DRAFT

Research Priorities for Conservation-Based Agriculture

Introduction

In 1988, a group of experts affiliated with conservation biology met to discuss research priorities within their field. A publication designed to inform and direct future directions for research resulted from that meeting. A similar effort could benefit the growing field of conservation-based agriculture. The following document represents the beginning of that endeavor. Through a combination of literature reviews and responses from authorities in fields related to biodiversity conservation and sustainable agriculture, Wild Farm Alliance (WFA) has created a draft of research priorities for conservation-based agriculture. Diversitas, an international program of biodiversity science aimed at linking biology, ecology and social sciences, has developed a framework for organizing multidisciplinary scientific inquiry. Following discussions with one of their contributors, WFA chose to follow their structure in order to synchronize our efforts with their ongoing work. Consequently, suggestions for research priorities have been placed under the following three categories:

bioDISCOVERY:

Assessing current levels of biodiversity; developing the scientific basis for monitoring and observing; understanding and predicting changes.

ecoSERVICES:

Expanding biodiversity and ecosystem functioning science to larger scales and over a greater breadth of the biological hierarchy; linking changes in ecosystem structure and functioning to changes in ecosystem services; assessing human response to change in ecosystem services.

bioSUSTAINABILITY:

Developing new knowledge to guide policy and decision making that support sustainable use of biodiversity; evaluating the effectiveness of current conservation measures; studying the social, political and economic drivers of biodiversity loss, as well as social choice and decision making.

*Further information about Diversitas is available at: http://www.diversitas-international.org/

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bioDISCOVERY

Landscape Level Considerations of the Agriculture/Biodiversity Interface

Future research needs to build an evidence base upon which we can design effective landscape management strategies for biodiversity (Norris 2008).

1. Document biodiversity changes over a range of wider landscape contexts in order to explore biodiversity retention across a variety of landscape conditions (Norris 2008).
2. More landscape-scale studies are needed in agricultural areas to understand the effects of varying landscape type on species distribution and demographics (e.g. reproductive success, dispersal, survival, metapopulation dynamics) as well as other ecological processes (e.g. ground/surface water quality and quantity, nutrient cycling) (Freemark 2005).
3. Further research is needed that investigates the underlying ecological mechanisms responsible for biodiversity patterns in relation to agricultural land-use such as changes in species richness or the occurrence/abundance of particular guilds (Green et al. 2005).
4. Regarding behavior and ecology of farmland species, what are the underlying mechanisms that influence species patterns relative to land use?
    a. In order to predict how restoration will affect wildlife, we need to know about their demography, dispersal patterns, metapopulation dynamics, movement rates, habitat use, etc. and how these characteristics are affected by intensification.
    b. What habitat improvements on individual farms do different types of narrow-ranging species require?
    c. What habitat improvements on multiple adjacent farms do different types of wide-ranging species require?
    d. What are the effects of biological control on biodiversity (Banks 2004)?
5. Which types of landscape scenarios best conserve vulnerable biodiversity?
    a. Benton et al. (2003) argue that habitat heterogeneity on multiple scales is the key to preserving biodiversity, and suggest that "…future research should develop cross-cutting policy frameworks and management solutions that recreate that heterogeneity as the key to restoring and sustaining biodiversity in temperate agricultural systems."
    b. Others state research focused on vulnerable biodiversity could help guide the establishment of policies in the midst of ongoing controversy over whether agricultural intensification and conservation "set-asides" or increased biodiversity across an agricultural matrix achieve the highest benefit for biological conservation.
    c. Further research is needed to determine the desirable percent of cultivated land, location and configuration, and the minimum optimal sizes and relative abundance for habitat patches on farms.
6. What is the value of corridors as a solution to habitat fragmentation (Levey et al. 2005, Donald and Evans 2006)?
    a. Which species benefit from corridors?
    b. Which species do not?
    c. How should corridors be designed to best wildlife facilitate movement through farms?
    d. How might management of wildlife corridors be tailored to landscape type?
    e. In terms of cost and effectiveness, how do corridors compare to other restoration methods?
7. Evaluate restoration success at a watershed scale for a variety of target species.
    a. Research landscape-scale processes in agricultural ecology. How do pest and beneficial species (e.g. pollinators and predators) respond to landscape arrangement and management?

   b. Research thresholds in relation to the amount of semi-natural habitats required for the preservation of threatened species.

8. Given that the effect of fragmentation varies among species, research is needed regarding how conservation priorities can be set for particular taxa in landscapes that are mosaics of agricultural and natural areas (Banks 2004).

Community Interactions

The distribution, abundance and interactions between coexisting of native and domestic species within agriculture needs further study.

1. How might theory-based approaches (e.g. metapopulations and island biogeography) be more fully incorporated into studying biodiversity conservation within agriculture (Banks 2004)?
2. Given that the majority of studies to date on biodiversity loss/retention tend to focus on describing biodiversity change, studies are needed that describe changes in species interactions and cascades (Van der Putten et al. 2004).
3. Further research could help inform the theory that an agricultural change could directly affect the persistence of a particular species, which could in turn indirectly affect the persistence of a number of others by modifying the ecological interactions between them (Memmott et al. 2004).
4. Interactions between primary producers and beneficial and pest insects should be examined.
5. The impacts of restoration can vary between groups and species. Thus, studies are needed that compare effects on various taxa (Donald and Evans 2006).
6. The basic assumption that management practices designed to aid wildlife conservation have similar effects on target species across the range of application needs further testing (Whittingham et al. 2007).
7. The influence of agricultural practices on native wildlife populations should be assessed.
   a. Target declining native species in a region-specific manner throughout the U.S. and determine which populations wildlife-friendly farming could support.
8. Create mathematical/statistical models to predict the impact of projected and/or predicted agricultural change on various species.
9. Do crop diversity and areas of on-farm natural habitat correspond with higher biodiversity across a region?
10. What is the effect of crop diversity on the composition and abundance of wild species?
    a. Which species in particular?
    b. How many rare/threatened species benefit from diverse cropping systems?
11. What is the value of chemical-free buffer areas to wildlife in agricultural regions?
12. Document the impacts of agrochemicals on biodiversity within agroecosystems.
13. What specific roles do particular native species play in agroecosystem function and regulation (Banks 2004 and Daily 1997)?

Climate Change

How climate change will alter the dynamic between agriculture and biodiversity should be addressed with further research.

1. In order to predict and plan for the effect of global warming on farmland, we need to integrate information on climate, landforms, landscape structure, and dynamics of species' distributions across a hierarchy of spatial and temporal scales (Freemark 2005).
   a. The use of remote-sensing technology and spatially explicit, multi-species models could help inform the potential effects of climate change on biodiversity in agricultural systems.
   b. Species' capacity to survive habitat changes resulting from global warming may depend

on the availability of suitable habitats within their transitional and final ranges and their ability to reach them. Research is needed that examines the potentially synergistic effects of landscape structure and climate change, a likely determinant of future ranges (Honnay et al. 2002; Opdam & Wascher 2004; Hulme 2005).

- c. Are wildlife corridors alone the most effective means for species movement, or would corridors function better if habitat quality within the larger agricultural matrix were improved (Baudry et al. 2003)?
- d. Further research could help determine whether a diverse and complex agricultural matrix is in fact more resilient to climate change and could also allow species to migrate in order to survive the related ecological changes (Freemark 2005).
- e. What restoration techniques could be implemented to make the agricultural matrix amenable to species movement?

2. In light of predictions that global warming will reduce food security (Battisti and Naylor 2009), will farms with higher biodiversity have higher resiliency and thus a heightened capacity to maintain productivity?
3. How will global warming impact pollinators?
    - a. To improve predictions of future change, ecologists particularly need data on phenological cues and on the behavioral flexibility of pollinators, and on pollinator life cycles (Memmott et al. 2007).

Ecological Roles of Species Perceived as Pests

Agricultural conflicts with wildlife needs further research.

1. What factors make an agricultural operation more or less vulnerable to livestock predation?
    - a. What is the relationship between habitat features/alteration and risk of predation?
    - b. How do predator species respond to habitat alteration at different spatial scales?
    - c. What husbandry methods make stock less vulnerable to predators?
    - d. Does maintaining higher populations of wild prey species decrease predation on domesticated species in different systems? If so, what are effective ways of maintaining wild prey populations?
    - e. Is predator-friendly ranching feasible at a large scale?
    - f. Research behavioral ecology of predators on farms and apply understanding of predator patterns to reducing depredation.
2. Which non-lethal methods for controlling specific predators are most effective in different systems?
    - a. What are the best methods for wolves and bears?
    - b. Which guard animals offer the best protection against coyotes?
3. What can be done to take the pressure off non-predatory wildlife in agriculture?
    - a. How can predator control methods be altered to reduce the impact non-target species?
    - b. How do organisms often targeted for destruction such as prairie dogs benefit the agroecosystem?
    - c. Further research is needed to determine whether wildlife species perceived as problematic are in fact a food safety threat.

Beneficial Organisms

Assessments of the current levels of biodiversity should be made.

1. Inventory all native pollinators.
2. Determine where and when reservoirs of native pollinators in wildlands occur.
3. Catalog the relationships between pollinators, plants they pollinate and the underlying ecological processes.

4. Which native pollinators, predatory, and parasitic insects are most valuable for various crops?
5. Determine the ideal proximity of forage for pollinators, predatory, and parasitic insects to crops.
6. Assess native/honeybee interactions.
7. Quantify distribution shifts in key pollinator groups, and in other important beneficial insect groups.

ecoSERVICES

Understanding Ecosystem Services Better

Ecosystem services to farmers (erosion control, soil, pest control, pollination, positive interactions between crops) and ecosystem services to the public (erosion control, reduce chemical applications, attractive farmland) should be addressed by further research.

Factors Affecting Ecosystem Services

1. For each ecosystem service, ecological data are needed to answer the following major questions:
    a. Which species are most important?
    b. How do these species, communities and the services they provide respond to alternative management regimes?
    c. What are their requirements for persistence in agricultural landscapes?
    d. How stable are species, communities and services over space and time?
    e. Over what scales do they provide services to agriculture?
2. The question of whether intensive or extensive agriculture best optimizes the various trade-offs associated with ecosystem service provision is an important issue requiring targeted research (Zhang et al. 2007).
    a. The ecological-economic problem needs to be addressed through identifying the mosaic of connected habitats that best supports both farm production and its value to farmers and the supply of off-farm ecosystem services that support off-farm values (Pascual and Perrings 2007).

Flow of Ecosystem Services and Scales They Require

3. Research needs to document and track the individual flows and their contributions to agricultural production and/or land value (Zhang et al. 2007).
4. Managing landscapes for ecosystem services, however, requires understanding the flows of services from one parcel to others e.g., flow of pollinators from natural areas to surrounding crops (Ricketts, 2004), flow of water provision services from upland areas to areas downstream (Guo et al., 2000).
5. We need a deeper understanding of the local and landscape management scales at which ecosystems provide services to people (Zhang et al. 2007, Tscharntke et al. 2005).
6. Ecosystem services supply and demand must be analyzed spatially across the landscape, in order to make explicit the locations of ecosystem services providers and consumers, and the flows of services from one to the other (Eade and Moran 1996; Kremen 2005; Naidoo and Ricketts 2006).
    a. Do wildlife inoculate soils with beneficial bacteria and fungi? If so, which species?
    b. What native predators provide pest control services on farms?
7. There is a need for more detailed case studies at the scale of typical land-use decisions (e.g., Guo et al. 2000; Ricketts et al. 2004), and then for meta-analyses to understand typical effect sizes and general trends (Kremen 2005).

a. What are the significant factors (e.g. scale) in determining the effectiveness of increasing on-farm plant biodiversity for the purposes of reducing crop pests and/or implementing IPM strategies (Banks 2004)?

Understanding How Management of Ecosystems Influences the Provision of Services

Context is important. Service providers vary in function and importance according to system type, and providers of the same service (e.g. different pollinator species) may react differently to management types (Zhang et al. 2007).

1. How much habitat is sufficient and in what configuration to keep respective ecosystems functioning at a level that will produce desired ecosystem services?
   a. Which plant characteristics attract beneficial organisms in a variety of semi-natural and natural habitats (Fielder and Landis 2007)?
   b. Which native plants should be installed in order for their flowering to support native pollinators, predatory, and parasitic insects during critical pollination and seasonal pest outbreaks of crops?
   c. Future research should evaluate combination plantings of highly suitable plants that provide overlapping bloom periods through the growing season (Tuell et al. 2008).
   d. What is the potential for native plants to enhance multiple ecosystem services beyond pest suppression (Fielder et al. 2008)?
   e. What aspects of native plant ecosystem structure and function decrease likelihood of pathogen presence and distribution?
   f. Refine quantification methods for determining the value of native vegetation for carbon sequestration.
   g. What functions do different week species have for agroecosystems? What species can be tolerated in different crops and on what basis?
   h. How do cover crops influence the presence of native animals that supply ecosystem services?
   i. To what degree are crops pollinator-limited in terms of production?
   j. When quantifying ecosystem services provided by conservation features like hedgerows, are results different or consistent across landscapes?
2. How can a healthy diverse soil fauna be retained?
   a. Study the importance of fallow areas in securing biodiversity and improving soil and water conservation.
   b. What are the effects of no-till vs. conventional tillage on native, ground-nesting bees?

Understanding the Consequences

The relative individual and combined importance of drivers of loss of beneficial organisms needs to be determined (land use, climate change, environmental chemicals, invasives and socio-economic factors).

1. Measure the biodiversity risks associated with the loss of services from beneficial organisms in agricultural and natural systems through the development of standardized tools and protocols.
2. Develop predictive models for loss of beneficial organisms and consequent risks.
3. Trade-offs of ecosystem services need better analysis (Kareiva et al. 2007).

bioSUSTAINABILITY

Evaluating Effectiveness of Current Conservation Measures

More robust studies are needed that evaluate the effectiveness of agrienvironment schemes for the protection of biodiversity (Kleijn et al. 2001; Kleijn & Sutherland 2003). Efficient measures will help to prioritize resource allocation accurately.

1. Design farm conservation incentives so that their impact can be evaluated scientifically.
    a. Ensure avian, fish, and other ecolabels provide measurable conservation benefits.
        i. Determine specifically if "predator-friendly" eco-labels are an effective means of raising rancher and consumer awareness regarding the connection between mega-fauna conservation efforts and livestock production.
    b. Evaluate factors that increase the success of eco-ag tourism operations.
        ii. Quantify benefits of predators that provide services to farmers such as reducing populations of pest animals and increasing potential value of ecotourism.
2. Investigate the effectiveness of achieving conservation goals through a regulatory approach.
3. Conduct cost comparisons that evaluate effective achievement of conservation goals and values within patterns of intensification and set-asides, and with agricultural matrix strategies.
4. Develop regionally-tailored assessments of the effectiveness of existing legal and financial mechanisms to protect the environment and native species in the agricultural environment.
5. Gather quantitative data demonstrating whether conservation plantings (like hedgerows) are effective at directly benefit farmers.
6. Explore the effectiveness of farmer-researcher cooperatives working with farmers as a strategy for restoring a more diverse agricultural matrix across large farms.
7. Increase the number of controlled field studies (i.e. at experimental stations) where you can standardize conservation areas and agricultural production.

Assessing Drivers of Biodiversity Gains

As data on biodiversity patterns grow and our understanding of the ecological processes driving these patterns improves, we will increasingly need to link conservation science with studies of agricultural and land-use change (Mattison & Norris 2005; Tallis and Kareiva 2006).

Economic Drivers That Promote Conservation

1. Determine the most cost-effective measures for achieving conservation goals within agriculture.
2. More research is needed that seeks to understand how different groups assign value to ecosystem services (Pascual and Perrings 2007). Refine methods for examining the economic value of biodiversity and ecosystem services.
3. How can studies address 'stacked' ecosystem services with multiple ecosystem service goals and management? (Fiedler, at al. 2008).
4. Studies are needed that link conservation with the farmer's bottom line.
5. Develop ways to compensate farmers for the possible losses they may face when incorporating wildlife-friendly farm practices (Banks 2004).
6. How can the transition from traditional/conventional to sustainable/organic farming be made economically viable? What are potential sources of assistance?
7. What new economic mechanisms could prevent reductions in populations of endangered species dependent on farmland?
8. Do subsidies and tax breaks distort farm-level decisions? If so, research how they affect biodiversity and how can they be changed to support it?

Other Types of Drivers That Promote Conservation

1. Study the benefit of wildlife-rich farmland to the wellbeing of rural dwellers and visitors.
2. Develop pesticide risk measurement tools to guide farmer choice.
3. Study how to increase the potential for safe harbor agreements that protect landowners and open up new opportunities for rare species research.
4. What effective means can be used to encourage farmers to implement practices that would decrease climate change impacts?

Decision Making and Incentives for Implementation

In order to retain biodiversity in agricultural landscapes, we need to better understand the value (both social and economic) of biodiversity to man, and develop mechanisms to return this value to rural communities managing the land (Norris 2008). Decision making by itself, and tied to incentives, needs to be more fully understood.

Values and Goals That Shape Decision Making

1. How do cultural values influence land use decisions?
2. How do the values that drive different restoration measures vary between people and landscapes?
3. Evaluate factors prevalent in farmer decision-making.
4. How do we determine guidelines for balancing multiple goals that may have different optimal implementation schemes?
5. Synergies among biodiversity conservation, ecological restoration, human cultural values, tourism, biological control and other ecosystem services have largely been overlooked in past habitat management research and require further study.

Collaborative Decision Making

1. Interdisciplinary research should be undertaken to explore the feasibility of implementing the "best" strategy (i.e. matrix or intensification) and the potential socioeconomic mechanisms that might need to be adopted to shape agricultural land-use in the desired way.
2. Investigate the importance of multi-stakeholder participation, grassroots and indigenous knowledge in developing strategies that lessen impacts.
3. Improve collaboration between conservation groups and growers to determine which conservation practices are best to implement.
4. Determine the role of rural, grass-roots social movements in promoting ecological farming techniques.

Incentives That Influence Decision Making

1. Well-designed economic research in collaboration with ecologists continues to be needed both to study values to motivate policy and to design effective incentives (Zhang et al. 2007).
2. Research ways to incorporate regional conservation priorities into conservation incentives.
3. How can we incentivize farmers to maintain carnivore populations?
4. What are the best incentives for encouraging farmers to conserve pollinators and other native beneficial insects?
5. Much research is still needed to determine economic valuation and the development of markets for biodiversity.

a. These efforts may be potentially effective providing that they successfully identify and measure biodiversity values as the benefits from conserving it which may not always be evident. (Pascual and Perrings 2007, Opschoor 1999; Jackson et al. 2007)
b. Policies must fully 'internalize' the environmental costs and benefits of agriculture into practices and markets (Freemark 2005).
c. Should premium market access be granted to wildlife friendly producers? If so, through which mechanisms?
d. How can farmers cope with market forces such as lack of incentives and rising costs of inputs?

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