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Enhancing Conservation Delivery and Economic Returns with Precision Agriculture

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Abstract:

Although there are many challenges related to intense agricultural production, agricultural landscapes are crucial for the preservation of natural resources. The primary obstacle is the conflicting economic results of agricultural production and conservation. Quantifying the economics of crop production and conservation enrollment is necessary to comprehend these results. By employing cutting-edge technology to measure spatially explicit profitability in agricultural areas, precision agriculture technology offers a way to meet these demands. The use of precision agriculture in conservation planning is an area of study that is expanding. I give a succinct introduction to precision agricultural technology and how it is used to conserve natural resources. I go over the potential contribution of precision agriculture to US conservation policy, point up obstacles to its uptake, and offer suggestions for its future use. I describe a novel strategy for targeted conservation delivery that emphasizes return on investment for farmers and go over how precision agriculture fits into this strategy. State wildlife agencies, nongovernmental organizations, farm managers, rural banks, and agricultural businesses will need to make significant investments in order to increase the adoption and use of this technology in the conservation of natural resources. The next paradigm change in natural resource conservation is represented by precision agriculture, where decisions are made spatially explicitly to maximize conservation and profitability and create multipurpose, environmentally resilient agricultural landscapes.

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Introduction:

According to Robertson and Swinton (2005) and Ribaudo (2010), agricultural landscapes offer ecological services that are generally advantageous to society. Unfortunately, the operation of these ecosystem services is also threatened by a number of negative externalities that are produced by intense agricultural production. Traditionally, there have been two approaches to addressing the negative externalities of agricultural production: either conservation is incorporated into agriculture (land sharing) or a clear distinction is made between agriculture and conservation. In order to balance the conflicting goals of sustainable food production and ecosystem services, conservation must be integrated into working agricultural landscapes. This is because most arable land is already used for agricultural production, and the world's growing population will necessitate significant agricultural intensification to meet future food demands. A large number of wildlife populations are dependent on agricultural landscapes as a component of ecosystem services. Remaining natural plant communities that offer ecosystem services are frequently the source of adequate animal habitat in agricultural environments. Maintaining healthy, sustainable wildlife populations is consistent with ecosystem service management and will call for creative ways to incorporate production agricultural systems. Because agricultural landscapes are dynamic, it is necessary to find dynamic solutions to address conservation priorities and counteract production's negative externalities.

Conservation Delivery

U.S. farm policy has evolved significantly, particularly in conservation efforts through recurring Farm Bills. The Conservation Reserve Program (CRP) is the primary mechanism for land retirement, paying farmers to convert environmentally sensitive agricultural lands into conservation-friendly areas.

The CRP delivers multiple ecosystem benefits, including:

- Reducing soil and pesticide loss
- Improving water and air quality
- Sequestering carbon
- Supporting pollination and beneficial insect populations
- Creating wildlife habitats

Despite these benefits, the CRP faces challenges. Between 2007 and 2012, approximately 28% of CRP land was converted back to cropland or pasture, driven by high commodity prices and contract expirations. This conversion has negatively impacted wildlife populations. The ongoing tension between agricultural economics and conservation efforts remains a critical issue, with efforts needed to stabilize landscape-scale conservation areas and mitigate the environmental impacts of intensive agriculture.

Economics of Conservation

Agricultural producers face multiple uncertainties in food production, including economic and environmental challenges. Key pressures include:

- 36% increase in input costs (2007-2012)
- 45% decrease in farm income (2013-2016)

The economic landscape demands profitable land-use alternatives that balance agricultural production with ecosystem services. Current conservation approaches often overlook the producer's economic perspective, focusing instead on societal benefits and cost-effectiveness.

Research suggests that return-on-investment (ROI) is crucial for conservation adoption. A promising strategy involves:

- Targeting low-quality, less profitable soils for conservation
- Identifying economically viable alternative land-use options
- Utilizing precision agriculture technology to quantify conservation opportunities

The goal is to create a more balanced approach that simultaneously addresses environmental conservation and agricultural economic sustainability.

Precision Agriculture

Precision agriculture has multiple definitions across disciplines. Pierce and Nowak's production-focused definition emphasizes managing spatial and temporal variability in agricultural production. Whelan and McBratney offer a broader perspective, viewing it as a philosophical shift aimed at improving profitability and environmental impact.

Despite varying definitions, precision agriculture's core goal is to farm more efficiently. Producers typically adopt this technology to:

- Reduce input costs
- Increase yield
- Simplify farming processes

The technology represents an opportunity to integrate more environmentally conscious practices into agricultural production.

Application of Precision Agriculture in Conservation

Research on precision agriculture for conservation has primarily focused on strategic conservation placement to minimize environmental contaminants and improve water quality. Key developments include:

Early studies quantified economic outcomes of conservation practices, introducing 'targeted conservation' by incorporating profitability into decision-making. Researchers used precision agriculture to:

- Prioritize conservation actions
- Assess subfield profitability
- Evaluate soil vulnerability and variability

Notable approaches include:

- McConnell and Burger's geospatial decision support tool for Farm Bill conservation enrollment
- Quantifying wildlife conservation economics and population responses

Currently, Pheasants Forever is a leading organization applying precision agriculture technology to conservation, working with producers to:

- Secure yield monitor data
- Identify unprofitable field regions
- Find alternative land-use decisions

More widespread adoption is needed across wildlife agencies, organizations, and agricultural sectors to achieve landscape-level conservation.

Constraints to Precision Agriculture

Precision agriculture technology adoption faces five key challenges:

1. Low technology adoption by producers
2. Limited data availability to natural resource managers
3. Insufficient understanding of conservation applications
4. Unclear economic benefits
5. Lack of decision support tools (DSTs)

Adoption barriers include:

- Perceived implementation costs
- Technological limitations
- Lack of trust in technology
- Data sharing hesitancy (particularly among lessee farmers)

Producers need:

- DSTs from trusted sources
- Tools integrating economic and conservation applications
- Clear demonstration of technology's value

These challenges present significant opportunities for improving precision agriculture's conservation potential.

Future Thrust

The evolution of targeted conservation reflects changing U.S. conservation priorities:

Traditional Approaches:

- Initially focused on soil erodibility
- Soil erosion decreased 43% from 1982-2007
- 1990 Farm Bill introduced Environmental Benefits Index
- Developed conservation practices for specific wildlife species

Proposed New Definition:

- Focus on return on investment (ROI) for agricultural producers
- Apply conservation practices only where they increase profitability
- Utilize precision agriculture technology to identify:
- Environmentally sensitive, low-profit field regions
- Alternative land-use options
- Opportunities for environmental services

Key Benefits:

- Addresses producer concerns about opportunity costs
- Prevents converting conservation land to cropland
- Increases environmental resilience
- Simultaneously improves landscape functionality and producer profitability

Potential Alternative Land Uses:

- Fallow vegetation
- Native forage grasses for grazing
- Ecosystem service-generating practices

Conclusion

In the US, agricultural landscapes play a critical role in conservation efforts. Although intensive agricultural production produces several environmental problems, the opportunity to construct more sustainable, environmentally resilient agricultural landscapes has never been greater. Although precision agricultural technology can act as a bridge between targeted conservation and production agriculture, it will also be required to address the sustainable intensification of production agricultur. This strategy will necessitate a paradigm change in the way managers of natural resources see conservation. Agricultural landscapes can be made more sustainable and multipurpose when conservation is viewed as an economic and environmental strategy. According to Sweikert and Gigliotti (2019), agricultural producers need incentives to take part in conservation efforts. Although the US Farm Bill is the most effective conservation delivery system in history, acceptance of conservation is hampered by its complexity. One piece of the conservation puzzle is missing: the ability to spatially quantify the economics of conservation decisions. This is due to the lack of understanding of the economic outcomes of conservation actions, complex conservation policy, and an overwhelming need for financial assistance. By supplying this missing component, farmers will be able to make wise choices. Only precision agriculture technology can accomplish this. Natural resource managers and agricultural producers can see and contrast the economic results of various conservation scenarios when precision agriculture data is incorporated into conservation eligibility using a DST.

Natural resource agencies, nongovernmental organizations, rural banks, and private agricultural businesses must take the lead in investing in and understanding the conservation and economic potential of this technology if the wildlife conservation community is to benefit from it. Natural resource managers will need to broaden their knowledge base and technological skill set in order to successfully implement this technology. Geospatial modeling, agricultural economics, and conservation eligibility and economics are all included in the conservation application of precision agriculture technologies. Natural resource managers will need to comprehend the foundations and integration of various fields of research more and more. As this technology becomes more important in the management of natural resources, the demand for DSTs is probably going to rise. Innovative, easily accessible, and reasonably priced DSTs will be required to address the increasing demands of a more knowledgeable, productive agricultural landscape. The next paradigm change in natural resource conservation is represented by precision agriculture, whereby spatially explicit conservation decisions are made to maximize conservation and profitability in order to create multipurpose, environmentally resilient agricultural landscapes.