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Remote Sensing Data for Life Cycle Assessment

Project proposal

PWRG 2

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Project proposal

The aim of this university assignment is to create a project proposal to demonstrate ability to get an overview of a research field, summarize the findings, identify a gap in the existing knowledge, define a research question, and outline a project plan to address it. Grading consists of the following parts: Scientific Publication: 50%, Supporting Material 15%, Oral Presentation 25%, Work Process / Project Management: 10%

The chosen research field is the use of remote sensing, in particular satellite data, for life cycle assessments (LCAs). In the first part of the scientific publication, a literature review of the current state of the art will be performed. One of the outcomes of the literature study will be the identification of a research gap. A proposed research project aimed at addressing this gap will then be developed and described in detail. The final part of the publication will present a project plan for conducting the suggested research.

1 Introduction

Life Cycle Assessment (LCA) as defined in (International Organization for Standardization, 2006a) and (International Organization for Standardization, 2006b) is a standardized tool used to evaluate the environmental impacts associated with every stage of a product or service's life, from raw material extraction through production, use, and disposal. Central to the accuracy and usefulness of an LCA is the availability and quality of the underlying data. Without robust and representative data, the conclusions drawn from an LCA risk being misleading or incomplete.

Remote sensing, particularly through satellites, provides vast amounts of data. Satellites offer a unique, large-scale perspective for continuous observation of the Earth's surface and atmosphere. They collect data that can be directly or indirectly used to assess land cover, vegetation health, surface temperatures, atmospheric gases, and ocean characteristics. All of these are essential for understanding environmental trends and changes over time. Satellite derived data supports a wide range of applications, from climate modeling and disaster response to agricultural planning.

The focus of this work is to explore if and how observational satellite data can be integrated into LCA to enhance the accuracy of environmental impact evaluations in various stages, especially in the inventory and modeling phases, where accurate, detailed, and geographically specific information is essential. While remote sensing supplies the observational data, LCA offers the framework for quantifying and interpreting environmental impacts.

2 Satellite data: types, use cases, data availability, and tools

At a high level, satellites can be categorized based on their orbital types, which determine their position and altitude, and consequently coverage and purpose.

1. Low Earth Orbit (LEO) satellites orbit at altitudes between 160 and 2.000 kilometers. They are known for their high resolution data. A subset of them, polar orbits, pass over the Earth's poles and provide global coverage as the planet rotates beneath them. Another subset is sun-synchronous orbits, which maintain a consistent position relative to the sun, allowing satellites to observe the Earth under similar lighting conditions with each pass.
2. Medium Earth Orbit (MEO) satellites operate at altitudes ranging above 2.000 and below 35.000 kilometers. They are typically used for navigation services such as devised based on Assisted Global Navigation Satellite Systems as defined in (3rd Generation Partnership Project (3GPP), 2019), which rely on acquiring and decoding satellite signals to determine their position.
3. Geostationary Earth Orbit (GEO) satellites are located above the equator at 35.786 kilometers, which matches the Earth's rotation period, to provide continuous observation of a fixed region of the Earth. They are know for providing low resolution data with high update frequency. The data provided is often used for weather and broad climate monitoring.

Each of these orbital types serves different observational and communication purposes. In this work, the focus is on satellites that provide observational data. There are many other use cases for satellites in communication, broadcasting, navigation, and for military purposes, which will not be discussed.

The satellite orbital types most useful for application in LCA are observational LEO and GEO satellites. In the following, an overview of available public domain and commercial observational satellite data of these types that could potentially be relevant for LCA is provided.

2.1 Geostationary Earth Orbit (GEO) satellites

Observational Geostationary Earth Orbit satellites provide continuous, real-time monitoring of atmospheric conditions, cloud cover, sea surface temperatures, and solar radiation over large fixed regions. They have lower spatial resolution compared to LEO satellites, but this is being compensation by providing high temporal resolution. Table 1 provides an overview of the existing GEO satellites, their operators, the regions covered, and the license the data is available under.

Table 1

Satellite / Series	Operator / Agency	Region Covered	Licensing
GOES series (GOES-16, GOES-17, GOES-18)	NOAA (USA)	Americas	Most data available under NOAA's data policy
Meteosat (MSG and MTG series)	EUMETSAT (Europe)	Europe, Africa, Atlantic Ocean	Open access under EUMETSAT's data policy
Himawari series (8 and 9)	JMA (Japan)	Asia-Pacific region	Open access for research and public use
INSAT/GSAT series (INSAT-3D, INSAT-3DR)	ISRO (India)	Indian subcontinent	Limited public access
Fengyun series (FY-2, FY-4)	CMA (China)	Asia-Pacific region	Restricted access for partners
Electro-L series	Russian Space Agency	Russia, Europe, parts of Asia	Limited public access

The three satellite series where data that is accessible under open licenses offer data delivery frequencies between 5 and 15 minutes for full images. They support rapid scan modes for their regions of focus with data delivery frequencies between 30 seconds and 5 minutes. These are used for detecting fast-changing weather and environmental events such as storms, tornadoes, wildfires and volcanic eruptions, and for short-term weather forecasting (called now-casting).

They provide similar imaging capabilities: 16 spectral ranges of wavelengths, called bands or channels, collected by the satellite sensor as discrete portions of the electromagnetic spectrum. Each series provides similar numbers of visible, near-infrared (NIR) and infrared (IR) channels:

- Visible bands detect sunlight reflected by clouds, land, and oceans, e.g., for red and blue visible light reflectance.
- Near-infrared bands are invisible to the human eye, strongly reflected by vegetation, and absorbed by water. This makes land cover, plant health, and boundaries between land and water easy to detect.
- Infrared bands, which are also invisible to the human eye, detect thermal radiation, i.e. heat, emitted from the Earth and atmosphere at day and night. This is useful for observation of temperature and moisture or dryness as well as atmospheric gaseous water vapor.

In summary, GEO satellites for Earth observation are most helpful for high-frequency monitoring of large-scale land and ocean processes, temperature, radiation, or atmospheric emissions.

2.2 Low Earth Orbit (LEO) satellites

Far more LEO satellites for Earth observation than GEO satellites exist: around 35 GEO satellites compared to around 1000 LEO satellites. Table 2 provides a listing of the most relevant ones and their resolution and revisit frequency.

Table 2

Satellite	Access	Resolution	Revisit Frequency	Region Covered & Notes
Landsat 8 & 9	open	15–30 m multispectral	16 days	Global coverage, land surface, long-term archive
Sentinel-1	open	5–20 m SAR	6–12 days	Global, all-weather radar imaging
Sentinel-2	open	10–60 m multispectral	5 days (with 2 satellites)	Global, vegetation, land use, coastal zones
MODIS (Terra, Aqua)	open	250 m – 1 km multispectral	Daily	Global, atmosphere, land, ocean
Biomass	open	~10 m P-band SAR	15–16 orbits per day	Global; forest biomass & carbon content monitoring; launched 2025
Planet Labs (Dove, Pelican)	commercial	3–5 m optical	Daily (global coverage)	Global, frequent revisits, commercial use
Maxar WorldView series	commercial	30–50 cm optical	Daily to weekly	High-resolution, commercial, detailed imaging
Airbus Pléiades	commercial	~50 cm optical	1–3 days	Global, high-resolution commercial imaging
BlackSky	commercial	~90 cm optical	Multiple times daily	Global, rapid revisit, analytics platform
Iceye	commercial	~1 m SAR	Daily (some areas)	Global, all-weather radar, commercial SAR constellation
Capella Space	commercial	~0.5 m SAR	Daily to sub-daily	Global, high-resolution SAR, commercial

Satellite	Access	Resolution	Revisit Frequency	Region Covered & Notes
FireSat	commercial	~5 m thermal infrared	Every 20 minutes globally	Global wildfire detection; launched 2025
OroraTech	commercial	Variable thermal IR	Near real-time	Wildfire monitoring, rapid alerts
Satellogic	commercial	<1 m multispectral	Daily	Global, medium-resolution multispectral
GHGSat	commercial	Variable	Variable	Global methane and greenhouse gas monitoring
RapidEye	commercial	5 m multispectral	Daily	Global, medium-resolution multispectral
Deimos-1 & 2	commercial	22 m (D1), 75 cm (D2) optical	1–3 days	Global, commercial EO satellites
RISAT-1 & 2	restricted	3–5 m SAR	Weekly	India region, radar imaging for agriculture and disaster monitoring
ALOS-2	restricted	1–3 m SAR	Weekly	Asia-Pacific region, wide-area radar imaging
Cartosat series	restricted	0.8–2.5 m optical	4–5 days	India and global, high-res optical

2.3 Tools and datasets

GlobalBuildingAtlas: https://github.com/zhu-xlab/GlobalBuildingAtlas?tab=readme-ov-file

Neumann et al. (2025) Forest stuff PhD student: https://github.com/SherryJYC

3 Literature study: Satellite data for LCA

Which aggregation levels are in use

Existing estimates for environmental impact of satellites

4 Project proposal

Forest loss and contrails

5 Project plan

References

3rd Generation Partnership Project (3GPP). (2019). *3GPP TS 36.355 V15.3.0 - LTE Positioning Protocol A (LPPa)*. 3GPP.

International Organization for Standardization. (2006a). *ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework*. International Organization for Standardization.

International Organization for Standardization. (2006b). *ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines*. International Organization for Standardization.

Neumann, M., Raichuk, A., Stanimirova, R., Sims, M., Carter, S., Goldman, E., Rey, M., Jiang, Y., Anderson, K., Poklukar, P., et al. (2025). *Natural forests of the world-a 2020 baseline for deforestation and degradation monitoring*.