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Defining and measuring sustainability: a systematic review of studies in rural Latin America and the Caribbean

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Abstract
Research on sustainability was ignited by the Brundtland Report and further fueled by the recognition that sustainability is a critical challenge for the twenty-first century. The explosion of sustainability literature necessitates continuous review and synthesis. This targeted review focuses on sustainable rural land use in Latin America and the Caribbean. A systematic selection process yielded 57 articles published between 1980 and 2016. The articles were categorized based on the definition of sustainable land use, measure(s), and their contributions to sphere(s) of knowledge—environment, economic, and/or social. Almost half of the articles were categorized into one sphere of knowledge, one-fifth in two spheres, and the remaining third in all three spheres. Generally, the definitions of sustainability matched the measures of sustainability and the spheres of knowledge. This results in high variation in definitions and measures across studies depending on which sphere or combination of spheres is emphasized. Recent studies are applying complex indicators of sustainability that cross all three spheres, thereby addressing the limitations of using a reductionist approach to measure the complexity of studying of multiple intersecting and overlapping land uses. This important trend will support the comparison of current land-use practices to sustainable goals and facilitate comparison across land uses. The development and incorporation of theoretical frameworks are generally absent from these studies limiting the generalizability across study sites.

Keywords Sustainable · Sustainability indicators · Rural · Land use · Latin America · Caribbean

1 Introduction

At the 2015 UN Summit, world leaders embraced the 2030 agenda for sustainable development as a strategy for advancing sustainable development. The agenda seeks to build upon millennium development goals (MDGs) and is based on the use of 17 sustainable development goals and 169 associated targets (UN 2015). Just over a year later, in March

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of 2016, 33 ministers and representatives, from countries in Latin American and Caribbean, agreed to the declaration of Cartagena, with an explicit statement to further progress in the region through the 2030 agenda for sustainable development. Such intergovernmental agreements seek to build scientific capacity, advance national sustainability plans, and highlight the region's presence in the global conversations around sustainability (Quevedo 2013). These and other calls for attention to sustainability are increasingly common from global to regional and local scales, as well as across a range of sectors including within science and academia.

The US National Research Council identifies shifting toward sustainability as a key objective for the twenty-first century (NRC 1999). Additionally, the Inter-American Network of Academies of Science and the World Academy of Sciences recognize this objective as a primary part of their mission and vision statements (IANAS 2016; TWAS n.d.). This increased attention on sustainability has yielded a rapid expansion of the work examining sustainability and its practice. These works provide new and continuously morphing evidence of how sustainability is conceptualized and implemented in various places and contexts. The importance and continuous development of this field, and its practice, necessitates repeat reviews of sustainability.

Reviews provide an opportunity for reflection on how concepts change over time, vary across disciplinary boundaries, shape research design and measures, and identify limitations that could be addressed in future studies. For example, one concern of sustainability results from a recognition that development is responsive to a growing population and its needs, and often leads to depletion of natural resources (Kajikawa 2008). Although the recent uptick in sustainability-related efforts may suggest this is a new interest, a call for moving in the direction of sustainability first emerged with the publishing of The Brundtland Report in the 1980s (World Commission on Environment and Development 1987). This report initiated global discussion regarding sustainability. Since then, the definition and concept of sustainability continue to be reworked through iterative global conversations (Fu and Zhang 2017). Thus, periodic reflection on how these global dialogues are shaping, and reshaping, the definition and concept of sustainability is central to further the advancement and realization of sustainability.

Sustainability frameworks and discussions are typically defined by the use of the three pillars of sustainability—environment, economics, and social equity—and the need for each pillar to be strongly present if sustainability is to be achieved. A systems approach to these pillars not only recognizes that each needs to be present, but also emphasizes the interdependence of the three pillars (O'Connor 2006). Bettencourt and Kaur (2011) indicate that the pillars represent the systems to manage primarily from a policy perspective and that the system-level nature of sustainability presents an inherent challenge to developing sustainability as a cohesive science. A challenge that potentially limits successfully moving from the concept of sustainability to its practice.

Land-use decisions are one way in which concepts of sustainability can be put into practice. Land use has the potential to augment or diminish sustainability efforts (Haberl et al. 2004). The concept of sustainability with regard to land use is particularly challenging in practice partly due to the large variety of land uses that shape, sometimes in opposing ways, the three pillars of sustainability. Yet, the influence of land use on ecosystems, economics, and other aspects of society is far-reaching and, given its significant role in these systems, is arguably inseparable from advancing sustainability (Turner et al. 2007).

Similar to the sustainability literature in general multiple published scientific reviews respond to the explosion of research under the umbrella of sustainable land use. Several themes emerge from these reviews focused on Latin America and the Caribbean. Around

half of them focused on different sustainability-oriented management strategies (i.e., agroecology and agroforestry) and their environmental, economic, and/or other social impacts (Altieri 1992, 2000a, b, c; De Beenhouwer et al. 2013; Ordonez et al. 2014; Lin et al. 2008; Bennett and Franzel 2013; Newton et al. 2009; Bailis et al. 2014; Wittman et al. 2015). Others have emphasized issues related to governance, including policy, decentralization of management, and participatory planning, on land cover and use (Larson 2003; Oltremari 2003; Nicholls and Altieri 1997). A third area of emphasis is the use of local and/or scientific knowledge in land management (Winklerprins and Barrera-Bassols 2004; Twomlow et al. 2002). We contribute to this land-use discourse, but the work described here approaches the conversation from the distinct perspective that, in practice, land uses are often overlapping, interdependent, and influenced by culture and history. As such, rather than focusing on a single land use, or a select few, we cover a multitude of land uses that is employed in the study region.

An evolving research theme evident in recent reviews is that of theoretical approaches and frameworks to guide sustainability (Wiek et al. 2012; Saint Ville et al. 2015) and assessment indicators to measure progress toward addressing those issues (Sebesvari et al. 2016). Wiek et al. (2012) evaluate the ability of the theoretical approach of sustainability science to provide resolutions for sustainability-related problems. Saint Ville et al. (2015) focus more specifically on the historical, economic, and innovation conditions that have inhibited sustainable agriculture development and associated issues of food security and called for the utilization of a new socially and ecologically focused framework to guide development. Sebesvari et al.'s (2016) assessment-related review focuses on the indicators to measure vulnerabilities of ecosystems. In this review, we build on this and similar works to include a wide range of sustainable land-use indicators to ensure the representation of the breadth of measurement approaches used in these studies.

Our review is situated within this last group of reviews and seeks to contribute to the ongoing discourse and associated reworking of the concept and practice of sustainability. This review is guided by Kates (2011) and Bettencourt and Kaur's (2011) characterization of the field of sustainability science as an applied field. The goal of this review is to encourage the development of applied research on sustainable land use, similar to that presented by Boillat et al. (2017), by ascertaining how sustainable land use has been studied and put into practice. More specifically, we identify how sustainable land use is defined and measured in research throughout the Caribbean and Latin America. We limit our review to an assessment of the literature focused on sustainable land use in rural landscapes in Caribbean islands and the countries of Latin America. The review focuses on the region of Latin America and Caribbean, a region identified as highly vulnerable to future environmental change (IPCC 2014) and in which multiple sustainability efforts are underway, such as those promoted and funded by the Inter-American Development Bank. The region itself is defined by a high diversity of land-use practices and heterogeneous land systems.

In this review, we use the three pillars of sustainability to examine where the research focus has been placed. However, we discuss these pillars with regard to the spheres of knowledge to which the research contributes, and we broaden the social aspect of sustainable land use to not only consider social equity but also consider governance and practice as it is historically and culturally influenced. Although a broader definition of the social aspect of sustainability might include economics, we leave this as a separate lens used for the review of the literature as in today's global economy land use is highly influenced by actions and decisions primarily driven by economics. Another unique aspect of this review is that we examine how sustainable land use is defined, which is foundational to these types of studies, yet has not been emphasized in other reviews.

We also place focus on land uses outside of the urban areas as multiple reviews exclusively focused on urbanization, urban systems, and sustainability are already present in the literature (Fu and Zhang 2017; Romero-Lankao and Gnatz 2013; McGranahan and Satterthwaite 2003). Rapid growth in urban centers, shaped by rural–urban migration, affects land-use practices in rural areas where a decreasing population density in part dictates current and future land-use practices (Grau and Aide 2008). Furthermore, rural landscapes cover expansive land areas and are often where some of the most vulnerable populations live. The rural landscape continues to be a highly valuable space in Latin America and Caribbean. Subsistence agriculture is frequently emphasized in research in this region; however, in practice a wide range of land uses exist and intersect. The land, and natural resources, in rural communities serves as natural capital for communities who may be more directly reliant on this capital for their livelihoods and well-being. Our focus on sustainability in the rural landscape represents this diversity and complexity of sustainability in rural land use.

2 Methods

The review was carried out using a two-tiered search approach. In both tiers, the literature was restricted to peer-reviewed journal articles, published between January 1, 1980, and April 13, 2016. Due to language restrictions placed on the search, there is an acknowledged bias toward disciplines and works published in English language journals. We selected January 1, 1980, to ensure that we identified the early literature corresponding to the emergence of sustainability studies (Kates 2011). The first tier of the search took place in Scopus, a comprehensive database that covers all disciplines and emphasizes coverage of interdisciplinary topics (Elsevier 2017). The first-tier searches were aimed at identifying articles which met all combinations of the search terms and strings related to "sustainable," "sustainability," and "land use." (Table 1 identifies the list of terms and strings used in the Scopus searches.) Then, the second-tier search was focused on the developing area of sustainability science. In this search, we continued to identify literature on sustainable land use in the study region, but specifically targeted sustainability-science-focused journals.

Table 1 Search terms and strings used in the literature search

Required (a)	Required (b)	Optional
Sustainable	Land	Management
Sustainability	Land use	Strategies
	Agriculture	
	Forest	
	Natural resources	
	Savanna	
	Livelihood	
	Tourism	
	Crops	

For each search, one term from the required search terms (a) and (b) was included. Terms from the optional column were added to extend the search parameters

These journals included Sustainability, Sustainability: Science, Practice, & Policy, Current Opinion in Environmental Sustainability, and Sustainability Science.

The identified articles were further filtered to ensure that the following inclusion criteria were met: (1) the work includes a case study based on empirical observations and (2) the methodology includes measures of at least one sustainability indicator. Through a standardized iterative process by the first two authors, the remaining articles were coded and categorized based on the definition of sustainable land use, sustainability measure(s) used, and the sphere(s) of knowledge to which the work contributes—environment, economic, social. The definitions of sustainable land use were presented by authors in the articles reviewed. The sphere(s) of knowledge to which the work contributes are closely affiliated with the three sustainability pillars, and the categorization was determined by the measures used to assess sustainable land use. Additionally, we identified the geographic location of study, land use, scale, and primary research focus of study.

3 Results

The searches yielded a combined, non-duplicate, total of 133 papers (Fig. 1). Forty-nine papers were eliminated because they were not case studies (inclusion criteria one), 4 focused on sustainable urban areas, 13 were discarded as sustainability was tangential to the core research presented, and 10 were discarded because they did not provide a measure of sustainability (inclusion criteria two). The 57 (from the original 133) papers that remained were further reviewed and analyzed. The studies presented in the 57 articles ranged in publication date from 1996 to 2016, with 70% of the articles published since 2006 ("Appendix"). The number of publications peaks in 2014 with eight articles, and an overall increase in the number of publications occurs across the time period. The studies are geographically situated in over 28 countries with concentrations occurring in Mexico, Colombia, Brazil, and Costa Rica. The studies in these countries include all spheres of knowledge and all combinations of spheres. The scale of study was defined as the level at which decision making about sustainable land use was observed. The most commonly occurring scale of study was at the local land-user level, and the majority of studies (67%)

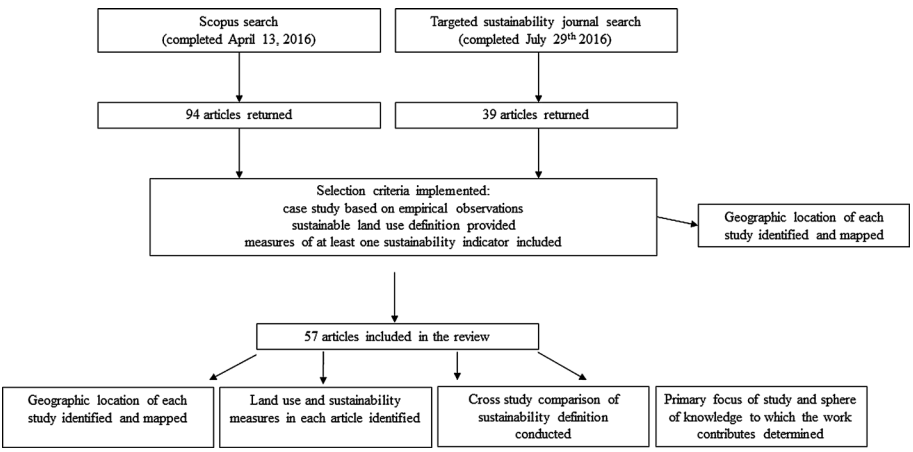

Fig. 1 Workflow diagram of review process

examined sustainable land use at only one scale. However, of the studies that used a multiple scale perspective, the combination of scales that was most prevalent was local land user and national government ("Appendix"). There were nine different land uses represented in these articles with 12% of the articles including more than one land use ("Appendix"). Figure 2 highlights the prevalence of the land uses in the literature examined. The most common land uses represented were conservation, especially of forests and including payment for ecosystems services and protected areas, and agriculture, including small and industrial scales. Other forest-related land-use activities followed in decreasing prevalence with agroforestry having the lowest prevalence of the forest-related land uses. The least studied land use related to the general natural resources category which included including water.

3.1 Spheres of knowledge in relationship to definitions and measures of sustainability

Among the approximately half (49%) of the total articles that focused on a single sphere of knowledge in their measures of sustainability (Table 2), the economic sphere was the least represented with only two articles. The unique features of the definitions of sustainability in this sphere were the emphasis on production and extraction of natural resources, the reference to the natural resource base as natural capital, and the ability to carry out future production as the goal of preserving natural capital. The bulk of the articles in this group were in the environmental sphere (17 articles). Although five different definitions were identified, the themes were similar in their emphasis on preserving or restoring the quality of natural resources or balancing the different spheres of knowledge. A moderate number of articles (9 articles) focused their measurements solely on the social aspects of sustainability. Similar to the environmental sphere articles, the definitions focused on balancing the

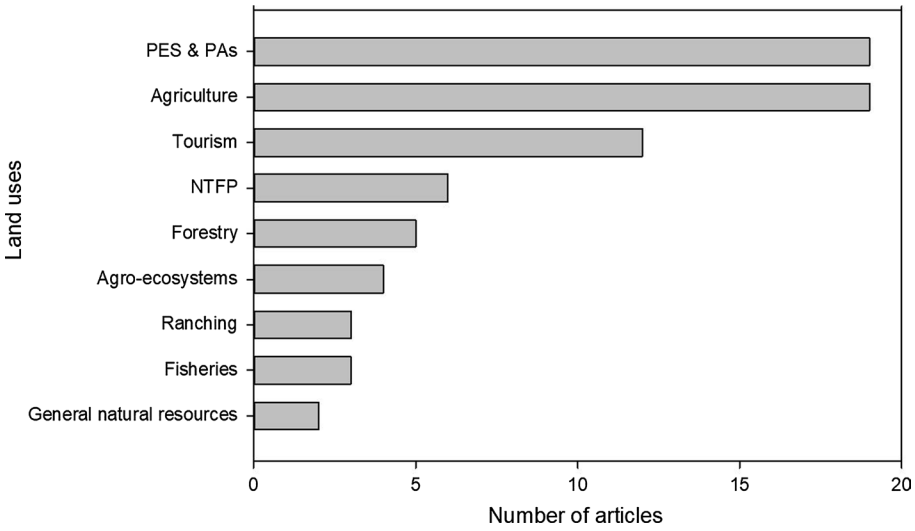

Fig. 2 Representation of the prevalence of land uses studied within the body of literature that met the review selection and criteria process

Table 2 Relationship between spheres of knowledge, definitions, and measures of sustainable land use

Spheres of knowledge	Definitions of sustainability	Measures of sustainability	Article quantity
Economic	Production and/or extraction natural resources, while preserving natural capital for future production	Income from natural resources	2
Environmental	Preserving and/or restoring plant and insect populations for ecological functioning	Plant and insect population dynamics	3
	Balancing environmental and economic interests		3
	Preserving and/or restoring natural resource quality	Soil and water quality indicators	6
	Increasing food production while preserving and/or restoring natural resource quality	Land cover change	3
	Balancing environmental, social, and economic interests	Review of environmental policies	2
Social	Balancing environmental, social, and economic interests	Stakeholder perceptions	5
		Stakeholder practices	3
	Preserving natural and cultural resources	Management planning	1
Economic, environmental	Balancing economic and environmental interests	Yield, income, pesticide use	4
		Income, environmental services	1
Economic, social	Appropriate technology	Costs, behavior	1
	None	Income, quality of life	2
	Maintaining and/or increasing food production while	Stakeholder perceptions, influence of economic	2

Spheres of knowledge were determined based on the measures used to assess sustainable land use, while the definitions shown in the table are the definitions of sustainable land use that author's presented in the literature

interests in all three spheres of knowledge. One article emphasized preserving resources, both natural and cultural.

More than a fifth (21%) of the articles emphasized two of the spheres of knowledge in their measures of sustainability. The five articles that included sustainability measures from both the economic and environmental spheres emphasized balancing interests in both of these spheres in their definitions. The same number of articles focused on the economic and social spheres in their measures with definitions emphasizing the appropriate use of technology and maintaining or increasing food production while balancing local interests in the different spheres. The three remaining articles included measures that fit in the environmental and social spheres of knowledge. The definitions in this group emphasized ecosystem health with measures to gauge that along with the theoretical framework utilized.

The remaining articles (30%) included measures in all three spheres of knowledge. Nine articles emphasized the maintenance of the natural resource base while carrying out economic activities. One article had no definition of sustainability (Granderson 2011). Another article defined sustainability as economic stability where the economy was no longer subject to the boom–bust cycles so common among capitalist economies (Le Tourneau et al. 2013). The remaining six articles extend the previous definition to including maintaining social resources, along with the natural, and define the period of time of the maintenance of these resources as indefinitely.

3.2 Research foci of studies

Results from our analysis indicated ten reoccurring research foci (Table 3). The primary focus of the review highlights areas within sustainable land use that are indicative of the main topic of study and context within which authors (of the reviewed literature) placed their work. We identified that the earlier publications emphasized the "environmental impact" of different land-use strategies with this theme continuing to the present. The most common theme, "management strategies," emerges a little later in 2002 and continues throughout the review period. For example, Manzo-Delgado et al. (2014) examined the role that the management strategy of payments for ecosystem services potentially serves in limiting the loss of forest and reducing deterioration of the land. In the last 2 years, more diversity of themes has occurred with articles focused on "social impact" and "governance." Articles during this period have also emphasized "sustainability assessment," where

Table 3 Distribution of articles published 1996–2016 and associated primary focus of study

Study focus	Numbers of papers	Time period of publication
Decision making	2	1996, 2009
Land cover	1	1997
Environmental impact	16	1997–2014
Management strategies	23	2002–2015
Economic impact	1	2006
Development project	1	2007
Sustainability assessment	3	2013, 2014, 2016
Social impact	4	2002, 2009, 2015, 2015
Governance	3	2006, 2013, 2016
Theoretical framework	1	2016

the sustainability of different land uses is measured and "theoretical framework," where a theoretical framework is used to guide sustainable land-use research.

3.3 Spheres of knowledge in relationship to research focus

The few articles in the economic sphere focused on decision making or economic impact of different land uses (Table 4). Papers classified as singularly contributing to the environmental sphere of knowledge were second greatest in number and had the highest diversity of study foci, with 6 of the 10 foci covered (Table 4). The social sphere is also well represented with a number of articles distributed across 50% of the foci with emphasis on social impact. The dual spheres are very sparsely represented with coverage in only 2 or 3 foci depending on the sphere combinations and most articles fall within management strategies. Research presenting a sustainability assessment either contributed to a single sphere or the dual combination sphere of economic–social, but are not found in the triple-sphere category. The triple-sphere articles, which were the most common, have research foci clustered in management strategies and environmental impact, although the majority of the environmental impact-focused articles are found in the environment-specific sphere. The more recent studies in the triple-sphere category apply (e.g., Brondizio et al. 2016), or frame (Delgado-Serrano et al. 2015a, b) their work in a more theoretical manner, relying on concepts such as resilience and socio-ecological systems.

4 Discussion

The results from this review identify three major patterns associated with how sustainability is conceptualized, how sustainability studies are designed, and which measures are used in these studies. The review highlights a mismatch between authors' definitions of sustainability and the measures implemented, in particular definitions tend to have a broader

Table 4 Relationship between spheres of knowledge and study foci for the articles published across the twenty-year time period

Study focus/sphere (s)	Eco.	Env.	Soc.	Economic and environmental	Economic and social	Environmental and social	Economic, environmental and social
Decision making	1	1					
Development project					1		
Economic impact	1	1					1
Environmental impact		9	1	1	1		4
Social impact			4				
Governance		1	1			1	
Land cover							1
Management strategies		3	2	4	3	1	10
Sustainability assessment		1	1			1	
Theoretical framework							1
Total	2	16	9	5	5	3	17

scope than the measures actually meet. Definitions also vary greatly, and the variation appears to be related to the discipline and the spheres to which the studies contribute. The majority of studies focus on a single scale of analysis, and a broad range of land uses were studied across the literature reviewed although few studies integrate an analysis of multiple land uses. The most glaring omission in the studies reviewed was the lack of an explicit presentation of a fully expanded theoretical framework upon which the study is based. In the following sections, we expand on each of these findings.

4.1 Spheres of knowledge in relationship to definitions and measures of sustainable land use

In the single-sphere articles, the measures of sustainability were closely linked with the sphere and guided by the definition of sustainability, although the definitions tended to be more holistic than the measures. The definitions and measurements in articles from two spheres were more closely linked than in the single-sphere articles. The measures used to represent each sphere tended to be reductionistic, and they varied from single-sphere to double- and triple-sphere articles, depending on the spheres with which they were combined. For example, the most common economic sphere measure was income; however, when the economic sphere was combined with the social sphere, measures were extended to include costs, and how economic benefits influence behaviors related to production. When the environmental sphere was on its own, the measures of sustainability focused most often on natural resource quality or ecological functioning, whereas when it was in concert with the economic sphere the amount of pesticide used or not was generally considered the environmental measure. The most common measures of social sustainability were stakeholder perceptions or behaviors which carried through when paired with the economic sphere. However, when included with environment the social measures became more varied and less well defined.

The articles in the triple-sphere group that defined sustainability as "the carrying out of economic activities while maintaining the natural resource base" had land-use-specific measures of sustainability similar to the reductionist measures found among the double- and single-sphere articles. The three-sphere articles that extended the definition of sustainability to include social resources and defined the period of time for maintaining the resources as indefinite were published more recently (2013–2016). Additionally, they employed more holistic and generalizable measures of sustainability than the previous land-use-specific measures; as did the Le Tourneau et al. (2013) article that defined sustainability as economic stability.

The heavy emphasis on the environmental sphere within sustainable land-use research is evident in this literature (72% of papers included contributions to the environmental sphere), yet the social sphere is also prevalent (60%) within the literature. One important issue is who is represented within the social sphere. There is a pattern of more recent consideration being given to the multiple land-use stakeholders who influence or are influenced by efforts to increase land-use sustainability. For example, in the study done by Granderson (2011), eight stakeholders were included in the study providing a broader representation in the social sphere than many other studies. This increase in the "who" of the

social sphere is accompanied by recent studies of community-based sustainable land use. For example, Delgado-Serrano et al. (2015a, b), and Holladay and Powell (2013) explicitly examine community-based management practices and also include measures of sustainability in all three of the spheres of knowledge.

Generally, the measures used for sustainability in each study match well with the definition of sustainability and the spheres of knowledge to which the study contributes. However, this has led to a high diversity and lack of consistency in the definitions of sustainability used across studies (Table 2). Definitions commonly relied on the use of terms and concepts such as "preserving," "balancing," and "maintaining." For example, in the triple sphere one definition that related to multiple papers conceptualized sustainability as "economic activity while maintaining social and natural resources bases indefinitely." However, the variation in definitions (see Table 2) could result from researchers trying to ground sustainability in the local context. This is most evident in the articles contributing to the economic and social domains, for example Hayes (2012) and Latawiec et al. (2014). However, in other cases this appears to be the result of disciplinary boundaries re-emerging through the emphasis placed in the sustainability definitions. For example, the definition of sustainability used by the articles in the economic sphere focuses on the importance of preserving resources with the goal of using them in future production, an area of interest for economists. In contrast, the definitions in the environment sphere tend to also emphasize preserving natural resources, but with the aim of improving the ecological functioning of those resources, an area of interests for ecologists, biologists, and other environmental scientists. An examination of this development of studies with regard to the spheres also highlights that studies have contributed to the three spheres since the late 1990s. However, the measures used in these studies have generally shifted from single-sphere indicators (e.g., seed germination, Sarmiento 1997) tied to a particular land use to more complex multi-sphere measures (e.g., 31 indicators, Locatelli et al. 2008) that can be applied across land uses. This shift is potentially the result of continuous reshaping and development of how sustainability is conceptualized. However, it is also important in the context of the interaction of multiple land uses which is so common in rural areas of Latin America.

Brondizio et al. (2016) is the only article to fully expand on the theory framing the case study application. The presence of only one study with a robust theoretical framing points to a shortcoming within sustainability studies, which has also been identified in previous research as a main issue that needs to be addressed within the science of sustainability (Bettencourt and Kaur 2011). The value of the strong theoretical framing for sustainability studies will enhance the generalizability of the work and help improve measures of sustainability, which can then feed back into informing the theory. There are several promising theoretical perspectives that can help guide interdisciplinary research in sustainability, particularly political ecology (Taylor 2014; Robbins 2012) and the ecosystem approach (Moran 1990). Political ecology addresses the intersection of the environment and development, with particular attention given to local conditions as related to distal forces, such as capitalism, and how the intersection is mediated by power dynamics (Turner and Robbins 2008; Baer and Singer 2014). This centrality of local contexts offers an appropriate framing for sustainability efforts, which continue to seek to bring together perspectives from the local to the global. One weakness of

this approach is the lack of incorporation of environmental data in the analyses, which is critical for understanding sustainability (Moran 1990). Framing sustainability efforts using the ecosystem approach supports the necessary focus on interconnectedness of different systems, including the natural environment (Moran 1990). The primary criticisms related to this approach are the potential overstating of equilibrium and lack of emphasis on individual actors (Moran 1990). Recent studies have sought to overcome these shortcomings by centralizing the dynamic nature of sustainability through the concept of resilience (Walker et al. 2004; Turner 2010).

4.2 Areas of research focus, land use, and scale

The research foci identified in articles covered a range of rural land uses (see Fig. 2). For example, studies where the main focus was evaluating land-use decision making were carried out in multiple land-use settings, including agriculture, ranching, forestry, and conservation. The concentrations on particular land uses (e.g., protected areas) and limited focus on other (e.g., natural resources and fisheries) could be a result of funding foci, or related to the more "charismatic" nature and/or long-established investment in the successes of some land uses as compared to others (e.g., protected areas). Additionally, certain land uses (e.g., fisheries) are potentially more complex in terms of their governance structures and equity within and across various user groups. This added complexity likely presents a greater challenge to the concept, definition, and measures of sustainability in these arenas, potentially resulting in the lesser focus on these land uses seen in the results of this review. The publication year indicates that certain areas of research focus remain consistently present in the literature, for example "environmental impact" is identified as a focus of research from 1997 to 2014. Other areas of research focus, for example "development project," which consists of 1 article published in 2007, are not consistently found throughout the time period of analysis. Also, some research foci have a relatively short history in the literature, as in the case of "sustainability assessment" which emerges in 2014. The short history of work focused on sustainability assessment in the literature is expected given the relatively recent emphasis on sustainability over the last 35 years and the subsequent development of sustainability research project and sustainability science. A clear pattern in the relationship between geographic distribution and focus of study is generally not evident. However, the research focus of "tourism" is an exception in that there is geographic clustering in the Caribbean nations as expected due to the high prevalence of tourism-focused land uses.

Over half of the studies explored a single land use. For example, Barrios and Trejo (2003), Campbell et al. (2011) and Holt-Giménez (2002) examine small-scale agriculture, yet this land use occurs within a larger matrix of land uses which are interconnected and expected to influence the sustainability of small-scale agriculture in the region. This pattern in the literature is likely in part due to the feasibility of multi-land-use studies with regard to cost, time, and complexity. Notable exceptions include Le Tourneau et al. (2013) where eco-tourism, agriculture, and non-forest timber production are examined. This added complexity is important for sustainable land-use studies as they attempt to address the connected nature of land use in a given space, and the role that interdependence plays

with regard to the continued sustainability of any individual land use within continuously changing physical and social contexts.

Finally, as sustainability continues to be a central point of discourse for governments and academics, it is important to continue to examine whether and how it is being realized in practice and to take into greater consideration scale. This review highlighted the lack of studies that research sustainable land use across scale. Additionally, those studies that do include different scales tend to limit it to local and national and/or international and exclude intermediary levels (i.e., regional and state). Jiménez Osornio (2011) highlights that in practice linkages across scales remain insufficiently developed and that sustainable land use requires consideration of multi-sectoral work, long-term planning, and regional policy implications. Thus, further studies of the implementation of sustainable land use would ideally integrate transdisciplinary approaches, science and practice, perspectives from multiple scales, and across interconnected land uses.

5 Limitations

A goal of this review was to broaden the scope beyond one land use, as is common in reviews of this type, to include the multiplicity of land uses practiced throughout the study region. Many of these land uses overlap geographically, politically, and economically; therefore, it is necessary for us to study them in conjunction so we can better understand how their interactions influence sustainability. However, for feasibility purposes we were required to reduce our scope and forfeit the inclusion of relevant languages besides English and broader search terms such as sustainable development. Additionally, we have limited this review to peer-reviewed journal articles. There is large body of writing about sustainability presented in books, book chapters, and project reports. These works contain valuable knowledge about the conceptualization and practice of sustainability which is not captured in this targeted review. For example, studies of biofuels did not meet the article selection and refinement process for this review and thus are not presented here. However, recent research on biofuels (Bailis et al. 2014; Solomon and Bailis 2014) demonstrates the current and future value of biofuels in Latin America and the Caribbean, a region which accounts for 27% of world's production of biofuels (Bailis et al. 2014). Future reviews focusing on the integration of research from a broader range of presentation formats, and on works in Spanish, Portuguese, French, and Dutch would be very complementary to this review and further help expand our understanding of sustainability and the indicators used to measure it throughout Latin America and the Caribbean.

6 Conclusion

This review identifies the definitions and measures used to characterize sustainable land use in the Caribbean, Mexico, and Central and South America. The corpus of work examined spans two decades, and the findings suggest that over time the nature of the studies

has changed. Studies primarily have measured sustainable land use using a limited number of reductionistic measures that are tied very closely to their distinct sphere of knowledge and their associated academic disciplines. Very recently, more complex composite indicators that are created with the goal of measuring the interactions among the environmental, economic, and social spheres are being implemented. These complex measures view sustainable rural land use from multiple perspectives and thus may potentially better support assessment of the sustainability of existing land uses and the implementation of more sustainable land uses. A potential area for further growth will explicitly incorporate robust theoretical perspectives with composite indicators, from multiple perspectives and scales, to further improve understanding the relationship between current and sustainable land-use practices. The current and anticipated challenges in Latin America and the Caribbean are linked to broader global changes, yet there is a need to adequately address local contexts. As such, sustainable land use will need to be addressed in a manner that speaks to the global call for action on sustainability, while also considering implementation at a regional and local level.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

See Table 5.

Table 5 Key characteristics of the articles reviewed

References	Land use(s)	Scale	Sphere(s) of knowledge	Primary focus of study
Howard and Valerio (1996)	Forestry, ranching, agriculture	Land users	Economic	Decision making
Koop and Tole (1997)	Conservation	National governments	Economic, environmental, social	Environmental impact
Sarmiento (1997)	Agriculture, conservation	National government	Environmental	Land cover
McElroy and de Albuquerque (1998)	Tourism	National governments	Economic, environmental, social	Economic impact
Geoghegan and Smith (2002)	Non-timber forest product	Local users, national government	Economic, environmental, social	Management strategy
Holt-Giménez (2002)	Agriculture	Land users	Economic, environmental, social	Environmental impact
Mercado and Lassoie (2002)	Tourism	Land users, national government	Social	Social impact
Barrios and Trejo (2003)	Agriculture	Land users	Environmental	Environmental impact
Garcia-Serrano and Del Monte (2004)	Agro-ecosystems	Land users	Environmental, social	Management strategy
Rivera (2004)	Tourism	Land users	Social	Management strategy
Grieg-Gran et al. (2005)	Conservation	International policy/markets	Economic, environmental, social	Management strategy
Yaw (2005)	Tourism	Land users	Economics, environmental, social	Management strategy
Mycoo (2006)	Tourism	National government	Environmental	Economic impact
Pyhälä et al. (2006)	Non-timber forest products	Land users	Economic	Economic impact
Winson (2006)	Tourism	National government	Environmental	Governance
Forero and Redclift (2007)	Non-timber forest products	Local users, State government, international	Economic, environmental, social	Management strategy
Hernández et al. (2007)	Conservation	Land users	Environmental	Environmental impact
Wing et al. (2007)	Natural resources	Land users	Economic, social	Development project
Dolisca et al. (2008)	Agriculture	National government	Economic, social	Environmental impact
Locatelli et al. (2008)	Conservation	Local users, national government	Economic, social	Management strategy
Tixier et al. (2008)	Agriculture	Local users	Economic, environmental	Management strategy
De Barros et al. (2009)	Agriculture	International policy/markets	Economic, environmental	Environmental impact
Funes-Monzote et al. (2009)	Agriculture	Local users	Economic, environmental	Management strategy
Newton et al. (2009)	Conservation	Land users	Environmental	Decision making
Nicholas et al. (2009)	Tourism	Land users	Social	Social impact
Alexis et al. (2010)	Agro-ecosystems	National government	Environmental	Environmental impact

Table 5 (continued)

References	Land use(s)	Scale	Sphere(s) of knowledge	Primary focus of study
Blanco and González (2010)	Forestry	Land users	Environmental	Environmental impact
Blazy et al. (2010)	Agriculture	Local users, national government, International policy/markets	Economic, environmental	Management strategy
Campbell et al. (2011)	Agriculture	Land users	Social	Environmental impact
Granderson (2011)	Conservation	Land users, national government	Economic, environmental, Social	Management strategy
Montagnini and Finney (2011)	Agriculture	International policy/markets	Economic, environmental	Management strategy
Williams (2011)	Conservation	Land users/national government	Environmental	Environmental impact
Hayes (2012)	Conservation	Land users, national government, international policy/markets	Economic, social	Management strategy
Avalos et al. (2013)	Non-timber forest products	Land users and national government	Environmental	Environmental impact
Chopin and Blazy (2013)	Agriculture	Land users, national government	Economic, environmental, social	Management strategy
Hassanali (2013)	Tourism	National government	Environmental, social	Governance
Holladay and Powell (2013)	Tourism	Local users	Economic, environmental, social	Management strategy
Bausch et al. (2014)	Agriculture	Land users	Environmental	Sustainability assessment
Benegas et al. (2014)	Agro-ecosystems, ranching	Land users	Environmental	Management strategy
Espinoza and Dockry (2014)	Forestry	Land users, national government, international policy/markets	Social	Management strategy
Forster et al. (2014)	Fisheries, tourism	Local users	Economic, environmental, social	Environmental impact
Latawiec et al. (2014)	Agriculture	National government and international policy/markets	Economic, social	Management strategy
Le Tourneau et al. (2013)	Tourism, agriculture, non-forest timber products	Land users, national government	Economic, environmental, social	Sustainability assessment
Manzo-Delgado et al. (2014)	Conservation	Land users and national government	Environmental	Management strategy
Paiva et al. (2014)	Conservation	International policy/markets	Economic, environmental, social	Environmental impact
Aguilar et al. (2015)	Agriculture	National government	Economic, environmental, social	Management strategy
Aslensis et al. (2015)	Agriculture	Land users	Environmental	Environmental impact

Table 5 (continued)

References	Land use(s)	Scale	Sphere(s) of knowledge	Primary focus of study
Barlagne et al. (2015)	Agriculture	Land users	Social	Social impact
Delgado-Serrano et al. (2015a)	Forestry	Land users	Economic, environmental, social	Management strategy
Delgado-Serrano et al. (2015b)	Natural resources	Land users, national government	Economic, environmental, social	Management strategy
Jasso and Abellán (2015)	Conservation, tourism	Land users, national government	Social	Social impact
Torres et al. (2015)	Non-timber forest products	Land users	Environmental	Environmental impact
Brondizio et al. (2016)	Fisheries	Land users, national government	Economic, environmental, social	Theoretical framework
Cochran et al. (2016)	Fisheries, agriculture	Land users	Social	Sustainability assessment
Montoya-Molina et al. (2016)	Ranching	Land users	Environmental	Management strategy
Schroth et al. (2016)	Agro-ecosystems	National governments, international policy/markets	Environmental	Environmental impact
Scullion et al. (2016)	Conservation	Land users, national government	Social	Governance

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