INTERNATIONAL JOURNAL OF SUSTAINABLE DEVELOPMENT & WORLD ECOLOGY, 2017 24:44-51
http://dx.doi.org/10.1080/13504509.2015.1136360

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The problems of weak sustainability and associated indicators

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ABSTRACT

Sustainability is a grand challenge of our time. While there is a universal recognition that sustainability includes social, economic, and environmental components, the relationship and interchangeability between these components has been debated, resulting in three distinct sustainability perspectives: weak, strong, and absurdly strong sustainability. However, despite this active debate, few have questioned which types of sustainability commonly utilized index forms actually measure. Here we provide such an analysis, focusing on the interplay between the mathematical forms of sustainability indices and the three sustainability perspectives. We show that the computational underpinning of a sustainability index defines what type of sustainability the index is capable of measuring, while also providing alternative forms. We then provide a brief example of how these different sustainability perspectives can radically alter measured sustainability. We end with a call for sustainability researchers to be conscious of the values underlying index formation, deliberate in index selection, and explicit in result presentation, so that the scientific and stakeholder communities are better informed of sustainability assessments.

ARTICLE HISTORY
Received 12 October 2015
Accepted 19 December 2015

KEYWORDS
Sustainability indicators; strong sustainability; weak sustainability

1. Introduction

Sustainability is the challenge of our time. Drawing on the combined knowledge of ecologists, economists, and social scientists, Sustainability Science has made enormous progress since its formalization (Kates et al. 2001; Kates 2011) and is rapidly becoming an established field of research (Bettencourt & Kaur 2011; Wu 2013). Due to human reliance on natural systems for provisioning and supporting services (MA 2005), sustainability is intrinsically linked to ecology. However, as ecologists have become increasingly involved in this transdisciplinary science, it has become clear that ecological principles are useful beyond simply analyzing the environmental components of sustainability. In particular, ecologists have proven successful at using their knowledge of ecological indicators to create sustainability indicators (Dale & Beyeler 2001; Niemi & McDonald 2004).

Yet, before sustainability can be measured, it must be concretely defined. The most widely accepted definition of the term comes from the 1987 Brundtland Report: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987). Further, it has been widely accepted that sustainability consists of three 'pillars' or 'bottom lines' – environmental, economy, and society. This approach, also known as the triple bottom line (TBL) (Figure 1b), has led to significant debate over the interrelationship and substitutability of these three components (Wu 2013; Huang et al. 2015). Even before the publication of the Bruntland Report in 1987, divides on this issue were apparent. Originally developed by Hartwick (1977) and Solow (1986), the development pathway that would become known as weak sustainability arose from the field of environmental economics and is fundamentally based on the assumption that different types of capital (social, environmental, and economic) are substitutable (Figure 1b). This approach was countered shortly after its creation, originally by Page (1983), and more famously by Daly and Cobb (1989), with strong sustainability, which rejects the tenet of substitutability by pointing out that social and economic capital are derived from environmental capital (Figure 1c).

In the decades following Daly and Cobb (1989), proponents of strong sustainability further diverged, with one wing taking a position that any conversion of natural capital to other forms is unacceptable (Holland 1997), while another claimed that substitution could occur within reasonable bounds (Daly 1995). These two lines of thought were qualified by Daly in 1995 where sustainability which accepts some, but not complete, substitutability when necessary is defined as strong sustainability, while the worldview that claims 'no species could ever go extinct, no non-renewable resource should ever be

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This article was originally published with errors. This version has been corrected. Please see Corrigendum (http://dx.doi.org/10.1080/13504509.2017.1251067).

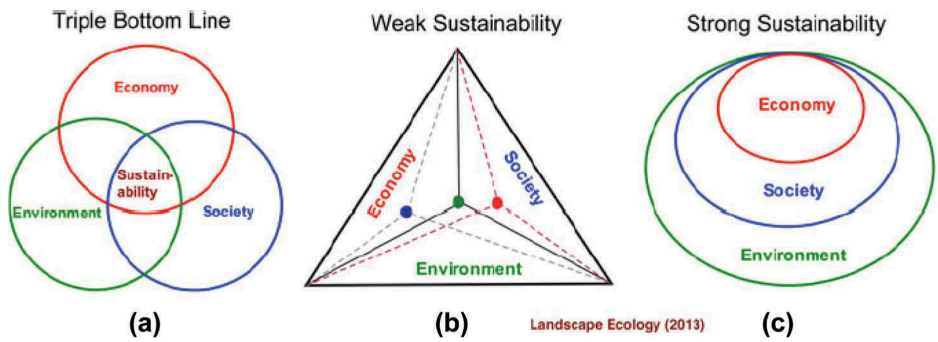

Figure 1. From Wu (2013): 'Illustration of the triple bottom line definition of sustainability (a) and weak sustainability (b) versus strong sustainability (c). The three situations in b are equally sustainable because weak sustainability allows for substitutability as long as the total capital (i.e., the sum of environmental, economic, and social capital) does not decrease.

taken from the ground, no matter how many people are starving' was (pejoratively) deemed absurdly strong sustainability.

In the years following these publications, a debate has raged through Sustainability Science that does not need to be rehashed here (but see Neumayer 2010 for details), resembling the SLOSS debate of the 1970s and 1980s (Wu 2008) in that all three types of sustainability are simultaneously necessary on multiple scales in the diverse circumstances of the modern world (Wu 2013). However, this debate has made it clear that, due to the irreversibility of environmental capital loss, weak sustainability is not sustainable over the very long term (Ekins & Simon 1999; Ekins et al. 2003; Wu 2013; Huang et al. 2015).

Running parallel to this debate has been the development of sustainability indicators. Meadows (1998) explicitly stated that indicators and indices are both representations of current values as well as a reinforcing force for future values, pointing out that indicators and indices are 'only partial reflections of reality, based in imperfect models,' which must differ because the worldviews from which they arise differ. A logical implication of this premise suggests that our models, though they may seem objective, are inherently value laden by their form. As such, given the strong intellectual divides between weak, strong, and absurdly strong sustainability, it is reasonable to ask which type of sustainability a given sustainability indicator or index (SI) represents.

Here we discuss how the choice of mathematical form can impact a SI's relationships with weak, absurdly strong, and strong sustainability. First, we focus on an equally weighted, additive SI and its connection to substitutability. Second, we define generalized forms for measuring weak, absurdly strong, and strong sustainability. Third, we provide an example of such how these different forms can radically impact measured sustainability using real-world data from Inner Mongolia, China, before concluding with a call for awareness by sustainability researchers to the connection between index forms and values.

2. Additive indicators, indices, and weak sustainability

An additive index can generally be defined as any index that is formed by the addition of any sub-indicators or indices, such that

$$\mathrm{INDEX} = \mathrm{Sub}-\mathrm{index}_1 + \mathrm{Sub}-\mathrm{index}_2 + \mathrm{Sub} - \mathrm{index}_3 + \ldots + \mathrm{Sub}-\mathrm{index}_n \tag{1}$$

In this case, the index in question is simply the sum of several sub-indices or their arithmetic average. In cases where the sub-indices do not have comparable units, as is the case for the vast majority of SI, sub-indices can then be normalized and then combined to give an equally weighted average such that

$$\mathrm{INDEX_{norm}} = (\mathrm{Sub}-\mathrm{index}_{1\ \mathrm{norm}} + \mathrm{Sub}-\mathrm{index}_{2\ \mathrm{norm}} + \mathrm{Sub}-\mathrm{index}_{3\ \mathrm{norm}} + \ldots + \mathrm{Sub}-\mathrm{index}_{n\ \mathrm{norm}})/N \tag{2}$$

where N is the total number of sub-indices.

This form is pervasive throughout the sustainability indicators literature, with many of the most common SIs adopting a normalized, equally weighted approach to measuring their unit of study (e.g., Human Development Index and Watershed Sustainability Index). For this form to be a comprehensive SI, it must include each of the TBL components (Figure 1a). To accomplish this goal, sustainability researchers generally select environmental, social, and economic sub-indicator sets, which are then normalized and averaged. Therefore, a generalized 'Sustainability Index' may take the following form:

$$\mathrm{SI} = (\mathrm{Environmental} + \mathrm{Social} + \mathrm{Economic})/3 \tag{3}$$

where 'SI' represents a generalized sustainability index, 'Environmental' the normalized environmental sub-index, 'Social' the normalized social sub-index, and 'Economic' the normalized economic sub-index. This form is exceedingly common and not particularly controversial. As identified by Morse et al. (2011), this equal weighting approach is often justified simply by the lack of evidence that weighting should not be equal. This may be true when SIs are measured over a single time period for a single locale. However, when these types of SIs are compared in time or space, SIs of this additive and averaged form become more problematic. In this case, the measured 'Sustainability' of the system can increase and decrease over time or space, and thus SIs of this formulation take on an additional assumption: each of the components of the SI is perfectly substitutable because losses in one sub-SI can be directly countered by gains in another without constraint until the sub-SI reaches its normalized maximum or minimum, respectively.

As this generalized indicator claims to measure 'sustainability,' and there are an infinite number of sub-SI scores that could lead to any given SI score, we must ask: 'Are all landscapes with the same SI score equally sustainable?' This is, obviously, depends on our definition of sustainability; and, given the visceral nature of the weak vs. strong sustainability debate described earlier, it is equally obvious that a single answer may not be easily reached. However, the math here is clear: if the SI measure does what it is supposed to do (i.e., to quantify sustainability), systems with the same score must be equally sustainable regardless of the pathway taken to get to the score. Continuing this concept to its logical extreme, this measurement system claims implicitly that a society with an environmental score of 0, but with maximal economic and societal scores, could conceivably be equally sustainable to systems with far more balanced approaches.

This form is clearly a measure of weak sustainability. Scientists who support such an approach have long claimed that as sustainability is fundamentally concerned with human well-being, as long as the total capital of the system increases, human well-being (and thus, sustainability) increases. However, quantifying 'Sustainability' in a way that allows limitless or nearly limitless substitution undermines the very definition of sustainability in the Brundtland Report. The absurdly strong sustainability perspective asserts that any form of substitutability between natural and human-built capital is fundamentally unacceptable, whereas the strong sustainability perspective allows for substitutability to a certain degree (Wu 2013; Huang et al. 2015). That is, relative gains in one of the three bottom lines at the expense of others are acceptable in limited circumstances where the growth of one component does not drive the others to go below a threshold value.

However, the form in Equation 3 does not include these limits. Rather, substitutability in Equation 3 is only constrained in two ways: 1) a perfect SI score, and 2) the minimum of a sub-SI score is 0. While there is only one possible way to score SI = 1 (to be the best at every measured variable), any score below SI = (1/3) allows for complete substitution (sub-SI = 0) for two sub-SIs, while any score below SI = (2/3) allows for the complete substitution of one sub-SI. Therefore, despite the fact that an SI = 1 demands no substitution, every score below 1 allows for some. Thus, Equation 3 fails to satisfy Daly's (1995) criteria for strong sustainability. Assuming that zero represents an undermined pillar, Equation 3 only limits substitution from one capital to another in the case where a sub-SI *already* equals zero, allowing for this final conversion (and complete removal of all of one type of capital) to still increase the measured sustainability of the system. Furthermore, TBL components may be compromised well before sub-SI = 0, allowing capital conversion long after a TBL component is already in danger. Because this general form (Equation 3) allows for substitutability even after a TBL component has been compromised, it cannot be a measure of strong sustainability unless the critical threshold for each dimension is clearly preset (Huang et al. 2015).

3. Measuring strong sustainabilty

As discussed earlier, the current trend toward additive indices is in opposition to the popularity of strong sustainability. In and of itself, this is not a problem; however, this realization does counter the concept discussed in Morse et al. (2011) that equal weighting should be the default because there is no good justification for other weighting systems. In fact, there is a perfectly good justification for questioning the validity of equal weighting systems as such an SI weighting scheme tends to support the view of weak sustainability. Thus, there is a great need to create SIs that both reflect our underlying values while not undermining their relative ease of use. Further, we present options to achieve this goal.

3.1. Absurdly strong sustainability SI

Any measure of absurdly strong sustainability must explicitly deal with Holland's (1997) assertion that 'nature ought not to be substituted even where it can be substituted.' In this way, absurdly strong sustainability asserts that any declines in natural capital are unacceptable. Therefore, an absurdly strong sustainability SI must constrain the SI so that gains in the human-built (Social and Economic) sub-SIs cannot come at the expense of natural capital while still allowing for development that does not reduce natural capital levels. The simplest way to do this is to define the equation for measuring absurdly strong sustainability such that

$$SI_{AS} = \Delta\text{Environmental} \tag{4}$$

where SI_{AS} is the absurdly strong sustainability index and the ΔEnvironmental represents the change in the Environmental sub-SI over a time step.

While the absurdly strong sustainability indicator does not preclude increases in human-built capital, it limits the conception of sustainability to the conservation of natural capital. In this case, if natural capital is increased over the study period the sustainability score is positive and if natural capital decreases over the study period, the sustainability score is negative. As this SI does not consider whether conversions of natural capital increased human well-being it meets the Holland definition of absurdly strong sustainability, namely that natural capital ought not to be substituted for human capital even where possible (1997, see above). However, a significant detraction to this method is that, due to the possibility of negative SI_{AS} scores, measured SI_{AS} is no longer directly comparable to more traditionally used weak SI scores (e.g., Equation 3).

3.2. Strong sustainability

Strong sustainability is intrinsically more difficult to calculate than either of the aforementioned schools of thought because it limits substitutability between the three TBL components only below acceptable levels that must be defined by the developer of the SI. In other words, a system can become more sustainable as long as it lives within the constraints of its environmental and social structures regardless of how the indicators themselves are substituted. Developing these thresholds could be done through careful study of thresholds within the socioeconomic system (see the discussion on the critical natural capital in Huang et al. 2015) or in the absence of such data, through more normative justifications.

As such, an index of strong sustainability must allow for some level of substitution while also providing reasonable limits to the growth of one form of capital at the expense of another.

An ideal solution to deal with the problem of substitutability explicitly would be to set minimum acceptable values (or threshold values) for each sub-SI for which the average SI could not exceed unless the sub-SI exceeded these minimums. For example, using Equation 3 as a template, assume a researcher determines the minimum acceptable values for the index considered are Environmental ≥ 0.5, Social ≥ 0.2, Economic ≥ 0.4 before determining that a real world study area has sub-SI scores of Environmental = 0.5, Social = 0.6, and Economic = 0.3. If Equation 3 were used directly the SI would equal and SI score of 0.47; however, since the Economic sub-SI is below the acceptable minimum determined by the researcher (in this case 0.3 compared to 0.4) the SI would be reduced to the critical sustainable threshold of 0.4. Thus, in this example, the SI could never exceed 0.5 unless Environmental ≥ 0.5, 0.2 unless Social ≥ 0.2, or 0.4 unless Economic ≥ 0.4.

The obvious challenge with this method is that the critical thresholds will be determined by what the sustainability scientist determines are acceptable values. Again, the most intellectually rigorous way to sidestep this would be the identification of non-linear, critical transition values for each sub-SI. This approach, termed the 'sustainability gap,' is based on quantifying critical natural capital, the natural capital that cannot easily be replaced by human-built capital (Ekins & Simon 1999; Ekins et al. 2003). A more normative, yet rigorous, approach is to look toward internationally accepted norms to determine minimum acceptable values. Using internationally agreed upon standards, such as the Millennium Development Goals (MA 2005), as a template could provide a pathway for such threshold identification. This process will be tedious and controversial, but is to some extent unavoidable when trying to measure a normative type of sustainability.

4. An example

To provide a concrete example of how these different conceptions of sustainability can impact the SI we present a contrived example of sustainability assessment of two counties (a.k.a. banners) in Inner Mongolia, China: Alashan Left Banner in the west and Arong Banner in the east. This analysis is not meant to be realistic, but rather to illustrate how substitutability assumptions can radically change measured sustainability. We therefore choose to use as few sub-SIs as possible, as a simple indicator framework makes the substitution between capital types more obvious.

4.1. Study system

The Inner Mongolia Plateau, located in the center of Asia and once headquarters of the Genghis Khan's Mongol Empire, is of global importance geopolitically and environmentally (Wu et al. 2015). Climate varies significantly across the plateau, from the relatively cold and mesic north to warm and arid south. Mean annual temperature varies from −2 °C to 6 °C, with a frost-free season of 70 to 160 days, while mean annual precipitation ranges from 450 mm in the east to about 40 mm in the west with a high inter- and intra-annual fluctuations. Elevation ranges between 700 and 1400 m.a.s.l., decreasing along south to north and west to east gradients. Typical topographies in this region are plains, tablelands, and hills with chernozem, chestnut, calcic, and brown (Wu et al. 2015). Alashan Left Banner is located within the desert region of the Alashan League, with a mean annual precipitation of 110 mm and mean annual temperature of 7.8 °C (Xie et al. 2015). Arong Banner is located in the Hulunbuir grassland region, which is relatively cooler and more mesic (Yang et al. 2013).

4.2. Methodology

Each component of the TBL was assessed through a sub-SI consisting of one or more freely available data sources from the years 2000 to 2010. The economic sub-SI was measured as per capita GDP in Chinese Yuan. As the social dimension of any system is not as simply measured, we chose to assess impact of both of life span and education. Therefore, the social sub-SI was measured as the arithmetic mean of yearly survivorship rates (1-death rate) and per capita student enrollment. These data were then averaged on a yearly basis to create social sub-SI. Finally, the environmental sub-SI was calculated as the NDVI of the banner. These results are shown in Table 1. Each sub-SI was then normalized on a 0–1 scale using the formula

$$\text{Sub} - \text{SI} = \left[\frac{X_i - X_{min}}{X_{max} - X_{min}}\right] \quad (5)$$

where X_i is the sub-SI score in a given year, X_{min} is the minimum observed valued of the sub-SI, and X_{max} is the maximum observed value of the sub-SI (Table 2).

These sub-SIs were then used to calculate weak, absurdly strong, and strong sustainability using Equations 3–5, respectively (Table 3). As no estimates of critical natural capital or other thresholds are available for this region, Strong sustainability was assessed

Table 1. Data used for the example of sustainability indicator calculation for two Banners of Inner Mongolia, China, from year 2000 to 2010.

Banner	Year	1-Death rate	Per capita gross student enrollment	Per capita GDP	NDVI
Alashan Left Banner	2000	0.996	0.144	10893	0.109
	2001	0.998	0.147	11735	0.104
	2002	0.998	0.152	14446	0.129
	2003	0.997	0.154	17576	0.131
	2004	0.994	0.153	24859	0.116
	2005	0.987	0.155	31967	0.112
	2006	0.997	0.156	43606	0.139
	2007	0.997	0.154	58459	0.121
	2008	0.996	0.149	98407	0.119
	2009	0.996	0.143	133782	0.119
	2010	0.997	0.142	169042	0.119
Arong Banner	2000	0.996	0.121	3314	0.836
	2001	0.997	0.158	3812	0.822
	2002	0.998	0.130	4523	0.849
	2003	0.998	0.131	3664	0.795
	2004	0.995	0.117	6671	0.758
	2005	0.997	0.106	8642	0.847
	2006	0.997	0.097	11155	0.839
	2007	0.997	0.091	13435	0.797
	2008	0.995	0.085	18731	0.833
	2009	0.995	0.080	22836	0.776
	2010	0.989	0.081	27268	0.819

Table 2. Final sustainability sub-indicator results. Results were calculated using raw data (Table 1), normalized on a 0–1 scale.

Banner	Year	Social	Economic	Environmental
Alashan Left Banner	2000	0.814	0.046	0.007
	2001	0.877	0.051	0.000
	2002	0.927	0.067	0.034
	2003	0.949	0.086	0.036
	2004	0.896	0.130	0.017
	2005	0.838	0.173	0.011
	2006	0.970	0.243	0.048
	2007	0.940	0.333	0.023
	2008	0.875	0.574	0.021
	2009	0.815	0.787	0.021
	2010	0.813	1.000	0.021
Arong Banner	2000	0.550	0.000	0.983
	2001	1.000	0.003	0.964
	2002	0.676	0.007	1.000
	2003	0.681	0.002	0.928
	2004	0.496	0.020	0.878
	2005	0.381	0.032	0.998
	2006	0.277	0.047	0.987
	2007	0.204	0.061	0.931
	2008	0.116	0.093	0.979
	2009	0.061	0.118	0.902
	2010	0.000	0.145	0.960

Table 3. The resulting sustainability indicators when calculated according to the tenets of weak, strong, or absurdly strong sustainability. Threshold values used for strong sustainability were social = 0.2, economic = 0.5, and environmental = 0.4.

Banner/County	Year	Weak	Absurdly Strong	Strong
Alashan Left Banner	2000	0.289		0.289
	2001	0.309	−0.007	0.309
	2002	0.343	0.034	0.343
	2003	0.357	0.002	0.357
	2004	0.348	−0.019	0.348
	2005	0.341	−0.006	0.341
	2006	0.420	0.036	0.400
	2007	0.432	−0.025	0.400
	2008	0.490	−0.002	0.400
	2009	0.541	0.000	0.400
	2010	0.611	0.000	0.400
Arong Banner	2000	0.511		0.500
	2001	0.656	−0.019	0.500
	2002	0.561	0.036	0.500
	2003	0.537	−0.072	0.500
	2004	0.465	−0.051	0.465
	2005	0.470	0.120	0.470
	2006	0.437	−0.011	0.437
	2007	0.399	−0.057	0.399
	2008	0.396	0.048	0.200
	2009	0.360	−0.077	0.200
	2010	0.368	0.058	0.200

using the minimum values social = 0.2, economic = 0.5, environmental = 0.4. These values, which were arbitrarily selected, are not meant to be actual estimates of threshold levels, but rather are used as a proof of concept for this example.

Data for both economic and social sub-SIs were gathered from the 2011 Inner Mongolia Statistical Yearbook. NDVI was assessed using MODIS data.

4.3. Example results and conclusions

In both these cases, the substitution of environmental capital to other capitals was minimal. However, despite this similarity, the underlying conception of sustainability used in SI formation caused measured sustainability to vary radically (Figure 2b). Not surprisingly, the relationships between weak, strong, and absurdly strong sustainability were largely determined by the relative amounts of natural capital in each system. Beginning with absurdly strong sustainability, Arong Banner showed significantly more variation in measured sustainability relative to Alashan Left Banner (Figure 2b). This is largely due to the fact that Arong Banner is located in the more mesic east, and thus, in this indicator framework, simply had more natural capital to lose than the drier Alashan Left Banner.

More interesting is the relationship between weak and strong sustainability in both these banners. Using the critical natural capital approach described here, measured weak and strong sustainability are equal unless the system is below a minimum level for any sub-SI. Using arbitrary minimum sub-SI values social = 0.2, economic = 0.5, and environmental = 0.4, Alashan Left Banner is environmentally limited from the years 2006 to 2010, while Arong Banner is economically limited from the years 2000 to 2003 and socially limited from 2008 to 2010 (Table 3). In the case of Alashan Left Banner, extremely strong economic growth, coupled with stable environmental and social conditions, allowed measured weak sustainability to readily outperform strong sustainability by the end of the study period (Figure 2b). However, because Alashan Left Banner is located in a drier area, measured environmental capital was low. Therefore, despite the fact that very little (if any) natural capital was substituted for human-built capital in this Banner, measured strong sustainability diverges from measured weak sustainability from the year 2006 on (Figure 2b). The circumstances in Arong Banner were essentially the opposite. Due to its strong environmental, but weak social and economic, sub-SI scores, strong sustainability was limited separately by social and economic sub-SI scores during the study period (Figure 2b). These results highlight the fact that strong sustainability is not wholly dependent on natural capital: through its insistence on allowing some, but not complete, substitution, strong sustainability is equally susceptible to losses in all forms of capital.

These results are not meant to suggest that one type of measured sustainability is better than any other, but rather simply to point out that the type of sustainability being measured can radically change the measured sustainability of any given study system. In these two particular cases there was relatively little substitution from environmental to other forms of capital. If that had not been the case, given the mathematical forms in play, it is reasonable to assume that the differences between measured sustainability types would be even larger. Therefore, if, as the most sustainability researchers assert, we wish to adhere to some form of strong sustainability it is critical that strong sustainability is actually measured.

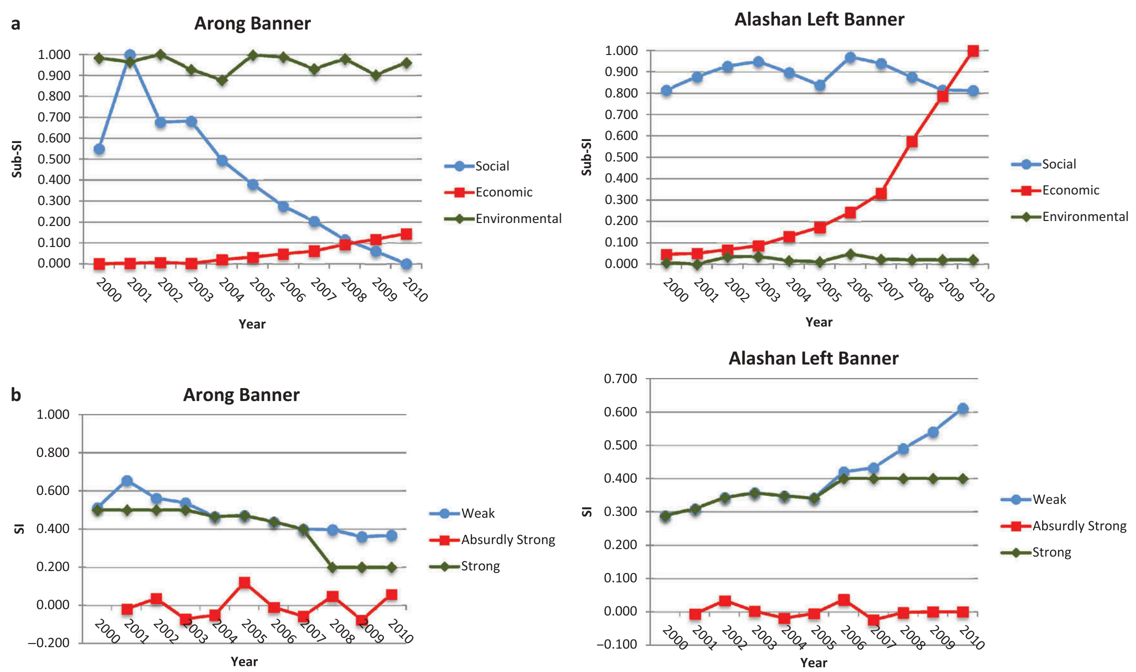

Figure 2. Graphical depiction of measured sustainability using methods that conform to weak, strong, and absurdly strong sustainability. Figure 2a shows environmental, social, and economic sub-indicator performance over the study period for both banners. Figure 2b shows how different conceptions of sustainability impact the substitutability of different forms of capital over time.

5. Discussion

Fifteen years later, the work of Donella Meadows seems almost presentient. It is clearly true that the mathematical forms of our SI unmask our underlying assumptions. As values vary greatly across Sustainability Science it is impossible that any one indicator can measure every type of sustainability. Here we have shown that the mathematical form of SIs determines which type of sustainability is actually measured. However, despite the overwhelming popularity of strong and absurdly strong sustainability, the stereotypical equally weighted approach taken in SI formation does not adequately measure the diversity of sustainability. To address this problem we suggested two alternative forms, one for each absurdly strong and strong sustainability, both of which remained easy to calculate but better integrated the values they purport to represent. Further, as shown through our example, the impact of these slight changes in SI form on measured sustainability is significant.

For adherents of weak sustainability, these results should come as no surprise. However, it is critical that scientists who wish to measure strong sustainability recognize that the current, equally weighted methods, which make no attempt to deal with the interconnections of the environmental, social, and economic structures are, on the most fundamental level, not measuring any type of strong sustainability. To measure absurdly strong sustainability, all environmental substitution must be eliminated. As strong sustainability is based on acceptable amounts of substitution, strong SIs will have components that approximate these levels. However, ignoring the connection between the mathematical forms of SI and the values they represent does not make it disappear; rather, the SIs we use today could reinforce the values we have tomorrow. As the indicator forms we presented here require no additional data to compute, a simple solution to these problems is to compute all three forms of sustainability so that the measured sustainability can be understood in all three contexts. At the very least, sustainability researchers must be clear about what type of sustainability their results describe when disseminating results.

More broadly, it is critical that the ecological community actively engages in this type of work. To reiterate: sustainability is the challenge of our time. Though Sustainability Science draws on the knowledge of ecologists, social scientists, and economists, ecological principles have proven critical in the formation of Sustainability Science. Given that weak sustainability is not sustainable over the very long term, ecological knowledge must be the fundamental backbone to Sustainability Science. However, the involvement of ecologists in this field should not be in limited simply to environmental assessments and management. Rather, it is critical that ecological principles be utilized in every level of this transdisciplinary field. Given the vast knowledge on the topic in this journal and others, the improvement of sustainability indicators seems a perfect place to start.

Acknowledgments

MW was supported in part by a grant from the National Science Foundation, grant number #1342754 during the writing of this manuscript. The authors wish to thank Qing Zhang and Runbing Yu for the assistance in data collection for section 4.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Directorate for Biological Sciences [1342754].

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