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The perennial question: Farmers' choices and the biofuel future

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Amy K. Wolfe[1], Mark E. Downing[1], Carolyn S. Hoagland[2]

[1]Oak Ridge National Laboratory, Environmental Sciences Division,
[2] Volkswagen Distinguished Scholar Intern at Oak Ridge National Laboratory, now at Colorado State University

1. INTRODUCTION

The U.S. Renewable Fuel Standard (RFS2) is a strategic response to concerns under the Energy Independence and Security Act (EISA) of 2007 about petroleum fuel supplies and environmental sustainability (EPA 2012). RFS2 regulations mandate specific amounts of renewable fuels to be blended into gasoline and diesel. The renewable fuels also need to emit fewer greenhouse gases than the displaced petroleum. In 2012, the target is for 9% of all fuel will be from renewable sources, or a minimum of 15.2 billion gallons of renewable fuel. By 2022, the target is for 36 billion gallons of renewable fuel to be blended into gasoline and diesel and of that amount, 16 billion gallons derived from cellulosic biofuels. While some advanced biofuel will be refined from forest, crop, and urban residues, this paper focuses on the patterns of farmers' choices regarding dedicated perennial lignocellulosic energy crops. Throughout this paper we use the term *perennial* as shorthand for warm season grasses such as those in the genus *Panicum* or *Miscanthus*, or short rotation tree crops such as those in the genus *Populus* or *Salix*. We focus on choices about these perennial crops because two thirds of the mandated advanced biofuels are expected to be converted at biorefineries from perennials (USDA 2010). RFS2 establishes the goals, but not mechanisms for achieving them. Mechanisms and incentives, however, are embedded in other legislation and programs. For example, the 2008 Farm Bill created the Biomass Crop Assistance Program (BCAP) that is designed to entice farmers to plant and deliver biomass feedstock to biorefineries and electrical plants. The effectiveness of this new program, however, has yet to be fully explored (Aguilar et al. 2011). In 2011, the program received over 40 project area proposals, exceeding the available funding, suggesting increasing adoption, or at least exceeding expectations of policymakers.

Analyses of the shifts in land use, crop management, and crop marketing implied by RFS2 typically either neglect or simplify farmers' choices, whether due to the investigative questions asked, the modeling frameworks used, or the suppositions made in those analyses. Much remains unexplored and, therefore, unknown about the bases for farmers' actual decisions to dedicate their land, labor, and resources to the production of perennials. Scientists have analyzed how much perennial biomass conceivably could be produced (Perlack et al. 2005), characteristics of land that is environmentally optimal for growing particular perennials (Dale et al. 2010), and production and refining schemes that would be most economic (Cardona and Sanchez 2007). Even in the high caliber analyses, there may be a tremendous gap between scientists' findings and farmers' practices. Farmers' management choices do not automatically mirror scientists' determinations of optimal bioenergy pathways. More broadly, there is increasing evidence that people's real-world decisions do not always conform to economic rational actor models in which choices are determined by least financial costs or greatest technological effectiveness for equivalent products and services (Akerlof and Kranton 2010, Ariely 2009, Thaler and Sunstein 2008).

This article aims to start narrowing the gap between science and practice by exploring the bases for a subset of farmers' choices, specifically those surrounding decisions to engage in perennial planting, management and marketing. We do not assume the processes that farmers' use to make decisions mimic the calculus of scientific optimization. Rather, we suggest farmers' behavior patterns, decision-making processes, and decision contexts are important variables that are worthy of investigation and of incorporating into to the scientific and policy-analysis mix. Information about farmers' choices can provide new depth to scientific analyses that are driven by such policies as RFS2. Perhaps most importantly, a better understanding of the bases for farmers' choices can provide information important for analyzing and developing a full range of effective policies and interventions.

We begin by exploring the who, what, where, when, and why questions surrounding farmers' choices related to perennials. This paper considers three inter-related questions about farmers' decisions. (1)What *choices* must farmers make so as to achieve the volumes of perennials-based biofuels implied in RFS2 and assumed in the many published and accepted economic and environmental analyses? (2)What *factors* influence the choices farmers make regarding perennials? (3)What are the social, economic, environmental, and policy *impacts and implications* of farmers' choices?

Further, we suggest that investigating farmers' choices will provide important insights whose omission may impinge upon the accuracy or value of scientific and policy analyses. For example, despite the sense of urgency that led to RFS2, major uncertainties remain regarding the temporal and spatial adoption of perennials. Temporal issues take two major forms — adoption trends and persistence. Will the adoption trend for perennial energy feedstock production mimic a smooth, S-shaped diffusion curve of early adopters, then later adopters and possibly laggards (Rogers 2003)? If so, over what period of time, and across what temporal and spatial scales? If, or once, farmers convert land to perennials, will they continue to grow perennials, especially when there are shocks in the system such as dramatically higher/lower transportation fuel prices, changes in regulations, changes in subsidies, etc.? To what extent will shifting influences over time result in shifting priorities in farmers' lives and choices? We demonstrate that farmers' choices are multi-layered, and that first choices may not automatically lead to particular outcomes. When aggregated across the landscape and through multiple years, the patterns of choices made on individual farms will play a part in determining whether energy policies fail or succeed.

Variations among farmers, perspectives, and contexts combine to make the consideration of farmers' choices extremely challenging. We therefore propose a framework that imposes a structure on this enormously complex realm. This framework helps to guide inquiry and potentially, serves as a tool that prompts its users to check that the logic of the underlying assumptions embedded in their work.

2. A PROPOSED CHOICE FRAMEWORK

Farmers' choices are embedded in multiple, cyclical contexts. Choices are conditioned and influenced by several factors, such as which farmer is doing the choosing, economic considerations, policy-related regulations and incentives. In turn, patterns of farmers' land-use choices result in economic, social, and environmental consequences that feed into new or modified policies, programs, and interventions. Our proposed conceptual framework (Figure 1) incorporates these three major components: farmers' choices; factors influencing those choices; and the potential impacts and implications of the choices. These three components constitute a cycle of conditions, choices and effects. We begin our exploration with farmers' choices, then back up to consider factors that influence choices, and end by focusing on the impacts and implications of farmers' choices.

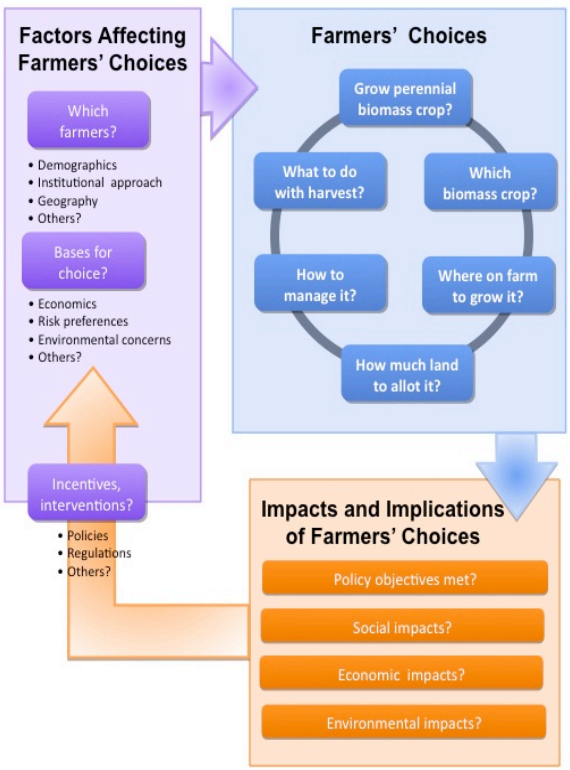

Fig. 1. Figure 1. Proposed framework to guide analyses of farmers' choices.

3. FARMERS' CHOICES

Figure 1 emphasizes the set of choices farmers make each crop cycle, starting with whether to grow a perennial and following through to what to do with the harvest. Though presented sequentially, farmers may consider these choices simultaneously, even before choosing a crop. For example, the crop choice may be constrained by crop management issues such as the availability of labor and machinery, or by post-harvest issues such as potential markets for the crop. Further, when viewed sequentially, each choice may affect later options. Once a crop has been chosen, certain aspects of its management and harvest are dictated by the characteristic needs of the plant in question. Farmers may use tools such as decision support software (DSS) to help make crop choices. DSS, in common use for several decades, can consider constraints for a single crop and/or constraints in light of whole farm operations. There are well-developed modules for corn, soybeans, cotton, cattle, hogs and many other crops, but none yet for perennials for biofuel production. Unless and until perennial biofuel modules are well developed, farmers will have to make decision in other ways, and almost certainly with imperfect information.

As Figure 1 depicts, a first choice farmers make is whether to grow a perennial crop. Farmers have many agricultural options for their land, including using it for food crops, fiber crops, range or pastureland, fallow, or conservation easements. These land-use choices can change over time, as farmers respond to new seeds, technologies, market or climate conditions. There are no guarantees that land that could be devoted to perennial bioenergy crops will be planted with those crops.

If farmers decide to plant perennial bio-energy crops, they must next decide what perennial to plant. Analyses at a national level indicate that enough perennials can be grown to achieve RFS2 policy objectives (Perlack et al. 2005). These analyses treat alternative perennials are as simple substitutes. However, the two main types of perennial choices—grasses and short-rotation tree crops—require different inputs and have different patterns of land use, yields and harvest cycles. Perennial grasses like *Panicum* can be planted with standard no-till equipment and can be grown throughout the Great Plains, Mid-Atlantic, Southeast and parts of the Northeast. *Miscanthus*, on the other hand, cannot be planted with no-till equipment. Short rotation woody crops like *Populus* or *Salix* require more water than rainfall provides throughout much of the Great Plains and the Southwest U.S and thus are more likely options for the northern tier states from Minnesota eastward, including the southeastern U.S. When compared with each other, early water quality studies show short rotation woody crops result in less nutrient loss, while perennial grasses result in less soil erosion. Further, these studies suggest that some combinations of crops may be environmentally superior to any single crop, alone (Nyakatawa et al. 2006). In these ways, perennial choices are not simple substitutes for one another; they result in different impacts and have different implications.

Once a crop is chosen, farmers must decide where to grow the crop, how much of their acreage to devote to the perennial crop they select, and how to manage it through the production and harvest cycle. The marketing of harvested biomass likely will be closely tied to commercial opportunities that are immature, though the marketing plan or contract may have been formalized prior to planting. Where crops are planted relative to such features as streams, irrigation canals, slopes, and soil types may make substantial differences environmentally, economically, and aesthetically. For example, to the extent that mono-cultured perennials replace marginal pastures, abandoned fields and part of the brushy land that currently is in the Conservation Reserve Program (CRP), some ecologists are concerned about a loss of biodiversity in these areas (Dale et al. 2010).

Further, farmers' choices about methods and timing for planting, fertilizing, and harvesting can have significant environmental impacts locally, regionally and globally. These choices also have implications for energy- and carbon budgets.

Farmers also must make post-harvest choices such as what to do with their harvested crops and how to manage residue in the field. Harvested perennials are similar in density to forage crops like hay or wood chip mulch. Because hauling low-density crops is relatively expensive, markets for perennials may be local. The large investment needed to start a biorefinery means that long-term contracts may be needed before financing is obtained and refinery construction can begin. This mode of operation is a different from the familiar annual contract or spot market that many farmers use now.

We cannot not yet know how farmers will make these choices; We suspect that these choices will be vary within local areas, across regions, or nationwide; these choices will evolve over time. Over time we will investigate what mechanisms, if any, will operate to limit the amount and focus the location of agricultural land devoted to perennial bio-energy feedstock production so as to safeguard food and fiber production.

4. FACTORS AFFECTING FARMERS' CHOICES

Farmers' choices are conditioned and influenced by a wide range of factors. Figure 1 suggests three ways to conceptualize these factors, in terms of the attributes of the (a) farmers who are making choices; (b) bases for choices; and (c) policies and interventions designed to influence those choices.

Information about farmers' choices can be drawn from the decisions that farmers who already grow perennials for pilot biomass supply programs such as those in Vonore, Tennessee and Chariton, Iowa have made. However, this set may not be representative of how farmers will behave when pilot incentives are removed. Often, participating farmers are hand-selected, and receive considerable personalized attention and subsidies that go far beyond current federal policies. Some insights can be gleaned about this process: farmers who are offered relatively high guaranteed returns have been willing to plant and harvest switchgrass. Still, it is not clear how applicable these insights would be to a broader population of farmers in the absence of generous pilot incentives.

Farmers do not constitute a homogenous group that behaves in a singular, consistent way. Determining how to disaggregate farmers most meaningfully is a matter for further analysis, but a few examples that distinguish farmers by demographic attributes may be useful. First, consider the farmer's age. The current average age of U.S. farmers is 57, many of whom rent their land and hire custom operators. Perennial crops with harvest lags of 5 years or more may be unattractive to older farmers, the majority of current operators. Yet older farmers in some pilot programs have been willing to adopt switchgrass, even though it often has a two-year harvest lag (Goddard 2010). As another example, one could disaggregate farmers by their farm-business type. Some farmers operate as sole proprietorships, some in contractual arrangements with cooperatives, some are corporate farms, and some are a combination of these alternatives. These business-types affect who makes decisions about what crops to grow. Family farmers in sole proprietorships make their own decisions, a situation markedly different from when a cooperative acts as a marketing agent that enters into contractual agreements on behalf of member farmers and individual farmers are obligated to fulfill these contracts.

Many factors separately and in combination underlie why farmers make particular choices. We discuss two factors here—economic drivers and risk preferences. Most farmers are businesspeople. Therefore, economic considerations likely loom large as they make the kinds of choice depicted in Figure 1. Simply put, business owners who place little emphasis on anticipated profitability and risk may find themselves out of business. Crop prices, a solid market for a crop, and variable and fixed costs are strong influences on farmers' choices. In this context, to the extent which farmers' decisions are influenced by such elements as the crop's contribution to reduced dependence on foreign oil or improved regional environmental sustainability is unclear.

Another strong influence on farmers' choices is their risk taking preferences and how those preferences translate into risk-taking strategies. Policy considerations depend on, and should provide incentives to reflect, farmers' interests and risk-taking preferences. Farming is inherently risky because of significant fluctuations in both growing conditions and market conditions. Costs of production, yields, and commodity prices all are linked and all are highly uncertain. In the face of those risks, farmers adopt a variety of strategies. Some farmers, for example may spread risks by allocating different portions of their property for different agricultural purposes. Such farmers may plant only a small portion of their land in perennial crops such as switchgrass or woods. Another approach to handling farming risks and uncertainties is to be agile in response to changing markets and conditions, for instance by altering which annual crops they plant. Insofar as planting perennials may alter farmers' planting flexibility, or alter the psychological and financial comfort they derive from having the ability to respond quickly to changing conditions, choosing perennials may be a risky proposition.

A study of farmers in Cumbria in the United Kingdom reported on interviews with farmers about their willingness to switch to growing bioenergy crops on marginal lands (Convery et al. 2012). The research outlined cultural factors such as family structure, a "follow the leader" mentality, and stability of food prices as factors that inhibit farmers from growing biomass. In this context, farming was seen as a lifestyle choice and economic drivers were not as strong as they are in the U.S. This case highlights the importance of context, and suggests that research findings associated with one setting should not automatically be presumed applicable to other settings.

A multitude of factors mediate farmers' risk perceptions, as well as the strategies and tactics they are willing to try so as to remain within their risk taking comfort levels. One such factor may be the extent to which farmers deem perennial bioenergy crops similar to or different from the crops with which they otherwise are familiar. Table 1 illustrates some ways in which perennials are different from other crops. Federally subsidized crop insurance also can alleviate the risks associated with disastrous weather conditions. Though this kind of insurance currently does not exist for perennials, the feasibility of insuring energy crops is being explored (W&A Crop Insurance 2011). However, research has not explored the extent to which one factor overwhelmingly drives farmers' judgments and subsequent actions regarding energy crops. We do know that some strategies may be effective in mediating farmers' risks. Thus while making a long-term commitment to a perennial crop may pose risks too great for many farmers to bear, contractual arrangements with biorefineries may prove to be an effective way to reduce farmers' risks. Contractually providing farmers with annual payments during the multiple years between planting and harvesting perennials is a strategy that both reduces farmers' risks and maintains a familiar money-flow pattern for farmers.

Type of Crop	Harvest Lag (Years)	Input Intensity	Ease of Conversion to Other Use	Commodity: Price Floor, Price Ceiling	Crop Insurance Available
Annuals: Corn, Cotton, Beans, Wheat	None	High	Yes	Yes	Yes
Perennial Hay, Alfalfa or Grass	1	High	Yes	No	Yes
Crop Reserve Program	1	Very Low	No	Fixed Payment	Not Needed
Berries Bushes, Bramble Fruit	1	Very High	Medium	No	Yes
Fruit or Nut Orchard	2 to 3	Very High	No	No	Yes
Perennial Biomass	2 to 5	Medium	No	No	No†
† Some perennial pilot programs support farmers, even when there is a crop failure					

Table 1. Illustrative differences between perennials and other agricultural crops

Farmers' risk-taking preferences are evident in their willingness to adopt innovative technologies or practices. That relatively few farmers are risk-taking innovators is not surprising. There are many theories associated with innovation and the diffusion of new ideas and technologies. Rogers' (2003) classic theory of diffusion of innovation developed with regard to agricultural innovation (see Figure 2) identified different categories of adopters along a bell-shaped diffusion curve. Innovators and early adopters fall on one tail end of the curve and laggards on the other. In between these extremes is the majority of the population, the early and late majorities. More recently, as brought to public notice through such popular-press publications as The Tipping Point (Gladwell 2002), researchers are trying to understand what makes some innovations catch on rapidly. There is no single answer. Researchers suggest that factors such as status within social networks, benefits versus costs, political settings, familiarity with the innovations (Wejnert 2002), and dynamics such as information flows and interactions among parties exchanging information (Bjornstad and Vogt 2010) influence the trajectory of technology diffusion. Insights from this kind of research may be particularly valuable in designing programs and interventions intended to catalyze or speed the normal diffusion process. Examples might include programs that rely on state agricultural extension agents, as familiar and trusted sources of information, who have well established networks of connections with farmers, to help alter agricultural practices. Less formally, interactions among farmers and observations of how the innovators fare when experimenting with new practices or technologies can be powerful in promoting or inhibiting their adoption by others.

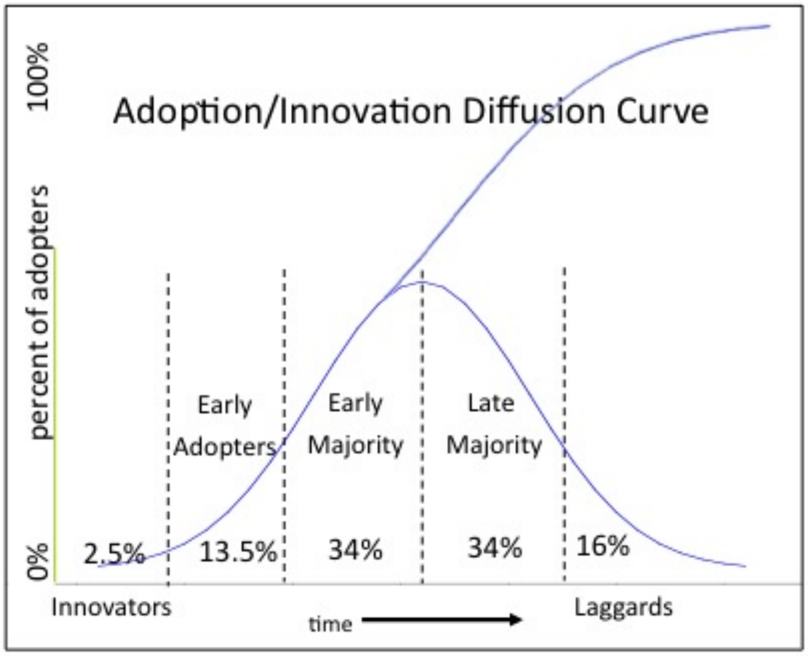

Fig. 2. Diffusion of Innovation, (Rogers 2003).

Some farmers' choices may be motivated by environmental concerns, either alone or in combination with other factors. In other situations, environmental effects are a byproduct of decisions made for other reasons. Farmers may reap dual benefits from their land, for instance by using the portions of their land planted in woods or grasses for recreation or hunting. Such farmers may or may not consider the wider environmental impacts of these kinds of on-farm decisions. However, business constraints prompt most to maintain topsoil, reduce insect resistance to pesticides or to avoid wasted fertilizer inputs. For example, perennial grasses have long been promoted by the government conservation agencies as streamside buffers to reduce erosion, capture nutrient runoff and attract wildlife. If optimally managed, perennial biomass crops may be similar in effect. Further, once established, they may require lower amounts of herbicides, pesticides, and other management inputs than annual crops.

5. IMPACTS AND IMPLICATIONS OF FARMERS' CHOICES

Figure 1 indicates that farmers' choices have social, economic, and environmental consequences. The figure also indicates that farmers' choices affect the degree to which policy objectives such those expressed in RFS2 are achieved. Each category of choices (whether to plant perennials, etc.) as well as the set of choices that farmers make creates near- and longer-term consequences. Further, while individual farmers' choices produce localized, small-scale effects, it is the patterns of farmers' choices, collectively, over space and time that will shape how future bioenergy scenarios play out economically, environmentally, and socially.

As this article has described, farmers' choices can be considered within a policy context and, collectively, affect the degree to which policy objectives are achieved. Nevertheless, an individual farmer's decision to plant perennial bioenergy feedstock crops may be motivated by a number of factors that go well beyond policy per se. For example, our first-hand observations in Tennessee and Iowa indicate that decisions to grow perennials are, in fact, decisions to convert only a portion of a farm's land; they are not all-or-none decisions. Such decisions may have the effect of spreading a farmer's economic risks by diversifying potential sources of income, particularly in the face of incentive programs, contractual arrangements, or insurance. As discussed, such decisions invoke risk-related trade-offs such as committing a portion of the land for a potentially unknown return on investment in future years. Decisions made by individual farmers in this sense are business choices. If many farmers in a locale or across the country consistently determine that they have better business options that do not involve planting perennials, the volume of perennial feedstock needed to fulfill the RFS2-defined bioenergy future may fail to be produced. This example simultaneously is the simplest and most extreme case of the linkage between farmers' choices and the ability to achieve policy objectives.

Farmers' choices about which perennials to plant, where to plant them, and how to manage them have substantial environmental implications. Since crop requirements for water and added nutrients vary, farmers' selection of which perennial to plant affects (and may be influence by) the needed inputs, runoff, and the like. These variables, in turn, affect local environmental quality on an individual farm and its immediate vicinity. Individual farmer's choices and the set of farmers' choices have downstream environmental impacts locally and regionally, as the example of hypoxia in the Gulf of Mexico demonstrates. In analyzing the potential impacts and implications of farmers' choices, it also is important to consider that those choices may not be fixed. An example discussed in this article surrounds choices surrounding the management of crops. Factors as diverse as unusual weather conditions and the evolving market for bioenergy crops may prompt farmers to choose to manage their crops in different ways over time, for instance by adding more nutrients than "required" so as to enhance yield. To the extent that such patterns of decision making unfold, the anticipated environmental benefits from a shift toward perennials-based biofuels may fail to materialize and unanticipated problems may emerge.

Just as a choice to grow perennials does not automatically indicate which perennial farmers will choose to grow, it may be imprudent to assume that any single choice depicted in Figure 1 automatically will result in a particular downstream choice. By extension, any number of variables can mediate between a choice and its impacts and implications. Take the example of farmers choosing to plant woody perennial species on the environmentally appropriate portions of their property, using environmentally and economically sound management methods. Even this suite of choices and behaviors need not lead farmers to sell their harvested crops to refineries that produce liquid fuels for transportation. This same harvested material could also be sold for more direct combustion as a fuel source for steam plants, through pelletization, or other options. Farmers' choices about what to do with their harvest may be affected by prior contracting arrangements, market conditions, or ownership in steam plant or pelletization operations, as examples. Therefore, analyses that link the growing of perennials directly to the production of liquid biofuels for transportation may be incomplete. Reliance on such analyses may lead to unanticipated consequences. Understanding linked and nested sets of choices can lead to better planning, and a more nuanced appreciation of both the elements and tradeoffs that are central to achieving multiple objectives.

By delineating the choices that farmers make and examining the factors that influence those choices, it becomes possible to identify systematically the elements that can impede the achievement of desired policy, environmental, economic, and social outcomes. Likewise, it also becomes possible to develop incentive structures and interventions that are more effective in promoting those desired outcomes.

6. DISCUSSION

Individuals' decisions and patterns of decisions across the landscape affect, and are affected by, economic, environmental, technological, regulatory, policy, social, and institutional factors. Understanding how these factors interact over time to influence farmers' perennial choices is essential to analyzing the potential ripple effects. This understanding also is critical for designing policies or interventions that achieve their intended aims without also spawning adverse unintended consequences.

Systematically investigating farmers' choices and analyzing the bases for these choices can aid in the design of effective policies and programs intended to nudge farmers in particular directions. Likewise, these investigations and analyses can help anticipate intended and unintended consequences of choices, policies, and programs for different populations, at different scales, and at different points in time. Understanding farmers' choices can improve the degree to which they (1) plant and persist in growing perennial biomass; (2) enter into contracts to supply it for liquid biofuel use; and (3) manage the crops over time in ways that are sustainable — all of which, combined, are key to achieving liquid biofuel policy and its associated environmental and economic objectives. Such inquiry is an essential complement to related economic and environmental analyses.

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