5-1-2011

Using precision agriculture technology to evaluate environmental and economic tradeoffs of alternative CP-33 enrollments

Mark Dewitt McConnell

Recommended Citation

McConnell, Mark Dewitt, "Using precision agriculture technology to evaluate environmental and economic tradeoffs of alternative CP-33 enrollments" (2011). *Theses and Dissertations*. 4903.
https://scholarsjunction.msstate.edu/td/4903

USING PRECISION AGRICULTURE TECHNOLOGY TO EVALUATE ENVIRONMENTAL AND ECONOMIC TRADEOFFS OF ALTERNATIVE CP-33 ENROLLMENTS

By

Mark Dewitt McConnell

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Wildlife Ecology
in the Department of Wildlife, Fisheries and Aquaculture

Mississippi State, Mississippi

April 2011

USING PRECISION AGRICULTURE TECHNOLOGY TO EVALUATE ENVIRONMENTAL AND ECONOMIC TRADEOFFS OF ALTERNATIVE CP-33 ENROLLMENTS

By

Mark Dewitt McConnell

Approved:

Loren W. Burger, Jr.
Professor of Wildlife Ecology
(Director of Thesis)

Samuel K. Riffell
Associate Professor of Wildlife Ecology
(Committee Member)

Steve W. Martin
Extension Professor of Agricultural Economics
(Committee Member)

Philip J. Barbour
Adjunct Professor of Wildlife Ecology
(Committee Member)

Eric D. Dibble
Professor of Aquatic Sciences
(Graduate Coordinator)

George M. Hopper
Dean of College of Forest Resources

Bruce D. Leopold
Professor and Department Head
Wildlife, Fisheries and Aquaculture

Name: Mark Dewitt McConnell

Date of Degree: April 30, 2011

Institution: Mississippi State University

Major Field: Wildlife Ecology

Major Professor: Loren W. Burger, Jr.

Title of Study: USING PRECISION AGRICULTURE TECHNOLOGY TO EVALUATE ENVIRONMENTAL AND ECONOMIC TRADEOFFS OF ALTERNATIVE CP-33 ENROLLMENTS

Pages in Study: 111

Candidate for Degree of Master of Science

United States Department of Agriculture's Farm Bill conservation programs provide landowner incentives to remove less productive and environmentally sensitive lands from agricultural production and re-establish them in natural vegetation to achieve conservation objectives. However, removal of arable land from production imposes an opportunity cost associated with loss in revenue from commodities that otherwise would have been produced. The Habitat Buffers for Upland Birds practice (CP-33) under the Continuous Conservation Reserve Program is a targeted conservation practice designed to increase northern bobwhite populations in agricultural landscapes. However, establishing CP-33 buffers on profitable farmland may be incompatible with economic objectives of landowners. To determine how CP-33 enrollment influenced field profitability and bobwhite abundance; I simulated CP-33 buffers on crop fields across a range of commodity prices and modeled profitability and predicted bobwhite abundance. CP-33 increased field revenue on a percentage of fields at all commodity prices and increased bobwhite abundance up to 30%.

Key words: northern bobwhite, precision agriculture, conservation reserve program, conservation profitability, precision conservation

DEDICATION

I dedicate this manuscript to my father, Kyle Albritton. Thank you for taking me outdoors and instilling in me your passion for the woods and wildlife. There is no doubt that I would not be here today if I were not your son.

"*It is not flesh and blood, but heart which makes us fathers and sons*."

- Friedrich von Schiller

ACKNOWLEDGEMENTS

First and foremost I want to thank Dr. Burger for giving me the opportunity to advance my education. It was literally a “dream come true” to work for Dr. Burger and I am eternally gratefully for his confidence and trust in my abilities. I must also thank Dr. Burger for his “sink or swim” mentoring approach! He allowed me to get just scared and panicked enough not to mess up and that is a lesson I will always remember. I would also like to thank my committee members Dr. Steve Martin, Dr. Sam Riffell, and Dr. Philip Barbour for their support and extreme patience in this endeavor. I am grateful to the CFR graduate community for their web of support whenever I needed to complain and complain a little more. Special thanks to Matt Palumbo and James Callicutt for their friendship and unwavering support from start to finish. Heath Hagy and Jonathan Fleming deserve special thanks as well for the friendship and assistance with statistics and GIS, respectively. I would like to thank Kristine Evans for her leadership, advice, confidence, patience, and friendship that she provided me from day one. One could not ask for a better colleague and friend. I am grateful to my parents for their support, my grandmother for her faith in me, and my brothers for setting an example of success. Last but certainly not least I thank my fiancée Mary Elizabeth. No one believed in me more and put up with more than her. She never once complained about late nights or weekends at the office. She has supported me, loved me, and encouraged me every day since we met. For that I am and will always be grateful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Northern bobwhite (*Colinus virginianus*, hereafter, bobwhites) are integrally linked to the rural American landscape. Although bobwhites serve important ecological, social, recreational, and economic functions (Burger et al. 1999, Burger 2006), they have experienced precipitous range-wide population declines averaging 3.9% annually since 1980 (Sauer et al. 2008). Bobwhite population decline has been attributed to a myriad of land use changes including intensification of agriculture and monoculture pine farming, disruption of natural fire regimes, conversions to exotic/invasive forage grasses, advanced natural succession, concentrated grazing, and geographic isolation of remaining populations (Stoddard 1931, Roseberry and Klimstra 1984, Brennan 1991, Roseberry 1993, Burger 2002, Smith 2004). Addressing bobwhite decline will require modifications of current land use practices on a massive scale (Dimmick et al. 2002). Considering nearly 50% of the land area in the contiguous 48 states is managed for row crop production or grazing (USDA 2003, Robertson and Swinton 2005), range-wide recovery will largely require focus on privately-owned agricultural landscapes.

Farmlands historically provided quality habitat for bobwhites, which are adapted to the ephemeral annual plant communities produced by frequent disturbance associated with crop management. However, exponential human population growth (Lutz et al. 2001, UNPD 2007) and associated increases in food demand (Bongaarts 1996), shifted the agriculture paradigm towards mass production of food and fiber resources (Tilman et al. 2002). Intensive agricultural practices (e.g., clean farming) across the bobwhite range have contributed to habitat loss on multiple scales (Klimstra 1982, Brennan 1991). Reduction in number of farms and associated increase in farm size over the last half-century has reduced the complexity and heterogeneous nature of agricultural landscapes (Brennan 1991, Burger 2002, Smith 2004). Clean farming practices have reduced abundance of herbaceous fence-rows, grass strips, and wooded edges that traditionally separated fields and delineated property lines. Selective herbicides and insecticides have effectively reduced diversity and abundance of herbaceous plants, insects, and invertebrates in agricultural landscapes (Potts 1986, Watkinson et al. 2000, Benton et al. 2002). Collectively, land use changes have degraded or eliminated thousands of hectares of bobwhite nesting and brood-rearing habitat (Roseberry and Klimstra 1984, Brennan 1991) and consequently, have been integral in contributing to range-wide bobwhite decline.

Numerous grassland songbirds have also experienced steep declines resulting from intensive use and conversion of grasslands to agriculture (Herkert 1994, Chamberlain et al. 2000, Murphy 2003, Brennan and Kuvlesky 2005, Sauer et al. 2008). Although large scale agricultural expansion has benefited some grassland bird species (Askins 1999), farming (conversion and intensification) is considered the single greatest danger to threatened bird species (Green et al. 2005) and the leading cause of grassland songbird decline (Vickery and Herkert 1999, Blackwell and Dolbeer 2001, Murphy 2003), further illustrating the need for a dramatic shift in agricultural production systems to maintain and enhance avian populations.

Northern Bobwhite Conservation Initiative

The Northern Bobwhite Conservation Initiative (NBCI) was developed to restore range-wide bobwhite populations to baseline densities observed in 1980. NBCI population goals are stated in terms of fall coveys, where one covey equals approximately 12 birds. Achieving NBCI objectives will require an addition of 2,770,922 coveys across 32.8 million ha of improvable land. However, the NBCI postulates that success of this goal could be achieved by altering land use on only 6-7% of improvable acreage, further stating that nearly 80% of proposed objectives could be met by affecting only 7.6 million ha of cropland, hayland, pasture, and Conservation Reserve Program (CRP) land (Dimmick et al. 2002). The primary programmatic vehicle for achieving NBCI goals on agricultural lands will be conservation programs implemented through the Farm Bill (Burger et al. 2006 (a)). Farm Bill is a general term for the compilation of Congressional Acts designed to enhance agricultural productivity and conservation on working farmland.

Conservation Buffers

Conservation buffers have long been recognized for their multiple environmental benefits including, but not limited to, erosion control (Dillaha et al.1989, Dosskey et al. 2005), sediment, nutrient, and herbicide retention (Daniels and Gilliam 1996, Webster and Shaw 1996, Das et al. 2004), and wildlife enhancement (Dover 1994, Puckett et al. 1995, Best 2000, Smith 2004, Conover et al. 2009). United States Department of Agriculture's (USDA) National Conservation Buffer Initiative (NCBI) has been instrumental in promoting buffer establishment on private lands nationwide (NRCS 1999). The vehicle for implementing conservation buffers has been Continuous Conservation Reserve Program (CCRP) under the conservation title of the Farm Bill.

Under CCRP a variety of conservation buffer practices (e.g., filter strips, forest riparian buffers, field borders, and upland habitat buffers) are available to accomplish specific conservation objectives associated with national conservation initiatives.

CP-33 Habitat Buffers for Upland Birds

In 2004 President George W. Bush announced the Presidential Bobwhite Initiative implemented under CCRP and charged USDA to develop a new conservation practice designed specifically to increase bobwhite habitat in agricultural landscapes (USDA 2005). Conservation Practice [CP] 33, Habitat Buffers for Upland Birds, was established to address the population recovery goals set by NBCI (FSA 2004). Upland habitat buffers are herbaceous communities maintained along cropped field edges. Under CP-33, agricultural landowners can enroll 9.1-36.5 meter upland habitat buffers along crop field edges by planting native warm-season grasses, forbs, legumes and shrubs, or by allowing natural succession to occur and maintain them in an early seral stage. Financial incentives include a $247.10/ha sign-up incentive (SIP), per hectare, county and soil-specific annual rental rate, 50% cost share assistance for cover establishment, and 40% practice incentive payment (PIP) for approved establishment costs (FSA 2004). Periodic planned disturbance is required for the life of contract period (10 years) and cost-shared up to 50%. The premise of CP-33 is that relatively small changes in a working agricultural landscape can significantly affect bobwhite and grassland bird abundance.

Factors that Influence Adoption

Agricultural producers operate under uncertainty created by environmental and market stochasticity. Consequently, financial concerns strongly influence producer decisions (Kitchen et al. 2005). Variations in global economies, federal policies (e.g., Farm Bill), commodity prices, subsidy payments, weather/climatic events, input costs, farm ownership, and equipment expenses together provide numerous financial obstacles for producers. Removing land from production for conservation imposes an opportunity cost associated with loss in revenue from commodities that otherwise would have been produced (USDA 2003). "Conservation must be compatible with profitability" (Kitchen 2005:422), and to make conservation implementation economically attractive to agricultural landowners, conservation programs must address economic concerns of producers (USDA 2003). Conservation and profitability can coexist if ecological and economic demands are taken into account (Holzkamper and Seppelt 2006). Because farm policy in the United States (implemented through the Farm Bill) has evolved to recognize the importance of financial concerns and profitability in adoption of conservation practices, numerous conservation programs provide financial incentives to compensate for opportunity costs of land retirement. Conservation buffer practices, including CP-33, address producers' financial and environmental concerns by providing substantial financial incentives for enrollment of environmentally sensitive lands. However, enrollment of all eligible land might not necessarily maximize financial returns, and thus may not be the best land use strategy. An enrollment that maximizes conservation benefits, subject to the constraint that economic benefits equal or exceed that under agricultural production might be considered optimal.

Currently a combination of land eligibility and landowner objectives are the decision making components of conservation program adoption. Landowners choose a program and are restricted to the management practices available under that program which may or may not be conducive to desired objectives (Burger 2006). Furthermore, implementation of such programs may not fully optimize the landowner's economic and conservation goals or potential (Burger 2006). Under the general signup CRP, eligible fields must meet a highly erodible land (HEL) criterion. Continuous signup CRP practices, such as CP-33, are not limited to HEL which creates the opportunity of removing moderate to highly productive land from cultivation. Although overall environmental benefits may be produced, profitability for a landowner may be reduced by enrollment. Removing highly profitable land from agricultural production is not an effective strategy for maximizing overall benefits of conservation programs. Efficacy of conservation implementation depends on maximizing whole field profitability and concomitantly providing the greatest environmental and wildlife benefits. Agricultural landowners will enroll in conservation programs that address environmental and wildlife concerns provided financial incentives are adequate (USDA 2003). To maximize societal, environmental, and economic benefits through conservation programs, strategic implementation is crucial. The vehicle for strategic conservation will be precision agriculture technology.

Agriculture is the world's largest industry and continues to dominate human land use (Robertson and Swinton 2005). With the human population expected to reach 9.4 billion and per capita arable land expected to be reduced by nearly 40% by 2050 (Lal 2000) intensification of agricultural production is expected. The mechanism of increase will involve either allocation of additional land to production or maximization of the potential (i.e., increase yield) of land already in use. Considering the most of the world's arable land is already in agricultural production (Baligar et al. 2001) future production demands will likely come from land currently in use. Precision agriculture provides a method for implementing the latter of these options by allowing producers to maximize yield and profitability in a spatially explicit and economically advantageous manner (Stull et al. 2004).

Precision agriculture [PA] is "the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production" (Pierce and Nowak 1999:1). Whelan and McBratney (2000:265) describe PA as "a philosophical shift in the management of variability within agricultural industries aimed at improving profitability and/or environmental impact (both short and long term)". The PA concept is based on reorganization of the agricultural system to low-input, high-efficiency, sustainable agriculture (Shibusawa 1998). The principal goal of PA is to maximize yield (Metric Tons/ha) and profitability ($/ha). When yield is maximized, amount of land needed to meet food demands and financial obligations is reduced. If financial obligations can be met with less cropped acreage, the opportunity for land reallocation is created. Less productive agricultural lands (i.e., those with reduced yields) are logical candidates for conservation implementation (Hyberg and Riley 2009). Conservation and food production goals can be linked through increasing yield on cultivated land, thereby freeing up land for conservation use (Green et al. 2005). PA can increase profitability for producers and concomitantly provide ecological benefits to the public (Zhang et al. 2000). Although, PA has existed since the early 1990s (Daberkow and McBride 2003), its applications for conservation planning have, until recently, been widely overlooked (Lowenberg-DeBoer 1996, Stafford 2000).

The emerging field of precision conservation uses PA technology to achieve conservation objectives. Precision conservation [PC] is "a set of spatial technologies and procedures linked to mapped variables directed to implement conservation management practices that take into account spatial and temporal variability across natural and agricultural systems" (Berry 2003:332). PC, much like PA, depends on geospatial tools such as global positioning systems (GPS), geographic information systems (GIS), digital landscape information, spatially explicit mathematical models, and intensive computer analysis (Dosskey et al. 2005). Numerous studies on PC's application in conservation planning have been conducted (Berry et al. 2003, Dosskey et al. 2005, Kitchen et al. 2005), but generally focus on nutrient loading and erosion control. PC has also been used in strategic establishment of conservation buffers to reduce nutrient runoff and topsoil erosion (Stull et al. 2004, Dosskey et al. 2005) and has been shown to increase buffer effectiveness. However, no studies currently exist that incorporate PA's or PC's use in wildlife conservation planning.

Research evaluating economic and environmental tradeoffs of implementing Farm Bill conservation programs is limited. CP-33 is the first conservation program to require wildlife monitoring to quantify its effectiveness and also among the most economically advantageous. Barbour (2006) found CP-33 enrollment to be economically beneficial or neutral when strategically applied to field borders with reduced yields. Evans and Burger (2006) showed a positive response in bobwhite and grassland bird densities to CP-33 enrollment at state and national scales. The next step in strategic conservation enrollment is to evaluate environmental benefits (increased bird abundance) and economic benefits (increased profitability) in a spatially explicit context.

The goal of my research was to develop an approach using PA and PC technology, predictive wildlife abundance models, and decision support tools to evaluate environmental and economic tradeoffs of strategic conservation buffer enrollment for northern bobwhites, thus integrating wildlife conservation into the broader field of precision conservation.

Specifically, my study was designed to:

1. Develop a geospatial decision support tool to illustrate conservation eligibility and characterize economic tradeoffs of conservation enrollment versus agriculture production.
2. Use site specific yield monitoring data, production budgets, and break-even economic analysis to construct spatially explicit profit surfaces for 34 row crop production fields.
3. Develop a Poisson regression model that predicts abundance of northern bobwhite as a function of landscape composition and structure.
4. Construct simulation models to evaluate environmental and economic tradeoffs among whole field agriculture production and alternative CP-33 enrollments (9.1, 18.2, 27.4, and 36.5 m).

This study will provide agriculture producers, crop consultants, wildlife biologists, and natural resource managers with tools to make informed decisions. Chapter II describes geoprocessing steps that make up the Precision Conservation Decision Support Tool. Chapter III describes economic benefits of alternative CP-33 enrollments under varying commodity price assumptions and crop types. Chapter IV describes effects of landscape composition and structure on bobwhite abundance in agricultural landscapes. Chapter V synthesizes the results of chapters II, III, and IV to evaluate environmental tradeoffs between production agriculture and CP-33 enrollment.

Literature Cited

Askins, R. A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology 19:60-71.

Baligar, V. C., N. K. Fageria, and D. I. He. 2001. Nutrient use efficiency in plants. Communications in Soil Science and Plant Analysis 32:921-950.

Barbour, P. J. 2006. Ecological and economic effects of field borders in row crop agriculture production systems in Mississippi. Dissertation, Mississippi State University, Starkville, USA.

Benton, T. G., D. M., Bryant, L. Cole, and H. Q. P., Crick. 2002. Linking agricultural practices to insect and bird populations: a historical study over three decades. Journal of Applied Ecology 39:673-687.

Berry, J. K., J. A. Delgado, R. Khosla, and F. J. Pierce. 2003. Precision conservation for environmental sustainability. Journal of Soil and Water Conservation 58:332-339.

Best, L. B. 2000. The value of buffer habitats for birds in agricultural landscapes. Pages 75-94 *in* W. L. Hohman and D. J. Halloum, editors. A comprehensive review of Farm Bill contributions to wildlife conservation, 1985-2000. U.S. Department of Agriculture, Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI-2000.

Blackwell, B. F., and R. A. Dolbeer. 2001. Decline of the Red-winged Blackbird population in Ohio correlated to changes in agriculture (1965-1996). Journal of Wildlife Management 65:661-667.

Bongaarts, J. 1996. Population pressure and the food supply system in the developing world. Population and Development Review 22.

Brennan, L. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Brennan, L. A. and W. P. Kuvlesky, Jr. 2005. North American grassland birds: An unfolding conservation crisis? Journal of Wildlife Management 69:1-13.

Burger, L. W. 2002. Quail Management: issues, concerns, and solutions for public and private lands-a southeastern perspective. National Quail Symposium Proceedings 5:20-34.

Burger, L. W. 2006. Creating wildlife habitat through federal farm programs: an objective-driven approach. Wildlife Society Bulletin 34:994-999.

Burger, L. W., D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010-1018.

Burger, L. W., D. McKenzie, R. Thacktson, and S. J. Demaso. 2006 (a). The role of farm policy in achieving large-scale conservation: bobwhite and buffers. Wildlife Society Bulletin 34:986-993.

Burger, L. W., M. D. Smith, R. Hamrick, W. E. Palmer, and S. D. Wellendorf (b). 2006. CP33-Habitat buffers for upland birds monitoring protocol. Southeast Quail Study Group and Southeast Partners in Flight miscellaneous publication.

Chamberlain, D. E., R. J. Fuller, R. G. H. Bunce, J. C. Duckworth, and M. Shrubb. 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. Journal of Applied Ecology 37:771-788.

Conover, R. R., L. W. Burger, and E. Linder. 2009. Breeding bird response to field border presence and width. The Wilson Journal of Ornithology 121:548-555.

Daberkow, S. G., and W. D. McBride. 2003. Farm and operator characteristics affecting awareness and adoption of precision agriculture technologies in the US. Precision Agriculture 4:163-177.

Daniels, R. B., and J. W. Gilliam. 1996. Sediment and chemical load reduction by grass and riparian filters. Soil Science Society of America Journal 60:246-251.

Das, C., W .J. Capehart, H. V. Mott, P. R. Zimmerman, and T. E. Shumacher. 2004. Assessing regional impacts of Conservation Reserve Program-type grass buffer strips on sediment load reduction from cultivated lands. Journal of Soil and Water Conservation 59:134-142.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural non-point pollution control. Transactions of the American Society of Agricultural Engineers 32:513-519.

Dimmick, R. W., M. J., Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina, USA.

Dosskey, M. G., D. E. Eisenhauer, and M. J. Helmers. 2005. Establishing conservation buffers using precision information. Journal of Soil and Water Conservation 60:349-354.

Dover, J. W. 1994. Arable field margins: factors affecting butterfly distribution and abundance. British Crop Protection Council Monograph 58: Field Margins: Integrating Agriculture and Conservation, Farnham, Surrey, UK.

Evans, K. O., and L. W. Burger. 2006. Conservation Reserve Program. Bird Monitoring and Evaluation Plan. 2006 Annual Report.

Farm Service Agency. 2004. Notice CRP-479 Practice CP-33, Habitat buffers for upland birds. U.S. Department of Agriculture, Farm Service Agency, Washington, D.C., USA.

Green, R. E., S. J. Cornell, J. P. W. Scharlemann, and A. Balmford. 2005. Farming and the fate of wild nature. Science 307:550-555.

Herkert, J. R. 1994. Breeding bird communities of mid-western prairie fragments: the effect of prescribed burning and habitat-area. Natural Areas Journal 14:128-135.

Holzkamper, A., and R. Seppelt. 2006. Evaluating cost-effectiveness of conservation management actions in an agricultural landscape on a regional scale. Biological Conservation 136:117-127.

Kitchen, N. R., K. A. Sudduth, D. B. Myers, R. E. Massey, E. J. Sadler, R. N. Lerch, J. W. Hummel, and H. L. Palm. 2005. Development of a conservation-oriented precision agriculture system: Crop production assessment and plan implementation. Journal of Soil and Water Conservation 60:421-430.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Bobwhite Quail Symposium 2:1-5.

Lal, R. 2000. A modest proposal for the year 2001: we can control greenhouse gases and feed the world…with proper soil management. Journal of Soil and Water Conservation 55:429-433.

Lowenberg-DeBoer, J. 1996. Economics of precision farming: payoff in the future. Purdue University, IN, USA. < http://pasture.-ecn.purdue.edu/~mmorgan/PFI/pfiecon.html>. Accessed 10 November 2008.

Lutz, W., W. Sanderson, and S. Scherbov. 2004. The end of human population growth in the 21st century: New challenges for human capitol formation and sustainable development. Earthscan, London, United Kingdom.

Murphy, M. T. 2003. Avian population trends within the evolving agricultural landscape of eastern and central United States. Auk 120:20-34.

Natural Resources Conservation Service. 1999. The National Conservation Buffer Initiative: A qualitative evaluation. U.S. Department of Agriculture, Natural Resource Conservation Service. <http://www.nrcs.usda.gov/feature/buffers/pdf/BuffQual.pdf>. Accessed 4 August 2008.

Pierce F. J. and P. Nowak. 1999. Aspects of precision agriculture. Advances in Agronomy 67:1-85.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and L. T. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505-516.

Potts, G. R. 1986. The partridge: pesticides, predation and conservation. Collins, London, U.K.

Robertson, G. P., and S. M. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Agriculture and the Environment 3:38-46.

Roseberry, J. L. 1993. Bobwhite and the "new" biology. Pages 16-20 *in* K. E. Church and T. V. Dailey, eds. Quail III: National Quail Symposium. Kansas Department Wildlife and Parks, Pratt, USA.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University, Carbondale, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.*

Shibusawa, S., 1998. Precision Farming and Terra-mechanics. Fifth ISTVS Asia-Pacific Regional Conference in Korea, October 20-22.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Dissertation, Mississippi State University, Mississippi.

Stafford, J. V. 2000. Implementing precision agriculture in the 21st century. Journal of Agriculture Engineering Research 76:267-275.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons, New York, New York, USA.

Stull, J., C. Dillon, S. Shearer, and S. Isaacs. 2004. Using precision agriculture technology for economically optimal strategic decisions: The case of CRP filter strip enrollment. Journal of Sustainable Agriculture 24:79-96.

Tilman, D., Cassman, D.G., Matson, P.A., and S. Polasky. 2002. Agriculture sustainability and intensive production practices. Nature 418:671-677.

United States Department of Agriculture. 2003. Natural Resource Inventory. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Inventory Division. <http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb>.Accessed 31 July 2008.

United States Department of Agriculture. 2005. Bush administration expands Conservation Reserve Program, launches innovative conservation measures for wildlife and wetlands. U.S. Department of Agriculture, Office of Communications, Washington, D.C., News release 0324.04, 4 August 2004. <http://www.fsa.usda.gov/pas/printstory.asp?StoryID=1798>. Accessed 2008 August 4.

United Nations Population Division, World Population Prospects; The 2007 revision population division of the department of economic and social affairs of the United Nations secretariat, world population prospects: The 2006 revision and world urbanization prospects: The 2007 revision. < http://esa.un.org/unup>. Accessed 01 August 2008.

Vickery, P. C., and J. R. Herkert. 1999. Ecology and conservation of grassland birds of the Western Hemisphere. Studies in Avian Biology No. 19. Cooper Ornithological Society, Camarillo, California, USA.

Watkinson, A. R., R. P. Freckleton, R. A. Robinson, and W. J. Sutherland. 2000. Predictions of biodiversity response to genetically modified herbicide-tolerant crops. Science 289: 1554-1557.

Webster, E. P., and D. R. Shaw. 1996. Impact of vegetative filter strips on herbicide loss in runoff from soybean (*Glycine max*). Weed Science 44:662-671.

Whelan, B. M., and A. B, McBratney. 2000. The “Null Hypothesis” of precision agriculture management. Precision Agriculture 2:265-279.

Zhang, N., M. Wang, and N. Wang. 2000. Precision agriculture-a worldwide overview. Computers and Electronics in Agriculture 36:113-132.

CHAPTER II

A GEOSPATIAL, DECISION SUPPORT TOOL FOR OPTIMIZING CONSERVATION AND PROFITABILITY IN AGRICULTURAL LANDSCAPES

Agriculture dominates human land use (Robertson and Swinton 2005) and influences environmental goods and services produced by agroecosystems. In the United States, 50% (382.8 million ha) of the contiguous 48 states is devoted to cropping or grazing land uses (USDA 2003). With exponential human population growth (Lutz et al. 2001; UNPD 2007) and associated increases in food demand (Bongaarts 1996), production agriculture continues to intensify, favoring mass production of food and fiber resources (Tilman et al. 2002). To meet global demands and remain competitive in global markets, modern agriculture emphasizes maximizing productivity (i.e., increased yield) and minimizing costs. With the human population expected to reach 9.4 billion and per capita arable land expected to be reduced by nearly 40% by 2050 (Lal 2000), further intensification of agricultural production is almost certain. Increased agricultural production will involve either allocation of additional land to production or maximization of the potential (i.e., increase yield) of land already in use. Given that most of the world's arable land is already in agricultural production (Baligar et al. 2001) future production demands will likely be met through increased production on land currently in use.

Precision agriculture (PA) provides a suite of technologies that can potentially increase yield and reduce costs and environmental impacts in a spatially explicit manner

(Stull et al. 2004). One goal of PA is to efficiently allocate inputs to maximize yield (Metric Tons/ha) and/or profitability ($/ha). When yield is maximized, amount of land needed to meet food demands is reduced. If production and revenue targets can be met with less cropped acreage, opportunity for land reallocation is created. Less productive (i.e., those with reduced yields or lower profitability) and environmentally sensitive agricultural lands are logical candidates for conservation implementation or alternative land use (Tilman et al. 2002). Conservation and food production goals can be linked through increasing yield on cultivated land, thereby freeing up land for conservation use (Green et al. 2005). Precision agriculture can increase profitability for producers and potentially enhance environmental services of agricultural systems and societal benefits (Zhang et al. 2000). Although, adoption of PA technologies have been increasing since the early 1990s (Daberkow and McBride 2003), its applications for conservation planning have, until recently, been widely overlooked (Lowenberg-DeBoer 1996; Stafford 2000).

The emerging field of precision conservation uses PA tools to achieve conservation objectives. Precision conservation [PC] is "a set of spatial technologies and procedures linked to mapped variables directed to implement conservation management practices that take into account spatial and temporal variability across natural and agricultural systems" (Berry et al. 2003:332). Much like PA, PC depends on geospatial tools such as global positioning systems (GPS), geographic information systems (GIS), digital landscape information, spatially explicit mathematical models, and intensive computer analysis (Dosskey et al. 2005). Prior research on PC's application in conservation planning have generally focused on nutrient loading or erosion control (Berry et al. 2003; Dosskey et al. 2005; Kitchen et al. 2005). PC has also been used in strategic establishment of conservation buffers to reduce nutrient runoff and topsoil erosion (Stull et al. 2004; Dosskey et al. 2005), and has been shown to increase buffer effectiveness. However, few examples of PA's or PC's use for wildlife conservation planning exist.

Agricultural producers operate under uncertainty created by environmental and market stochasticity, consequently, financial concerns strongly influence producer decisions (Kitchen et al. 2005). Variations in global economies, commodity prices, agricultural policies (e.g., Farm Bill, trade agreements), subsidy payments, weather/climatic events, input costs, and equipment expenses together influence risk and profitability for landowners and producers. Removing land from production for conservation imposes an opportunity cost associated with loss in revenue from commodities that otherwise would have been produced (USDA 2003). "Conservation must be compatible with profitability" (Kitchen et al. 2005:422), and to make conservation implementation economically attractive to agricultural landowners, conservation programs must address economic concerns of producers (USDA 2003). Conservation and profitability can coexist if ecological and economic demands are accounted for (Holzkamper and Seppelt 2006). Farm policy in the United States, as codified in the Farm Bill and implemented through commodity and conservation programs, has evolved to recognize importance of financial concerns and profitability in adoption of conservation practices. Consequently, conservation programs provide financial incentives to offset direct and opportunity costs of conservation practice adoption.

Conservation buffers represent a suite of best management practices designed to take the most environmentally sensitive lands out of production and address specific resource concerns (e.g., soil erosion, water quality, wildlife conservation) in a manner that is compatible with row crop production systems by removing the least amount of ground from production. These targeted conservation practices often carry extra economic incentives (i.e., signup incentive payments, increased cost-share, elevated rental rates) to induce adoption. To increase the degree of targeting, eligibility of cropland for conservation buffer practices is constrained based on spatial relationships such as hill slope position, proximity to water bodies and wetlands, proximity to field margins, or other ecologically sensitive features. Buffer width, configuration, and plant materials are constrained so as to achieve desired resource outcomes. However, enrollment of all eligible land might not necessarily maximize financial returns, and thus might not be the best land use from a profitability standpoint. A strategic enrollment that maximizes conservation benefits, subject to the constraint that economic benefits equal or exceed that under agricultural production might be considered optimal from a producer standpoint and might increase adoption.

Effective implementation of PC will require computation and analysis of spatially explicit field-level information to identify enrollment opportunities (eligibility criteria) and spatial variation in profit under production versus alternative management strategies. However, few agricultural producers possess the geospatial processing skill required to conduct even rudimentary analyses. Decision support tools (DST) can assist producers in making informed decisions regarding tradeoffs among production and conservation enrollments. However, to date, no DST exists to assist producers in comparing profitability of crop production with conservation program enrollment in a spatially explicit context.

In this study I describe a geospatial decision support tool that identifies spatially explicit conservation program opportunities and characterizes economic tradeoffs of conservation program participation versus agriculture production. I illustrate the utility of this tool on a 1,200 ha (~2965 ac) row crop production farm in Tallahatchie County, Mississippi, USA (Figure 2.1). I chose 12 production fields from this farm based on availability of spatially explicit yield data. I present geoprocessing steps for identifying conservation and economic opportunities and provide an example of economic benefits of conservation enrollment created by this decision support tool at the farm and field level. I use conservation buffer practices as an example to illustrate ability of the tool to provide economic information to inform the decision making process. This tool will provide agricultural producers and natural resource professionals with data needed to make informed land management decisions that optimize their specific goals.

Methods

This geospatial decision support tool is designed to operate as a script or an extension in ArcGIS (ArcInfo version 9.3.1) software. It was coded in Python to ensure forward compatibility with ARCGIS version 10.x. The tool consists of 2 distinct modules: 1) to define practice-specific eligibility for 2 conservation buffer practices and 2) to construct profit surfaces from spatially explicit yield data and compare profitability under production versus alternative buffer enrollments. To illustrate conservation opportunities and economic tradeoffs I chose a candidate set of conservation buffer practices and ran simulation models to identify their eligibility on a production agriculture farm in Tallahatchie County, Mississippi, USA.

Eligibility Tool

The vehicle for implementing conservation buffers has been the Continuous Conservation Reserve Program (CCRP), implemented through the Farm Bill. Under

CCRP a variety of conservation buffer practices (i.e., filter strips, riparian forest buffers, field borders, and upland habitat buffers) are available to accomplish specific resource conservation objectives associated with national conservation initiatives. Each conservation practice has a unique set of eligibility criteria and financial incentives associated with its adoption. Therefore, my tool first identifies those regions of an agricultural field where a particular practice is eligible, based on spatial relationships. Multiple inputs are required to quantify eligibility for each practice contingent on its specific resource objective. I used Conservation Practice 21 (CP-21): Filter Strips and Conservation Practice 33 (CP-33): Habitat Buffers for Upland Birds to illustrate how this tool identifies conservation opportunities.

All fields must meet a cropping history criterion as defined in the current Farm Bill (4 of the 6 years 1996 – 2001 under the 2002 Farm Bill, 2002 – 2007 under the 2008 Farm Bill). Once cropping history criteria is met, implementation of a conservation practice on a particular field is a function of practice-specific eligibility criteria. Filter strips enrolled under CP-21 must be adjacent and parallel to a wetland or water body (e.g., streams, lakes, wetlands, sinkholes, etc). The field portion within 36.5 m of the wetland edge is eligible for enrollment in CP-21 (National FSA 2-CRP Handbook 2005). Minimum average buffer width is 9.1 m and maximum average buffer width is 36.5 m for CP-21. Whereas filter strips are typically on the downslope side of a field, CP-33 can be established around any field boundary. Average buffer width must be between 9.1-36.5 m (National FSA 2-CRP Handbook 2005).

Defining spatially-explicit practice eligibility requires a set of user-provided spatial data layers. Required spatial data layer inputs include (1) hydrography, (2) field boundaries, (3) digital soil maps, and (4) county and soil specific CRP rental rates. To maximize breadth of applicability, I have designed the tool to use National Hydrography Dataset (NHD), USDA-Far Service Agency (FSA) Common Land Unit (CLU) field boundaries, and Soil Survey Geographic database (SSURGO) soil layers. County and soil-specific CRP rental rates are provided in a spreadsheet joined to the soils layer. Users may substitute user-developed layers with appropriate geometry and attributes (e.g., field boundaries) for any of these inputs by pointing the tool to appropriate patch and file name. Once required inputs are obtained, the tool performs a series of geoprocessing steps to spatially define regions of practice-specific eligibility within the planning extent. These practice-specific eligible regions are output as a shapefile and illustrated in the view window on a georeferenced aerial photograph (e.g., NAIP imagery). I will describe the conceptual framework of this process acknowledging that the process will change for each practice based on eligibility criteria. To model these parameters in spatially explicit context I used ArcGIS (ArcInfo version 9.3.1) software.

Eligibility Tool will perform 6 major functions:

1. Identify and buffer all eligible boundary layers (field boundaries and/or water bodies) within geographic extent (e.g., farm boundary) by maximum width for that practice.
2. Combine eligible buffers into one buffer feature layer.
3. Intersect buffer feature layer with soils layer.
4. Calculate weighted SRR for each buffer based on three most prevalent soils.
5. Calculate area for each buffer.
6. Output single part, multiple feature buffer layer with buffer specific area and weighted SRR.

Profitability Tool

Several inputs and geoprocessing steps are required to calculate profitability of agriculture fields. The most essential element is spatially explicit yield data. Yield data is obtained from GPS yield monitors. Data is downloaded from memory cards, calibrated to dry yield, loads are combined into fields, yield data is passed through a series of filtering steps to eliminate erroneous data commonly associated with GPS yield data (fluctuations in speed, partially full header, non-cutting header position, GPS signal loss, and sensor calibration errors) (Carlson et al. 2002), then exported as a shapefile.

In addition to yield data, economic information about each conservation practice is necessary to calculate profitability under alternative buffer scenarios. Buffer practices under CCRP typically include a Signup Incentive Payment (SIP), Practice Incentive Payment (PIP), cost share assistance, and county and soil-specific soil rental rates (SRR). Together, these values less any incurred costs (i.e., maintenance costs), account for total buffer revenue. Payments and costs are amortized over the 10 year contract to produce annual per hectare costs and revenues.

Agricultural producers understand that they often experience yield reductions at field margins. These reductions are from such factors as production practices (field traffic causing compaction), variable inputs (herbicide, fertilizer, etc), greater weed and insect pressure, and competition with adjacent vegetation for sunlight, water, and nutrients. Yield data is useful for identifying field regions with reduced productivity. Converting yield data into a spatially explicit profitability map is more useful because it illustrates where revenue is gained or lost. Once calibrated and cleaned, yield data can be imported into the tool where necessary attributes and calculations will be carried out.

Profitability Tool will perform 5 preliminary functions:

1. Create 6 attribute fields: Commodity Price, Gross Revenue, Government Payments, Total Revenue, Production Costs, Net Revenue
2. Assign and calculate values for each field:
    a. Commodity Price = [User Input]
    b. Gross Revenue = [Commodity Price * Yield]
    c. Government Payments = [User Input]
    d. Total Revenue = [Gross Revenue + Government Payments]
    e. Production Costs = [User Input]
    f. Net Revenue = [Total Revenue – Production Costs]
3. Interpolate yield data by Inverse Distance Weighting using Net Revenue Field to generate profit surface
4. Calculate mean Net Revenue (i.e., profitability) using Zonal Statistics to generate whole field profitability under production alone
5. Export profit map

Calculating whole field profitability under agricultural production alone identifies field regions where revenue is lost or reduced; whereas, calculating whole field profitability under alternative conservation buffer enrollments identifies field regions where profitability under conservation enrollment is greater than that of production alone. Running this analysis for multiple conservation practices and alternative enrollments within a practice provides a multitude of land use options for agricultural producers.

Profitability Tool will then perform 6 final functions:

1. Create alternative width buffer polygons adjacent to eligible boundary layers (field boundaries and/or water bodies)

2. Add practice specific financial incentives to previously calculated weighted SRR to generate Buffer Revenue Field
3. Convert buffer layer to raster using Buffer Revenue Field
4. Replace buffer region from previously created profit surface with newly created buffer layer using Raster Calculator
5. Calculate mean Net Revenue (i.e., profitability) using Zonal Statistics to generate whole field profitability under each buffer scenario
6. Export profit map
7. Calculate difference in profit for alternative buffer widths relative to full production

Results

Eligibility Tool

On the Tallahatchie County farm, the tool identified 104 ha (~260 ac) eligible for CP-21 and 307 ha (~758 ac) eligible for CP-33 (Figures 2.2 and 2.3, respectively). This information provides land managers and producers with a thorough understanding and visualization of how and where conservation opportunities exist on the landscape. Although noteworthy, this estimate only reflects conservation opportunity and not economic opportunity. It is important to note that not all land eligible for conservation is more profitable under conservation enrollment compared to agriculture production. The need for economic analysis is essential to effective conservation enrollment.

My research demonstrates the utility and effectiveness of PA technologies coupled with a geospatial DST to identify conservation opportunities in agricultural landscapes. Quantifying conservation eligibility is paramount because most producers and natural resource planners cannot visualize where and how conservation programs fit into their production systems. Illustrating eligible land for multiple conservation practices provides options to producers to optimize not only their economic interests but also their specific natural resource concerns (i.e., water quality, soil loss, wildlife habitat). Use of geospatial technology is essential to this process and the DST produces simple, spatially explicit maps that producers can use to inform land use decisions.

Profitability Tool

This tool uses PA technology to identify economic opportunities in agricultural fields. Spatially explicit profit maps are generated to visualize monetary distribution of alternative enrollments (Figures 2.4 and 2.5). Simple calculations are then done to compare profitability of production alone to one of many conservation scenarios (Figures 2.6 and 2.7). Clearly, year-specific profitability does not capture the full range of spatial and temporal variation associated with stochastic environmental conditions and crop rotations. Spatially-explicit profit surfaces can be averaged over multiple years to better inform decision making.

Figures 2.8 and 2.9 illustrate how conservation buffers can be used to increase whole field profitability by removing marginal land from production and enrolling it in a conservation practice. It is important to note that not all fields experience yield reductions near field margins at a magnitude that would justify conservation enrollment, however, across an entire farm this process can be instrumental at increasing total revenue if applied strategically (conservation only where profitable).

My analysis illustrates the utility of this tool to provide economic information that can be used to make informed land management decisions. Across a range of fields and crop types in my analysis it is clear that some amount of CP-33 enrollment is economically beneficial (Figures 2.10 and 2.11) for this particular farm. However, the premise of this tool is that decisions can and should be made at the field level (i.e., targeted conservation). Hence, my analysis of individual fields indicates that conservation enrollment (e.g., CP-33) can be economically beneficial across a range of buffer widths. For example, in the soybean field an enrollment of 27.4 m generated the greatest financial return, whereas on the corn field financial return peaked at 9.1 m and then declined. Such information can then be used to make informed decisions about conservation enrollment on those fields without jeopardizing profitability.

Discussion

Traditionally, conservation implementation in agricultural landscapes has been perceived to hinder or directly reduce profitability. However, as financial incentives increase in scope, quantity, and specificity, strategic enrollment of conservation programs can actually increase profitability. The key to realizing the potential in these programmatic opportunities is helping producers visualize spatially explicit economic and environmental tradeoffs. Precision agriculture technology used in a precision conservation framework can help to optimize profitability and environmental benefits. Although most producers desire to be good stewards of natural resources and value environmental services that their land produces, economic constraints often hinder adoption. Natural resource professionals must find innovative solutions that balance environmental and economic tradeoffs. Precision conservation provides the necessary tools to implement profitable conservation in a spatially explicit framework that optimizes financial returns to the producer. My research provides a geospatial decision support tool that identifies conservation and economic opportunities in agricultural landscapes and evaluates economic tradeoffs of conservation enrollment versus agricultural production. This tool can aid in achieving landscape or watershed level conservation goals by increasing adoption of conservation practices.

Literature Cited

Baligar, V. C., N. K. Fageria, and D. I. He. 2001. Nutrient use efficiency in plants. Communications in Soil Science and Plant Analysis 32:921-950.

Berry, J. K., J. A. Delgado, R. Khosla, and F. J. Pierce. 2003. Precision conservation for environmental sustainability. Journal of Soil and Water Conservation 58:332-339.

Bongaarts, J. 1996. Population Pressure and the food supply system in the developing world. Population and Development Review 22.

Carlson, C. G., J. Kleinjan, J. Chang., J. Wilson, D. Humburg, D. Clay, and D. Long. 2002. Cleaning Yield Data. In review for PPI site specific guideline paper. <http://plantsci.sdstate.edu/precisionfarm/Publications.htm>. Accessed 10 November 2008.

Daberkow, S. G., and W. D. McBride. 2003. Farm and operator characteristics affecting awareness and adoption of precision agriculture technologies in the US. Precision Agriculture 4:163-177.

Dosskey, M. G., D. E. Eisenhauer, and M. J. Helmers. 2005. Establishing conservation buffers using precision information. Journal of Soil and Water Conservation 60:349-354.

ESRI (Environmental Systems Resource Institute). 2009. ArcMap 9.3.1 ESRI, Redlands, California.

Green, R. E., S. J. Cornell, J. P. W. Scharlemann, and A. Balmford. 2005. Farming and the fate of wild nature. Science 307:550-555.

Holzkamper, A., and R. Seppelt. 2006. Evaluating cost-effectiveness of conservation management actions in an agricultural landscape on a regional scale. Biological Conservation 136:117-127.

Kitchen, N. R., K. A. Sudduth, D. B. Myers, R. E. Massey, E. J. Sadler, R. N. Lerch, J. W. Hummel, and H. L. Palm. 2005. Development of a conservation-oriented precision agriculture system: Crop production assessment and plan implementation. Journal of Soil and Water Conservation 60:421-430.

Lal, R. 2000. A modest proposal for the year 2001: we can control greenhouse gases and feed the world…with proper soil management. Journal of Soil and Water Conservation 55:429-433.

Lowenberg-DeBoer, J. 1996. Economics of precision farming: payoff in the future. Purdue University, IN, USA. <http://pasture.-ecn.purdue.edu/~mmorgan/PFI/pfiecon.html>. Acessed 10 November 2008.

Lutz, W., W. Sanderson, and S. Scherbov. 2004. The end of human population growth in the 21st century: New challenges for human capitol formation and sustainable development. Earthscan, London, United Kingdom.

National FSA 2-CRP (Revision 4) Handbook. 2005.

Robertson, G. P., and S. M. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Agriculture and the Environment 3:38-46.

Stafford, J. V. 2000. Implementing precision agriculture in the 21st century. Journal of Agriculture Engineering Research 76:267-275.

Stull, J., C. Dillon, S. Shearer, and S. Isaacs. 2004. Using precision agriculture technology for economically optimal strategic decisions: The case of CRP filter strip enrollment. Journal of Sustainable Agriculture 24:79-96.

Tilman, D., Cassman, D.G., Matson, P.A., and S. Polasky. 2002. Agriculture sustainability and intensive production practices. Nature 418:671-677.

United States Department of Agriculture. 2003. Natural Resource Inventory. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Inventory Division. <http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb>. Accessed 31 July 2008.

United Nations Population Division, World Population Prospects; The 2007 revision population division of the department of economic and social affairs of the United Nations secretariat, world population prospects: The 2006 revision and world urbanization prospects: The 2007 revision. < http://esa.un.org/unup>. Accessed 01 August 2008.

Zhang, N., M. Wang, and N. Wang. 2000. Precision agriculture-a worldwide overview. Computers and Electronics in Agriculture 36:113-132.

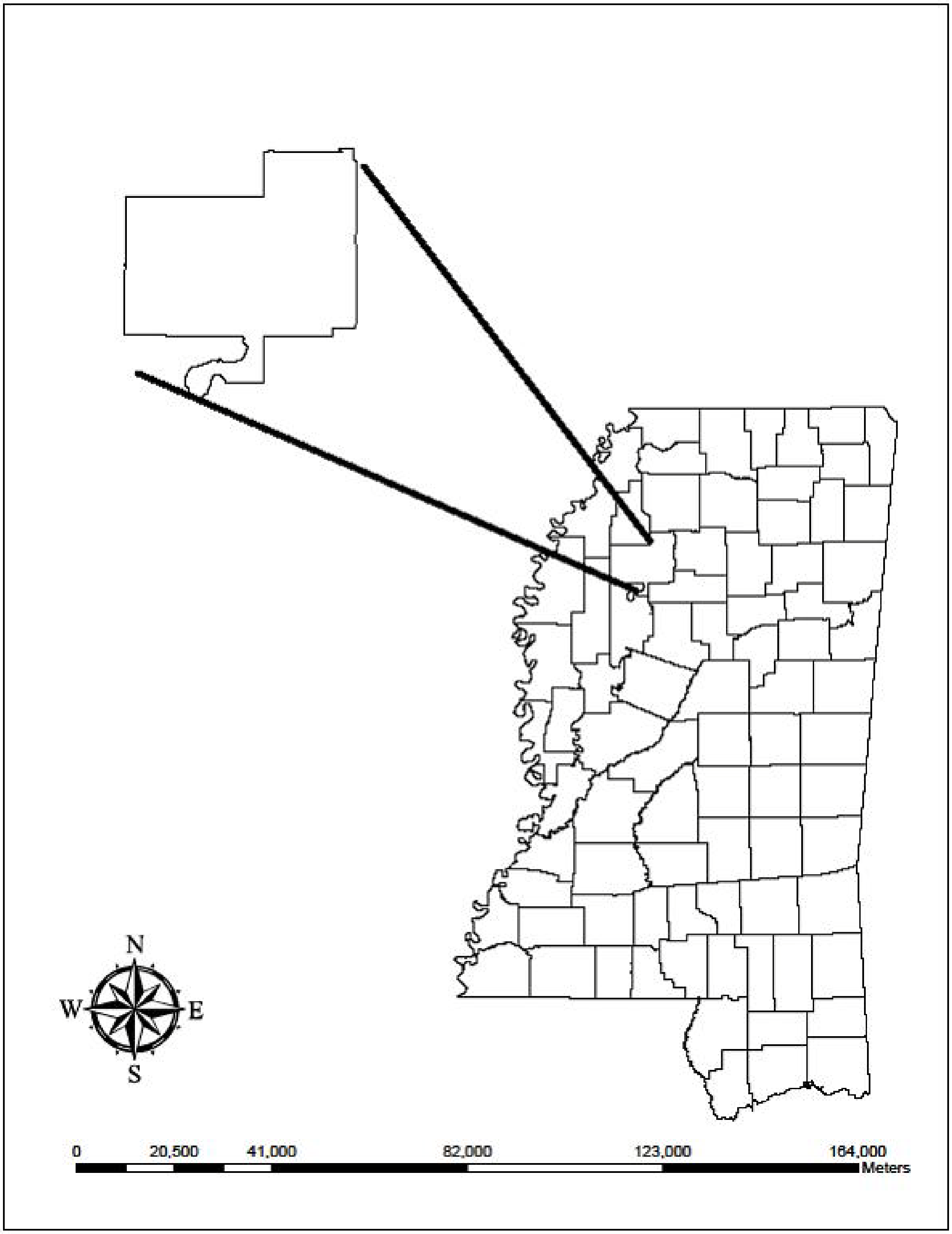

Figure 2.1 Location of Tallahatchie County, Mississippi, USA.

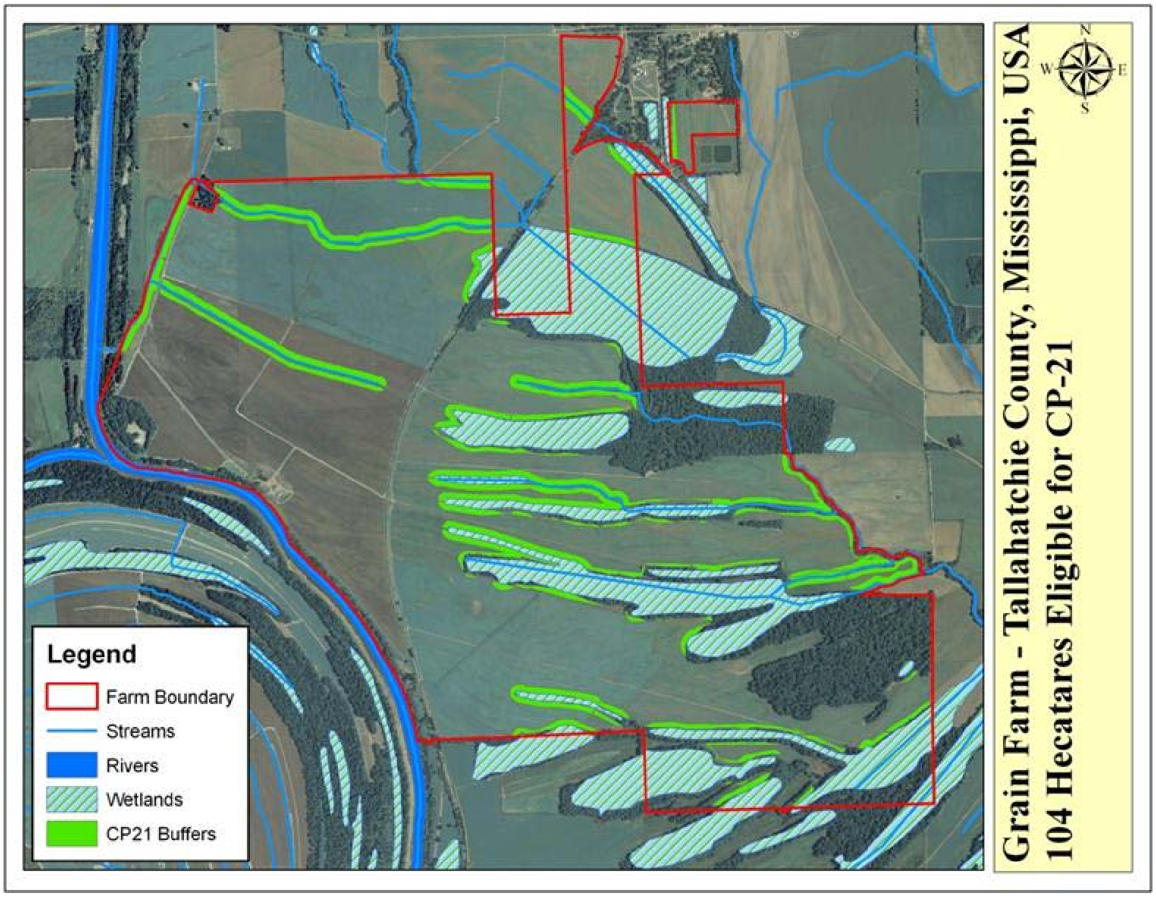

Figure 2.2 Total eligible area for Conservation Practice 21, Filter Strips on a 1,200 ha grain farm in Tallahatchie County, Mississippi, USA, 2007.

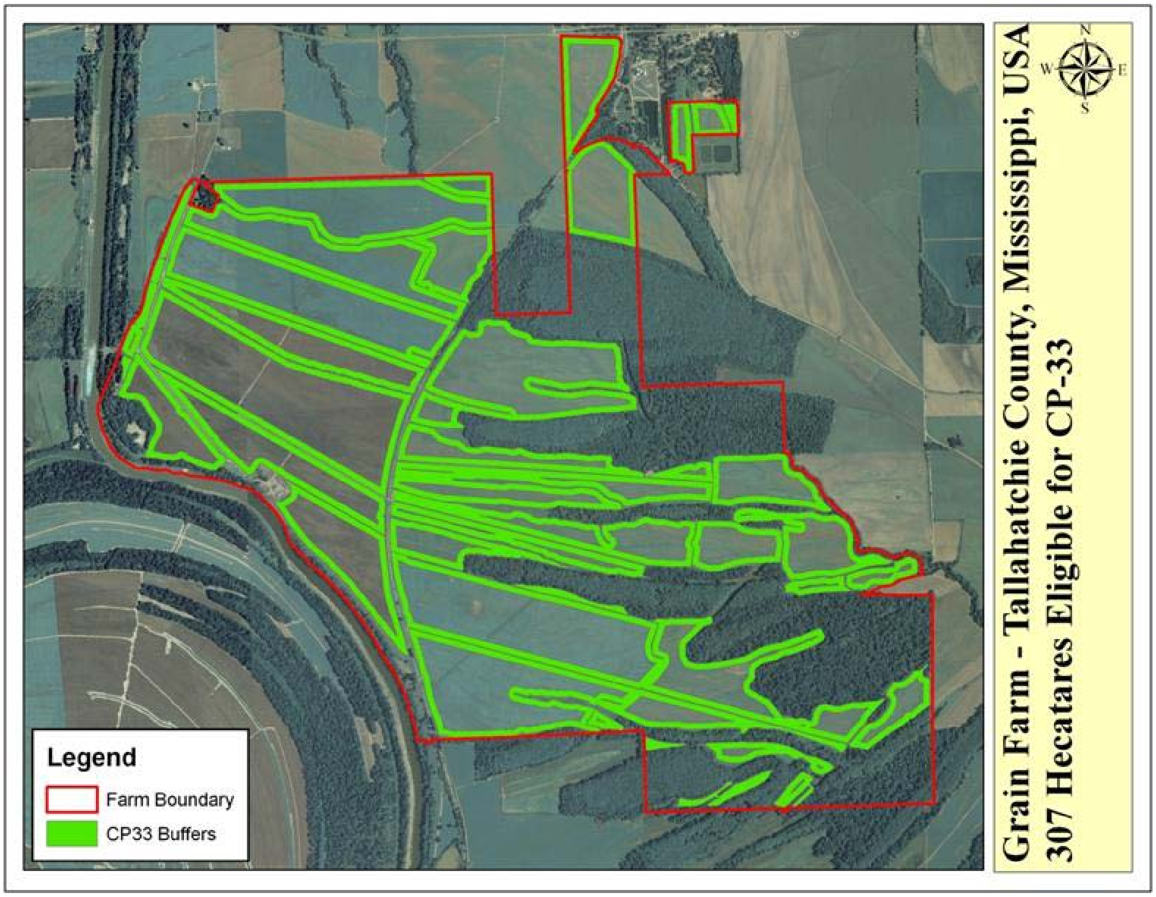

Figure 2.3 Total eligible area for Conservation Practice 33, Habitat Buffers for Upland Birds on a 1,200 ha grain farm in Tallahatchie County, Mississippi, USA, 2007.

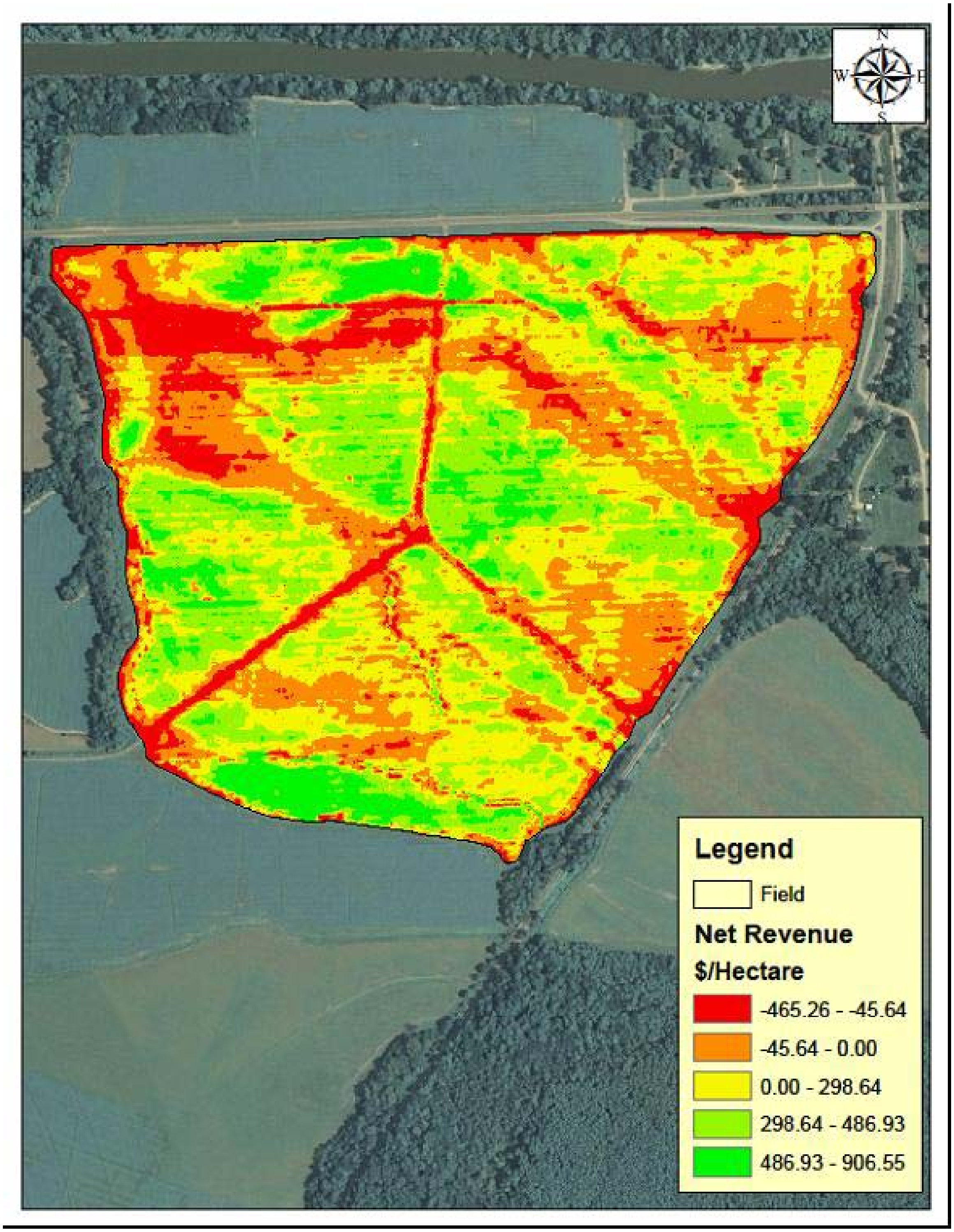

Figure 2.4 Profit surface for center-pivot irrigated soybean field assuming a $331/Metric Ton commodity prices and $597.87/ha production cost in Tallahatchie County, Mississippi, USA, 2007.

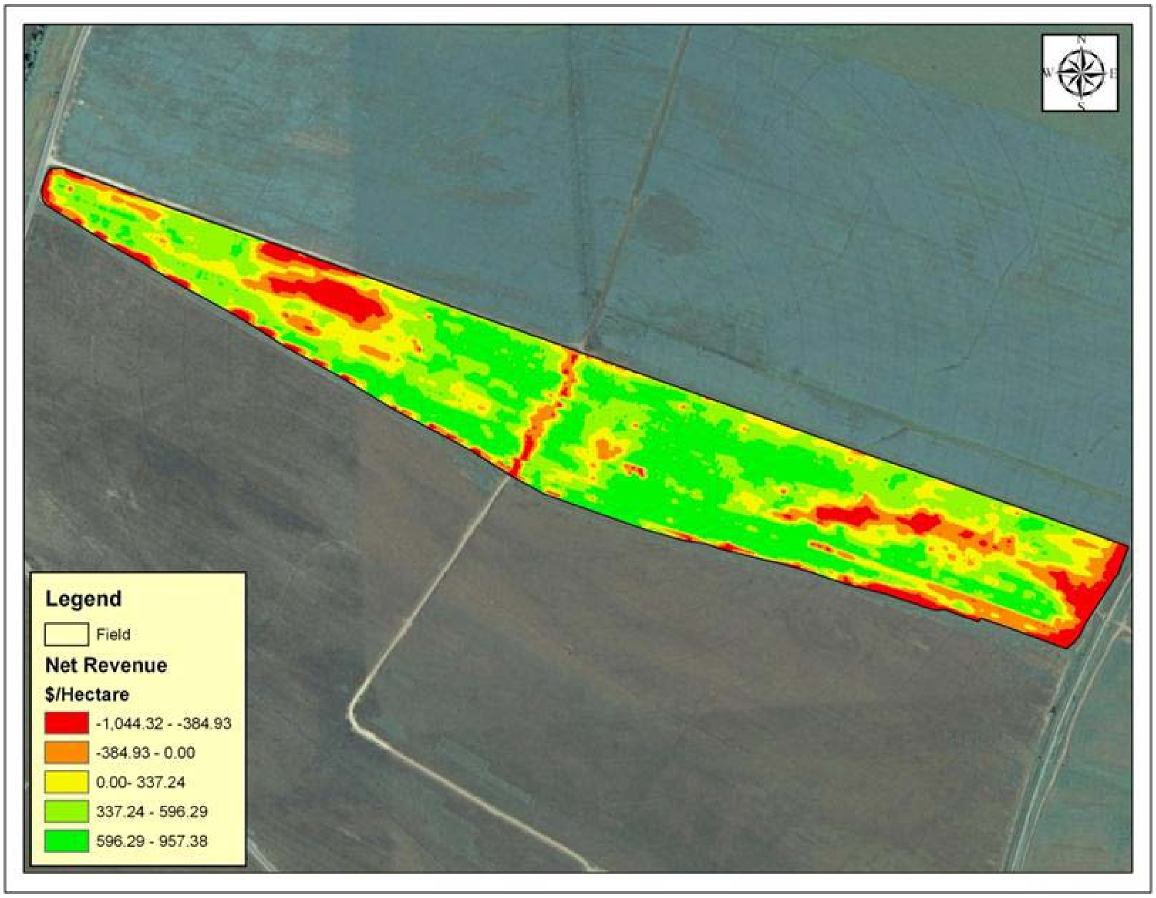

Figure 2.5 Profit surface for center-pivot irrigated corn field assuming a $138/Metric Ton commodity price and $1237.53/ha production costs in Tallahatchie County, Mississippi, USA, 2007.

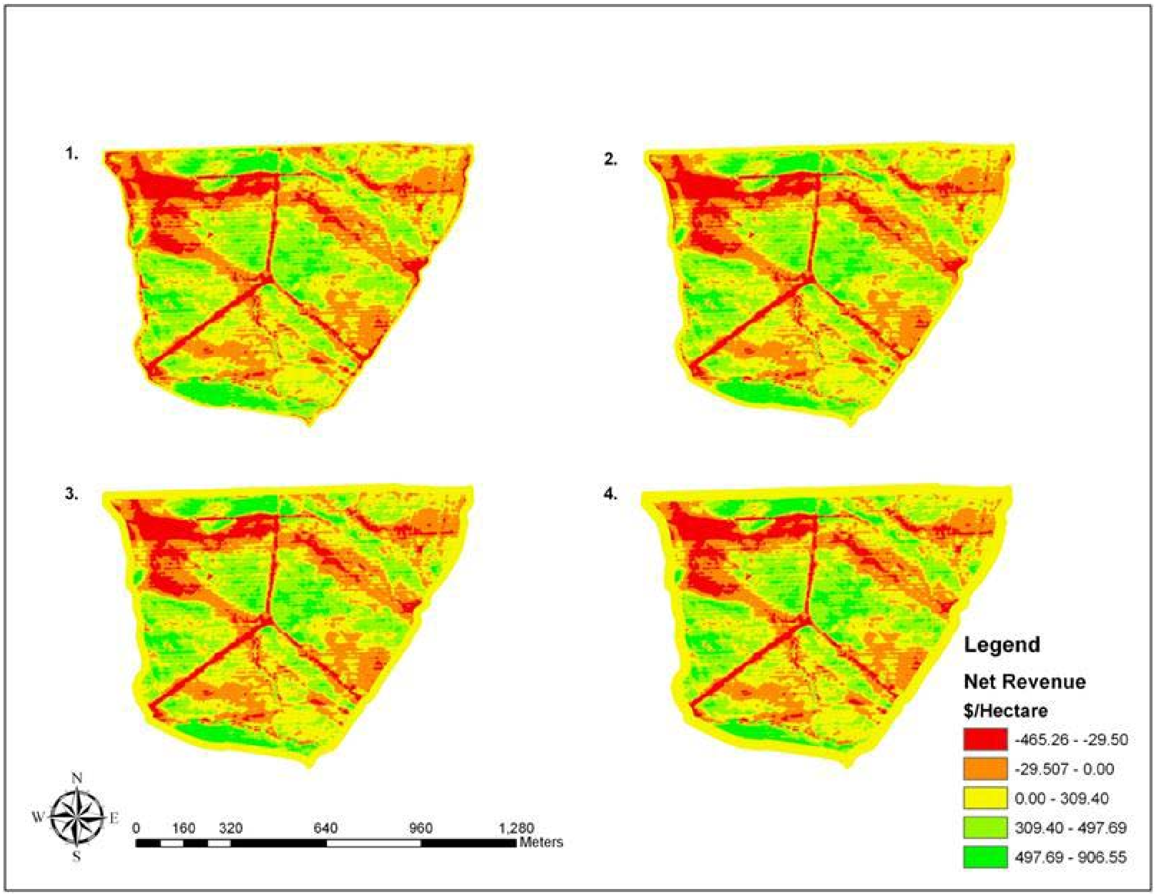

Figure 2.6 Profit surfaces for alternative CP-33 buffer widths on center-pivot irrigated soybean field in Tallahatchie County, Mississippi, USA, 2007. (1) 9.1 m CP-33 buffer (2) 18.2 m CP-33 buffer (3) 27.4 m CP-33 buffer (4) 36.5 m CP-33 buffer.

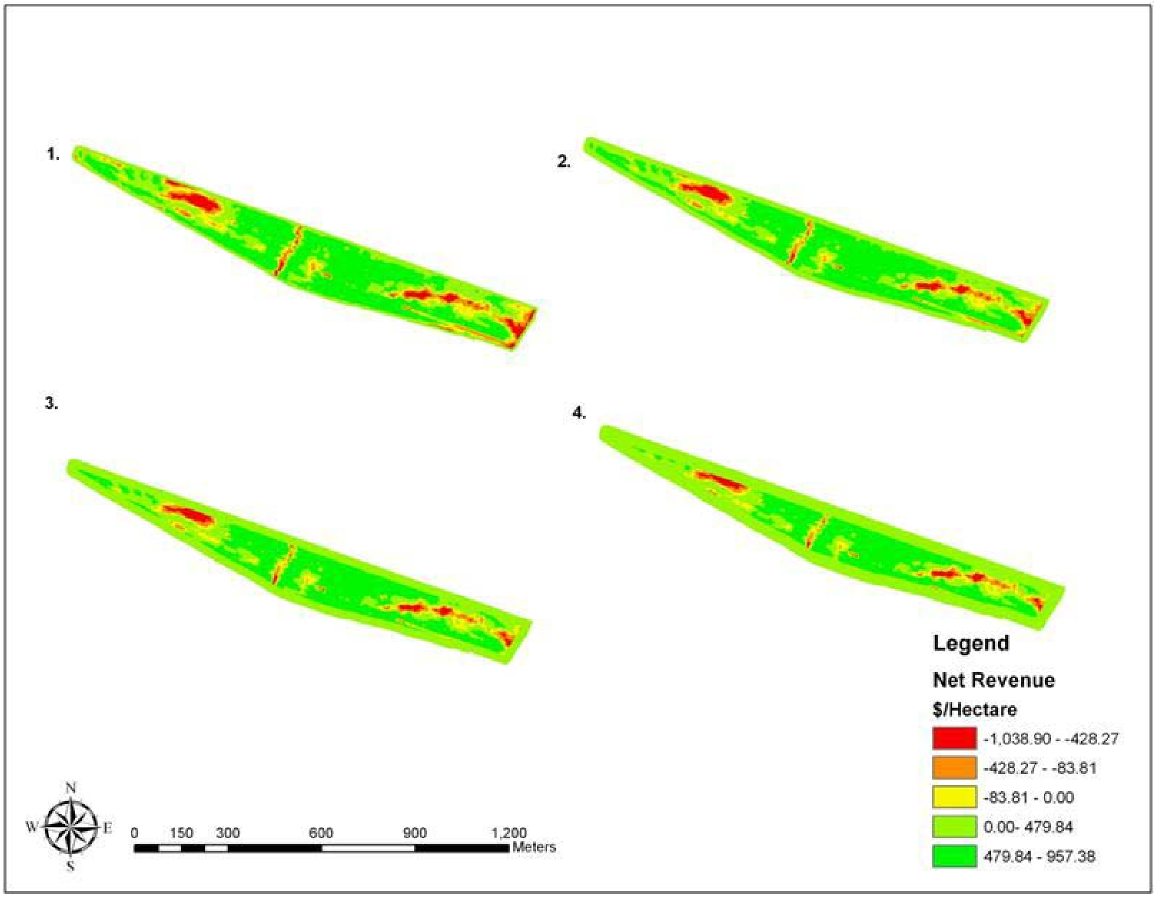

Figure 2.7 Profit surfaces for alternative CP-33 buffer widths on center-pivot irrigated corn field in Tallahatchie County, Mississippi, USA, 2007. (1) 9.1 m CP-33 buffer (2) 18.2 m CP-33 buffer (3) 27.4 m CP-33 buffer (4) 36.5 m CP-33 buffer

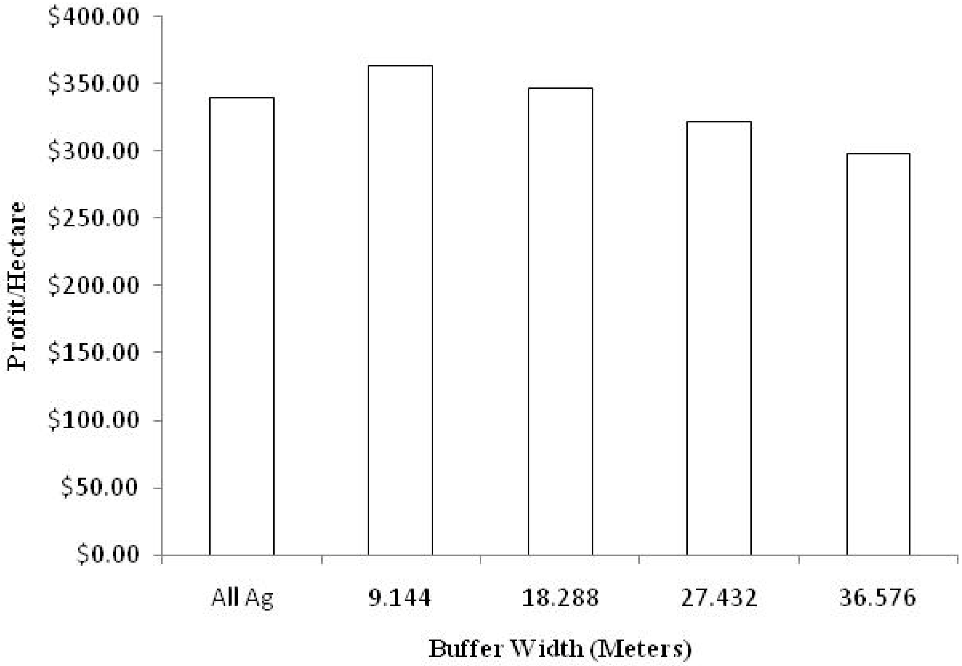

Figure 2.8 Whole-field net revenue of alternative CP-33 buffer widths on center-pivot irrigated corn field in Tallahatchie County, Mississippi, USA, 2007 (Mean yield = 11.19 Metric Tons/ha; Commodity Price = $138/Metric Ton).

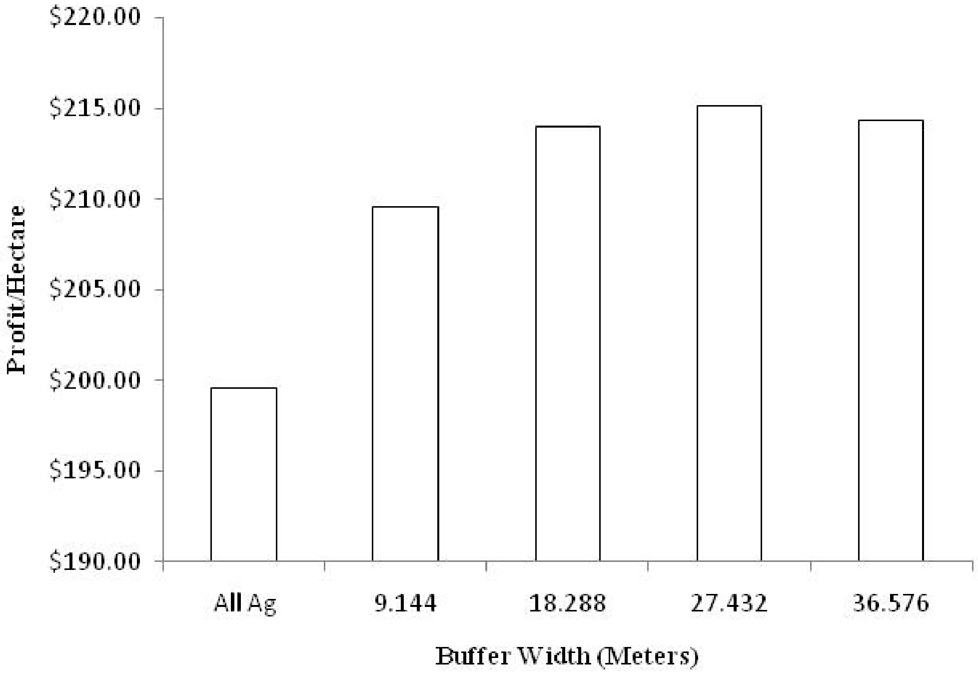

Figure 2.9 Whole-field net revenue of alternative CP-33 buffer widths on center-pivot irrigated soybean field in Tallahatchie County, Mississippi, USA, 2007 (Mean yield = 2.32 Metric Tons/ha; Commodity Price = $331/Metric Ton).

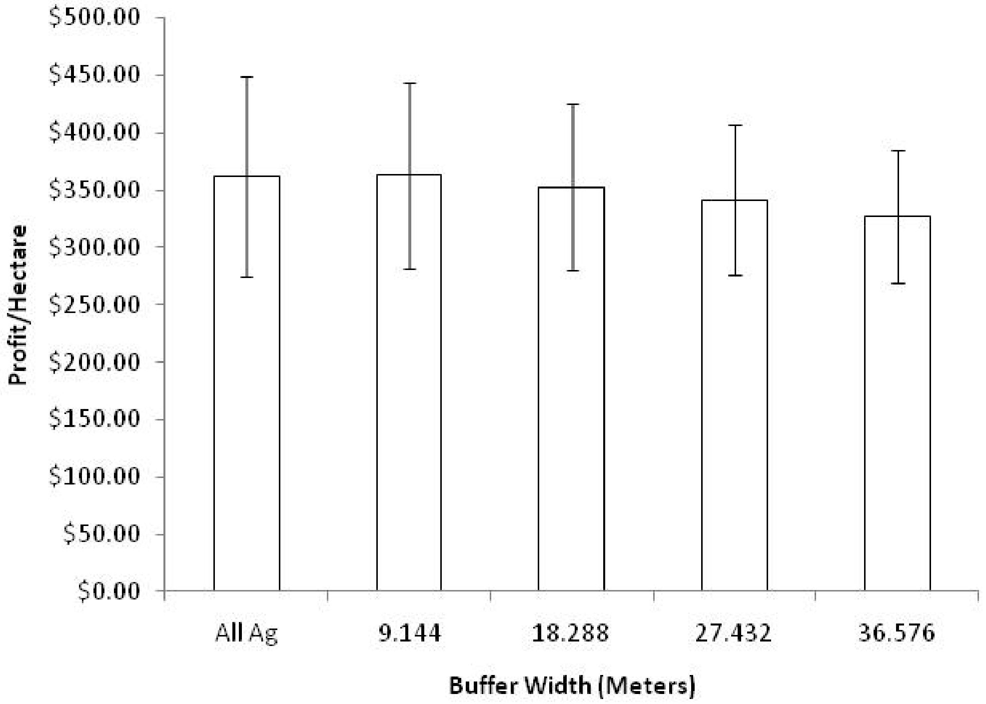

Figure 2.10 Average whole-field net revenue (± SE) of alternative CP-33 buffer widths across multiple soybean fields (N=7) in Tallahatchie County, Mississippi, USA, 2007 (Commodity Price = $331/Metric Ton).

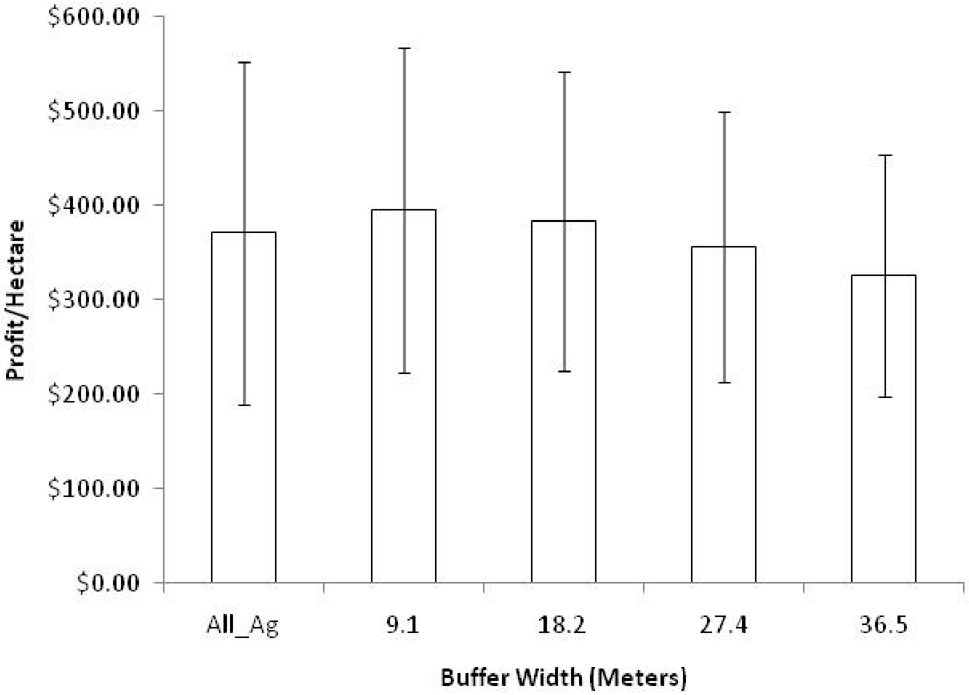

Figure 2.11 Average whole field net revenue (± SE) of alternative CP-33 buffer widths across multiple corn fields (N=5) in Tallahatchie County, Mississippi, USA, 2007 (Commodity Price = $138/Metric Ton).

CHAPTER III

ECONOMICS OF IMPLEMENTING ALTERNATIVE CP-33 BUFFER WIDTHS ON ROW CROP PRODUCTION FIELDS IN THE BLACK PRAIRIE REGION OF MISSISSIPPI

Conservation buffers have long been recognized for their multiple environmental benefits including, but not limited to, erosion control (Dillaha et al.1989, Dosskey et al. 2005), sediment, nutrient, and herbicide retention (Daniels and Gilliam 1996, Webster and Shaw 1996, Das et al. 2004), and wildlife enhancement (Dover 1994, Puckett et al. 1995, Best 2000, Smith 2004, Conover et al. 2009). United States Department of Agriculture's (USDA) National Conservation Buffer Initiative (NCBI) has been instrumental in promoting buffer establishment on private lands nationwide (NRCS 1999). The vehicle for implementing conservation buffers has been the Continuous Conservation Reserve Program (CCRP) under the conservation title of the Farm Bill. Under CCRP a variety of conservation buffer practices (e.g., filter strips, forest riparian buffers, field borders, and upland habitat buffers) are available to accomplish specific conservation objectives associated with national conservation initiatives.

In 2004 President George W. Bush announced the Presidential Bobwhite Initiative implemented under (CCRP) and charged USDA to develop a new conservation practice designed specifically to increase northern bobwhite (*Colinus virginianus*) habitat in agricultural landscapes (USDA 2005). Conservation Practice [CP] 33, Habitat Buffers for Upland Birds, was established specifically to address population recovery goals set by the Northern Bobwhite Conservation Initiative (NBCI) (FSA 2004). Upland habitat buffers are herbaceous communities maintained along edges of cropped fields. Under CP-33, agricultural landowners can enroll 9.1-36.5 m of upland habitat buffers along crop field edges by planting native warm-season grasses, forbs, legumes and shrubs, or by allowing natural succession to occur and maintain them in an early seral stage. The premise of CP-33 is that relatively small changes in a working agricultural landscape can significantly affect bobwhite and grassland bird abundance.

Agricultural producers operate under uncertainty created by environmental and market stochasticity, consequently, financial concerns strongly influence producer decisions (Kitchen et al. 2005). Variations in global economies, commodity prices, agricultural policies (e.g., Farm Bill, trade agreements), subsidy payments, weather/climatic events, input costs, and equipment expenses together influence risk and profitability for landowners and producers. Removing land from production for conservation imposes an opportunity cost associated with loss in revenue from commodities that otherwise would have been produced (USDA 2003). “Conservation must be compatible with profitability” (Kitchen et al. 2005:332), and to make conservation implementation economically attractive to agricultural landowners, conservation programs must address economic concerns of producers (USDA 2003). Conservation and profitability can coexist if ecological and economic demands are taken into account (Holzkamper and Seppelt 2006). Because farm policy in the United States, implemented through the Farm Bill, has evolved to recognize the importance of financial concerns and profitability in adoption of conservation practices, numerous conservation programs provide financial incentives to compensate for opportunity costs of land retirement. Conservation buffer practices, including CP-33, address producers’ financial and environmental concerns by providing substantial financial incentives for enrollment of environmentally sensitive lands. However, enrollment of all eligible land might not maximize financial returns, and thus may not be the best land use strategy. An enrollment that maximizes conservation benefits, subject to the constraint that economic benefits equal or exceed that under agricultural production might be considered optimal.

Precision agriculture technology (PA) provides a wealth of data to inform the decision-making process on agricultural land management. Specifically, yield monitors provide spatially explicit information about field productivity which provides managers with an opportunity to adjust management strategies. Yield monitors accurately illustrate spatial variability of yield (Metric Tons/ha), but provide no economic information on how yield effects revenue ($/ha). Connecting yield to profit is paramount to adoption of conservation programs. Because traditional yield maps provide no financial information, profit maps are a more efficient tool for indentifying conservation opportunities. Profit maps illustrate regions of decreased revenue which managers can use to make informed decisions. Given that financial considerations generally have the greatest influence on producer decisions (Kitchen et al. 2005); profit maps are a logical tool for identifying conservation opportunities and quantifying conservation tradeoffs of adoption.

This research extends work by Stull et al. (2004) and Barbour (2006) which quantified economic opportunities of replacing marginal farmland with conservation buffers. Stull et al. (2004) and Barbour (2006) used PA technology (i.e., GPS yield monitors) to identify field regions where monetary benefits of conservation enrollment outweighed agricultural production. Stull et al. (2004) strategically optimized conservation buffer enrollment using historic yield data to identify field margins where revenue from conservation payments exceeded production. Historic yield data was useful for identifying field regions where conservation buffer enrollment could increase field revenue more so than enrolling the whole field in conservation or not enrolling at all (Stull et al. 2004). Specifically, use of PA to enroll only those areas where current management was below a break-even economic point increased average whole field net revenue most (Stull et al. 2004). Barbour (2006) quantified effects of adjacent plant communities on crop yield near field margins and showed that some adjacent plant communities reduced yield ≤ 60% relative to field interior. Thus, replacing low yielding field edges with CP-33 could be more profitable than cropping (Barbour 2006). CP-33 was economically advantageous up to 2 combine swaths (14.64 m wide) for corn fields but not economically advantageous for soybean fields in the Gulf Coast Plain of Mississippi (Barbour 2006).

Stull et al. (2004) and Barbour (2006) represent most current use of PA technology to compare conservation enrollment to agriculture production. However, Barbour (2006) was not spatially explicit and Stull et al. (2004) was limited to only three production fields. Both studies used partial budget, break-even equations to quantify change in revenue of different management strategies and used yield maps to calculate average net revenue. Partial budgets are useful for comparing profitability between 2 management alternatives with final result being expected change in profit (Kay and Edwards 2004). I used enterprise budget format equations to calculate profit for each buffer width and crop production separately, then combined results in a geographic information system and compared results of each option. Enterprise budgets provide estimates of potential revenue on a per unit basis (e.g., ha) and are useful for comparing profitability of alternative enterprises (Kay and Edwards 2004). Both studies also used a fixed commodity price for economic calculations. As future commodity prices remain uncertain, modeling a range of price scenarios will be necessary to facilitate adaptive decision making. I built on previous research (Stull et al. 2004; Barbour 2006) by incorporating spatially explicit profit maps, multiple production fields, and a range of commodity price assumptions to simulate economic outcome of implementing 4 operational CP-33 buffer widths (9.1, 18.2, 27.4, and 36.5 m) on corn and soybean production fields on 2 farms in the Black Prairie region of Mississippi.

Study Area

Study area consisted of 34 row crop fields (696.73 ha total area with mean field size of 20.49 ha) on 2 privately owned farms in Monroe and Chickasaw counties, located in the Black Prairie region of Mississippi, USA. Mean soybean field size was 18.36 ha (n = 26, range = 5.76 ha – 38.29 ha) and total area in soybean fields was 477.51 ha. Mean corn field size was 27.40 ha (n = 8, range = 4.88 ha – 99.41 ha) and total area in corn fields was 219.22 ha.

All fields in Monroe County were on Houston-Brooksville-Vaiden association, characterized by well drained and somewhat poorly drained clay soils of the upland (Murphree et al.1966). Most of Chickasaw County fields were on Leeper-Belden-Una association characterized by somewhat poorly drained and poorly drained, level soils that have clayey and loamy subsoil. Other fields in Chickasaw County occurred on Kipling-Brooksville-Okolona association characterized by poorly drained and well-drained, level to sloping soils that are clayey below the surface (Murphree et al. 1974).

Methods

I collected spatially explicit yield data from custom combine operators [8 corn (*Zea mays*) fields and 2 soybean (*Glycine max*) fields] in Monroe County (2007) and [24 soybean fields] in Chickasaw County (2009). Yield data was downloaded from memory cards (John Deer Green Star^{TM} and Ag Leader^{TM}) onto a personal computer and converted to shape files using ArcMap GIS software (ESRI 2009). Coordinate systems were defined and data uploaded to ArcMap. I visually inspected the quality of yield data (i.e., correct spatial location, missing data, etc.). Multiple sources of inherent error may occur in yield data (Blackmore and Moore 1999) which, can lead to erroneous conclusions (Sudduth and Drummond 2007). Therefore data was initially cleaned in Yield Editor software to remove erroneous data points commonly associated with GPS yield monitors such as grain flow delay, time delays, rapid velocity changes, position errors, etc. (Sudduth and Drummond 2007).

I used query builder in ArcMap to filter out yield points where combine header status was up (not cutting) instead of down (cutting) to eliminate non-yield data points (e.g., 0's). I exported data from first query to a new shape file and filtered out points outside of a predetermined range for each crop type (corn: 15.69 Metric Tons/ha – 0.63 Metric Tons/ha; soybean: 5.38 Metric Tons/ha – 0.34 Metric Tons/ha) based on expert opinion from crop consultants about dry yield potential for sample fields and knowledge of common yield monitor errors. I exported results from second query to Microsoft® Excel and calculated mean and standard deviation (SD) for 'Dry Yield Volume'. Third query eliminated those points beyond ± 3 SD from previously calculated mean yield. This process eliminated isolated outliers without affecting areas of true variation (Sudduth and Drummond 2007) and normalized yield data distribution.

Profitability drives producer decisions, but yield maps characterize only one component of profitability; therefore I converted yield maps to spatially explicit profit surfaces using a multi-step process. I created 6 new fields in the attribute table of cleaned yield shapefiles to calculate per hectare profitability (i.e., Net Revenue), as follows:

1. Commodity Price – Dollar value per Metric Ton of Grain;
2. Gross Revenue – Product of Commodity Price and Dry Yield Volume;
3. Government Payments – County Average Direct (base) Payments for Respective Crop Type;
4. Total Revenue – Gross Revenue plus Government Payments;
5. Production Costs – Dollar value Per hectare of Production of Respective Crop Type;
6. Net Revenue – Total Revenue minus Production Costs;

I used the following equation to calculate per hectare Net Revenue for corn and soybean row crop fields:

$$\sum \mathrm{NET\_REVcij} = \sum \mathrm{GRcij} + \sum \mathrm{GOVT\_PMNTScij} - \sum \mathrm{PRODcij}\ ,\ \forall c\ ,$$

Where NET_REV = mean net revenue; GR = gross revenue; GOVT_PMNTS = government payments; PROD = productions costs independent of yield; c = management unit or cell; i = year; and j = crop commodity. ∑ is the "sum across" and ∀ is "for all" which indicates there is a separate equation for each cell (Stull et al. 2004). I used adjusted production costs (crop budgets) obtained from Mississippi State University, Department of Agricultural Economics, Corn and Soybean 2008 planning budgets. Total specified expenses were $901.91/ha for corn (Stale seedbed, Roundup Ready seed, 8-row 30", All Areas) and $443.11/ha for soybeans (Early planted, Roundup Ready seed, reduced tillage, 12-row 20", Non-Delta Area). Government payments represent per hectare, county specific direct payments (DP) averaged over 4 years (2005-2008) for corn and soybeans. Specific information on DP was obtained through a Freedom of Information Act request to the national FSA office in Kansas City, Kansas.

I used field calculator in ArcMap to generate values for each attribute and calculated a final Net Revenue value for each cell using above equation. Filtering process removed numerous data points and left gaps in yield data. Traditional approaches did not address gaps created by filtering process (Barbour 2006, Stull et al. 2004). Those field areas without a yield estimate, in reality, do not represent 'Null Value' yields, but are erroneously treated as such in calculation of Net Revenue. I used an interpolation technique which uses surrounding data to estimate values of missing data. Interpolation techniques operate under the assumption that items close to each other are more similar than items farther apart (ESRI 2009). I used Inverse Distance Weighted (IDW) interpolation technique in Spatial Analyst to generate a field level profit surface which generates estimates for gaps in data based on a distance-weighted estimate of surrounding data (i.e., closer points are weighted greater than farther points). This process converts vector point files to raster format (i.e., cells). I used Zonal Statistics in Spatial Analyst to calculate Mean Net Revenue for each field under row crop production alone. Profit surfaces provide accurate depictions of how profitability varies spatially across a field, providing useful information about where alternative management strategies might generate more revenue.

To simulate economic benefits of CP-33, I created buffer profit surfaces that depict per hectare net revenue of each buffer. CP-33 payments include $247.10/ha sign-up incentive (SIP), per hectare, county and soil-specific annual rental rate (SRR), 50% cost share assistance for cover establishment, and 40% practice incentive payment (PIP) for approved establishment costs (FSA 2004). Periodic planned disturbance is required for contract period (10 years) and is cost-shared up to 50%. I calculated a weighted SRR for each buffer width on each field based on 3 most prevalent soil types within eligible buffer area. I also calculated SIP by amortizing the SIP payment ($247.10/ha) over 10 years at 6% interest which provided an annual payment of $45.02/ha. Combined, these payments represent revenue derived from CP-33 enrollment. However, to calculate Net Revenue of CP-33, cost of buffer establishment and maintenance for the contract period must be incorporated. I used a native grass and legume mix was used which cost $459.62/ha to establish. After accounting for cost-share assistance and PIP, the remaining establishment cost was amortized over 10 years resulting in $14.00/ha/year in out of pocket expenses. I used the following equation to calculate average, per hectare buffer revenue:

$$\sum \mathrm{NET\_REV}_{ci} = \sum \mathrm{SRR}_{ci} + \sum \mathrm{SIP}_{ci} - \sum \mathrm{COST}_{ci}, \ \forall_{c}$$

Where SRR = per hectare, county and soil-specific rental payments; SIP = SIP payment amortized over 10 years at 6%; and COST = per hectare establishment and maintenance costs minus cost-share assistance and PIP amortized over 10 years. I assigned buffer-specific net revenue to each buffer and converted to raster format using IDW interpolation technique in Spatial Analyst. I replaced profit surface cells with those of each specific buffer cells and combined buffer profit surface with profit surface for remaining field interior (field surface minus buffer surface) using Raster Calculator to calculate mean net revenue of each field under each buffer scenario (i.e., 9.1, 18.2, 27.4, and 36.5 m).

Commodity prices have increased considerably over the last decade, and commodity prices influence farm management decisions. Price instability in the modern agriculture setting creates confusion and hesitation to convert cropland to conservation

(Hyberg and Riley 2009). Recently inflated U.S. corn and soybean prices create an incentive to farm rather than retire land. Most agricultural producers assume that large commodity prices will yield greater revenue than conservation payments. Although often true, such a blanket statement should not drive producer decisions without field-specific investigation. Commodity prices are unpredictable and therefore impose an element of risk to producers. As risk increases, the allure of consistent, annual Farm Bill conservation payments becomes an increasingly attractive management option (Hyberg and Riley 2009). I investigated economics of implementing alternative buffer widths across a range of commodity prices to simulate a range of market conditions. Range of commodity prices simulated adequately covers spectrum of prices paid to farmers from 2000-2009 in Mississippi (Mississippi Agricultural Statistics Service 2010 (Corn, Soybeans). Technique outlined above provide decision makers with realistic economic data across a range of commodity prices that will inform the decision making process of agriculture land management.

I used fixed buffer widths to calculate mean net revenue of each field, and consequently all field margins had equal buffer widths. CP-33 guidelines allow buffer width to vary on each field margin on condition that average buffer width for entire field is no greater than 36.5 m and no less than 9.1 m (National 2-CRPHandbook 2005). Therefore it is conceivable for each field margin to have variable buffer widths. Because field margins can exhibit varying degrees of yield and profitability, it follows that conservation implementation should accurately account for this variability. Spatial variability also exists within each field margin where yield and profitability can vary considerably. Accounting for such variability with conservation buffers in a spatially explicit format is difficult. Unfortunately, spatial modeling techniques required to perform such task were beyond the scope of this research. However, I provide a surrogate to more flexible modeling by calculating proportion of eligible buffer area where CP-33 enrollment exceeds mean net revenue of crop production to illustrate that considerable area often exists where CP-33 revenue exceeds that of cropping. For modeling simplicity, I defined eligible buffer area as a 36.5 m buffer around the field margin.

I calculated mean per hectare net revenue for corn and soybean fields under 5 management scenarios which include cropping only, and cropping with 4 CP-33 buffer width options implemented from the field edge (9.1, 18.2, 27.4, and 36.5 m). Thus, I investigated which buffer widths, if any, produced the greatest financial gain compared to traditional cropping. I averaged results across all fields, crop types, and buffer width options to generate patterns in data. However, considering spatial variability in field productivity, it behooves natural resource planners and producers to examine efficacy of management strategies on a field by field basis. Therefore, in addition to overall averages, I calculated metrics that illustrate financial outcomes of each CP-33 buffer width on each field to illustrate that conservation should not be blindly applied to all fields but rather a strategic approach based on empirical data should be used. I also calculated percentage of eligible buffer area that generated more revenue than cropping to illustrate the need for strategic decision making to maximize monetary returns of conservation buffers.

Results

Corn

Mean net revenue for corn fields varied by commodity price and buffer width. All CP-33 buffer width scenarios increased per hectare net revenue when commodity price was $98/Metric Ton. Specifically, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue by 37.41% (SE=19.35%), 59.24% (SE=19.95%), 82.43% (SE=26.64%), and 100.40% (SE=30.64%), respectively. When commodity price was $138/Metric Ton CP-33 buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue by 34.66% (SE=4.21%), 49.81% (SE=7.04%), 61.58% (SE=8.93%), and 63.57% (SE=11.52%), respectively. As commodity prices increased, percent of increase in revenue decreased with increasing buffer width. For example, when commodity price for corn was $177/Metric Ton, 9.1 meter CP-33 buffers increased mean net revenue by 1.21% (±10.84%) whereas additional buffer widths decreased mean net revenue. For all additional simulated commodity prices, all CP-33 buffers widths decreased mean net revenue (Figure 3.1, Table 3.1).

Number of corn fields where CP-33 increased mean net revenue varied by buffer width and commodity price. When commodity price was $98/Metric Ton all CP-33 buffer widths increased mean net revenue on 100% of fields. When commodity price was $138/Metric Ton, buffer widths of 9.1, 18.2, and 27.4 m increased mean net revenue on 100% of fields whereas a buffer width of 36.5 m increased mean net revenue on 87.50% of fields. When commodity price was $177/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue on 62.50%, 37.50%, 35.00%, and 25.00% of fields, respectively. When commodity price was $217/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue on 25.00%, 25.00%, 12.50%, and 12.50% of fields, respectively. When commodity price was $256/Metric Ton, each buffer width increased mean net revenue on 12.50% of fields (Figure 3.2, Table 3.2).

Percentage of eligible buffer area where CP-33 enrollment exceeded row crop production on corn fields varied by commodity price. When commodity price was $98/Metric Ton, $138/Metric Ton, $177/Metric Ton, $217/Metric Ton, and $256/Metric Ton, 99.84% (SE=0.07%), 62.73% (SE=7.50%), 37.26% (SE=9.69%), 24.05% (SE=7.26%), and 17.26% (SE=5.35%) of eligible buffer area, respectively, was more profitable under CP-33 enrollment compared to crop production. These results provide considerable evidence to support use of conservation buffers as a tool for increasing revenue on corn production fields (Figure 3.3, Table 3.3).

Soybeans

Mean net revenue for soybean fields also varied by commodity price and buffer width. When commodity price was $184/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue by 19.89% (SE=8.98%), 36.13% (SE=16.04%), 49.13% (SE=21.80%), and 59.80% (SE=26.93%), respectively. When commodity price was $220/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue by 4.93% (SE=34.61%), 5.39% (SE=57.24%), 5.98% (SE=74.16%), and 5.66% (SE=59.88%), respectively. For all additional simulated commodity prices, all CP-33 buffers widths decreased mean net revenue. As with corn, this trend was expected for greater commodity prices where conservation payments are outweighed by increased revenue derived from low yielding land. However, although mean net revenue decreased at greater commodity price simulations, it is important to note those figures represent overall average across all fields. As previously mentioned the premise of PA technology is to provide field specific data for decision making. A more proactive approach to evaluating economic impact of CP-33 buffers is to report proportion of fields where each buffer width increased mean net revenue (Figure 3.4, Table 3.4).

The number of soybean fields where CP-33 increased mean net revenue varied by buffer width and commodity price. When commodity price was \$184/Metric Ton all CP-33 buffer widths increased mean net revenue on 88.46% of fields. When commodity price was \$220/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue on 69.23%, 57.69%, 50.00%, and 50.00%, respectively. When commodity price was \$257/Metric Ton, buffer width of 9.1 m increases mean net revenue on 42.31% of fields, whereas buffer widths of 18.2, 27.4, and 36.5 m all increased mean net revenue on 38.46% of fields. When commodity price was \$294/Metric Ton, buffer width of 9.1 m increased mean net revenue on 30.77% of fields whereas buffer widths of 18.2, 27.4, and 36.5 m all increased mean net revenue on 23.08% of fields. When commodity price was \$331/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue on 23.08%, 19.23%, 15.38%, and 18.18% of fields, respectively. When commodity price was \$367/Metric Ton, buffer widths of 9.1, 18.2, 27.4, and 36.5 m increased mean net revenue on 11.54%, 7.69%, 11.54%, and 13.04% of fields, respectively (Figure 3.5, Table 3.5).

Percentage of eligible buffer area where CP-33 enrollment exceeded row crop production on soybean fields varied by commodity price. When commodity price was \$184/Metric Ton, \$220/Metric Ton, \$257/Metric Ton, \$294/Metric Ton, \$331/Metric Ton, and \$367/Metric Ton, 72.09% (SE=5.16%), 52.10% (SE=6.83%), 40.61% (SE=6.79%), 27.29% (SE=5.90%), 16.93% (SE=4.66%), and 14.98% (SE=3.96%) of eligible buffer area was more profitable under CP-33 enrollment compared to crop production. Results for corn and soybean provide considerable evidence to support the use of conservation buffers as a tool for increasing field revenue. This analysis also provides evidence for use of PA technology in providing economic insight that would have been overlooked by prior methods. (Figure 3.6, Table3.6).

Discussion

Quantifying economic implications of implementing conservation buffers is critical to achieving national conservation initiatives. Agricultural landowners will enroll in conservation programs that address environmental and wildlife concerns provided financial incentives are adequate (USDA 2003). Therefore, it behooves natural resource managers and agricultural producers to implement conservation buffers only when economic returns outweigh that of traditional cropping. Natural resource managers and economists must find innovative solutions to increase adoption of conservation buffers. My results provide a systematic approach to conservation enrollment and data to support the use of CP-33 buffers to increase mean net revenue on agricultural fields in the Black Prairie region of Mississippi.

Fields used in this study represented a range of productivity and management intensity commonly found in production agriculture. Yield averages for corn and soybean were 6.98 Metric Ton/ha and 2.78 Metric Ton/ha, respectively. Corn yield for Monroe County fields was above county average for 2007 (4.82 Metric Ton/ha) (Mississippi Agricultural Statistics Service (Corn)). Soybean yield for Chickasaw County fields was also above county average for 2009 (2.35 Metric Ton/ha) (Mississippi Agricultural Statistics Service (Soybean)). Management decisions for fields were informed by a progressive crop consultant who used PA technology and consequently produced above average yields. My results represent the economic effects of CP-33 buffers on fields with above average productivity. Less productive fields or fields with a less proactive management strategy would produce even greater economic advantage of conservation buffer adoption.

For corn and soybean fields in the Black Prairie region of Mississippi, CP-33 buffers increased mean net revenue at differing levels across a range of commodity prices. CP-33 buffers increased mean net revenue on a percentage of fields for all buffer width and commodity price simulations. As commodity prices increased, revenue derived from low yielding land became increasingly competitive with conservation payments. Consequently, increasing commodity prices increased mean net revenue, even at low grain yields, which eventually exceed buffer revenue. However, even at greater commodity prices, CP-33 buffers offered a competitive economic advantage to cropping on corn and soybean fields. Although on average, CP-33 buffers decreased revenue for fields at greater commodity price simulations, multiple fields increased revenue with CP-33 buffers. From an economic perspective, applying CP-33 buffers to all fields within farm or management area would be illogical if CP-33 enrollment did not maximize economic returns. However, using PA technology to identify fields and field regions where CP-33 revenue exceed that of cropping would be a viable management strategy.

For fields where fixed width CP-33 buffers decreased revenue it is important to evaluate the proportion of eligible buffer area where revenue was increased by CP-33 enrollment. CP-33 buffers are not constrained to fixed widths for the whole field (i.e., buffer widths can vary for each field margin, mean width is constrained between 9.1 and 36.5 m). Spatial distribution of yield and profitability is often non-uniform among field margins. Therefore, non-uniform distribution of reduced profitability would warrant non-uniform design of CP-33 buffers. Evaluating the proportion of eligible buffer area where CP-33 increases revenue provides information about how spatial arrangement of buffers should be implemented. My results indicate that eligible CP-33 buffer area can generate more revenue than cropping across a range of commodity prices, and provides spatially explicit data to inform the decision making process of buffer placement.

In recent years increasing commodity prices have impeded landowner willingness to enroll in conservation (Hyberg and Riley 2009). Although Farm Bill conservation payments attempt to stay competitive with commodity markets, future conservation enrollment will likely occur on marginal farmland with reduced productivity. When and if commodity prices stabilize, conservation payments will become more competitive on marginal farmland (Hyberg and Riley 2009). However, at present, natural resource managers are increasingly charged with the responsibility of identifying and implementing conservation buffers with economically advantageous results. This research provides a conceptual framework for identifying field level conservation opportunities. CP-33 buffers provide a viable management strategy for natural resource planners and agricultural producers who wish to provide ecosystem services and increase field revenue.

Agricultural fields often exhibit yield reductions near field margins which inevitably lead to decreased revenue. Magnitude of revenue reduction is strongly influenced by commodity price and therefore subject to temporal stochasticity. I modeled effects of CP-33 buffers on economics of corn and soybean production fields in the Black Prairie region of Mississippi. My results indicate that CP-33 can increase whole-field, mean net revenue at varying levels on corn and soybean fields across multiple commodity prices. Although at greater commodity prices CP-33 on average decreased revenue across all fields, further analysis indicated that CP-33 buffers increased revenue on a notable proportion of fields across all commodity prices, indicating that efficacy of conservation enrollment should be investigated at field level as opposed to farm level. Further analysis also indicated that CP-33 buffer revenue exceeded that of cropping on a measurable proportion of eligible buffer area on all fields and commodity prices. This research provides support for use of PA technology to identify and evaluate conservation and economic opportunities in production agriculture. This information illustrates the necessity for strategic conservation enrollment to maximize whole field economic returns. I argue that conservation buffers should be implemented strategically only on those areas where conservation revenue exceeds crop production. My results provide evidence to support use of CP-33 buffers as an effective management tool to increase field revenue.

Literature Cited

Best, L. B. 2000. The value of buffer habitats for birds in agricultural landscapes. Pages75-94 *in* W. L. Hohman and D. J. Halloum, editors. A comprehensive review of Farm Bill contributions to wildlife conservation, 1985-2000. U.S. Department of Agriculture, Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI- 2000.

Barbour, P. J. 2006. Ecological and economic effects of field borders in row crop agriculture production systems in Mississippi. Dissertation, Mississippi State University, Starkville, USA.

Blackmore, S. and M. Moore. 1999. Remedial correction of yield map data. Precision Agriculture 1:53-66.

Conover, R. R., L. W. Burger, and E. Linder. 2009. Breeding bird response to field border presence and width. The Wilson Journal of Ornithology 121:548-555.

Daniels, R. B., and J. W. Gilliam. 1996. Sediment and chemical load reduction by grass and riparian filters. Soil Science Society of America Journal 60:246-251.

Das, C., W. J. Capehart, H. V. Mott, P.R. Zimmerman, and T. E. Shumacher. 2004. Assessing regional impacts of Conservation Reserve Program-type grass buffer strips on sediment load reduction from cultivated lands. Journal of Soil and Water Conservation 59:134-142.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural non-point pollution control. Transactions of the American Society of Agricultural Engineers 32:513-519.

Dosskey, M. G., D. E. Eisenhauer, and M. J. Helmers. 2005. Establishing conservation buffers using precision information. Journal of Soil and Water Conservation 60:349-354.

Dover, J. W. 1994. Arable field margins: factors affecting butterfly distribution and abundance. British Crop Protection Council Monograph 58: Field Margins: Integrating Agriculture and Conservation, Farnham, Surrey, UK.

ESRI. 2009. ArcGIS Desktop and Spatial Analyst. Environmental Systems Research Institute, Inc. Redlands, CA.

Farm Service Agency. 2004. Notice CRP-479 Practice CP-33, Habitat Buffers for Upland Birds. U.S. Department of Agriculture, Farm Service Agency, Washington, D.C., USA.

Holzkamper, A., and R. Seppelt. 2006. Evaluating cost-effectiveness of conservation management actions in an agricultural landscape on a regional scale. Biological Conservation 136:117-127.

Hyberg, B. T. and R. Riley. 2009. Floodplain ecosystem restoration: commodity markets, environmental services, and the Farm Bill. Wetlands 29:527-534.

Kay, R. D. and W. M. Edwards. 2004. Farm Management. Fifth Edition. McGraw Hill, Boston, USA.

Kitchen, N. R., K. A. Sudduth, D. B. Myers, R. E. Massey, E. J. Sadler, R. N. Lerch, J. W. Hummel, and H. L. Palm. 2005. Development of a conservation-oriented precision agriculture system: Crop production assessment and plan implementation. Journal of Soil and Water Conservation 60:421-430.

Mississippi Agricultural Statistics Service. 2010. Corn – Planted harvested, yield, production, price, All States 2000-2020. <http://quickstats.nass.usda.gov/results/E1AC0E4D-095D-3133-91B7-33FA1E08D3FA#9C148F0D-09A6-334B-AC23-390F77FDAD28>. Accessed 30 December 2010.

Mississippi Agricultural Statistics Service. 2010. Soybeans – Planted, harvested, yield, production, price, All States 2000-2010. On line at <http://quickstats.nass.usda.gov/results/A506DD34-7BAE-361B-A169-76F403D0CC4C#A776141A-F6E3-383D-8EE4-0EFE3D587762>. Accessed 30 December 2010.

Murphree, L. C., J. L. Anderson, R. M. Ferguson, M. C. Garber, M. G. Martin, K. H. Miller, L.H. Nichols, and R. E. Fulgham. 1966. Soil Survey of Monroe County, Mississippi.U.S. Department of Agriculture, Soil Conservation Service and MississippiAgricultural Experiment Station.

Murphree, L. C., J. S. Huddleston, and L. H. Nichols. 1974. Soil Survey of Chickasaw County,Mississippi. U.S. Department of Agriculture, Soil Conservation Service, Forest Service,and Mississippi Agricultural and Forestry Experiment Station.

National FSA 2-CRP (Revision4) Handbook. 2005.

Natural Resources Conservation Service. 1999. The National Conservation Buffer Initiative: A qualitative evaluation. U.S. Department of Agriculture, Natural Resource Conservation Service. <http://www.nrcs.usda.gov/feature/buffers/pdf/BuffQual.pdf>. Accessed 4 August 2008.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and L. T. Sharpe. 1995.Bobwhite nesting ecology and modern agriculture: a management experiment.Proceedings of the Annual Conference of the Southeastern Association of Fish andWildlife Agencies 49:505-516.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices inMississippi. Dissertation, Mississippi State University, Starkville, USA.

Stull, J., C. Dillon, S. Shearer, and S. Isaacs. 2004. Using precision agriculture technology for economically optimal strategic decisions: The case of CRP filter strip enrollment. Journal of Sustainable Agriculture 24:79-96.

Sudduth, K. A. and S. T. Drummond. 2007. Yield Editor: Software for removing errors from crop yield maps. Agronomy Journal 99:1471-1482.

United States Department of Agriculture. 2003. Natural Resource Inventory. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Inventory Division. <http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb.pdf>.Accessed 31 July 2008.

United States Department of Agriculture. 2005. Bush administration expands Conservation Reserve Program, launches innovative conservation measures for wildlife and wetlands. U.S. Department of Agriculture, Office of Communications, Washington, D.C., News release 0324.04, 4 August 2004. <http://www.fsa.usda.gov/pas/printstory.asp?StoryID=1798>. Accessed 4 August 2008.

Webster, E. P., and D. R. Shaw. 1996. Impact of vegetative filter strips on herbicide loss in runoff from soybean (*Glycine max*). Weed Science 44:662-671.

Table 3.1 Per hectare net revenue (± SE) for production only and alternative CP-33 buffer widths averaged for corn fields (N=8) in Monroe County, Mississippi, USA, 2007 across multiple commodity prices.

	Mean Net Revenue ($/ha)									
	Agriculture Only		Agriculture with CP-33 Buffers (m)							
Commodity Price ($/Metric Ton)	No Buffer	(SE)	9.1	(SE)	18.2	(SE)	27.4	(SE)	36.5	(SE)
98	-183.94	43.87	-115.13	47.6	-74.97	44.36	-32.31	44.33	0.73	43.88
138	94.93	61.91	127.83	58.58	142.22	53.95	153.39	49.01	155.28	42.88
177	366.83	79.51	371.27	72.54	353.96	63.92	334.44	54.86	305.28	44.55
217	645.71	97.58	620.94	86.96	571.14	74.53	520.13	61.8	459.12	48.24
256	917.6	115.19	864.42	101.03	782.89	85.1	696.38	68.51	609.13	53.38

Table 3.2 Percentage of total fields (N=8) where alternative CP-33 enrollment increases mean net revenue across a range of commodity prices on corn fields in Monroe County, Mississippi, USA, 2007.

	Buffer Width (m)			
Commodity Price ($/Metric Ton)	9.1	18.2	27.4	36.5
98	100.00%	100.00%	100.00%	100.00%
138	100.00%	100.00%	100.00%	87.50%
177	62.50%	37.50%	25.00%	25.00%
217	25.00%	25.00%	12.50%	12.50%
256	12.50%	12.50%	12.50%	12.50%

Table 3.3 Percentage of eligible buffer area where mean net revenue under CP-33 enrollment exceeds revenue of crop production across a range of commodity prices on corn fields (N=8) in Monroe County, Mississippi, USA, 2007.

Commodity Price ($/Metric Ton)	Percentage of Eligible Buffer Area	(SE)
98	99.84%	0.07%
138	62.73%	7.50%
177	37.26%	9.69%
217	24.05%	7.26%
256	17.26%	5.35%

Table 3.4 Per hectare net revenue (± SE) for production only and alternative CP-33 buffer widths averaged for soybean fields (N=26) in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009 across multiple commodity prices

	Mean Net Revenue ($/ha)									
	Agriculture Only		Agriculture with CP-33 Buffers (m)							
Commodity Price ($/Metric Ton)	No Buffer	(SE)	9.1	(SE)	18.2	(SE)	27.4	(SE)	36.5	(SE)
184	83.36	24.64	99.94	22.19	113.485	19.95	124.31	17.78	133.21	15.73
220	183.34	29.46	192.38	27.39	193.22	23.82	194.29	21.19	193.71	18.7
257	286.19	34.41	282.34	31	275.15	27.84	266.11	24.81	255.83	21.96
294	389.05	39.37	374.79	35.48	357.2	31.91	338.01	28.51	318.02	25.36
331	491.47	44.4	466.93	40.01	439.61	36.03	410.01	32.27	380.15	28.85
367	591.98	49.14	557.16	44.32	519.05	39.98	482.08	35.62	440.63	32.3

Table 3.5 Percentage of total fields (N=26) where alternative CP-33 enrollment increases mean net revenue across a range of commodity prices on soybean fields in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009.

	Buffer Width			
Commodity Price ($/Metric Ton)	9.1	18.2	27.4	36.5
184	88.46%	88.46%	88.46%	88.46%
220	69.23%	57.69%	50.00%	50.00%
257	42.31%	38.46%	38.46%	38.46%
294	30.77%	23.08%	23.08%	23.08%
331	23.08%	19.23%	15.38%	18.18%
367	11.54%	7.69%	11.54%	13.04%

Table 3.6 Percentage of eligible buffer area where mean net revenue under CP-33 enrollment exceeds revenue of crop production across a range of commodity prices on soybean fields (N=26) in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009.

Commodity Price ($/Metric Ton)	Percentage of Eligible Buffer Area	(SE)
184	72.09%	5.16%
220	52.10%	6.83%
257	40.61%	6.79%
294	27.29%	5.90%
331	16.93%	4.66%
367	14.98%	3.96%

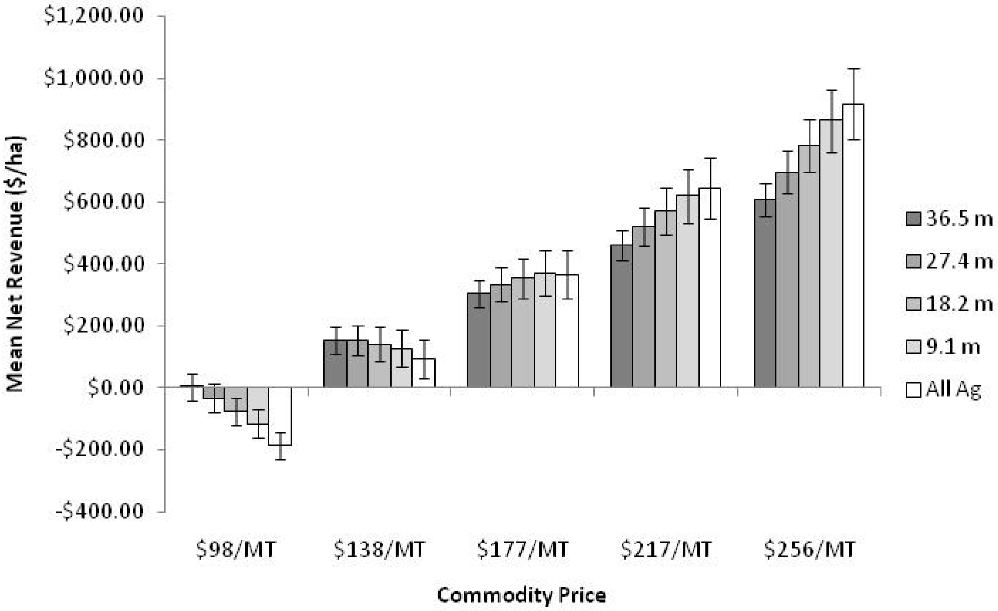

Figure 3.1 Per hectare net revenue (± SE) for production only and alternative CP-33 buffer widths averaged for corn fields (N=8) in Monroe County, Mississippi, USA, 2007 across multiple commodity prices.

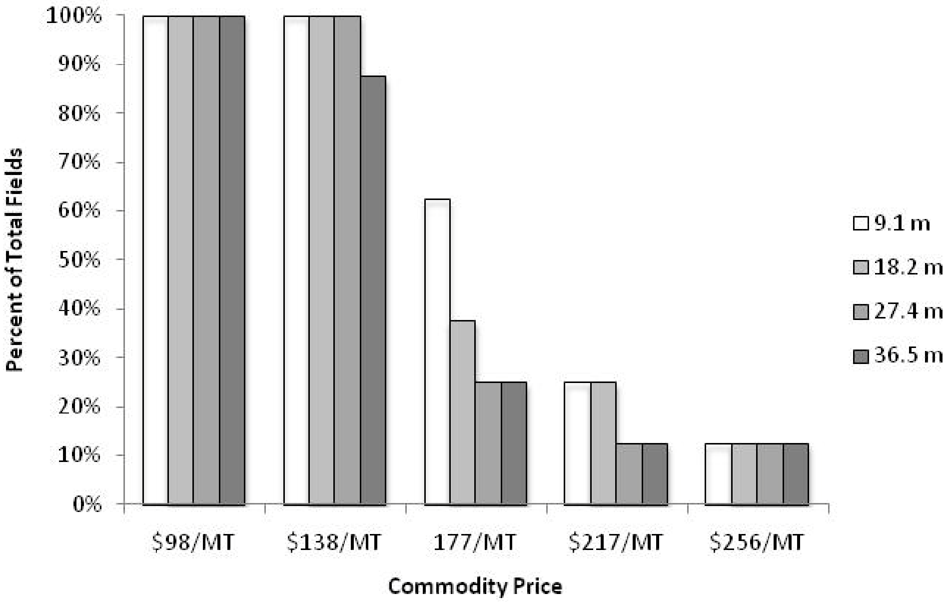

Figure 3.2 Percentage of total fields (N=8) where alternative CP-33 enrollment increases mean net revenue across a range of commodity prices on corn fields in Monroe County, Mississippi, USA, 2007.

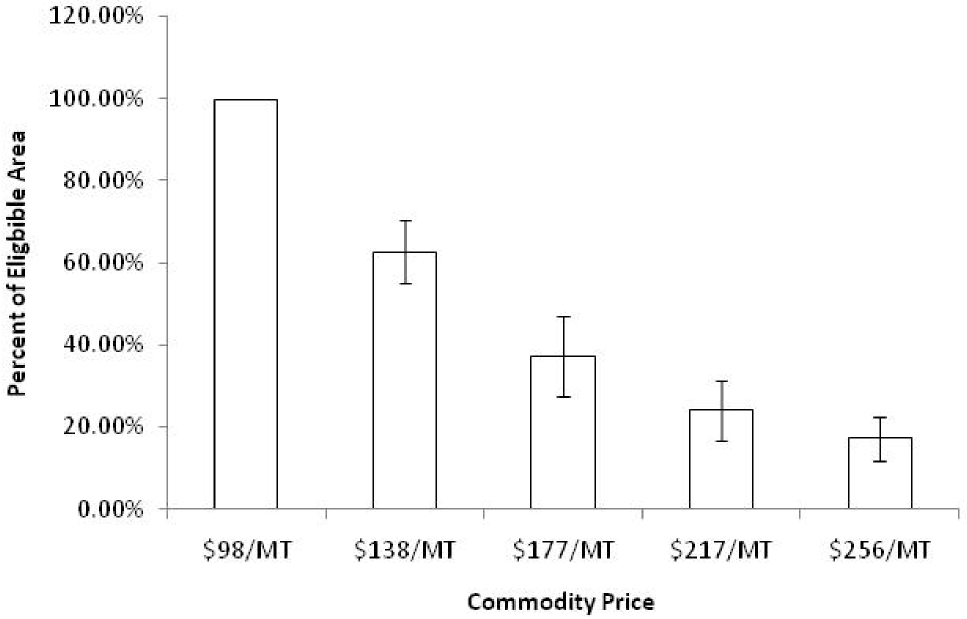

Figure 3.3 Percentage of eligible buffer area where mean net revenue under CP-33 enrollment exceeds revenue of crop production across a range of commodity prices on corn fields (N=8) in Monroe County, Mississippi, USA, 2007.

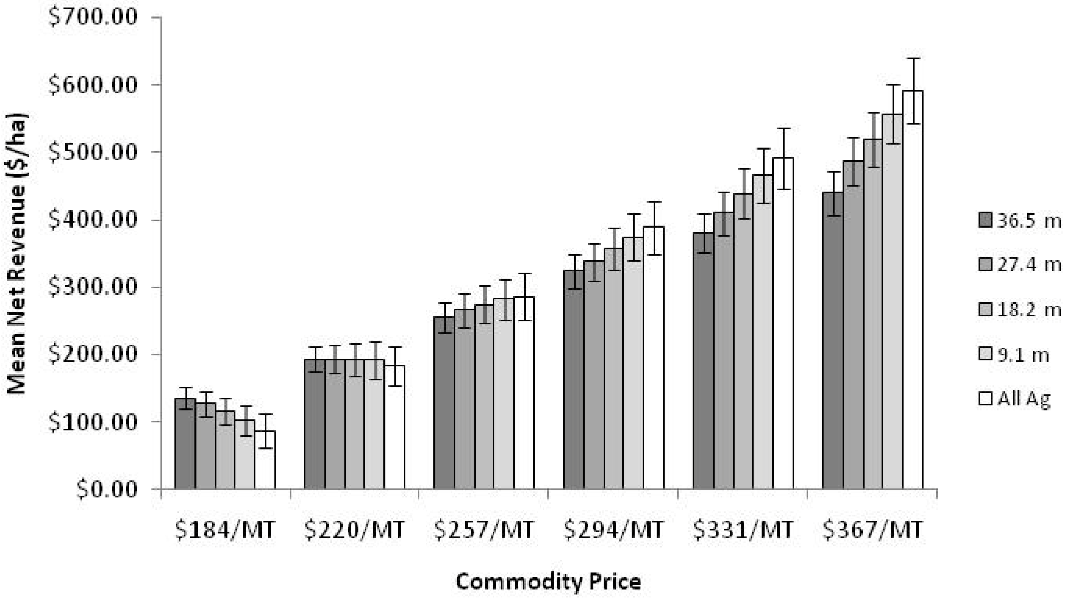

Figure 3.4 Per hectare net revenue (± SE) for production only and alternative CP-33 buffer widths averaged for soybean fields (N=26) in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009 across multiple commodity prices.

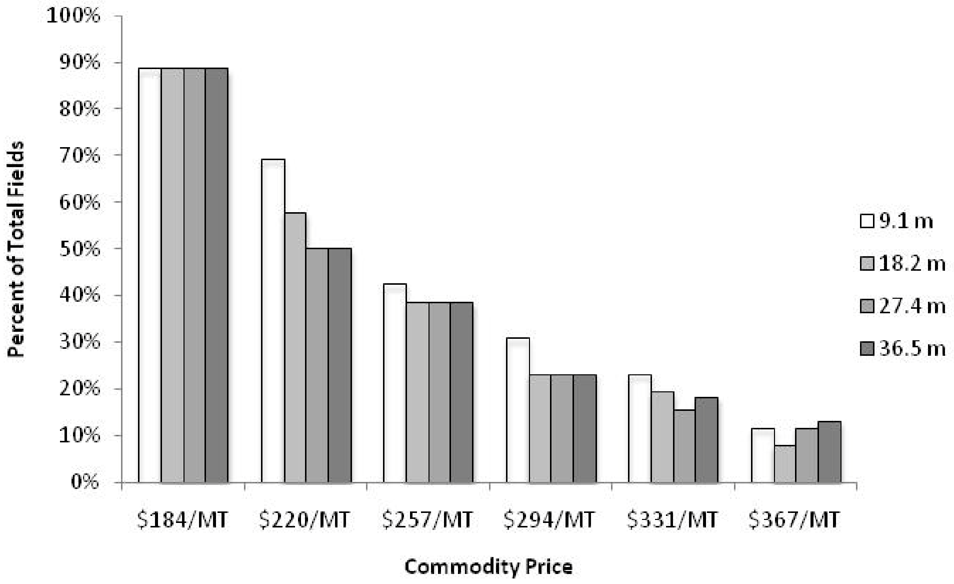

Figure 3.5 Percentage of total fields (N=26) where alternative CP-33 enrollment increases mean net revenue across a range of commodity prices on soybean fields in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009.

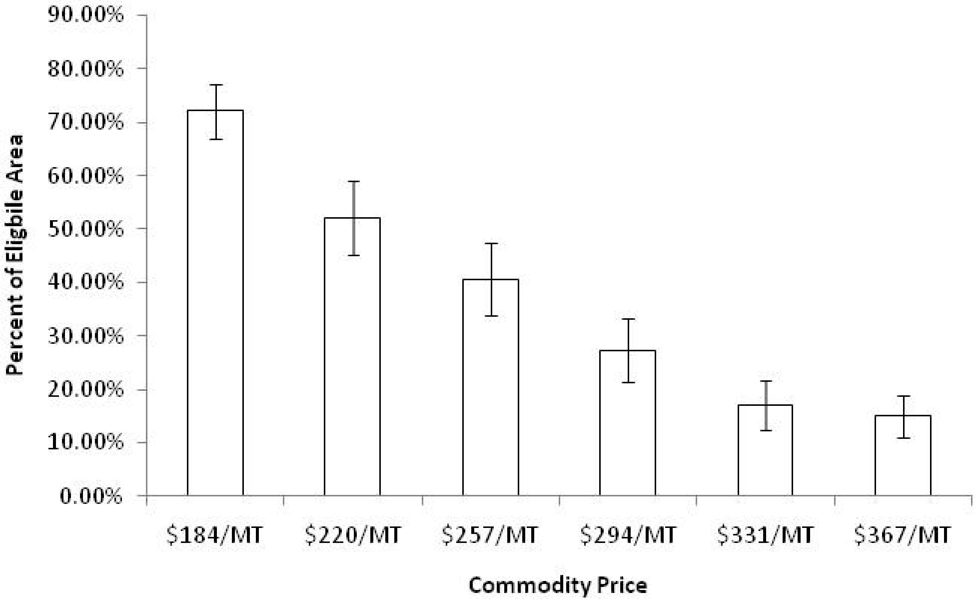

Figure 3.6 Percentage of eligible buffer area where mean net revenue under CP-33 enrollment exceeds revenue of crop production across a range of commodity prices on soybean fields (N=26) in Monroe and Chickasaw counties, Mississippi, USA, 2007, 2009.

CHAPTER IV

EFFECTS OF LANDSCAPE COMPOSITION, STRUCTURE, AND CP-33 BUFFERS ON NORTHEN BOBWHITE ABUNDANCE IN A MISSISSIPPI AGRICULTURE LANDSCAPE

Northern bobwhite (*Colinus virginianus*, hereafter, bobwhites) are integrally linked to the rural American landscape. Although bobwhites serve important ecological, social, recreational, and economic functions (Burger et al. 1999, Burger 2006), they have experienced precipitous range-wide population declines averaging 3.9% annually since 1980 (Sauer et al. 2008). Bobwhite population decline has been attributed to a myriad of land use changes including intensification of agriculture and monoculture pine farming, disruption of natural fire regimes, conversions to exotic/invasive forage grasses, advanced natural succession, concentrated grazing, and geographic isolation of remaining populations (Stoddard 1931, Roseberry and Klimstra 1984, Brennan 1991, Roseberry 1993, Burger 2002, Smith 2004). Addressing bobwhite decline will require modifications of current land use practices on a massive scale (Dimmick et al. 2002). Considering nearly 50% of the land area in the contiguous 48 states is managed for row crop production or grazing (USDA 2003, Robertson and Swinton 2005), range-wide recovery will largely require focus on privately-owned agricultural landscapes.

Farmlands historically provided quality habitat for bobwhites, which are adapted to the ephemeral annual plant communities produced by frequent disturbance associated with crop management. However, exponential human population growth (Lutz et al.

2001, UNPD 2007) and associated increases in food demand (Bongaarts 1996), shifted the agriculture paradigm towards mass production of food and fiber resources (Tilman et al. 2002). Intensive agricultural practices (e.g., clean farming) across the bobwhite range have contributed to habitat loss on multiple scales (Klimstra 1982, Brennan 1991). Reduction in number of farms and associated increase in farm size over the last half-century has reduced the complexity and heterogeneous nature of agricultural landscapes (Brennan 1991, Burger 2002, Smith 2004). Clean farming practices have reduced abundance of herbaceous fence-rows, grass strips, and wooded edges that traditionally separated fields and delineated property lines. Selective herbicides and insecticides have effectively reduced diversity and abundance of herbaceous plants, insects, and invertebrates in agricultural landscapes (Potts 1986, Watkinson et al. 2000, Benton et al. 2002). Collectively, land use changes have degraded or eliminated thousands of hectares of bobwhite nesting and brood-rearing habitat (Roseberry and Klimstra 1984, Brennan 1991) and consequently, have been integral in contributing to range-wide bobwhite decline.

Numerous grassland songbirds have also experienced steep declines resulting from intensive use and conversion of grasslands to agriculture (Herkert 1994, Chamberlain et al. 2000, Murphy 2003, Brennan and Kuvlesky 2005, Sauer et al. 2008). Although large scale agricultural expansion has benefited some grassland bird species (Askins 1999), farming (conversion and intensification) is considered the single greatest danger to threatened bird species (Green et al. 2005) and the leading cause of grassland songbird decline (Vickery and Herkert 1999, Blackwell and Dolbeer 2001, Murphy 2003), further illustrating the need for a dramatic shift in agricultural production systems to maintain and enhance avian populations.

Northern Bobwhite Conservation Initiative

The Northern Bobwhite Conservation Initiative (NBCI) was developed to restore range-wide bobwhite populations to baseline densities observed in 1980. NBCI population goals are stated in terms of fall coveys, where one covey equals approximately 12 birds. Achieving NBCI objectives will require an addition of 2,770,922 coveys across 32.8 million hectares of improvable land. However, the NBCI postulates that success of this goal could be achieved by altering land use on only 6-7% of improvable acreage, further stating that nearly 80% of proposed objectives could be met by affecting only 7.6 million hectares of cropland, hayland, pasture, and CRP (Dimmick et al. 2002). The primary programmatic vehicle for achieving NBCI goals on agricultural lands will be conservation programs implemented through the Farm Bill (Burger et al. 2006 (a)). The Farm Bill is a general term for the compilation of Congressional Acts designed to enhance agricultural productivity and conservation on working farmland.

Conservation Buffers

Conservation buffers have long been recognized for their multiple environmental benefits including, but not limited to, erosion control (Dillaha et al.1989, Dosskey et al. 2005), sediment, nutrient, and herbicide retention (Daniels and Gilliam 1996, Webster and Shaw 1996, Das et al. 2004), and wildlife enhancement (Dover 1994, Puckett et al. 1995, Best 2000, Smith 2004, Conover et al. 2009). United States Department of Agriculture's (USDA) National Conservation Buffer Initiative (NCBI) has been instrumental in promoting buffer establishment on private lands nationwide (NRCS 1999). The vehicle for implementing conservation buffers has been Continuous Conservation Reserve Program (CCRP) under the conservation title of the Farm Bill. Under CCRP a variety of conservation buffer practices (e.g., filter strips, forest riparian buffers, field borders, and upland habitat buffers) are available to accomplish specific conservation objectives associated with national conservation initiatives.

CP-33 Habitat Buffers for Upland Birds

In 2004 President George W. Bush announced the Presidential Bobwhite Initiative implemented under CCRP and charged USDA to develop a new conservation practice designed specifically to increase bobwhite habitat in agricultural landscapes (USDA 2005). Conservation Practice [CP] 33, Habitat Buffers for Upland Birds, was established to address the population recovery goals set by NBCI (FSA 2004). Upland habitat buffers are herbaceous communities maintained along cropped field edges. Under CP-33, agricultural landowners can enroll 9.1-36.5 meter upland habitat buffers along crop field edges by planting native warm-season grasses, forbs, legumes and shrubs, or by allowing natural succession to occur and maintain them in an early seral stage. Financial incentives include a $247.10/ha sign-up incentive (SIP), per hectare, county and soil-specific annual rental rate, 50% cost share assistance for cover establishment, and 40% practice incentive payment (PIP) for approved establishment costs (FSA 2004). Periodic planned disturbance is required for the life of contract period (10 years) and cost-shared up to 50%. The premise of CP-33 is that relatively small changes in a working agricultural landscape can significantly affect bobwhite and grassland bird abundance.

Effective Conservation

Under 2002 and 2008 Farm Bills, Congress charged USDA with more effectively quantifying environmental outcomes to justify societal investments in agricultural conservation. Blanketing the landscape with a myriad of conservation practices may yield multiple environmental benefits, but such an assumption must be quantifiable. Non-targeted approaches to conservation implementation not only potentially limit environmental benefits but also fail to optimize limited resources available for agri-environmental conservation (Batary et al. 2010). Similarly, Schonhart et al. (2010) indicated that spatial targeting of agri-environmental programs is more cost effective. Effective conservation requires monitoring and evaluation of practices that target specific natural resource goals. Effective monitoring will provide a plethora of information regarding how, when, and where conservation programs and practices work in the landscape thus improving efficacy of agri-environmental management schemes (Davey et al. 2010). Monitoring will also provide information needed to build predictive models that can be used to optimize future enrollments. Models that assess which landscape variables, conservation programs, and management practices influence species occurrence, abundance, and life history characteristics will provide a new innovative foundation on which to base future, targeted conservation enrollment.

Species-specific conservation practices like CP-33 are designed to meet a specific conservation objective (i.e., increase bobwhite abundance). Therefore, Farm Service Agency (FSA) mandated that bobwhite and priority songbird response to CP-33 implementation be monitored (USDA 2004). Results of monitoring have shown greater bobwhite and select grassland bird densities on fields enrolled in CP-33 compared to fields with no CP-33 (Evans et al. 2009). However, increased densities from one site to another provide limited information about true effectiveness of CP-33. Although presence of CP-33 has been shown to increase density, magnitude of increase and how it relates to amount of CP33 in the landscape remains unknown. Also, how landscape composition and configuration affects bobwhite and grassland bird abundance irrespective of or in addition to CP-33 in the Southeastern Coastal Plain (SCP) Bird Conservation Region (BCR) also remains unknown. Most importantly, in relation to bobwhite populations, what type of population response can landowners who enroll in CP-33 expect from enrollment? These questions can be answered by constructing simulation models based on empirical data that predict bobwhite abundance relative to CP-33 enrollment.

To better understand the relationships among landscape structure and composition, CP-33, and bobwhite abundance, I constructed simulation models to predict bobwhite abundance in a production agricultural landscape in Mississippi. I modeled bobwhite abundance in relation to multiple landcover metrics to provide a predictive model for conservation planning. Results of this study can be used to quantify bobwhite response to CP-33 and inform the decision making process of conservation management in agriculture landscapes.

Study Area

I used 2 study areas to conduct this analysis, one to develop predictive models between landscape metrics and bird abundance, and a second independent study site with no CP-33 enrollment was used to evaluate predicted response to a range of buffer enrollment options. Study Area 1 consisted of 58 bird monitoring locations on 58 production agriculture fields across 8 counties in Mississippi (Calhoun, Chickasaw, Clay, Itawamba, Monroe, Newton, Prentiss, and Union) within the SCP BCR (Figure 4.1). Each CP-33 field was paired with a non-CP-33, control field. Control fields exhibited similar cropping regimes and were located > 1 and < 3 km from selected CP-33 fields to obtain comparative measures of bird response to CP-33 establishment. Landscape surrounding each paired CP-33 and control field was dominated by row-crop production primarily corn (*Zea mays*) soybean (*Glycine max*), and livestock forage production. I quantified bird-landscape relationships using fields in Study Area 1.

Study Area 2 consisted of 34 production agriculture fields in Monroe and Chickasaw counties on which I had spatially explicit yield data for a related research project (Chapter III) (Figure 4.2). I used fields and the surrounding landscape from Study Area 2 to simulate bird response to addition of CP-33. Study Area 2 was comprised of 2 farm-scale geographic subsets of the spatial extent of Study Area 1, but included no fields used in model development. An independent study site with no CP-33 was required to adequately evaluate predicted effects of buffer establishment. I used Study Area 1 to develop a predictive model for bird abundance in relation to the surrounding landscape and used Study Area 2 to run predictive models and estimate change in bird abundance relative to changes in CP-33.

Methods

Quantifying Bird-Landscape Relationships

I conducted breeding season, fixed radius point counts on 58 bird monitoring locations to generate relative abundance estimates for bobwhite. I adhered to CP-33 - Habitat for Upland Birds Monitoring Protocol (Burger et al. 2006 (b)). Each location was surveyed 2-3 times annually during June from 2006-2008. I recorded individual singing male bobwhites during a 10 minute period on treatment and control (CP-33; no CP-33) simultaneously between sunrise and 10:00 AM. Data from each visit was pooled and observations were averaged across repetitions by point for each year to produce a yearly estimate of bobwhite abundance. I did not account for detection probability (Buckland et al. 2001); therefore, abundance estimates likely represent an underestimation of actual populations.

I used ‘heads up’ digitizing in ArcMap (ESRI 2009) to classify landcover within a 250-m radius of 58 bird monitoring locations in Study Area 1. I assessed landcover from 2007 aerial photographs obtained from National Agriculture Imagery Program (NAIP) database. Features were grouped into following categories that accurately depict dominant landcover types in a production agricultural landscape: 1) row crop, 2) exotic forage grass 3) fallow grass, 4) CP-33, 5) woody cover, and 6) unsuitable (Table 4.1). Assigned landcover classes were verified on the ground via personal inspection to ensure accurate designation. I converted vector format landcover to raster format using Spatial Analyst in ArcMap. I assigned a 1-meter cell size to facilitate accurate simulation modeling of CP-33 buffers and to minimize overestimation of edge metrics common with raster format landcover analysis (Figure 4.3).

I calculated landscape metrics based on landcover classes within 250-m radius surrounding each monitoring location using FragStats software (McGarigal and Marks 1995). I used a 250-m radius because it was the effective radius of detection (Buckland et al. 2001) for bobwhite in Mississippi based on distance sampling (K. O. Evans, Mississippi State University, personal communication). I generated 9 class metrics and 2 landscape metrics considered to be positively associated with bobwhite abundance (Veech 2006, Roseberry and Sudkamp 1998, Twedt et al. 2007) (Table 4.2).

Landcover Considerations

Several landscape-scale studies have spatially modeled landscape suitability for bobwhites (Roseberry and Sudkamp 1998, Veech 2006, Twedt et al. 2007, Riffell et al.

2008). These studies quantified landscape composition and structure within 3 to 25 km buffers around North American Breeding Bird Survey routes and used breeding male bobwhite detections to index bobwhite abundance. Veech (2006) and Riffell et al. (2008) used 1997 Natural Resources Inventory (NRI) (USDA NRCS 2000) data, whereas Roseberry and Sudkamp (1998) used a combination of state-level landcover databases and spectral interpretation, and Twedt et al. (2007) used National Land Cover Data and Land Use Land Cover (Vogelmann et al. 2001) to quantify land cover composition across landscapes. Although these databases are effective in quantifying land cover and land use at macro-scales they can be measurably erroneous at local spatial scales. Thogmartin et al. (2004) expressed caution in using 1992 NLCD data with respect to recognition of grassland-herbaceous landcover, stating that grassland-herbaceous had the smallest accuracy rate (97% error of omission and 91% error of commission) of all other land cover classes. Arguably, grassland herbaceous landcover class generally accounts for a small percentage of the landscape. However, when investigating spatial landcover associations with grassland obligate or early successional bird species, such as bobwhite, misclassification can be a substantial source of error (Thogmartin et al. 2004). To combat errors in landcover classification resulting from remote sensing techniques, I digitized current (2007) NAIP aerial photographs and ground-truthed classification personally to minimize error. I characterized all habitat features greater than or equal to my minimum map unit (5m x 5m). I also used a smaller spatial scale (250-m radius) to minimize possible errors associated with large scale classifications.

Bobwhites require permanent usable space (Guthery et al. 1997), therefore research often investigates the relationship between usable space and bobwhite abundance (Bridges et al. 2002, Veech 2006, and Twedt et al. 2007) However, large-scale landscape studies are often limited to large-scale landcover databases that group classifications for simplicity. For example, Twedt et al. (2007) identified landscape characteristics that were correlated with distribution and abundance of bobwhite in the West Gulf Coastal Plain BCR. Due to scale of that analysis and database used, NLCD 1992, (Vogelmann et al. 2001) 'grassland' class included the following grass types: grass, herbaceous, pasture, hay, or fallow (Twedt et al. 2007). Although NLCD does distinguish between 'Grassland/Herbaceous' and 'Pasture/Hay', considering the scale of that analysis (West Gulf Coastal Plain) collapsing of cover types was probably necessary to simplify modeling. Results indicated that detection of bobwhite was positively associated with proportion of grassland in the landscape (Twedt et al. 2007). The 'Pasture/Hay' classification generally consists of monocultures of exotic forage grass used for grazing or haying. Such landcover classifications are thought to be non-conducive to bobwhite life history (Washburn et al. 2000, Greenfield et al. 2002). However, Veech (2006) found declining populations and populations with less than average abundance to be associated with less cropland, pastureland, and rangeland in the landscape. In landscapes largely devoid of grasslands (i.e., those dominated by agriculture), influence of pastureland (typified by exotic forage grasses) may warrant separate investigation. Therefore, I differentiated among multiple grass landcover types to better understand how grass types influence bobwhite abundance in agriculture dominated landscapes. Because I used a smaller spatial scale which allowed me to verify classifications on the ground, I was able to accurately depict abundance and distribution of each grass type. Previous studies were limited by the accuracy of the landcover source they used, which can drastically underestimate grassland-herbaceous landcover classes (Thogmartin et al. 2004).

Model Development

I calculated 11 landcover metrics (Table 4.2) for landscapes surrounding all 58 bird-monitoring points and used them to create two sets of a priori candidate models. One set of models was used to quantify which landcover metrics influence bobwhite abundance in landscapes with no CP-33; therefore I used only locations without CP-33 for analysis (Table 4.3). The second set of candidate models was used to quantify which landcover metrics influence bobwhite abundance in landscapes with CP-33. Therefore I used locations with and without CP-33 for analysis (Table 4.4). I modeled landcover metrics relative to ‘Count’ defined as mean number of breeding males detected for each point, each year (2006-2008). I modeled effects of landcover metrics on bobwhite relative abundance using a Poisson regression in Program SAS (PROC GLIMMIX; SAS 2006). I evaluated model adequacy using an information theoretic approach (Akaike 1973, Burnham and Anderson 1998) wherein I compared candidate models based on Akaike’s Information Criterion (AIC) adjusted for small sample size (AICc) (Burnham and Anderson 1998). (Tables 4.3, 4.4).

To generate predictions of bobwhite abundance relative to changes in landcover metrics, I quantified landcover for a 250-m radius around 34 agricultural fields with which I used for a separate analysis (Chapter III). Those 34 fields and surrounding landscapes became Study Area 2 which I used to generate predictions of bobwhite abundance relative to simulated changes in landcover. I classified landcover into the same categories as Study Area 1, and used the same approach in FragStats to generate landcover metrics that influence bobwhite abundance.

To quantify how CP-33 buffers influence bobwhite abundance, I created 5 separate landcover databases, each with a different proportion of CP-33 buffers on the center field. Specifically I simulated: no CP-33, 9.1, 18.2, 27.4, and 36.5 m of CP-33 around the center field of a 250-m radius landscape (Figure 4.4). After simulating alternative buffer widths for each database, I ran FragStats analysis to generate landcover metrics which I then used to predict bobwhite abundance using Poisson regression estimates derived from Study Area 1 (Tables 4.5 and 4.6). Specifically, I used estimates from 'No CP-33' model set to predict abundance in 'No CP-33' simulation and used estimates from the model set that included CP-33 to predict abundance for alternative buffer width scenarios. I used these predictions to estimate bobwhite abundance with increasing CP-33 acreage to determine possible influences of CP-33 on bobwhite abundance in an agriculture dominated landscape. Such predictions can be useful in assessing relative influence of conservation practices on bobwhite populations at multiple scales.

Model Application

I ranked models from smallest to largest based on AICc values and excluded models more than 4 units away from the top model based on (Δ_i) for candidate sets which yielded 5 competing models for No-CP33 analysis and 7 competing models for CP-33 analysis (Tables 4.7 and 4.8, respectively). Of these models, each had a high likelihood of being the best model. Therefore, I used model averaging to derive parameter estimates for each landscape metric that comprised the competing models. I applied model averaged parameter estimates of competing models ($\Delta_i \leq 4$) to landcover parameters derived from FragStats to predict number of breeding male bobwhite for each landscape. I recalculated model weights (w_i) based of competing models and derived β estimates and intercept values from Poisson regression. I used these values to predict bobwhite abundance on Study Area 2 where I simulated the proportion of CP-33 in the landscape. For each simulation in Study Area 2 (i.e., 34 fields) I applied the following Poisson regression equation for all metrics in competing models:

$$\text{Pred}_{\text{NOBO}} = \exp\left[\text{Intercept} + (\beta\ \text{estimate} \quad \text{landscape metric})\right]$$

I multiplied recalculated model weight by $\text{Pred}_{\text{NOBO}}$ calculation. I then summed results across all competing models from Study Area 2 to generate an estimate of bobwhite abundance (λ).

I calculated predicted abundance (λ) on each field in Study Area 2 under alternative CP-33 buffer simulations and no buffer simulations (e.g., agriculture only). I simulated alternative buffer widths of 9.1, 18.2, 27.4, and 36.5 m which comprised 3.64%. 7.35%, 11.10%, and 14.87% of the 250-m radius surrounding landscape, respectively. I used equation (1) to calculate a predicted bobwhite abundance estimate, (λ), for each buffer width alternative simulated on each field. I compared estimates from each simulation to predict bobwhite response to CP-33 establishment and percentage of CP-33 in the landscape.

Results

Landcover Analysis

Analysis of landscape metrics indicated study areas were dominated by agriculture production with varying amounts and types of grass in the landscape (Table 4.9). Study Area 1 contained a notable amount of CP-33 (8.97%) because half of those locations (29 points) were randomly chosen from a sample of existing CP-33 contracts to facilitate accurate monitoring of bobwhite and grassland birds (Burger et al. 2006 (b)). Study Area 2 had no CP-33 and less grass cover, providing an opportunity to quantify how addition of CP-33 to an agricultural dominated landscape affects bobwhite abundance. I used Study Area 2 to simulate varying amounts of CP-33 in the landscape and calculated predicted bobwhite abundance relative to CP-33 using Poisson regression estimates derived from bird-landscape modeling from Study Area 1.

Bobwhite Abundance

Predicted bobwhite abundance on Study Area 2 increased with increasing amount of CP-33 in the landscape. As CP-33 buffer width increased, the amount of CP-33 in the landscape also increased. On average, every 9 m increase in buffer width yielded a ~3.72% increase in the amount of CP-33 in the landscape. Similarly, for every incremental increase in CP-33, bobwhite abundance increased 7.66% on average. Predicted bobwhite abundance increased from 0.55 males detected with no CP-33 to 0.85 males detected with 36.5 m of CP-33 on the center field. Thus, there is a 30.63% increase in predicted abundance from 0% CP-33 to 14.87% CP-33 in the landscape (Figure 4.5). My analysis indicated modest changes in predicted bobwhite abundance with an increase in CP-33 buffers, however, addition of CP-33 (0 - 3.36%) alone increased abundance ~23.22%. Further incremental increases in CP-33 area yielded a smaller, on average increase in abundance (i.e., 2.47%). Most noteworthy is the increase in abundance from 0 to 3.64% of the landscape in CP-33 which was equivalent to a 9.1 m buffer around the center field. The presence of a minimum CP-33 enrollment (i.e., 9.1 m) can have a measurable effect on bobwhite abundance. My estimates for bobwhite abundance for landscapes with no CP-33 are likely over estimated due to sampling design and modeling limitations. Therefore my estimates of the magnitude of change in bobwhite abundance are likely conservative. My results indicate that presence of CP-33 can increase bobwhite abundance, with additional increase as more CP-33 is added to the landscape.

Discussion

As bobwhite populations continue to decline natural resource managers are charged with creating innovative and effective management solutions. Although traditional bobwhite management techniques are still effective, additional management options applicable across multiple habitat types will be needed to reverse or slow down bobwhite decline. Range-wide bobwhite restoration will require innovative, large-scale solutions on working lands. CCRP provides multiple options for creating wildlife habitat in agricultural landscapes. CP-33, Habitat Buffers for Upland Birds, is one such practice designed specifically to increase bobwhite populations in working agricultural landscapes. Whereas CP-33 buffers have been shown to increase bobwhite abundance when compared to fields without CP-33, no research currently exists that evaluates bobwhite response to different amounts of CP-33 in the landscape.

The premise of CP-33 is that a relatively small change in the landscape can yield a measurable response in a bobwhite population. NBCI set a goal of restoring bobwhite populations to densities observed in baseline year 1980. Achieving this goal will require altering land use on 32.8 million ha of farm, forest, and rangeland, across the bobwhite range; however NBCI assumed those goals could be achieved by altering primary land use on only 6-7% of this land (Dimmick et al. 2002). Conservation buffers were identified as a tool for meeting NBCI population recovery goals in agricultural landscapes (Dimmick et al. 2002, Burger et al. 2006 (a)). Because CP-33 was designed specifically to meet NBCI objectives it follows that research aimed at quantifying bobwhite response to CP-33 receive due attention. NBCI set a target population goal of 188,204 fall coveys (one covey equals 2 birds) to be added in Mississippi and a density of 1.13 birds per ha across the SCP. Bobwhite restoration goals are based on fall density estimates, but managers and researchers typically use breeding season male counts as their default metric for population monitoring. Much debate exists regarding the use of breeding season male counts to predict fall abundance (Rosene 1969, Curtis et al. 1989, Hansen and Guthery 2001, and Norton et al. 1961). Unfortunately there is no generally accepted method for translating breeding season male abundance to fall bird abundance. Therefore my results are difficult to illustrate in terms of NBCI goals. However, in Mississippi there are 1,270,178 ha of improvable cropland (Dimmick et al. 2002). Assuming my results are logical for a typical agricultural landscape, if 6-7% of this land base (~88,912 ha) were enrolled in CP-33 my research indicates that breeding season abundance would increase by about 25%. CP-33 buffers provide a logical and effective tool to increase bobwhite abundance with minimal change to agricultural production framework.

My results indicate an increase in bobwhite abundance with an increasing amount of CP-33 in the landscape. Bobwhite abundance is influenced by multiple habitat types and configurations in agricultural landscapes and previous research has identified these parameters and their associated effects (Roseberry and Sudkamp 1998, Veech 2006, Twedt et al. 2007). My model selection approach identified several parameters also indentified in other studies as relevant to bobwhite ecology such as row crop, row crop edge, fallow grass, fallow grass edge, and patch density. Simulating effects of these additional landcover parameters was beyond the question of interest for this study but is warranted for future research projects. However, models with greatest likelihood were %

CP-33 and % Row crop (See Table 1.3). These metrics had the greatest influence on bobwhite abundance. Parameter estimates from Poisson regression indicate a positive relationship with % CP-33 and a small, negative relationship with % Row crop. Whereas similar research across the SCP shows a positive relationship between bobwhite and % Row crop (K. O. Evans, Mississippi State University, unpublished data), it is important to note that in areas within the Mississippi portion of SCP agriculture drastically dominates land use which can be deleterious to bobwhite abundance.

Predicted increases in bobwhite abundance that I reported were small in comparison to results reported for Mississippi in the national CP-33 monitoring report for the same time period (Evans et al. 2009). CP-33 monitoring in Mississippi encompassed two BCRs: Mississippi Alluvial Valley (MAV) and SCP. I removed MAV from my analysis for logistic reasons. Unfortunately MAV represented roughly 28% of original data set so fewer observations in the sample may explain a small amount of difference between data sets. Also, I did not conduct distance sampling for my analysis (Buckland et al. 2001), like national monitoring analysis. Detection probabilities generated from distance sampling would likely have affected the magnitude of observed effect size. Therefore the absence of detection probabilities likely explains, to some degree, different effect sizes in my analysis.

My results were not dissimilar from previous research investigating bobwhite response to grassland field borders (Puckett et al. 2000, Palmer et al. 2005) which saw measurable increases in bobwhite abundance between buffered and non-buffered landscapes. Puckett et al. (2001) reported a 59.1% increase in breeding abundance on sites with herbaceous filter strips compared to those without. Field borders in that study represented 4.9-9.4% of the landscape. Similarly, Palmer et al. (2005) reported a 40%

increase in breeding abundance on sites with field borders compared to those without. Smith and Burger (2006) also observed a 23.3% increase in breeding abundance on bordered versus non-bordered sites with field buffers comprising 0.8-1.3% of the landscape. My results also indicated a 23.22% increase in breeding abundance with CP-33 comprising only 3.64% of the landscape. My results represent simulations based on empirical data to predict bobwhite abundance relative to changes in percentage of CP-33 in the landscape and not a measure of difference between controls and treatments. My results are consistent with previous research assessing effects of herbaceous field borders on bobwhite abundance. My results indicate a disproportionate increase in predicted bobwhite abundance relative to increase in usable space (Guthery 1997). A 3.64% increase in the amount of CP-33 in the landscape increased bobwhite abundance by 23.22%. Such a response suggests that bobwhite respond disproportionately to the amount of usable space in the landscape. Questions still remain concerning magnitude, direction, and intensity in which bobwhite respond to CP-33. Future research should focus on quantifying bobwhite response to amount, location, and management of CP-33 in the landscape. NBCI recovery goals will not be met with CP-33 alone but implementation of CP-33 can enhance bobwhite populations with minimal changes in primary land use. However, accurate investigation into long term effects of CP-33 on bobwhite populations will provide natural resource planners with reliable estimates and provide data to support formulation of realistic goals.

Management Implications

Quality bobwhite habitat is limited in modern agricultural landscapes (Dimmick et al. 2002, Brennan 1991). Thus range-wide population recovery will require creation and maintenance of new habitat patches. Creation and maintenance of native grass and forb communities is essential to enhancing habitat quality of agriculture landscapes, and CP-33 buffers provide these essential requirements for bobwhite by altering a small percentage of land use.

Bobwhite population decline impose an economic and intrinsic cost to society and the ecosystem. Management strategies that produce measurable increases in local populations are most likely to be adopted. Research that provides support for efficacy of a management strategy are necessary to inform the decision making process. My research provides evidence to support the use of CP-33 to increase bobwhite populations in agricultural landscapes. My results indicate a 23.22% increase in abundance by enrolling 3.64% of the landscape in CP-33 and a 30.63% increase by enrolling 14.87%. Therefore, I would recommend use of CP-33 as a bobwhite management tool. Research investigating economic outcome of CP-33 enrollment (Chapter III) has shown that CP-33 enrollment can also increase whole-field profitability. Therefore, when applied strategically, CP-33 could have measurable effects on bobwhite populations and profitability across the bobwhite range.

Literature Cited

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control 19:716-723.

Askins, R. A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology 19:60-71.

Batary, P., Baldi, A., Kleijn, D., and T. Tscharntke. 2010. Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. Proceedings of the Royal Society. 1-9.

Benton, T. G., D. M., Bryant, L. Cole, and H. Q. P., Crick. 2002. Linking agricultural practices to insect and bird populations: a historical study over three decades. Journal of Applied Ecology 39:673-687.

Best, L. B. 2000. The value of buffer habitats for birds in agricultural landscapes. Pages 75-94 *in* W. L. Hohman and D. J. Halloum, editors. A comprehensive review of Farm Bill contributions to wildlife conservation, 1985-2000. U.S. Department of Agriculture, Natural Resources Conservation Service, Wildlife Habitat Management Institute, Technical Report, USDA/NRCS/WHMI-2000.

Blackwell, B. F., and R. A. Dolbeer. 2001. Decline of the Red-winged Blackbird population in Ohio correlated to changes in agriculture (1965-1996). Journal of Wildlife Management 65:661-667.

Bongaarts, J. 1996. Population Pressure and the Food Supply System in the Developing World Population and Development Review 22.

Bridges, A. S., M. J. Peterson, N. J. Silvy, F. E. Smeins, and X. B. Wu. 2002. Landscape-scale land-cover change and long-term abundance of scaled quail and northern bobwhite *in* Texas. Pages 161-167 in S. J. DeMaso, W. P. Kuvlesky, Jr., F. Hernandez, and M. E. Berger, eds. Quail V: Proceedings of the Fifth National Quail Symposium. Texas Parks and Wildlife Department, Austin, TX.

Brennan, L. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Brennan, L. A. and W. P. Kuvlesky, Jr. 2005. North American grassland birds: An unfolding conservation crisis? Journal of Wildlife Management 69:1-13.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling. Oxford University Press, Oxford, UK.

Burger, L. W. 2002. Quail Management: issues, concerns, and solutions for public and private lands-a southeastern perspective. National Quail Symposium Proceedings 5:20-34.

Burger, L. W. 2006. Creating wildlife habitat through federal farm program: an objective-driven approach. Wildlife Society Bulletin 34:994-999.

Burger, L. W., D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010-1018.

Burger, L. W., D. McKenzie, R. Thacktson, and S. J. Demaso (a). 2006. The role of farm policy in achieving large-scale conservation: bobwhite and buffers. Wildlife Society Bulletin 34:986-993.

Burger, L. W., M. D. Smith, R. Hamrick, W. E. Palmer, and S. D. Wellendorf. 2006 (b). CP33-Habitat Buffers for Upland Birds Monitoring Protocol. Southeast Quail Study Group and Southeast Partners in Flight miscellaneous publication.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Chamberlain, D. E., R. J. Fuller, R. G. H. Bunce, J. C. Duckworth, and M. Shrubb. 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. Journal of Applied Ecology 37:771-788.

Conover, R.R., L.W. Burger, and E. Linder. 2009. Breeding bird response to field border presence and width. The Wilson Journal of Ornithology 121:548-555.

Curtis, P. D., P. D. Doerr, R. M. Oates, and K. H. Pollock. 1989. Whistling-cock indices as a measure of northern bobwhite harvest in North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:253-259.

Daniels, R. B., and J. W. Gilliam. 1996. Sediment and chemical load reduction by grass and riparian filters. Soil Science Society of America Journal 60:246-251.

Das, C., W.J. Capehart, H.V. Mott, P.R. Zimmerman, and T.E. Shumacher. 2004. Assessing regional impacts of Conservation Reserve Program-type grass buffer strips on sediment load reduction from cultivated lands. Journal of Soil and Water Conservation 59:134-142.

Davey, C., J. Vickery, N. Boatman, D. Chamberlain, H. Parry., and G. Siriwardena. 2010. Regional variation in the efficacy of Entry Level Stewardship in England. Agriculture, Ecosystems, and Environment. 139:121-128.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural non-point pollution control. Transactions of the American Society of Agricultural Engineers 32:513-519.

Dimmick, R. W., M. J., Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Miscellaneous publication of the Southeastern Association of Fish and Wildlife Agencies, South Carolina.

Dosskey, M. G., D. E. Eisenhauer, and M. J. Helmers. 2005. Establishing conservation buffers using precision information. Journal of Soil and Water Conservation 60:349-354.

Dover, J. W. 1994. Arable field margins: factors affecting butterfly distribution and abundance. British Crop Protection Council Monograph 58: Field Margins: Integrating Agriculture and Conservation, Farnham, Surrey, UK.

ESRI. 2009. ArcGIS Desktop and Spatial Analyst. Environmental Systems Research Institute, Inc. Redlands, CA.

Evans, K. O., L. W. Burger, M. D. Smith, and S. Riffell. 2009. Conservation Reserve Program. Bird Monitoring and Evaluation Plan. 2006-2008 Final Repot.

Farm Service Agency. 2004. Notice CRP-479 Practice CP-33, Habitat Buffers for Upland Birds. U.S. Department of Agriculture, Farm Service Agency, Washington, D.C., USA.

Green, R. E., S. J. Cornell, J. P. W. Scharlemann, and A. Balmford. 2005. Farming and the Fate of Wild Nature. Science 307:550-555.

Greenfield, K.C., L.W. Burger, M. J. Chamberlain, and E. W. Kurzejeski. 2002. Vegetation management practices on Conservation Reserve Program fields to improve northern bobwhite habitat quality. Wildlife Society Bulletin 30:527-538.

Guthery, F.S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291-301.

Hansen, H. M., and F. S. Guthery. 2001. Calling behavior of bobwhite males and the call-count index. Journal of Wildlife Management 29:145-152.

Herkert, J. R. 1994. Breeding bird communities of mid-western prairie fragments: the effect of prescribed burning and habitat-area. Natural Areas Journal 14:128-135.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Bobwhite Quail Symposium 2:1-5.

Lutz, W., W. Sanderson, and S. Scherbov. 2004. The end of human population growth in the 21st century: New challenges for human capitol formation and sustainable development. Earthscan, London, United Kingdom.

McGarigal, K., and B. J. Marks. 1995. FRAGSTATA: spatial pattern analysis program for quantifying landscape structure. USDA Forest Service General Technical Report PNW-351.

Murphy, M. T. 2003. Avian population trends within the evolving agricultural landscape of eastern and central United States. Auk 120:20-34.

Natural Resource Conservation Service. 1999. The National Conservation Buffer Initiative: A qualitative evaluation. U.S. Department of Agriculture, Natural Resource Conservation Service. <http://www.nrcs.usda.gov/feature/buffers/pdf/BuffQual.pdf>. Accessed 4 August 2008.

Norton, H. W., T. G. Scott, W. R. Hanson, and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite populations in autumn. Journal of Wildlife Management 33:237-249.

Palmer, W. E., S. D. Wellendorf, J. R. Gillis, and P. T. Bromley. 2005. Effect of field borders and nest predator reduction on abundance of northern bobwhites. Wildlife Society Bulletin 33:1398-1405.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J R. Anderson, Jr., and L. T. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505-516.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Pages 26-31 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Potts, G. R. 1986. The partridge: pesticides, predation and conservation. Collins, London, U.K.

Riffell, S., D. Scognamillo, and L. W. Burger. 2008. Effects of the conservation reserve program on northern bobwhite and grassland birds. Environmental Monitoring and Assessment 146:309-323.

Robertson, G. P., and S. M. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Agriculture and the Environment 3:38-46.

Roseberry, J. L. 1993. Bobwhite and the “new” biology. Pages 16-20 *in* K. E. Church and T. V. Dailey, eds. Quail III: National Quail Symposium. Kansas Department Wildlife and Parks, Pratt, USA.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University, Carbondale, USA.

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895-992.

Rosene, W. 1957. The bobwhite quail: Its life and management. Rutgers University Press, New Brunswick, NJ, USA.

SAS Institute. 2006. The GLIMMIX Procedure. SAS Institute Inc., Cary, NC, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Schonhart, M., Schauppenlehner, T., Schmid, E. and A. Muhar. 2010. Integration of bio-physical and economic models to analyze management intensity and landscape structure effects at farm and landscape level. Agricultural Systems 104:122-134.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Dissertation, Mississippi State University, Starkville, USA.

Smith, M.D. and L.W. Burger. 2009. Population response of northern bobwhite to field border management practices *in* Mississippi. Pages 220-231 in Cedarbaum S.B., Faircloth, B.C., Terhune, T.M., Thompson, J.J., Carroll, J.P., eds. Gamebird 2006: Quail VI and Perdix XII. 31 May -4 June 2006. Warnell School of Forestry and Natural Resources, Athens, GA, USA.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner’s Sons, New York, New York, USA.

Thogmartin, W. E., A. L. Gallant, and M. G. Knutson, T. J. Fox, and M. J. Suarez. 2004. Commentary: A cautionary tale regarding use of the National Land Cover Dataset 1992. Wildlife Society Bulletin 32:970-978.

Tilman, D., Cassman, D.G., Matson, P.A., and S. Polasky. 2002. Agriculture sustainability and intensive production practices. Nature 418:671-677.

Twedt, D. J., R. R. Wilson, and A. S. Keister. 2007. Spatial models of northern bobwhite populations for conservation planning. Journal of Wildlife Management 71:1808-1818.

United States Department of Agriculture. 2003. Natural Resource Inventory. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Inventory Division. <http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb>. Accessed 31 July 2008.

United States Department of Agriculture. 2004. Practice CP33 habitat buffers for upland wildlife. Farm Service Agency, Notice CRP-479, Washington, D.C., USA.

United States Department of Agriculture. 2005. Bush administration expands Conservation Reserve Program, launches innovative conservation measures for wildlife and wetlands. U.S. Department of Agriculture, Office of Communications, Washington, D.C., News release 0324.04, 4 August 2004. <http://www.fsa.usda.gov/pas/printstory.asp?StoryID=1798>. Accessed 4 August 2008.

United Stated Department of Agriculture. Natural Resources Conservation Service. 2000. Summary Report: 1997 National Resources Inventory (revised December 2000), Washington, D. C. & Statistical Laboratory, Iowa State University, Ames, Iowa. <http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/>. Accessed 01 June 2007.

United Nations Population Division, World Population Prospects; The 2007 revision population division of the department of economic and social affairs of the United Nations secretariat, world population prospects: The 2006 revision and world urbanization prospects: The 2007 revision. < http://esa.un.org/unup>. Accessed 01 August 2008.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922-930.

Vickery, P. C., and J. R. Herkert. 1999. Ecology and conservation of grassland birds of the Western Hemisphere. Studies in Avian Biology No. 19. Cooper Ornithological Society, Camarillo, California, USA.

Vogelmann, J. E., S. M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and N Van Driel. 2001. Completion of the 1990's National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources. Photogrammetric Engineering and Remote Sensing 67:650-652.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97-104.

Watkinson, A. R., R. P. Freckleton, R. A. Robinson, and W. J. Sutherland. 2000. Predictions of biodiversity response to genetically modified herbicide-tolerant crops. Science 289: 1554-1557.

Webster, E. P., and D. R. Shaw. 1996. Impact of vegetative filter strips on herbicide loss in runoff from soybean (*Glycine max*). Weed Science 44:662-671.

Table 4.1 Six landcover types used to characterize landscapes relative to bobwhite abundance in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA using 2007 NAIP imagery.

Landcover Type	Description
Row Crop	Annually cultivated crops
Exotic Forage Grass	Introduced, monotypic perennial vegetation use for forage production
Fallow Grass	Idle land comprised of annual and perennial grasses, herbaceous vegetation, and < 10% woody vegetation
CP-33	Buffer strips comprised of annual grasses, forbs, and legumes with <5 % shrub cover
Woody Cover	Closed canopy woody vegetation
Unsuitable	Urban, barren, water bodies, manmade structures

Table 4.2 Landcover metrics obtained from FragStats analysis within 250 meter radius landscape in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA using 'heads up' digitizing of 2007 NAIP imagery after aggregation of landcover classes: row crop, exotic forage grass, fallow grass, CP-33, woody cover, and unsuitable.

Metric	Description
% Row crop	Percentage of row crop in the landscape
Row crop Edge	Amount of row crop edge in the landscape / total area
% Exotic Grass	Percentage of exotic forage grass in the landscape
Exotic Grass Edge	Amount of exotic forage grass edge in the landscape / total area
% Fallow Grass	Percentage of fallow grass in the landscape
Fallow Grass Edge	Amount of fallow grass edge in the landscape / total area
% CP-33	Percentage of CP-33 in the landscape
CP-33 Edge	Amount of CP-33 edge in the landscape / total area
Woody Cover Edge	Amount of woody cover edge in the landscape / total area
Patch Density	Number of patches in the landscape / total area
Edge Density	Amount of edge in the landscape / total area

Table 4.3 Akaike's Information Criterion adjusted for small sample size (AICc), model parameterization (K), deviations from minimum AICc (Δ_i), model weight (w_i), and model likelihood (w_i/w_{max}) for 19 candidate models relating northern bobwhite abundance (2006-2008) and 9 landcover metrics obtained from FragStats analysis of 5 landcover classes (no CP-33) in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Candidate Model	AICc	K	Δ_i	w_i	w_i/w_{max}
Patch Density	270.471	2	0.000	0.412	1.000
Row Crop Edge	271.481	2	1.010	0.248	0.603
% Fallow Grass	272.651	2	2.180	0.138	0.336
Edge Density	273.171	2	2.700	0.106	0.259
Fallow Grass Edge	274.061	2	3.590	0.068	0.166
% Row Crop	276.541	2	6.070	0.019	0.048
% Fallow Grass, Patch Density	281.937	3	11.465	0.001	0.003
Exotic Forage Grass Edge, Row Crop Edge	282.617	3	12.145	0.000	0.002
% Fallow Grass, Woody Cover Edge	283.257	3	12.785	0.000	0.001
Fallow Grass Edge, Row Crop Edge	284.017	3	13.545	0.000	0.001
% Fallow Grass, Edge Density	284.227	3	13.755	0.000	0.001
% Row Crop, Woody Cover Edge	284.817	3	14.345	0.000	0.000
% Exotic Forage Grass, % Fallow Grass	284.907	3	14.435	0.000	0.000
% Row Crop, % Fallow Grass	285.007	3	14.535	0.000	0.000
% Row Crop, Patch Density	285.807	3	15.335	0.000	0.000
% Exotic Forage Grass, % Row Crop	285.957	3	17.655	0.000	0.000
% Row Crop, Fallow Grass Edge	288.127	3	17.985	0.000	0.000
% Row Crop, Edge Density	288.457	3	17.985	0.000	0.000
Global	354.378	10	83.906	0.000	0.000

Table 4.4 Akaike's Information Criterion adjusted for small sample size (AICc), model parameterization (K), deviations from minimum AICc (Δ_i), model weight (w_i), and model likelihood (w_i/w_{max}) for 25 candidate models relating northern bobwhite abundance (2006-2008) and 11 landcover metrics obtained from FragStats analysis of 6 landcover classes (including CP-33) in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Candidate Model	AICc	K	Δ_i	w_i	w_i/w_{max}
% CP-33	542.102	2	0.000	0.339	1.000
% Row Crop	542.392	2	0.290	0.293	0.865
Fallow Grass Edge	544.922	2	2.820	0.082	0.244
Patch Density	545.162	2	3.060	0.073	0.216
Row Crop Edge	545.212	2	3.110	0.071	0.211
CP-33 Edge	545.962	2	3.860	0.049	0.145
% Fallow Grass	546.032	2	3.930	0.047	0.140
Edge Density	547.452	2	5.350	0.023	0.068
% Row Crop, Fallow Grass Edge	550.404	3	8.300	0.005	0.015
% CP-33, Patch Density	552.584	3	10.482	0.001	0.005
% Row Crop, % CP-33	552.844	3	10.742	0.001	0.004
% Exotic Forage Grass, % Row Crop	552.864	3	10.762	0.001	0.004
% Row Crop, Woody Cover Edge	553.914	3	11.812	<0.001	0.002
% CP-33, Edge Density	554.504	3	12.402	<0.001	0.001
% Row Crop, Patch Density	554.634	3	12.532	<0.001	0.001
% Row Crop, Edge Density	556.734	3	14.632	<0.001	<0.001
% CP-33, Woody Cover Edge	556.814	3	14.712	<0.001	<0.001
% Exotic Forage Grass, % Fallow Grass	556.894	3	14.792	<0.001	<0.001
% Row Crop, CP-33 Edge	556.894	3	14.792	<0.001	<0.001
% Fallow Grass, Patch Density	557.104	3	15.02	<0.001	<0.001
Fallow Grass Edge, Row Crop Edge	558.144	3	16.042	<0.001	<0.001
% Fallow Grass, Woody Cover Edge	558.754	3	16.652	<0.001	<0.001
% Fallow Grass, Edge Density	558.764	3	16.662	<0.001	<0.001
CP-33 Edge, Row Crop Edge	559.044	3	16.942	<0.001	<0.001
Global	620.210	9	78.108	<0.001	<0.001

Table 4.5 Parameter estimates (β), intercept, and recalculated model weights (w_i) for 7 competing models used to characterize bobwhite abundance (2006-2008) in agricultural landscape (including CP-33) in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Model	β-value	Intercept	Model Weight (w_i)
% CP-33	0.01727	-0.334	0.354
% Row crop	-0.00644	0.141	0.306
Fallow Grass Edge	-0.00004	-0.150	0.086
Patch Density	0.00727	-0.530	0.076
Row crop Edge	0.00056	-0.203	0.074
CP-33 Edge	0.00327	-0.381	0.051
% Fallow Grass	0.00787	-0.235	0.049

Table 4.6 Parameter estimates (β), intercept, and recalculated model weights (w_i) for 5 competing models used to characterize bobwhite abundance (2006-2008) in agricultural landscape (no CP-33) in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Model	B-value	Intercept	Model Weight (w_i)
Patch Density	0.00324	-0.6805	0.422
Row Crop Edge	0.00278	-0.8056	0.255
% Fallow Grass	0.01379	-0.6172	0.142
Edge Density	0.00128	-0.7149	0.109
Fallow Grass Edge	0.00106	-0.5829	0.070

Table 4.7 Akaike's Information Criterion adjusted for small sample size (AICc), model parameterization (K), deviations from minimum AICc (Δ_i), recalculated model weight (w_i), and model likelihood (w_i/w_{max}) for 5 models with greatest likelihood among 25 candidate models relating bobwhite abundance (2006-2008) and landcover metrics (no CP-33) obtained from FragStats analysis of 6 landcover classes in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Candidate Model	AICc	K	Δ_i	w_i	w_i/w_{max}
Patch Density	270.471	2	0.00	0.422	1.000
Row Crop Edge	271.481	2	1.01	0.255	0.603
% Fallow Grass	272.651	2	2.18	0.142	0.336
Edge Density	273.171	2	2.70	0.109	0.259
Fallow Grass Edge	274.061	2	3.59	0.070	0.166

Table 4.8 Akaike's Information Criterion adjusted for small sample size (AICc), model parameterization (K), deviations from minimum AICc (Δ_i), recalculated model weight (w_i), and model likelihood (w_i/w_{max}) for seven models with greatest likelihood among 25 candidate models relating bobwhite abundance (2006-2008) and landcover metrics (including CP-33) obtained from FragStats analysis of 6 landcover classes in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Candidate Model	AICc	K	Δ_i	w_i	w_i/w_{max}
% CP-33	542.102	2	0.00	0.354	1.000
% Row Crop	542.392	2	0.29	0.306	0.865
Fallow Grass Edge	544.922	2	2.82	0.086	0.244
Patch Density	545.162	2	3.06	0.076	0.216
Row Crop Edge	545.212	2	3.11	0.074	0.211
CP-33 Edge	545.962	2	3.86	0.051	0.145
% Fallow Grass	546.032	2	3.93	0.049	0.140

Table 4.9 Percentage of the landscape for various landcover types of Study Areas 1 and 2 (2007) for a 250-meter radius (~19 ha) around agricultural fields in the Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA.

Landcover	Study Area 1	Study Area 2
Row crop	50.10%	84.00%
Exotic Forage Grass	10.35%	4.05%
Fallow Grass	7.60%	0.54%
Woody Cover	17.33%	8.28%
CP-33	8.97%	----
Unsuitable	5.62%	3.11%

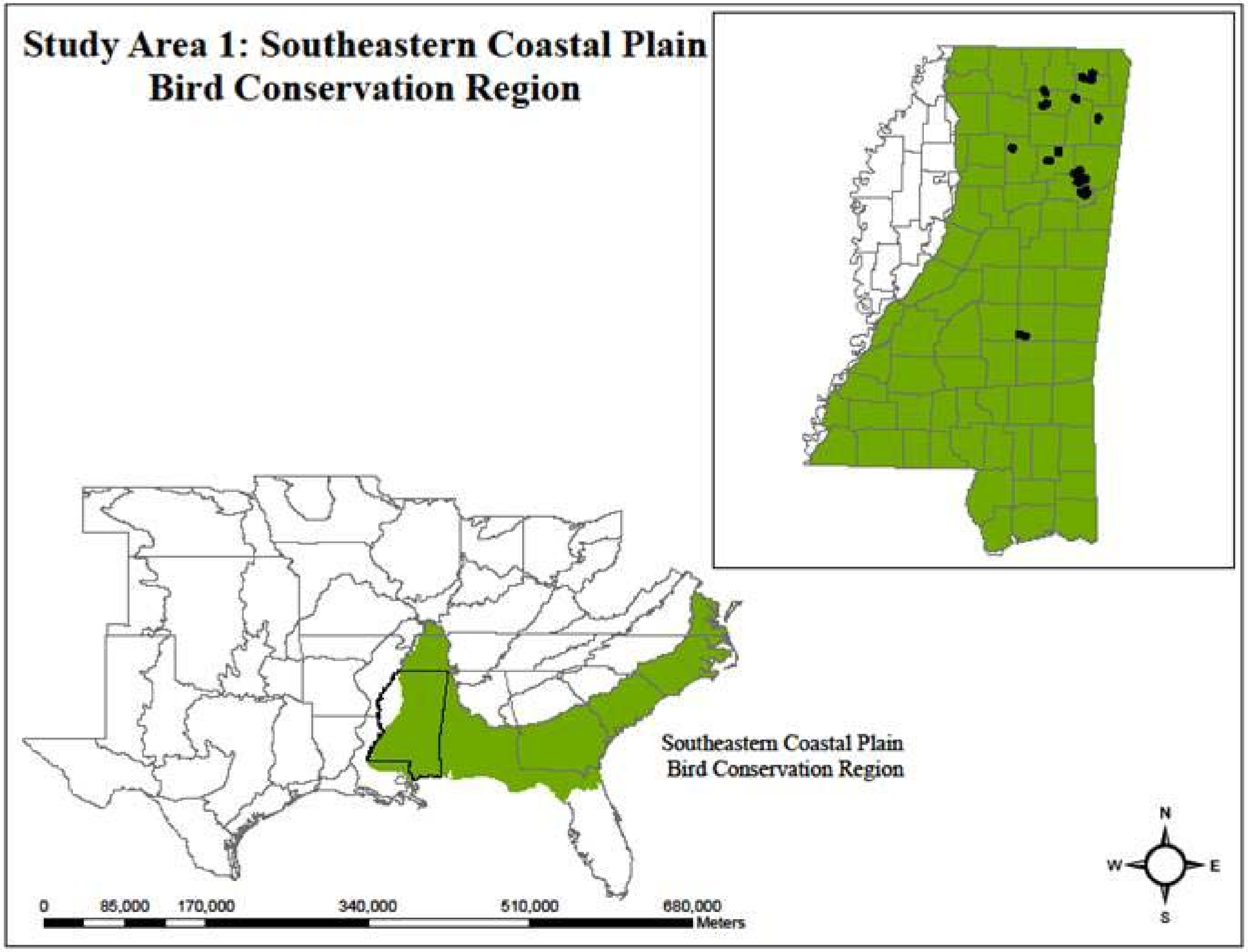

Figure 4.1 Study Area 1: Bobwhite monitoring locations in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA, (2006-2008).

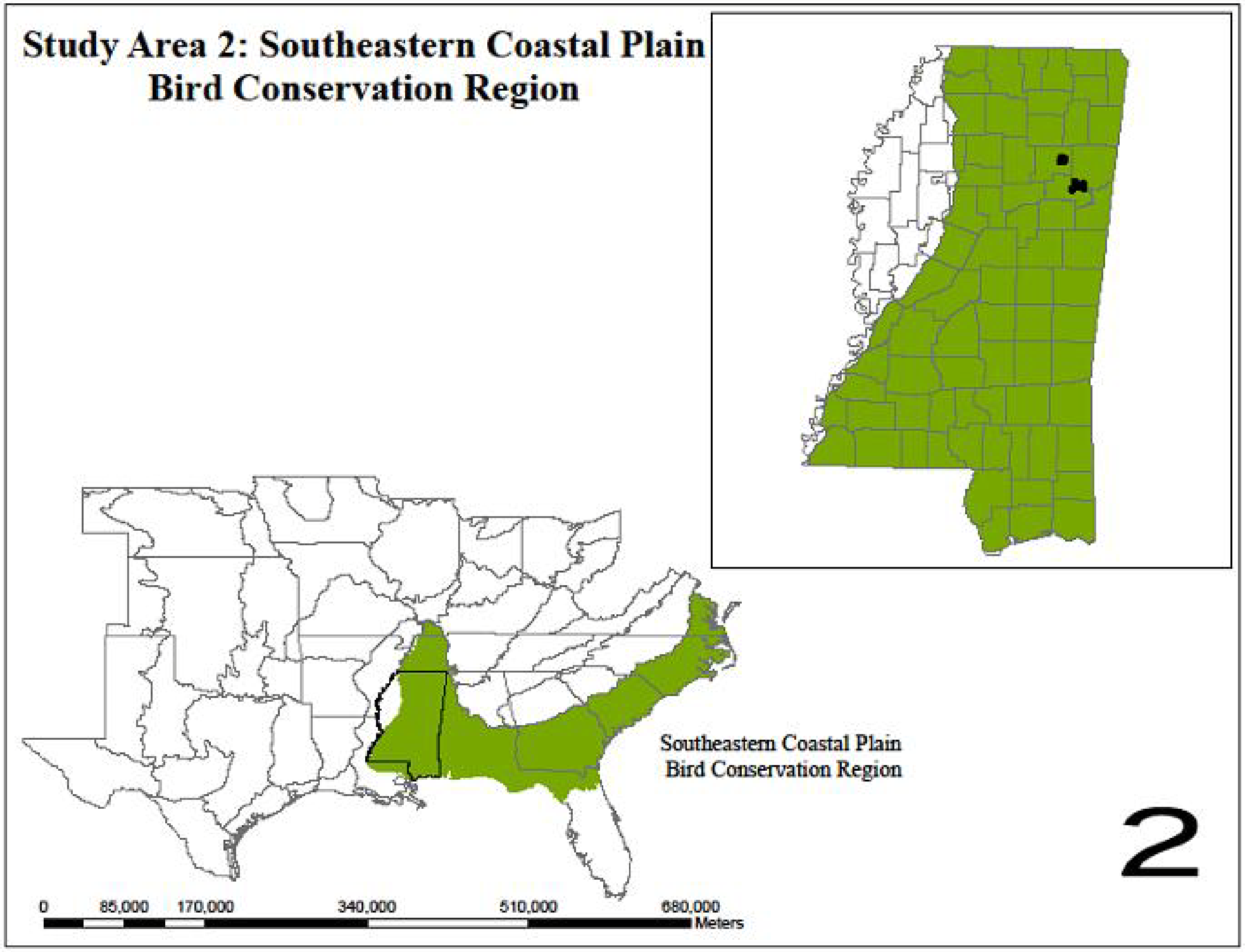

Figure 4.2 Study Area 2: Bobwhite abundance simulation locations in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA, 2007.

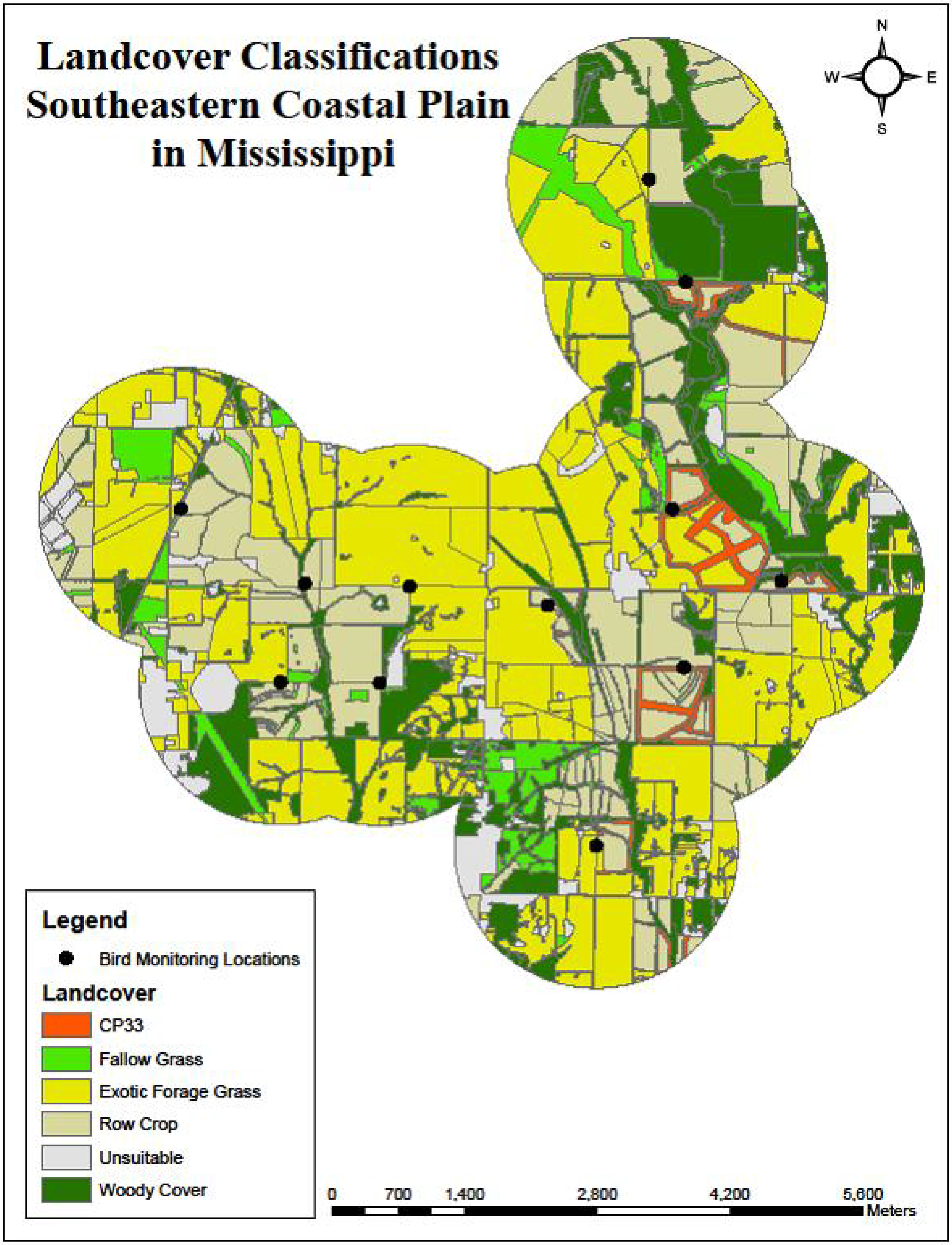

Figure 4.3 Landcover database for landscape surrounding bobwhite monitoring locations in Southeastern Coastal Plain Bird Conservation Region, Mississippi, USA, 2007.

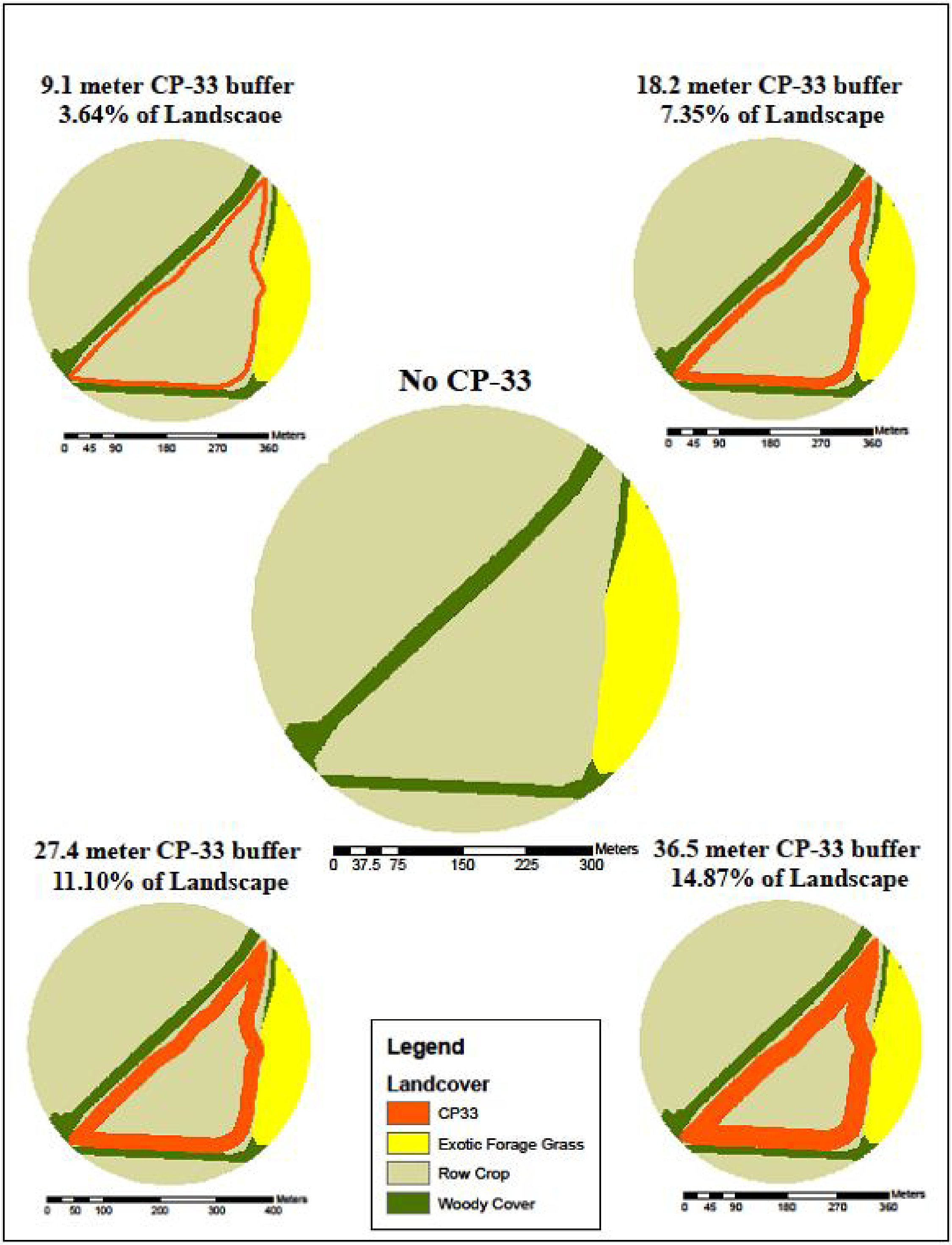

Figure 4.4 Landcover simulations of alternative CP-33 buffer widths on agricultural fields in Southeastern Coastal Plain Bird Conservation Region of Mississippi, USA, 2007.

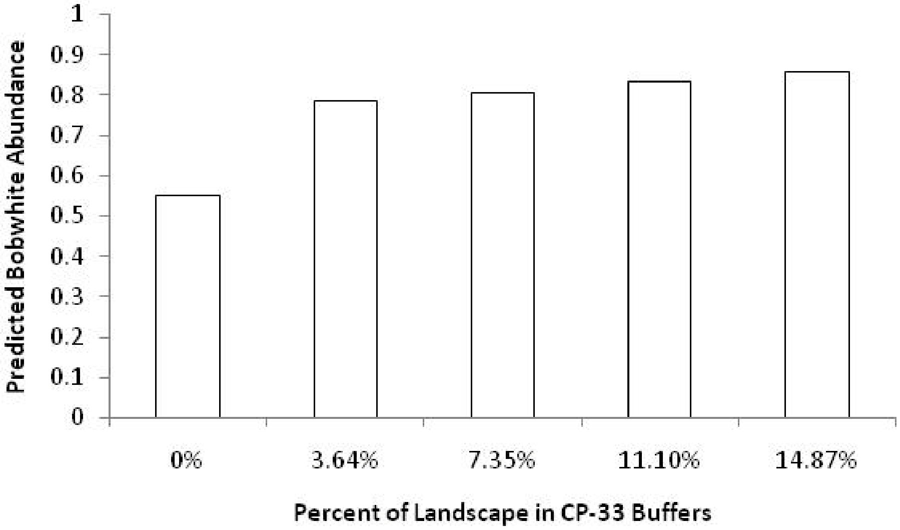

Figure 4.5 Predicted bobwhite abundance in response to percentage of CP-33 in the landscape for 34, 250-meter radius landscapes in the Southeastern Coastal Plain, Mississippi, USA, 2007.

CHAPTER V

SYNTHESIS AND CONCLUSIONS

To reverse northern bobwhite (*Colinus virginianus*, hereafter, bobwhite) decline, new and innovative management strategies will be required across the bobwhite range. Although land currently managed for bobwhite must be maintained, to reverse bobwhite decline managers must create more usable space in the landscape (Guthery 1997). Additional usable space will be targeted on new ground (i.e., land not currently conducive to bobwhite). Considering nearly 50% of the land area in the contiguous 48 states is managed for row crop production or grazing (USDA 2003, Robertson and Swinton 2005), range-wide recovery will largely require focus on privately owned agricultural landscapes. Therefore, creation of usable space will likely require alterations to current land management practices such as row crop production. Effective management practices will be defined by those that generate greatest bobwhite response relative to smallest change in land use without negatively affecting revenue.

United States Department of Agriculture's (USDA) National Conservation Buffer Initiative (NCBI) has been instrumental in promoting buffer establishment on private lands nationwide (NRCS 1999). The vehicle for implementing conservation buffers has been Continuous Conservation Reserve Program (CCRP), implemented through the Farm Bill. Under CCRP a variety of conservation buffer practices (i.e., filter strips, forest riparian buffers, field borders, and upland habitat buffers) are available to accomplish specific conservation objectives associated with national conservation initiatives.

CCRP provides landowners with financial incentives to remove marginal lands from agricultural production and reestablish them to natural vegetation (e.g., native grasses, trees, etc.). Whereas often used to create wildlife habitat, CCRP offers multiple conservation practices that provide environmental services such as erosion control and sediment retention. Conservation Practice [CP] 33, Habitat Buffers for Upland Birds was designed specifically to increase bobwhite populations in agricultural landscapes (FSA 2004). Upland habitat buffers are herbaceous communities maintained along cropped field edges. Under CP-33, agricultural landowners can enroll 9.1- 36.5 m of upland habitat buffers along crop field edges by planting native warm-season grasses, forbs, legumes and shrubs, or by allowing natural succession to occur and maintain them in an early seral stage. CP-33 provides habitat for bobwhite by reallocating arable field margins to native vegetation conducive to bobwhite ecology. The premise of CP-33 is that relatively small changes in a working agricultural landscape can significantly affect on bobwhite populations. However, removal of arable land from production imposes an opportunity cost associated with loss in revenue from commodities that otherwise would have been produced.

Understanding how conservation practices fit into a working agricultural landscape is paramount to conservation adoption. Within CCRP there are numerous conservation buffer practices available each with a different set of eligibility criterion. Agricultural producers can be overwhelmed with the task of understanding where their land is eligible which can hinder adoption. Many natural resource managers are trained in conservation planning but the multitude of options can be difficult to comprehend. I developed a geospatial decision support tool to inform the decision making process of conservation buffer enrollment in working agricultural landscapes. This tool illustrates eligibility of agricultural fields across a range of conservation practices and can be used for landscape-scale conservation planning.

Agricultural producers operate under uncertainty created by environmental and market stochasticity, consequently, financial concerns strongly influence producer decisions (Kitchen et al. 2005). Variations in global economies, commodity prices, agricultural policies (e.g., Farm Bill, trade agreements), subsidy payments, weather/climatic events, input costs, and equipment expenses together influence risk and profitability for landowners and producers. Considering such preexisting variations and risks associated with farm profitability, prospect of removing land from production and enrolling in a conservation practice creates a surmountable degree of uncertainty and reservation. Consequently, many agricultural producers are unwilling to enroll in conservation programs because financial ramifications are unclear. Therefore it is the responsibility of natural resource managers to elucidate financial opportunities provided by conservation buffer enrollment.

Understanding how conservation programs influence field-level economics is paramount to effective conservation buffer enrollment. Precision agriculture [PA] technology (e.g., yield monitors) is required to provide spatially explicit information concerning variability in yield and profit across a field. My decision support tool uses PA technology to identify conservation and economic opportunities across production fields. This tool is designed to evaluate economic benefits of replacing arable field margins with conservation buffers. With the eligibility tool I identified more than 300 ha of eligible working agricultural land for CP-33 across one production farm in Tallahatchie County, Mississippi. My economic analysis also indicates that CP-33 can increase field revenue across of range of commodity prices in the Black Prairie region of Mississippi.

Equally important to economic outcome of CP-33 enrollment are effects on bobwhite populations. How bobwhite respond to CP-33 enrollment is essential to meeting population recovery goals and determining efficacy of future enrollment. Because CP-33 is the first conservation practice to require landscape level monitoring (USDA 2004) there is abundant data to answer this question (Evans et al. 2009). In addition to bobwhite response to the presence of CP-33 it is vital to understand how bobwhites respond to amount of CP-33 in the landscape. I used predictive simulation models to estimate change in bobwhite abundance relative to changes in amount of CP-33 in the landscape. My analysis indicates that a minimum CP-33 enrollment (9.1 m; 3.64% of landscape) can increase breeding season bobwhite abundance up to 23.22%. Such information suggests that bobwhite may respond disproportionately to the amount of usable space in the landscape.

Decision support tools and simulation analysis are essential components for targeted conservation planning. Identifying spatial eligibility of conservation practices in conjunction with their financial implications and effects on wildlife abundance provides landowners and natural resource planners with necessary tools to make responsible and profitable land use decisions. Understanding conservation practice eligibility can increase the speed and magnitude in which practices are implemented. Likewise, spatially targeting conservation enrollment to increase revenue ensures financial gain which also increases adoption. Lastly, understanding the magnitude in which conservation practices increase wildlife abundance provides the framework for formulating population recovery goals. Collectively this information provides the building blocks for future targeted, landscape-level conservation planning and enrollment.

To date, no conservation practice's effects on economics and wildlife enhancement have been mutually investigated. I provide considerable evidence to support the use of CP-33 as a tool for increasing field revenue and bobwhite abundance. Results of this study provide tools for an executable framework for targeted conservation planning. With this information, landowners and natural resource planners can make informed decisions about intentional conservation enrollment. This analysis also provides support for use of PA technology in providing economic insight to inform the decision making process of conservation enrollment. My results show that across a range of commodity prices and buffer width alternatives CP-33 increases whole field revenue and concomitantly increases bobwhite abundance. Such information can be used strictly for economic gain or bobwhite response, or both. By using PA technology CP-33 buffers can be placed on field margins with less than profitable economic returns thus effectively accounting for opportunity costs associated with removing arable land from production. Furthermore simulation analysis provides accurate estimates for magnitude of bobwhite response land managers and agricultural producers can expect from CP-33 enrollment.

In summary, CP-33 buffers are an effective and profitable management tool for increasing field revenue and increasing bobwhite populations in agricultural landscapes. PA technology is necessary to provide spatially explicit information about productivity and profitability of field margins. Such information can be used to effectively and efficiently to alter land management decisions and strategies. Increases in bobwhite abundance coupled with increases in revenue make CP-33 an attractive solution for natural resource managers and agricultural producers. CP-33 buffers provide a 'win –

win' solution for a range of problems associated with modern production agriculture. I recommend the use of CP-33 when applied strategically and responsibly on field margins with marginal profitability.

Literature Cited

Evans, K. O., L. W. Burger, M. D. Smith, and S. Riffell. 2009. Conservation Reserve Program. Bird Monitoring and Evaluation Plan. 2006-2008 Final Repot.

Farm Service Agency. 2004. Notice CRP-479 Practice CP-33, Habitat Buffers for Upland Birds. U.S. Department of Agriculture, Farm Service Agency, Washington, D.C., USA.

Guthery, F.S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291-301.

Kitchen, N. R., K. A. Sudduth, D. B. Myers, R. E. Massey, E. J. Sadler, R. N. Lerch, J. W. Hummel, and H. L. Palm. 2005. Development of a conservation-oriented precision agriculture system: Crop production assessment and plan implementation. Journal of Soil and Water Conservation 60:421-430.

Natural Resources Conservation Service. 1999. The National Conservation Buffer Initiative: A qualitative evaluation. U.S. Department of Agriculture, Natural Resource Conservation Service. <http://www.nrcs.usda.gov/feature/buffers/pdf/BuffQual.pdf>. Accessed 4 August 2008.

Robertson, G. P., and S. M. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Agriculture and the Environment 3:38-46.

United Stated Department of Agriculture. Natural Resources Conservation Service. 2000. Summary Report: 1997 National Resources Inventory (revised December 2000), Washington, D. C. & Statistical Laboratory, Iowa State University, Ames, Iowa. <http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/>. Accessed 01 June 2007.

United States Department of Agriculture. 2003. Natural Resource Inventory. U.S. Department of Agriculture, Natural Resources Conservation Service, Resource Inventory Division. <http://www.nrcs.usda.gov/technical/NRI/2003/Landuse-mrb>. Accessed 31 July 2008.

United States Department of Agriculture. 2004. Practice CP33 habitat buffers for uplandwildlife. Farm Service Agency, Notice CRP-479, Washington, D.C., USA.