Assessment of Hyperspectral and SAR Remote Sensing for Solid Waste Landfill Management

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Presentation Overview

- **Space Research Centre and Integrated Waste Management Centre**
- Research **Background** and **Rationale**
- **Objectives**
- **Methodology**
- **ENVISAT ASAR & PROBA CHRIS Acquisitions**
Space Research Centre
Integrated Waste Research Centre

• SRC
  - Spacecraft design, miniaturisation, formation flying, applications (EO), and end-of-life technologies relevant to space debris. Cranfield also has active research in manned spaceflight and in launcher technologies.
  - Extensive work on SAR data processing and interpretation.
  - Collaborations with Centre for Geographical Information Management

• IWRC
  - Waste logistics and policy assessment, application of biosolids to land, composting practice, technology and analytical techniques development for waste diagnostics and research on the remediation of contaminated land and associated polluted waters

Imaging Products and Information
Tailored to End-Users
Research Background


Landfills → Best Practicable Environmental Option for certain types of waste in the foreseeable future.

Methane and carbon dioxide emissions and leachate land contamination.
Research Background

World Bank Report

Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America


Low- and middle-income countries: **high urban expansion**

Limited legislation, regulation and guidance

The **open dump approach** remains the predominant waste disposal option

**Future establishment of uncontrolled and illegal landfilling** activities of both hazardous (e.g., clinical and chemical wastes) and non-hazardous wastes is therefore an **urgent problem**
Solid Waste Landfill: Involved Entities

- Waste industry managers
- Landfill operators
- Environment protection institutions
- Landfill regulators
- Private individuals
- Property land owners & Real estate companies

...different needs, therefore different requirements on EO systems!!
Applications of Earth Observation

1. Waste production quantities and characterisation (land classification)
2. Landfill siting (site geology & hydrology studies, waste transportation management, urban planning support)
3. Onsite waste management (operations support, void-take up surveys, surface water run-off analysis)
4. Landfill monitoring (area of the site, respect of procedures and regulations, prevention of environmental pollution)
5. Monitor change in time and collect site history for private concerns such as health and security issues, legal litigation, real estate value.
6. Illegal site detection
Research Rationale

- Detection & monitoring has been proved to be ambiguous
- Largely qualitative studies
- Never with SAR

- From Multi to Hyperspectral
- SAR data
- Multi-sensor data fusion
Site Detection

A priori knowledge!
Site Detection

Ambiguous spectral signature
- areas undergoing some type of development
- or simply not reclaimed disturbed areas

Hyperspectral Data
SAR Interferometry

Pair of SAR images
Backscattered signal

Interferometric Coherence

\[ \gamma = \frac{E\{y_1 y_2^*\}}{\sqrt{E\{|y_1|^2\} E\{|y_2|^2\}}} \]

Multiplicative Interferometry

Earth Flattering and Phase Unwrapping

Phase shift (0-360°)

\[ \Delta \phi = 2 (r_2 - r_1) \frac{2\pi}{\lambda} \]

\[ z(x) = h - r_1 \cos \theta \]

Topography DEM
Research OBJECTIVES

Objectives:

(1) to develop methods of detecting and mapping landfill sites using hyperspectral and radar data separately

(2) to correlate data with on-site operational procedures, and

(3) to evaluate further potentials for extrapolation of the techniques beyond the UK

Pilot Project with UK Landfills
Images from Brogborough Landfill
Images from Brogborough Landfill

High variability of characteristics in TIME and SPACE
Objective 1: to develop methods of detecting and mapping landfill sites using hyperspectral and radar data separately

- Required data sets should have seasonal coverage (April/May to August)
- Initial algorithm development using test sites (Brogborough & Stewartby managed by Waste Recycling Group Ltd.)
- Algorithm validation with other sites in the area

- Analysis targets the whole site: spectral and spatial statistical characteristics
- Radiometric/Geometric Correction for hyperspectral data
- SAR Interferometric Coherence analysis
Research METHODOLOGY

Objective 2: to correlate data with on-site operational procedures

- Development and validation phase
- Extensive observations within the site (clay stockpiles, open/closed cells)
- Use of ground based SAR system to characterise specific features
- GPS survey reference data for subsidence values
Monitor change in time

Change detection techniques

Results potentially useful for REGULATORS and ENVIRONMENTAL INSTITUTIONS

Spot 2 - 1992  
Landsat 4 - 1992  
Landsat 7 - 2001
Objective 3: to evaluate further potentials for extrapolation of the techniques beyond the UK

- Data fusion
- Knowledge-based techniques (e.g. Fuzzy logic)
Data Fusion

Multi-sensor Fusion

Spectral signature

Loss of coherence in certain areas

Topographic characteristic
PROBA CHRIS Acquisition

CHRIS data should be acquired as close as possible in time to the selected **ENVISAT ASAR** dates:

- 9\(^{th}\) May
- 13\(^{th}\) June
- 18\(^{th}\) July
- 25\(^{th}\) July
- 22\(^{nd}\) August
- 29\(^{th}\) August

**CHRIS mode** should be in **Mode 3** at full spatial resolution, full swath, and using 18 bands for land/aerosols. **NADIR** only.