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Are Community-Based Approaches to Manage Herbicide Resistance Wisdom or Folly?

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Farmers have long organized cooperatively for the purpose of marketing and promoting agricultural commodities. Yet, taking collective actions affecting individual on-farm production decisions remains challenging. A few exceptions to this tradition include efforts to tackle serious pests that cross farm boundaries, such as eradicating the pink bollworm in California and the boll weevil in the South. Those cooperative efforts accomplished their pest control objective, while saving farmers money in the long run (Carlson, Sappie, and Hammig 1989; CDFA, 2016). Yet, it took considerable time and investment for them to work. Now, attempts to tackle citrus greening are experimenting with area-wide approaches to avert a major pest crisis that threatens that industry (Bergamin Filho et al., 2016).

If a cooperative, community-based (CB) approach can work for invasive insect problems, can it be used to control the spread of herbicide resistant weeds? The answer is, "it depends!" While in some settings, a CB approach may be unnecessary or economically unattractive, in others there are compelling economic reasons that may make CB approaches a good option.

A Tragedy of the Commons?

Whether a cooperative approach is necessary to curb resistance turns mainly on the relative mobility of the pest (Miranowski and Carlson, 1986). Early research on pest resistance viewed mobility as a problem with insects, but not with weeds. There is growing evidence, though, that weed mobility is a more significant problem than previously thought (Ervin and Frisvold, 2016). Mobility can occur via pollen drift from resistant weeds, from seeds hitchhiking on machinery that moves across multiple farms, counties and states, movement of hay, and via weed seeds floating down streams and rivers. For example seed dispersal of Palmer amaranth has been reported via irrigation, birds, mammals, plowing, mowing, and harvesting.

If herbicide resistance traits are mobile, the susceptibility of those weeds to herbicides becomes a common pool resource—a resource shared by operators across the affected community. It is in the collective interest of farmers to delay resistance and conserve the efficacy of an herbicide in such cases. Yet, actions taken by individual farmers to conserve the usefulness of an herbicide cost time and resources. Each farmer has an individual incentive to use the herbicide in the short run, without considering the effects on neighbors. By neighbors, we mean farmers close enough that weeds seed and pollen can reach the farmer's field and vice versa. Just as every farmer pumping groundwater knows that over-drafting can deplete an aquifer, each still has an individual incentive to pump in the short run. Individual farmers may not manage resistance because they are not assured their neighbors will match their stewardship actions.

If resistant weeds are significantly mobile, it sets up a "tragedy of the commons" where the susceptible weed gene pool will be exhausted without control. Garrett Hardin coined this phrase in his famous *Science* essay about the population explosion and the threatened depletion of natural resources held in common, such as communal pastures. Hardin argued that human conscience is not an effective remedy to excessive use and that forms of "need for mutual coercion, mutually agreed upon (p. 1246)" to redress these problems. His arguments have often been interpreted as the need for some form of top down government intervention to remedy the potential tragedy. Yet, subsequent research by the late Elinor Ostrom, 2009 Nobel Laureate in Economics, and her colleagues documented numerous common pool resource situations where voluntary, collective action by local users led to effective resource management. Voluntary, collective efforts do not take root and succeed in many common pool resource situations, though. So, critical questions are when are CB approaches really needed and what are the keys to their success?

One can envision three main approaches to control access to the common resource: (1) top-down government regulation; (2) public or private payment schemes to discourage practices that diminish the resource stock, and (3) bottom-up, community-based programs. Many environmental programs use top-down regulations to control access to common property resources. The Clean Air and Clean Water Acts are prime examples. The regulations typically prescribe acceptable treatment practices or emission discharge levels. In general, farmer production practices have not been directly regulated through command and control regulations. A primary reason is that the pollution sources must be clearly identified and monitored. Monitoring the on-farm production and weed resistance management practices of the more than two million U.S. farms would be very costly and politically infeasible. Alternatively, herbicide use could be regulated indirectly, for example through regulations that approve certain pesticides for use only in alternating years. However, pesticide cancellations or broad use restrictions can be blunt and expensive instruments because they do not account for differences in farming conditions across crops and regions.

One approach to alter farm production practices has been to provide payments to farmers in return for their adopting more environmentally friendly practices. Since the 1980s, U.S. farm legislation has introduced government payment programs to conserve resources, with a mixed record of success. Under these programs, payments are based on the use of particular practices or technologies not on actual environmental performance—such as the concentration of fertilizers in water runoff—as the latter is very difficult to monitor at the farm level. A problem with payments is that practice adoption may not have desired environmental outcomes in all settings. Payment schemes may also have limited leverage in changing farmer behavior, termed "additionality." Payments are additional only if they induce farmers to adopt practices that they would not undertake without the payments. If producers receive payments for practices they have already adopted or that would be profitable anyway, these payments do not lead to additional resource conservation. They simply become income transfers to farmers, a form of inefficiency that has plagued some agricultural conservation programs. Similarly, payment levels may be too low for some farmers, providing insufficient incentives to conserve resources. Payment schemes require significant monitoring and data collection to assure the payments result in the desired impacts. Some payment-based programs to improve resistance management have been implemented by industry—such as Monsanto's rebate payments to encourage residual herbicide use. But, it remains an open question if such programs are large enough or sufficiently well-targeted to generate much additionality.

How and When Might Community-Based Programs Work?

The bottom-up CB approach has been documented by Ostrom and others who found that open access does not always lead to uncoordinated and competitive resource exhaustion. In such cases, resource users are actively involved in the design, financing, and implementation of programs. Usually, there is collaboration with industry, government, and universities. The role of government is distinctly different from that of the top-down, command-and-control or payment-based approaches. It is often as a facilitator and provider of scientific knowledge and complementary investments. Implementation still requires significant design, monitoring and compliance resources as well as a clear delineation of the relevant community of stakeholders, beyond just the growers. While resource users may benefit from government technical and financial assistance, they often must also provide their own additional funds through internal support schemes.

The possible development of community-based approaches for resistance management rests on three rationales. First, farm operators have the most intimate knowledge of the local natural resource and social conditions. Second, as such, they are more likely to develop resistance management practices that fit their local agronomic, economic, and social circumstances. Third, resource users have a direct stake in creating institutions that are fair and effective because they need assurance that their neighbors will reciprocate their good stewardship actions. This last argument implies that the resource users have an interest in conducting monitoring and applying appropriate penalties when some operators do not comply with locally prescribed resistant management practices. That inclination will likely lead to more reasonable monitoring and enforcement costs than with top-down approaches.

Despite the persuasive rationales, CB efforts will not form in all resource settings. Based on extensive research, ten factors affect the likelihood of users to self-organize (Ostrom, 2009).

1. *Size of the resource system* – Moderate sized systems that produce enough valuable services are most conducive to self-organization.
2. *Productivity of resource system* – There is an inverted U-shaped relationship between resource productivity and self-organization. If resources are abundant and productive, there is little demand for controlled management. If resources are severely depleted, there is little gain from managing an unproductive system.
3. *Predictability of resource system dynamics* – Accurate prediction and management requires adequate scientific understanding of the system.
4. *Resource unit mobility* – Self-organization is less likely for highly mobile resources, such as wildlife or water in an unregulated river that ranges over great distances.
5. *Number of users* – The effect of group size on self-organization depends on the socio-ecological system and is indeterminate. Smaller group size reduces transactions costs, but can also encourage strategic (mis) behavior.
6. *Leadership* – When certain resource users have entrepreneurial skills and enjoy the respect of others, the likelihood of collective action increases.
7. *Norms/social capital* – Users of resource systems who share moral and ethical standards have lower transaction costs and be more likely to self-organize.
8. *Knowledge of the socio-ecological system* – If users share common knowledge of the vulnerabilities and resilience of resource systems, they have lower costs of organizing.
9. *Importance of the resource to users* – If the resource plays a significant role in the welfare of the users, they are more likely to perceive net gains from collective action.
10. *Governance rules* – If users have full authority to develop and enforce rules, they face lower transaction costs of organizing and less expense in implementing controls.

Seven design principles for effective CB efforts emerge from these insights: (1) clearly define the boundaries of the common pool resource; (2) adapt the rules to local conditions; (3) assure broad participation; (4) implement monitoring accountable to the appropriators; (5) impose graduated sanctions for violations of the agreement; (6), implement inexpensive conflict resolution mechanisms, and; (7) use multiple levels of governance for multi-jurisdictional issues (Ostrom et al., 2012).

Community-Based Programs Have a Long History

Various types of CB efforts to control insects and weeds have been used in U.S. agriculture dating back as far as the 1930s. What makes them "community based?" First, local, private land managers are actively involved in defining the design and implementation of the programs. Local farmers, ranchers, or political jurisdictions agree upon any mandates and regulations beforehand. In these programs, local entities do not just participate in the programs, but have key leadership roles. Successful implementation of these programs often relies on community social networks to effect change. So, while farmers have a prominent place in these efforts, effective program implementation requires participation from universities, cooperative extension, local, state and federal agencies, farm organizations (as opposed to just individual farmers), crop consultants, local agricultural input dealers, and environmental groups with a stake in downstream effects.

There has been a long history of areawide programs to control cotton insect pests. An early Community Management program began in the mid-1970s to control cotton bollworm and tobacco budworm (Hardee and Henneberry, 2004). A key program feature was pest scouting with treatment thresholds based on community-wide evaluations rather than field-specific thresholds on individual farms. Several other areawide programs have produced effective pest control and positive economic returns (Ervin and Frisvold, 2016). Notably, the programs involve the private sector working collaboratively with public universities and government entities.

Insect *pest eradication programs* may be thought of as a “weakest link” public good problem because program success depends on the performance of those putting in the least effort (Perrings et al., 2002). For pest control, “uniform suppressive pressure applied against the total population of the pest … will achieve greater suppression than a high level of control on most, but not all of the population" (Knipling, 1972). “A few free-riders or 'refuseniks' can negate many positive impacts of AW [areawide] programs" (Hendrichs et al., 2007). Indeed, a high level of effort by only some producers may completely fail. This means the adoption and diffusion of effective eradication measures will not proceed under patterns discussed by Rogers (2003) from early adopters to later adopters and non-adopters. In weakest-link problems, there may be few early benefits to stimulate widespread participation, and non-adopters can negatively affect returns to early adopters (Rebaudo and Dangles, 2011). In short, eradication requires something closer to universal participation from all growers. For this reason, pest eradication programs in the U.S. have instituted mandatory compliance for all growers. As examples, growers have voted for boll weevil and pink bollworm eradication programs in referenda on a state-by-state basis, with a two thirds majority required in the region (Grefenstette, El-Lissy, and Staten, 2009). Once approved, however, all growers in eradication area are subject to the program mandate. This action represents Hardin’s “mutual coercion, mutually agreed upon.”

Eradication programs share a number of key elements, including joint financing by the federal and state governments, and growers (Dumas and Goodhue, 1999). In this way, growers have “skin in the game.” The U.S. Department of Agriculture (USDA) has provided technical expertise and financed additional public investments, such as sterile moth releases (Grefenstette et al., 2009). Cooperative extension staff actively engage to provide the scientific understanding of how the eradication program works and the short-run and long-term benefits and costs. That intelligence is key as the programs often involve a short-term increase in pesticide use and so can meet with criticism. However, they tend to significantly reduce long-term pesticide use and cost. Because continued monitoring is needed to prevent re-infestations, some program activities and costs never completely end. However, the estimated net economic and environmental benefits of pest eradication programs have been substantial (Frisvold, 2009).

The USDA Areawide Program also included projects addressing invasive plants (Ervin and Frisvold, 2016). These projects have much in common with the insect programs but also have important differences. Many have addressed issues on lands managed by federal agencies that have public responsibilities for managing the pests. As the sources and sinks for invasive weed species extend beyond cropping systems, the types of land uses and land managers can be quite heterogeneous, forming complex “management mosaics” (Epanchin-Niell et al., 2009). With greater sub-divisions of land, land managers become more diverse with smaller shared incentives for control. As such, land controlled by the “weakest link” actors can become re-infestation sources.

Local weed districts have been established under state legislation dating back to the 1930s (Fiege, 2005). Some districts had legal authority to require landowners to control specified noxious weeds. If the landowner failed to comply, the district could treat the weeds itself and require the landowner to pay for the treatment (Clawson, 1977). County weed programs, which receive annual county funding and operate within the confines of county borders, have regulatory authority to enforce local weed control ordinances. Cooperative Weed Management Areas (CWMAs) are partnerships of federal, state and local government agencies, tribes, individuals and other interested groups that manage noxious weeds or invasive plants in a defined area (MIPN, 2011). CWMAs coordinate activities across diverse jurisdictional boundaries. Weed Prevention Areas (WPAs) are similar to CWMAs in overall structure, but emphasize prevention, while CWMAs often focus on established invasive plants (Goodwin et al., 2012). Evaluations of local weed management organizations indicate that a “light hand” approach with regulation used as a backstop but not exercised vigorously, achieved significantly greater participation than standard voluntary or regulatory led efforts (Hershdorfer, Fernandez-Gimenez, and Howery, 2007). The State of Delaware Noxious Weed Program appears to be following this “light handed” approach (Ervin and Frisvold, 2016).

What Lessons Do Past Programs Have for Herbicide Resistance Management?

These community-based efforts offer some key lessons for application to herbicide resistance that reinforce the findings by Ostrom and colleagues. First, having a solid scientific understanding of underlying biological mechanisms at work, supported by published evidence, is needed both to obtain farmer acceptance and to obtain financial and technical assistance from federal agencies. Second, scientific principles need to be communicated effectively. This requires strong linkages between university and private sector research and extension programs. Pilot studies, that apply an incremental approach, can help demonstrate program potential to wider areas. Third, successful programs have had active collaboration from social scientists to provide understanding about the social context of farmer decision making, barriers to adopting new practices, and group dynamics. Economic analysis can demonstrate the potential gains of program implementation and estimate the economic benefits of successful, mature programs. Fourth, projects all emphasized the need for a strong leader or coordinator. CB efforts entail significant transactions costs that can be an overwhelming time commitment for most farmers. Cooperative extension staff may play this role, but coordinating CB activities will likely be a full-time responsibility. Having an ongoing system for monitoring, reporting and evaluating a program is also crucial. Ideally, grower groups already in place could perform the monitoring and practice compliance. Readily observable land use practices can be monitored over time and provide neighbors assurance of compliance. Finally, it will be important to establish clear geographic program boundaries to prevent in-migration of resistant weeds from outside a resistance management area. Adopting comprehensive boundaries presents challenges in areas with diverse cropping systems and producers. Commodity organizations may be insufficiently comprehensive and cross-commodity approaches may be necessary. Groups outside agriculture may also need to participate, for example public lands agencies.

Are CB Programs Folly or Wisdom?

The striking increase in herbicide resistant weeds could have serious repercussions for farming and the countryside unless bold new efforts are forged. The common approach of imploring individual famers to adopt Best Management Practices (BMPs) via education and technical assistance and limited industry subsidies simply has not worked well. When significant mobility exists, as it often does, CB approaches can help invent sustainable herbicide resistance management strategies. Boasting a proven track record, they are surely not folly. Knowing that collective action is necessary does not make it easy. Progress will require experiments that draw together theory and experience from successful common pool resource regimes.

Not all weed management in agriculture requires a CB approach. When mobility is not significant, resistance management becomes an individual farmer problem to solve by comparing the costs of managing resistance over time, e.g., labor and machinery costs of more tillage, with the yield and other benefits of avoiding resistance in future years. This situation can be facilitated with a standard extension approach. In other situations, mobility may be a factor, but the individual grower still has an incentive, to manage resistance no matter what neighbors do. Here, collective adoption across a broader area may be the best overall strategy, but individual growers can still benefit from adoption even when their neighbors do not. A recent analysis by Livingston, Fernandez-Cornejo, and Frisvold (2016) suggests this outcome for corn.

When mobility is a large enough that managing resistance is a weakest link public good problem, a farmer's net benefits can be negated if neighbors do not manage as well. Because the welfare of a farmer is dependent on the actions of all other farmers, the farmer who manages least determines the outcome for the community as a whole. This result was found in one example of soybean production systems (Livingston, Fernandez-Cornejo, and Frisvold, 2016). Even in this case, successful CB models will need to be adapted to specific, local socio-ecological situations. Research on the adoption and diffusion of innovations suggest that resistance management practices will be more widely adopted if they exhibit a clear economic advantage, are not too complex, are adoptable on a limited, trial basis, have rapidly observable benefits, and are consistent with pre-existing farming practices (Rogers, 2003).

Managing Herbicide Resistance: We Don't Have to Start from Scratch

The rapid escalation of herbicide resistant weeds poses serious yield, economic and environmental risks. Some farmers have spent $50 or more per acre for hand weeding resistant weeds. The traditional extension approach of education and technical assistance programs has not worked—farmer adoption of resistance management practices has been spotty at best. When resistant weeds are mobile, resistance management will suffer from a "tragedy of the commons" characterized by low farmer participation and a mounting variety of herbicide resistant weeds. Command-and-control regulatory strategies to manage resistance are unlikely to be implemented in the foreseeable future and have always been unpopular and difficult to enforce in agricultural settings. The approval of new "stacked" seed varieties resistant to multiple herbicide modes of actions will give farmers relief from specific resistance problems in the short run. But, this strategy is relying on expanded use of old chemistries, some with less desirable environmental performance than current herbicides, and it is only a matter of time before new resistance problems evolve.

What is to be done? First, we can recognize the wisdom of the Nobel Economic Sciences Prize Committee for awarding Elinor Ostrom part of the 2009 prize in economics for "for her analysis of economic governance, especially the commons."—Oliver Williamson deservedly shared the prize for his "analysis of economic governance, especially the boundaries of the firm". There is now a rich body of research on managing common pool resources that can inform community-based approaches to resistance managements. Second, to organize to prevent herbicide resistant weeds, farmers and other stakeholders do not have to start from scratch. The multiple examples of community-based programs to control mobile insects and invasive weeds illustrate that farmer groups—in collaboration with and assistance from the research and extension communities—have organized effectively to overcome barriers to collective action problems. There is legal and administrative precedent as well as institutional memory that could aid farmers in developing resistance management programs based on programs they are already familiar with and which have a record of success. The particulars of herbicide resistant weed management will certainly differ from such insect and invasive weed programs. Insect biology and movement differs in spatial and temporal dimensions from that of weeds. And insect eradication programs have at times relied on mandatory area-wide spraying or practiced area-wide sterile insect releases. While both these actions took discretion out of the individual farmer's hands, they were actions that farmers collectively accepted. Other organizational arrangements may also serve as useful examples. Endres and Schelsinger (2015) suggest that drainage districts perhaps provide a structure that can be replicated for effective community-based herbicide resistance programs.

Economists can play crucial roles but interdisciplinary collaborations with other scientists are vital (Ervin and Jussaume, 2014). Beyond science, there is a need for legal expertise to discover institutional models that can deal effectively with cross boundary issues. Building the institutional capacity necessary to design and implement community-based program will take time and maintenance. The character of the herbicide resistance problem requires experimentation and adaptive management to discover an approach that works within specific communities.

Finally, a critical early step is to engage all groups in the locality who have a stake in managing herbicide resistance. Stakeholders extend beyond farmers to their public and private cropping advisers, including input suppliers, to local government and community organizations and to conservation and environmental groups. Bringing their distinct motivations and experiential knowledge to bear is essential. Broad engagement takes more time and increases cost but builds social capital and lowers transaction costs to discover a more effective and resilient approach. Neutral facilitators and respected local leaders are vital to conducting a constructive stakeholder process. Pursuing this community-based approach will push many agricultural economists out of their comfort zones—perhaps this is what the Nobel Committee had in mind in awarding Ostrom a non-economist the Economics Science Prize. Investments in new skills and training by the public and private sectors will be necessary to equip these collaborative efforts for success.

For More Information

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