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# A Systematic Review Highlights the Need for Holistic Modeling of the Sustainable Development Goals

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## ABSTRACT

The Sustainable Development Goals (SDGs) are behind schedule for achievement by 2030. To avoid focusing on certain goals at the expense of others, all aspects of the SDGs must be considered in decision-making and planning. Models have proven to be a crucial tool for analyzing scenarios, showing optimal pathways to a more sustainable world, and finding synergies and trade-offs between the SDGs and their indicators. Therefore, there is a need for a comprehensive understanding of the existing literature on SDG modeling. To address this need, our study provides a systematic overview of models used for the SDG research by analyzing 146 articles screened from 1511 records during an initial search. Our overview presents the types of models used for the SDG research and their applications. Further, we depict the spatial coverage of the models in these 146 articles and what SDGs are addressed by the various model types. Our results indicate that equity, collaboration, and social justice (SDGs 5, 10, 16, and 17) receive limited attention in these articles. Therefore, more attention to these goals is necessary in model-based studies to accelerate the holistic achievement of the SDGs. Better integration of all SDGs into models and explicit addressing of their synergies and trade-offs can lead to better decision-making for progress toward all the SDGs. Our study also highlights that only a small portion of the studies account for regional variations in models, while these variations significantly impact which SDGs require prioritization and how the goals can be achieved.

## 1 | Introduction

Since 2015, policymakers and researchers worldwide have used the 2030 Agenda for Sustainable Development as a reference for sustainable transformation. The United Nations adopted the 2030 Agenda, consisting of the 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved by 2030 to transform towards a better and more sustainable world. This agenda underscores the urgency of collective actions, with the principles of universality, integration, indivisibility, and leaving no one behind. These principles emphasize the importance of achieving all the SDGs in all regions.

Despite the comprehensive framework, the SDGs have had limited transformative political impact (Biermann et al. 2022), and calls for reforming them are emerging (Biermann et al. 2023). Living conditions for many people have not sufficiently improved, nor have environmental impacts been drastically reduced. Significant policy changes are needed to accelerate the SDGs, as countries are not on track to achieve them by 2030 (Sachs et al. 2024). To address this, more effective strategies are required.

Modeling serves as a powerful tool in this context, enabling scenario analysis, pathway optimization, and evaluation of policy strategies (Aly et al. 2022). In this study, we consider SDG models as conceptual representations that simplify the complexities of real-world systems by integrating social, environmental, and economic dimensions while covering several SDGs for their analysis. These models can help understand the interactions between SDGs, that is, synergies and trade-offs, and project the outcomes of various policy strategies. Also, understanding the capabilities and limitations of existing SDG models can support effective decision-making and advance scientific insights into the SDG interactions (Horvath et al. 2022). Without this understanding, trade-offs can be overlooked, and potential synergies are not fully leveraged, leading to failures to achieve the SDGs (Pradhan et al. 2017).

The SDGs are deeply interconnected. Progress on certain goals can generate synergies or trade-offs with others, making it crucial to understand these interactions to advance the SDGs effectively (Pradhan 2019). Models play a key role in identifying and quantifying these relationships, helping to uncover unintended side effects of progress on one goal for others (Pradhan et al. 2024). However, synergies and trade-offs are highly context-specific as they depend on regions, sectors, and challenges (Nilsson et al. 2018; Zhang et al. 2025; Warchold and Pradhan 2025). For instance, achieving social goals in Western Europe has different effects on environmental goals than in Sub-Saharan Africa. Moreover, synergies and trade-offs can vary at a local scale differently than at a global scale (Zhao et al. 2021). Therefore, it is important to consider the regions and scales that SDG models cover. While recent studies have examined the geographic focus of local SDG models (Moallemi et al. 2021) and the spatial resolution of SDG models (Aly et al. 2022), a comprehensive analysis is still needed, one that evaluates which regions are studied, including larger areas, alongside the scales and resolutions of these regions.

In addition, it is important to explore how the SDGs are included in various models to understand their capabilities in capturing SDGs and to assess the scope of existing research on SDG modeling. Certain models include all the SDGs, while others focus on a few. So far, an overview of how different models include the SDGs is lacking, although studies have evaluated the SDG coverage of specific model types (Zaidan and Fadel 2024; Moallemi et al. 2021; Orbons et al. 2024). While focusing on a limited number of SDGs allows for a more detailed analysis and a better understanding of specific synergies and trade-offs, excluding certain goals or targets risks overlooking important dependencies and missing the broader picture (Pradhan et al. 2024). Both approaches are valuable and complementary. Since all SDGs are interconnected and equally important, each goal should be examined in detail. There is a need to identify the extent to which SDG models address the goals and whether certain goals are consistently underrepresented in SDG models and, if so, which ones.

To address these research gaps, we systematically screened 1511 initial records on SDG models using the PRISMA methodology (Page et al. 2021), resulting in 146 relevant articles. We then analyzed these articles to determine which SDGs the models incorporate, along with the regions and scales they cover. To better understand the modeling approaches used to analyze SDGs, we classify them into six model-type groups: network, system dynamics, integrated, equilibrium, regression, and other models. We provide insights into the limitations and potential of each model type, particularly regarding the extent to which SDGs are incorporated. In this study, we explore three key questions. What SDG models are used for, e.g., to assess synergies and trade-offs or scenario analysis? What are the spatial coverage and spatial resolution of various SDG models? How is each SDG represented across different model types, and how has the coverage of SDGs evolved? Through this analysis, we present a comprehensive overview of the current state of SDG modeling, offering valuable insights into how models contribute to SDG research.

## 2 | Methods

We conducted a systematic review of scientific literature on SDG models to analyze the state-of-the-art. Our analysis includes scientific articles that used one or more models. Through rigorous screening, we ended with 146 articles from which we extracted the model type used, regions addressed, and SDGs covered. With this information, we fill the research gaps mentioned in the introduction.

### 2.1 | Identification of the Relevant Articles

This study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to conduct a systematic literature review of relevant studies on SDG models (see Figure 1) (Page et al. 2021). The PRISMA method provides structured and transparent guidance for identifying and selecting articles. We gathered articles with a keyword search in Scopus and Web of Science, databases chosen for

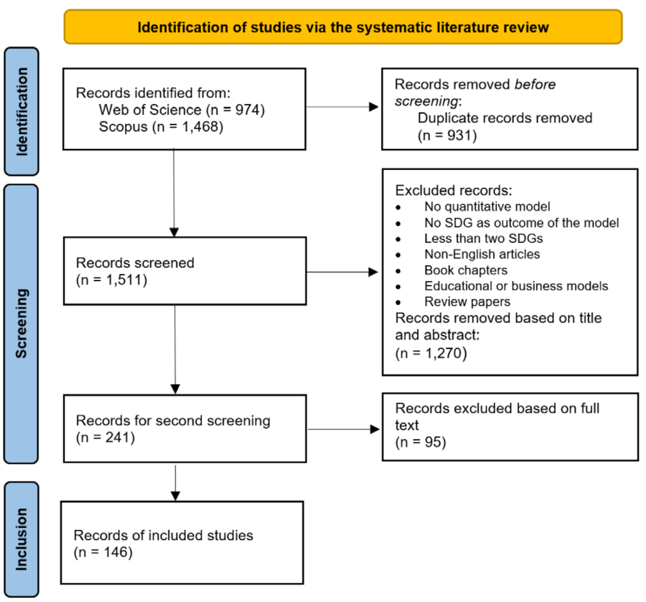


**FIGURE 1** | An overview of the selection process of articles on SDG models using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, where *n* stands for the number of records. The reviewing process consists of three major steps. First, 1511 records were retrieved from the databases. Second, a twofold screening process was conducted through rigorous filtering of records based on title and abstract, after which 146 relevant articles on SDG models were selected. These articles form the core of the systematic literature review.

their extensive coverage of environmental science publications (Mishra et al. 2024).

For Scopus, we implemented the following search strategy to find articles on SDG models: "TITLE-ABS-KEY(sustainab* AND (SDG* OR "sustainable development goal*") NEAR/10 (model* OR simulat*))". An equivalent keyword search was used in Web of Science. In our keyword search strategy, the terms *SDG** and "sustainable development goal*" are included to focus the search on the SDGs, and the terms *model** and *simulat** are used to ensure the article explicitly addresses a model. We applied the *NEAR/10* function to make these terms appear close to each other in the abstracts. By using this function, we got a selection that is predominantly composed of records with models directly related to the SDGs, and we removed a large number of irrelevant records. Additionally, we included *sustainab** in the search so that *SDG* refers specifically to the Sustainable Development Goals, minimizing unrelated uses of the abbreviation.

Combining the records from the two databases resulted in 1511 different records. We did the article search on Scopus and Web of Science on September 15, 2024. As the SDGs were adopted in 2015, the set includes records published from 2015 to 2024. The next step was to screen the abstracts of the articles and exclude irrelevant records to make a finer selection. The inclusion criteria are listed below, where all must be met. The last requirement reflects the highly interlinked nature of the SDGs, as these interconnections are central to meaningful SDG analysis.

- Articles were included only if they presented a quantitative or mixed-method model. We define a model as a conceptual representation that simplifies the complexities of real-world systems.
- For an article to be included, the SDGs must be an outcome of the model.
- The analysis must incorporate at least two SDGs.

We only considered articles, so we excluded book chapters and other records. Further, we only considered English articles. The database search frequently returned records on educational or business models. Articles on educational models typically focus on encouraging sustainable behaviors or teaching sustainability sciences and were therefore excluded. Similarly, articles on business models that aim to advise sustainable business practices that align with the SDGs were excluded. Although review papers provide valuable information on SDG models, they were removed from the list as they do not introduce new models.

After screening the records based on their abstracts, 241 records remained. Based on the full text of these records and after applying the same criteria, we ended with the final list of 146 articles, which was used for classification and analysis.

## 2.2 | Information Extraction

We aim to provide insights into SDG models by examining how regional differences are incorporated and which SDGs are prioritized. To achieve this, we collected relevant information from each article by extracting its spatial coverage, model specifications, and SDGs addressed in the models. Since accessing all the models is challenging, we focus on analyzing the information provided within the articles rather than conducting an external examination of the models.

We classified the models into common model types used in SDG analysis. We based our categorization on the underlying structural characteristics of each model. Grouping models in this way allows for systematically identifying the strengths, limitations, and applications of different modeling techniques, and facilitates comparison across various types. Categorizing the models helps to determine which model types are best suited for different analyses. We identified the following types: network models, integrated models, system dynamics models, equilibrium models, regression models, and other model types. For the basic theory of each model type, we refer to Supporting Information (Table S1 and Figures S1–S5).

Our model categorization was adapted from the framework proposed by Aly et al. (2022), which grouped the models into the following types: Bayesian networks, network models, integrated models, system dynamics models, economic models, econometric models, agent-based models, knowledge-based models, and mathematical quantitative models. Based on our initial review of the articles, we modified their categorization. First of all, we grouped Bayesian networks with network models. Although Bayesian networks use a distinct technique to form networks, they are not fundamentally different from other network models in terms of purpose and structure. We replaced economic models with equilibrium models to capture methods typically used in economics, which are now applied beyond economics. Similarly, we replaced econometric models with regression models, as regression has broader applications beyond the field of economics.

We did not classify knowledge-based modeling, such as surveys and expert interviews, or mathematical quantitative models, as separate model types because these are methods that have been used to define relations in the other model types, but not used as a separate technique to do SDG modeling in the articles we analyzed. For example, these modeling techniques define relationships between nodes in a network model or between variables in a system dynamics model. However, they are rarely used independently for direct SDG analysis. In contrast, while regression is also used for other model types, many articles employ regression directly for SDG analysis. Therefore, we categorized this method as a separate model type. If surveys, expert interviews, mathematical equations, or regression have been used to create a network, system dynamics, integrated, or equilibrium model, we categorized it by the latter. Further, agent-based models were not categorized as a distinct category due to their limited occurrence. Other modeling approaches could be applied to SDG analysis. However, those used by only a few studies or not used at all were not categorized individually. Instead, we created the *other model types* category to group less common model types. In some studies, multiple models were used for analysis; in such cases, we treated the models separately. The Supporting Information (Text S1) outlines the criteria used to classify models into their respective groups.

Besides identifying model types, we assessed what each model was used for, focusing more on how the models were utilized in

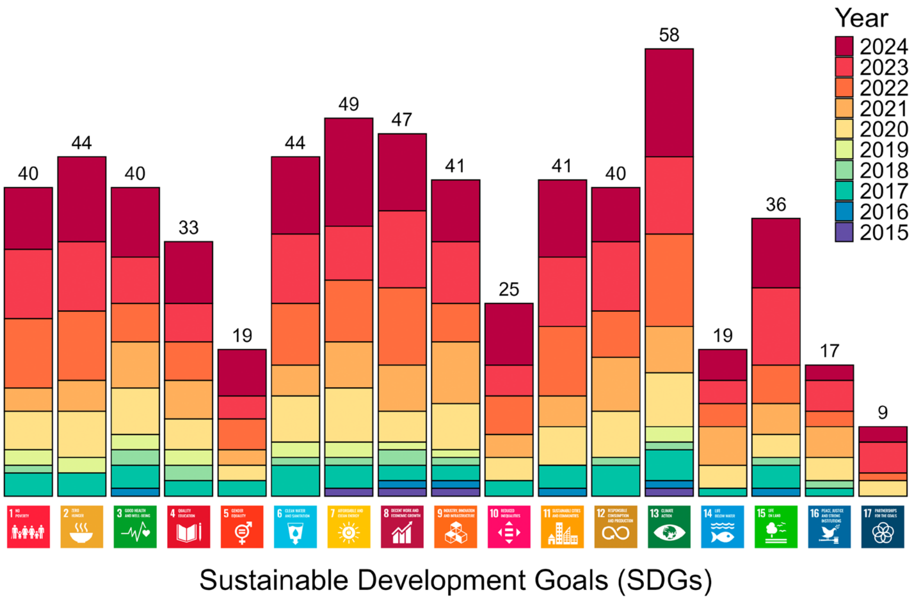


**FIGURE 2** | The count of the coverage of each SDG in the articles with temporal distribution. All 17 SDGs gained momentum from 2015 to 2024. SDGs 13 (Climate Change) and 7 (Affordable and Clean Energy) emerged as the goals that have received the most attention and are most comprehensively modeled. In contrast, SDGs 17 (Partnerships for the Goals) and 16 (Peace, Justice, and Strong Institutions) are among the least studied goals. This figure only includes the 85 articles that do not incorporate all SDGs. Additionally, but not plotted, 61 models integrate all SDGs.

the articles rather than their potential applications. For instance, is it a model used to assess synergies and trade-offs, or is it applied to scenario analysis? By extracting the aim of each model, we could identify which model types and techniques are most suited for different tasks. We further assessed each article's key messages and findings by analyzing the abstracts and conclusions. This process enabled us to summarize central outcomes and identify recurring conclusions, offering insights into common findings across the literature. Additionally, we investigated which SDGs are addressed by each model. This leads to valuable information regarding gaps in research on specific SDGs. We also extracted the regional coverage and spatial resolution of analysis in each study to understand how different model types are used to address regional differences and which regions have been examined. After extraction, we identified relationships between model type, SDG coverage, regional coverage, and spatial resolution, leading to meaningful insights.

## 3 | Results

### 3.1 | SDG Coverage

Our results reveal differences in SDG coverage in the 146 relevant articles related to the SDG models (Figure 2). Interestingly, 61 of them cover all the SDGs. Of the 85 articles that do not integrate all the SDGs, only nine include SDG 17 (Partnerships for the Goals). Also, SDGs 5 (Gender Equality), 10 (Reduced Inequality), 14 (Life Below Water), and 16 (Peace, Justice, and Strong Institutions) are relatively often overlooked in these articles (see Figure 2). SDG 13 (Climate Action) is the most frequently modeled goal, namely 58 times. We did not find a relative increase in the coverage of SDGs in these articles over the past years (see Figure 2). Neither is there a relative increase in models that cover all SDGs. This suggests that while SDG-related modeling continues to evolve, there has been no strong shift toward filling gaps in underrepresented goals or adopting a more integrated, holistic approach. Instead, SDG coverage appears to be shaped by the predefined system boundaries of modeling frameworks, along with the thematic preferences and research priorities of those developing and applying the models.

A key issue for their low coverage is the lack of reliable data for their SDG indicators, particularly for developing countries. For instance, gender equality data is often unavailable in the Global South due to limited prioritization, capacity constraints in data collection, and the lack of standardized frameworks for measuring gender-disaggregated indicators (Goulart et al. 2021). In contrast, the SDGs related to climate change, poverty, and economic growth have more available data, which makes them better represented in models. One reason SDG 14 is less represented in the literature is that many studies do not focus on marine and coastal ecosystems.

The way SDG models are originally designed significantly influences which goals receive more attention. Equilibrium models tend to focus on SDGs 7 (Affordable and Clean Energy) and 13 (Climate Action), while integrated models place greater focus on SDGs 2 (Zero Hunger), 6 (Clean Water and Sanitation), and 7 (Figure 3). Additionally, the theoretical background of models plays a crucial role in shaping their priorities. Since many models come from economics or natural sciences disciplines, their studies often emphasize economic and environmental aspects over social and political dimensions. Another reason for the uneven coverage of SDGs is that some goals are inherently more difficult to implement in certain models. In the next section, we analyze why certain models do not include specific SDGs.

Apart from SDG 14, the less-included SDGs (5, 10, 16, and 17) share the common focus of representing aspects of social interaction and aiming for a fairer and more just world. All SDGs are essential and should be pursued collectively. Neglecting

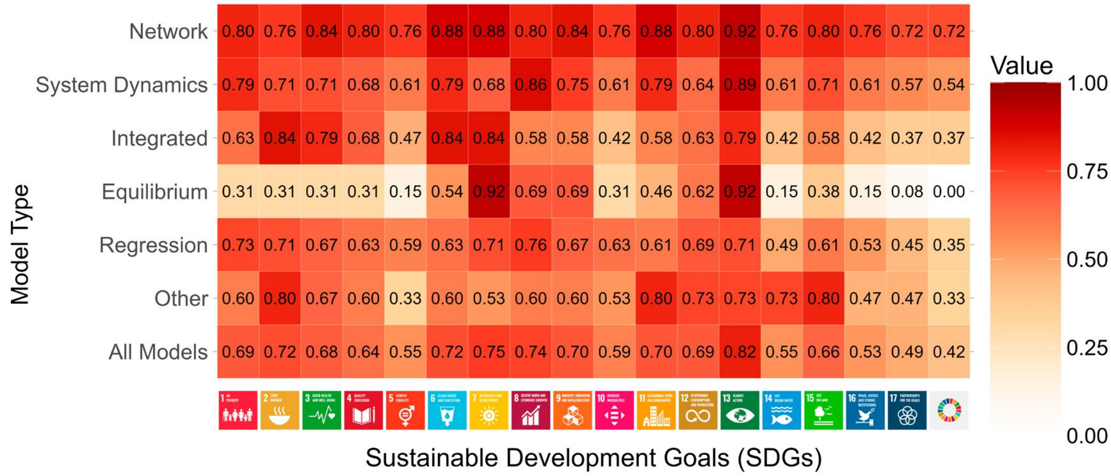


**FIGURE 3** | The proportion of the coverage of the SDGs for the different model types, where the value 1 means that all models of a certain model type include the corresponding SDG, for example, 92% of the network models consider SDG 13 (Climate Action). The column on the right indicates the models that incorporate all SDGs. Seventy-two percent of the network models address all SDGs, while no equilibrium model does. Other notable findings include the strong presence of SDGs 2 (Zero Hunger) and 6 (Clean Water and Sanitation) in integrated models, as well as the strong representation of SDGs 7 (Affordable and Clean Energy) and 13 in equilibrium models.

some may lead to biases and limit the effectiveness of sustainable development strategies. SDGs 5, 10, 16, and 17 interact highly with other goals, meaning that policies on other goals can highly influence them, or that focusing on them contributes to more effective strategies for achieving other SDGs (Anderson et al. 2022). To make SDG modeling more holistic, SDGs 5, 10, 16, and 17 should receive greater attention.

## 3.2 | SDG per Model Type

Nearly all SDG models can be classified into one of the five model types mentioned in the methods: network, system dynamics, integrated assessment, equilibrium, and regression models. The diversity of modeling approaches highlights the variety of analytical frameworks currently applied in SDG research (see Figure 4). This diversity stems from the range of research conducted on the SDGs, addressing multiple dimensions of SDG analysis.

Each year, a growing number of research articles use models to analyze the SDGs (see Figure 4). Notably, more articles on SDG models have been published by mid-September 2024 than in any previous year. The largest increase comes from regression techniques, which have been used frequently to model the SDGs since 2020. The rise in SDG models can result from the higher data availability over the past years (United Nations 2024). Multiple model types have been used to give valuable insights regarding the SDGs, emphasizing the need for a diverse approach to SDG modeling. In the rest of this section, we will discuss each model type separately, focusing on their strengths, limitations, and applications.

### 3.2.1 | Network Models

Many network models cover all 17 SDGs, which allows for a more comprehensive analysis of synergies and trade-offs (see

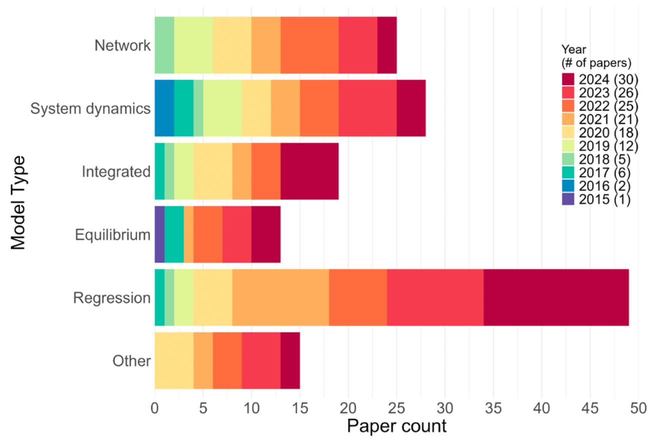


**FIGURE 4** | The distribution of model types and publication year of articles on SDG models. There is a growing trend in articles published on SDG models over time. Regression models are the most used model type, followed by network and system dynamics models.

Figures 2 and 3). Network models are frequently created to map interactions among SDGs, aiming to predict how achieving one SDG influences other areas of sustainable development, which is crucial as the SDGs represent a highly interconnected system where progress in one goal impacts the others (Bali Swain and Ranganathan 2021). Network models are also used to find policy spillover effects or to identify so-called key SDGs. Key SDGs are goals that can boost large improvements in sustainable development as they have a strong amplifying effect on others and minimal dampening effects.

Studies that employ network models, such as Kumar et al. (2018) and Anderson et al. (2022), repeatedly advocate for considering synergies and trade-offs in policy-making and SDG modeling. These studies also highlight the importance of accounting for all 17 SDGs. Excluding certain goals risks cherry-picking and can negatively affect the goals omitted from the analysis. The same holds for excluding interactions between SDGs. Furthermore, network models could be significantly improved by adding directionality between nodes (Assubayeva and Marco 2024).

Representing an SDG accurately requires including multiple targets, which demands using several indicators per goal (Allen et al. 2025). Network models are particularly often able to address many indicators per goal. The reason is that the edges of network models can be determined by analyzing data, as they are often the interactions between indicators, and because network models exclude variations over time. Most network models incorporate all 17 SDGs, though they vary in depth of analysis: some consider the goals as a whole, while others focus on the individual indicators. For most of these studies, the availability of data determines which indicators are included. Conversely, network models, where the edges are based on expert interpretations, often focus on the goal level.

Due to their ability to integrate numerous indicators, network models are well-suited for identifying direct and indirect synergies and trade-offs among the SDGs. For example, there are strong synergies among the environmental goals, namely SDGs 13, 14, and 15 (Life on Land) (Bali Swain and Ranganathan 2021). At the same time, SDGs 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation and Infrastructure) often exhibit significant trade-offs with the environmental goals (Anderson et al. 2022). Despite these challenges, the overall findings indicate that synergies among SDGs outnumber trade-offs, highlighting a predominantly supportive framework for sustainable development (Bali Swain and Ranganathan 2021; Anderson et al. 2022).

Different network models evaluate which SDGs should be prioritized to maximize synergies and minimize trade-offs. SDG 4 (Quality Education) is often recognized as a critical driver of sustainable development (Sebestyén et al. 2019b; Kumar et al. 2018). Besides education, studies show significant differences in which SDGs should be prioritized. For instance, SDG 12 (Responsible Consumption and Production) is identified as a critical driver in India (Zaini and Akhtar 2019), while a global study suggests that responsible consumption and production have a minimum impact on the entire network (Qazi et al. 2023). There are two key differences in ranking SDGs using a network model (Assubayeva and Marco 2024). First, there is no definitive, systematic way to rank, resulting in outcomes that are highly dependent on the modeler's choices. Additionally, the results are sensitive to changes in the interactions between nodes, meaning that a slight difference in SDG relations can affect which goal is prioritized. These interactions vary strongly per region and over time, further influencing SDG prioritization.

In general, network models are used to find which SDGs or targets influence each other and to reveal correlations across goals. However, they are not suited to calculate future outcomes of goals, as these models typically capture static relationships. This means that they show how indicators are related at a specific point in time or over a historical period, without accounting for dynamic changes, time-dependent behavior, or causality. As a result, they lack the mechanisms needed to simulate how interventions or evolving conditions might influence progress toward the SDGs over time. Other model types are needed to analyze future projections.

### 3.2.2 | System Dynamics Models

While most network models are static, system dynamics models simulate variables over time, allowing them to capture synergies and trade-offs dynamically. System dynamics models can represent many SDGs, reflecting the interconnected nature of the SDGs and providing integrated planning (Pedercini et al. 2020), though the implementation of SDG indicators is limited. Remarkably, the system dynamics model studies cover either (nearly) all SDGs or only a small set of SDGs (see Figure 5). While many system dynamics models can incorporate most SDGs at the goal level, they face challenges in integrating enough SDG targets. For example, the iSDG model uses one indicator for climate action (SDG 13): the number of deaths, missing persons, and persons affected by disasters (SDG indicator 13.1.1) (Millennium Institute 2021). While this captures climate adaptation, it overlooks mitigation efforts. This limitation can create unintended biases, where countries with lower disaster impacts appear to perform better on climate action, regardless of their emissions levels. Incorporating all SDG targets into system dynamics models is challenging due to the complexity of coupling indicators with the rest of the model, while having correct time-dependent relations.

System dynamics models are typically used to explore the impacts of different scenarios on indicators. However, indicators such as 5.1.1 and 14.6.1 depend on whether a policy is implemented, and not on the system variables. Therefore, they are not suited as the output of a system dynamics model. System dynamics models are not suited to determine if policies are made depending on other variables; rather, they measure how variables inside the model change over time. Therefore, not all indicators are suitable for implementation in SDG models. Certain goals have different indicators that can be easily implemented in system dynamics models, such as indicator 8.1.1, which measures the growth rate of real GDP per capita, and indicator 13.2.2, which tracks total annual greenhouse gas emissions. Goals with indicators that are more suited for implementation in system dynamics models are more represented in these models (see Figure 3). In addition, the variation in SDG coverage across system dynamics models also reflects the individual focus and priorities of the researchers involved.

System dynamics models are mostly tailored to the country and local levels, enabling them to effectively capture local and regional differences. For instance, the iSDG model includes determinants for all SDGs within a system dynamics framework, providing country-level guidance by analyzing various scenarios (Pedercini et al. 2020). Other local system dynamics models show specific interactions between different goals. The interactions between SDGs 2, 6, 8, and 15 are discussed in detail at a local level in Victoria, Australia (Bandari et al. 2023), and SDGs 3 (Good Health and Well-being), 4, and 7 in Tanzania (Collste et al. 2017).

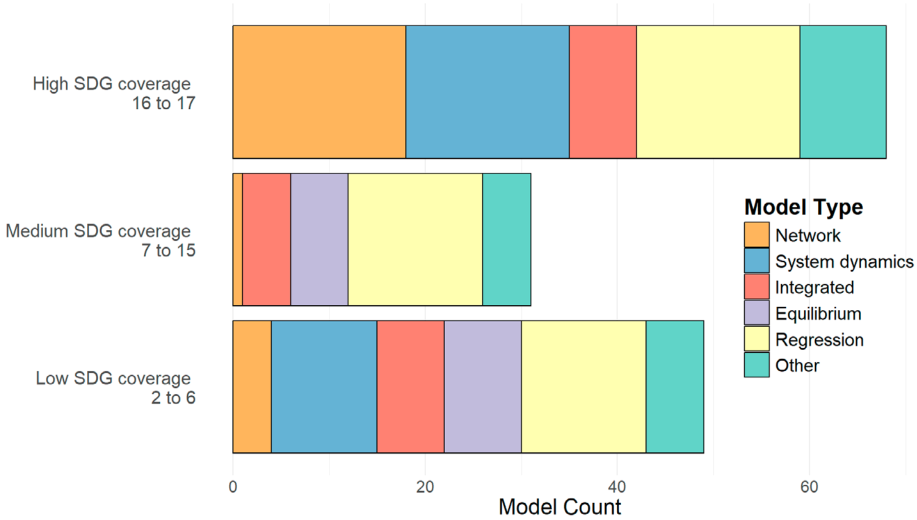


**FIGURE 5** | The number of SDGs covered per model type. Of the 68 articles that have high SDG coverage, half of them are conducted using network models and system dynamics models, indicating their suitability for comprehensive coverage and assessment of SDG synergies and trade-offs. Regression models take up a considerable percentage across all SDG coverage spectra, indicating their high flexibility. On the contrary, in the 146 reviewed studies, no equilibrium model covers more than 15 goals.

Two strong characteristics of system dynamics models are their flexibility in regional coverage and their ability to incorporate emerging factors beyond the SDGs. First, these models provide insights at both local and global levels. They can address regional specifics in depth and provide local advice, but they can also offer analysis at the global level to inform international policies. For a case study in India, system dynamics modeling has shown that integrating water and energy policies improves multiple SDGs (De Stercke et al. 2020), while in Eswatini, improvements in education and health positively influence other SDGs (Pedercini et al. 2020). At the global level, Randers et al. (2019) used system dynamics to argue that the SDGs are incompatible with the planetary boundaries. Second, system dynamics models are also flexible enough to incorporate new, emerging factors beyond the SDGs that are influencing global development, such as artificial intelligence (AI), pandemics, and geopolitical issues. The effects of the COVID-19 pandemic on the SDGs in Egypt are identified using a system dynamics model (Marzouk et al. 2022), while another evaluates the impact of AI on SDGs for multiple countries. This shows the capability of system dynamics models to find the effects of global trends on the SDGs.

System dynamics models consistently show that a business-as-usual scenario is insufficient to achieve the SDGs (Pedercini et al. 2018; Allen et al. 2019, 2021, 2024; Chapariha 2021). In almost all reviewed studies, the most ambitious scenario projected the best long-term results for achieving the SDGs. Significant shifts in focus, such as prioritizing health programs, education, and renewable energy production, are shown to positively impact sustainable development without creating conflicts between the goals (Spaiser et al. 2017). Also, actions targeting shifts in power dynamics, inequality, and development in lower-income countries are crucial for maintaining ecosystem services and promoting well-being (Henderson and Loreau 2023). However, economic growth is often shown to negatively impact environmental goals and contribute little to achieving the SDGs (Biglari et al. 2022).

### 3.2.3 | Integrated Models

A considerable number of studies use integrated models for SDG analysis. Integrated models stand out for their ability to encompass numerous variables and dependencies, enabling them to examine subsystems in detail. These models require significant computational resources and time to build. Despite this, integrated models are valuable for scenario analysis of SDG progress and exploring different Sustainable Development Pathways. Instead of creating such a model from scratch, many well-established models already exist, which are solid foundations that can be adapted or expanded to address specific research questions related to the SDGs (Soergel et al. 2024).

Like system dynamics models, integrated models can simulate sustainable development over time. As integrated models consist of multiple modules that cover various sectors, they can capture detailed sector-specific information and dependencies. Integrated models often cover multiple disciplines of sustainable development in depth. For example, most integrated assessment models (IAMs) were initially developed to study interactions between energy, the economy, climate, and land use (Van Soest et al. 2019), providing inputs for climate policies and IPCC reports Pradhan et al. (2025). They have been expanded to incorporate the socioeconomic aspects of sustainable development. Their origin provides IAMs with relatively strong coverage of SDGs 2, 6, and 13. Sociopolitical and human development goals are not as well represented because of the design and historical development of IAMs (Van Soest et al. 2019). This results in less attention to SDGs 5, 10, 16, and 17. This trend is visible in the coverage of SDGs by integrated models (see Figure 3).

The complexity of including all SDGs comprehensively, so by including enough indicators per SDG, is visible from the study by Soergel et al. (2021), which considers 56 indicators or proxies covering all 17 SDGs. While Soergel et al. (2021) tried to cover the SDGs as completely as possible, it was not possible to capture all 231 indicators. They explain that they could not include a large part of the indicators because they are not suitable for their model. For example, SDG 17 on partnerships between the goals has 25 indicators, but only one was included in their modeling. Acknowledged by the authors, gender equality is addressed by the gender education gap, a target for SDG 4, but used as a proxy, while the governance-related aspects of SDG 16 are treated endogenously. These limitations highlight the complexity of connecting indicators for these goals in integrated models. The study mentioned above shows that integrated models can be expanded to address all SDGs. However, not all indicators are suitable for this model type, with the consequence that not all SDGs are comprehensively covered.

While system dynamics models often focus on local contexts, integrated modeling primarily analyzes global pathways toward sustainability. Among others, Shared Socioeconomic Pathways (SSPs) are used as reference pathways (Orbons et al. 2024). Tagomori et al. (2024) analyze multiple pathways to find that a healthier diet and less meat consumption positively influence multiple SDGs, while Van Soest et al. (2019) demonstrate that environmental policies such as the Paris Agreement show significant co-benefits with the SDGs. However, Soergel et al. (2021) show that even the current ambitious climate policies are insufficient for achieving the SDGs. They provide a scenario that includes additional international climate finance, progressive redistribution of carbon pricing revenues, sufficient and healthy nutrition, and better access to modern energy, all of which improve SDG achievements.

### 3.2.4 | Equilibrium Models

Equilibrium models are primarily used to analyze interactions and balances within economic systems. Among such models are computable general equilibrium (CGE) and input–output (IO) models. Equilibrium models focus primarily on goals 7, 8, 9, and 13 (see Figure 3) and typically cover only a limited number of SDGs (see Figure 5). These models were originally developed to focus on the economy and industry, making them suitable for studying interactions within the economic system, energy use, water flows, and carbon flows, areas that align with the frequently modeled SDGs. Indicators related to these SDGs are easily compatible with equilibrium models, while social SDG indicators are less frequently incorporated. Because of the methodological characteristics of equilibrium models, most indicators cannot be modeled directly.

To address indicators, equilibrium models often rely on proxies, which are indirect measures used when direct indicators are lacking. The key challenge in modeling SDGs with equilibrium models is to match indicators to the proxies. Proxies on water, energy, employment, material, and land use are commonly included in these models. However, proxies for SDGs 3, 4, 5, 16, and 17 are often lacking, which contributes to the low representation of these goals, as seen in Figure 3. The structure and origin, along with the interests and research fields of equilibrium modelers, result in a large variation in coverage of the SDGs, as shown in Figure 3. We found that none of the examined articles on equilibrium models address all the SDGs (see Figure 2). To implement equilibrium models effectively, one must work with existing datasets and frameworks, such as IO tables, as constructing a new model from scratch is not typically feasible. A thorough understanding of the model structure and methodology is essential before using them to ensure accurate analysis.

Equilibrium models are regularly combined with multi-criteria decision-making to inform recommendations on SDG achievements and to incorporate dimensions of sustainable development that these models cannot capture. Often, equilibrium models are applied to assess the effects of various sectors on the SDGs. Studies have related the coal industry, trade, and the bio-economy to SDGs (Vögele et al. 2023; Li et al. 2023; Többen et al. 2024). A computational general equilibrium model has generated detailed household-level SDG outcomes for multiple countries across three SSPs. The study highlights the importance of incorporating distributional aspects and disaggregated data in SDG studies (Wilts and Britz 2024).

A recurring observation in the literature is the significant trade-offs between economic and environmental goals, which remain a central focus of the equilibrium models. A study shows that the negative macroeconomic impacts of carbon and energy taxes are small relative to emission reduction gains in Malaysia (Yahoo and Othman 2017). Another study highlights the need to increase energy demand to encourage economic goals and employment in the United Arab Emirates (Jayaraman et al. 2015). While these equilibrium models provide valuable insights, they often neglect social goals and broader environmental indicators beyond greenhouse gas emissions, which are crucial for holistically achieving the SDGs (see Figure 3).

### 3.2.5 | Regression Models

Regression models use historical data to show how SDGs relate to each other and how policies have impacted trends in SDG achievement. If sufficient data is available, regression models are versatile and suitable for a wide range of scenarios. As a result, they form the most commonly employed model type in the reviewed articles (see Figure 4).

We find that for 76% of the reviewed articles, the spatial resolution of regression models is at a country level, presumably as most data is available at this level. A lack of data on SDG indicators, particularly for developing countries, complicates adequate analysis (Barbier and Burgess 2019). Often, only one indicator per SDG is used in a model. However, selecting a different indicator for the same SDG could lead to different results (Barbier and Burgess 2019; Warchold et al. 2022), supporting the importance of good data collection.

Regression models are relatively easy to construct and do not depend on extensive predefined structures or external modeling frameworks, such as equilibrium and integrated models. In principle, any SDG indicator could be implemented in these models as long as sufficient data is available. The representation of the SDGs by the model is largely driven by the topics related to research questions. While most SDGs are frequently analyzed, SDGs 14, 16, and 17 are the least represented in articles on regression models (see Figure 3). We also found that regression models have been used to look at all SDGs and subsets of SDGs (see Figure 2), depending on research interest.

Regression modeling underscores that countries are not on track to achieve the SDGs by 2030. For instance, Portugal is unlikely to achieve any of the 17 SDGs entirely by the deadline (Firoiu et al. 2022), while Chinese cities, if continuing on their current trajectories, are projected to reach an average of only five SDGs by 2030 (Xiao et al. 2022). However, models using regression techniques have not integrated future changes in dynamics, which makes them unable to fully capture the dynamic properties of the SDGs. In addition to forecasting, regression models have been used to analyze past outcomes to identify which policies have influenced changes in SDG performance. For example, analyses of SDG indicators related to climate-related policies reveal that they have often negatively impacted social SDGs, exposing trade-offs between environmental and social objectives (Fairbrass et al. 2024).

Regression models show varying results across different countries. This corresponds with the need to prioritize distinct areas of development depending on local conditions and contexts (You et al. 2024). Between developed countries and developing countries, there is a difference in prioritization. Where developed countries benefit most by focusing on social and environmental goals, developing countries see the biggest SDG improvement by focusing on social and economic goals (Swain and Yang-Wallentin 2020). Strengthening governance structures and increasing investment in education is important in Sub-Saharan Africa to foster sustainable development (Pasara 2021), while in Colombia, investment in science, technology, and innovation is emphasized (Pardo Martnez and Cotte Poveda 2021). For Algeria, there is a call for greater government support for development initiatives (Abderzag et al. 2024). In China, prioritizing ecosystem services (Xu et al. 2022; Liu et al. 2023), advancing education, and improving gender equality are essential (Feng et al. 2022). In Austria, improving taxation systems is identified as a key strategy for enhancing sustainability (Maldet et al. 2023), while in Pakistan, a shift towards sustainable energy is essential for long-term development (Wang et al. 2024).

#### 3.2.6 | Other Model Types

Out of 146 articles, 15 discuss models that could not be grouped into any of the aforementioned model types. As several model methods are grouped together, the SDG coverage varies per article and per modeling method. Some of these models have been specifically designed to provide political advice, using tailor-made frameworks suited to answer questions that cannot be answered with the other model types. For example, the Inequality and Poverty Assessment Model has been constructed for Austrian cities to conduct a detailed analysis to provide energy-efficient, affordable, and climate-friendly housing (Bukowski and Kreissl 2022).

Geographic information system (GIS) mapping has been applied in relation to the SDGs through multi-criteria modeling to assess SDG-related policies and impacts in urban planning for Naples, Italy (De Toro et al. 2023). Similarly, mathematical modeling has been combined with multi-criteria decision-making to optimize public employment policies in line with SDGs in India (Muneeb et al. 2022). As in the examples above, many models use multi-criteria decision-making to relate multiple SDGs to designing policies and interventions.

Another common method is modeling based on expert interpretation. In this approach, experts determine which SDGs influence each other and identify the priorities for specific cases. Expert interpretation has been applied to predict the effects of COVID-19 on the SDGs (Hannan et al. 2022). In addition, a workshop of experts has suggested that current SDGs lack explicit recognition of planetary boundaries and resource constraints, which are essential for achieving strong sustainability (Giannetti et al. 2020).

Machine learning, in addition to being used for regression analysis, has been applied to text analysis (Wulff et al. 2024) and to processing large datasets related to the SDGs (Mwitondi et al. 2020). The articles that utilize machine learning for SDG modeling have been published recently, suggesting that this approach is likely to play a more significant role in SDG research in the coming years.

Many other techniques could potentially be used for SDG analysis, such as agent-based models. However, the models not addressed in the articles were not analyzed for the results.

### 3.3 | Regional Inclusion

For more than half of the models, the regional specificity is at the national level (see Figure 6). Approximately 31% of the articles focus on subnational or city levels, while around 6% do not incorporate any spatial variation. Spatial resolution determines the level of detail a model can capture, influencing its ability to implement regional factors that influence sustainable development. The studies that have a small spatial resolution underline the importance of incorporating regional specificities that influence the SDGs. Since SDG interactions vary significantly across regions (Warchold et al. 2020; Sebestyén et al. 2019a), models should be fine-tuned to account for environmental, cultural, political, and socioeconomic differences to ensure accurate and context-specific insights.

SDG interactions differ not only by region but also by scale. For example, better schooling has a different effect on economic growth at a regional scale than at a global scale. Fortunately, SDG modeling studies span a wide range of spatial scales. SDG modeling studies address the world, world regions, countries, and local regions (see Figure 6).

The countries most analyzed by SDG models for local or national analysis are China (18 articles), India (6 articles), and Iran (4 articles) (see Figure 7a). The high focus on China at a local or national scale coincides with the results of Moallemi et al. (2021), a review on modeling local sustainability. While some European countries have been analyzed individually, the European Union or Europe as a whole has been extensively analyzed in six studies, reflecting the focus on the SDGs across the continent (see Figure 7b).

In contrast to the substantial number of models focusing on Europe and Asia, North and South America remain

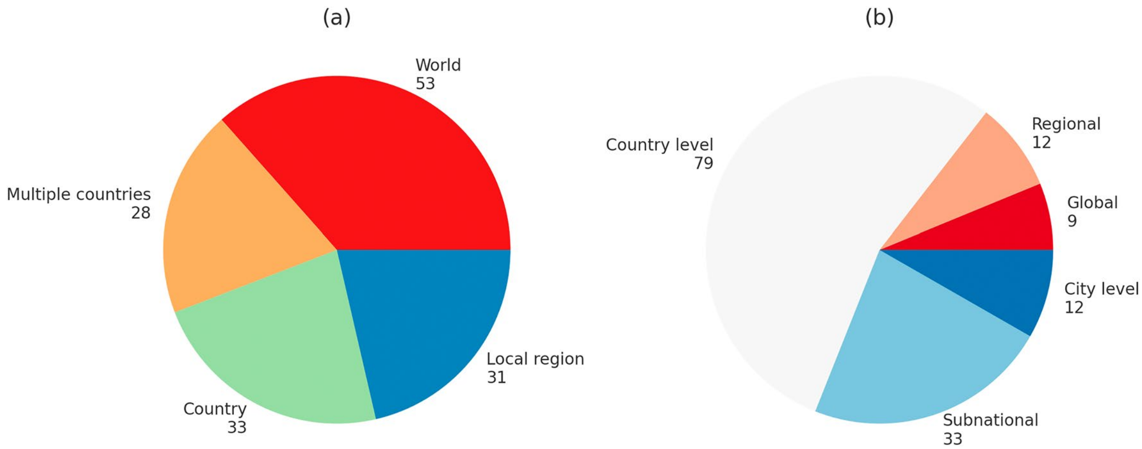


**FIGURE 6** | The spatial coverage and resolution of regions analyzed in SDG model-based studies. (a) he spatial coverage that the models analyze. Fifty-three studies apply a global scope. Further, a notable portion concentrates on localized areas or single-country contexts. (b) Resolution of analysis that is considered by the models. The chart reveals that a majority of studies prioritize country-level analysis, aligning with the SDGs' intended application at a national scale. Encouragingly, several studies also employ subnational resolutions, acknowledging that sustainable development interactions can vary significantly across regions. The global-level resolutions, on the other hand, denote studies that do not distinguish between specific regions.

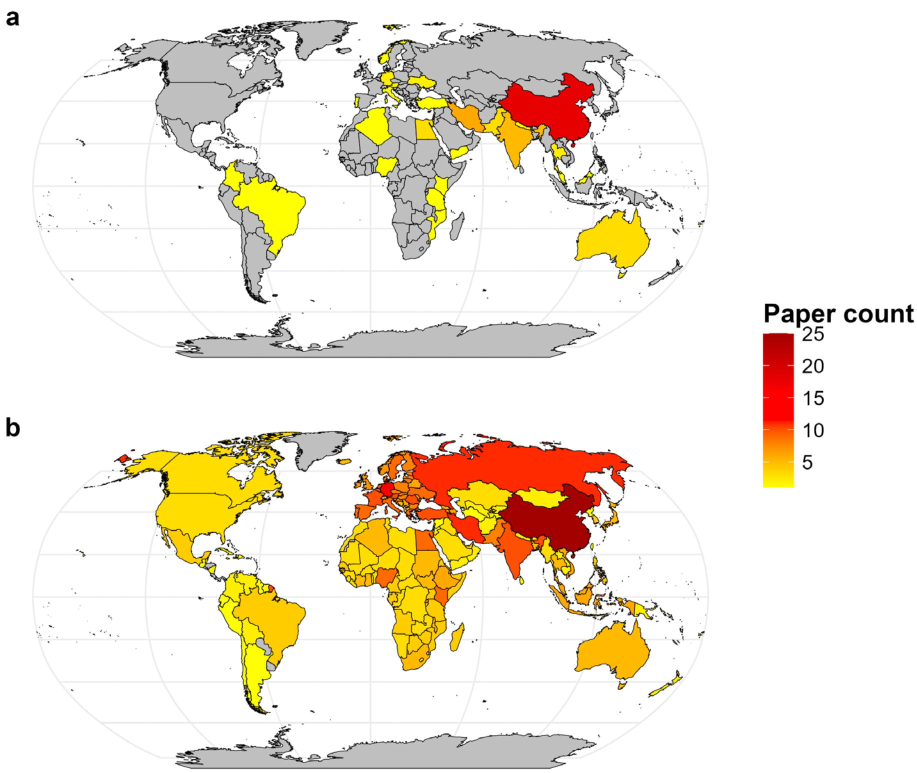


**FIGURE 7** | Regions analyzed in SDG model-based studies. (a) How often a national and subnational analysis is performed for each country. (b) Studies that cover multiple countries, added to the studies on the country and subnational levels. China is most analyzed by SDG models. The 54 articles that analyze the entire world are not included in the plot as they do not change the relative spatial coverage.

underrepresented in SDG-related modeling efforts. Interestingly, no article has looked at the United States individually or at a subregion of the United States. This is particularly remarkable given the significant volume of research and publications on sustainable development originating from the United States (Mishra et al. 2024; Yumnam et al. 2024). A lack of SDG modeling articles in a region signals that more attention should be paid to this field of study. To enhance the effective implementation of the SDGs, it is essential to analyze all regions of the world individually through SDG models.

More articles on SDG models focus on developing countries than developed countries. Out of 146 analyzed, 68 articles are on developing countries, 18 on developed countries, and 60 cover both. Still, a lack of high-quality data from developing countries complicates their accurate analysis (Hughes et al. 2021).

Many articles on SDG models highlight the importance of incorporating region specificity in models. The interactions between SDGs are inherently region-specific. For instance, the impact of improved education on gender equality varies significantly between regions where all girls have access to schooling and those regions where this access is still limited. Social, environmental, economic, and cultural factors play pivotal roles in the outcomes of sustainable development initiatives, further emphasizing the need for regional fine-tuning (Warchold et al. 2020). There is a large variation between regions regarding strategies to balance priorities and optimize progress toward sustainable development. This variation exists not only between developed and developing countries but also among developed countries themselves. For example, the cities of Munich (Germany) and Kagawa (Japan) should prioritize different aspects of sustainable development (Llorca et al. 2020).

Another finding is that most global studies 63% include all the SDGs in their model. In contrast, the more detailed the spatial scale, the lower the percentage of incorporating all SDGs. Only 9% of the local studies include all SDGs. This is partly because local studies often focus on a specific topic or case, for which not all SDGs are always relevant. There are also regional variations in the models' SDG coverage. Articles on China barely cover SDGs 5, 10, 16, and 17, corresponding with the overall coverage of SDGs in models. Countries in the Middle East have a relatively high focus on SDGs 1, 8, and 13.

## 4 | Discussion

By conducting a systematic literature review, we analyze key aspects of models to contribute to the SDGs. Our results highlight that only a small portion of models take regional differences into account, even though these variations significantly influence study outcomes. We also found that models are used for a wide range of analyses. However, insufficient attention is given to SDGs 5 (Gender Equality), 10 (Reduced Inequalities), 16 (Peace, Justice, and Strong Institutions), and 17 (Partnerships for the Goals) in modeling efforts. We highlight our innovative contributions in more detail below, including a discussion of the limitations of this study and a conclusion in which we address several key challenges in SDG modeling.

Our results reveal that many studies fail to address the important SDGs on gender equality (SDG 5), reducing inequality (SDG 10), life below water (SDG 14), peace, justice, and strong institutions (SDG 16), and partnership for the goals (SDG 17). This result is mostly in line with other review articles. In a survey, model experts addressed the difficulty of incorporating these SDGs in IAMs (Van Soest et al. 2019). Meanwhile, a review study on local sustainability shows that the two SDGs on equality are highly underrepresented in system dynamics modeling (Moallemi et al. 2021). Another literature study finds particularly low coverage of SDGs 5 and 16 in modeling efforts (Zaidan and Fadel 2024). Overlooking these goals in models risks undervaluing them and not considering them in decision-making, which is problematic as all SDGs are essential and require attention.

Notably, SDGs 5, 10, 16, and 17 have in common that they represent aspects of social interaction and aim for a fairer and more just world. Emphasizing them is essential not only for advancing social development but also for fostering environmental sustainability (Barbier and Burgess 2019; Sultana 2023). In contrast, a focus on improving socioeconomic goals related to material needs, such as SDGs 1 (No Poverty), 2 (Zero Hunger), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), and 12 (Responsible Consumption and Production), regularly leads to trade-offs with environmental sustainability (Spaiser et al. 2017; Pradhan et al. 2017). Further, SDGs 5, 10, 16, and 17 also have in common that most of their indicators are hard to quantify. More effort is needed to include qualitative indicators, such as those related to gender equity, in models. Network and regression models are highly flexible and allow the inclusion of qualitative and stakeholder-informed indicators, as well as large data sets, and are therefore most suited. For example, gender-disaggregated labor input data or indicators of representation in decision-making processes could be layered onto sectoral nodes within the network to assess inclusivity in supply chains. Regarding SDG 17, localized and context-sensitive analysis is crucial. Participatory modeling approaches, such as stakeholder-informed system mapping or co-created network structures, can enhance the relevance and legitimacy of analyses. These methods allow local actors to define relational structures, priorities, and barriers in partnership dynamics, thereby enriching model inputs with grounded knowledge.

Even mentioning all 17 SDGs does not always mean a good representation of SDG targets and indicators. Often, one indicator from the 2030 Agenda is used to represent an SDG, missing a complete representation of the SDG. For example, target 2.5 is about genetic diversity in agriculture. A model that includes SDG 2 by modeling a single indicator for genetic diversity does not represent hunger. Multiple indicators must be used per SDG to encompass the SDGs holistically and to give a good analysis of the goals (Anderson et al. 2022; Bali Swain and Ranganathan 2021; Kluza et al. 2021). Unfortunately, many articles provide only one indicator per goal when modeling the SDGs. This result coincides with the review of policy guidance and SDG modeling by Allen et al. (2025). More attention is needed to the inclusion of the SDGs at the indicator level.

We found that network and regression models are well-suited for analyzing all SDG indicators within a single framework. In contrast, incorporating indicators into system dynamics, integrated, and equilibrium models often presents significant challenges. This is because indicators are not suited to be related to time-dependent mathematical equations, while this is needed for system dynamics and integrated models. Furthermore, certain indicators cannot be analyzed with equilibrium models if they cannot be represented directly or by a proxy that aligns with the underlying optimization structure of these models.

Next, our results emphasize that SDG models are highly sensitive to regional variability, as local conditions influence interactions between SDGs. Incorporating local variation into models can enhance our understanding of the SDGs and make models more effective when implemented in practice. However, we found that few studies account for variations below the national scale. This differs from the results of Aly et al. (2022), where approximately one-third of the studies focus on a subnational scale. This difference is likely a consequence of our article selection on SDG models. Aly et al. (2022) includes studies that focus on a single SDG, whereas we analyze articles that address multiple SDGs. The articles that include a few SDGs are more often studies with local variation, while studies that include all SDGs are limited in their local variation. This is logical because of the trade-off in spending effort on multiple SDGs and local variability. That trade-off is reflected in the review of system dynamics models for local sustainability by Moallemi et al. (2021). This review of system dynamics models addresses the importance of integrating all SDGs. Still, it highlights that including multiple SDGs and their interactions at a local scale in models can have major complications. This indicates a gap in the coverage of all SDGs for models that incorporate detailed variation, and the other way around, a gap in the inclusion of detailed local variation in models that include all SDGs. To fill this gap, combining multiple modeling techniques could be applied to cover all SDGs. For example, by integrating system dynamics principles, such as feedback among goals and scenario-based iteration, together with SDG-related data to compare indicators among 16 SDGs (Xu et al. 2023) projected local variations in SDG achievements across 41 cities in the Yangtze River Delta.

Our analysis highlights that most models cannot integrate all SDGs while addressing detailed variations due to increasing complexities. However, including only a few SDGs risks missing significant synergies and trade-offs with the goals that are left out, leading to unforeseen side effects and regressing SDG achievements (Fu et al. 2019). Meanwhile, the models focusing on a few SDGs provide valuable insights for local analysis or highlight critical synergies and trade-offs between certain goals (Bandari et al. 2023). Thus, to fully understand the SDGs, both models that include all goals and those that focus on a subset of them are needed (Pradhan et al. 2024). Note that when focusing on a few SDGs, it is important to be aware of critical synergies and trade-offs with the goals that are left out, as the SDGs form a highly connected system. To ensure that models focusing on a few SDGs are correctly used, all factors significantly influencing the models' outcomes must be included, while irrelevant ones can be excluded. Models should be utilized only for the insights they can provide within their scope of application. Knowing a model's limitations and boundaries is crucial to minimizing the risk of making progress on one goal at the expense of another (Forouli et al. 2020).

Developing new models can be time-consuming. While network and regression models can be constructed from scratch, the construction of most models requires considerable time and expertise. For system dynamics models, the relations between parameters must be constructed and validated by comparing outcomes with historical data. Alternatively, one can adapt an existing framework of a validated model. Adding missing indicators and relevant interactions for a specific analysis enables a wide range of analyses. As integrated models are often larger and more complex than system dynamics models, the same reasoning applies to developing such models or adapting existing ones. Similarly, building new equilibrium models from scratch for SDG analysis is highly resource-intensive because these models must integrate detailed data on economic or resource flows and require accurate calibration. Alternatively, existing IO tables or models can be applied for SDG analysis.

SDG research often utilizes existing models and adapts them to address specific research questions. The extent to which a model needs to be adapted depends on the area of analysis and the parameters that need to be considered. Before applying any model, it is essential to understand its underlying structure, the limitations, and the boundary conditions. However, if one wants to adapt a model, knowledge of the modeling technicalities and how the relations between variables are determined is needed, as well as mathematical and programming skills. The time to understand a new model technique, while not having prior knowledge, increases as the complexity of the model increases. Integrated models are, in general, the most complex, and network and regression models are often the easiest.

Other modeling approaches, such as agent-based models, remain underutilized in SDG analysis. However, they hold strong potential for capturing the complex, adaptive, and multi-actor dynamics of sustainable development. Agent-based models can help formalize qualitative sustainability theories and simulate behavioral interactions supporting SDG-related decision-making (Secchi et al. 2024). Similarly, AI has the potential to be a powerful tool for SDG analysis, but did not appear frequently in our selected articles. This low representation is a consequence of the fact that articles on AI often do not refer to modeling or simulating, which is a requirement to appear in our keyword search. However, AI has recently been applied to project SDG outcomes and evaluate scenarios (Ghamisi et al. 2025; Gosselink et al. 2024). As highlighted in a recent systematic review, AI techniques are increasingly applied to water conservation, urban planning, and clean energy optimization (Alam et al. 2024). The study also shows that artificial neural networks are the most frequent AI technique for SDG analysis. Alam et al. (2024) emphasize that reinforcement learning, a method in AI, has a large potential for modeling sustainable development. Meanwhile, this remains underutilized in the literature. Furthermore, AI can be used to analyze large datasets, potentially finding relations between SDGs. In general, the increase in computer power enables future research to analyze large datasets and run more detailed and expanded models.

This review study distinguishes itself through its holistic approach by examining a wide range of model types across multiple scales rather than focusing on a specific type or scale. However, this broad perspective comes at the cost of in-depth discussion on individual models, specific scales, or certain topics, potentially omitting details. A limitation of this study is that we examined the coverage of SDGs in models, but not which specific interactions or indicators were incorporated. As discussed, it is important to encompass multiple indicators per SDG to represent the goal thoroughly and to have a holistic view of sustainable development. For a more in-depth analysis, a literature study on the indicator coverage of SDG models is needed. We chose to extract only the SDG coverage because not all articles explicitly specify which indicators are incorporated into their models. Despite this, our analysis at the goal level provides important results regarding the SDG coverage of models. Our goal-level analysis provides further insight into how well different model types perform relative to one another in covering the SDGs, which also applies to the indicator level. Another limitation of this study is that we did not examine how well the resolution is implemented when determining the models' spatial resolution. Similarly, we did not compare the model quality. All articles have been peer-reviewed and published, and making statements of model quality is out of the scope of this research.

A deeper understanding of the models could be achieved not only by analyzing the information presented in the articles but also by directly examining the models themselves. In our procedure, we did not examine the potential of the models; instead, we focused on their application in the specific study. We did not have the resources to review each model in detail, so instead, we extracted information from the articles on the models. Still, by examining the articles, we can determine what these models have been used for, which reflects the models' capabilities. It is important to note that the results of regional and local studies are heavily dominated by research focused on China. Twenty-eight percent of the local and national studies are on China. This concentration suggests that the findings from regional analyses may not be fully representative of other parts of the world, particularly North and South America, where local or national SDG analyses remain limited. Another interesting point that could be extracted from the articles, but which we did not look at, is the inclusion of cross-boundary effects in SDG models. The spatial interconnections between different countries or regions have a significant impact on SDGs, as the achievement of sustainable development in one region affects other regions Zhang et al. (2024). Finally, when we selected the relevant records for the initial screening, some articles featuring SDG models may have been overlooked if they did not mention models or SDGs in their title, abstract, or keywords. Nevertheless, this keyword search resulted in a large and diverse collection of articles on SDG models.

Our research provides valuable insights for researchers, modelers, and policymakers who are integrating the SDGs in their work. Our work offers an overview of the different modeling methods available for analyzing SDGs while showing their strengths and limitations. Based on the research questions of interest and the available methods and data, this research can serve as an indicator for selecting the most suitable model. Our research is valuable for modelers, as it addresses gaps in current research and highlights aspects that require further attention. We emphasize what models should focus on when integrating the SDGs and the importance of providing a holistic view of sustainable development to be aware of synergies and trade-offs. Finally, the overview of SDG research provides policymakers with the knowledge that various model types can offer insights into policies, particularly in light of the importance of considering all aspects of sustainable development. Although many outcomes, regional variation needs to be taken into account when analyzing the SDGs. We also highlight the importance of conducting analyses on SDG trajectories at various levels of governance. This is because no region is on track to achieve the SDGs, many regions lack SDG analysis, and there is variation between regions in terms of actions and approaches to tackling the SDGs. Models could provide invaluable insights into these matters and should be considered more frequently. Finally, when developing frameworks for sustainable development, the suitability of indicators to be modeled should be considered, as such frameworks can be better tested and projections made to guide policymakers.

We summarize with three main conclusions. First, regional variability needs to be sufficiently addressed in SDG models. Although modeling efforts have been undertaken at various scales, from global projections to city-level strategies, most research has concentrated on the country level due to data availability and the national implementation focus of the SDGs. Future research should prioritize incorporating regional specificity in models. Developing models that incorporate regional disparities will enhance their applicability and ensure that sustainable development strategies are tailored to the unique challenges faced in different parts of the world, thereby filling the gap for multiple regions that lack detailed analysis of the SDGs. Second, the various model types employed for SDG analysis reflect the challenges in understanding the 2030 Agenda and implementing it effectively. Models provide critical insights into how the SDGs are interconnected, what pathways project optimal futures, and how to guide policymakers in considering multiple aspects of sustainable development. Finally, excluding certain goals and indicators from models risks overlooking crucial trade-offs, which could lead to policy blind spots. To reduce this risk, greater emphasis should be placed on SDGs 5, 10, 14, 16, and 17, goals that are fundamental to achieving truly sustainable and equitable development but are often overlooked by many articles. Further research should pay greater attention to these goals and consider multiple indicators per goal to ensure a sufficient representation of an SDG, as the choices of indicators heavily influence the results. Integrating our study's findings can help modeling practices, enabling users to incorporate local variations and adopt a more holistic perspective on the goals. By using more comprehensive, multi-scale, and inclusive methodologies, future modeling efforts can better support the transition toward a more just, resilient, and sustainable world, contributing to the acceleration of the SDGs and formation of the post-2030 agenda.


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## Conflicts of Interest

The authors declare no conflicts of interest.

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## Supporting Information

Additional supporting information can be found online in the Supporting Information section.