Word count: 1225

In the context of SDG monitoring and reporting, to what extent are satellite observations essential, rather than just "nice to have"?

The Urgency and the Plan

It is difficult to overstate the existential danger posed by the twin crises of climate change and biodiversity loss. Two representative reports are:

- In 2021, the Intergovernmental Panel on Climate Change (IPCC)[1] of the United Nations (UN) stated that "Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years" (Figure 1) [2].

- Sánchez-Bayo and Wyckhuys report [3] dramatic rates of insect loss worldwide that may lead to 40% of insect species becoming extinct in the next few decades - the main cause being intensive agriculture.

These interlocking crises are already causing impacts such as extreme weather events, food insecurity, migration and loss of life.

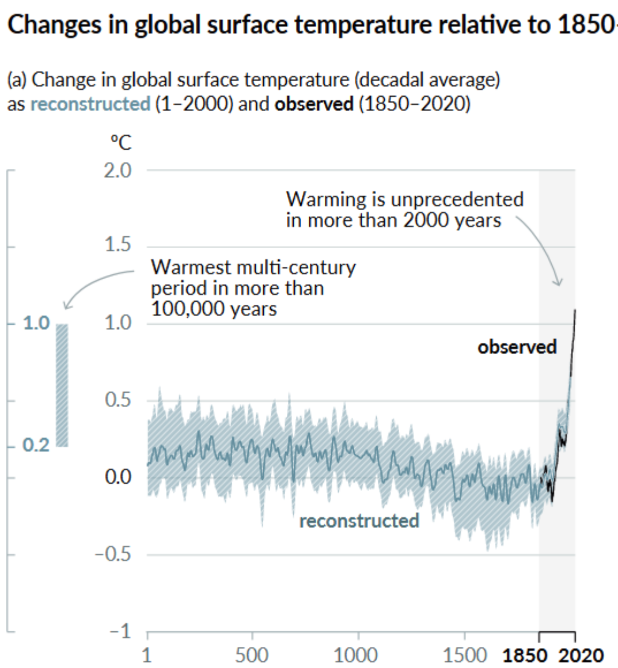

Fig. 1: from IPCC report p6 [2]

In 2015, the UN built on previous work to adopt the 2030 Agenda for Sustainable Development [4], introducing a framework of 17 goals, and the targets to achieve them. Many of the goals address aspects of the climate and biodiversity crises, but the most relevant are Goal 13 *Climate Action*, Goal 14 *Life Below Water*, and Goal 15 *Life on Land* [5].

Setting targets also requires a means to measure the impact of actions taken, ensuring progress is being made, and resources are directed where needed. This was recognised by the UN from the very start of the Sustainable Development Goals (SDG) programme in their 2014 report [6].

A global framework of indicators to support the Agenda [7] were the responsibility of the UN Inter-agency and Expert Group on SDG Indicators (IAEG-SDGs), set up in 2015.

The IAEG-SDGs classifies the indicators into tiers, based on how well the data collection methodology is developed, and whether data is being collected. Tier I has the most maturely-monitored indicators; Tier II represents indicators that have an agreed collection methodology, but data is not being regularly produced; and Tier III indicators have no agreed methodology. The IAEG-SDGs reported in December 2020 that 130 indicators were in Tier I, and 97 in Tier II [8].

Notably no indicators remain in the Tier III category, but approximately 40% of them are still in Tier II, a substantial data deficit.

The cost of gathering data

Traditional data-gathering techniques consist of censuses and surveys, requiring resources (employees, computers, administration) that can be unaffordable for low-income countries. Stable governance is also a requirement for effective data-gathering. Even in countries that meet these conditions a typical census period is 10 years, meaning this data is too infrequent to be effective for monitoring the SDGs.

A 2015 investigation into the resource needed to provide a strong statistical infrastructure in 77 lower-income countries in order to monitor progress towards the SDGs estimated this would cost US $1 billion a year, over the 15 year period (at average 2010-15 prices) [9]. Clearly, cost will be an important factor in whether the SDGs are met, and non-traditional data sources such as satellite (or Earth) observations (EO) should be considered.

There are two aspects to the cost of EO: the cost of developing and launching a satellite; and the cost of access to the data.

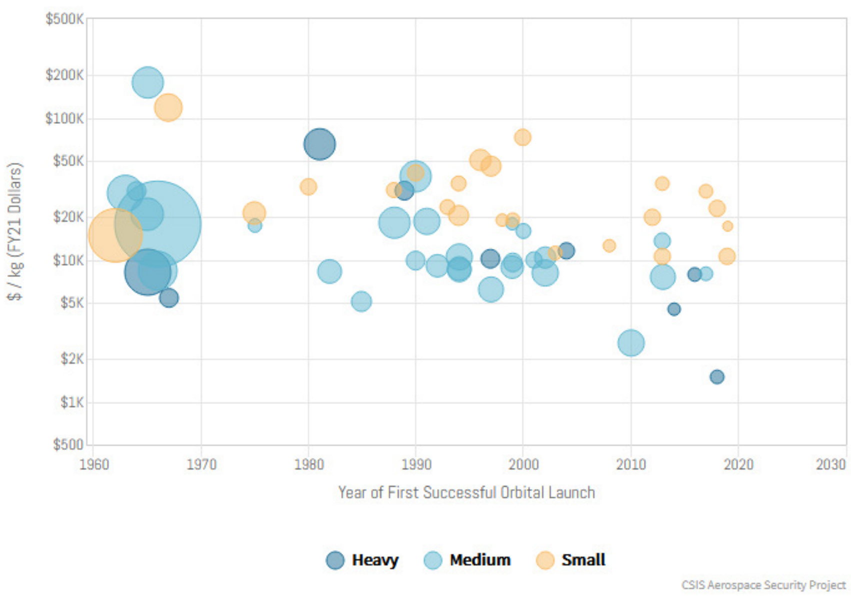

Fig. 2: Comparing Costs for Space Launch Vehicles [10]

Satellites are cheaper to launch than they used to be (Figure 2) [10]. This chart (interactive at source) shows the cost per kilogram of payload to launch to low Earth orbit. For example, in the 1960s it cost the USA 177,900 $/kg to place a satellite in low Earth orbit using the Delta E launch vehicle. Contrast this with their Falcon 9 launcher which in 2010 cost 2,600 $/kg (at 2021 prices).

The cost of launching a satellite is expected to fall further in future. Lea [11] describes the current generation of 'nanosatellites', weighing between 1 - 10kg and built from standardised parts; they are quick to produce and can be launched from a standard vehicle. This results in an average launch cost of US $575,000 per nanosatellite, a thousand times less than the cost of launching a typical satellite.

An open data policy (where governments, researchers and private enterprises allow access to data at no cost) is also a significant factor in the cost of EO data. Andersen et al [12] report how removing the cost barrier to access Landsat data (available at US $500 per image prior to 2008) resulted in the average number of daily downloads jumping from 53 to 5,700. An advisory committee set up to review the value of this information found that just one year of Landsat data provided far greater value than the cost of building, launching and managing the satellites over many years. [12]

The cost advantage of EO data is particularly significant in less-developed countries where resources for traditional data-gathering techniques are likely to be lacking.

Existing and potential EO uses

A European Environment Agency (EEA) report [13] gives the following examples:

- For Goal 14, many aspects of water quality are captured by NASA's Aqua satellite to assist the protection of the Great Barrier Reef;

- Similarly the not-for-profit organisation OceanMind [14] uses radar and optical EO data to identify illegal fishing (estimated to produce about one fifth of the world's total catch per year);

- For SDG 15, again using both optical and radar data, example uses include monitoring forest management, land degradation, biomass, soil moisture among others.

Some SDG indicators cannot be measured directly through EO, but models can be developed to proxy these, training them on the existing ground-measured data. An example of this is SDG 7 *Affordable and Clean Energy*, where observations captured at night show the presence of electric light. This cannot be an exact correlation with access to energy (in particularly recently with the spread of low energy LED lighting), but it is an important complement to household surveys [12].

Additionally, Hargreaves and Watmough [15] review the capabilities of EO to provide data to measure progress towards SDG 1 *End Poverty*, and set out necessary steps to broaden the usefulness of this technique.

A potential use is described by the space technology company Maxar [16], describing how the combination of satellite images and machine learning (convolutional neural networks) can effectively monitor elephants in near real-time, thus supporting their conservation. This is particularly relevant to SDG indicator 15.7.1 *Wildlife Poaching and Trafficking*, which is currently reported [17] as having no data.

Conclusion

There is still work to be done in incorporating EO and other non-traditional data sources into national statistics. A TReNDS report [18] puts forward a framework to increase the trust in non-traditional data, with case studies of official use of EO in Mexico and Ghana.

However the significance of EO in monitoring progress towards the SDGs should be clear. The EEA report [13] recognises “the fundamental, strategic importance of satellite Earth observation data to the 2030 Agenda“. Ferreira et al [19] say that in the context of monitoring progress towards the SDGs “Satellite imagery may be perhaps the only cost-effective technology able to provide data at a global scale”.

Given the foregoing, it should be clear that any additional data sources that can assist in monitoring the SDGs are urgently needed. Satellite observations, with their proven track record, low (and falling) cost, and active research community are ideally placed to make an essential contribution.

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