ENVIRONMENT

Sustainable Development of the Agricultural Bio-Economy

A U.S. farm policy shift to joint production of commodities and ecological services will advance sustainable agriculture.

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A "bio-economy" based on agricultural biomass is emerging in the United States that offers an avenue toward energy independence and a more "green" economy (*1*). Models for biomass production range from monocultures of annual and perennial crops to seminatural plant communities (*2, 3*). Monocultures are simpler to implement, but will likely perpetuate problems that have arisen from current monocultures of annual crops (mainly corn, soybean, wheat, and cotton). Recently, market-based agricultural policies have resulted in large payments to farmers and landowners to make up the difference between low commodity prices and costs of production (*4*); from 1997 to 2006, producers received 30% of their net farm income in direct government payments (*5*). Environmental problems are frequently associated with cultivation of the annual crops that are eligible for subsidy payments, including degradation of water quality with sediment, nutrients, and pesticides; hydrologic modifications contributing to flooding and groundwater depletion; disruption of terrestrial and aquatic wildlife habitats; emission of greenhouse gases; and degradation of air quality with odors, pesticides, and particulates (*6*).

Farm size has increased, and few people are able to enter farming, harming rural communities socially and economically (*7*). In the Corn Belt states such as Iowa, over half the land is owned by absentee landowners (*8*), which makes implementation of conservation practices more difficult. Now, excess corn and soybean stocks are being converted to biofuels, and demand for corn has skyrocketed, resulting in a considerable expansion of corn production and concomitant environmental impacts (*9*).

Despite troubling implications of these current trends, research and development (R&D) and policy have focused on maximizing biomass production and optimizing its use (*1*), with far less emphasis on evaluation of environmental, social, and economic performance (*9*). This imbalance may provoke many interest groups to oppose growth of such an agricultural bio-economy (*10*).

Current federal programs and policy on environmental quality in agricultural landscapes mainly subsidize retirement of land from active production. This has produced substantial environmental benefits (*11*), but serious problems remain. Major additional gains may result from a "working landscape" approach that improves environmental performance of active farmland by rewarding farmers for delivering environmental benefits, as well as food and biomass (*12*). Our proposals aim to promote working landscapes by capitalizing on the potential of "multifunctional" agriculture.

Multifunctional landscape in Iowa, USA.

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Multifunctional Production Systems

Agricultural multifunctionality is defined as the joint production of standard commodities (e.g., food or fiber) and "ecological services." Examples of the latter include increased recreational opportunities in agricultural landscapes and protection of biodiversity and water quality (*13*). Biomass-production systems such as mixtures of multiple species (*3*), tree cropping on farmland (*14*), and managed wetlands (*15*) use perennial plant species as the basis of joint production. There is mounting evidence that these systems can produce certain ecological services more efficiently and effectively than agroecosystems based on annual crops. Examples include (i) soil and nitrogen loss rates from perennial crops are less than 5% of those in annual crops (*16*); (ii) perennial cropping systems have greater capacity to sequester greenhouse gases than annual-based systems (*17*); (iii) in certain scenarios, some perennial crops appear more resilient to climate change than annuals, e.g., increases of 3° to 8°C are predicted to increase North American yields of the perennial crop switchgrass (*Panicum virgatum*) (*18*); and, (iv) among species of concern for conservation, 48% increased in abundance when on-farm perennial land cover was increased in European Union incentive programs (*19*).

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Multifunctional production systems can be highly valuable. The 34-million-acre Conservation Reserve Program (CRP) has been estimated to produce $500 million/year in benefits from reduced erosion and $737 million/year in wildlife viewing and hunting benefits at a cost of ~$1.8 billion (*11*). If benefits such as carbon sequestration are added, CRP likely produces a net gain in many areas, if not for the entire nation.

Diversified grassland agroecosystems on degraded agricultural land can increase both carbon storage and net energy gain in biofuel production (*3*). This could provide 15% of electricity demand and eliminate 15% of CO_2 emissions if implemented globally.

Restored wetlands on flood-prone farmland can provide biomass, increase wildlife abundance, and improve water quality by processes such as denitrification (*15*). Denitrification in managed wetlands is estimated to reduce costs of biological nutrient removal in municipal water treatment by about 15%.

An assessment of the potential economic, social, and environmental performance of multifunctional systems is provided by a simulation study performed for two representative agricultural watersheds in the upper Midwest United States [subbasins of Wells Creek (16,264 ha) and the Chippewa River (17,994 ha) in Minnesota] (*13*). Results indicated that benefits could be attained by increased cultivation of perennial crops without increasing public costs. Environmental benefits included improved water quality, increased fish abundance, increased carbon sequestration, and decreased greenhouse gas emissions. Economic benefits included social capital formation, greater farm profitability, and avoided costs associated with specific environmental damages. The most extensive land-use change scenario (7 to 14% conversion to perennials) was projected to produce the greatest reductions in sediment and nutrient loading to waterways; sediment loading was reduced by as much as 80%. Total government payments were projected to decline by 13%. These projections offer a widely applicable model for agroecosystems in the Midwest United States.

Testing the Model

Multifunctional systems have been tested only at relatively small scales. We propose creation of a network of research and demonstration projects to establish and evaluate economic enterprises based on multifunctional production systems. This program will also help test and refine federal farm-bill policy to support biomass production.

State, federal, and private agencies should pool their resources to support this network. These projects must be sufficiently scaled to address the complexity inherent in landscape-scale multifunctionality and in the feedback loops connecting natural, human, and social resources. They should be established in medium-sized watersheds (~5000 km^2) and should be managed by groups that encompass multiple stakeholders and levels of government. Such an effort is under way in a larger subbasin of the Chippewa River in Minnesota (*13*), focused on development of grasslands for biofuel and meat and dairy food production.

Financial and policy support should be given to the multi-stakeholder processes of learning, deliberation, negotiation, and experimentation that are needed to establish and evaluate research and demonstration projects. Such processes might help, for example, to simplify complex funding landscapes of subsidy policy like the one that appears to be hindering biofuel development in the United Kingdom (*20*). Stirrings of the necessary approach are evident in recent strategic alliances among regional and national groups concerned with the environment, renewable energy development, and agriculture [e.g., see (*21*, *22*)].

Research must be focused on the trade-offs that arise, e.g., between wildlife habitat and biomass production. Models indicated that the form of the trade-off determined whether wildlife-friendly farming was more cost-effective than an alternative policy, the retirement of "marginal" farmland to increase wildlife habitat (*23*). More broadly, modeling has indicated that many trade-off problems might be overcome if a sufficient range of ecological services (e.g., water-quality protection, as well as wildlife conservation) was provided (*13*). Empirical research is urgently needed in the context of specific enterprises, such as biofuel production.

Conclusions

Two key policy instruments to achieve the goals we have described are the omnibus farm bill and the existing agricultural R&D infrastructure. Agricultural subsidies in 2005 exceeded $24 billion, and the 2007 farm bill deliberations should highlight how these federal dollars could better achieve national priorities. In particular, the new farm bill should provide the agricultural R&D infrastructure with incentives to evaluate multifunctional production as a basis for a sustainable agricultural bio-economy. We judge that this can be done with very modest public investments (~$20 million annually). A variety of strong political constituencies now expects a very different set of outputs from agriculture, and the U.S. farm sector could meet many of these expectations by harnessing the capacities of multifunctional landscapes.

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