Institutional policies and stakeholder engagement: Comparing top-down and bottom-up approaches of environmental indicators for decision-making

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Abstract

Indicators are used to measure or assess the trend, status, or performance of a given system. In our everyday lives, we come across indicators whether or not we have defined them as so. For example, gross domestic product, or GDP, is an indicator used to assess the health of a country's economy. Indicators are also useful for succinct messaging to help inform decision-making. In this paper, a framework is developed to analyze how environmental indicators come to fruition, such as through government agencies or broad stakeholder involvement. Case studies involving climate change indicators and rangeland health indicators are used to demonstrate the production of such indicator systems along a top-down to bottom-up gradient of approach. Use of only a top-down approach may lack a decision-relevant component, while a bottom-up strategy may not necessarily support institutional policies or programmatic structures. Combining both approaches provides clear structure and objectives on the indicator system, while also identifying knowledge gaps, building stakeholder networks, and engaging with those decision-makers who may actually use such information.

Introduction[1]

Since the Industrial Revolution humans have conducted a global scale experiment never before experienced by the planet Earth (Revelle and Suess, 1957). Given the amount of carbon dioxide that has been pumped into our atmosphere over the past two centuries, changes in our climate have been observed through shifts in temperature and precipitation (IPCC, 2013). More recently we have come to learn how climate change affects the world's diverse ecosystems (Walther et al., 2002; Weltzin et al., 2003). Thus, understanding the complex interactions of coupled human and natural systems, including water, carbon, and nitrogen dynamics, represents a grand challenge in environmental science research (Liu et al., 2007; NRC, 2007). Measuring, modeling, and monitoring the Earth's changing landscape can give us insight into unintentional and unforeseen impacts of human activity.

Rangelands provide an ideal opportunity to investigate the interactions among global climate drivers, human management (e.g. grazing), and ecosystem processes. Comprising at least a third of the United States' land cover, rangelands support forage production for livestock grazing. These areas help meet the growing demand for meat and other protein products, as well as contribute to the economy (Reeves and Mitchell, 2012). In addition to agricultural production, rangelands provide other ecosystem goods and services such as soil carbon storage, biodiversity, and open space for recreation (Maczko and Hidinger, 2008; White et al., 2000). While these areas can provide many biological and societal benefits, rangelands are extremely vulnerable to changes in climate and human activities (Brown and Thorpe, 2008). A better understanding of

[1] Note to reader: This most recent draft discusses the characteristics of environmental systems that lead to top-down and bottom-up approaches using a policy implementation framework. It does not include discussion on how to incorporate both approaches in an environmental indicator system. The case study that will be used to demonstrate the effective use of both top-down and bottom-up approach is the National Climate Indicator System developed through the U.S. Global Change Research Program, which produced the National Climate Assessment in May 2014.

these coupled interactions in rangelands is needed so that they can be properly managed and sustained for future generations (Bestelmeyer and Briske, 2012; Brown and Thorpe, 2008).

But what metrics are most appropriate in measuring the ecological, economic, and societal impacts due to climatic changes? And what is the most effective means to communicate such knowledge to diverse audiences? As a means to communicate a complex reality using simple, yet informative relationships and variables, indicators can provide information related to the status, trends, vulnerabilities, and/or impacts of a particular system (Smeets and Weterings, 1999). For example, the gross domestic product and unemployment rate act as indicators painting a broad picture of the current state of the economy. Our body temperature can act as an indicator of our health; temperatures above the average 98.6 degrees Fahrenheit may suggest fever and/or an accompanying illness.

Indicators are therefore often used to describe complex environmental problems using key variables of interest. When coupled with decisions on policy, indicators can serve three purposes: (1) information on the environmental problem, (2) support of policies, and (3) system monitoring as a response to the policy (Smeets and Weterings, 1999). Regarding global climate change, indicators can be effectively used to translate this dispersed (spatially and temporally) and wide-reaching problem (Gardiner, 2013; Smeets and Weterings, 1999). Various indicators can provide representative information on rangeland health which can be used by land and resource managers for both local and regional decision-making. As such, there exist numerous indicator systems for both tracking climate change and also measuring rangeland health. Climate change indicators are available through a variety of U.S. government agencies, such as the Environmental Protection Agency (EPA), National Aeronautics and Space Administration

(NASA), and National Oceanic and Atmospheric Administration (NOAA).[2] Organizations outside the United States have also adopted programs to develop and implement indicators for climate change.[3] Indicators for monitoring rangeland health have been developed by federal agencies, such as the U.S. Bureau of Land Management, and through stakeholder groups like the Sustainable Rangelands Roundtable.[4] These different indicator systems can be used to analyze trends over time which can, in turn, be used to increase our scientific knowledge of the problem, guide us toward the development of more tools (e.g. models), provide relevant information to decision-makers for policy-making, and grow public awareness of these important issues.

The overarching objective of this work is to better understand approaches to environmental indicator systems within the context of a policy implementation framework. The Mazmanian and Sabatier (1983) framework is extended to different environmental indicator systems related to global climate change and rangeland health. The general tractability of the environmental problem, implementation structure, and stakeholder involvement are described for these indicator systems. By applying biophysical and socio-economic aspects of each environmental system to the policy framework, a top-down and bottom-up approach to indicator development is constructed. In this new context, certain environmental indicators come to fruition through institutional policies (i.e. top-down) or stakeholder-driven processes (i.e.

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[2] For more information regarding climate change indicators at U.S. federal agencies, please visit the following websites:
EPA Climate Change Indicators (http://www.epa.gov/climatechange/science/indicators/)
NASA Global Climate Change (http://climate.nasa.gov/)
NOAA Global Climate Change Indicators (http://www.ncdc.noaa.gov/indicators/)

[3] For international organizations hosting climate change indicator systems, see:
European Environmental Agency (http://www.eea.europa.eu/themes/climate/indicators);
International Geosphere-Biosphere Program Climate Change Index (http://www.igbp.net/globalchange/climatechangeindex)
World Bank Climate Change Knowledge Portal (http://sdwebx.worldbank.org/climateportal/index.cfm)

[4] For more information on rangeland health indicators, see:
U.S. Bureau of Land Management Tech. Ref. 1734-6: Interpreting Indicators of Rangeland Health;
Mitchell, J.E. (ed). 2010. Criteria and indicators of sustainable rangeland management. (http://sustainablerangelands.org/pdf/SM56.pdf)
National Research Council. 1994. (http://www.nap.edu/openbook.php?record_id=2212&page=97)

bottom-up) depending on the complexity, ubiquity, and tractability of the problem. Additionally, this top-down and bottom-up approach is discussed through other lenses, such as Levins' (1966) work on scientific modeling. This paper improves our understanding of how environmental indicators are developed and used within the scientific and decision-making communities.

Background

In its broadest sense, implementation can be thought of as governmental actions and processes after a policy decision has been made and before a policy outcome or goal has been achieved (Smith and Larimer, 2009, 157). Implementation can involve the "carrying out of a basic policy decision" through a statute via the legislative process, an executive order, and/or a court decision (Mazmanian and Sabatier, 1983, 20). Executive branch agencies typically "translate" what the legislative or judicial branches have decided and then determine how to accomplish it (Smith and Larimer, 2009).

Mazmanian and Sabatier (1983) developed the notion of "perspective", meaning implementation can be viewed differently by groups, organizations, or levels of government (12). There are three types of perspectives: (1) the *center*, the initial policymaker, (2) the *periphery*, actual field-level officials doing the implementing, and (3) the *target group*, actors whom the policy is directed towards (Mazmanian and Sabatier, 1983, 12). From the center, implementation is a top-down approach involving the formulation of the policy, translation by agencies, and enforcement by officials (Smith and Larimer, 2009, 164). From the periphery, implementation refers to how lower-level officials and institutions respond and adapt to decisions made from higher-level and authoritative entities or agencies (Smith and Larimer,

2009, 164). The target group may see implementation as to how policy affects citizens' daily lives (Smith and Larimer, 2009, 164).

Using this language, one can argue a top-down or bottom-up approach to implementation based on their perspective. A top-down approach to implementation may focus on translating formal policy objectives through a bureaucracy down to the target audience (Smith and Larimer, 2009). Also known as forward mapping, a top-down implementation typically consists of a statement or intent from Congress, delineation of agency regulations and administrative actions, assignment of responsibilities to regional or local offices, focus on a particular target group, and defined outcome based on the initial language from the policymakers (Elmore, 1979). On the other hand, bottom-up implementation, or backward mapping, starts the policy implementation analysis with those actors closest to the problem or issue (Elmore, 1979; Sabatier, 1986). Referred to as "bottom-uppers", they believe that there are not actual policy stages (i.e. formation, implementation, evaluation), but rather individuals and organizations in pursuance of objectives that may or may not address a particular mandate from a central or higher authority (Sabatier, 1986). A bottom-up approach considers the "specific behavior at the lowest level of the implementation process that generates the need for a policy" (Elmore, 1979, 604). Essentially, top-downers may be more focused on outcomes, while bottom-uppers may be interested in the target group's behavior and choices (Smith and Larimer, 2009).

The dichotomy in policy implementation analysis has been studied greatly and each group has characteristics that define it from the others. Top-downers may be interested in "finding consistent, recognizable patterns in behavior across different policy areas" (Matland, 1995, 147). Additionally, many have found top-down approaches to be simply an administrative process and focusing on hierarchical aspects (Elmore, 1979; Matland, 1995). They are interested

in the effectiveness of programs and their actual implementation by agencies (Sabatier, 1986). Bottom-uppers see implementation through the eyes of the target audience. However, they may be preoccupied with actors' strategies and networks and their relation to the policy problem instead of the policy decision (Sabatier, 1986). It is interesting to note that top-downers may put too much focus on the center perspective and bottom-uppers on the periphery or target group (Sabatier, 1986). The purpose of each implementation school of thought is different; however, and serves different purposes. In essence, the "debate" between top-downers and bottom-uppers may be seen as different ways of looking at the implementation process, referring to the notion of perspectives (Smith and Larimer, 2009).

Mazmanian and Sabatier (1983) developed a framework to systematically analyze the policy implementation process[5]. Their implementation framework, henceforth referred to as MSIF, identifies variables which contribute to achieving the goals, objectives, or outcomes of the policy at hand. The MSIF is considered a top-down approach because of its perspective from the initial policymaker and almost linear explanation from policy to outcome (Elmore, 1979; Smith and Larimer, 2009). These independent variables are divided into three broad categories: (1) tractability of the problem being addressed, (2) ability to effectively structure the implementation process, and (3) effects of exogenous agents acting on the implementation process (Mazmanian and Sabatier, 1983, 21). The three categories of the MSIF describe the general issues surrounding the implementation problem, including both endogenous issues to the process itself (i.e. structural, within agency, etc), and the exogenous variables affecting the implementation (i.e. political and societal issues). The first category, the tractability of the problem, refers to the

[5] The policy implementation framework proposed by Mazmanian and Sabatier is actually considered a top-down approach (Smith and Larimer, 2001). While it is "top-down" in its approach to policy implementation, the framework itself may be useful in gleaning new knowledge for environmental indicator systems.

technical understanding of the problem, the behavior to be affected, the diversity of the target group, and the target group's relative proportion to the entire population. The second category, the effective structure of the implementation process, describes the internal ability of the agency to implement the policy – their financial resources, relationships with non-agency actors (i.e. stakeholders), and clarification of the policy objectives (Mazmanian and Sabatier, 1983). The third set of variables in the MSIF describes the exogenous factors affecting the implementation process. New and available technology, socio-economic conditions, public support, and historical events (i.e. antecedent conditions) also affect how successful agencies and/organizations are in implementing a policy (Mazmanian and Sabatier, 1983).

Application

Here, the MSIF is applied to environmental systems and relevant indicators used to describe, monitor, or address an environmental problem or issue (Figure 1). Variables within the MSIF are "converted" to represent those in environmental systems and address two specific examples: global climate change and rangeland health (Table 1). While the MSIF is focused on the implementation of a policy program, this paper focuses on the implementation of an environmental indicator system. As such, some of the original variables were combined with others and/or excluded from this new application.

The original MSIF organizes variables into three categories; this structure is also maintained for this environmental extension. The first category, "tractability of the problem", refers more to the actual science behind the indicator system, as well as impacts. For example, "technical difficulties" addresses the scientific understanding of the particular environmental issue. These technical issues translate to the scientific complexity of the environmental problem,

perception of the issue by the public and media, and tangible nature of the problem and impacts. Global climate change is a complex issue, but attention is usually focused around the "scientific dispute." Similarly, rangeland health could is also a complex issue; however, the focus is on impact. The inherent difference in scale (global vs. regional/local) creates more tangible and tractable impacts on rangelands to the concerned citizen and/or stakeholder.

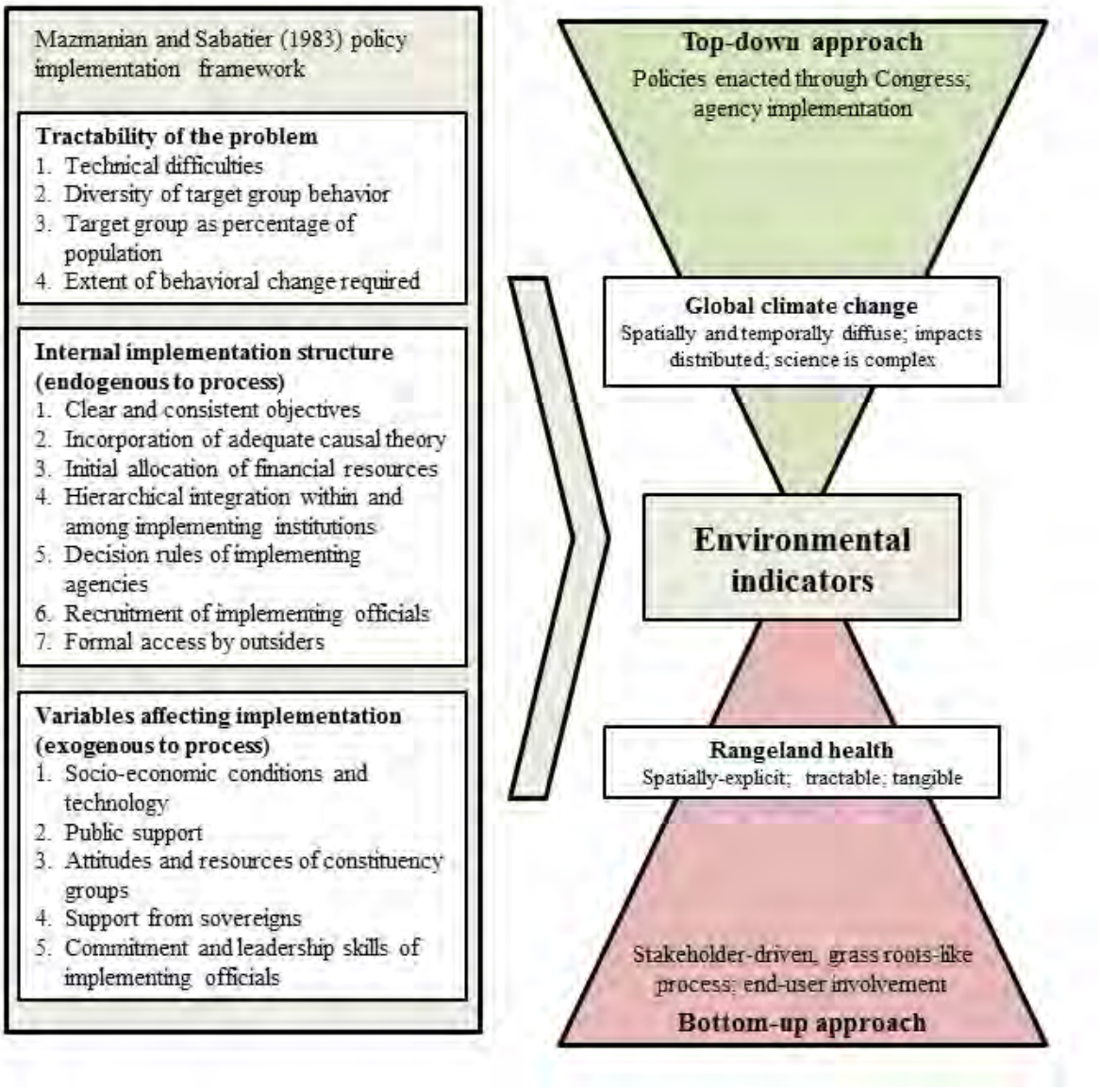

Figure 1. Application of the Mazmanian and Sabatier (1983) implementation framework to environmental indicators.

Table 1. Application of the implementation framework from Mazmanian and Sabatier (1983) to environmental indicators. Two examples are included in this analysis: global climate change and rangeland health.

Original MSIF variables	Application of MSIF to environmental indicators	Global climate change	Rangeland health
Tractability of the [environmental] problem			
Technical difficulties	Understanding of the scientific causal linkages	Complex, includes both direct and indirect linkages Focus on biophysical processes, sometimes disputed	Complex, mechanistic understanding of linkages not necessarily considered Focus on impacts
Diversity of proscribed behavior Extent of behavioral change required	Diversity and extent of impacts	Spatially and temporally dispersed; global to local with short-term and long-term effects	Impacts are confined to specific terrestrial ecosystem – rangelands and/or individual ranch
Target group as a percentage of population	Target group affected	Global population	Ranchers, land managers, rural communities, regional areas
Internal implementation structure: Indicator system structure [endogenous to process]			
Clear and consistent objectives Incorporation of adequate causal theory	Goals of the indicator system	Understanding and predicting	Understanding and managing (controlling/changing)
Initial allocation of financial resources	Financial resources	Continuous; agency programmatic funds	Start-up through workshop, working group; non-governmental and independent organization
Hierarchical integration within and among implementing institutions Decision rules of implementing agencies	Coordination among federal agencies and relevant groups	Final product is housed within agency; process can involve multi-agency collaboration	Final product is produced through independent organization; process involves multiple governmental levels and stakeholder groups
Recruitment of implementing officials	Commitment level	Multi-agency/working group commitment at federal level	Multi-stakeholder commitment with diverse organizations at all levels (local, state, federal, tribal)
Formal access by outsiders	Outside influence	Low; typically interagency collaboration of federal scientists with some academic/research outreach	High; diverse organizations are represented to bring relevant expertise and experience to project
External/outside variables affecting implementation [influencing indicator system]			
Socio-economic conditions Public support	Public, media, and political attention	High	Low
Attitudes and resources of constituency groups	Non-federal, stakeholder resources	High	High
Support from sovereigns	Bureaucratic oversight	High	Low

The second category of the MSIF focuses on the internal nature of the implementation process including variables related to the infrastructure and effectiveness of the agency or organization to do the actual implementing. Applying this to environmental indicators, the category is similar, but covers the organizational structure in charge of developing and implementing the indicators. In any case, both the original variables and applied environmental science variables share a similar theme of factors endogenous to the process, whether that is a policy implementation or environmental indicator system. For example, "clear and consistent objectives" from the MSIF can also be applied as the general goals or objectives of the indicator system.

The last category of the MSIF when applied to environmental systems refers to the external or exogenous variables influencing implementation of the indicator systems. For example, public support and socio-economic conditions refer to how much attention is given to each particular issue. While the original framework focused more on constituency groups and implementing officials, the application to environmental systems addresses those actors outside the federal government and/or the indicator implementation structure.

Discussion

Global climate change and rangeland health are not mutually exclusive environmental issues. However, unique characteristics of each environmental issue provide insight into how indicators are developed differently (Table 2). Applying the MSIF to these environmental concerns suggests the following: large-scale, diffuse, and fairly complex scientific problems require top-down indicator systems, while are more tractable, spatially explicit, and tangible environmental issues tend to build indicator systems from the bottom-up.

Criteria used to develop indicators for both climate change and rangeland health support the top-down and bottom-up approach. For example, criteria employed by the EPA in their climate change indicators include "usefulness" and "understandable to the public" (EPA, 2014). These descriptors refer to indicators that may address issues of national importance and are easily comprehended by the average citizen (EPA, 2014). Similarly, rangeland health indicators proposed by the Sustainable Rangelands Roundtable include "the degree of understanding that stakeholders and the general public have for the indicator" as a criterion (Mitchell, 2010). While both indicator systems share a common goal of public understanding and accessible science, indicators for rangeland health seem to also be of use to those who might use that information such as ranchers and land managers. The Bureau of Land Management proposes rangeland health indicators that are more effective in that they are used for better management of our lands (Toevs et al. 2011).

Top-down approaches refer to institutional policies through government agencies and/or Congressional actions, which set the stage for monitoring impacts, such as with global climate change. The aforementioned indicator systems for climate change were developed, implemented, and hosted through federal agencies (i.e. EPA, NASA, and NOAA). In contrast, a bottom-up approach in developing indicators may start with those actors who may find this information most meaningful and useful for their decision-making. In rangelands, the target group of ranchers or land managers and field-level officials from a local or state agency (i.e. the "periphery") may begin the process of selecting and developing indicators (Mazmanian and Sabatier, 1983, 12). Indicators vetted through the bottom-up approach may be more localized and provide more decision-relevant information. Using rangeland health as an example, indicators could include plant productivity, forage quality, and soil health. Instead of describing the drivers

of these variables (i.e. precipitation, temperature), stakeholders are concerned with indicators that describe impacts to their land, which they depend on for their economic livelihood.

Table 2. Characteristics of top-down and bottom-up approaches to environmental indicators.

	Top-down	Bottom-up
Spatial extent of impact	Global; dispersed	Regional, local, ecosystem-specific
Spatial unit of analysis	Varies depending on focus	Regional, local, ecosystem-specific
Temporal extent of impact	Near-term to long-term	Near-term to medium-term
Actors using information gleaned from indicators	Policy makers, scientists, governing/legislative bodies	Land/resource managers; local/state/regional officials; concerned citizens
Primary outcome from indicator system	System understanding/prediction/policy	System management/modification

The argument presented for a top-down and bottom-up approach might also be strengthened through Richard Levins' work on model construction, which has been highly influential among biologists and philosophers of science (Weisberg, 2006). In his model building framework for population ecology, he describes that models typically maximize a dual combination of generality, realism, and precision to achieve goals of understanding, predicting, and modifying a system (Levins, 1966; Weisberg, 2006). Understanding refers to the ability to explain some phenomena occurring. Predicting is the act of making accurate predictions based on historic data. Modification considers how one can intervene or change nature[6].In this case, top-down and bottom-up indicator systems may have different goals employing Levins' language (1966).

In achieving these goals, the actions of those using these indicators differ following the top-down and bottom-up approach. Perhaps climate change indicators, which are developed via

[6] It can also be argued that modification requires an understanding of the system at hand, and also accurate predictions, which can be used to ascertain potential impacts from changes or interventions to the system (Weisberg, 2006).

top-down mechanisms, aim towards understanding and predicting. Decision-makers rely on these indicators to provide information to the public on current status and trends, but also baseline information for modeling and predicting the future. For example, policymakers can use climate change indicators as justification for reducing carbon dioxide emissions. Scientists can use this information to help improved physically-based processed in their global climate models to ensure biophysical relationships are represented as realistically as possible.

The goals of prediction and modification match the intent of rangeland health indicators. Stakeholders, such as ranchers and local decision-makers, would like to use these indicators to help predict unforeseen impacts so that they may respond appropriately. Ranchers and land managers might use rangeland health indicators for more effective management of their land, which is their economic livelihood. Indicators can help them sustain their source of income through better land management as a response to changes occurring on their land (i.e. more variable precipitation, warmer temperatures).

Through the goals mentioned by Levins (1966), people's behaviors differ when using information gleaned from indicators. Data from top-down indicator systems are used for policy-making and/or further understanding of the system itself. In the case of climate change, indicators can be used to support governmental actions to limit emissions and/or pollutions, as well as increase research funding to deepen our understanding of the problem and predictive ability of future impacts. Bottom-up indicator systems provide information that local managers and land owners can use for effectively managing their land. For example, rangeland health indicators can be used to determine what new management strategy may be used to sustain productivity in the face of changing weather patterns and/or policies. In summary, the actors most likely to use top-down indicators may be those with the "center" perspective, while bottom-

up indicators may appeal to the “target group” or even “periphery” more (Mazmanian and Sabatier, 1983).

Conclusions

Using the Mazmanian and Sabatier (1983) policy implementation framework, a top-down and bottom-up approach to environmental indicator systems is developed. The primary characteristics that define an environmental system to one approach are scale, goals, and resulting actions. A top-down approach is typically used for environmental problems that are large-scale, scientifically complex, distributed in impacts (spatially and temporally), and may have communication barriers and conflict regarding the underlying biophysical processes. These indicators provide information on system understanding and prediction, which can be used in policymaking and/or further scientific research. The bottom-up approach is most useful for problems that are spatially constrained to a region or ecosystem type (i.e. rangelands), aim for understanding and modifying the environment, and produce tangible impacts. Local and regional officials, land managers, and/or relevant stakeholders most often use this information to effectively manage their environmental systems. Global climate change exhibits top-down characteristics, while rangeland health displays attributes of a bottom-up approach. This framework provides relevant context for environmental indicators, which can be used by scientists, decision-makers, and private citizens in developing new indicators that are effective and appropriate to their own system.

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