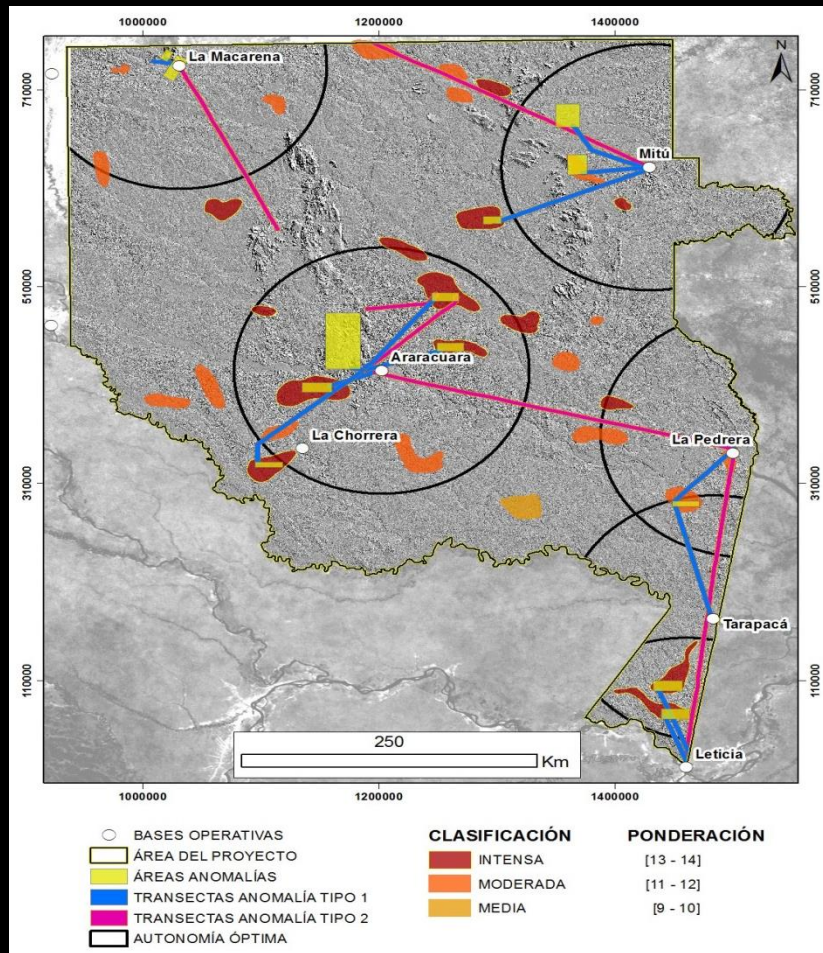
## ✓ Phase 4. Field Validation

## Geochemical Survey



# ✓ Phase 4. Airborne & Field Hyperspectral Validation

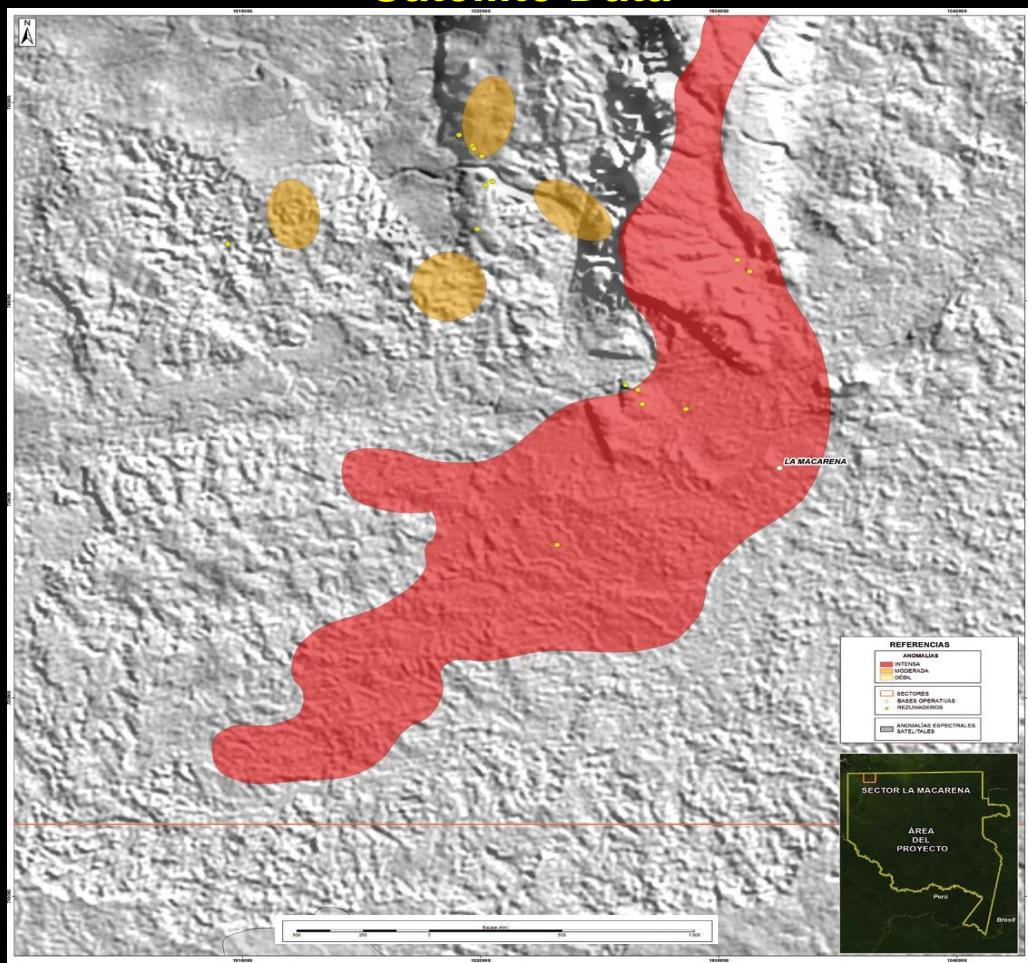
## Airborne & Field Hyperspectral Survey





## ✓ Phase 5. Identification of Target Areas

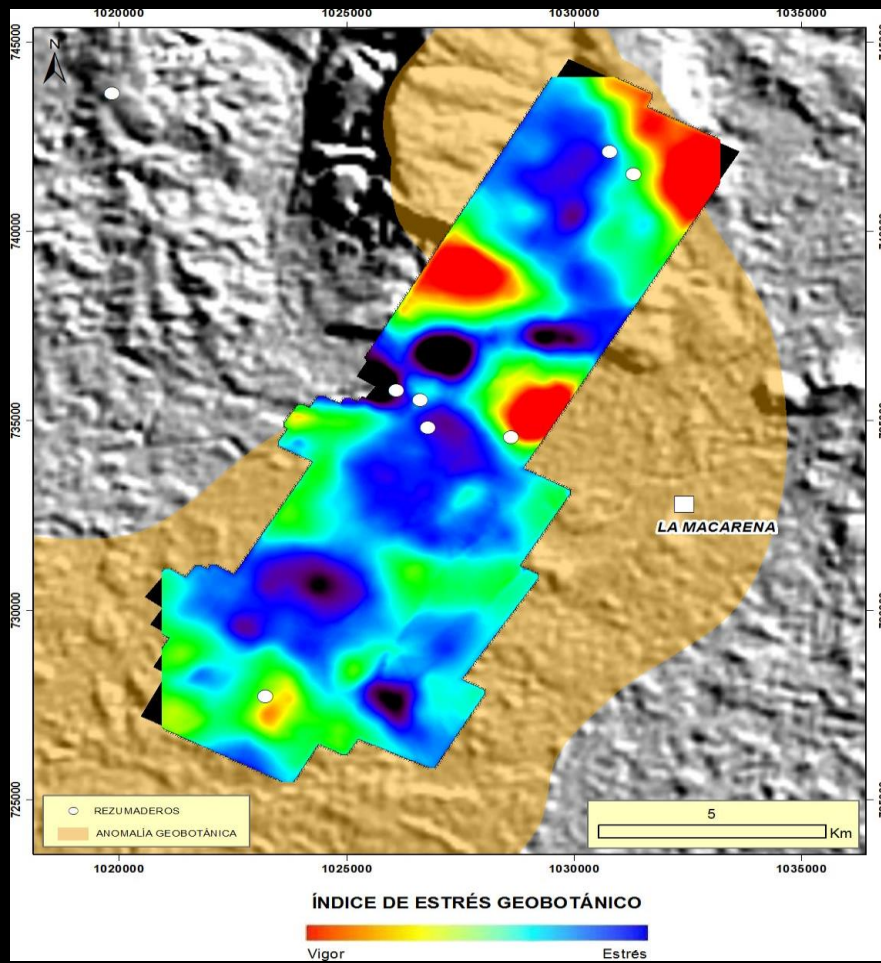
### Satellite Data



**La Macarena Sector**

## ✓ Phase 5. Identification of Target Areas

### Satellite, Airborne & Field Data

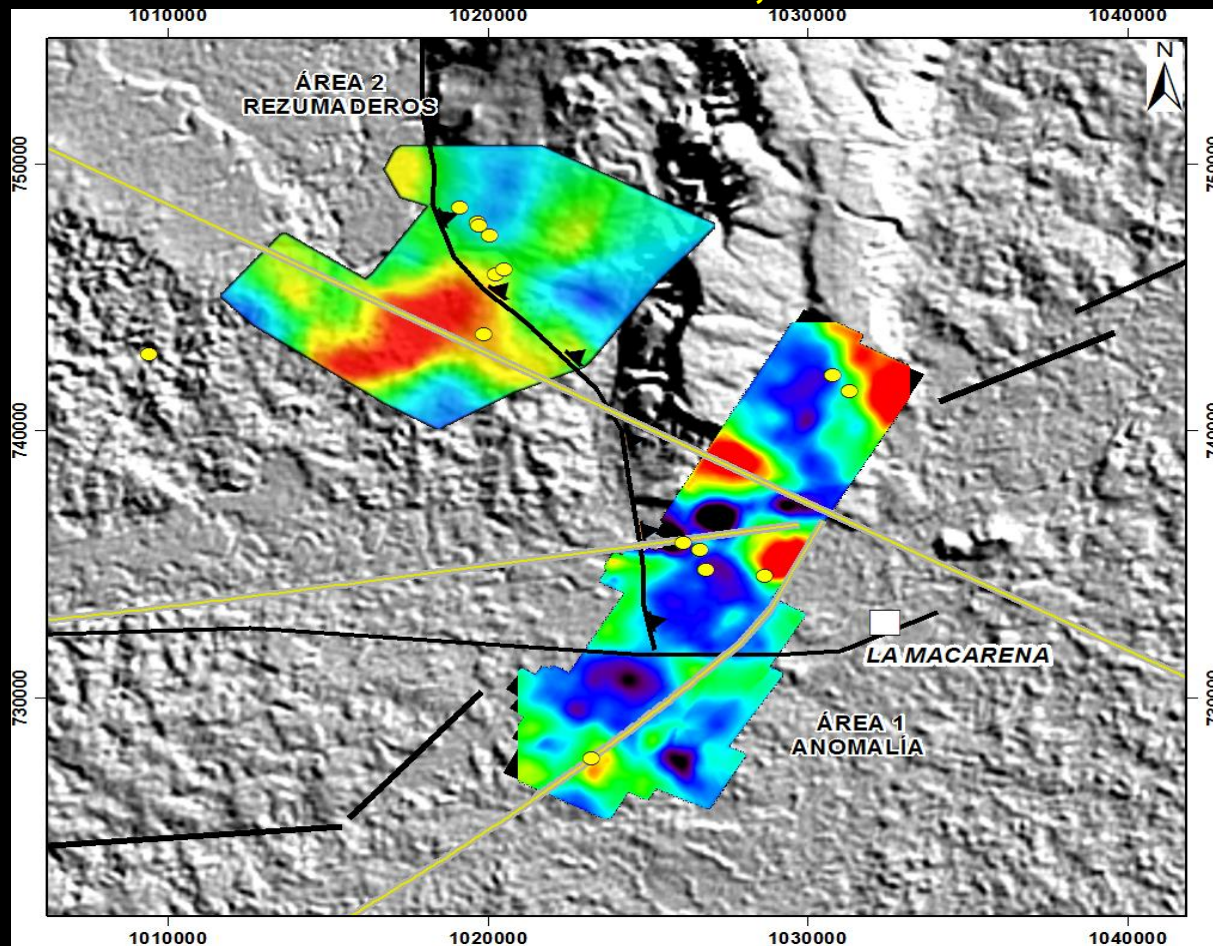


**La Macarena Sector:  
Area I**



## ✓ Phase 5. Identification of Target Areas

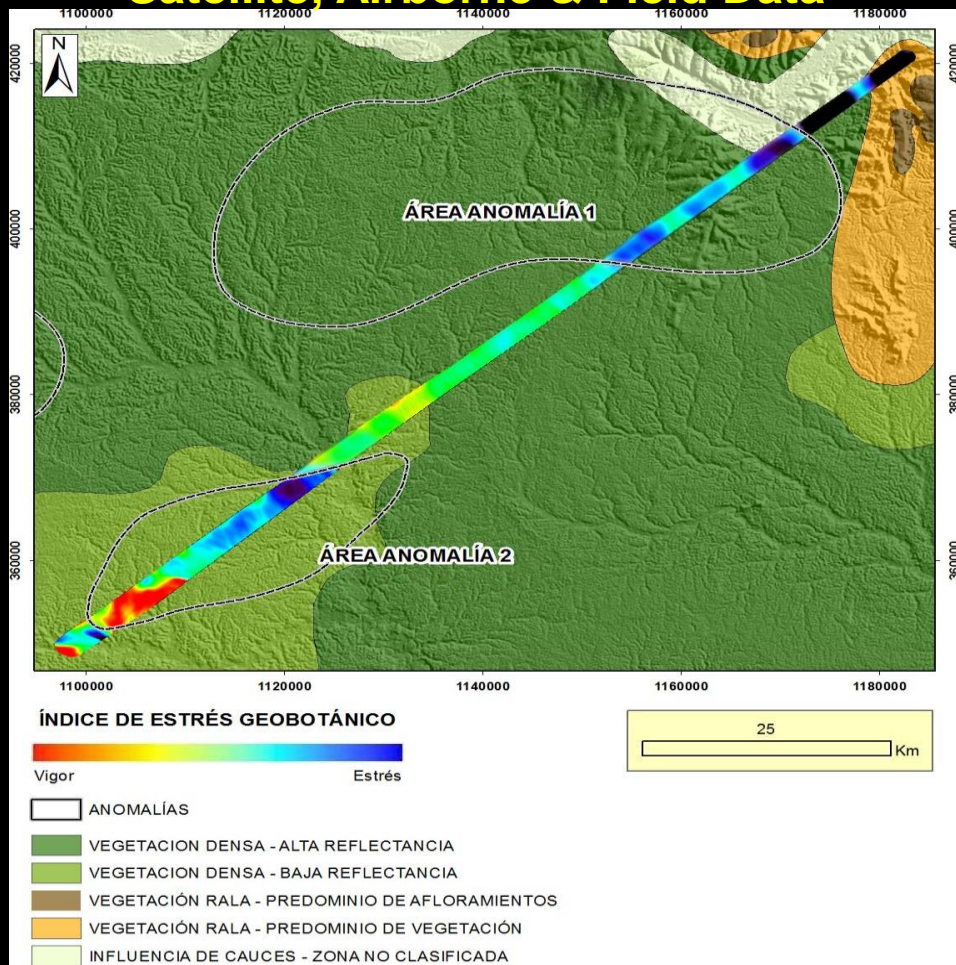
### Satellite, Airborne & Field Data



**La Macarena Sector:  
Area I**

# ✓ Phase 5. Identification of Target Areas

## Satellite, Airborne & Field Data

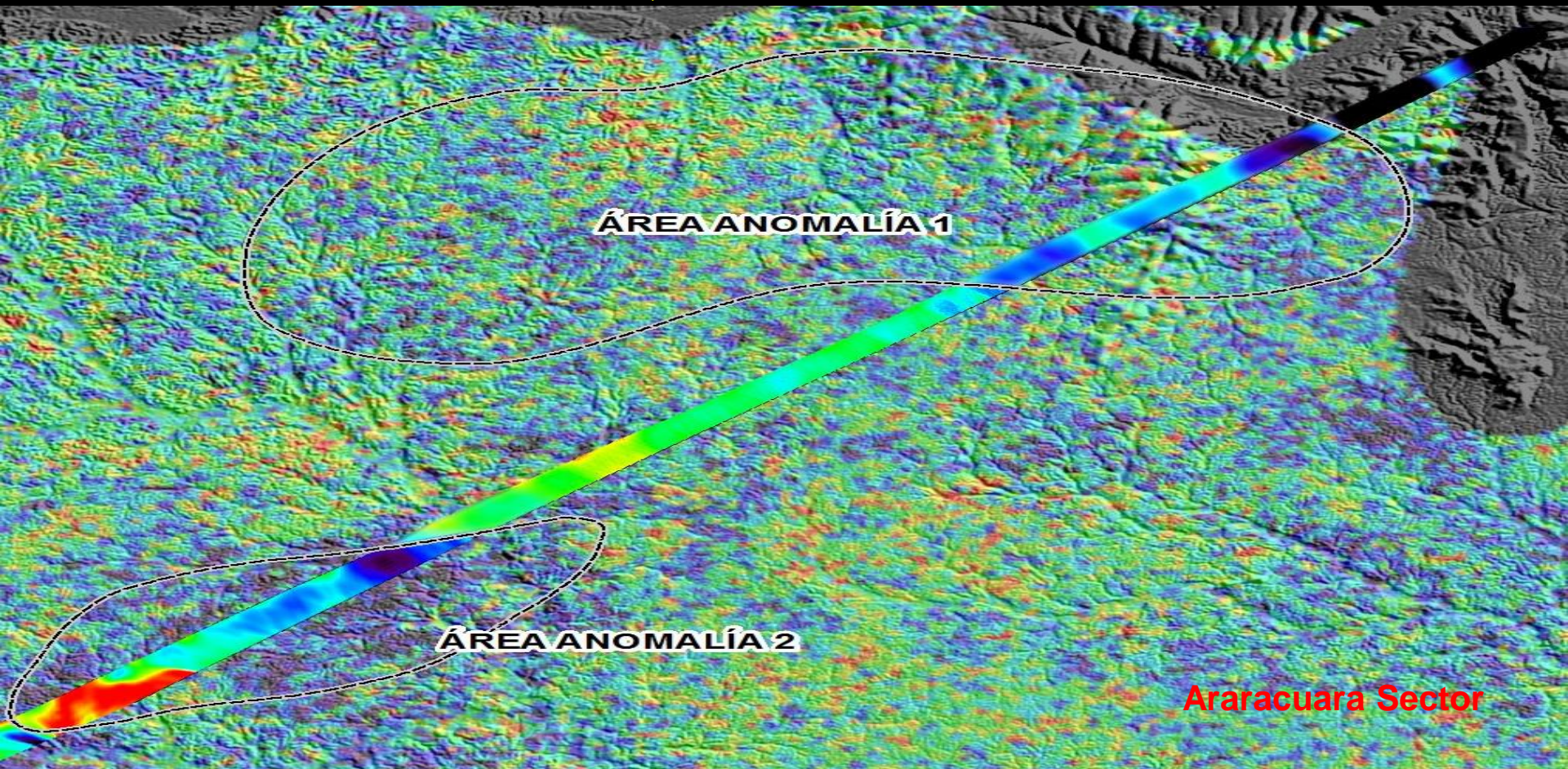


**Araracuara Sector**



## ✓ Phase 5. Identification of Target Areas

### Satellite, Airborne & Field Data



**Araracuara Sector**



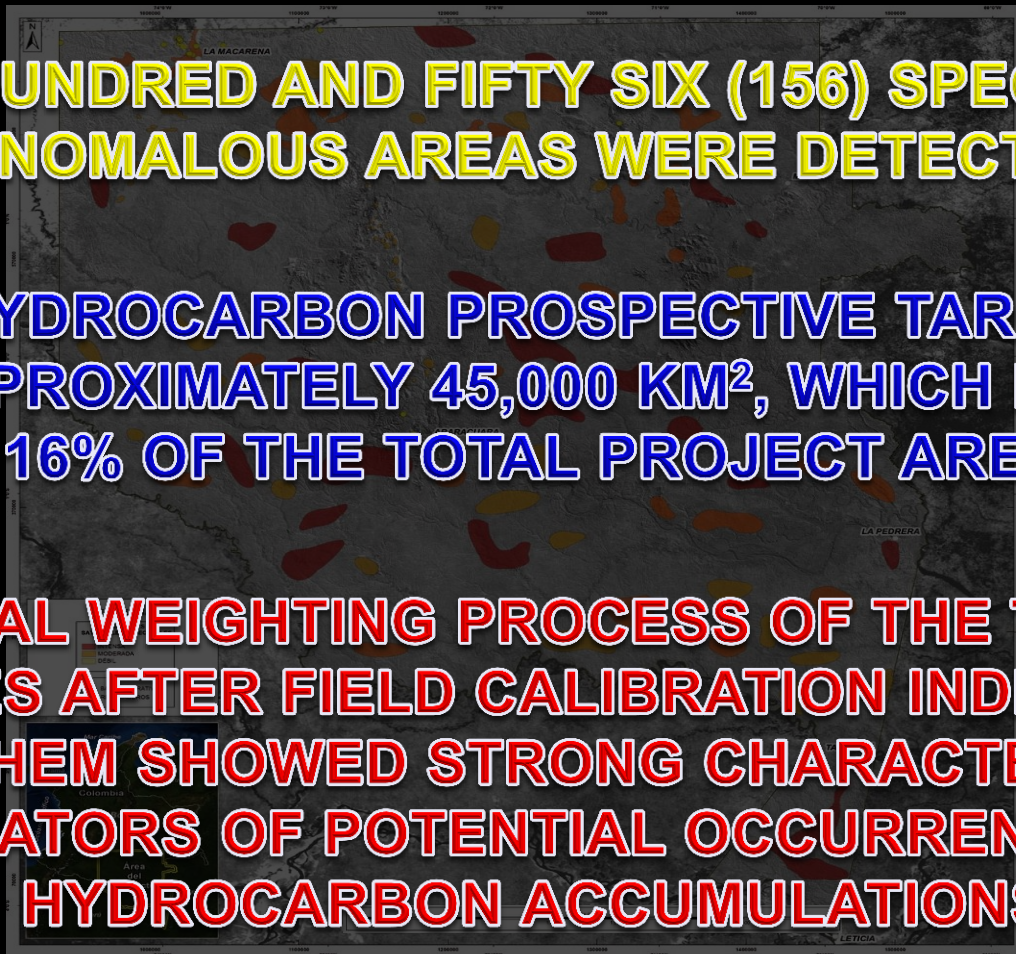
## ✓ Phase 5. Identification of Potential Hydrocarbon Target Areas

### STUDY RESULTS

❖ **ONE HUNDRED AND FIFTY SIX (156) SPECTRALLY ANOMALOUS AREAS WERE DETECTED.**

❖ **THESE HYDROCARBON PROSPECTIVE TARGET AREAS COVER APPROXIMATELY 45,000 KM<sup>2</sup>, WHICH REPRESENTS 16% OF THE TOTAL PROJECT AREA.**

❖ **THE FINAL WEIGHTING PROCESS OF THE TARGETED ANOMALIES AFTER FIELD CALIBRATION INDICATED THAT 12% OF THEM SHOWED STRONG CHARACTERISTICS AS INDICATORS OF POTENTIAL OCCURRENCES OF HYDROCARBON ACCUMULATIONS.**





# **BENEFITS**

- ❖ **Adquisition of Data**
- ❖ **Re-interpretation of Existing Information**
- ❖ **Enhancement of the Geological Knowledge of the Region**

## **Allowed the**

- **Identification of Hydrocarbon Potential Target Areas in the Vaupés – Amazonas and Caguán – Putumayo Basins**
- **Generation of Specific Technical Information for such Areas to be applied in their Future Promotion and Exploration Contracts**
- **Strategic Planning for National and Foreign Investment in these Remote Sectors of the Country.**



# ADDITIONAL BENEFITS

**The Acquired Data can also be applied in:**

- ✓ **Environmental Studies**
- ✓ **Land Use Maps**
- ✓ **Generation of Sensibility Maps**
- ✓ **Multi- Temporal Studies**
- ✓ **Infraestructure Planning**



**THANK YOU FOR YOUR  
ATTENTION !**

