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Nitrogen Sustainability: Impediments to Action and Communication

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ABSTRACT: "Sustainability" is widely used to imply the presence of explicit consideration of environmentally friendly needs and that high societal-value is placed on those needs. However, it is abundantly clear after 30 years that talking about sustainability and achieving it are two entirely different things. The core concept underlying sustainability is that current human practices and activities be conducted so as to not degrade prospects for future generations. With nitrogen, conflicts about sustainability in-theory and sustainability in-practice are close to the surface because of nitrogen's central role in food production and economic activity. Measures of nitrogen inputs commonly range as high as 10x the ability of ecosystems to process them: there can be little room for discussing sustainability when waters and floodplains are saturated with 1000% greater loads of nitrogen than they are adapted to handle. The desire to appear reasonable and reduce discussions about nitrogen to its effects where problems become visible has had the insidious effect of enabling on-going high depositions and loads elsewhere in watersheds. How far are we from sustainability in fact? If we believe we know the outcome of our efforts to move toward a sustainable future we are not understanding how far the culture has to move to achieve it: we are only thinking about marginal change to existing systems and not actual needs and provisioning a real future for our descendants.

KEYWORDS: Nitrogen, Sustainability, Sustainababble, Ecosystem, Overshoot, Language

INTRODUCTION

Sustainability is the core term of a large collection of related expressions used to imply the presence of explicit consideration of environmentally friendly (i.e., green) needs (Engelman 2013) with an accompanying, strongly-implied, suggestion that high societal-value is placed on those needs. Now, 30 years after the Brundtland Report (World Commission on Environment and Development 1987) it ought to be evident that talking about sustainability and achieving it are two entirely different things: however this evidence appears to not be accepted. In part, this is because sustainability is an ambiguous term, both requiring and resisting further definition. What are we trying to sustain? It has even been said that the outcome of a cultural turn toward sustainability is *"impossible"* to know (Meadows 2004; 269) such would be the magnitude of the change. Something that is *"impossible"* to know is also hard to define. Suggesting that something is *"impossible"* to know can also be used as an effective foil to rationalize inaction. Such a turn of events, paralysis by defini-

tion, is not what Meadows et al., (2004) and others intended but it is the path we have been on for many years (Catton, Jr. 1980; Steffen et al. 2015).

Sustainability became mainstream in the 1987 Brundtland Report (World Commission on Environment and Development 1987);

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

By way of comparison, Meadows et al. (2004; 254) says;

"... a sustainable society is one that can persist over generations; one that is farseeing enough, flexible enough, and wise enough not undermine either its physical or its social systems ...."

USEPA's definition is essentially very similar;

"Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.

Sustainability is important to making sure that we have and will continue to have, the water, materials, and resources to protect human health and our environment."

(http://www.epa.gov/sustainability/basicinfo.htm#sustainability)

It is an easy observation to note that each of the definitions above, offered with the best intentions, is loaded with ambiguous and imprecise terms that mean different things to each reader. For instance; *"development", "needs", "compromising", "future generations", "farseeing", "flexible", "wise", "undermine", "everything", "survival", "well-being", "natural", "productive harmony", "fulfilling",* and *"requirements."* These ambiguities lead to "sustainababble" (Engelman 2013).

When Meadows et al. (2004) discuss sustainability they are talking about sustainability of the entire human project across the entire planet, but in many/most individual cases, when people think about sustainability it is in accordance with their own experience at local sites (e.g., a sustainable farm, a net-zero energy building, a local transit system). The need is global but most applications are very local and site specific. This dichotomy of need further contributes to miscommunication.

FOR EXAMPLE; NITROGEN

In ecosystems, nitrogen seldom acts alone (Davidson et al. 2014) but is one limiting factor of concern among many routinely identified in the context of sustainability (Paerl 2009; Lewis, Jr. 2011; Folke 2013; Steffen et al. 2015). Concern about nitrogen sustainability doesn't actually involve sustaining nitrogen *per se*. Nitrogen sustainability refers to a collective interest and perceived need to enable the creation and use of bioavailable nitrogenous compounds for the purposes of food and energy production, while also avoiding deleterious effects to multiple components of ecosystems, especially aquatic ecosystems (wetlands, surface waters, stream and rivers, estuaries,), ground water, ecosystem services, and climate change (e.g., Altieri and Gedan 2015).

A threshold question posed by Daly (1990) is; what type of resource is nitrogen? Is it renewable, non-

renewable, or a pollutant? *"Any activity that causes a renewable resource stock to fall, or a pollution sink to rise, or a nonrenewable resource stock to fall without a renewable replacement in sight, cannot be sustained"* (Meadows et al. 2004; 55). Use of bioavailable nitrogen is dependent upon mined non-renewable resources, occurring far in excess of ecosystems' abilities to render inputs innocuous to waters and food webs (Steffen et al. 2015). Therefore, the uses of nitrogen currently enjoyed are fundamentally un-sustainable and they are un-sustainable in a virtual parallel relationship with fossil fuels (e.g., Zencey 2013; Jones and Warner 2016).

Still, industrial transformation of unavailable into bioavailable nitrogen to make fertilizer is needed to support on-going agricultural practices. Therefore, soil productivity and agricultural production are vital interrelated topics (Montgomery 2007). Any interruption or shortfall in these processes will cause drastic cultural, social, and economic change that will clearly affect perceptions of sustainability.

MEASURES, INDICATORS, AND INTERVENTIONS

If sustainable is quantified as deviation from historic natural or background conditions, then in the United States, roughly 10 times as much bioavailable nitrogen is used as is sustainable (USEPA 2011). We depend upon creation of 10x bioavailable nitrogen on an on-going basis to 1) maintain our current economic and social condition and 2) we are depending upon ecosystems to absorb and cycle 10x bioavailable nitrogen without deleterious effects. Neither of these potentials can be sustained.

In many cases, there is continuous exposure to high loads of excess nitrogen (National Research Council 2000; Howarth et al. 2000, 2002; Steffen et al. 2015). It is estimated that perhaps 30% of the available nitrogen that is introduced each year ends up in coastal waters and estuaries (Howarth et al. 2002). Continuing use of bioavailable nitrogen in the manner we're accustomed to will continue to stress multiple systems that are already impaired, perhaps beyond tipping points (Steffen et al., 2015); even permanently destroying their productive capacity in timeframes meaningful to people and posing existential risks (Rockstrom et al. 2009a,b; Baum and Handoh 2014).

Even comparatively low amounts of excess nitrogen are known to change ecosystems. Pardo (2011) estimated critical loads consistent with actual atmospheric deposition levels across much of the eastern United States (Weathers and Lynch 2011). Such deposition has been on-going ever since measurements were initiated decades ago. Forests in the NE United States evidence nitrogen saturation (Aber et al. 2003). Old field sites in the western portion of this area (Oklahoma) are sensitive to even small additional exposures to available nitrogen (Jorgensen et al., 2005). Biota and ecosystem function are changed and available nitrogen begins to leak out of the system as exposures are increased even slightly. Therefore, by the most conservative criteria, ecosystems in the eastern United States are exposed to more than sustainable levels of available nitrogen by atmospheric deposition alone (e.g., Porter et al. 2001, 2005; Jorgensen et al. 2005; Lovett et al. 2009; Pardo et al. 2011).

Deleterious impacts from nitrogen cause or are closely associated with other ecosystem-degrading effects. Erosion, lost soil fertility, run-off and transport, impervious surfaces, altered temperature regimes in watercourses, changed food webs, species displacement, and invasive species are all observed in conjunction with excess bioavailable nitrogen (Montgomery 2007; Steffen et al. 2015).

For several decades, the focus of nitrogen management has been to reduce the inputs and mitigate the effects of bioavailable nitrogen on landscapes/ecosystems. The literature is densely populated with these works (Bernhardt and Palmer 2007). However, in practice the many successes that have been achieved with input management and effect mitigation have not been used to maintain ecosystem health but instead have been used been used to enable continued application of bioavailable nitrogen to landscapes/ecosystems vastly in excess of the ability of landscapes/ecosystems to sustainably absorb and process the inputs.

We know clearly that the scale of bioavailable nitrogen effects and the scale of our management interventions is significantly mis-matched (Conley et al. 2009). Nitrogen processing is highly variable both temporally and spatially and much work has been conducted in identifying and characterizing the extent and reach of this variability (Boyer et al. 2006). Recognition of this variability has caused researchers to narrow their questions to (seemingly) more tractable scales (e.g., Helton et al. 2011) and produced a plethora of investigations detailing nitrogen processing within riparian/floodplain soils and structures over time (Galloway et al. 2003; Samaritani et al. 2003; Steiger and Gurnell 2003; Helton 2011; Weibel 2011; Welti et al. 2012). Considering the increasing level of effort and attention devoted to nitrogen use and management of its effects (Bernhardt et al. 2005), one could reasonably think that there has been great success at reducing and eliminating nitrogen's deleterious effects. Of course, this is not the case: water quality and the ecosystem goods and services attached thereto are in decline (Rockstrom et al. 2009a,b; Bernhardt and Palmer 2011; Caballero-Alfonso et al. 2015). This is true in stream reaches (Roni et al. 2008; Palmer et al. 2010): problems are increasing exponentially in estuaries (Diaz and Rosenberg 2008; Gooday et al. 2009; Rabalais et al. 2010; Altieri and Gedan 2015) and are observed in oceans (Diaz and Rosenberg 2008; Altieri and Gedan 2015; Karstensen et al. 2015). Problems associated with nitrogen are increasing, not decreasing.

Worse, under many scenarios nitrogen use is projected to increase further, making a difficult problem even less tractable (Tilman et al. 2001; Fixen and West 2002). What does "sustainable" mean when we've long been demonstrably damaging ecosystems with current loads and are seemingly planning to do more of the same (e.g., Barnosky et al. 2012)? Is asking that question even allowed?

For emphasis, the foregoing is not meant to downplay localized cases of success over short time frames, but rather is meant to cast the brightest light on the fact of on-going and expanding degradation over wide areas and the failure of such a strategy to approach sustainability.

Purposefully (even needfully) limiting the temporal and spatial scope of riparian research and management has unintentionally led to an effort to deliver prescriptions for sustainability that cannot meet the spatial and temporal scales of the problem (Allen and Hoekstra 1993; Bernhardt and Palmer 2011). The seemingly tractable view that easily scaling-up stream reach scaled data fails before the real spatial and temporal complexity encountered on the ground and strong external pressures to declare success (Jahnig et al. 2011).

The understandable tendency to seek to tackle "doable" problems and projects leads to an insidious outcome that is widely observed in a multitude of human endeavors; even with seeming success at some spatial and temporal scales, overall resource degradation continues unabated (Montgomery 2003, 2007). Helton et al. (2011; 237) recognized the trend

for watersheds to be pushed *"toward unprecedented states."* We avert our eyes from the real problem (and therefore the real solution) and convince ourselves through on-going action that things are better, when the long view of decades tells us otherwise;

"Clearly, more of the same won't work. Projecting past practices into the future offers a recipe for failure." (Montgomery 2007; 240)

Nitrogen sustainability goes far beyond riparian reach/hydrogeomorphology interventions (important though these are in their own right and for their own purposes). However one chooses to frame the important work being done in stream reaches, rivers, and estuaries, sustainability is no closer.

WHAT THEN SHALL WE DO?

At this point it is expected practice to offer a series of prescriptions to fix the shortcomings identified earlier. This is a tall order. It is posturing to presume to present durable actionable-solutions to a predicament that has existed and increased for decades in a single contribution (e.g., Catton, Jr. 1980). Action must ultimately be expressed in the physical world, but it starts with acceptance of different thinking, evidenced in language. In this there is deficiency.

More of the same (attempted management of inputs, landscapes, and ecosystems to mitigate the effects of the nitrogen loadings we've become accustomed to) will not lead to sustainability. In recent months, similar views, that doing more of the same is only leading to ruin, are rising to the surface in the closely related areas of energy and climate (Anderson 2015). Anderson urges that the problem at hand is not the science itself but the practice of science;

"... we simply have not been prepared to accept the revolutionary implications of our own findings, and ... are reluctant to voice such thoughts openly."

"... many are ultimately choosing to censor their own research."

"It is not our job to be politically expedient with our analysis or to curry favor with our funders."

So it is also when we strain to call "sustainable" a level of resource use for bioavailable nitrogen that is vastly in excess of the ability of ecosystems to absorb and process without impairment. After so many decades, what plurality of practitioners actually believes that more extensive and detailed mitigations will, in fact, lead to sustainability? Is there ever a point where it can be said we are just fooling ourselves?

I find myself thinking a great deal about the limits of that research in solving real-world problems ... it has become increasingly obvious to me that policy and management decisions are about much more than science (Palmer 2012).

Language is the start. Sustainability has been co-opted for the purposes of green-washing. When environmental professionals use the term today they run the risk of appearing co-opted too. The environmental, economic, social, and cultural interactions associated with nitrogen cycling are such that the risk in communication lies with oversimplification. If knowledgeable professionals can't be counted on to face complex issues without reducing them to slogans and buzzwords, then how can non-specialist citizens be expected to be more discerning?

More attention needs to be paid to the tendency to use sustainability as a euphemistic reference. The meaning intended 30 years ago has been lost in today's conversation. There needs to be a broad public discussion about what it is exactly that we are

trying to sustain. Without such discussion and an ultimate policy with wide buy-in, we will continue blindly along the path we're on, not knowing where it leads, until consequences are asserted (Catton, Jr. 2009; White 2015).

Recognition of the nitrogen problem and refinement of its parameters over the last several decades has not led to sustainability. In 1973 the USEPA SAB recognized the potential for nitrogen saturation and cascades; stating *"at present, all known trends appear to be ones that can be managed and kept within control, if appropriate steps are taken now"* (USEPA 1973). Clearly, despite recognition of the advancing risk, "appropriate steps" were not taken. Now we search to find a few linchpin points that will allow sustainability to blossom. We know better. It took decades to arrive at our current condition, retracing our steps to something more akin to sustainability will be a journey.

"It is as impossible now for anyone to describe the world that could evolve from a sustainability revolution as it would have been for the farmers of 6000 BC to foresee the corn and soybean fields of modern Iowa, or for an English coal miner of AD 1800 to imagine a Toyota assembly line" (Meadows et al. 2004; 269).

If we believe we know the outcome of true efforts to move toward a sustainable future we are not understanding how far the culture has to move to achieve it. But move we will, by choice or by circumstance. We should choose now.

There is a wide audience outside the scientific mainstream who believe they have valuable insights and practices to contribute (e.g., Salatin 2011). The room to have these discussions needs to be enlarged.

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