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RESEARCH ARTICLE

Diagnosing environmental problems and their possible policy responses: A tool for assessing initial options

Krister Andersson[1,*], Christina Boyes[2], and Kenneth Richards[3]

The complexities of many environmental problems make the task of identifying potential solutions daunting. We present a diagnostic framework to help guide environmental policy analysts and practitioners to think more systematically about the major types of environmental problems and their possible policy responses. Our framework helps the user classify a problem into1 of the3 main problem categories, and then for each of the problem types think about contextual factors that will influence the choice of policy responses. The main problem types are **(1)** common-pool resource (CPR) problems (e.g., overfishing, groundwater depletion, and forest degradation); (2) pollution problems (e.g., greenhouse gas emissions, eutrophication, acid rain, and smog); and (3) hazards (natural and human-made hazards, including hurricanes, wildfires, and levy collapse). For each of these problems, the framework asks users to consider several contextual factors that are known to influence the likely effectiveness of different policy responses, particularly fast-thinking behavior. The framework is a heuristic tool that will help novice analysts develop adeeper understanding of the problems at hand and an appreciation for the complexities involved in coming up with workable solutions to environmental challenges. The proposed framework is not prescriptive but analytical in that it asks users guiding questions to assess multiple aspects of a problem. The resulting problem assessment helps to narrow down the number of viable options for environmental policy responses, each of which may, in turn, be assessed with an eye toward their legal, political, and social viability.

Keywords: Diagnostic, Environmental policy, Public policy, Governance, Environmental studies

1. Introduction

The motivation to tackle environmental problems is at an all-time high. Governments and corporations take turns in setting ambitious goals for reducing their ecological footprints, especially when it comes to climate change. The European Union declared in June 2021 that its members will work to reduce their greenhouse gas (GHG) emissions by 55% before 2030 (European Commission [EC].2021).A few months earlier, online retailer Amazon committed to becoming carbon neutral by 2040 (Amazon, 2019). While such commitments are welcome news for the planet, they also raise questions about how such goals can beachieved.

What mix of policy responses will most effectively improve targeted environmental outcomes while safeguarding economic prosperity and human dignity? Once societies and their multiple organizations commit to improving outcomes, the hard work of figuring out how to achieve these goals begins.The purpose of this article is to present a diagnostic framework to guide environmental policy analysts and practitioners to think systematically about environmental problems and their possible policy responses. By developing such analytical skills, analysts will beable to become more active participants in society's search for more effective policy solutions.

The complexities of many environmental problems make the task of identifying potential solutions daunting. The nonlinear behavior of the systems in which environmental problems occur complicates the search for viable policy responses. One of the central messages in this article is that because of these complexities, general blueprint solutions to environmental problems are rarely effective. Potential human responses to existing problems abound. Policy analysts face an increasing number of potential policy alternatives and one of the central challenges they encounter is to identify nuanced interventions that are likely to work in the specific contexts in which a problem is occurring. We propose that a good starting point for students in making sense of this complexity is to study and appreciate the problem at hand and the multiple

[1] Keough School of Global Affairs, University of Notre Dame, South Bend, **IN,** USA

[2]Centro de Investigaci6n y Docencia Econ6mica (CIDE), Mexico City, Mexico

[3]School of Public andEnvironmental Affairs, Indiana University, Bloomington, IN, USA

*Corresponding author:
Email: kanderss@nd.edu

contextual factors associated with it. This problem-orientation approach, we believe, will help analysts in their exploration of suitable policy responses.

Here, we present a framework designed to assist aspiring policy analysts to engage in the diagnosis of environmental problems and their possible solutions. The framework will not prescribe specific policy interventions, but it will prompt the user to ask several questions about the problem and the context that surrounds it. By addressing these questions, the analysts will be able to narrow down the number of appropriate policy options.

The design of this framework is intentionally simplified to allow users to process some of the key features of the complex social-environmental systems in which the problem is occurring.The purpose of the framework is primarily to offer novice analysts a tool to make an initial assessment of policy options. For more advanced policy analysts engaged in empirical analysis of policy instrument choice, we recommend using this framework as a starting point for subsequent, more specialized, and in-depth analysis.[1]

Environmental policy frameworks are plentiful, but many are quite complex and abstract, which can hinder accessibility for the environmental policy novice (e.g., Little et al., 2019). Existing policy frameworks often fall short of offering practical applicability for novice policy practitioners who can find it challenging to define what the fundamental characteristics of the problem are and to think about what an appropriate response might be for a given problem. Policy analysis is often a complex task, and the main purpose of this diagnostic framework is to provide its users with a structure that makes this task more manageable.We hope that learning to use this framework will help the users-students, practitioners, and other analysts-to develop new analytical skills that they will apply in their future pursuit of sustainability solutions.

After a brief introduction to the proposed framework, we explain the multiple diagnostic questions it asks. To illustrate its utility for real-world problem diagnosis and exploration of possible policy responses, we apply the framework to 4 case studies of different problem domains: (1) overexploitation of groundwater commons in Colorado, USA; (2) acid rain pollution in the United States; (3) urban heat hazards in Ahmedabad, India; and (4) behavioral barriers to drinking water conservation in Bogota, Colombia. We conclude with a discussion of the ethical, political, and legal constraints on the selection of policy responses.

1. The more detailed and in-depth analyses will benefit from using more specialized analytical frameworks such as those developed for (a) pollution control by Richards and van Zeben (2020), Stavins (2003), and Tietenberg and Lewis (2018); (b) for CPR problems developed by Ostrom (2009), Ostrom and Cox (2010), and Andersson (2006); (c) fast-thinking problems by Thaler and Sunstein (2008), Shafir (2013), and Grune-Yanoff et al., (2018), and (d) for responses to hazards by Smith and Lenhart (1996), Donahue and Joyce (2001), and Berkes (2007).

2. A framework to diagnose environmental problems and explore potential responses

The proposed framework provides a simplified decision tree that allows fora step-by-step analysis of human-environmental interactions that sometimes result in environmental problems.The framework distinguishes between 3 major classes of environmental problems, including the overextraction of CPRs (e.g., unsustainable fisheries, deforestation, and groundwater depletion), pollution (e.g., air and water pollution, ozone depletion, ocean acidification, and climate change), and natural hazards (e.g., wildfires, floods, and drought). We include an additional category of problems-problems caused by fast-thinking or habitual "nondecisions" (e.g., littering, excessive household consumption of water, energy, and polluting consumer goods), which cuts across the 3 main categories of problems.

The framework is structured as a decision tree that starts by asking the user a series of questions about the problem at hand and its proximate causes. For example, is the problem caused byexcessive extraction or use of a natural resource, such as a forest or groundwater? Or is the problem caused by a corporation emitting pollutants into the natural environment? Depending on the answers to these and other initial questions, the user of the framework will get a sense of the magnitude of the problem, and what it would take to address it effectively. After establishing which type of environmental problem the analyst is dealing with, the framework asks a second set of questions about the particular social-environmental contexts in which the problem is occurring. The framework pays particular attention to how human behavioral quirks affect the manifestation of different problems, be they hazards, pollution, or CPR problems.The framework's questions help narrow down the number of plausible policy responses that are likely to work in the given context. For any given problem, the framework prompts the analyst to address 7 basic questions, outlined in **Table 1.**

These questions provide the basic structure of the diagnostic framework. The order of these questions is important because the answers to the first 3 questions will determine which specific sub-questions the analyst should address during the diagnostic analysis.The purpose of this analytical exercise is not to generate predictive decision support, but rather a systematic, guided exploration and initial assessment of the problems at hand and the identification of a range of possible and desirable policy responses.

Policy analysts and researchers will recognize much of the content in the followingsubsections as integral to, but perhaps not overtly stated, in many of the frameworks already applied in the field of public policy. Most of the questions in the framework are about the context-that is, the biological, physical, socioeconomic, and political environment-in which a problem occurs. The reason for this focus on context is that the effectiveness of any given policy intervention often depends on how the policy interacts with the particularities of the context; the traditions and customs of the people targeted by the policy, the attributes of the ecosystem, and other policies and laws

Table 1. Overview of the core diagnostic questions

Diagnostic Question	Policy Analyst's Task
Which type of environmental problem is it?	- Characterize and dassifythe environmental problem
Does the observed problem warrant a public policy response?	- Establish "costs" of inaction, especially to vulnerable members of society
What are the root causes of the observed problem?	- Attribute problem to its causes - Target a cause for intervention
Which human behaviors contribute to the problem?	- Inventory "problem behaviors" - Identify desirable, alternative behaviors
Are effective solutions to the problem known?	- Take stock of existing solutions and their track records
How does the proposed intervention affect the more vulnerable populations in society?	- Consider equity and justice implications of proposed policyinterventions
Are decision-makers motivated to implement existing (or new) solutions?	- Identify the plausible political, social, and economic drivers of policy action

Source: Authors' elaboration.

that already exist, to mention a few contextual conditions that are likely to matter. As a result, there are particularities associated with each of the 4 major categories of problems that require the policy analyst to go beyond the 7 core diagnostic questions identified above, addressing contextual factors that arespecific to each of the problems in question.Those additional diagnostic questions are outlined in the problem-specific sections (4.1-4.4) below.

3. Overview of the framework

The analyst starts by describing the perceived problem at hand.What we observe is often the consequence of deeper environmental problems. For example, we might notice that the air is smoky and hazy and learn that there is a nearby wildfire burning. The proximate cause of the observed air pollution is wildfire, but what caused the fire in the first place may be more difficult to sort out Policies that fail to address a problem's true cause are unlikely to produce noticeable improvements to the status quo. The wildfire may be caused by a number of factors, such as reckless hikers losing control of their campfire, fire-suppressing forest management strategies, a drier and hotter climate, or a combination of all these factors. A policy response that merely focused on the behavior of reckless hikers would likely be quite ineffective in reducing the incidence of wildfires in the longrun. On the other hand, a policy that only focused on the deepest root cause-trying to mitigate climatic change-may be expensive without necessarily reducing the incidence of wildfires in the short term.

While it is important to establish a nuanced understanding of the causal process behind an environmental problem, it is not always wise to target only the deepest root cause to an observed environmental problem. It is the task of the policy analyst to attribute an observed environmental problem to its true root causes, but that is just the first part of the analyst's job.The perhaps more challenging task is to figure out which of these causes may be addressed by specific policy interventions at a reasonable cost.

3.1. Which type of environmental problem is it?

The framework asks the analyst a series of questions that allows her to pin down what fype of environmental problem she is facing. Is it a problem characterized by the emission of a foreign substance into the natural environment (pollution)? Is it a problem characterized by the extraction of natural resources at a rate that exceeds the ecosystem's capacity to regrow and regenerate (CPR problem)? Or is the problem associated with a disastrous event taking place, such as a wildfire, flood, or a building collapse (hazard)? Depending on the analyst's answer to these questions, the framework identifies 3 major classes of environmental problems: overextraction of CPRs (e.g., unsustainable fisheries, deforestation, and groundwater depletion), pollution (e.g., air and water pollution, ozone depletion, ocean acidification, and climate change), and hazards (e.g., wildfires, floods, and building collapse). **Table 2** presents an overview of these environmental problems, their proximate causes, as well as possible consequences.

3.2. Does the observed problem warrant a public policy response?

Looking at the manifestation of the problem at hand, is doing nothing in response harmful to society? In other words, does the **problem** warrant a public policy response? If the spatial extent of the problem is limited and the problem does not do harm to a third party, leaving the problem alone may be justified. For example, if a farmer's barn catches on fire, your truck has an oil leak that ends up spoiling a part of your lawn, or your neighbor cuts down the trees in her backyard, the impact of these problems is limited to a very small portion of the population. If environmental problems occur on a small scale and harm mostly individuals who were ultimately responsible

Table 2. Three major (and one cross-cutting) types of environment.al problems

Major Types of Proximate Causes for Environmental Problems	Examples of Environmental Symptoms/Problems	Possible Consequences and Environmental Impact
Overextraction of Common• Pool Resources	Reduced regrowth and regeneration of natural resource stocks	Degraded ecosystems with reduced ecological functionality, reduced biodiversity
Pollution	Increased toxicity in nature, contaminated foods, water, air	Unhealthy living conditions, poisoning, respiratoiy illne
Hazards	Extreme weather, hunicanes, heat waves, droughts, wildfire, earthquakes, levyor dam collapse	Damage to people, buildings, and public infrastructure; increased emissions, pollution
Fast-thinking behavior	A *cross-cutting problem* that can contribute to CPR, pollution, and hazard problems. Habitual overconsumption of natural resources	Greenhouse gas emissions, pollution, deforestation, increased hazard risk

Source: Authors' elaboration.

for the problem in the first place, it would be difficult to justify an external intervention. Even if it does inflict *some* harm on some members of society (which is arguably the case in all the examples above), it is not always economically efficient for governing bodies such as homeowner associations, cities, or federal government agencies to intervene because the costs of doing so may outweigh the benefits. As Nobel laureate Ronald Coase (1960) once said of government intervention, sometimes "it will cost too much to set things right". One of the most important tasks of policy analysis is to consider the efficiency of any proposed intervention, which requires a careful estimation of the costs of the intervention. In some cases, it may be best to leave the problems alone.

There are situations when the main purpose of policy interventions is precisely to set things right, to repair damage inflicted on people and their natural environment. Such interventions may seek justice for victims of wrongdoing and harm, including harm from environmental degradation and pollution. For example, in 2022 communities in Louisiana, USA, long exposed to the pollution from nearby oil refineries, launched an environmental justice campaign called "Beyond Petrochemicals: People Over Pollution," to stop the expansion of petrochemical projects in an area called "Cancer Alley," located along the Mississippi River between Baton Rouge and New Orleans. The communities, supported by a donation from the Bloomberg Foundation, work with local environmental justice groups to hold polluting firms and government officials accountable (Smith, 2022).

Addressing inequalities, inequities, and injustices related to environmental issues requires the analysts to acknowledge that societies are complex social entities with a diverse range of actors and social groups that often vary greatly in their values, politics, and preferences.What one group sees as a problem may not be a problem for another group. The same goes for the perception of solutions and policy interventions. The key to understanding the equity implications of public policies is for analysts to consider how the costs and benefits of a particular problem or policy may vary across different groups in society.[2]

3.3. What are the root causes of the observed problem?

If the analyst concludes that leaving the problem alone is not an option because doing so would cause significant harm to society, **it** means it is a public problem that calls for a response. Moving forward in considering possible responses to the problem at hand, it is useful to start with a basic definition of the problem. What are the defining characteristics of the problem? What are the possible causes of the observed problem situation? In doing so, it often makes sense to limit the depth of the analysis to the factors or behaviors that can plausibly be influenced byan intervention. While it may be the underlying economic system (e.g., capitalism or centrally planned economy) that may represent the ultimate root cause to a given environmental problem, these deep, system-level causes are beyond the influence of environmental policies. As a result, our more pragmatic approach distinguishes between *underlying* systemic causes and *operational* causes. Our framework asks the analysts to identify the *operational causes* because these are the ones that policy can influence. If the analyst cannot identify the main causes of the observed environmental problem, the analyst will want to investigate the problem further, possibly with fellow citizens and researchers who she knows or has seen working in the area. The joint production of such knowledge between stakeholders and researchers may lead to new insights about what the main operational cause of the observed problem is and what might be done about it.

2. We thank Alastair lies for pushing us to emphasize the distributional effects of both environmental problems and their associated policy responses.

3.4. Which human behaviors contribute to the problem?

Effective policies target specific human behaviors that contribute to the observed environmental problems. Knowing what these behaviors are is the first stepto identifying effective policy responses. The specific problem behaviors may entail fishing vessels overfishing a particular species, corporations emitting harmful pollutants into the air or water, or a city government not preparing emergency response plans for potential haz.ard events. The more precise the analyst can be in identifying problematic behavior, including which specific individuals contribute to such behaviors, the better. Having a detailed understanding of the problem behaviors that will need to change, and the factors that cause such behaviors, will allow the analysts to develop a more nuanced and targeted policy response. It will also allow the analysts to identify opportunities for pursuing low-cost policy responses to behavioral problems.

There are some environmental problems that do not require pervasive and intrusive policy interventions. Some problems are caused by fast-thinking behavior-habitual, everyday decision-making that produces unintended environmental damages in the aggregate-which may be addressed by using a much less invasive and costly policy approach (such as using information campaigns, behavioral "nudges" or "boosts" as discussed later in the article). From a policy analysis perspective, it makes sense to start the diagnostic assessment of appropriate policy responses by considering whether a given problem has an element of fast-thinking behavior to it, and if so, may be addressed by low-cost policy that targets a specific fast-thinking behavior.

For many environmental problems, however, the root causes are associated with economic factors-such as lack of public transportation systems, poor public infrastructure for renewable energy, and prohibitively expensive green products, like electric vehicles or rooftop solar panels. When such economic factors stand in the way of improved environmental outcomes, society facesa **market failure.** Market failures occur when individual citizens behave in ways that are in their short-term economic interest, but such behaviors result in damage to society overall. For example, while it may make economic sense for a company to keep its production costs down by dumping some of its waste products into the nearby river, this pollution may cause serious ecological damages as well as health problems to water users downstream. When market failures exist, policies are needed that fundamentally alter people's costs and benefits when choosing modes of production, transportation, energy sources, or consumer goods.

Another cause of environmental problems is **governance failures,** which happen when a policy response causes the original problem behavior to get even worse. For example, in an effort to diffuse air pollution from coal-powered power plants, government policies in many industrialized nations ordered these plants to increase the height of their smokestacks, often inducing companies to increase their total air pollution (since the local effects of the air pollution diminished). A more subtle example of governance failure is a policy **"lock-in,"** which occurs when it is exceedingly difficult to modify or reform an existing set of policies even though such policies may contribute to environmental damages. For example, farmers may receive substantial government subsidies for growing certain crops or using certain production methods, even though these behaviors and practices contribute to increases in nonpoint source water pollution. Since changing the existing agricultural policies is very difficult, especially if such changes involve the reduction of subsidies to farmers, this policy lock-in complicates efforts to address behaviors contributing to nonpoint source pollution.[3]

3.5. Are effective solutions to the problem known?

During this phase, the analyst considers existing and proposed solutions to the identified problem, and the extent to which these are likely to be effective as the basis for new policy. Several scenarios are possible here.The knowledge of potentially effective solutions does not yet exist in the public domain. Theoretical knowledge of potential solutions may exist but has not been tried out in the field. Or, robust knowledge of what would work well as a solution not only exists, but the solution has achieved good results in some places, yet this knowledge has not been applied as the basis for a public policy response. The analyst would consider different courses of action depending on the state of knowledge about available solutions.

3.6. How does the proposed interventionaffect the more vulnerable populations in society?

Whatever solution is selected as the basis for the policy intervention, it is important to consider the equity implications of the intervention. Some interventions may disproportionately inflict harm on already vulnerable segments of society. For example, in the aftermath of 2017 Hurricane Harvey in Houston, TX, one study found that the federal government aid to repair and rebuild affected areas disproportionally benefited homeowners with relatively high incomes. Poorer households, in rented homes, suffered the proportionally greatest loss from the event but did not get as much help from the public policy interventions, a situation that contributed to an increase in socioeconomic inequalities (Howell and James, 2019).

3.7. Are decision-makers motivated to implement existing (or new) solutions?

Even if effective solutions exist, they may not make it into public policy responses to problems because politicians may not be motivated to propose such policies. The lack of such motivations may be related to a number of political, economic, and social factors. For example, if the decision-maker thinks that a policy will increase the chances of re-election or re-appointment, mobilizing additional resources for their organiz.ation/district, or earn the

3. For more on policy lock-ins, see Seto et al. (2016).

approval of important and powerful peers, they will be motivatedto pursue such policy proposals. Ifthere isa lack of such motivating factors, policy proposals may struggle to make it into new public policy and law.

The next section starts to spell out the details of the diagnosis of the 4 types of environmental problems. The framework starts byasking theanalyststo identifythecauses of CPR problems, pollution, and haz.ards (the 3 major environmental problems that our framework focuses on). A fourth type of causal factor that can contribute to all 3 of these problems isfast-thinkingbehavior.Because oftheprevalence ofthese problems,and becausetheyoften requireless costly and invasive policyresponses,we conclude thesection withadiscussion of howtheframework can helptheanalysts indealing with these type of problems.and that bydoingso may avoid having to resort to proposing more comprehensive and costly policy responses that are often less likely to get public support

4. Exploring potential policy responses to environmental problems

Each of the 4 types of environmental challenges suggests a different approach for the policymaker. This diagnostic approach has 2 phases. First, the analyst goes through the 7 core questions to gain a deeper appreciation of the problem, itscontext,and the urgency of a policy response. The first phase prepares the analyst for the second phase, which will shift the focus toward the development of a suitable policy response. During the second phase, the analyst will get into more specific questions about the targeted behaviors, populations, and plausible strategies to influence their decision-making. The analytical steps described in each of the problem-specific sections below guide the analyst through the exploration of possible intervention responses.

4.1. Common-pool resources

CPRs are large resource systems that are difficult to manage because they are subtractable (once a user consumes a resource unit, that unit is no longer available to others) and difficult to protect from other people's use(costly exclusion). Examples of CPRs include fisheries, groundwater aquifers, and forests. Because of these attributes, CPRs are susceptible to overuse, especially when there are no clear property rights that control who can access a resource or regulations in place that prescribe how the resource may or may not be used. If this is the type of problem an analyst is dealing with,there are a series of follow-up questions that will help narrow down the different options for policy responses that may beconsidered.**Figure 1** providesa flowchart that identifies a series of sequential questions about the specific characteristicsof the CPR problem under study and suggests possible responses depending on how these questions are answered by the analyst.

The first question toaddressiswhether the root cause of the CPR problem is known. In many cases, especially in the developing world, the root cause of the unsustainable use of CPRs is weak or insecure property rights. Ifthe local user groups do not have dearand uncontested property right to the resource they depend on, they have limited incentives to invest in protecting and using the resource sustainably. Such a situation often creates a race to the bottom, in which each resource user seeks to extract as much of the resource as possible before somebody else grabs it. Research has found that insecurity in property rights is one of the major causes of the overuse of CPRs. If this is the case, then interventions are needed to improve the clarity and legitimacy of resource property rights in a way that does not exclude people who rely on the CPR for their livelihoods.Sometimes, but notalways,this meansa process of formal land titling to either groups or individuals.

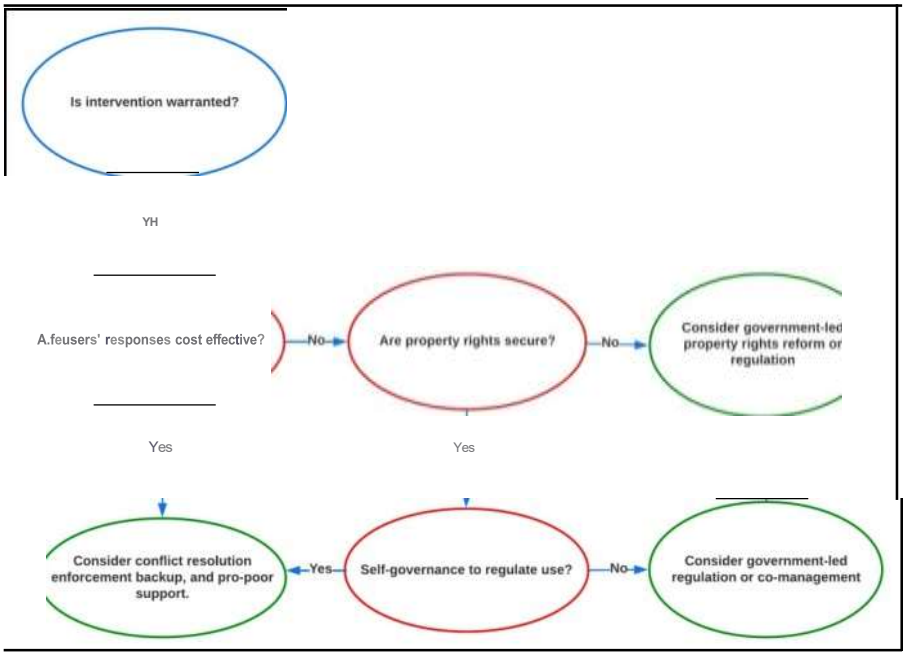

Figure 1. Schematic overview of analyzing possible responses to common-pool resource problems. Source: Authors' elaboration.

Even if property rights are clear and secure, however, it does not mean that the CPR will be used sustainably.[4] Such rights do provide some assurance to right holders that any management and improvement efforts that they put in will provide a future flow of benefits to them; they will be rewarded for their work. Having such rights can provide users with the motivation to work together to come up with rules for use and management that promote sustainability, but unless the users actually develop and enforce such rules, the shared resources are still under threat. In other words, sustainable management of CPRs requires clear and secure property rights, but just as important are the development and enforcement of rules, socially binding agreements, about how the resources must, may, or may not be used.

Other underlying causes of the overexploitation of CPRs include incentives to generate short-term commercial profits, larger numbers of users, and reduced availability of the resource due to extreme weather, conflicts, or natural disasters (York et al., 2021). If these forces are at work, then interventions are needed to reduce their negative environmental impact on the shared resources. If it is not possible to increase the availability of the resource, resource users need to reduce the quantity of resources used. If the underlying causes are not known, more research may be needed, which may require the allocation of more public resources to this research or it is unlikely to happen.

Fast-thinking behavior can also contribute to CPR problems. For instance, individual farmers may decide how much groundwater to pump for irrigating their crops without knowing exactly how these decisions will affect the future water table of the entire aquifer. Whenever people lack information about better alternatives or societal harms associated with their choices, they tend to stick to their established habits (i.e., the status quo)-they repeat the same decision strategies that they have used in the past (Samuelson and Zeckhauser, 1988).

The next major question to address is whether there are readily available solutions to the CPR problem. If there are such solutions, are the CPR users already implementing those as a response to the ongoing degradation of their shared resources? If they have already responded in an efficient manner,there may not be a need for further external intervention; in fact, intervening without recognizing the local users' efforts of restoration may make things worse. If, on the other hand, the local efforts to respond to the CPR problem exist but are somehow falling short, it is important to understand why the local efforts are not achieving good management outcomes. Is it because not all local users are on board with the local effort or is it because outsiders poach on the resource? Alternatively, the local users may not be able to perform all the work required to protect the resource from further degradation, unable to patrol the resource boundaries, monitoring rule compliance, or enforcing sanctions on those who violate local rules. In cases where the local users are motivated to address the problem but are constrained from doing so ina cost-effective manner, an intervention to create a comanagement arrangement between an external organization and the local user group may be an option. Such arrangements can provide technical support, legal backup, help with conflict resolution, and human resources to perform tasks that are needed to manage a CPR system (Ostrom, 1990).

4.1.1. Illustration: Overexploitation of groundwater commons in Colorado, United States

Farmers in the San Luis Valley of Colorado are in the middle of a 20-year "mega-drought" (Cody et al., 2015). Some say that it is the new normal-warmer and drier climate and less snowmelt from the mountains for irrigating crops. As surface water is becoming increasingly scarce, farmers pump up groundwater to make up for the shortfall. Until recently, pumping groundwater was not regulated by the state government.Without clear property rights over the groundwater, the resource-a classical CPR-was a free-for-all. But when more and more farmers turned to pumping groundwater to make up for shortfalls in surface water, the groundwater tables started to fall drastically; to the point where the state government sounded the alarm bells (Smith et al., 2017). The state government started to intervene in river basins where the situation was particularly dire.They even shut down some wells in neighboring areas, which essentially put those farmers out of business. Without groundwater to irrigate crops, many farmers did not have enough water to grow their crops.

San Luis Valley farmers saw this happening and realized that they had a choice-either they proactively start to work together to address the falling water tables or wait for the state agencies to come in and regulate for them and possibly start shutting off wells.

In 2012, a majority of San Luis Valley farmers voted to start their own, homegrown water conservation program to try to stabilize the groundwater levels. With support from the local water conservation district as well as federal government employees living in the area, the farmers decided to create their own water conservation policy: Farmers who pump groundwater for irrigation must pay a pumping fee or a tax of $17 per acre-foot of pumped water (Cody et al., 2015). The collected tax revenue was then put into a common fund designated for payments to farmers who agreed to take some of their land out of production. This self-imposed tax had a significant effect on pumping behavior: The group of farmers subject to the tax reduced their pumping of groundwater by over 30%, compared to similar farmers who were not subject to the tax (Smith et al., 2017).

What started as a relatively small experiment in one district of the basin is now being implemented throughout the entire San Luis Valley.The experiment has worked quite well. Despite a continuing drought and groundwater levels that continue to be below normal, the interventions appear to have made a difference. Although the ongoing drought has caused a tremendous amount of stress on

4. For more on property rights reform andCPRs, see Ostrom and Hess (2000) and Anderson and Libecap (2014).

farmers and their land, the self-governance initiative has been successful in keeping the top-down regulations of the state government at bay, empowering the irrigators to continue to manage their shared groundwater resource.

The case illustrates 3 broad lessons from applying the diagnostic framework to problems associated with CPRs. First, resource users are often both capable and motivated to work together to develop their own rules to manage shared resources but may sometimes need a push to do so. The real threat of heavy-handed state government intervention pushed farmers in the San Luis Valley to set aside differences and self-regulate their resource use. Second, feedback to users on how their interventions are working is important to sustain the farmers' motivation for cooperation. If resource users cannot see that their self-sacrifice is paying off through an improved outcome, they may lose interest in continuing their cooperation. Finally, effective communication between resource users and governmental organizations can help bring about more creative and locally appropriate policy responses to existing environmental problems, moving beyond top-down regulation and interventions that ignore local solutions.

4.2. Pollution

If the nature of the underlying issue is not CPR but rather **pollution,** policymakers can engage in a different type of analysis, considering a different set of policy instruments. **Pollution problems** are caused by human activities that produce emissions of substances that contaminate the natural environment and degrade its ecological functions. Severe water and air pollution in North America and Europe in the 1950s and 1960s made pollution a political issue and citizens started organizing large social movements to push their national governments to introduce new environmental policies to regulate the emission of several pollutants. Most of the early policies that emerged in the 1960s and 1970s were centralized regulations, or command-and-control policies, which set pollution or technology standards enforced by national government agencies. For example, 2 of the major environmental policies in the United States, the Clean Air Act (1970) and the Clean Water Act (1972), were primarily command-and-control interventions to regulate pollutants in both air and surface water. Over time, alternative ways of dealing with air and water pollution have made their way into the policymakers' repertoire of environmental policy interventions.

Depending on the characteristics of the problem at hand, decision-makers no longer presume that top-down regulation is always the best response to pollution problems (Tietenberg and Lewis, 2018). Which type of intervention will be the most cost-effective response to pollution depends on a host of factors, some of which the framework prompts analysts to consider when diagnosing the pollution problem. The most fundamental step in applying the framework to pollution problems is to identify the underlying cause of the problem **(Figure** 2). Generally, excess environmental damage arises from one or more of 3 causes: (1) society needs deeper understanding of the nature of the environmental problem and potential solutions; (2) individuals in society need better access to available knowledge of the nature of the environmental problem and potential solutions; or (3) individuals in society need to be induced to use the knowledge they have to pursue potential solutions to environmental problems. All 3 causes involve social dilemmas-situations when individual short-term interests are at odds with the overall welfare of society.While most of this section's focus is on the third element of this analysis, it is critical to understand that all 3 elements must be addressed, none to the exclusion of the others. As illustrated in **Figure 2,** the 3 red nodes in the framework invite the policy analyst to

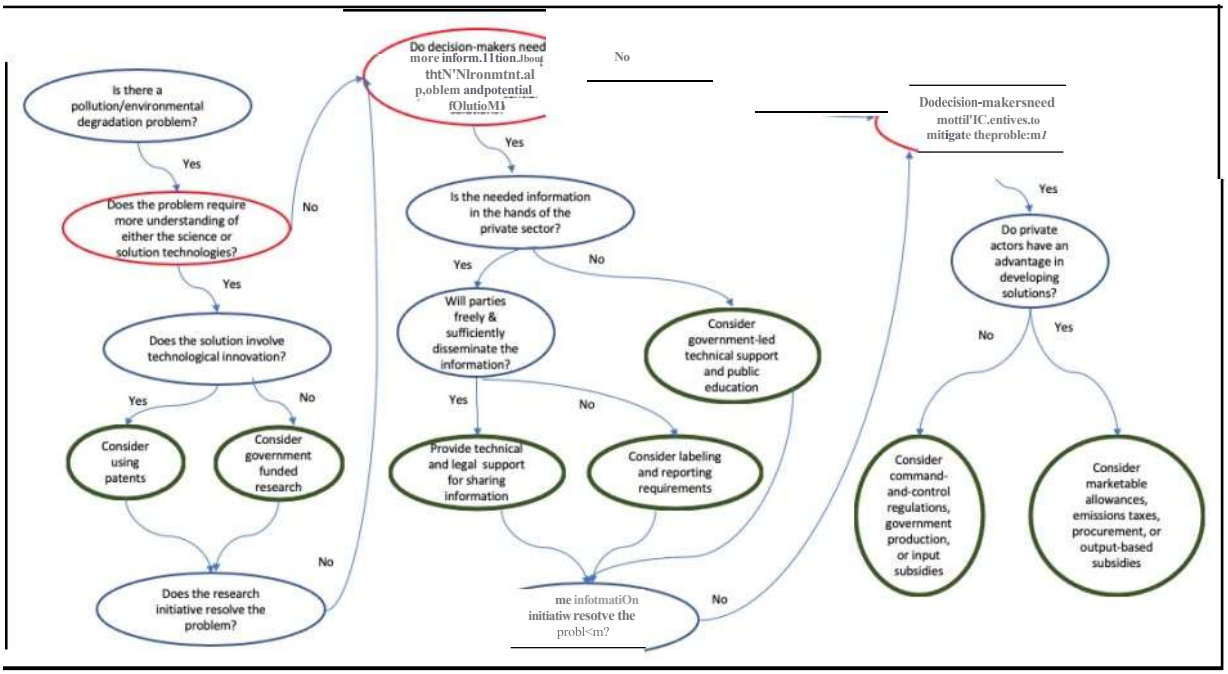

Figure 2. A policy instrument guide for pollution applications. Source: Authors' elaboration.

consider which of these barriers is the root of the problem. Often,the first step in addressing a pollution problem is to characterize the nature, pathways, and magnitude of the health and environmental risks, as well as to identify or develop solutions. This can require significant investment of human and capital resources.

The creation of knowledge through research and innovation provides a public good, a resource that is freely available to society. The challenge is that private parties are generally reluctant to invest in collective activities (e.g., public goods) when they cannot appropriate the benefits of their efforts. Governments can promote research and innovation through a couple of different strategies. First, if there is a need for innovation-say a new building efficiency technology-governments can provide patents creating intellectual property rights that allow inventors to appropriate the financial benefits of their research and development investments through licensing. Second, when governments want to promote more basic research (or if they want to accelerate technological innovation), they can provide funding to conduct that activity through government laboratories, research grants, or public-private collaborations.

Even when society understands the nature of an environmental pollution problem and has accessto reasonable solutions, to be effective that information must be in the hands of decision-makers-producers, consumers, government officials, and others who affect the level of pollution. Often, the information is in the hands of private parties, such as public interest organizations, and the role of the government is simply to help create and enforce the rules (e.g., truth in advertising, libel and slander rules, and tax deductions for donations to environmental organizations) as well as infrastructure (e.g., internet, satellites, and public access broadcasting) for dissemination. This is a relatively passive role for the government. There are circumstances where the government may need to force private parties to share information through mandatory emissions reporting or labeling laws. In some cases, however, the challenge is that the information needs to be collected, organized, and actively promoted. Here the government can step in with public education campaigns, data collection and dissemination services, and technical support programs. While they are often used to disseminate facts and figures, public education programs can also be an important mechanism for governments to influence fast-thinking behavior and habits, as discussed in more depth below (see Section 4.4).

Even when there is a full understanding of the environmental problem and polluters understand their options for abating pollution, they often choose not to incur the cost. When this is the case, governments can intervene to induce or force pollution abatement and dean up. Here, the fundamental question is whether the government allows private parties discretion with respect to the methods they use to reduce pollution. In some cases, the government will allow private parties very little discretion regarding how the emission reductions are achieved. For example, the government might require polluters to use specific technologies to reduce their emissions, a command-and-control approach. In others, the government might specify a particular level of performance, for example, percent pollution removed, that facilities are required to achieve, thereby leaving the specific action to be chosen by the actor. In still other cases, such as wastewater treatment plants, the government may provide the pollution abatement service directly. Finally, governments can specify the technologies for treatment but provide equipment subsidies to encourage their adoption. Notice that under the command-and-control approaches the polluter pays for the treatment, and under the government provision and equipment subsidy approach, the government pays.

In some cases, particularly where there are many polluters in a variety of circumstances, and when there are significant opportunities for innovation and adaptation in pollution control, the government may decide that it is better to allow polluters to decide for themselves how to reduce emissions. In this case, they can use market-based instruments.These include marketable emissions allowances, where the government places a capon total emissions and allows parties to buy and sell allowances, and emissions taxes (variations of which are called charges, fees, and levies), where the government sets a price on emissions. Alternatively, the government can pay parties to reduce their emissions via a subsidy (price-based) or procurement (quantity-based).

While the framework is described as a step-by-step decision tree, it is seldom so straightforward. Even if the diagnostic analysis of the problem suggests that there is a specific policy response that is likely to be both efficient and equitable, there are several additional factors to consider before making a final policy recommendation. These additional factors include the ethical, legal, and political considerations associated with a particular policy recommendation. We return to discuss these additional considerations in Section 5 of the article.

4.2.1. Case illustration: Theacid rain program of the United States

Acid rain, which is precipitation that has reacted with air pollutants such as sulfur dioxide and nitrogen dioxide, causes a great deal of environmental damage. Its damage is most visible in forests and aquatic environments, such as rivers, lakes, and swamps. The acidic rainwater causes aluminum to leach from the soil, which in turn can kill plants and animals.

Most of the SO2 and NOx that cause acid rain come from burning fossil fuels. In the United States, one study found that almost 70% of all SO2 pollution (in 1980) could be traced back to one type of pollution source: coal-fired power plants (Environmental Protection Agency (EPA), 2005). Ironically in the late 1970s, direct regulation through the Clean Air Act exacerbated the acid rain problem by forcing these power plants to build taller smokestacks, thus amplifying long-range transport of the air pollution.

To reduce the SO2 and NOx air pollution, in 1990, the US Congress authorized the EPA to set up the Acid Rain Program. The program embraced a more flexible,

market-based approach to reducing pollution causingacid rain, which was the result of increasing opposition, from both the public and industries to the top-down direct government regulations (Schmalensee and Stavins, 2019). The new program targeted mostly coal-fired power plants and established an emissions cap-the total amount of emissions that the entire group of power plants were allowed to emit-and then defined the reduction goals for each of the individual plants. The policy goal was to reduce SO_2 pollution by 50% over a 20-year period.While the policy set the emission reduction goal, it did not prescribe how each plant should goabout achieving this goal. Each plant had the freedom to pursue its ownstrategy.The program allows for emissions trading, which means that power plants can buy and sell emission permits (called "allowances") according to their individual needs and costs_ The EPA monitors compliance by making sure that each source holds sufficient allowances to cover its total SO_2 emissions.

The idea is to provide an economic incentive to those firms that can reduce emissions at relatively low cost to do more than their proportional share of the sector's total reduction goals. Plants that may have older equipment may find it economical to buy more emission permits (from firms that have a surplus of allowances because they have already reached their goals) rather than reducing SO_2 pollution.When this market for tradeable allowances works well, it is a cost-effective way to reduce pollution_

There is evidence that the Acid Rain Program has helped improve air quality in the United States. EPA has reported that the program reduced the total amount of SO_2 and NOx pollution by more than half, compared to 1980 levels (EPA, 2005). Not only did this reduction help ecosystems recover from acid rain effects, but positive human health effects have also been observed. In addition, there are other particle pollutants, such as PM2.5, that are released from coal-fired power plants alongside SO_2 and NOxthat areextremely harmful to people. Studies have shown that long-term exposure to PM2.5 can cause severe cardiorespiratory problems (Du et al., 2016). As SO_2 decreased as a result of the Acid Rain Program, so did PM2.5 pollution, resulting in a significant drop in deaths associated with cardiorespiratory problems (Barreca et al., 2021). These initial accomplishments notwithstanding, it is worth noting that little progress has been made during the last decade when it comes to further reducing SO_2 and NOx pollution in the United States, as the country's Congress has failed to produce new reduction targets.

4.3. Hazards

If the analyst believes that the observed symptoms are caused by a **hazard,** then the framework will ask about the specific characteristics of such an event and the context where it exists. A hazard is an event that may cause harm to society. Hazards include natural hazards, such as earthquakes, wildfires, droughts, hurricanes, and floods, among others. Hazards also include human-made hazards such as nuclear power plant meltdowns, bridge and building collapses, and broken levees and dams. Hazardous events are sometimes the consequences of other environmental problems, such as pollution, overextraction of CPRs, or even fast-thinking behaviors. For example, climate change (caused by GHG pollution) is likely to increase the frequency and severity of extreme weather events, such as hurricanes, droughts, and floods. Other hazards, such as mudslides and wildfires, may be caused by degraded forest systems (a CPR).

While not all hazards are always connected to environmental hazards, their nature and extreme potential damage to societies present a difficult challenge for public policy. Hazards put extreme demands on decision-making and service delivery in affected communities. In many cases, responding to hazards is beyond the capacity of the local governments in the places where they occur, and to deal with such events effectively, local decision-makers need external assistance. There is also a lot of uncertainty about the likelihood of a hazard resulting in a future disaster event[5] This reality poses a serious challenge to analysts who are working on finding appropriate policy responses to deal with the risks and impacts of hazards. When it comes to policy responses to hazards, analysts distinguish between 4 different types:

1. **Mitigation:** Preventative activities undertaken before a disaster strikes, seeking to reduce the longer-term risks and negative impacts of hazards. These activities strive to reduce social, economic, as well as biophysical vulnerabilities to risk among exposed populations.
2. **Preparedness:** Preventative activities that are also carried out before disaster strikes that seek to improve the short-term readiness of people and their communities to respond to disasters.
3. **Emergency response:** Adaptation activities undertaken immediately following a disaster to provide emergency assistance to victims and manage further short-term threats.
4. **Recovery:** Short- and long-term adaptation activities undertaken in the aftermath of the hazard event to help affected people to recover, restore, and rebuild.

Which of these policy responses the analysts should recommend in a given situation will depend on at least 5 questions: (1) Has the hazard event occurred? (2) What are the root causes of a hazard producing societal damage? (3) Who faces the greatest risks? (4) Which available solutions are likely to work best? and (5) What is the role of government and other governance actors in crafting a policy response?

4.3.1. Has the hazard event occurred?

If the event has already happened, the policy response should prioritize emergency responses and recovery

5. We distinguish between hazards and risks. A hazard is an event that may cause harm to society. A risk is the probability that such harm will materialize (which will depend on how exposed members of a society are to the hazard at hand).

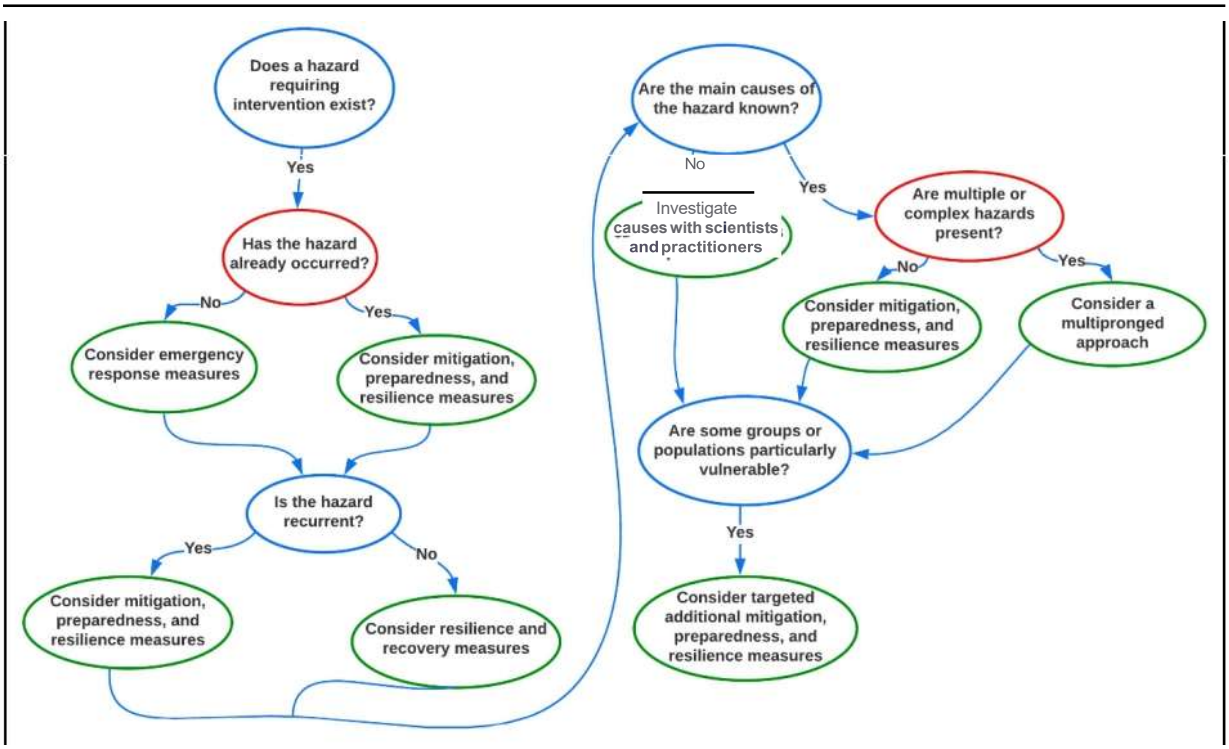

Figure 3. Diagnostic framework for Hazard problems. Source: Authors' elaboration.

actions. If the event has occurred and is also likely to repeat itself (e.g., extreme weather events), it makes sense to pursue a multipronged response that combines all 4 types of policy responses, but where emergency response is prioritized so that people directly affected by the hazards are tended to before recovery, mitigation, and preparedness actions begin.

In the aftermath of a disaster, the social and economic toll on a society is largely a function of the number of people who have lost the ability to participate in social and economicactivities. Policy interventions should therefore seek to minimize such lossand get as many people as possible back on their feet as quickly as possible. Reasonable performance metrics for both emergencyand recovery interventions are therefore the number of lives saved and how soon people can return to their pre-disaster levels of social and economic activities. If a hazard event has not yet occurred, the analysts should focus their efforts on designing appropriate prevention actions, namely mitigation and readiness activities.To design such prevention interventions, the analyst will use the framework to understand the main causes to the observed risks associated with the hazard. **Figure 3** illustrates the flow of questions related to problems and possible responses related to hazard events, past and future.

4.3.2. Are the main causes of the risks associated with hazards known?

One of the key distinctions in the analysis of hazards is that between **risks** and **hazards.**Ahazard isan event that may cause harm to society. A risk is the probability that such harm will be done.The risk, in turn, is the result of at least 2 things interacting with one another: exposure and vulnerability.The more exposed people are to the physical attributes associated with the hazard (e.g., how extreme/powerful the event is and how near the affected area people live) and the more vulnerable the affected people are (e.g., in what type of dwellings do people live and how well do public services work there), the greater the risk. The main objective of policy responses to hazards is to reduce the **risk** presented by hazards, by trying to decrease people's exposure to the hazard, reducing their vulnerability, or both. To design policy responses that effectively reduce risk, policy analysts need to understand the main causes of hazard-related risk, and then craft intervention proposals that target these causes. If the casual factors of these risks are not well known, the analysts need to investigate these, possibly in collaboration with scientists and practitioners, before starting the design of possible interventions.

For some hazards, the causes are well known but there is little policy can do to affect their occurrence. Prolonged lack of precipitation causes drought, too much precipitation causes many floods, and shifts in the tectonic plates can cause earthquakes. These causes may be beyond the direct control of policymakers, but policy may still play a role in reducing the **risk** of these hazards causing damage to societies. For example, mitigation and readiness interventions may target individuals and households to encourage them to make their dwelling structures less exposed to risk associated with extreme events. Interventions to mitigate such risks could involve providing technical assistance to reduce the flammability of building structures or making sure stormwater drainage systems are up to grade. Another type of preparedness intervention would be encouraging families to prepare evacuation

kits with their basic necessities so that they are ready to evacuate quickly if and when disaster strikes. These interventions minimize the risk of the disaster event causing major damage to societies.

4.3.3. Who faces the greatest risks?

Are some individuals in a community more exposed to risks associated with a hazard event? Targeted policy interventions to reduce these risks and damages for the most vulnerable groups of individuals will help societies' overall ability to prepare for (as well as recover from) hazards. Such interventions seek to reduce the vulnerabilities of particular groups in society by improving the resilience of their dwellings, providing supplemental funding for community infrastructure projects (improved storm drains, early warning systems, etc.), readiness training, moving people out of harm's way, finding alternative housing, and making food and medical services available for people who need assistance.

If a hazard event has not yet occurred but may occur in the future, mitigation and prep.1redness activities may target decision-making organizations that oversee building and maintaining infrastructure in areas that are particularly exposed to risk. Such interventions may work with local governments to update their building codes and zoning rules so that people do not build in high-risk areas, and wherever they do build, they do so using techniques and materials that are more resilient to hazards such as extreme floods, fires, or earthquakes. Some neighborhoods are particularly exposed to hazards, because of their location. There may be infrastructure improvements that can help reduce the exposure to risk in such settings.

4.3.4. Which available solutions are likely to work best?

At thisstage, the analysts will inventory the existing solutions that are available to address the risks of hazards. If more than one solution is identified, the task is to analyze which of these policy responses is likely to work best This analysis requires the analysts to define the most important evaluation criteria, such as cost-effectiveness, justice, equity, and reduced vulnerability.

If the analysts are unable to identify any readily available or suitable solutions, there is a need for analysts to explore plausible intervention options, possibly in collaboration with researchers, technical experts such as engineers, and practitioners with expertise in hazards policy. Sometimes, there are plenty of potential policy responses that analysts view as promising for reducing hazard-related risks and damage, but there may be little or no political interest among decision-makers to pursue such solutions.This is an area explored in the next stage of the analysis of policy responses to hazards.

4.3.5. What is the role of government and other governance actors in the crafting of policy responses?

Coming up with effective policy responses to hazards is itself a challenging analytical task. An even more serious challenge to effective responses is weak political motivation: While it may make perfect economic sense to invest tax dollars in preventative intervention activities which will help societies deal better with the risks associated with hazards, the political motivation to make such investments is often weak.The problem is often that prevention activities are under-prioritized by local politicians because hazards prevention can be expensive, requiring large public investments in physical and social infrastructure, and the payoff forthese investments often takes a long time to materialize, after the elected officials' time in office. Hazards are also relatively rare events and to reduce the negative impact of such events require long-term planningand strategic investments in infrastructure improvements. Local politicians, however, have both electoral and financial incentives to prioritize short-term spending-the kind of spending that will win votes to keep them in office. As a result, policy actions to reduce the risk of natural and man-made disasters are often under-prioritized[6] and in short supply. Analysts need to be aware of such predispositions so that they can build alliances with interest groups and governance actors that are motivated to advance the development of both innovative *and* politically viable policy proposals that can effectively reduce the risk and damage of hazards.

4.3.6. Case illustration: Addressing urban heat hazards in Ahmedabad, India

Extreme heat events can have a disastrous effect on human societies. Evidence suggests that such events are likely to occur more frequently due to climate change. For instance, Vautard et al. (2020) and Zachariah et al. (2022) find that the heat waves in the Indian subcontinent in 2022 and in Europe in 2019 were made more likely due to human-induced climate change. However, a crucial factor that exacerbates the negative effects of heat waves, especially in cities in the Global South, is unplanned growth, compounded by high levels of poverty. Hence, to address the negative effects of heat waves in such regions, one not only has to pay specific attention to preparedness measures that local governments can employ in the short term to tackle the effects of heat waves in their immediate aftermath but must also consider policy measures through which future events may have a dampened effect, such as mitigation measures. In this case, we focus on extreme heat events in urban India and the subsequent policy responses. The case also explores the limitations of current policy measures, and how exposure and vulnerabilities could be better addressed.

In 2010, Ahmedabad, a western Indian city faced the brunt of a heat wave that resulted in roughly 1,300 excess deaths (Azhar et al., 2014). The city is the fifth-largest in India in terms of population and isa major industrial hub in the western region. In the aftermath of the heat wave, the Ahmedabad Municipal Corporation, along with the Natural Resource Defense Council, the Indian Institute for Public Health, and the Climate and Development Knowledge Network started working on a heat action plan for

6. One exception is in the wakeof disaster, while the public considers hazards a priority.

the city (see Knowlton et al., 2014). This eventually led to the development of India's, and Asia's, first heat action plan in 2013-2014 (Knowlton et al., 2014), and subsequently shaped future heat stress planning in India.

The plan involved a combination of preparedness and emergency responses to address the immediate needs and reduce exposure and susceptibility to extreme heat. For instance, the plan involved awareness campaigns that let the public know how high the temperature was going to be on a particular day, usinga color-coded alert system, so that people are more prepared and aware of the potential exposure to high heat Heat stress is often related to direct exposure to extreme heat. However, existing socioeconomic conditions often determine exposure and vulnerabilities. Households with the financial capacity to obtain air conditioners are far less likely to be exposed to extreme heat than poor households. This in turn determines vulnerability. The heat action plan had tried to incorporate these underlying conditions that can make certain groups of people more vulnerable into the heat action plan.The city administration, for instance, provided access to drinking water stations throughout the city, especially around bus stations where people are more likely to take shelter during high temperatures. The public were also made aware of basic coping measures such as increasing fluid intake on extremely hot days or using a wet doth on the head to cool oneself. These measures were especially relevant to the poor who lack access to air conditioning and often must work outside all through the day. The municipal administration, based on forecast warnings, also operationalized campaigns to reach out to people through media channels.

These baskets of options, adopted through the Heat Action Plan, resulted in fewer summer all-cause mortalities in 2014-2015 relative to 2007-2010 (Hess et al., 2018). However, since these options were predominantly preparedness and emergency response measures, future iterations of the heat action plan incorporated other mitigation measures, such as the Ahmedabad Cool Roof Program in 2017, which aimed at reducing indoor temperatures using reflective paints. This is especially important because the poor are often disproportionately affected by extreme heat events since they often live in dwellings that lack proper ventilation and do not have access to active cooling, which further increases indoor heat stress.

The Ahmedabad Heat Action Plan had a multiplier effect, with the Indian Government subsequently, through its National Disaster Management Authority (2016), providing an institutional impetus to lower levels of government to formulate city-specific heat action plans. But as cities in this region continue to grow in an unplanned manner, the long-term effectiveness of the above measures will be under question, especially since heat stress is a recurrent haz.ard. For instance, urban regions are particularly susceptible to high heat due to a phenomenon known as the Urban Heat Island effect. Lack of green spaces and high building density can raise the temperature of urban regions compared to greener peri-urban spaces. Hence, in the longer term, it is necessary to adopt mitigation policies that can address future vulnerabilities through proactive measures (Magotra et al., 2021), and mainstream justice and equity into urban planning and heat stress action plans. Hence, for hazards like heat stress that are more likely to reoccur, we would need a comprehensive policy approach that incorporates not just preparedness and emergency response but also building long-term, preventative and adaptive capacities amongall governance actors throughout society, not just in government

4.4. *Cross-cutting problem: Fast-thinking behavior*

So far, our discussion of the 3 big categories of environmental problems has focused on major policy instruments, often involving national legislatures and governmental agencies. Before analysts recommend such major intervention instruments, which can often be expensive for governments and be perceived as intrusive by citizens, analysts should consider whether the problems at hand have an element of fast-thinking behavior to them. If they do, there may be less costly and invasive options for policy response, which are discussed in detail.

"Fast-thinking behavior"is widespread in all sorts of decision-making and includes implicit biases that can skew our judgment so that we make decisions that harm society and even ourselves. We drive our cars short distances when we could easily walk or ride our bikes. We use plastic bags at the grocery store when we could bring reusable bags. We eat red meat several days a week when we could eat more vegetable-based protein, which would likely improve both our healthand carbon footprint "Fast-thinking behavior" is part of human nature. We are likely to see fast-thinking behaviors contributing to problematic behaviors and flawed decision-making associated with CPR extraction, pollution, and hazards. In a sense, this type of environmental problem cuts across all other categories of environmental problems.

When people do things out of habit, without consciously making decisions, it can be challenging for policy interventions to adjust the problematic behavior, precisely because people may not perceive the problem. This unconscious nature of problems is a feature that can make correcting these behaviors challenging. However, the framework provides some guidance regarding possible interventions to induce such behavior change.

Fast-thinking behavior problems are so widespread that they often permeate all decision-making, even the task of selecting effective policy instruments. Politicians and policymakers certainly are not immune to these problems and may decide to respond to an environmental problem using an unintentionally biased analysis. For example, decision-makers may make biased assumptions about the root causes of a problem, which will distort the search for an appropriate policy response. Policymakers who are told about the haz.ard of deteriorating infrastructure may choose to ignore such warnings because, in their minds, (1) the engineering report was very technical but it seemed to confirm what everybody already knew: the problem was not that bad (confirmation bias and cognitive bias); (2) the infrastructure problem is probably not so

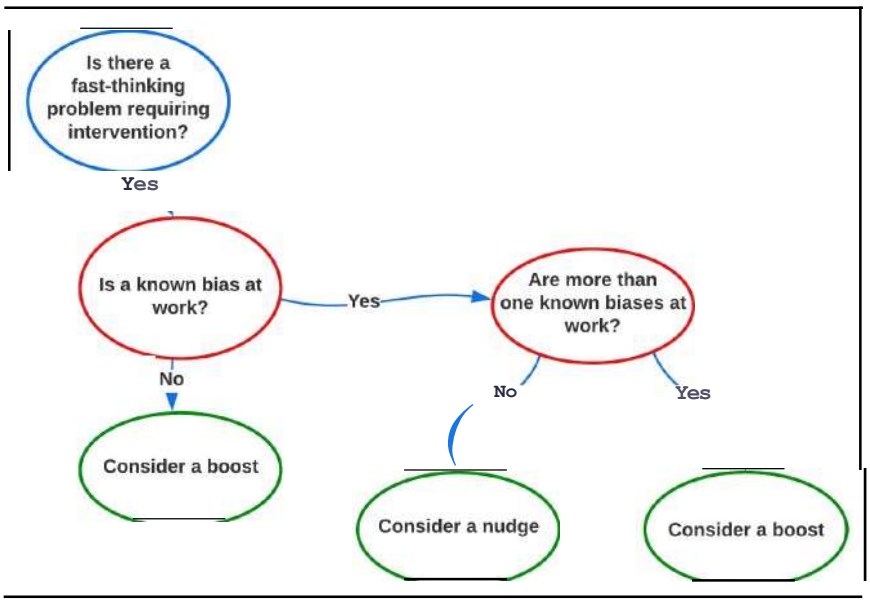

Figure 4. Diagnostic framework for analyzing responses to fast-thinking behavior. Source: Authors' elaboration.

urgent that it warrants inteiventions right away (present bias), or (3) in the past, policymakers have always come to the same conclusion that the infrastructure is well built and does not need more public funding than our schools or hospitals (confirmation and status quo bias).

The framework distinguishes between 2 different interventions to correct fast-thinking behaviors: nudges and boosts.[7] Which of these will be most appropriate to use in a given situation depends on several contextual factors. The framework can help determine which intervention type is the most sensical in a particular situation and context. A schematic oveiview of the framework is presented in **Figure 4.**

Nudges and boosts are similar in that they are interventions that seek to change people's decisions and actions without modifying material incentives or coercing them through heavy-handed directives or regulations. There are, however, some important differences in how they go about trying to influence human decisions and actions. **Nudges** seek to change behavior by altering the decision-making environment, for example, by presenting options in a particular order or changing the default option for a particular choice (the fullback option that is chosen for the participants who do not make an active choice). **Boosts,** on the other hand, try to change behavior by training people to make decisions in situations that are better for themselves and society.

After the analyst determines that there are at least some elements of fast-thinking and biased behavior contributing to the obseived environmental problem, the analysis turns to describing the decision-making situation more precisely. First, is the problem behavior caused by a known bias? Common biases include status quo bias (when you repeat routine decisions because you resist change and want things to stay the same), discounting bias (when you favor current benefits over future benefits), or confirmation bias (when you look for facts and data to support your existing point of view). If a known bias is the cause of the problem for a large group of known individuals, then a **nudge** may be the best intervention. A nudge uses the knowledge about the existing decision bias to bring about better choices by changing the decision-making context or environment, expecting that the individuals will change their behaviors as a response to the changed environment, not because people are intentionally changing their preferences or decision-making strategies.

An example of a nudge may be as simple as having the default settings for printers set to duplex rather than simplex (Egebark and Ekstrom, 2016) or providing real-time feedback on energy use (Tiefenbeck et al., 2016). Buffet restaurants may shrink plate sizes to reduce food waste (Kallbekken and Saelen, 2011), and airlines can cut energy use by sending personalized reminders to pilots that include dear, individual targets for fuel efficiency (Gosnell et al., 2016).

What happens if it is not possible to identify a specific decision bias or if different people make bad decisions for different reasons, not just because of known biases? In those cases, **boosts** maywork better than nudges. A boost intervention is different from a nudge in that it engages directly with the people responsible for poor decisions, raises awareness about problematic behaviors, and seeks to motivate the adoption of more productive decision-making strategies. Boosts work best when people are already aware of their problem behavior and are motivated to change their ways. Boosts teach simple decision strategies, or heuristics, that will help change behavior and that can be applied in a variety of decision-making settings.

7. Our discussion of nudges and boosts builds primarily on Grune-Yanoff et al. (2018).

Increasing statistical literacy, coproducing knowledge with local communities, and using graphics to illustrate different choices are examples of potential cognitive boosts. Ferster et al. (2020) used cognitive boost to encourage solar development by facilitating cooperation among stakeholders. A community without prior solar development ended up adopting 2 projects because of the intervention, and the cooperative behaviors stakeholders in the community learned were carried over to other decision-making settings with the community.

Since fast-thinking problems cut across all environmental problems and may play a contributing role in many other types of environmental problems, it raises the possibility that nudges and boosts may be pursued as complements to policy responses to other environmental problems including pollution, hazards, and CPR problems (Loewenstein and Chater, 2017). It is also worth considering how boostsand nudges may be used to sway decision-makers, who are also subject to implicit biases when trying to decide which policy inteIVentions make the most sense in a given context, to make more informed policy choices.

4.4.1. Illustration: Behavioral interventions and water conservation in Bogota, Colombia

Bogota, Colombia, faced a major water crisis in the mid-1990s.The city depends on the Chingaza tunnel system to deliver potable water to its residents from freshwater sources in the surrounding high plateaus. The Chingaza tunnel suffered 2 collapses within days of each other, cutting off the system's ability to deliver water to the city. ReseIVoirs within the city held sufficient water to last for a few weeks, but repairs were expected to take longer than the available water would last if consumption rates remained constant

The national government of Colombia pushed for drastic water cuts and rationing, and declared a state of emergency. The national government wanted the city to implement a top-down solution that would regulate water use by controlled and decreased flows. Yet, the city government had already implemented similar measures following a previous tunnel collapse, and the potential for further universal reductions in household water use seemed unlikely. Additionally, when citizens of Bogota saw that the national government declared a state of emergency, many of them panicked and started to stockpile water. As a result, in the days following the collapse, household water consumption in Bogota started to increase, rather than decrease. The national government policy response had failed.

The city government in Bogota recognized that the top-down solution was not viable and pushed for a series of behavioral interventions, resembling behavioral boosts (although the term did not exist at the time). A part of the "Citizen Culture" initiative of then-mayor Antanas Mockus, the interventions provided Bogota's residents with information on the collapse and encouraged rational household decision-making and water savings by giving citizens information on specific actions they could take to save water. The city government also involved youth, clergy, and other key community members in campaigns to encourage water savings. Humor and other emotions were used to make water savings tactics memorable (e.g., a 1V commercial with the mayor and his wife showering together to save water).

The behavioral inteIVentions proved quite successful, decreasing Bogota's water consumption drastically and preventing the need for water cuts or rationing. Additionally, Bogota experienced a sustained reduction in potable water use. In 2012, consumption of the city of Bogota was 0.16 m^3 per capita per day, much lower than per capita consumption in other capital cities in the region like Brasilia, Brazil (0.21) and Santiago, Chile (0.20) that same year (Plappally and Lienhard, 2012).

5. Additional policy response considerations

Once the analyst has narrowed down the possible policy responses, there are a few additional considerations that need the analyst's attention before she can present a more definitive recommendation for a policy response.The analysis prompted by the framework is largely technical in nature, but coming up with a response that makes technical sense is merely the first step of the policy analysis. For a proposed policy response to be successful and gain traction among decision-makers, it needs to pass 3 additional evaluative criteria.

First, there may be **legal constraints** in the jurisdiction where the problem is occurring-constraints that limit the choice of policy instruments that would be legal to apply. Some inteIVentions may make sense from a technical or analytical perspective, but the existing laws and policies in a particular place may not allow for these interventions to be implemented. For example, in some contexts, local governments may not be allowed to set pollution standards or introduce environmental taxes on industries operating within their territories. In some cases, national government agencies are the only entities authorized to introduce environmental policy responses that target private firms and industry. The analyst needs to make sure that the specific intervention strategies that she chooses to develop and recommend to the decision-makers are actually legal in the particular context.

Asecond type of constraint is **political** in nature. Some inteIVentions that make technical sense may not be politically feasible. Political feasibility is often difficult to assess for analysts because it requires deep knowledge of how politicians and their constituents think, and what is politically feasible or viable in one context may be political suicide in another.The public generally as well as influential interest groups, government agencies, and politicians can all introduce barriers to implementation of what the technical analysis suggested to be the best choice in policy instruments. For example, the framework tree might indicate that for a particular pollution externality, emissions taxes are the best option because they provide polluters the freedom to choose their abetment methods. However, if parties resist the tax, the government may have to compromise with a voluntary program or a command-and-control approach.

Table 3. Summary of plausible policy responses to the 4 major types of environmental problems

Problem	Possible Policy Instruments	Discussed on Page
Common-Pool Resources	1. Property rights, individual or community rights to a flow of benefits (could be based on land, or resource units)	6–7
	2. Comanagement, involving resource users and a government entity (or other governance actor)	7
	3. Support to community collective management, conflict resolution, enforcement backup, resource monitoring	7
	4. Direct regulation of use and access	7
Pollution	5. Direct regulation of pollution levels	8
	6. Setting and enforcing standards related to equipment or production process	8
	7. Voluntary programs	9
	8. Market-based subsidies, taxes, tradable pollution permits, and so on	9
Hazards	9. Prevention measures (training, readiness, infrastructure improvements, land-use zoning)	11-12
	10. Mitigation measures (humanitarian aid, rebuilding)	11-12
Fast-thinking behavior	11. Nudges (when biases are known in population)	14-15
	12. Boosts (unknown bias and/or groups)	14-15

Source: Authors' elaboration.

In some cases, a government faced with strong political and legal barriers to instruments designed to address externalities might opt to adopt policies to encourage research and innovation or to disseminate information because these strategies generate less resistance. While this approach may be politically popular and may even lead to marginal improvements in environmental conditions, for serious problems it is unlikely to lead to major reductions in environmental damage.

Finally, and perhaps most importantly, the policy analyst needs to consider the **ethical implications** of recommending a certain policy intervention. For example, some critics argue that it is unethical to use public funds to subsidize corporations to adopt cleaner technologies, or to allow private corporations to buy pollution reduction offsets from other firms rather than reducing pollution themselves, especially if the existing practices expose citizens to environmental harm. Part of these ethical considerations includes studying the distributional effects associated with a recommended policy intervention. Will the selected policy instrument improve environmental justice-reducing the vulnerabilities and improving the environmental health for all groups in society-or will it benefit mostly those members of society who are already better off?

Should the policy recommendation not clear the legal, political, and ethical criteria, the analyst may need to reconsider the recommended course of action, go back to the drawing board, and craft a new policy response strategy that measures up against all 3 criteria.

6. Conclusion

careful policy analysis has the potential to identify a suite of workable solutions to mounting environmental and social problems in society. The framework presented in this article can support analysts to think more systematically about potential policy responses to a wide variety of environmental problems. The framework is designed to help analysts think through the particularities of different environmental problems and their potential solutions, paying careful attention to the ways in which new policy responses can complement existing efforts to deal with the problems at hand. If policy recommendations fail to build on existing efforts, interventions can end up making problems worse. One contribution of this framework is that it can help avoid overly simplistic thinking about the role of public policy responses to several major environmental problems.

The article discusses 4 major types of environmental problems and the various policy intervention options that theanalysts have.**Table 3** summarizes the potential policy responses that apply to each of the 4.

In using this framework, it is important to be mindful of its limitations for applied policy work. The diagnostic framework asks questions about problems and the context in which they occur, but it does not offer definitive answers to those questions. The questions are there to stimulate thinking about the problem and its particularities, which we hope will lead to a deeper appreciation of the biophysical, socioeconomic, and political aspects of the problems at hand. What the framework will not do is prescribe the best response to any given situation. In that sense, the purpose of the framework is to elicit analytical thinking, not prescriptive commanding. The framework does not address how policy analysts might go about designing policy responses, which is a process that can be very important for the performance of policy proposals. How policy responses are conceived of, developed, and

eventually implemented-especially with regard to how involved a diversity of stakeholders are in this process-can play a big role in their eventual effectiveness (Matson et al., 2016), but this is an area of work that the sustainability science literature has already produced a considerable volume of studies (for a summary see Clark, 2007).

All public policy responses are imperfect human constructs that need continuous updating and tweaking to stay effective and relevant. No matter how innovative and ingenious a new policy initiative may seem, it is not likely to perform exactly as expected. Human-environmental interactions are complexand ever-changing, which means that any efforts to tinker with these interactions will produce unintended consequences. Policy analysts need to keep a close eye on how interventions are faring so that the intervention may be adjusted.This adjustment process requires good data on the performance of the intervention, which, in turn, requires the creation of robust systems for monitoring and evaluation (systems for collecting data on how human behavior may have changed because of the intervention). The need for learning about policy performance through active monitoring and evaluation is another area that the diagnostic framework does not address directly but is nevertheless an important component of the design and implementation of effective public policy. It is also an area in which independent researchers have an important role to play-to provide decision-makers with unbiased and scientifically sound evidence on policy performance.

The framework will help analysts conduct a context-sensitive analysis of plausible policy responses to common environmental problems. Proposing a technical recommendation, however, is but a first step in the policy process. An effective policymaking process requires engagement of multiple interestsand expertise.The policy analyst plays an important role in this process, but it is one of many actors involved. Effective policy analysts are humble, creative, system thinkers,who know how to adapt to a variety of decision-making environments. They know that their technical analysis of the problem and potential solutions represent just 1 ingredient in the overall policy strategy to address a problem. By being sensitive to the ethical, legal, and political circumstances of that environment, policy analysts will be able to facilitate a productive public debate about what to do about pressing environmental problems.

Data accessibility statement

Only publicly available bibliographic information was used for the analysis presented in this article.

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Author contributions

Contributed to conception and design of the framework: KA, CB, and KR

Contributed to acquisition of case studies: KA and CB

Contributed to analysisand interpretation ofcasestudies: KA, CB, and KR

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Domain Editor-in-Chief: Alastair lies, University of California Berkeley, Berkeley, CA, USA

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