CASA0023 Learning Diary

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2 Welcome to CASA0023 Learning Diary

This is my learning diary for CASA0023. It contains weekly reflections and notes on various topics.

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References and additional materials are included at the end of each note.

3 Wk1_Introduction_to_remote_sensing

4 1 An Introduction to Remote Sensing

4.1 1.1 Summary

4.1.1 1.1.1 Definition of remote sensing

Remote sensing is the science of obtaining information about objects or areas from a distance using sensors that detect electromagnetic radiation. The electromagnetic spectrum is crucial to understanding which wavelengths are useful for different applications. The key diagram to include would be the electromagnetic spectrum chart showing different wavelengths and their applications in remote sensing.

4.1.2 1.1.2. Resolution Types in Remote Sensing

The four essential resolution types determine what can be detected:

Type	Definition
Spatial resolution	The size of one pixel in ground units
Spectral resolution	Number and width of spectral bands
Temporal resolution	How often data is collected
Radiometric resolution	Sensitivity to differences in reflected/emitted energy

It Includes the comparative images showing the same area captured at different spatial resolutions (e.g., 30m vs. 10m) to illustrate how detail changes.

4.1.3 1.1.3. Satellite Systems and Their Applications

Major satellite programs like Landsat (historical importance since 1972) and Sentinel (newer European missions) provide different capabilities for urban monitoring. The lecture highlights specifications including revisit time, spatial resolution, and spectral bands. Include the satellite timeline diagram showing the evolution of Earth observation satellites and their operational periods.

4.1.4 1.1.4. Urban Remote Sensing Applications

Remote sensing enables monitoring urban environments through applications like land use classification, urban heat island detection, and change detection over time. The thermal imagery showing urban heat islands and comparison images of urban growth over decades would be essential visuals.

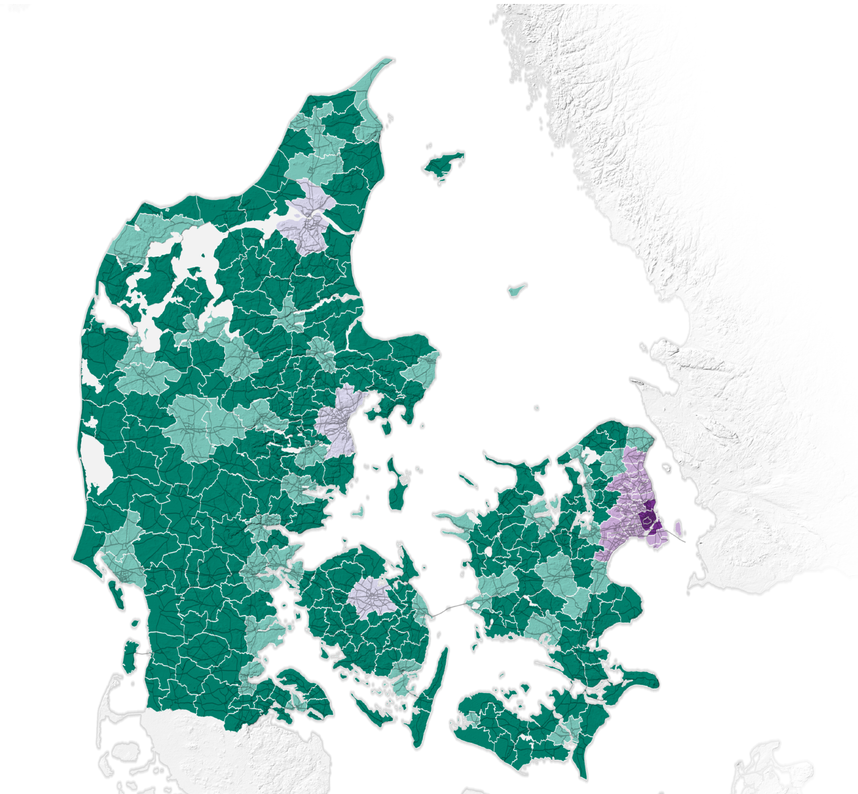
4.2 1.2 Applications

In my research on remote sensing applications, I have found that these technologies provide tools for understanding the urban environment.

How land use mapping is changing urban planning is one such application. By analyzing imagery over time, we can track patterns of sprawl and even identify informal settlements that traditional surveys might miss. This capability is important for rapidly growing cities facing housing challenges. Advanced machine learning techniques like object-based image analysis (OBIA) now enable automatic classification of urban morphology with accuracy exceeding 85%, allowing planners to quantify not just expansion but also densification processes.

In addition to this, urban heat island analysis applications are also one of the options as climate issues become more serious. I find it compelling that heat sensors can accurately identify hot spots that need intervention. NASA Earth Observatory documents a clear pattern of temperature differences of up to 10°C between urban and rural areas (NASA Earth Observatory, 2021). This could change the way we approach urban greening initiatives. Thermal infrared bands on satellites like Landsat 8 (bands 10-11) and ECOSTRESS provide surface temperature data at resolutions fine enough to correlate UHI intensity with specific urban features and materials.

Finally, remote sensing appears to have the most significant impact in disaster management applications. Its ability to provide timely information throughout the disaster cycle - from vulnerability mapping to response guidance and damage assessment - can save countless lives and improve recovery efforts. For example, floods, hill fires, and crop damage can all be assessed and predicted accordingly. Synthetic Aperture Radar (SAR) sensors like those on Sentinel-1 have revolutionized disaster monitoring by providing cloud-penetrating imagery day or night, enabling near real-time flood extent mapping even during severe weather conditions when optical sensors fail.



The relationship between green space and relative mental health Source: NASA Earth Observatory

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4.3 1.3 Reflection

As I engaged with the fundamentals of remote sensing, several thoughtful connections emerged about this technology's place in science and society.

The evolution of Earth observation technology is remarkable - from early Landsat missions to today's specialized satellite constellations. This progression mirrors other scientific fields where technological advancement has transformed understanding, with remote sensing uniquely turning our technological gaze back toward Earth itself.

The concept of different resolutions highlighted an important philosophical point about observation. Our choice of resolution determines what patterns become visible - broad land cover at coarse resolution, individual buildings at finer scales. This reinforces that all scientific observation involves choices about scale that fundamentally shape understanding.

The democratization of satellite imagery particularly interests me. What was once the exclusive domain of governments and corporations is increasingly accessible, creating new possibilities for citizen science and community monitoring. This shift raises important questions about who gets to observe our environment and whose perspectives inform the resulting narratives.

I found myself contemplating how remote sensing changes our relationship with cities. The bird's-eye perspective offers insights unavailable to most urban dwellers yet differs significantly from lived experiences at street level. How might these different ways of knowing be integrated for more comprehensive urban understanding?

Moving forward in this course, I'm particularly interested in exploring how remote sensing data intersects with local knowledge and qualitative understanding of places. The most valuable insights likely emerge when technological observation and human experience are brought into thoughtful conversation rather than treated as separate domains.

5 Wk2_Presentation

6 2 Presentation

These are the introduction slides for the sensor ASTER(Advanced Spaceborne Thermal Emission and Reflection Radiometer)

use this Link

7 Wk3_Corrections

8 3 Classification I

8.1 3.1 Summary

In this lecture, I learned about the fundamentals of remote sensing, focusing on data acquisition, sensor technologies, data processing, and their applications in urban and environmental studies. The session was divided into two main parts: image correction and data mosaicing and enhancement. Below are the key takeaways:

8.1.1 3.1.1 Sensor Types and Mechanisms

Remote sensing sensors are at the core of remote sensing technology, and different types of sensors employ different imaging mechanisms. The following table compares two common types of sensors:

Sensor Type	Working Principle	Pros & Cons
Whisk broom (cross-track scanner)	Uses a rotating mirror to reflect light onto a single detector, covering a large area	Wide coverage, but moving parts can wear out
Push broom (along-track scanner)	Uses detector arrays for faster and more efficient imaging	High efficiency, but requires precise calibration
MSS (Multispectral Scanner)	Uses a digital approach to capture multispectral data (visible + near-infrared)	Provides better data continuity and accuracy

Through these different sensor technologies, remote sensing systems are able to capture various types of land feature data based on specific needs.

8.1.2 3.1.2 Data Correction Process

Satellite imagery often requires correction before it can be used for analysis. The following diagram shows the typical correction process:

- Start with a Raw Satellite Image.
- Perform Geometric Correction to fix distortions caused by sensor motion or the Earth's curvature.
- Apply Atmospheric Correction to remove haze or scattering effects, for example, using dark object subtraction.
- Proceed with Terrain Correction to adjust for elevation differences, such as through orthorectification.

Data correction is a crucial first step to ensure the accuracy and usability of remote sensing imagery. By applying geometric correction, atmospheric correction, and terrain correction, we can eliminate external disturbances and improve the precision of the data.

8.1.3 3.1.3 Data Mosaicing and Enhancement

Mosaicing and enhancement techniques are vital for improving remote sensing imagery, especially for urban and environmental studies. However, these techniques must be chosen based on the specific needs of the study. Standard mosaicing methods may not always be suitable for satellite imagery, as there can be discrepancies in lighting and radiometric calibration between images.

Enhancement Method	Description	Challenges in Urban Applications
Mosaicing	Combines multiple images into one seamless image	Standard methods may cause radiometric inconsistencies
Contrast Enhancement	Improves clarity by enhancing feature contrast	May over-complicate images, hindering research
Creating New Datasets	Uses band composition/feature extraction	High computational load and analysis complexity

These enhancement methods can improve image contrast and clarity, helping to analyze land cover changes more effectively. However, whether added complexity truly benefits the research objectives needs careful consideration.

8.2 3.2 Applications

Landsat satellites, providing over 50 years of Earth observation data since 1972, have had a profound impact on monitoring urban growth, deforestation, temperature changes, and more.

8.2.1 3.2.1 Urban Growth & Land Use Mapping

One of the most powerful applications of remote sensing is its ability to monitor urban growth and land use changes over time. Satellites like Landsat and Sentinel-2 have been invaluable in tracking the transformation of landscapes, especially as urban areas expand. The integration of Landsat with other datasets, like Sentinel-2 through the Dynamic World project, enables near-real-time land cover mapping, which is crucial for monitoring urbanization, deforestation, and the spread of infrastructure. For example, through the combination of these datasets, researchers can track the extent of urban sprawl, assess changes in built-up areas, and even identify shifts in the types of land cover (e.g., from agriculture to residential). This kind of information is vital for city planners and policymakers in managing sustainable urban growth and mitigating the environmental impact of development. Additionally, urban heat islands, a key environmental concern in cities, can be monitored using thermal infrared data, which helps identify regions that are overheating due to dense urbanization and limited vegetation.

8.2.2 3.2.2 Environmental Monitoring & Disaster Response

Remote sensing also plays a critical role in environmental monitoring, particularly in disaster response and management. Landsat and Sentinel-2 satellites have been used extensively to monitor wildfires, floods, and changes in ecosystems. For example, Landsat's long-term data series allows for the analysis of wildfire spread and recovery over decades. These data sets provide valuable insights into the impact of fire on vegetation and soil, and how these ecosystems recover over time. Similarly, Sentinel-2's high temporal resolution makes it an excellent tool for monitoring environmental changes more frequently, such as detecting the early stages of flooding or tracking the aftermath ofS extreme weather events. Remote sensing also supports vegetation health monitoring by detecting anomalies in plant reflectance, particularly using the near-infrared spectrum, which is sensitive to plant stress. This capability is essential for agriculture, forestry, and conservation efforts, enabling early intervention when vegetation shows signs of degradation, drought, or pest infestations.

8.3 3.3 Reflection

This week's practical exercise on atmospheric correction provided invaluable hands-on experience that deepened my understanding of the challenges involved in working with real-world remote sensing data. By applying the Dark Object Subtraction (DOS) method and exploring more advanced techniques like the 6S model, I developed a new appreciation for the delicate balance researchers must strike between accuracy and practicality.

The most enlightening moment came when I compared my corrected NDVI values with field measurements. While the DOS method clearly enhanced my results compared to using raw data, I observed significant variations in urban areas, where identifying true "dark" pixels proved difficult. This highlighted a crucial limitation I had not fully considered before – preprocessing methods that rely on specific assumptions might work well in certain environments but fail in others.

What surprised me most was realizing the profound impact these technical decisions can have on research outcomes. A seemingly minor choice of correction method could potentially influence conclusions about vegetation health or urban heat patterns. This made me wonder how many published studies might be affected by similar preprocessing limitations, which may not always be clearly explained in the methods sections.

Additionally, the exercise made me reflect on the resource constraints researchers face in real-world situations. While I learned about theoretically superior methods like the 6S model, I now understand why many researchers opt for simpler approaches. The time, data requirements, and computational costs associated with advanced methods can be prohibitive, particularly for students or small research teams.

Overall, data correction and enhancement are essential steps in improving the quality of remote sensing data, enabling more accurate monitoring of urban development and environmental changes. However, increasing the complexity of imagery does not always enhance the research value, and its benefits must be carefully considered in relation to the specific research goals.

9 Wk4_Policy

10 4 Policy

Week 4 focused on the applications of remote sensing to policy, and I made a case study in Singapore.

10.1 4.1 Summary

10.1.1 4.1.1 City Summary

Singapore is a highly urbanized city-state located at the southern tip of the Malay Peninsula in Southeast Asia. With a land area of just 728 km^2 and a population of 5.9 million, Singapore is one of the world's most densely populated countries. The nation faces unique challenges due to its limited land resources, including food security concerns as it imports over 90% of its food supply, vulnerability to climate change effects like sea-level rise, and urban heat island intensification due to its dense urban development.

10.1.2 4.1.2 Policy Summary

1. **Global Policy Overview**:

   Sustainable Development Goals (SDGs) Singapore has committed to implementing the United Nations' Sustainable Development Goals (SDGs), with particular emphasis on SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). As a highly urbanized nation with limited natural resources, Singapore has prioritized creating a sustainable, resilient urban environment.

2. **Singapore Green Plan 2030** (Singapore Ministry of Sustainability and the Environment, 2021)

   The Singapore Green Plan 2030, launched by the government in 2021, serves as a national roadmap toward sustainable development and net-zero emissions. The plan integrates remote sensing technology to monitor environmental changes, track policy implementation, and evaluate effectiveness across various domains. Singapore's Urban Redevelopment Authority (URA) and National Environment Agency (NEA) have partnered with research institutions to employ Earth observation data for urban planning, environmental monitoring, and climate adaptation. This partnership leverages remote sensing to map urban heat islands, monitor green space development, and assess coastal changes to inform policy decisions and future planning.

Goal	Target
Increasing urban green cover	From **47% to 50%** by 2030
Green spaces and trees	**1,000 hectares** of green spaces, **one million additional trees**
Local food production	**20%** of Singapore's total food demand by 2030
Waste reduction	**30%** reduction in waste sent to landfill by 2030
Solar energy expansion	**8,000 hectares** of solar panels on rooftops and reservoirs by 2030
Climate resilience	Strategies against **sea-level rise and extreme weather events**
Water resource management	Sustainable management through **catchment management**

Source:Singapore greenplan

10.2 4.2 Application

This section identifies how remotely sensed data could be used to contribute to Singapore's policy goals, answering the question: **'How could the data be applied to solve the policy challenge?'**

10.2.1 4.2.1 Data Sources

Singapore employs multiple remote sensing platforms to support its Green Plan implementation:

- **Satellite Imagery:**
  - **Sentinel-2**: Provides 10m resolution multispectral data to monitor urban vegetation changes.
  - **Landsat data**: Offers a historical perspective for long-term change analysis.
  - **Thermal Mapping**:
    - Landsat 8/9 thermal bands and ECOSTRESS data identify urban heat islands.
    - Temperature readings are accurate to within 1°C.
- **Unmanned Aerial Vehicles (UAVs):**
  - Provides ultra-high resolution (sub-meter) imagery.
  - Used for monitoring specific urban projects, tree health in parks, and rooftop gardens.
- **Aerial LiDAR Surveys:**
  - Creates detailed 3D models of the urban environment.
  - Essential for vegetation structure analysis and building-level energy studies.

10.2.2 4.2.2 Techniques

- **Urban Heat Island Monitoring**

1. Acquire thermal infrared imagery from satellites and aerial platforms.
2. Calibrate and correct imagery for atmospheric effects.
3. Generate surface temperature maps across the urban area.
4. Identify heat island hotspots and correlate with urban features.
5. Track temperature changes in relation to green infrastructure implementation.
6. Develop targeted cooling strategies for hotspot areas.

- **Green Space Assessment**

1. Acquire high-resolution multispectral imagery.
2. Calculate vegetation indices (**NDVI, EVI**) to quantify greenery.
3. Classify urban vegetation types (**tree canopy, shrubs, grass**).
4. Monitor changes in green cover over time.
5. Evaluate effectiveness of tree-planting initiatives.
6. Identify priority areas for new green space development.

- **Coastal Change Monitoring**

1. Acquire satellite and aerial imagery of coastal areas.
2. Use **SAR imagery** for high-precision elevation measurements.
3. Detect changes in shoreline position and elevation.
4. Monitor effectiveness of coastal protection measures.
5. Model areas vulnerable to sea-level rise.
6. Develop adaptive strategies for coastal infrastructure.

- **Urban Agriculture Mapping**

1. Identify existing and potential rooftop farming locations.
2. Monitor productivity of urban farms with multispectral imagery.
3. Calculate potential food production capacity across the city.
4. Track progress toward **30% local food production goal**.
5. Optimize urban farming techniques based on remote sensing data.

References:

Singapore Ministry of Sustainability and the Environment (2021). "Singapore Green Plan 2030" (Official government website) https://www.greenplan.gov.sg/

10.3 4.3 Reflection

Singapore's application of remote sensing technologies to support its Green Plan 2030 demonstrates how a land-constrained city-state can leverage Earth observation data to inform sustainable development policies. The integration of satellite, aerial, and UAV platforms provides multi-scale monitoring capabilities that match the precision requirements of Singapore's urban planning and environmental management needs.

What I find most interesting about Singapore's approach is how necessity has driven innovation. With extremely limited land resources and high vulnerability to climate change, Singapore cannot afford planning mistakes or ineffective environmental policies. Remote sensing provides the evidence base needed to optimize every square meter of the urban landscape for multiple benefits – from cooling effects to food production to biodiversity support.

Singapore's coastal monitoring is particularly critical given that approximately 30% of the island lies less than 5 meters above sea level. The combination of satellite-based monitoring and detailed elevation modeling enables planners to prioritize adaptation measures where they're most needed, potentially saving billions in infrastructure costs through targeted interventions.

The city-state's approach to urban heat island mitigation could serve as a model for other tropical cities. By systematically mapping surface temperatures against urban morphology and vegetation cover, Singapore has developed precise guidelines for how much and what type of urban greenery is needed to achieve specific cooling targets. This data-driven approach to climate adaptation could be valuable across Southeast Asia, where many megacities face similar heat challenges. An output of Singapore's urban greening policy can be seen in Figure, showing the integration of vegetation into high-density urban areas through innovative vertical gardens.

Vertical gardens on residential buildings in Singapore Source

11 Wk6_GEE