# Technical Proof Document

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## Introduction

This report outlines the source, reliability, and methodology behind the Earth Observation data being used for your analysis. The data is acquired from the **Sentinel-2 L2A satellite collection**. It includes details of data acquisition frequency, processing methodology, and the scientific foundation of the vegetation and water quality indicators derived.

User must understand the methodology how the comparison is made. This expectation is set in the "Important Note on Accuracy of Values" section.

Two parts to this report:

1. Client friendly explanation of the report
2. Technical Proof Document: Sentinel-2 L2A Data

As name says, first part is for non-technical explanation and details are covered in second part.

## Important Note on Accuracy of Values

When working with satellite imagery (such as Sentinel-2 L2A from **Copernicus Sentinel Program**), it is essential to clarify how the results are derived:

1. **Values are Not Exact Physical Measurements**
    - The outputs you see in the report (e.g., NDVI, NDWI, NDBI, other vegetation/water/urban indicators) are **indexes** derived from mathematical formulas applied to satellite imagery bands (e.g.,

Red, Green, Blue, Near-Infrared, Shortwave Infrared).

- These values are **relative indicators** rather than exact field measurements (e.g., soil moisture, biomass, chlorophyll, or crop yield).

2. **How These Indexes Are Calculated**
   - Each index is a **ratio or difference** between different spectral bands. For example:
     - **NDVI (Normalized Difference Vegetation Index):**
       $NDVI = \frac{(NIR - Red)}{(NIR + Red)}$
       This highlights green vegetation. High NDVI means healthy vegetation, low NDVI indicates stressed vegetation or non-vegetation.
     - **NDWI (Normalized Difference Water Index):**
       $NDWI = \frac{(Green - NIR)}{(Green + NIR)}$
       This helps in detecting water bodies.
     - **NDBI (Normalized Difference Built-up Index):**
       $NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$
       Useful for identifying urban or built-up areas.
   - These ratios are **scientifically proven indicators** widely used in research and industry.
3. **From Indexes to Real-World Meaning**
   - By themselves, these indexes are **dimensionless numbers** (ranging between -1 and +1, depending on the index).
   - To **map these indexes to real-world values** (e.g., crop yield, vegetation density, water stress, soil quality), scientific calibration and ground-truthing

are required.
    - For example, researchers may collect **field survey data** (actual soil moisture or crop height) and then establish **statistical models** correlating NDVI values to those measurements.
4. **Why This Method Works**
    - Satellite images provide **consistent, repeatable, and large-scale observations** over time.
    - By comparing imagery **across dates**, we can identify **changes and trends** (growth, decline, stress, water coverage).
    - This allows us to make **relative decisions**:
        - Which area has more vegetation health compared to others?
        - Which region shows signs of urban expansion?
        - Which season shows higher water coverage?
5. **Client Value Proposition**
    - Even though the values are not exact physical readings, this method provides:
        - **Scalable insights** across large areas.
        - **Historical analysis** (backward-looking trends from 2015 onwards).
        - **Near real-time monitoring** (images updated every 5 days).
        - **Decision support** for agriculture, urban planning, water management, and environment monitoring.

# 📘 Client-Friendly Explanation of the Report

## 1. Input Land Dimensions

These are the basic details about the land parcel being monitored. They help uniquely identify and locate the area of interest.

- **lp_no** → Just a serial number to keep track of each entry.
- **extent_ac** → The total land area measured in acres. Larger areas may include mixed land uses, while smaller areas are more specific.
- **POINT_ID** → A unique code given to the parcel for tracking across reports.
- **EASTING-X / NORTHING-Y** → Technical map coordinates that precisely locate your land on Earth. Used by GIS systems.
- **LATITUDE / LONGITUDE** → Universal coordinates to identify the location anywhere in the world.

📌 *Relevance:* These fields ensure we are monitoring the **exact same piece of land** every time, without confusion.

## 2. Baseline Dates (Reference Period)

This is the **"before" timeframe**. Satellite images are taken from this period to act as the **reference condition**.

- **Before Period Start / End** → The time range in which the satellite collects images of your land before any change occurs.

📌 *Relevance:* This helps us understand the **original condition of the land** before new development, vegetation growth/loss, or water changes.

## 3. Current Dates (Comparison Period)

This is the **"after" timeframe**. Satellite images are taken here and compared against the baseline.

- **After Period Start / End** → The time range for the comparison images.

📌 *Relevance:* This period helps us measure **how much change occurred** between "before" and "after."

## 4. Output: Vegetation (NDVI)

NDVI (Normalized Difference Vegetation Index) measures the

NDVI (Normalized Difference Vegetation Index) measures the **health and greenness of plants** using satellite data. Values range from **-1 to +1**.

- **NDVI Before Value** → Average vegetation condition during the baseline period.
- **NDVI After Value** → Average vegetation condition during the current period.
- **NDVI Difference** → Change between "before" and "after." (After – Before).
- **NDVI Interpretation** → A human-readable explanation (e.g., "Vegetation improved" or "Vegetation declined").
- **NDVI Significance** → Tells whether the change is real and meaningful, or just small/insignificant fluctuations.

📌 *Relevance:*

- Higher NDVI = healthier plants.
- Negative or very low NDVI = barren land or construction.
- This gives confidence on whether crops, forest cover, or greenery is improving or declining.

## 5. Output: Built-up Area (NDBI)

NDBI (Normalized Difference Built-up Index) detects **urban/construction activity** like roads, houses, or concrete surfaces.

- **NDBI Before Value** → Built-up level in the baseline period.
- **NDBI After Value** → Built-up level in the current period.
- **NDBI Difference** → Change in built-up area (After – Before).
- **NDBI Interpretation** → Plain language explanation (e.g., "New construction detected").
- **NDBI Significance** → Whether the change is meaningful or negligible.

📌 *Relevance:*

- Higher NDBI = more construction activity.
- If values increase significantly, it indicates **new development or urbanization**.

## 6. Output: Water and Moisture (NDWI)

NDWI (Normalized Difference Water Index) measures **water bodies and soil moisture** using satellite data.

- **NDWI Before Value** → Water/moisture availability during the baseline period.
- **NDWI After Value** → Water/moisture availability during the current period.
- **NDWI Difference** → Change in water/moisture (After – Before).
- **NDWI Interpretation** → Simple explanation (e.g., "Water availability reduced").
- **NDWI Significance** → Whether the change is real/important or just noise.

📌 *Relevance:*

- Positive NDWI = more water/moisture.
- Negative NDWI = dry/barren or urban surfaces.
- This helps detect changes in **ponds, lakes, rivers, irrigation, or soil wetness**.

## 7. API Status (Technical Field)

- **Conversion_status** → Indicates whether the analysis ran successfully.
- If it says "Successful," it means the data was extracted and calculated correctly.

📌 *Relevance:* Gives confidence that the report is **technically valid and reliable**.

# Technical Proof Document: Sentinel-2 L2A Data

## 1. Data Source & Acquisition

- **Satellite Constellation**: Sentinel-2A and Sentinel-2B, launched by ESA (European Space Agency).
- **Orbit & Revisit Frequency**:
  - Polar sun-synchronous orbit at ~786 km altitude.
  - **Revisit time**: 5 days at the equator with both

satellites operating (higher frequency at mid-latitudes).

- **Sensor**: Multispectral Instrument (MSI).
- **Spatial Resolution**: 10 m, 20 m, and 60 m depending on band.
- **Swath Width**: 290 km, ensuring wide coverage.
- In depth:
  - Satellite Mission: Sentinel-2, part of the European Space Agency's Copernicus program.
  - **Collection Used:** DataCollection.SENTINEL2_L2A.
  - **Spatial Resolution:**
    - 10 m (Visible & Near-Infrared bands: B2, B3, B4, B8)
    - 20 m (Red Edge, SWIR bands: B5, B6, B7, B8A, B11, B12)
    - 60 m (Atmospheric correction bands: B1, B9, B10)
  - **Temporal Resolution (Revisit Frequency):**
    - 5 days at the equator with both Sentinel-2A and Sentinel-2B satellites.
    - More frequent coverage at higher latitudes.
  - **Atmospheric Correction:** L2A product provides *surface reflectance values*, already corrected for atmospheric effects.
    This ensures consistency and scientific validity of the data used for vegetation and water quality assessment.

## 2. Data Product Used: SENTINEL-2 L2A

- **L1C → Top-Of-Atmosphere (TOA) reflectance.**
- **L2A → Bottom-Of-Atmosphere (BOA) reflectance**, i.e., atmospherically corrected data.

**Atmospheric correction** (L2A) is performed using the **Sen2Cor processor**:

- Accounts for **aerosols, water vapor, ozone, and terrain effects**.
- Provides **surface reflectance values** that are physically

comparable across time and space.

- Includes **Scene Classification Layer (SCL)**:
  - Classes such as vegetation, bare soil, water, clouds, cirrus, shadows, snow/ice.

## 3. Band Information

Sentinel-2 MSI captures **13 spectral bands**:

| Band | Resolution | Central Wavelength (nm) | Primary Use |
|---|---|---|---|
| B1 | 60 m | 443 | Aerosol detection, coastal |
| B2 | 10 m | 490 | Blue, water bodies, bathymetry |
| B3 | 10 m | 560 | Green, vegetation |
| B4 | 10 m | 665 | Red, chlorophyll absorption |
| B5 | 20 m | 705 | Vegetation Red Edge |
| B6 | 20 m | 740 | Vegetation Red Edge |
| B7 | 20 m | 783 | Vegetation Red Edge |
| B8 | 10 m | 842 | NIR, biomass |
| B8A | 20 m | 865 | NIR narrow |
| B9 | 60 m | 945 | Water vapor |
| B10 | 60 m | 1375 | Cirrus cloud detection |
| B11 | 20 m | 1610 | SWIR, moisture, burned areas |
| B12 | 20 m | 2190 | SWIR, geology, snow/ice |

## 4. Derived Indicators (Indices)

Clients usually care about **vegetation, water, soil, and built-up area monitoring**.

Below are the **key indices and their calculation formulas**:

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## 4.1 Vegetation Indicators

- **NDVI (Normalized Difference Vegetation Index)**
  Formula:
  NDVI=(NIR−RED)(NIR+RED)=(B8−B4)(B8+B4)NDVI = \frac{(NIR - RED)}{(NIR + RED)} = \frac{(B8 - B4)}{(B8 + B4)}NDVI=(NIR+RED)(NIR−RED)=(B8+B4)(B8−B4)
  - Values range from -1 to +1.
  - Higher values indicate healthy vegetation.
- **NDRE (Normalized Difference Red Edge)**
  NDRE=(B8A−B5)(B8A+B5)NDRE = \frac{(B8A - B5)}{(B8A + B5)}NDRE=(B8A+B5)(B8A−B5)
  - More sensitive to chlorophyll content than NDVI.

## 4.2 Water Indicators

- **NDWI (Normalized Difference Water Index)**
  NDWI=(B3−B8)(B3+B8)NDWI = \frac{(B3 - B8)}{(B3 + B8)} NDWI=(B3+B8)(B3−B8)
  - Used to monitor open water bodies.
- **MNDWI (Modified NDWI)**
  MNDWI=(B3−B11)(B3+B11)MNDWI = \frac{(B3 - B11)} {(B3 + B11)}MNDWI=(B3+B11)(B3−B11)
  - Stronger suppression of built-up land noise.

## 4.3 Soil & Moisture Indicators

- **NDBI (Normalized Difference Built-up Index)**
  NDBI=(B11−B8)(B11+B8)NDBI = \frac{(B11 - B8)}{(B11 + B8)}NDBI=(B11+B8)(B11−B8)
  - Identifies urban/built-up areas.
- **NDMI (Normalized Difference Moisture Index)**
  NDMI=(B8−B11)(B8+B11)NDMI = \frac{(B8 - B11)}{(B8 + B11)}NDMI=(B8+B11)(B8−B11)
  - Indicates vegetation water stress.
- **BAI (Burn Area Index)**
  BAI=1(0.1−RED)2+(0.06−NIR)2BAI = \frac{1}{(0.1 - RED)^2 + (0.06 - NIR)^2}BAI=(0.1−RED)2+(0.06−NIR)21
  - Detects burned areas using B4 (Red) and B8 (NIR).

# 5. Accuracy & Reliability

- **Radiometric Accuracy**: 12-bit (reflectance scaled

0–10000).

- **Geometric Accuracy**: < 20 m RMSE.
- **Cloud Masking**: Uses B10 (cirrus) and Scene Classification Layer (SCL).
- **Validation**: ESA & Copernicus services benchmark L2A data against ground measurements.

## 6. Why This Data is Trustworthy for Clients

- **Government-backed mission (Copernicus / ESA)** – free, global, scientific standard.
- **Systematic acquisitions** – no "on-demand bias"; entire Earth is covered at fixed revisit intervals.
- **Transparent algorithms** – Sen2Cor and indices are well-documented in peer-reviewed literature.
- **Validation** – ESA compares against in-situ (ground truth) reflectance and atmospheric conditions.
- **Global Adoption** – Used in agriculture, forestry, urban planning, disaster management, insurance.