Growing needs: Enhancing agricultural productive use demand forecasting using satellite data and machine learning

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Electrification planning must address electricity demand constraints to ensure economic growth stimulation. Can we use satellite data and predictive data analytics to identify potential electricity demand for agriculture? We propose a unique approach to identify areas with existing diesel-powered irrigation that can be targeted for electrification.

Key messages and recommendations

- Predictive data analytics using publicly accessible satellite data can be used to identify locations with latent electricity demand for irrigation with 75% accuracy, potentially offering utilities a consistent and substantial source of revenue to supplement the low residential demand from rural customers.
- Improving accessibility and availability of high-quality ground-truth data from surveys, energy systems and other technologies could enhance the use of satellite data and machine learning for data-driven electrification planning.
- Researchers should collaborate with policymakers to learn how to make satellite data and predictive data analytics outputs actionable.

There is a Need to Bridge a Data Gap in Electrification Planning

Sub-Saharan Africa is faced with the challenge to reach the twin goals of providing universal electricity access and achieving net zero emissions. Policymakers and development partners are therefore grappling with the question of how to couple electrification planning with climate action and sustainable development of other sectors of the economy. To achieve this balance, policymakers and other energy sector stakeholders should rely on data-driven insights to drive decision-making. However, the required data are often not well documented and, if collected by governments, utilities, and private entities, are usually in an unusable format, behind a paywall, or entirely inaccessible to the research and policy community.

Recent advancements in technology such as remote sensing, digitization, and machine learning have enabled the availability of vast amounts of publicly accessible data along with tools for interpretation. Satellites, in particular, have become a reliable measure of ground-level conditions, which can be useful in electrification planning. Combined with machine learning, the use of satellite data in predictive data analytics for electrification planning is largely untapped. Previous efforts in this space have focused on supply-side electrification planning, mainly evaluating the least-cost technology pathways for providing universal access.

Addressing Demand Constraints in Electrification Planning is Vital

Electrification planning must address electricity demand constraints at every stage, not least the planning stage, to ensure that electrification can reach as many customers as possible while stimulating economic growth. From a utility's standpoint, adequate demand from anchor customers is crucial, since these offer a consistent and substantial source of revenue to supplement the low demand from rural customers and the basis to set cost-reflective and affordable tariffs. The question remains: How can communities with significant potential electricity consumption be identified?

With support from the World Bank, the Government of Ethiopia launched the National Electrification Plan (NEP) in 2017, including a comprehensive plan to reach 100% electricity access by 2025. Ethiopia's NEP prioritizes grid access to areas with the highest potential for irrigation and agricultural processing, considering the particular importance of agriculture for rural livelihoods.

To inform the NEP, researchers from the University of Massachusetts Amherst and the RWI – Leibniz Institute for Economic Research applied a unique approach to identifying areas with existing diesel-powered irrigation in Ethiopia by combining data from an agricultural survey with satellite-measured pollution, crop cover, elevation, and surface water data (Lukuyu et al. 2022). Locations with diesel-powered irrigation represent sites more likely to adopt electricity and provide stable revenue from electricity sales. This information can be of significant value to grid extension planning in settings where little other economic activity exists in rural areas. Further, reducing the use of diesel-powered irrigation pumps could reduce macro and micro dependence on fossil fuels, yield cost savings among farmers and accelerate Ethiopia's climate action plan.

Our Predictive Classification Model in Brief

We collected real examples of where irrigation is happening in Ethiopia's Amhara and Oromia regions, as well as ground-truth information on the method of irrigation used. We clustered the areas into 250m patches and labelled them based on the prevalent irrigation method (diesel- or non-diesel). We defined each patch's characteristics (GPS coordinates, pollution, crop cover, elevation, population, and proximity to surface water) and trained a machine learning model to distinguish between diesel-based and non-diesel-based irrigated areas based on these characteristics.

Predictive Data Analytics Could Identify Latent Electricity Demand for Irrigation

This approach leverages an essential characteristic of diesel pumps: the emission of pollutants that can be measured remotely by a satellite instrument. Further, it is based on the hypothesis that diesel-irrigation activity is detectable by matching pollution patterns to irrigation seasonality. That is, only during months with irrigation activity do areas with a prevalence of diesel-based irrigation activity have higher pollution levels than areas irrigated with other non-pollution methods. During the other months, the pollution levels are not significantly different.

We trained a predictive classification model to distinguish areas with diesel-based irrigation activity from areas with non-diesel-based irrigation activity (see Box). Our model correctly identified the areas in our sample with diesel-powered irrigation with 75% accuracy. Further, we applied our predictive model to the Amhara region, which predicted that 20% of the irrigation activity in the area is diesel-powered and primarily takes place in the south-western part (Figure 1). A caveat to note is that our model was trained on limited samples presenting a challenge in scaling the application of our prediction model beyond the study area. Further, we acknowledge that other prominent sources of emissions, such as transportation and agricultural post-processing activities, can confound these findings, potentially inhibiting the performance of our technique in settings with other significant sources of emissions.

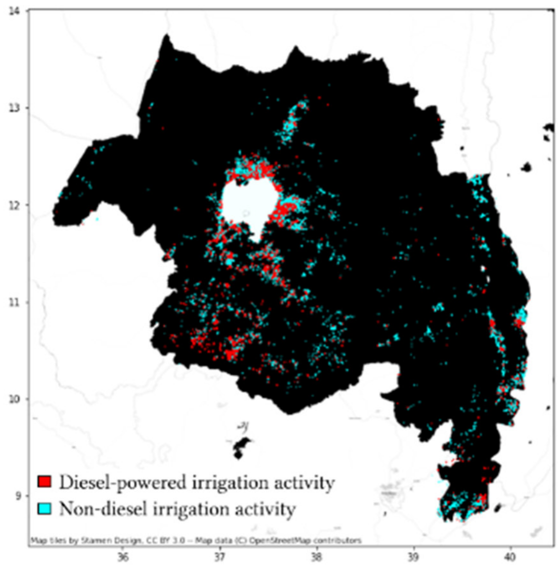

Figure 1: Predictions of diesel-powered irrigation activity in the Amhara region of Ethiopia.

Policy Recommendations

To enhance the use of publicly accessible satellite data and machine learning approaches to support data-driven decision-making for energy, climate, and development policy in Sub-Saharan Africa:

- Governments and other private actors should increase efforts to make high-quality ground-truth data from surveys, energy systems and other technologies accessible and available to researchers to overcome the barrier of collecting large ground truth samples, which is highly resource-intensive and logistically challenging. Additionally, methods for data collection should be developed with machine learning applications in consideration and standardized for repeated applications.
- Researchers and policymakers should collaborate to learn how to make satellite data, and predictive data analytics outputs interpretable and actionable.
- The research community should create platforms for data sharing and examples of research outputs presented in a readily usable format by policymakers.

Reference

Lukuyu, J., G. Bensch, T. Conlon, A. Patel, V. Modi and J. Taneja (2022), Diesel GenSat: using satellite data to detect diesel-powered irrigation for guiding electrification in Ethiopia. *e-Energy '22: Proceedings of the Thirteenth ACM International Conference on Future Energy Systems*, 325–337. DOI: 10.1145/3538637.3538862

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