

ZURICH UNIVERSITY OF APPLIED SCIENCES
SCHOOL OF LIFE SCIENCES UND FACILITY MANAGEMENT
INSTITUTE OF NATURAL RESOURCES SCIENCES (IUNR)

Remote Sensing Data for Life Cycle Assessment

Project proposal

PWRG 2

by

Michlmayr, Elke

Environment and Natural Resources

Submitted: TBD

Supervisor:

Itten, Renè

ZHAW School of Life Sciences and Facility Management

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.

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, an introduction to the topic aimed at readers who are not familiar with LCA or Earth Observation with satellites will be provided. After that, a literature review of the current state of the art in employing satellite data for LCA will be performed, and an overview of relevant tools and dataset that are publicly available and potentially applicable will be provided. The outcomes of the literature study and the data and tools review will be the identification of a research or data/tooling gap. A research question will be defined based on these insights. A proposed research project aimed at addressing the research question will then be developed and described in detail. The final part of the publication will present a project plan for conducting the suggested research.

Grading consists of the following parts: Scientific Publication: 50%, Supporting Material 15%, Oral Presentation 25%, Work Process / Project Management: 10%

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 Overview: Satellite data for earth observation

The focus of this work is on satellites that provide observational data of the Earth for environmental monitoring. The many other existing use cases for satellites in communication, broadcasting, navigation, and for military purposes will not be discussed.

There are several different types of methods to sense the data: optical, thermal, and radar based as summarized in Table 1. Optical methods detect sunlight reflected by clouds, land, and oceans, e.g., for red and blue visible light reflectance. Near-infrared (NIR) and infrared (IR) is invisible to the human eye. NIR is strongly reflected by vegetation, and absorbed by water. Therefore, NIR based methods make land cover, plant health, and boundaries between land and water easy to detect. IR detects 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. Synthetic Aperture Radar (SAR) is an active method that works at night and through clouds (unlike the other methods). It detects surface structure and moisture.

Table 1

Method	Key feature	Works at night	Cloud penetrating
Optical (incl. Near-Infrared, NIR)	Reflects sunlight	No	No
Thermal Infrared (IR)	Detects heat	Yes	No
Synthetic Aperture Radar (SAR)	Uses radar	Yes	Yes

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 known 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 satellite types serves different purposes. The satellite orbital types most common for earth observation are 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 compensated by providing high temporal resolution. Table 2 provides an overview of the existing GEO satellites, their operators, the regions covered, the type of access and, if relevant, the license that the data is available under.

Table 2

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 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 comparable numbers of optical, near-infrared and infrared channels.

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).

To summarize, GEO satellites for Earth observation are most helpful for high-frequency monitoring of large-scale land and ocean processes.

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 3 provides a non-exhaustive listing of the most relevant providers together with the resolution and revisit frequency of the data provided. Note that some providers have more than one satellite on offer. In these cases only the one with the highest resolution and revisit frequency is listed. The newest satellites are Biomass from ESA for forest biomass and carbon content monitoring, and FireSat and OroraTech for wildfire detection. The (*) sign indicates future plans.

Table 3

Satellite / provider	Access	Resolution	Revisit Frequency
Landsat 8 & 9	open	15 – 30 m multispectral	8 days (combined)
Sentinel-1 (A & B/C)	open	5 – 20 m SAR	6 days (combined)
Sentinel-2 (A, B & C)	open	10 – 60 m multispectral	5 days (combined)
MODIS (Terra, Aqua)	open	250 m – 1 km multispectral	Daily
Biomass	open (*)	10 m P-band SAR	Up to 16 orbits/day
Planet Labs	commercial	3 – 5 m optical	Daily
Maxar WorldView	commercial	30 – 50 cm optical	Up to 15 orbits/day
Airbus	commercial	30 cm optical	1–3 days
Iceye	commercial	0.5 m SAR	Daily to sub-daily
Capella Space	commercial	0.5 m SAR	Daily to sub-daily
GHGSat	commercial	25 m	Variable
FireSat	commercial	5 m thermal IR	30 minutes (*)
OroraTech	commercial	Variable thermal IR	30 minutes (*)

To summarize, LEO satellites play a crucial role in Earth observation, particularly for high-resolution and frequent monitoring. The revisit frequency is primarily determined by the size of the satellite constellation. Larger constellations, such as those with over 100 satellites, can achieve revisit frequencies approaching those of geostationary systems.

2.3 Data availability for research purposes

While a few public providers offer open-access data with comparatively low resolution, many different commercial options for very high resolution data are on the market. The pricing models of the commercial options depend on the amount of data required and the use case, and are available upon request. Limited opportunities to access the commercial data under a research license exist. The NASA-led Commercial Satellite Data Acquisition Program NASA Earth Science Division (2024) provides access to some of the data for research purposes, most notably for the Maxar WorldView data. It has been used in a number of scientific articles as assessed by Zhao et al. (2022) who conducted a literature study of scientific articles referencing EO satellite missions and found that their number is exponentially growing, and while some cite commercial sources, most of the work is based on the freely available data. In this project, the focus will be on data that is available for research purposes.

3 Literature study: Satellite data for LCA

- (2014) Assessing biodiversity loss due to land use with Life Cycle Assessment: are we there yet? <https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12709> LCA mainly introduces biodiversity as an endpoint category modeled as a loss in species richness due to the conversion and use of land over time and space. The functional and population effects on biodiversity are mostly absent due to the emphasis on species accumulation with limited geographic and taxonomical reach. Current land-use modeling activities that use biodiversity indicators tend to oversimplify the real dynamics and complexity of the interactions of species among each other and with their habitats.
- (2015) Life-cycle assessment to guide solutions for the triple planetary crisis <https://www.nature.com/articles/s4023-00449-2>
- (2016) Monitoring of Land Use Change Using Satellite Remote Sensing for Sustainable Resource Management https://www.jstage.jst.go.jp/article/lca/18/4/18_213/_article/-char/en
- (2017) Life cycle assessment in road infrastructure planning using spatial geological data <https://link.springer.com/article/10.1007/s11367-016-1241-3>
- (2018) Coupling GIS and LCA for biodiversity assessments of land use <https://link.springer.com/article/10.1007/010-0199-9>

Groups: https://en.wikipedia.org/wiki/Space_for_Climate_Observatory

Journals: International Journal of Applied Earth Observation and Geoinformation

People: Remote sensing agriculture: Bruno Basso <https://scholar.google.com/citations?user=EItklHoAAAAJ&>

Problems: Amazon often full with clouds, gets exploited by loggers

Open questions: Which aggregation levels are in use?

Use cases: forest https://scholar.google.com/scholar?hl=en&as_sdt=0,5&qsp=2&q=forest+loss+life+cycle+as+water (?) contrails (??)

3.1 Environmental impact of satellites

Quantifying the Environmental Impacts of Manufacturing Low Earth Orbit (LEO) Satellite Constellations <https://www.mdpi.com/2071-1050/16/21/9431>

Estimates for environmental impact of satellites: <https://pre-sustainability.com/customer-cases/environmental-impacts-satellite-mission/>

4 Tools and datasets

In the following, datasets and tools that could be valuable as input for LCAs are assessed.

4.1 AlphaEarth Foundations

An embedding field model for accurate and efficient global mapping from sparse label data <https://deepmind.google/discover/blog/alphaeearth-foundations-helps-map-our-planet-in-unprecedented-detail/>

Brown et al. (2025)

Unprecedented volumes of Earth observation data are continually collected around the world, but high-quality labels remain scarce given the effort required to make physical measurements and observations. This has led to considerable investment in bespoke modeling efforts translating sparse labels into maps. Here we introduce AlphaEarth Foundations, an embedding field model yielding a highly general, geospatial representation that assimilates spatial, temporal, and measurement contexts across multiple sources, enabling accurate and efficient production of maps and monitoring systems from local to global scales. The embeddings generated by AlphaEarth Foundations are the only to consistently outperform all previous featurization approaches tested on a diverse set of mapping evaluations without re-training. We will release a dataset of global, annual, analysis-ready embedding field layers from 2017 through 2024.

https://developers.google.com/earth-engine/datasets/catalog/GOOGLE_SATELLITE_EMBEDDING_V1_AN

4.2 Planetary Computer

The Planetary Computer combines a multi-petabyte catalog of global environmental data with intuitive APIs, a flexible scientific environment that allows users to answer global questions about that data, and applications that put those answers in the hands of conservation stakeholders.

<https://planetarycomputer.microsoft.com/>

4.3 GlobalBuildingAtlas

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

4.4 Cropland Data Layer

Agriculture: The Cropland Data Layer (CDL) is a dataset provided by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) that provides information about crop types across the United States.

4.5 Forest baseline

(2025) Natural forests of the world-a 2020 baseline for deforestation and degradation monitoring Neumann et al. (2025) Forest stuff PhD student: <https://github.com/SherryJYC>

5 Project proposal

Ideas:

- Plan a project to use ESA Biomass satellite for LCA for forest loss (data not yet in the public domain)
- Plan some kind of LCA project based on AlphaEarth Foundations (could use data within Google Earth Engine for analysis and visualization for research or educational use. Downloading, redistributing, or incorporating the data into other software is not permitted.)
- LCA to assess the environmental impact of satellites in comparison to their benefits (How to assess the environmental impact of a large wildfire? How to assess the total benefits of all the use cases for a satellite?)

6 Project plan

References

- 3rd Generation Partnership Project (3GPP). (2019). *3GPP TS 36.355 V15.3.0 - LTE Positioning Protocol A (LPPa)*. 3GPP.
- Brown, C. F., Kazmierski, M. R., Pasquarella, V. J., Rucklidge, W. J., Samsikova, M., Zhang, C., Shelhamer, E., Lahera, E., Wiles, O., Ilyushchenko, S., Gorelick, N., Zhang, L. L., Alj, S., Schechter, E., Askay, S., Guinan, O., Moore, R., Boukouvalas, A., and Kohli, P. (2025). *AlphaEarth foundations: An embedding field model for accurate and efficient global mapping from sparse label data*. <https://arxiv.org/abs/2507.22291>
- 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.
- NASA Earth Science Division. (2024). *Commercial smallsat data acquisition (CSDA) program*. <https://www.earthdata.nasa.gov/esds/csda>.
- 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*.
- Zhao, Q., Yu, L., Du, Z., Peng, D., Hao, P., Zhang, Y., and Gong, P. (2022). An overview of the applications of earth observation satellite data: Impacts and future trends. *Remote Sensing*, 14(8), 1863.