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Optimal Design of Climate-Smart Policy for Agriculture: Economic Principles and Political Considerations

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Many countries implement policies to address farming-related conservation issues such as soil erosion reduction, water quality protection, and soil carbon sequestration for climate change mitigation (Salzman et al., 2018). These policies are often referred to as conservation programs or agri-environmental policies (Baylis et al., 2022). Incentive schemes are typically built into these voluntary programs to encourage participation. Under such schemes, farmers often receive payments in exchange for adopting conservation practices or engaging in climate-smart activities. Such payments are often called payments for ecosystem services (PES) or green payments.

PES is not a new idea, but it is perhaps even more relevant today than in the past, partly because both public and private expenditures on ecosystem services have increased significantly over the years (Figure 1); this trend will likely continue given the potential role that PES could play in building resilience to climate change (Rausser and Zilberman, 2023). For example, the Inflation Reduction Act (IRA), signed into law by President Biden in August 2022, provided an additional $19.5 billion to support the USDA's conservation programs, including $8.45 billion for the Environmental Quality Incentives Program and $3.25 billion for the Conservation Stewardship Program (USDA, 2023). The European Union has historically spent considerably less on agri-environmental programs but has tripled its conservation expenditure since 2007 (Hodge, 2014; European Commission, 2023).

The rapid increase in conservation spending is by no means coincidental. There is broad public support for such programs. To farmers, PES is a new way of securing farm income support. To environmentalists, it is a new way of securing resource conservation and environmental protection. For many NGOs and international organizations, it is a new way of fighting poverty. To others, it is a new way of preserving the status quo of farm income support. Because of the broad support, conservation expenditures will likely continue in the future.

With increasing public expenditures on conservation, several issues have been raised, including:

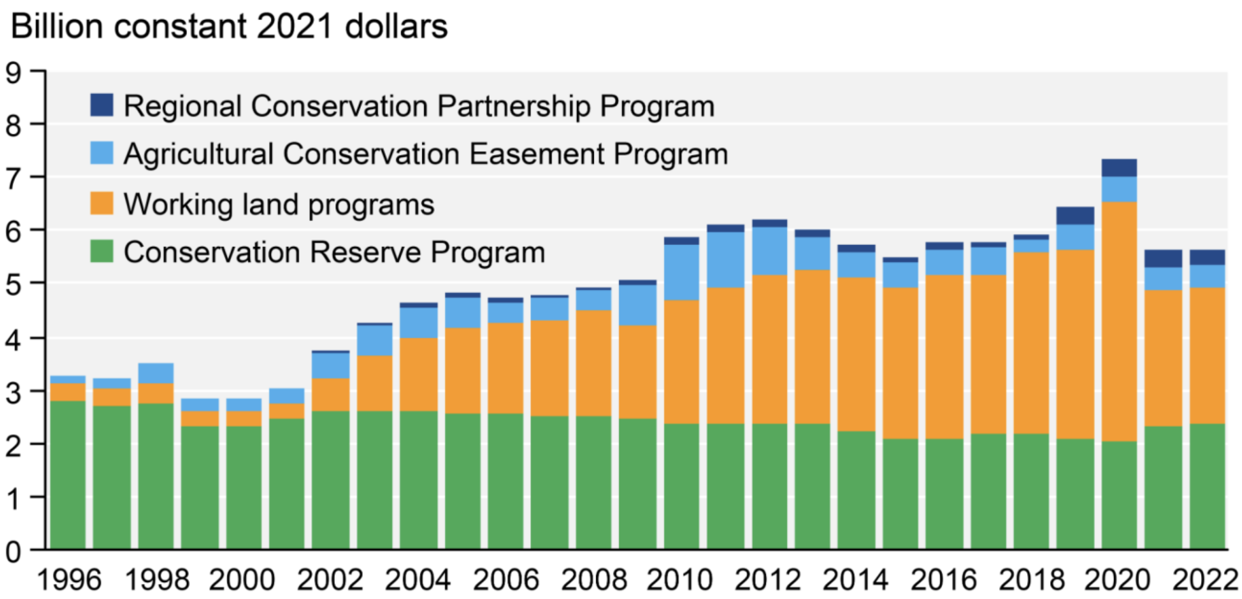
- How should conservation funds be allocated among different geographic areas or jurisdictions?
- Within a given geographic area, what criteria should be used to target resources for conservation?
- Should payments be based on adopting certain conservation practices (e.g., establishing riparian buffers or no-till practices) or some measures of environmental benefits (e.g., improved water quality or increased fish production)?
- How should the government deal with the additionality issue (i.e., farmers may demand payments for conservation practices that they would adopt anyway)?
- What are the distributional implications of alternative conservation targeting strategies?
- If poverty reduction is a policy goal, what are the most effective targeting criteria for achieving this goal?

In this article, I first describe several commonly used criteria to target resources for conservation and then discuss their environmental and political economy implications. Finally, I discuss the challenges of designing a truly efficient conservation program and propose an approach to addressing those challenges.

Targeting Conservation Efforts

Policymakers have many options at their disposal when targeting resources for conservation. For example, they can target resources that provide the highest

Figure 1: Major USDA Conservation Program Expenditures, Fiscal 1996-2022



Note: Working land programs include the Environmental Quality Incentive Program (EQIP), the Conservation Stewardship Program (CSP), program-related technical assistance, and predecessor programs. Values adjusted to 2021 dollars using the Gross Domestic Product Implicit Price Deflator.

Source: USDA (2023c)

environmental benefit per resource unit. The U.S. Fishery and Wildlife Service targets wetlands and other conservation resources based on biophysical criteria. Policymakers can also target marginal lands or least expensive resources for conservation. Previous studies have found that the enrollment patterns of the Conservation Reservation Program (CRP) were consistent with this targeting criteria at the early stage of its implementation. Policy makers can also target resources that offer the highest benefit-cost ratios or preserve resources that lead to the largest environmental benefit for a given budget, which is the stated objective of several recent conservation programs, including the EQIP and CREP. These four approaches have been referred to as benefit targeting, cost targeting, benefit-cost ratio targeting, and benefit-maximization targeting, respectively (Wu, Zilberman, and Babcock, 2001). Conservation-targeting approaches have evolved significantly over the years due, to a large extent, to our better understanding of the economic, environmental, and distributional implications of these targeting approaches.

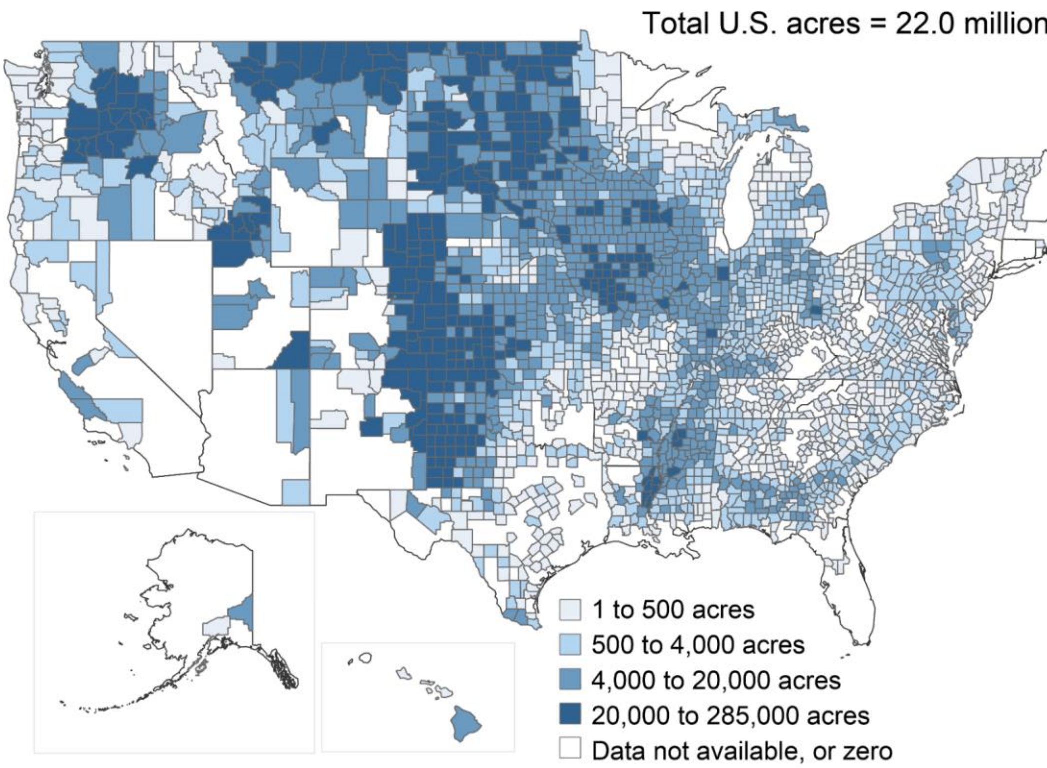
Performance of Alternative Targeting Criteria

Different targeting criteria can lead to dramatically different economic, environmental, and distributional outcomes. Wu, Zilberman and Babcock (2001) compared the performance of alternative targeting criteria in terms of 1) the amount of land in conservation, 2) the amount of land in production, 3) total output, 4) output prices, 5) total environmental benefits, 6) consumer surplus, and 7) producer surplus. They found that cost targeting leads to the largest amount of land in conservation and the smallest amount of land in production. As a result, it leads to the lowest total output, the highest output price, and the largest producer surplus. Thus, cost targeting should be the landowner's most favored targeting strategy. In addition, cost targeting leads to the lowest demand for labor and other agricultural input. Thus, it should be labor and input suppliers' least preferred strategy. Cost targeting is the most pro-poor policy if the poor are the landowners. However, if the poor are laborers or input suppliers but not the landowners, it will be the least pro-poor policy. Zilberman, Lipper, and McCarthy (2008) argued that PES is not necessarily progressive; it may actually hurt the poor.

In contrast, benefit targeting leads to the lowest output price and the highest consumer surplus because it leads to the smallest amount of land in conservation and largest amount of land in production. Therefore, it should be consumers' most preferred strategy, particularly among those who benefit little from the environmental improvements. Labor and input suppliers may also support this strategy because it leads to the largest amount of resource in production and the highest demand for labor and other agricultural input. It is the landowners' least preferred strategy because it results in the lowest output price and the smallest producer surplus.

Benefit-cost ratio targeting is the most efficient strategy (i.e., maximize the sum of producer surplus, consumer

Figure 2: Conservation Reserve Program Total Enrolled Acres by County, 2022



Note: Total acres include continuing and newly enrolled acres as of September 30, 2022.

Source: USDA (2023b)

surplus, and environmental benefit for a given budget). However, it is not the most preferred strategy of any interest group.

Benefit-maximization targeting would be equivalent to benefit-cost ratio targeting if the output price were not affected. However, if the conservation program is large enough to raise the output price, benefit-maximization targeting will generate more environmental benefits for a given budget than benefit-cost ratio targeting. By preserving more high-benefit and high-cost resources, benefit-maximization targeting will cause less reduction in total output and a smaller increase in output prices. As a result, fewer acres of marginal land will be brought into production (i.e., less slippage).

Another important political economy consideration in the design of agri-environmental programs is the spatial distribution of program benefits among jurisdictions. For example, CRP land and the associated economic and environmental benefits are highly spatially concentrated, with most program benefits being accrued to the Great Plains, Montana, the Columbia River Basin, and some areas in the Corn Belt (Figure 2). Given that broad program participation has been an important policy goal, it is important to ask if it is possible to spread the program's benefits without sacrificing its efficiency.

Wu and Yu (2017) analyzed this issue using individual bid data from the 18th CRP sign-up. They showed that if a farmer is compensated for their opportunity cost of participation, maximizing environmental benefit per dollar expended is equivalent to maximizing the Marshallian aggregate surplus (i.e., the sum of consumer surplus, producer surplus, and total environmental benefits). Therefore, they measured efficiency by the total environmental benefit per dollar expended. In addition, they measured distributional equity using several indicators, including a Gini coefficient constructed based on the CRP payment per capita of rural farm population. They also measured the performance of different targeting criteria relative to the efficiency-equity frontier. They found that the USDA forfeited about 9% of efficiency for an 18%–23% gain in distributional equity, depending on the equity indicator used. The CRP targeting criterion could be redesigned to achieve both higher efficiency and higher distributional equity.

Challenges for Designing an Efficient Conservation Program

Historically, U.S. conservation programs have been designed to protect specific resources, managed by different agencies, and targeted using some onsite, physical criteria (Wu and Boggess, 1999). A major problem with such a targeting approach is that it ignores some key features of ecosystems, including threshold effects, ecosystem linkages, and spatial interactions among ecosystems.

A threshold effect is present when a significant environmental improvement can be achieved only after conservation efforts reach a certain threshold (Wu, Adams, and Boggess, 2000). Threshold effects have been found in many conservation efforts, particularly those involving fish and wildlife. For example, in a study of the relationship between the northern spotted owl survival and suitable habitat, Lamberson et al. (1992) found that when suitable habitat is less than 10% of the landscape, the chance for northern spotted owl survival is almost zero, however, when suitable habitat reaches 15% of the landscape, the chance for survival reaches 80%, and when suitable habitat reaches 20% of the landscape, the chance for survival reaches 95%. This nonlinear relationship has important implications for conservation fund allocation: If conservation funds are divided equally between two watersheds and the funds are only enough to restore 10% of landscape in each watershed, little benefit would come out of the effort in terms of northern spotted owl survival. However, if all money is allocated to one watershed and 20% of the landscape is protected, the chance for survival in this watershed would reach 95%. This simple example suggests that when threshold effects are ignored, funds tend to be overly dispersed geographically, and substantial benefits could be lost.

We have conducted several case studies to demonstrate the importance of considering the threshold effect in the design of conservation programs. In every case study, we found that program efficiency would increase significantly if this key feature of ecosystems were considered. For example, in one of the case studies, we focus on salmon restoration in the U.S. Pacific Northwest. Salmon restoration is an important issue in the region because salmon have disappeared from 40% of their historical breeding ranges, and many of the salmon runs have been listed as endangered and threatened under the Endangered Species Act. Because of the complex life cycle of salmon, many reasons have been cited for the declining salmon population, including overharvesting, unfavorable ocean conditions, dams that block their migration routes, and freshwater habitat degradation caused by land use practices such as deforestation and grazing. To address the problem of declining fish population, billions of dollars of taxpayer money have been spent on salmon restoration during the last 30 years. A common practice in habitat restoration is to target streams for restoration based on riparian conditions. For example, under Oregon and Washington's Conservation Reserve Enhancement Programs, farmers are compensated for restoring riparian conditions along the salmon streams.

Threshold effects are present because of the nonlinear relationship between stream water temperatures and fish production. Salmon, a cold-water species, cannot survive when the temperature is above a certain level. However, when targeting is based on riparian conditions, streams with very high temperatures may receive funding, even if conservation efforts will not lower temperatures enough to benefit fish. Similarly, streams that have very low temperatures but poor riparian vegetation, may be targeted for conservation. Improving streamside vegetation in those streams will not generate any benefit. Wu and Skelton (2002) calculated benefit losses if targeting is based on stream riparian conditions and found that such on-site targeting criteria could lead to substantial benefit loss.

The second problem with the traditional targeting approaches is that they ignore the relationships between alternative environmental benefits. Such relationships can take two forms: interactions or correlations (Wu and Boggess 1999). Interactions refer to the causal relationships between different environmental benefits. For example, improving stream water quality also enhances fish habitats. The correlation refers to the situation where the same conservation effort jointly produces two environmental benefits, although these two benefits have no causal relationship. For example, land retirements provide both wildlife habitat and groundwater quality benefits, although the two benefits have no direct causal relationship.

To demonstrate the importance of considering ecosystem linkages, Wu and Skelton (2002) examined the effect of stream water temperatures on a warm-water fish species (speckled dace) and a cold-water fish species (rainbow trout) in several watersheds in Oregon. As riparian conditions improve and the water temperature goes down, the number of speckled dace decreases while the number of rainbow trout increases. Four speckled dace would be lost for every $100 gained from increasing cold-water fish species. Speckled dace is not an endangered species, so the trade-off favors the cold-water species. But if the warm-water species were also an endangered species, the decision would not be as clear cut.

The third problem with the current targeting approaches is that they ignore the spatial interactions between ecosystems. Spatial interactions of ecosystems can take many forms, some more subtle than others. For example, land use upstream affects water quality downstream. Conservation in one place may affect environmental quality in the surrounding areas.

In a case study of the Grande Ronde Basin in Oregon, Watanabe, Adams, and Wu (2006) demonstrated the importance of considering the spatial interactions in the design of conservation programs in a river system. If the objective is to reduce water temperatures at the end of the basin downstream and the desired temperature reduction is only 1ºC, the most efficient way to achieve this objective is to restore riparian conditions near the end of the basin. However, as the desired temperature reduction increases, it becomes necessary to apply conservation in upper stream reaches. If the desired temperature reduction is 4ºC or above, the riparian buffers for the entire basin need to be restored. Also, the optimal spatial allocation of conservation efforts can be dramatically different for different water quality standards. Furthermore, if the ultimate objective is to maximize salmon populations in the basin, targeting based on water quality can be very inefficient. For example, if the water quality standard is 22º C and the fund is allocated to maximize the stream length where the water quality standard is reached, it can only achieve 12% of the total benefit that would be obtained when the conservation efforts are targeted explicitly for fish benefits.

Approaches to Improving Conservation Efficiency

In the presence of threshold effects, ecosystem linkages and spatial connections, a three-step approach can be used to improve program efficiency. First, divide the entire landscape into small basins. This requires a thorough consideration of soils, climate, vegetation, and the region's topographical, hydrological, and biological features. Each basin must be large enough to include a whole watershed and small enough to capture the spatial variations across the landscape. For example, New Zealand is divided into 85 ecological regions and 268 ecological districts using information about geology, topography, climate, and biota to establish a bio-reserve system (New Zealand Biological Resources Centre, 1987). U.S. Environmental Protection Agency (2023) uses a watershed approach to address water resource challenges, and claims it is the most effective framework.

Once the basins are defined, in the second step, a bidding process like the one used in the CRP could be used to select resources for conservation. Each bid must specify the conservation practices it will adopt and the annual rental payment from the program.

In the third step, bids are accepted into the program based on benefit-cost ratios. In addition, fund allocations across basins should ensure that 1) thresholds are reached in all funded basins and 2) the marginal benefits of conservation spending are equalized across the funded basins. In some situation, threshold effects may be unobservable. If so, policymakers could adopt an all-or-nothing approach: conserving all or nothing in a basin. This all-or-nothing approach could be more efficient than an approach that pay for the targeted benefit explicitly in the presence of threshold effects (Lewis, Plantinga, and Wu, 2009).

Concluding Comments

In most conservation investments, strong non-linearities and ecosystem linkages can mitigate politically feasible targeting criteria. The design of agri-environmental programs must consider these complexities. Formulas or guidelines based on political consideration, or keyed to a specific on-site physical criterion, can result in substantial efficiency losses. In addition, the design of agri-environmental programs must consider their distributional implications; while a well-designed agri-environmental program can be progressive, a poorly designed one can be counterproductive. Previous studies suggest programs that enhance agricultural practices tend to lead to more employment, whereas land diversion can have the opposite effect (Zilberman, Lipper and McCarthy, 2008). With growing concerns about climate change, PES can play a key role in introducing conservation practices that increase carbon sequestration and build resilience to climate change (Rausser and Zilberman 2023). While challenges are daunting, they are not insurmountable. With the aid of artificial intelligence, machine learning and other advanced technologies, interdisciplinary collaboration in the design of conservation programs can lead to large improvements in both efficiency and distributional equity.

For More Information

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