Historic International EO Usage Case Study

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Purpose and aim

The overall aim of this project was to evaluate critically the ability of existing or near launch Earth Observation (EO) sensors to fulfil the activity data requirements of the future integrated Agriculture, Forestry and Other Land Use (AFOLU) inventory of Greenhouse Gas (GHG) emissions. This document relates this overarching aim to deliver an in-depth study of the use of EO for two GHG inventory activities carried out by individual member countries in the Global Research Alliance (GRA) on Agricultural Greenhouse Gases.

Background

As part of the overall project, an international stocktake on EO use by GRA member countries was carried out through an on-line questionnaire. The questionnaire responses were collated to form a skeleton for case studies of existing and successful international EO utilisation. The two sets of activity area responses were then selected and, via more detailed interaction with the selected GRA members, this skeleton was fleshed out to report on:

- the drivers for use of EO data;
- its implementation process and timescale;
- issues met and overcome in the use of EO data;
- opportunities and plans for improvement based on emerging EO products and EO data processing technologies.

Approach

From the international questionnaire responses, only Canada, Mexico and New Zealand expressed willingness to support more detailed case studies of their reasons for using EO data, their experiences and plans for the future. The number of activities available for a case study is shown in Table 1.

Table 1 List of GHG activity areas where each country used EO data and was willing to participate in the case study

Canada	Mexico	New Zealand
Forest area		Forest area
Cropland area	Cropland area	Cropland area
Grassland area		Grassland area
		Wetland area
	Change detection	Change detection
	Land Inundation (flood irrigation)	
	Cropland cover crop	
	Cropland rotation (perennial)	
	Cropland rotation (annual)	
	Cropland water stress	
	Crop area estimation	
	Seeding monitoring	

Two activities were chosen where EO was identified as the primary data source: change detection for New Zealand and Mexico and grassland area for Canada.

Change detection – New Zealand

New Zealand is in the unusual position, internationally, of having a relatively high proportion of methane and nitrous oxide and low share of carbon dioxide. This reflects the largely decarbonised electricity generation sector combined with extensive pastoral-land activities (see Figure 1). The AFOLU inventory is a key component of UNFCCC and Kyoto Protocol reporting by New Zealand.

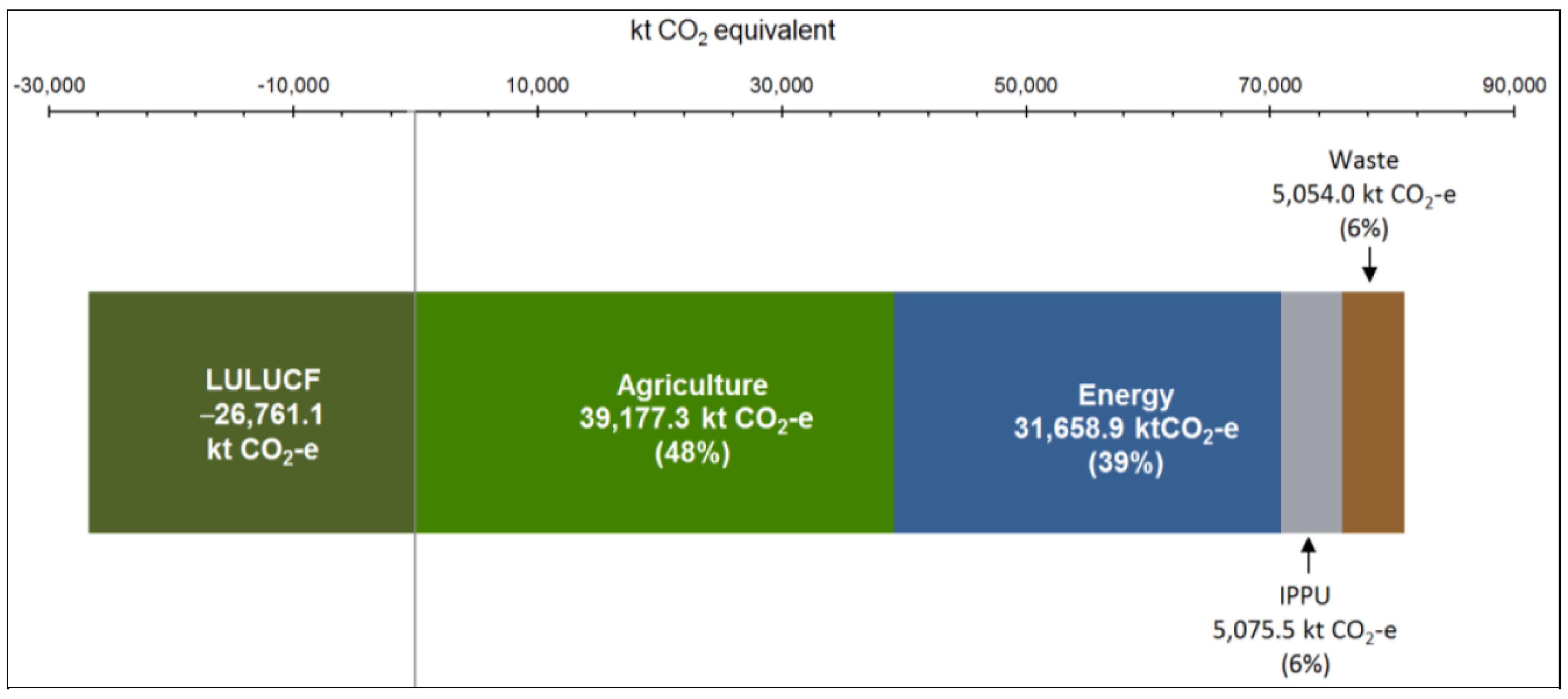

Figure1 Breakdown of GHG emissions (in CO_2e MT) for New Zealand (2013) showing the importance of the agriculture and LULUCF

The initial impetus for use of EO data came from New Zealand becoming a party to the United Nations Framework Convention on Climate Change (UNFCCC). At that time New Zealand did not have a mapped forest inventory with only non-spatial information on land use, acquired by postal surveys. What was required, however, was a robust spatial system to monitor land use change because the country was potentially in a position to claim significant GHG removals during the first Commitment Period (CP1) of the Kyoto Protocol, from the growth of forests planted after 1990.

Other factors which made an EO approach attractive include:

- the inaccessibility of some areas for ground based mapping and detection of change due to the ruggedness of terrain;
- a high proportion of private forest ownership including a large number of forest smallholdings making aggregation of forest management data difficult.

Land Cover DataBase (LCDB) and Land Use Map (LUM) campaigns used a mixture of Landsat and SPOT data. The choice of data was driven, for each mapping exercise, by the historic availability of good quality, cloud free data, spatial resolution and spectral coverage. In terms of data processing, New Zealand benefitted from a strong capability within the research community who had worked with Landsat data since the 1970s. This research base also had the maturity required to "operationalise" techniques for atmospheric correction, cloud clearing and standardising reflectance across rugged terrain. The researchers and mapping staff also had access to a supercomputer network to assist with the more computationally intensive tasks.

Accurate classification of land use change (especially to distinguish deforestation vs. harvesting / replanting cycles) is the main reason for EO failing to fully meet annual change detection requirements. The use of Sentinel-2 for enhanced annual forest loss detection and also for use in the national wall-to-wall land use mapping is currently being investigated. L-Band polarimetric SAR data may also play an important role if ALOS-3 is successfully launched and tasked to systematically monitor global land surface.

Change detection – Mexico

For Mexico, the exploration of EO to support the change detection inventory activity was driven by a combination of the desire to reduce the scale of the monthly observations carried out by field technicians and a requirement to perform monitoring that was both statistically and spatially continuous.

Change detection using EO data is being investigated as part of the project "Spatial dynamic of the agricultural frontier, 2004-2014". The aim is to identify both areas that have remained unchanged during the study period and those that have changed from agricultural use to another land use. The main objective is to identify the areas that have ceased to be of agricultural use but retain productive potential (i.e. idle land).

Stage 1 of the project involved national coverage change detection based on medium (250 m) resolution MODIS data. In Stage 2, high (10 m – 6 m multispectral) resolution SPOT 5, 6 and 7 imagery is used to focus on areas where changes were detected using the coarser MODIS products. The 30 m sampling of Landsat data is too course to resolve typical parcels land in the Mexican landscape.

Seasonal time-series of MODIS NDVI data were used for national coverage and detection of change to be investigated with the high resolution SPOT data. Classification of this high resolution data employs a combination of Principal Components Analysis, image segmentation, segment texture measures and SPOT-derived NDVI. Processing times are minimised by only using the first two principal components of the SPOT multi-spectral imagery which contain the bulk of the variability present in the data.

For change detection, the biggest issue for Mexico is the diverse nature of historic data sources used for calibrating and validating with the derivation of information from EO. All this historic data need to be verified and approved in a single database. Going forward, technical standards have been established for conducting statistical and field surveys that ensure better control over the quality of the information used with EO data.

The potential for improvements using EO data is constrained by the need for change detection from a defined (historic) baseline. That said, in fast evolving areas, such as those of urban or agricultural expansion, the potential of EO to improve the change detection activity is more pronounced, easier to realise and recognise. Current plans for EO include the generation of DEMS SPOT 6 and 7 stereoscopic pairs and application of InSAR based on satellite SAR missions to detect changing land surface elevation.

Grassland Area - Canada

Uptake of EO was driven by the realisation that the use of the agricultural census "Natural land for pasture" variable had several limitations, especially at regional or local levels, and when temporal analyses were required. Not all grassland is used for agriculture, the land managers were inconsistent in the application of the variable, and spatially, land was related to the location of the farm headquarters.

The first satellite-based inventory was carried out in 2006-2008 utilizing supervised classification procedures with extensive visual interpretation and digitization. Landsat was selected as:

- spatial resolution is adequate for most agricultural landscapes in Canada;
- data is inexpensive and readily available with national coverage;
- staff had considerable prior experience with the imagery;
- SPOT data was tested but found to be too expensive so current efforts rely primarily on Landsat and Radarsat-2.

Visual interpretation and digitization have been virtually eliminated from Canadian agricultural land mapping activities with a decision-tree approach to cropland and grassland classification via the See5 data mining/classification tool (https://www.rulequest.com/see5-info.html). The biggest issue for the grassland area inventory activity was identifying and delineating 'native-species' grassland from 'tame-species' grassland from 'improved pasture' and hay.

The problems with using EO to distinguish grassland types relate to their similarities in vegetative reflectance. Visually, areas which have been cultivated in the past are quite discernible but this distinction is based more on recognition of the straight (field) boundaries than on inherent reflectance properties.

Plans include modification of the classification system to incorporate new satellite data such as the Radarsat Constellation Mission (RCM) and the Sentinel satellites missions. New classifier algorithms, such as Random Forest (RF), have become available offering better accuracy and considerably boosted performance.

Summary and conclusions

These three historic case studies illustrate both common and divergent themes as national authorities face both similar technical issues but with distinct national landscape, land use, climatic and financial contexts. When signing up to the UNFCCC, all three countries started with survey information that was repurposed for GHG inventory requirements. Common drivers were the need for capturing inventory relevant information, greater consistency in terms of the information and statistics gathered and spatially continuous national coverage.

Common themes in the selection of different EO technologies and platforms were: data availability (especially for historic baseline information); accessibility; existing expertise and experience; cost and the ability to resolve differences and changes in land cover / use. The interplay of these criteria, resulted in different EO data being selected as each authority responded to their particular national circumstances. All based their work on optical data (principally VNIR with some SWIR) but also investigated SAR data.

The countries studies carried out their own data processing rather than rely on existing high-level data products, although the degree and nature of the processing differed. Despite different national contexts, the range of classification approaches used suggest that there is scope for more joint working to establish and parameterise best practice classification strategies across GRA members. As with the current data processing approaches, there seems a clear benefit in GRA members sharing experiences with new EO data in order to accelerate EO technology utilisation, develop consistent and transparent best practice approaches, and reduce costs.

References

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Webinar: Historic International EO Usage

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