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ECONOMIC MODELS OF CLIMATE CHANGE: SYSTEMATIC REVIEW OF BENEFITS, LIMITATIONS, AND FUTURE DIRECTIONS

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ABSTRACT

Climate change substantially impacts the community's livelihood, affecting their socioeconomic status. Considering the severity of impacts in the developing country context, economic models have been identified as a feasible application to determine the socioeconomic impacts of climate change. Consequently, this study provides benefits, limitations and future directions of economic models, which can be used as guidance to apply the economic models to determine the community impacts of climate change and thereby contribute to sustainable development. A systematic literature review has been adapted as a methodology to identify 18 benefits and 14 limitations of economic models of climate change. In addition, 18 future directions for applying and improving economic models of climate change have been derived. Benefits are mainly associated with the financial and decision-making aspects, while the limitations highly encounter due to possibility of producing misleading results and uncertainty. Future directions of economic modelling of climate change mainly concentrate on modelling for uncertainty and integrating multiple climatic conditions, livelihood status, models, technologies, and stakeholders in economic modelling. The findings are helpful for policymakers to successfully apply the economic models to address the climate change issues in the community. Further, the community will ultimately benefit from the set of policies and management strategies that occurred with the guidance of these findings. Further research can be conducted on addressing the identified limitations of the economic models and developing them.

Keywords: *Change; Climate; Economic-Modelling; Livelihood; Socioeconomic; Systematic Literature Review (SLR).*

1. INTRODUCTION

Climate change and the persistence of the community are two related activities which have mutual impacts on each (Matsumoto, 2019). Climate change is a critical global issue that significantly and uniquely impacts different regions (Hashida & Lewis, 2022). According to Evans (2019), climate change refers to "a dynamic, multidimensional system of changes in environmental conditions that will likely influence human

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behaviour" (p.2). Global climate change is characterised by average temperature and rainfall changes simultaneously with the associated physical impacts of it (Ogada et al., 2020; Sánchez, 2018). Climate change negatively impacts people; however, the magnitude and direction of impacts display some variations at the national and regional levels (Wang et al., 2021). Further, as stated by Hossain et al. (2019), the effects of climate change illustrate differences based on location. Henceforth, it can be argued that climate change creates broad socioeconomic impacts like increase poverty, be a cause of conflicts, and reduce resource availability for consumption (Rising et al., 2022) on different communities worldwide.

Climate change impacts primary production, causing reductions in harvest revenue and affecting the downstream industries, thereby negatively impacting the net welfare of people (Hashida & Lewis, 2022; Wang et al., 2021). Specifically, it threatens people's livelihoods and affects their socioeconomic status (Adego & Woldie, 2022). Similarly, climate change impacts different parameters of the community, including their demography, social status, and economy and constitutes challenges to the community's existence (Navarro & Tapiador, 2019). Consequently, there is a dire necessity for actions to cope with climate change to ensure the socioeconomic status of the community.

Mitigation and adaptation are two important focuses of climate change to diagnose and reduce the risks and costs associated with climate change (Rising et al., 2022). Further, Antle et al. (2018) highlight that integrating mitigation and adaptation practices helps to manipulate the climatic impacts and will ensure the resilience of the communities to survive amidst climate change. Moreover, there is a requirement to determine the welfare impacts of climate change and introduce adaptation strategies to manage the socioeconomic impacts (Adego & Woldie, 2022; Gurgel et al., 2021). Since adaptation refers to responses given by nature and humans to an actual or predicted climatic condition, use of adaptation actions manipulate the impacts of climate change (Adego & Woldie, 2022). Using a systematic method assists in deriving planning, adaptation, and mitigation actions to be resilient to climate change (Meijl et al., 2018).

Economic modelling is a practical approach to assessing the costs and benefits of climate change on people's livelihoods, which helps to generate optimal actions to manage the impacts of climate change and achieve climate goals (Rising et al., 2022). A similar view has been expressed by Khabbazan (2022); there is an urgency to address climate change which can get significant findings using rigorous economic models and analytical frameworks to inform climate change decisions. Economic models of climate change are theoretical frameworks used to predict the economic impact of climate change, including costs associated with physical, environmental and social effects (Nikas et al., 2018). Further to Rising et al. (2022), economic models combine the opposite views of multiple disciplines, including climatic variations and their non-linear impacts, to detect the risks and benefits of climate change on livelihood.

The economic impacts of climate change on livelihoods are expected to be more severe in developing countries (Aryal et al., 2020), and there is a deficiency of adaptation measures taken to resist climate change (Wang et al., 2021). Hence, economic models of climate change can be applied to address the socioeconomic impacts of climate change. Henceforth, this article focuses on articulating the benefits, limitations, and future trends of economic models of climate change, which could be used to determine the impacts of climate change on the community.

2. RESEARCH METHODOLOGY

2.1 SYSTEMATIC LITERATURE REVIEW

This study used a systematic literature review (SLR) to identify the benefits, limitations and future trends in climate economic modelling. It provides the basis for researchers to identify patterns, trends, and inconsistencies in the available evidence adhering to a structured methodology. Accordingly, Preferred Reporting Items for Systematic Literature Reviews and Meta-Analyses (PRISMA) were used as the research method.

Among the variety of SLR search tools, this study considers PICO as the most appropriate tool considering the coherence and cohesion of its element to appropriate into the context of climate economic modelling. PICO stands for the four elements of the population (P), intervention (I), control (C), and outcome (O). Considering the expectations of the SLR and PICO elements, the research question was formulated as "What are the characteristics, benefits and limitations of the economic models which are to manage the socioeconomic impacts of climate change". This research question was based on a manual initial keyword search. The researcher identifies that the articles to extract findings about the future trends of climate economic modelling link their future directions with the characteristics, benefits, and limitations. The research question was located with the PICO elements and identified global context as the population since the researcher focuses on the entire community to identify future directions. In addition, climate change and economic models were respectively identified as intervention and control, while the characteristics, benefits, and limitations were identified as the outcomes. Subsequently, a logic grid was developed, including the alternative terms to finalise a comprehensive search string with all possible keywords. Table 1 depicts the keywords used under each PICO element.

Table 1: The logic grid of Systematic Literature Review

Population	Intervention	Control	Outcome
Global context	Climate change	Economic models	Characteristics
			Benefits
			Limitations
	Climat*	Econom* W/0 model*	Econom* W/0 value*
			Character*
			Feature
			Benefi*
			Barrier*
			Advantage*
			Disadvantage*
			Limitation
			Challenge

As shown in Table 1, since the global context has been identified as the population, the term was not included in the search string. Database selection is vital to ensure the success of SLR. This study used three databases, namely Scopus, Web of Science, and Science Direct, which are related to the context of the study and have been identified as top databases for academic research. Moreover, the "title-abstract-keyword" search was used to have a precise and comprehensive result. However, climate change, which is the

intervention of this study, has undertaken a "title only" search, as there are plenty of articles that use the term "climate" in their abstracts that are irrelevant to climate change. In addition, instead of the phrase climate change, variations of the word "climate" were used for the search as it covered the phrase "climate change" as well.

Moreover, wildcards (*, W/n) and Boolean operators (AND, OR) were used to increase the findings' versatility. The search criteria were set for the last five years (since 2018) to eliminate outdated results and increase accuracy. Since the paper focuses to capture benefits, limitations and future directions, which are three of frequently updating areas, this time frame of five years were continued to maintain. Further, publications in the language of English were only considered. Overall, the below-mentioned search string was used to identify the records.

(TITLE-ABS-KEY
((econom* W/0 value*) OR character* OR feature OR benefit* OR barrier* OR advantag* OR disadvantag* OR limitation OR challenge* AND (econom* W/0 model*)) AND TITLE (climat*))

2.2 SYSTEMATIC LITERATURE REVIEW RECORD RESULTS

As stated in *Systematic Review: PRISMA* (2022) guidelines, the flow diagram for "systematic reviews which included searches of databases and registers only" was applied for this study, and Figure 1 shows the summary of the process followed in this study for the three main stages of SLR.

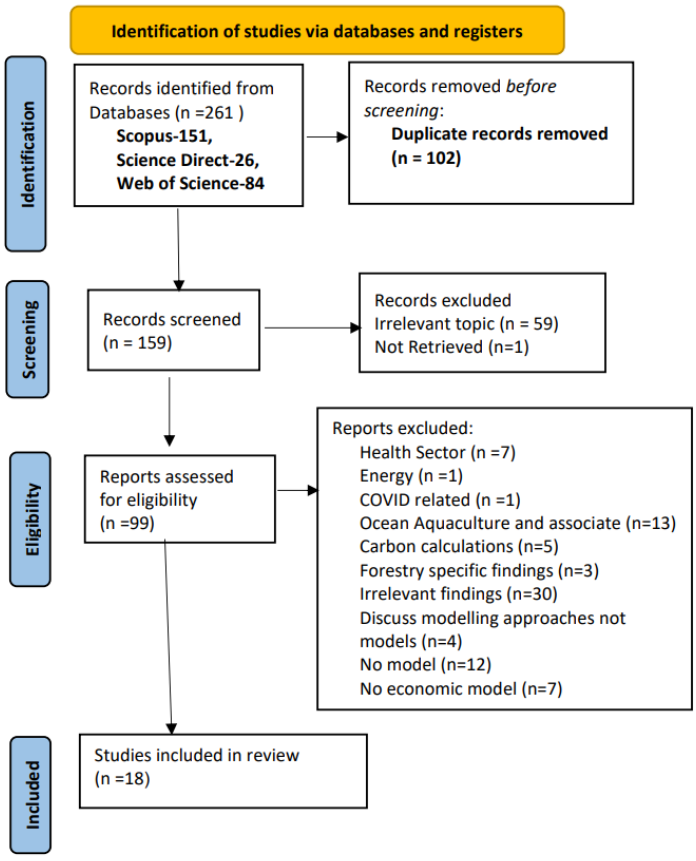

Figure 1: Identification of studies in the Systematic Literature Review

As per Figure 1, since the study focuses on identifying the future of climate economic modelling relevant to livelihoods, areas which do not discuss livelihoods (health, COVID, forestry, ocean, aquaculture, carbon calculations) were removed. Further, the articles with no model or no economic model were eliminated from the study. Moreover, irrelevant findings like managing food demand in the phase of climate, fertiliser, transport, and fossil fuel depreciation were disregarded. Finally, 18 records were selected for the detail processing, and the chart in Figure 2 summarises the type and number of articles accepted for the study.

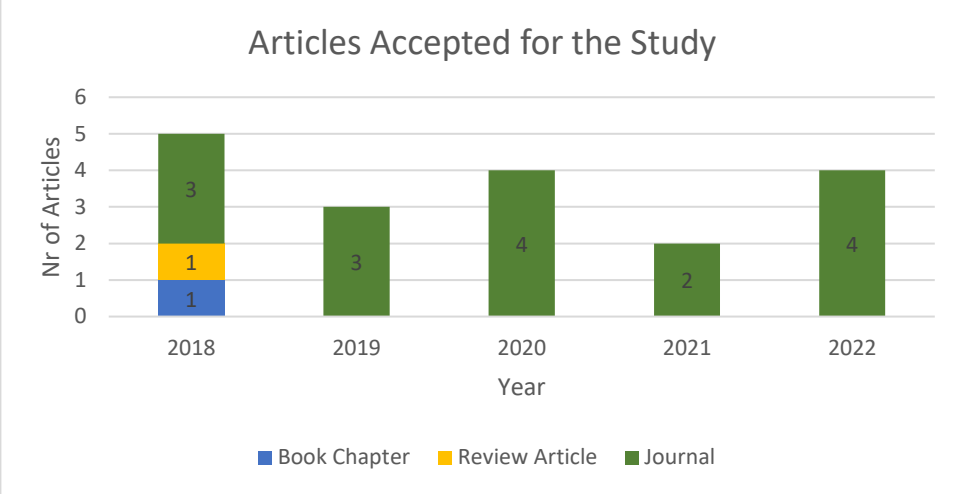

Figure 2: Summary of accepted articles

3. RESULTS AND DISCUSSION

As the next step, 18 articles screened out from SLR were subjected to a detailed analysis to identify the (i). benefits, (ii). limitations, and (iii). future directions of economic models of climate change in the context of socioeconomic development. The following section presents the outcomes of the analysis.

3.1 RESULTS- BENEFITS AND LIMITATIONS OF ECONOMIC MODELS OF CLIMATE CHANGE

Following the findings of SLR, 19 benefits and 14 limitations of using economic models of climate change to determine the socioeconomic impacts on the community have been recognised which are presented in Figure 3.

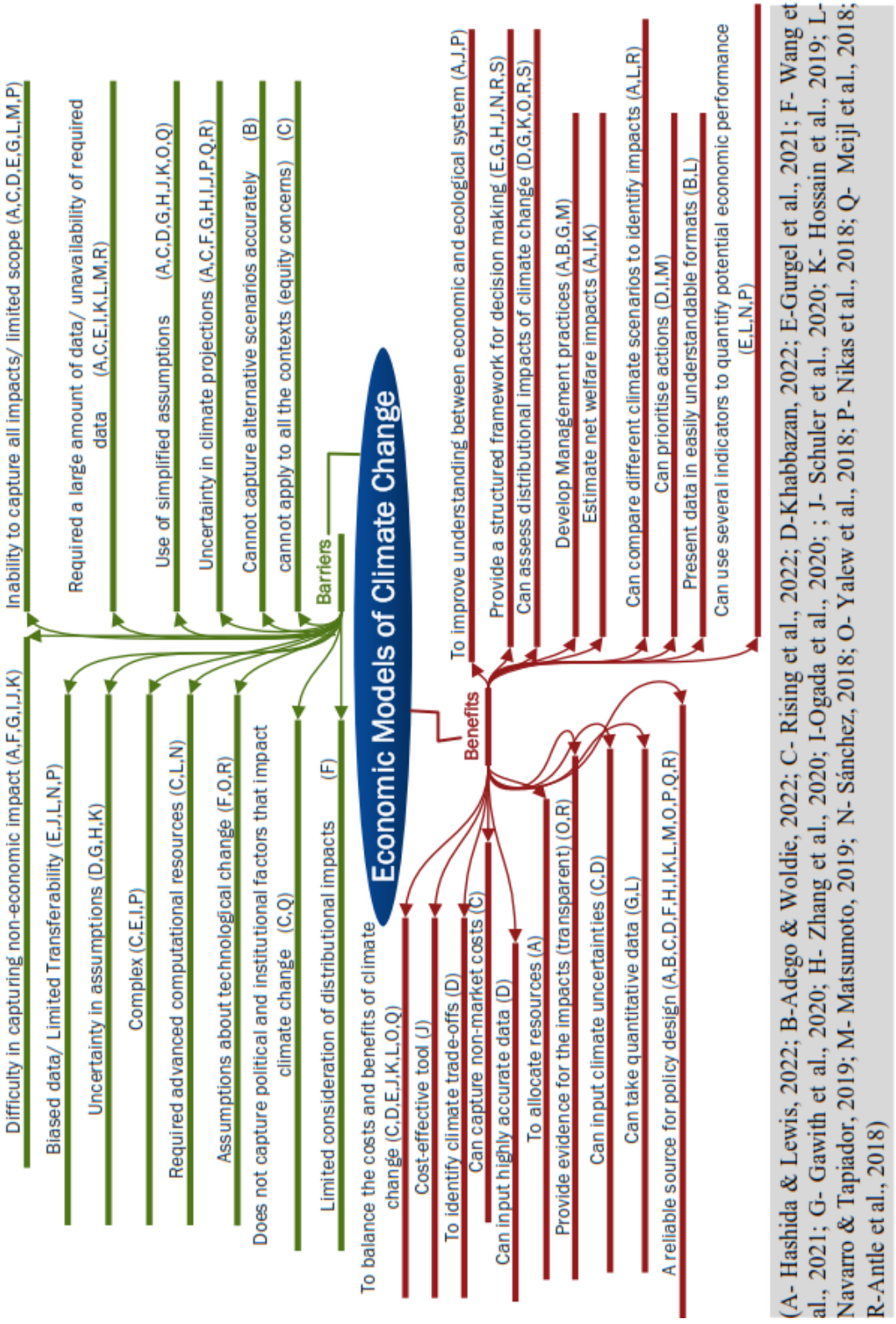

Figure 3: Benefits and limitations of economic models for determining socioeconomic impacts of climate change

The findings expressed in Figure 3 identify the benefits of climate change which can be discussed through the two main aspects of benefits in decision-making and the financial

aspects which will ultimately benefit the community. Moreover, the limitations recognised from the SLR can be discussed under the two main areas of uncertainty and less accuracy. Accordingly, the knowledge of the benefits and limitations of economic models of climate change expressed in Figure 3 can be used to determine the impacts of climate change on the community.

3.2 BENEFITS OF ECONOMIC MODELS OF CLIMATE CHANGE

The benefits of using economic models of climate change for determining the socioeconomic impacts of climate change can be broadly discussed under two main areas of assistance in decision-making and financial aspects.

3.2.1 Benefits in Decision-Making

According to the findings of SLR, most articles have emphasised the guidance of economic models in policy-making as an advantage. Policies play an essential role in adapting to climate change, specifically in the context of developing countries (Adego & Woldie, 2022; Wang et al., 2021). Further, climate change is a significant and urgent global challenge that requires effective policies to mitigate its impacts (Khabbazan, 2022; Rising et al., 2022). These policy decisions will support the sustainable and resilience of the community under changing climatic conditions (Hashida & Lewis, 2022). Moreover, Adego and Woldie (2022) revealed that policies enlighten the agricultural community's socioeconomic status by regulating farmers' adoption decisions to withstand climate change.

In addition to the benefits in policy-making, economic models possess a variety of matrices to smooth the decision-making process and help to determine the potential economic importance to derive practical management actions (Gurgel et al., 2021). Specifically, economic models derive the net welfare impacts with numerical shreds of evidence identifying income losses (Hashida & Lewis, 2022) and changes in domestic assets (Ogada et al., 2020). Moreover, actions to mitigate or adapt to climate change can be managed and prioritised based on the findings of economic models, which will ultimately benefit decision-making. For example, according to the findings of Gurgel et al. (2021), through the use of computable general equilibrium (CGE) models, efforts to study the impact of climate change on crops can be prioritised. Overall, it can be highlighted that economic models of climate change assist in the decision-making process by making it convenient and comprehensive.

3.2.2 Financial Aspects

Performing a cost-benefit analysis of climate change impacts using economic models has become a popular approach for accounting financial values of climate change (Hossain et al., 2019). Specifically, Rising et al. (2022) have identified economic modelling as an aspect which allows capturing non-market costs, risks to non-market goods and non-market damages, including loss of biodiversity, costs of injuries and deaths. However, the authors further stated that it is an undeveloped area which should be further developed to make it beneficial. Furthermore, the ability to use several indicators to quantify economic performance is also identified as a benefit of climate change, which in return is beneficial to engage in a comprehensive assessment by identifying interconnections among different indicators. This view has been adduced by several authors (Gurgel et al., 2021; Navarro & Tapiador, 2019; Nikas et al., 2018).

Moreover, the benefits address the concept of trade-off, which refers to a situation or action when something is given up in favour of something else that is viewed as having higher worth. Accordingly, economic models help capture and implement climate trade-offs by including trade-off parameters to detect welfare losses and mitigation actions (Khabbazan, 2022). Overall, economic models provide an opportunity to account for the impacts of climate change using various cost indicators.

Awareness of the limitations of the economic models of climate change is essential to determine the socioeconomic impacts of climate change on the community, as it provides impressions about the required areas of development and the degree of reliability of the determined impacts.

3.3 LIMITATIONS OF ECONOMIC MODELS OF CLIMATE CHANGE

3.3.1 Uncertainty

10 out of 18 papers have identified uncertainty of climate projections as a limitation to using economic models to identify the impacts of climate change on the community's livelihood. Several reasons lead to uncertainties in economic models of climate change. Moreover, Khabbazan (2022) and Yalew et al. (2018) highlighted that economic models tend to use simplified assumptions, which allow no space to incorporate uncertainties. Further, an economic model of climate change can capture data from limited scope (Gawith et al., 2020; Matsumoto, 2019) and, therefore, is uncertain about accounting for variations. In addition, economic models are complex and require advanced computational skills, leading to uncertainty (Rising et al., 2022). Similarly, economic models tend to make wrong assumptions about the technology, which provides uncertain feedback in return (Meijl et al., 2018; Wang et al., 2021). Overall, consequent to the abovementioned reasons, economic models of climate change have become a limitation to determining the socioeconomic impacts on the community's livelihood.

Possibility of producing misleading results because policy decisions are frequently reliant on the forecasts produced by economic models of climate change, the accuracy of economic models is vital when anticipating the socioeconomic implications of climate change. Inaccurate forecasts can result in ineffective or unproductive policies, negatively impacting the economy and society. Zhang et al. (2020) state that the limited incorporation of all related data will capture the intensity and nature of the actual scenario emphasising Ethiopia, a developing country. This limitation with data application causes a reduction in the accuracy of the output of economic models. Moreover, most economic models cannot accurately capture alternative climatic and economic scenarios (Adego & Woldie, 2022), as they have been designed to examine the relationship between and among a particular set of variables and cannot predict the changes in variables. Further, economic models of climate change are developed concerning a particular context (eg: climatic condition, region, livelihood sector, etc.) and therefore have low equity concerns (Rising et al., 2022). In addition, economic models incorporate political and institutional factors into their models, which limits the practical implementation of findings (Antle et al., 2018).

Contradictory views of the benefits and limitations of economic models of climate change have emerged through the SLR. Accordingly, Rising et al. (2022) state that economic models can capture the non-market costs of climate change, while 1/3rd of the articles subjected to SLR argue that it is difficult to capture. The non-market costs identified by

the authors include value reduction in forests and crops (Hashida & Lewis, 2022), conflicts, and migration (Rising et al., 2022) as aspects which are easily observable as non-market impacts. Therefore, it is argued that the non-market costs are challenging to quantify in economic models, and consequently, it is a limitation.

Moreover, several authors developed their argument by mentioning that the economic models can capture the distributional impacts of climate change (Antle et al., 2018; Rising et al., 2022; Schuler et al., 2020; Wang et al., 2021) while there are opposing views by a few authors (Hashida & Lewis, 2022; Nikas et al., 2018; Rising et al., 2022). Since the articles encountered in SLR represent a combination of studies conducted focusing on a particular region/livelihood sector and articles with a macro focus on climatic impacts, it can be argued that distributional impacts of climate change can be quantified through economic models. However, they are less applied and less investigated.

3.4 FUTURE DIRECTIONS OF CLIMATE ECONOMIC MODELLING

The findings of the SLR disclose 18 future directions of climate economic modelling. Accordingly, integrating different climatic impacts and multiple livelihood scenarios generates more impactful results (Hossain et al., 2019; Nikas et al., 2018; Sánchez, 2018; Meijl et al., 2018). Further, instead of isolating economic models to determine the climate change impacts on livelihood, integrating them with other models will increase the accuracy of the socioeconomic impacts determined in the models (Gawith et al., 2020; Khabbazan, 2022). A few authors have already initiated this approach. However, further developments and effective integration are still below the requirement. For example, Rising et al. (2022) and Zhang et al. (2020) identified a vital view: increasing stakeholder collaboration from different perspectives in a single model could generate versatile results.

Embedding technology to economic modelling also has been identified as another valuable direction for improving climate economic models. For example, spatial technology has been identified as a potential future application for climate economic modelling (Navarro & Tapiador, 2019; Meijl et al., 2018), which will be helpful in scenario analysis and climate information mapping. Similarly, Table 2 demonstrates the findings of SLR regarding the future directions of climate economic modelling.

Table 2: Future directions of climate economic modelling

Future Direction	Citation
Consideration of multiple scenarios and pathways (multiple sectors and impacts)	(B, E, F, G, I, K, N, P, Q)
Integration with different models	(B, C, F, K, L, M, N, O)
Improve representation of uncertainty	(A, B, D, F, G, P, R)
Improving the modelling of adaptation	(F, G, I, J, L, Q)
Study the extreme conditions where land use is difficult to manage under climatic changes	(A, G, I, R)
Improve modelling techniques	(C, F, L, O)
Study non-market values of different goods and services impacted by climate change	(A, F, J)

Investigation regarding substitution possibilities	(E, M, Q)
Integrate technology	(I, L, N)
Incorporate feedback loops into economic models	(B, Q)
Enhance stakeholder engagement from different perspectives	(C, H)
Use of in-depth data	(G, Q)
Increasing spatial resolution	(L, R)
development of comprehensive models that can capture heterogeneity	(C)
Increase the use of open information	(C)
Study on delayed action scenario	(D)
Integrate trade-off	(J)
Integrate holistic approach	(K)

(A- Hashida & Lewis, 2022; B-Adego & Woldie, 2022; C- Rising et al., 2022; D-Khabbazan, 2022; E-Gurgel et al., 2021; F- Wang et al., 2021; G- Gawith et al., 2020; H- Zhang et al., 2020; I-Ogada et al., 2020; ; J- Schuler et al., 2020; K- Hossain et al., 2019; L- Navarro & Tapiador, 2019; M- Matsumoto, 2019; N- Sánchez, 2018; O- Yalew et al., 2018; P- Nikas et al., 2018; Q- Meijl et al., 2018; R-Antle et al., 2018)

According to Table 2, it is clear that the future trends of economic models of climate change are more towards integration as it considers the integration of different technologies, stakeholder perspectives, models, climate scenarios, and modelling techniques to generate informed and accurate results. Simultaneously studies on alternative actions to be resilient in climate change and accounting for uncertainty should approach in the future.

4. CONCLUSIONS

This paper presented the findings of the systematic literature review (SLR) regarding the benefits, limitations, and future directions of economic models to determine the socioeconomic impacts of climate change on the community. SLR findings portrayed 19 benefits of economic models, mainly associated with decision-making and financing. Thus, economic models have been identified as a reliable source for policy design, developing management practices, prioritising actions, and allocating resources. Furthermore, the 14 limitations identified regarding applying economic models to determine people's socioeconomic status were directed towards the two main complications of uncertainty and low accuracy. The complexity followed this low accuracy, use of simplified assumptions, and use of few data than the requirement. Uncertainty has occurred consequent to the difficulty of capturing changes in climatic conditions. Therefore, the future direction of economic models of climate change prefers an integration approach merging multiple climatic conditions, livelihood status, models, use of more detailed information, and encountering uncertainties. Overall, the findings are assisting the government, climate authorities, researchers and economists to apply the economic models of climate change to their country context to derive actions and policies which will results the increasing of the community resilience to climate change by smoothing their livelihoods and mitigating socioeconomic impacts. Moreover, further researches can be conducted to develop economic models, by addressing the identified limitations.

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