Crediting Uncertain Ecosystem Services from Working Landscapes: Balancing Program Integrity and Cost-effectiveness

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The use of market-based instruments is expanding beyond traditional pollutants to include incentivizing voluntary ecosystem service provision from working landscapes, such as agriculture and forestry. These services are estimated with much greater uncertainty than traditional point source pollutants. Using protocols for greenhouse gas offsets in California as an example, I discuss the use of discounting ecosystem services to ensure program integrity and highlight tradeoffs between achieving reported service provision with high confidence and program cost-effectiveness.

In California, greenhouse-gas offset protocols take a conservative approach to crediting under measurement uncertainty through confidence deductions.

Incentivizing the provision of ecosystem services (ES) from working landscapes like forestry and agriculture is a key component to achieving a host of environmental goals. Improved management holds promise for bolstering services like greenhouse gas (GHG) mitigation, water pollution mitigation, soil protection, and species conservation. There is growing interest in developing policy options for encouraging the participation of private landowners in supplying ES.

Market-based approaches offer a promising approach for incentivizing the voluntary provision of ES without imposing new obligations on landowners. For example, offsets, mitigation banking, or payments for ES can be used to encourage changes in private land management that provide environmental benefits. However, quantifying the level of services provided presents a distinct challenge since direct measurement of many ES is not economically feasible at large scales.

In lieu of direct measurement, in many cases quantification will rely on models to map management changes into ES improvements—a process sensitive to both model and input uncertainty. In this context, protecting the integrity of environmental programs requires a mechanism for ensuring that reported outcomes are achieved with the requisite level of confidence. However, achieving high confidence involves tradeoffs.

Requirements for intensive monitoring or the use of purposely conservative estimates will likely reduce net returns to landowner participation and therefore increase overall program costs. Realizing the potential of working landscapes to provide ES will require balancing the competing objectives of cost-effectiveness and confidence.

Greenhouse Gas Offsets

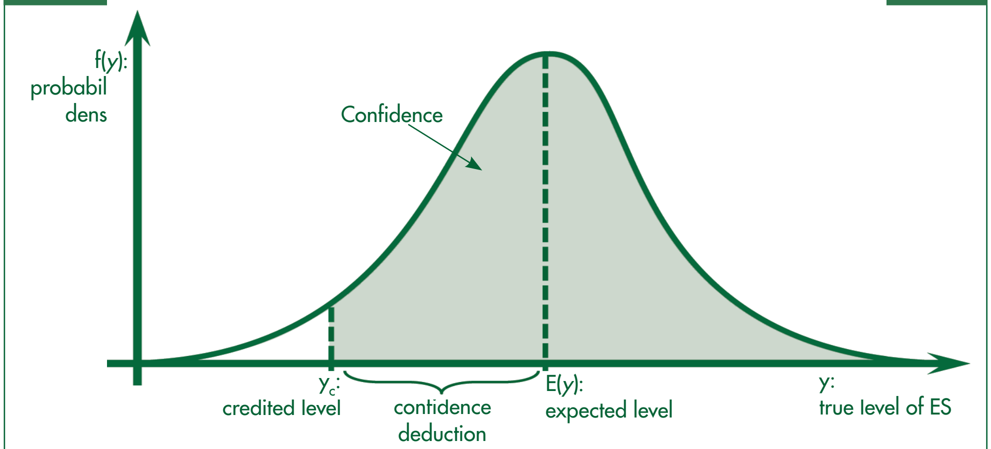
Recent developments in the use of GHG offsets in California provide a rich case study for exploring issues of measurement and uncertainty in the context of ES provision. The final regulation order for California's Global Warming Solutions Act of 2006 specifies the terms for GHG permit trade and for the voluntary provision of GHG offsets from sectors that are not covered by the cap (e.g., agriculture and forestry).

Relative to smokestack emissions, the determination of avoided or sequestered GHG emissions from land management changes is subject to large uncertainty. Instead of direct measurement of emissions, which is not economically feasible, emissions from rice farming, for example, are slated to be modeled using a biophysical process model (DAYCENT).

Since verification of GHG offsets from management of working landscapes is difficult to do with precision, the California Air Resources Board (CARB) requires offset suppliers to conservatively account for uncertainty, largely via use of a confidence deduction. This is illustrated in Figure 1(page 10), which depicts a probability distribution, f, summarizing uncertainty surrounding the true level of ES provided, y.

If f(y) is symmetric (e.g., a normal distribution) then the expected level, E(y), is also the most likely outcome—crediting at this level would ensure a 50% chance that the true level of ES

Figure 1. Uncertainty Over the True Level of ES Provided and the Confidence Deduction



met or exceeded the credited level. A typical target level of confidence (shaded area) in this setting is substantially greater, e.g., 90% in the case of existing and proposed offset protocols in California. This conservative approach involves crediting a lower level of ES, e.g., y_c, and thus involves a confidence deduction relative to E(y). The greater the uncertainty about the true level of ES provided, the greater the dispersion in the distribution and the larger the confidence deduction.

While such conservative crediting of ES reduces the likelihood of over-crediting, it is also likely to impose costs. A leading concern is that discounted compensation may reduce landowner participation. Even if participation is held fixed, the credited level of ES made available to the market is decreased by the confidence deduction. As the number of ES credits made available to the market is discounted and as potential sources of low-cost mitigation drop out, the overall cost of achieving GHG reduction targets is likely to rise.

Aggregation and Uncertainty

Uncertainty in the level of ES provided can be ameliorated to some degree by aggregating over multiple sites. As long as drivers of measurement uncertainty are uncorrelated across sites, pooling contributions will reduce uncertainty about the average level of ES being provided. Intuitively, we might expect errors of over-estimation and under-estimation to tend to cancel out as the number of bundled sites increases.

In the context of GHG offsets, CARB is allowing for "Authorized Project Designees" to act as intermediaries to bundle together emissions reductions across multiple sites to achieve economies of scale. Figure 2 illustrates this pooling process from sites to bundles, and finally to the aggregate level of GHG offsets provided to the market.

While uncertainty may attenuate to some degree due to aggregation, this process raises challenging policy design questions. Not least of these is the question of where in this process of aggregation should preferences with respect to uncertainty be imposed? For example, if the regulator wishes to be 90% confident that true provision of ES meets or exceeds the credited level, should that requirement be imposed at each site, each intermediate bundle, or the overall pool provided to the market? While this may appear at first to be a relatively minor consideration, the following example illustrates the surprisingly strong implications of this choice.

Suppose an intermediary bundles together emissions reductions from 10 sites (assuming for simplicity that each site shares the same mean and standard error of estimated ES provided). If a confidence level of 90% is imposed for each of the individual sites, this results in a surprisingly stringent implicit level of confidence achieved at the bundle level of 99.998%.

In California, GHG offset protocols adopted for forestry and under development for crops include confidence deductions applied at the site or project level. This creates the potential for particularly stringent response to uncertainty when viewed from an aggregate perspective.

While the example above shows that applying risk preferences at the site level may lead to an unintentionally stringent aggregate response, there are information and coordination challenges to applying risk preferences at aggregate levels. These challenges arise due to a potential mismatch between the scale of participation (site) and the scale at which uncertainty matters.

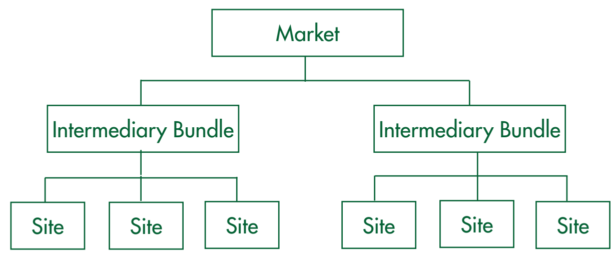
For some ES, it may be the case that achieving credited outcomes with high confidence at each individual site is desirable. This would be true if the benefits of ES provided at a site are non-linear. For example, this concern could be salient given changes to a pollutant subject to hotspots concerns or spatially dependent biodiversity objectives.

However, when dealing with an ES like GHG mitigation for which benefits are essentially linear and not spatially dependent, it is less clear that achieving high levels of confidence at the site level is required. Thus, uncertainty might matter at an aggregated scale while decisions about participation occur at a disaggregated scale.

Addressing uncertainty at an aggregate level requires measurement information from all sites to be known before any confidence deduction can be evaluated. While the average confidence deduction falls as uncertainty requirements are imposed at higher levels of aggregation, potential participants have less certainty over what deduction to expect.

The basic model of confidence deductions and aggregation presented above is complicated by the potential for correlated error across sites in the estimation of ES provided. When error is random, accounting for uncertainty is relatively straightforward and aggregation across sites ameliorates uncertainty to some degree. However, estimation error may be correlated across sites when, for example, there is error in a particular model for estimating ES that is applied across sites (e.g., the DAYCENT model proposed for rice crop offsets).

Figure 2. Aggregation of ES from Sites to Intermediary Bundles and the Overall Pool Provided to the Market



If present, bias has two important implications. First, in contrast to random error, uncertainty generated from bias is not ameliorated by aggregating across sites. Second, the uncertainty generated by bias will be overlooked if confidence deductions occur solely at the site level.

Under the basic model discussed above, it was also suggested that as the desired level of conservativeness increases, confidence deductions increase and participation likely falls. However, this relationship is not as clear cut as it first appears. When a confidence deduction is imposed, two competing effects determine supplier participation and welfare.

First, for each unit of expected mitigation provided, suppliers are credited for less than a unit. But the deduction also means that buyers have to secure more units of expected mitigation to achieve the same level of credited mitigation. If demand is sufficiently inelastic (unresponsive to price) and the latter effect dominates, the imposition of a confidence deduction could on balance drive an increase in the quantity of expected mitigation demanded, and thus increase supplier participation and welfare.

Transactions Costs, Co-benefits and Additionality

Some level of participation costs associated with monitoring and reporting are essential but nonetheless a disincentive for participation. Given likely increasing returns to scale in this activity, we might expect smaller landowners to be less likely to participate since they would be less likely to recoup these transactions costs. While this may raise distributional concerns, implications for cost-effective provision of the ES itself appear limited. However, in the presence of co-benefits, such selection on participation by size may be a cause for concern.

Changes in agricultural practice to reduce GHGs can affect soil erosion and water pollution. Changes in forestry practice can affect biodiversity. To the degree that such co-benefits provided differ by landowner size, the presence of transactions costs could have unintended consequences for the type and spatial distribution of co-benefits. For example, small agricultural landholders may be concentrated near populated areas or small forestry landholdings might support a different set of species than large landholdings.

Conclusions

Regulators face difficult policy design tradeoffs in the design of market-based polices for the provision of ES from working landscapes. How should uncertainty be addressed to find the right balance between maximizing confidence in program integrity and minimizing the overall cost of achieving environmental objectives? Furthermore, at what scale should the regulator impose preferences with respect to uncertainty when the scale at which uncertainty matters diverges from the scale of participation?

In the case of GHG offsets in California, there are compelling reasons to move from imposing risk preferences at the site level to a higher level of aggregation. However, such an approach generates information and coordination challenges for implementation. Finding the balance between tradeoffs in these design questions will be an empirical challenge to address as new markets get off the ground.

Suggested Citation:

Springborn, Michael. 2014. "Landscapes: Balancing Program Integrity and Cost-effectiveness." *ARE Update* 17(4):9-11. University of California Giannini Foundation of Agricultural Economics.

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Springborn, M., B.L. Yeo, J. Lee, and J. Six. 2013. “Crediting Uncertain Ecosystem Services in a Market.” *Journal of Environmental Economics and Management*, 66(3), 554-572. www.sciencedirect.com/science/article/pii/S0095069613000648.