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Remote Sensing Data for Life Cycle Assessment

Project proposal

PWRG 2

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Abstract

The aim of this work is to create a project proposal to demonstrate ability as a student to get an overview of a research field, summarize the findings, identify a gap in the existing knowledge, define a research question, and a project plan to tackle it.

The chosen topic is using remote sensing, in particular satellite data, for life cycle assessments (LCAs). In the first part of the paper, a literature study of the state of the art is performed. As the outcome of this study, a research gap is identified. Based on that, a proposed project to close the gap will be developed and described in detail. The final part of the paper includes a project plan.

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 quality and availability of data. Reliable data allows to quantify energy use, emissions, resource depletion, and other key metrics, making it possible to compare alternative options, and to support informed decision-making. 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 how 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 can improve the reliability of results. 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. The data provided is often used for weather and broad climate monitoring.

Each of these orbital types serves different observational and communication purposes based on their unique geometries. In this work, the focus is on observational data and its use cases for LCA. There are many use cases for satellites for communication, broadcasting, navigation, and military purposes, which will not be discussed.

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

2.1 Geostationary Earth Orbit (GEO) satellites

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, tornados, 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 are also invisible to the human eye. They detect thermal radiation, i.e. heat, emitted from the Earth and atmosphere at day and night, for observation of temperature and moisture or dryness as well as atmospheric gaseous water vapor.

2.2 Low Earth Orbit (LEO) satellites

There are far more LEO satellites than GEO satellites.

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

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*.