Evaluation from the Bird's-Eye View: Innovative Use of Remote Sensing Techniques

Leppert, Gerald; Lech, Malte; Ghaffarian, Saman; Kerle, Norman

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DEval
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INSTITUTE FOR
DEVELOPMENT
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EVALUATION FROM THE BIRD'S-EYE VIEW: INNOVATIVE USE OF REMOTE SENSING TECHNIQUES

Summary

In November 2013, the Philippines faced one of the most powerful tropical cyclones ever recorded. Typhoon Haiyan devastated large parts of the central Philippine archipelago, leading to over 6 000 casualties in the country. Within a long history of extreme weather events, the typhoon is the latest severe episode to reveal the country's high vulnerability to climate change. In a disaster situation, such as in the aftermath of Haiyan, a bird's eye view is necessary to get a clear picture of the situation: to map the extent of damage, to provide emergency help, and to support disaster recovery. The use of remote sensing (RS) technologies is integral to this. Figure 1 gives an example of an RS analysis of the extent and type of damage in typhoon-devastated Tacloban City.

A bird's-eye view also opens new perspectives for evaluators. A spatial impression of changes in local conditions (e.g. in forest cover, in reconstruction, or the effects of climate change) improves understanding of the impacts and effectiveness of development programmes. A systematic use of RS data opens a door for evaluators to better address evaluation questions by adding a spatial dimension. This policy brief highlights DEval's methodological approach to the analysis of high-resolution RS data through the application of image classification and machine-learning (ML) techniques. DEval has been developing this approach in close cooperation with RS experts from the Faculty of Geo-information Science and Earth Observation (ITC) at the University of Twente in the Netherlands.

The goal of using innovative RS techniques is to improve evaluability by incorporating an additional methodological approach into a mixed-methods evaluation toolkit. The key advantages of an RS-based approach are:

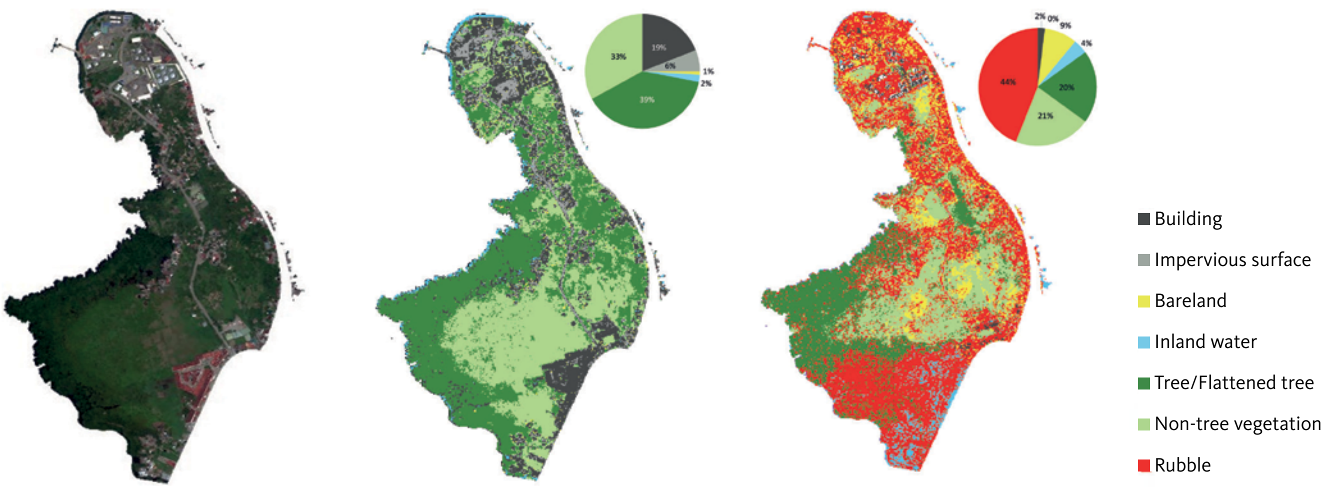
- the extension of an evaluation's time-frame, as archived RS data are often available for the period both before and after a development intervention or specific event (e.g. a natural disaster)
- the possibility of covering areas that are difficult to access (e.g. due to conflict or disaster)
- the ability to track immediate but also gradual changes in the human and physical environment.

The study on disaster risk management (DRM) in the Tacloban area provided a case for the application of an advanced land-cover and land-use (LCLU) classification system, supported by state-of-the-art ML-techniques. The methodological approach enabled the measuring of complex indicators of disaster resilience and socio-economic change. Put simply, by using a system to detect and measure changes in land use (almost) automatically we assessed disaster recovery through proxy indicators. The ML-based approach allowed an assessment to be made at a larger geographic scale. The proxy-based approach paves the way for further impact assessments using RS data, for example in the field of climate change adaptation (CCA) – an increasingly important yet methodologically challenging topic for the evaluation community.

Innovative use of RS to address complex evaluation objectives

Development cooperation and the evaluation thereof face increasing complexity, a greater spatial reach of interventions and a growing demand for rigorous impact assessments. An example is the field of CCA. Climate-change-induced incidences of severe weather events and changes in vegetation, land use and water scarcity require human response and adaptation. Thus, evaluators need to be able to assess interventions on climate

Figure 1 LCLU classification of barangay 69 in Tacloban City before and after typhoon Haiyan



(a) Original image before disaster (T0)

(b) LCLU classification before disaster (T0)

(c) LCLU classification directly after disaster (T1)

Source: Lech et al., 2020

change mitigation, CCA, and DRM, including long-term development measures and gradual changes.

Related evaluation questions challenge the current toolkit of evaluators, as they require geospatial data and analysis. Beyond maps and pre-classified geographic data, innovative use of RS techniques allows the assessment and measurement of interventions and human responses, including gradual changes and changes at large scale.

RS is a geospatial data-collection method that employs a multitude of sensors deployed on platforms such as satellites, unmanned aerial vehicles and aeroplanes. The spectral bands from different sensors range from visible light to near infrared and radar signatures. The collected data can be assessed using geographic information systems (GIS) and image-analysis algorithms. Scale can vary from very small feature-based assessment (e.g. the structure of buildings and roofs) to land cover on a global scale. An ML[1] algorithm permits the identification of complex and variable features, such as a specific land-use or disaster damage, from a small number of samples of the target feature coupled with very large existing image databases, thus expanding local analysis to a larger scale.

The flexibility of RS data allows for a multitude of different applications within evaluations. Because RS data collection happens independently from the evaluation process, it is possible to obtain RS data collected prior to the evaluation and the development intervention, which may provide important baseline information otherwise not available. Comparisons of imagery from different points in time unveil changes and allows rigorous impact assessments. By using RS data from different spectral bands, not only can visible features be identified but also a large variety of other features, such as building materials, vegetation, or physical changes.

DEval and ITC developed a methodological approach that uses state-of-the-art ML for land-use classification to assess disaster resilience (Lech et al., 2020; Kerle et al., 2019). ML has the advantage that it is able to reliably classify large datasets (i.e. land areas) with high efficiency and accuracy based on trained and self-optimising computing procedures. DEval tested the approach on a case study in the Philippines that is based on an evaluation of comprehensive land-use planning (Leppert et al., 2018). Our study applied a mixed-methods design by integrating existing survey data on planning and DRM in communities with information derived from high-resolution RS imagery collected over a period of several years. The goal of the case study was to develop a proof of concept for method integration, integrating RS with ML and econometric evaluation methods, to obtain reliable information on disaster extent, recovery performance and resilience.

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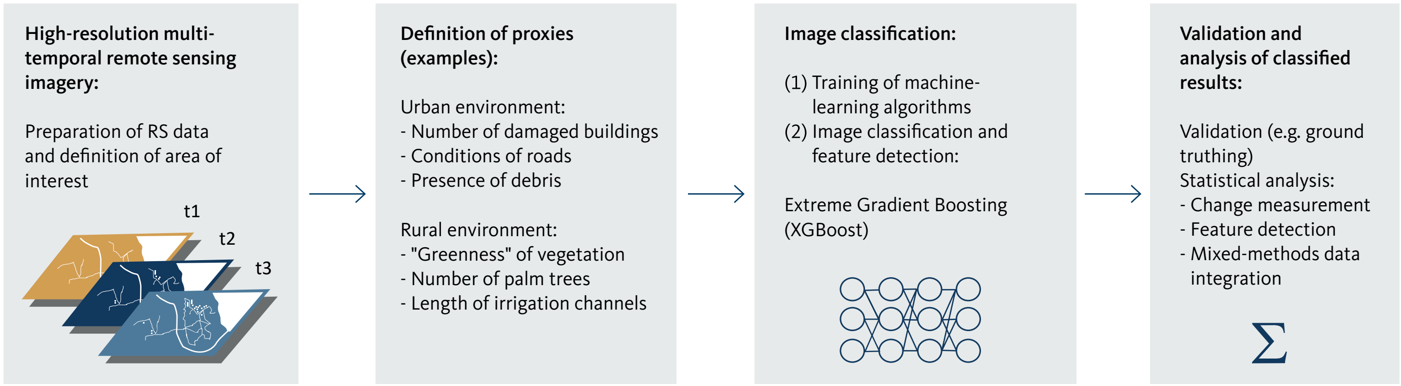
[1] *Machine learning is a form of artificial intelligence (AI). Its algorithms progressively improve their performance on a specific task, for example the recognition of patterns in large datasets. They become more accurate in predicting outcomes by improving with experience.*

Figure 2 **Stylized workflow of proxy-based RS analysis**



High-resolution multi-temporal remote sensing imagery:

Preparation of RS data and definition of area of interest

→

Definition of proxies (examples):

Urban environment:
- Number of damaged buildings
- Conditions of roads
- Presence of debris

Rural environment:
- "Greenness" of vegetation
- Number of palm trees
- Length of irrigation channels

→

Image classification:

(1) Training of machine-learning algorithms
(2) Image classification and feature detection:

Extreme Gradient Boosting (XGBoost)

→

Validation and analysis of classified results:

Validation (e.g. ground truthing)
Statistical analysis:
- Change measurement
- Feature detection
- Mixed-methods data integration

Source: DEval, own figure

Methodological approach to couple RS data with machine learning

In our methodological approach to measuring disaster resilience, we defined certain visual patterns as proxies for disaster reconstruction and socio-economic change, ranging from damage assessment to agricultural and socio-economic recovery.

For the case study, we used spectral data from commercial satellites, including WorldView-2/3 and Pleiades. These satellites are able to obtain images in the visual and near infrared spectral range, up to a spatial resolution of 50 cm – a level of detail needed to detect small objects such as individual vehicles, information on building material or small-scale crop patterns.

We derived a catalogue of proxies from an in-depth analysis of LCLU data. In this approach, evaluators visually identified different land classes in the RS data, manually selected training areas of RS imagery for each class, and implemented the classification method based on these areas. Indicators ranged from general LCLU classes, such as building structures or areas covered in debris or rubble, to roofing patterns. The catalogue of proxies not only allowed the damage to be measured but also sought to obtain functional assessments and to approximate socio-economic status, e.g. by identifying informal settlements. An ML-based classifier, specialised for image analysis, then applied the ML training scheme to the classification of substantially larger areas. We predominantly used the ML algorithm Extreme Gradient Boosting (XGBoost) – a supervised learning model that allows classification with a high degree of precision and performance through reinforced and progressive learning. ML-based analysis has strong advantages, particularly in larger land areas, and where complex features or patterns are to be detected that cannot be easily or unambiguously described, as necessary in more traditional classification training approaches.

We carried out a multi-temporal analysis with RS data obtained at four points in time to detect and quantify changes: the pre-disaster situation, just after the typhoon, and at two points in the post-disaster phase, thus allowing for an assessment of damages and recovery processes in different areas. For example, by measuring the presence of construction material and vehicles, evaluators could assess the degree of infrastructure development and socio-economic change.

Opportunities and challenges

The proxy-based approach to RS image analysis opens up a number of opportunities for evaluations by enabling an assessment of changes, from small- to large-scale, from vehicle traffic or crop composition to changes in LCLU stretching over many kilometres. Spectral information beyond the visual range of the human eye widens its application, for example to the analysis of ecological systems or agricultural production. The approach enables an extrapolation of socio-economic conditions of areas not covered in any survey data, such as characteristics of houses, functionality of road infrastructure, and presence of public institutions. In addition, it enables an identification of more subtle large-scale changes, such as those that occur in crop composition, which are difficult to appraise on the ground.

Although RS data is now widely available and ML techniques are becoming more efficient and accurate at classifying data, validated proxies are still rare (Lech et al., 2020). Also,

"ground-truthing" – the triangulation with more detailed, local information to improve the quality of ML algorithm training – continues to be important, for example for the verification of project data. The high cost of commercial (very) high-resolution RS data, amounting to USD 25–35 per square kilometre, remain a constraint for extending the scale of analysis. On the other hand, there is an increasing stock of suitable open-access RS data, for example the European Sentinel or Planet Labs data.

Future developments: it is time to add RS analysis to your toolkit

ML-based classification of RS data offers great potential for evaluations of development cooperation, adding a spatial dimension. Its application stretches (far) beyond environmental, DRM or CCA interventions to those on urban and rural development, migration and transformative approaches. Advancements will allow the detailed measurement of current economic activity, infrastructure utilization, farming and cropping techniques, and ecological conservation.

Our case study on DRM in the Philippines was relatively simple, as the process of reconstruction is very localised and was triggered by a clearly defined event (the typhoon). More gradual environmental processes and diverse human interventions or activities require further technological advances, as well as new and enhanced proxies. Thus, we aim to extend the set of proxy indicators to other environmental and socio-economic indicators, such as vegetation change, agricultural production, and soil fertility. For example, in an evaluation on CCA, we are conducting a geospatial impact analysis on the effects of German Development Cooperation's irrigation interventions in Mali. Other areas for improvement are a better integration of ground-truthing and a systematic inclusion of RS-based analyses in mixed-methods designs.

The variety and quality of RS data has increased as the cost has decreased. Improved computing power and more sophisticated ML classification methods continually expand the spectrum of possible applications. It is time to add innovative RS techniques as an integral and flexible part of the evaluator's toolkit.

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Dr Gerald Leppert, *Team Leader, DEval*

Dr Malte Lech, *former Evaluator, DEval*

Dr Saman Ghaffarian, *Wageningen University*

Professor Dr Norman Kerle, *ITC, University of Twente*

ITC
UNIVERSITY
OF TWENTE.

German Institute
for Development Evaluation (DEval)

Fritz-Schäffer-Straße 26 · D-53113 Bonn, Germany
Phone +49 228 33 69 07-0

info@DEval.org
www.DEval.org