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FORECASTING SUSTAINABLE DEVELOPMENT GOALS: A TIME-SERIES ANALYSIS USING PROPHET MODEL ON GLOBAL SDG INDICATORS

DR EIMAD ABUSHAM
Faculty of Computing and Information Technology, Sohar University, Oman
Email: eabusham@su.edu.om
ORCID: 0000-0002-4895-2057

DR SALAHALDIN ABDULKADER JEBARAH
Faculty of Business, Sohar University, PO Box 44, Sohar, PC 311, Oman
Email: SAbdulkader@su.edu.om
ORCID: 0009-0001-0762-7821

DR AHMAD KAYED AHMAD KAYED
Faculty of Computing and Information Technology, Sohar University, Oman
Email: akayed@su.edu.om
ORCID: 0000-0002-0417-0440

DR MAHMOOD AL-BAHRI
Faculty of Computing and Information Technology, Sohar University, Oman
Email: mbahri@su.edu.om
ORCID: 0000-0002-0176-0680

ABSTRACT

PURPOSE: To construct a transparent, reproducible pipeline of modelling SDG regional trajectories towards 2030 to use Prophet, harmonising data and regions, visualising observed and projected performance, and determining key policy priorities in inclusion, city systems and ecological governance.

DESIGN/METHODOLOGY/APPROACH: Region-goal, we specied Prophet using piecewise-linear trend, no seasonality, additive errors; make predictions out to 2030 and truncate at 0-100.

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FINDINGS: Europe and North America lead in social services and infrastructure, Asia, Latin America, and the Caribbean are mixed but improving, Oceania is split between Australia/New Zealand and Pacific nations, and Africa is recovering from basic services, ecosystems, and institution collapses.

VALUE: A fully scripted, end-to-end workflow that automates data harmonisation and cartography, yields a compact figure suitable for high-impact outlets, and supports consistent cross-region, cross-goal comparisons.

RESEARCH LIMITATIONS/IMPLICATIONS: Results inherit limitations of the underlying SDG indicators (coverage, comparability, and potential measurement error).

KEYWORDS: *Time-Series Forecasting; Sustainable Development Goals; Global Indicators; Prophet Model; Predictive Modelling; Trend Analysis.*

INTRODUCTION

The green paper on the Sustainable Development Goals (SDGs) of the United Nations requires timely and reliable information on the progress that countries are making and the direction they will take in the future. There is a growing demand on the part of policy-makers, donors, and researchers to have short- to medium-term forecasts to organise interventions, resource allocation, and evaluation of the possible effects of shocks. However, SDG indicators are not uniform in frequency and scale, usually tend to have gaps and outliers, and have breaks in their structure (because of a policy change or crisis, e.g., COVID-19). These characteristics make the classical time-series modelling more challenging, and are the reason the robust and transparent methods are in use.

In this paper, forecasts of global SDG indicators are made based on a decomposable time-series model, which is applied to Prophet. Prophet models each series as the cumulative (or logistic) product of trend and seasonality, and optional external regressors; it is also supposed to be resistant to missing values and outliers as well as non-expert interpretable. We train Prophet using (indicator, country)-sensitive models, in order to obtain localised dynamics, and train them with the same algorithm on the full set of indicators with upper and lower limits on a 0-100 scale. We do suitable transformations to ensure that natural limits are observed.

An SDG index file developed between 2000 and 2022 is the starting point of the empirical pipeline and is used as a basis in the next stage of the empirical pipeline, the structured data engineering step. The validation of required fields, conversion of the data into long format (ds, y schema), standardisation of the country names, and normalisation of the region labels to six macro-regions is used to create a summary visualisation. In order to give descriptive context, we compute the most recent year observed regional and indicator means, and display a world choropleth and tight regional panels that we export as both figures and the underlying CSV tables to allow the reproduction of the result. Such descriptive products do not only audit the input, but also base further forecasts on the latest empirical distribution.

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The paper has three contributions, (i) scalable, clear SDG forecasting pipeline on top of sound pre-processing and disciplined cross-validation; (ii) systematic comparative evaluation versus conventional baselines on a variety of indicators and countries; and (iii) outputs that are easy to use, i.e., maps, regional panels, calibrated forecast tables, and band of scenarios, can be directly used in policy debates. The rest of the paper presents information and preparation, model definition and testing, findings by indicator and geographical unit, and the consequences of SDG monitoring and planning.

RELATED WORK

The Sustainable Development Goals (SDGs) system, which was adopted at the international level in 2015, introduces the ambitious plan of the inclusive, equitable, and sustainable development on economic, social, and environmental levels. However, the monitoring and prediction of progress to these objectives is a problem at the methodological level, due to the heterogeneity, complexity, and often incompleteness of SDG-related data. Over the last few years, time-series forecasting techniques, specifically the Facebook Prophet model, have become promising in terms of predicting the direction of SDG indicators; this would facilitate the formulation of improved policy and intervention strategies.

Time-Series Forecasting for SDG Monitoring

Time-series forecasting has become prevalent in SDG research, especially given that longitudinal data have become more available in areas such as health, climate, energy, and disaster resilience. Linear time-dependent data have been widely calculated using the traditional models of ARIMA and SARIMA. An example is a study done by Chaturvedi *et al.* (2022) to compare SARIMA, LSTM, and Prophet on the energy demand forecasting of India; they discovered that the choice of models has an important impact on the accuracy, based on the seasonality and data granularity.

The Facebook Prophet model, which was created to allow predicting business activities, has been successfully repurposed to SDG areas. Its benefits are its simplicity, scalability, and the possibility of dealing with missing data and seasonality (Ahmad *et al.*, 2025; Arslan, 2022). Prophet was used by Ahmad *et al.* (2025) to project the number of deaths associated with disasters in SDG 11.5, and by Hasnain *et al.* (2022) to forecast air pollution in China, where the results were feasible.

Prophet + LSTM or SARIMA models have also demonstrated a higher level of accuracy and robustness. Arslan (2022) designed a Prophet-LSTM model that predicts

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energy consumption that, as opposed to standalone models, yields better results. Likewise, Kenyi and Yamamoto (2024) suggested a hybrid of SARIMA-Prophet to predict river streamflow in South Sudan in support of SDG 6 (clean water and sanitation).

Comparative Performance of Prophet and Other Models

Several researchers have compared Prophet with other models. Serrano *et al.* (2024) performed a comparative study between Prophet, SARIMA, and ARIMA using Brazilian energy data and found out that Prophet data were better at reproducing seasonal trends, while ARIMA data were more sensitive to short-term changes. Similarly, Anand *et al.* (2024) discovered Prophet to be as competitive as artificial neural networks (ANNs) to predict tasks where the model interpretability and autonomy were more important.

The models used by Sah *et al.* (2022) in epidemic trend forecasting, and applied to SDG 3 (good health and well-being) were Prophet and hybrid LSTM-GRU. Their results revealed that Prophet could work well in modelling seasonality, but hybrid models have an improved overall predictive power. This was supported by Chhabra *et al.* (2024) who used Prophet with ARIMA, Polynomial Regression, and SARIMA to predict epidemics in India.

In the case of environmental SDGs, forecasting tools have been crucial in active policy planning. Dommelen (2021) compared Prophet to predicting the demand of hotel rooms; this is indirectly affiliated with SDG 8 (decent work and economic growth) and tourism sustainability. In the meantime, Prophet and hybrid predictive models were used by Feng (2022) to predict carbon emission and energy consumption, needed to monitor the achievement of SDG 7 (affordable and clean energy) and SDG 13 (climate action).

There is also the increasingly common hybrid time-series models Wen *et al.* (2023). The accuracy of the forecast on SDG-relevant indicators, including CO2 emissions (SDG 13), has proven to be better with hybrid LSTM and ARIMA techniques, and more reliable forward prediction than individual statistical or deep learning baselines. Ripatti (2025) built on this idea by including Prophet, LSTM, and XGBoost to predict the use of medication that is one of the fields where health equity is correlated. These developments are indicative of a general inclination: stand-alone models, although convenient, can be easily overtaken by an integrated architecture in complex SDG settings.

Alharbi (2023) suggested a hierarchical model based on the combination of Prophet, neural networks, and ARIMA to predict the SDG progress in a country and in regions. The need of models, providing control over the heterogeneity of space and different time patterns, is emphasised in his work. Prophet is also strong because of its flexibility. Ansari and Alam (2024) adopted Prophet in a cloud-based, Internet-of-Things (IoT)-based system

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to predict air pollution in 2024. In the same way, Esro *et al.* (2025) combined Prophet and ARIMA in flood forecasting using IoT. These applications imply that Prophet can be used outside of a static time series and can accept real-time data feeds, an important feature with respect to dynamic SDG environments.

Limitations and Future Directions

Prophet has its limitations, although it also has its strengths. It does not assume additive seasonality, which might not suit a wide range of data, neither does it support the deep context learning of neural networks such as LSTM. Santos-Romero and Sanabria (2024) have discovered that predicting rainfall was better with Prophet, but non-linearities were more adequately represented by models such as Random Forest and LSTM. Not every SDG indicator is organised in the form of clean time-series data, which is difficult to realise. This requires the prior pre-processing and transformation of data and can affect the accuracy and interpretability of the forecasts. In the future, explainable AI can be integrated with time-series forecasting in order to build trust and transparency in SDG monitoring. As the complexity and interpretability of the models are important concerns to high-stakes SDG policy choices, a trade-off between predictive performance and transparency and explanation is necessary to ensure that predictions are not only accurate but also actionable to stakeholders and policy-makers (Chenary *et al.*, 2024; Rabbi, 2025).

Prediction of SDGs with the Prophet model and its hybrids is an important methodological step forward in sustainable development analysis. Its use in fields such as the health and energy arenas, as well as the water and air quality fields, shows flexibility, interpretability, and practical applicability. Although it is not a panacea, Prophet presents a useful point of departure to national and global SDG monitoring work. The need to investigate hybrid models, real-time data integration, and explainable frameworks to increase the usefulness of time-series forecasting to sustainable development should be a topic of future research.

METHODOLOGY

We use the SDG Index dataset (sdg_index_2000-2022.csv, country-year scores 0-100 for SDG 1-SDG 17) by Hore (2024). Data are reshaped to long format, country names harmonised, and countries mapped to six macro-regions (North America, Latin America and the Caribbean, Europe, Asia, Africa, Oceania). For each region-goal time series we estimate a Prophet model with a piecewise-linear trend, no seasonality, and additive errors, then project to 2030; very short series fall back to a trailing three-year mean. Because SDG

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scores are bounded, forecasts are clipped to 0-100 and the regional average is computed as the unweighted mean of SDG 1-SDG 17. Results are shown via a methodology framework (Figure 1).

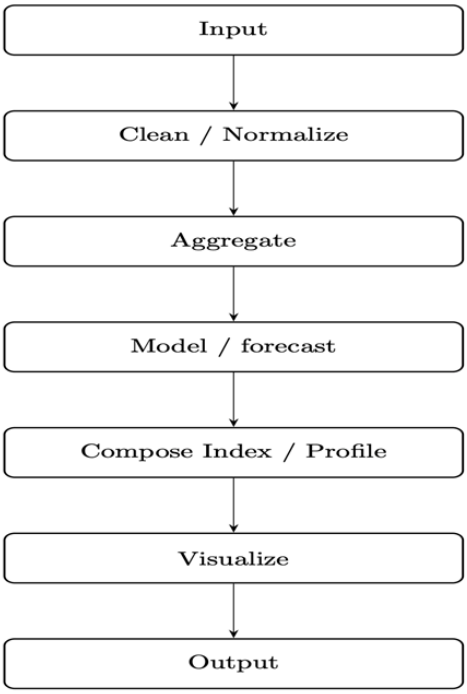

Figure 1: Methodology Framework

Source: Constructed by authors

RESULT AND DISCUSSION

Figure 2 shows the heatmap overview of six world regions based on the SDGs on a scale of 0-100 (darker green = better performance, yellow/orange = worse performance). Reading down each row, the average column presents all the overall attainment, with Europe and North America at the top, Asia and Oceania in the middle, Latin America and Caribbean somewhat below them and overall Africa at the bottom. The analysis of the columns shows uniform strengths and weaknesses. Europe and North America have the highest education and innovation (SDG 4, SDG 9), and both are comparatively good on SDG 1-SDG 2 (poverty and hunger), whereas Asia is quite strong and Oceania is pronounced on SDG 1-SDG 2 (poverty and hunger). Latin America and the Caribbean show an ambivalent score: they have average social goals but are comparatively higher in SDG 12-SDG 13 (responsible consumption and climate). Africa has the lowest score in most of the social and

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service-delivery goals (SDG 1-SDG 8, SDG 11), but shows a relatively high score on SDG 12-SDG 13; this reflects improvement on environmental/climate aspects relative to other regions. We can see two cuts-across pressure points that can be seen almost everywhere, SDG 10 (inequality) and SDG 11 (sustainable cities); these are often lighter (lower) even where high performance is achieved. All in all, the figure gives three messages at a glance: the existence of large between-region disparities in average SDG performance, within-region disparities across goals, and global challenges in inequality and urban sustainability.

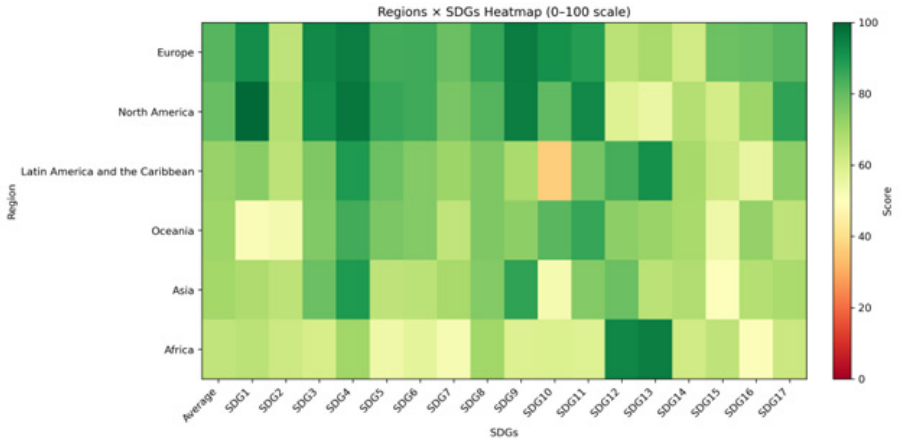

Figure 2: Heatmap overview of six world regions

Source: Constructed by authors

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The world choropleth of latest observed country averages (Figure 3) provides complementary views of current status and projected trajectories.

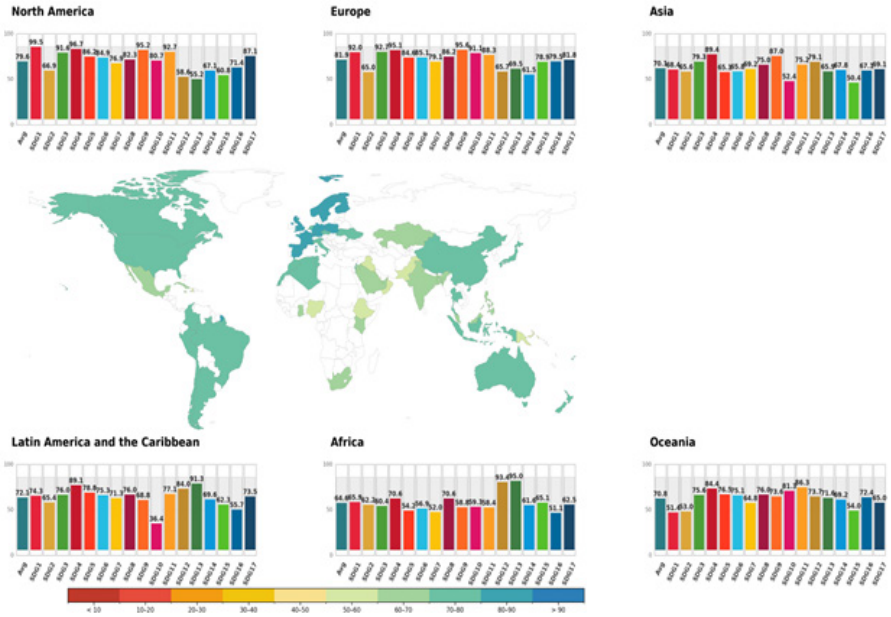

Figure 3: World Choropleth

Source: Constructed by authors

North America

According to the projected 2030 profile of North America, the developing profiles are high attainment on the foundation societal goals, namely, No poverty (SDG 1), Good health (SDG 3) and Quality education (SDG 4), as well as on the productive-capacity goals Industry and innovation (SDG 9) and Partnerships (SDG 17). Solid but not frontier-level is affordable and clean energy (SDG 7) and Decent work (SDG 8), showing an uneven clean-energy penetration and even labour-market dualism. There are evident areas of pressure in Sustainable cities (SDG 11), Responsible consumption (SDG 12) and Life below water (SDG 14): the issue of urban affordability/transport emissions, material footprints, and the impact on the coast and marine areas are fixing factors. Inequality (SDG 10) is rated in the middle-band, between the global levels and the movement towards the best performance. The implication of the policy is that the provision of services (mainly mature) will be shifted to structural sustainability: deep building renovations and transit-

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oriented development (SDG 11), circular-economy instruments and extended producer responsibility (SDG 12), and a blue-economy governance of fisheries, runoff, and plastics (SDG 14). The transitions can be stepped up via leadership on R&D (SDG 9).

Europe

Europe demonstrates the most well-balanced high performance in terms of goals, and there are always high projections regarding SDG 3, 4, and 9, and good environmental pillars for SDG 12-13. Zero hunger (SDG 2), associated with price volatility and diet-associated targets, and Sustainable cities (SDG 11) are the key areas of weakness, with congestion, housing affordability, and legacy building stock slowing down gains. The low scores for Inequality (SDG 10) point to partial coverage both of regions and cohorts. The frontier issue, with its social protection and human capital already at a high gear, is systemic decarbonisation and demand-side efficiency: raising rates of building renovation, electrification movement, and growing the magnitude of the circular-materials markets (SDG 12) and remaining competitive with innovation (SDG 9). The response to SDG 2 is likely to revolve around the use of diets and food waste, as well as sustainable input use, and not necessarily the yield.

Asia

Asia's profile is heterogeneous but positive: Education (SDG 4), Industry and innovation (SDG 9) and Economic dynamism (SDG 8) are at a high level, in line with the high rate of skill acquisition and manufacturing depth. On the other hand, Inequality (SDG 10) and Sustainable cities (SDG 11) are structural issues, representing megacity sprawl, informality, and spatial inequalities. The performance is average in the domain of environmental performance with Climate action (SDG 13) and Clean energy (SDG 7) performance improving, whilst Life on land (SDG 15) and Life below water (SDG 14) become performance-laggers across several sub-regions due to land-use change and coastal pressures. The overarching trend will consist of twofold transformation: (i) inclusive urbanisation (public transport, affordable housing, universal municipal services) to keep SDG 1011 on target, and (ii) clean industrial upgrading - renewables, storage, efficiency and green supply chains - to keep SDG 7 and 9 gains and SDG 14-15 in balance.

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Latin America and the Caribbean (LAC)

LAC is a combination of pillars with immense human-capital and climate (including Education (SDG 4) and Climate action (SDG 13)) with mid-tier energy (SDG 7) and responsible production (SDG 12). The only weak outlier is Inequality (SDG 10) that is relatively low compared to others and pulls the average of the region forward despite the other goals that have been achieved. These are Peace/Institutions (SDG 16) and Life on land (SDG 15) and appear in the mid/lower band and are the signs of governmental conflict and biomass pressures (deforestation, fires). The priorities of SDG 10 lifting policy are thus financial/transfer progressivity and labour-market formalisation, and the managing jurisdiction forest, sustainable commodities certification, and nature-payments to ecosystem services, leave rural income intact, to safeguard SDG 15. Visionary leadership and SDG 12-13 consolidated leadership can establish a regional green-growth narrative.

Africa

Africa has extensive medium scores in social goals, yet marginal improvement in Health (SDG 3) and Education (SDG 4) and a broad service disparity on Energy (SDG 7), Water and sanitation (SDG 6) and Cities (SDG 11). One of the bright spots is the environment policy core (SDG 12-13) where the panel shows that there is relatively high achievement; this indicates low historical emissions, quickly emerging policy framework, and nature-related potential. However, Land and biodiversity (SDG 15) is not on the frontline as a result of deforestation and habitat fragmentation. The findings suggest an ordered scale-up: (i) last-mile infrastructure (distributed renewables, safe water, sanitation) to strengthen SDG 6, 7 and 11; (ii) productive inclusion (agri-value chains, digital finance) to strengthen the benefits of SDG 12-13, and (iii) nature-positive development to monetise carbon and biodiversity co-benefits to sustain the benefits of SDG 12-13 and improve SDG 15 performance.

Oceania

Oceania has a two-speed development trajectory, with overall results being mediocre, lower results in responsible consumption and production (SDG 12) and climate action (SDG 13), and better performance in education (SDG 4), sustainable cities and communities (SDG 11), and selected social goals; smaller, remote economies in the region perform worse than larger, more prosperous countries. There is moderate inequality (SDG 10) on the basis of geographic dispersion and service delivery among islands. The policy lever is a blue-and-green resilience agenda policy that has a climate-resilient infrastructure, regional labour

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mobility and social protection against SIDS, and circular-economy standards and build-out on high-income anchors. Nature-based and targeted protection and fisheries governance that can complement SDG 14-15, can protect livelihoods.

There are three general patterns that are evident across the regions. Primarily, the most durable headwinds, such as urban systems and inequality (SDG 11 and SDG 10), pose a challenge to even the high-performing regions; this is why place-based housing policies, mass-transit investments, and targeted inclusion policies are important. Second, innovation capacity (SDG 9) is closely related to the overall SDG progress, meaning that research, development, and technology diffusion are the effective goals multipliers. Third, the environmental pillars are separating: various areas are progressing further on climate action and responsible consumption (SDG 13/12) than on biodiversity and oceans (SDG 15/14), so land- and ocean-use governance is the ecological boundary keystone. The combination of the results is indicative of a policy agenda that is focused on social, resilient urban form, and ecological governance, facilitated by clean-technology diffusion.

CONCLUSIONS

This paper builds a transparent and reproducible pipeline to review and visualise the world's progress in achieving the Sustainable Development Goals (SDGs). We normalised countries into six macro-regions with a harmonised country year panel, calculated regional time series of each SDG and produced 2030 projections with a limited Prophet specification. The compound product – an observed-data choropleth of nations and forecast panels of areas – provides a single glance at the state of the globe today and where it is reasonably likely to go in the near future assuming the current patterns continue.

There are three insights that are being repeated. The most intractable barriers, even in the highest performers, are first, urban systems and inequality (SDG 11, SDG 10); this explains why place-based housing policy, expansion of mass-transit, and inclusion instruments are necessary. Second, innovation capacity (SDG 9) is strongly related to other broader attainments, and R&D investment and technology diffusion are shown to be the cross-goal multipliers. Third, environmental development is not symmetrical: areas are improving more on climate and consumption (SDG 13/12) than biodiversity and oceans (SDG 15/14), thus suggesting that land- and ocean-use policy is now the normative ecological boundary.

In our paper we presented a methodological approach to (i) reconcile naming and regional taxonomies; (ii) predicting in the natural scale of the SDGs (with implicit clippings); and (iii) integrating the results of the model with decision support visuals (regional strips, heatmaps and world maps). Using both of these together, we can enhance

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comparability, decrease the likelihood of excessive interpretation of more noisy series, and convert very complicated tables into policy signals understandable at a glance.

The analysis has limitations. Forecasts are extrapolations of recent trends and fail to incorporate structural breaks, policy shocks or non-linear tipping behaviour; short series are simply forecasted by trailing means, which is conservative without being structural. Regional heterogeneity of countries can conceal local outliers, and no equal weighting of goals gives consideration to country or inter-goal trade-offs.

Future studies ought to incorporate policy-clear scenarios (i.e., accelerated retrofits, nature-based solutions, social-protection expansions), provide the integration of the pipeline with causal or structural models, and scale-down findings to sub-national and urban scales where SDG implementation takes place. The forecasts would also be connected with the requirements of investment and co-benefits (health, jobs, damage avoided), which would further facilitate prioritisation. Nevertheless, the findings are an empirically demonstrable roadmap: social inclusion and robust urban structure among couples accelerate the spread of clean-technologies, and strengthen land and ocean governance to alter existing trajectories of sustainable SDG benefits by 2030.

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BIOGRAPHY

Dr Eimad Eldin Abusham is an Associate Professor of Computer Science with extensive expertise in Artificial Intelligence, Cybersecurity, and Biometric Systems. With a strong academic and research background, Dr Abusham has taught and supervised undergraduate and postgraduate students across institutions in Oman, Malaysia, and Sudan. He has published in reputable journals and has led several high-impact research projects focused on AI-driven solutions for national development, including legal tech, biometric authentication, and sustainable smart systems.

Dr Salahaldin Abdulkader Jebarah is a seasoned legal scholar and practitioner with extensive academic and professional experience across Sudan, the Netherlands, the UK, and the Gulf region. He holds a PhD in Commercial Law from the University of Wolverhampton and an LLM in International Business and Commercial Law from the University of West London; he has practiced as a solicitor in the UK. Dr Jebarah has served as a judicial trainer for the Sudanese Ministry of Justice and previously led the College of Law at Gulf University in Bahrain. He is currently expert of the Commercial Law Department at the College of Business, Sohar University, Oman. He has published widely in the fields of commercial law and dispute resolution.

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Professor Ahmad Kayed Ahmad Kayed is the Dean of the Faculty of Computing and Information Technology at Sohar University, Oman, and a Full Professor of Computer Science with over 35 years of experience spanning academia, research, quality assurance, and the IT industry. He earned his PhD from the University of Queensland, Australia, and previously served at Monash University. Professor Kayed has published more than 50 peer-reviewed papers and supervised numerous PhD and MSc students. His expertise includes cloud computing, database security, and semantic technologies, as well as extensive leadership in programme accreditation and institutional quality assurance across Oman, the UAE, KSA, Jordan, and Australia.

Dr Mahmood Al-Bahri is an Assistant Professor at the Faculty of Computing and Information Technology, Sohar University, with over seven years of experience in teaching and research in information and communication technologies. He is an Associate Fellow of the Higher Education Academy (AFHEA), Editor-in-Chief of SUJEITI, and Program Coordinator for Computing and Multimedia. His research interests include IoT and smart systems, with over 20 Scopus-indexed publications. He is the author of the Arabic book Introduction to IoT and a frequent keynote speaker at international conferences. AL-Bahri was awarded the Vice Chancellor's Outstanding Award for Distinguished Teaching in recognition of his excellence in education.

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