ECONOMIC BENEFITS OF INCORPORATING COVER CROP AND LIVESTOCK GRAZING IN CORN-SOYBEAN CROPPING SYSTEMS IN MIDWEST REGION

A THESIS PRESENTED TO THE SCHOOL OF AGRICULTURAL SCIENCES IN CANDIDACY FOR THE DEGREE OF MASTER OF SCIENCE

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DECEMBER 2016
ABSTRACT

The incorporation of cover crops in cropping systems offers economic benefits that farmers are often not aware. Lack of information and technical know-how on the establishment and benefits of cover crops are the main reasons cited by farmers for their reluctance in incorporating cover crops in their programs. The aim of this study was determining economic benefits of including cover crops and livestock grazing in corn-soybean cropping system in Midwest region.

The methodologies used in this research were meta-analysis and NRSC partial budgeting Cover Crop Economics analysis tool. Results of analysis revealed that both short- and long-term incorporating of cover crops and livestock grazing into agronomic crop rotation systems increased farm income by $44.08/ac/yr and $45.24/ac/yr on average respectively.
ACKNOWLEDGEMENTS

I want to bless the name of the Lord God for His mercy, provision and wisdom, and for seeing me through my graduate program. I also want extend my profound gratitude to my Advisors, Dr. J. Arley Larson and Dr. Nigel Hoilett for their continual help, advice and guidance, support during my research.

I would like to thank Northwest Missouri State University, Graduate School, for their financial assistant during my years of study at Northwest Missouri State University. I want to thank all the faculty staffs of School of Agriculture Sciences for helping me out when needed.

Thanks to all my family and friends who believe in me and gave me support when needed. Mrs and late Mr Ogundiran, my loving sister Ronke, my cousin Oluwakemi Oni, Mr and Mrs Oni, all my nephews and nieces thank you so much for your prayers and care!

I want use this opportunity to say big thank to Pastor and Mrs Hawk and all my unit members at the Bridge Church Maryville, you are the best! I want say thank you to Dr. Ben Bradford, Dr. Bayo and Mr and Mrs Johnson.

I want also to thank the International Office Center staffs for their endless support to international students, and for being helpful from the first day of my arrival in Maryville. I want to thank to especially Dr. Jeff Foot, Mrs Ashely B and Lisa M for supporting all international students.
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ABSTRACT

The benefits of incorporating cover crops in contemporary agricultural systems never be over emphasized. Most farmers are unaware of economic benefits of cover crops; in addition farmers often express they lack information and technical know-how on establishing and maintaining cover crops. The willingness of farmers to adopt and use cover crops is centered on the perception that cover crops will increase their farm income, whether in the short run or in at the long run.

Therefore, the intent of this study was to determine economic benefits of including cover crops and livestock grazing in corn-soybean cropping system in Midwest region.

The objectives of this study were a) Analyze economic benefits of including cover crops in the management of agronomic cropping systems; b).Determine the economic benefits of using cover crops for livestock grazing.

To address our objectives, we used data on cover crop use from different sources (meta-analysis) and partial budgeting analysis in conjunction with the NRCS Cover Crop Economics tool, to calculate overall costs and benefits for both short and long term cover crop use. The data on agronomic variables such as, yield, organic matter content, erosion reduction, available nitrogen, herbicides reduction, and water storage and infiltration capacity over a 25-year period was utilize to determine the economic value of cover crop incorporation combined with livestock grazing.

The results from this analysis showed that short term incorporation of cover crop when amortized over long term analysis had an annual earnings $73.98/acre/year. The long term amortized benefits and total benefits were calculated at $20.47 acre per year and $90.88 acre per year, respectively. As a result, the total net benefits for the long-term was $44.08 per acre per year.
CHAPTER 1: INTRODUCTION

This study examines the economic benefits of including cover crop and livestock grazing in corn-soybean cropping systems in Midwest region of United States. Globally, the use of cover crops have been increasing in the hope of solving problems with erosion, leaching, water quality, weed control, and soil health in contemporary agriculture. Cover crop are crops grown mainly to control weeds, improve soil fertility, manage soil erosion, improve soil biodiversity, increase yield, improve soil physical and chemical properties, and reduce diseases and pests (Lauren, 2014). In addition to the earlier listed benefits, cover crops protect water quality by reducing the transport of nutrients pesticides, and sediment into water systems.

However, the percentage of farmer growing cover crops in the U.S. is very minute due to farmer’s perception that the cost of establishing cover crops outweigh the economic benefits of including these crops into their farming systems (Hoorman & James, 2009). Farmers also believe that planting cover crops have no immediate economic and harvestable benefits.

Cover crops such as winter rye, wheat, or triticale are typically planted in the fall into standing corn and soybean and they can be terminated either by mechanical (mowing, rolling) or chemical (herbicide) methods. In addition cover crops may also be grazed prior to planting of the subsequent cash crop (Margret, 2013), especially during drought years and winter months ensuring a steady supply of affordable feed for livestock farmers. Cover crops can increase pasture productivity and reduce dependence on harvested forage, thus increasing farm productivity (Margaret, 2013).
Grazing cover crops can effectively increase the pasture acreage on crop-livestock farming system. It also provides huge environmental benefits such as reduction of nonpoint source of pollution and sediment associated with runoff. Cover crops also take up excess nitrogen, reduce compaction and increase water infiltration which decreases leaching of nutrients (Margaret, 2013).

**Benefits of Cover Crops**

Cover crop can increase the farmer profit margin the first year they are planted by reducing herbicide input cost and increasing cash crop yield. Annual inclusion of cover crops in agronomic cropping systems can improve the bottom line even more over the years due to improved soil health benefits (Clark & Andy, 2008). Cover crops included in cropping system tend to enhance soil structure, improved soil fertility, reduce disease and improved environmental and water quality (NRCS/USDA, 2014).

One of the primary benefits of cover crops is to protect soil from water and wind erosion which are major cause of loss in soil mass and fertility (Dabney *et al.* 2001). When permeable soil is exposed to raindrops it can cause crust formation, which reduces water infiltration rate in soil, thus increasing runoff (Morin *et al.*, 2001). Cover crops aid in reducing crusting of the soil surface by increasing soil organic matter, especially when the soil moisture is low, which improves soil water infiltration and holding capacity (Fageria *et al.*, 2005). Plant cover also reduce rain fall impact by intercepting raindrops and reducing the velocity at which raindrops hit the soil. Thus, cover crops reduces splash erosion and (Hartwig, 1988). Cover crops are known to be effective in reducing nutrient loss from soils into rivers and streams (Franzluebbers 2007; Kaspar & Singer 2011); improving soil physical (Franzluebbers 2007; Franzluebbers and Steadman 2015) and chemical (Kaspar
& Singer 2011) properties; and reducing soil degradation and soil carbon loss (Kasper & Singer 2011).

Mixture of two or more cover crops sometimes are more effective than planting single species, because each crop from the mix can serve different purposes in regards to pest, and soil properties. In addition species react differently to weather condition (SARE, 2012). For instance a rye and wheat or barley mix can serve two roles; they trap surface water and add organic matter to increase infiltration to the crop root zone. Medic and Indianhead lentils are water efficient legumes that can provide cover crops benefits in dryland while conserving more moisture than normal bare fallow (Sims, 1993).

Cover crops provide habit for wildlife and increase biodiversity (Jill, 2015). Biodiversity brings flexibility to the soil health by enhancing a healthy interaction between organisms and plants and small animals forming a web of biological activity (Jill, 2015). Using cover crops enables farmers to influence the biological life in the soil and potentially improve crops function. For example, flax, corn and sunflowers depend on healthy mycorrhiza population; whereas canola and brassicas can develop without mycorrhiza associations. Knowing this, farmers can assist crop growth by promoting mycorrhiza population through crop rotation ensuring beneficial organisms are there to work with targeted crops.

Cover crops are good at scavenging excess nitrogen left in the soil after cash crop are harvested. For instance, rye in particular was estimated to uptake between 25-100 percent of residual N from conventional and no-till corn fields in Georgia (Jordan. et al., 1994). Similarly barley removed 64 percent of soil nitrogen in at the same location (Jordan, 1994). Graminae and brassicae families are excellent cover crops because they grow
rapidly and establish extensive root system up to depths of 80 to 150 cm (Frye et al., 1985; Sarrantonio, 1992; Weinert et al., 1995), accumulate large amounts of dry matter and uptake up to 68 lbs N ha\(^{-1}\) nitrogen (Wagger and Mengel, 1988; Bowen et al., 1991; Brinsfield and Staver, 1991; Hoyt and Mikkelsen, 1991; Shennan, 1992; Ditsch et al., 1993; Weinert et al., 1995).

**Uses of Cover Crops in the Midwest Compare to Other Region.**

The uses of cover crops have continued to gain attention across the States. Farmers and crop advisors propose the benefits of planting cash crops to cover or build soil, and many farmers are willing to invest their money and time to grow and manage planting cover crops between seasonal cash crops such as soybean and corn.

In the Midwestern regions of the U.S, corn and soybean cropping system with and without cover are uncommon thing. Cover crops are mostly use in vegetable systems but rarely integrated into crop rotational system like corn-soybean (Tom, 2008).

Due to recently adoption of no-tillage system in Northeast for instance in Pennsylvania and Maryland, cover crops are becoming integral part of crop system in the region; because cover crops can be manage better with no-till systems which are the major cropping system in the Northeast (Tom, 2008).

Although most of the Midwest soils contain higher levels of organic matter than other regions. (Kaspar, 2008), current specialized cropping systems in the Midwest (monoculture, short-term crop rotation,) can lead to soil degradation, soil erosion, nutrient leaching and environmental hazard (Franzluebbers 2007; de Paul 2012). Although the level of soil protection offered by cover crops following corn stover removal are not yet fully understood, the inclusion of cover crops in corn-soybean cropping systems can reduce
the rate of soil degradation associated with the monoculture crop management popular in this region.

Most of the cover crops growing in Northeast are rye, wheat, oat, crimson clover, brassica and ryegrass. The No-Till Farmer Alliance in Pennsylvania actively promote cover crops to improve soil quality, In Maryland, state government programs in 2006 provide subsidy of $30 to $50 per acre to establish cover crops which led to increase cover crops acreage, thus protecting nitrogen and phosphorus from reaching Maryland waterways.

In Southeast U.S, soil are highly acidic, weathered and susceptible to erosion because of low organic matter content. Therefore high residue cover crops e.g, hairy, wheat, oats, vetch and crimson clover are recommended for conservation system in this region. (Kipling, 2008).

Wind erosion occur frequently in Southern Great Plains, historically the “Dust bowl” area. Residue production in these dryland areas are generally low (Louis, 2008); thus farms in the Southern Great Plains could benefit from including cover crops in their cropping systems to reduce wind erosion and improve water conservation. (Louis, 2008).

The major factors affect the use of cover crops in Pacific Northwest are winter precipitation and limited availability of water (Hal, 2008). Soil from Pacific Northwest are developed from flood deposit and Aeolian materials originating from volcanic activity and the last continental glaciations (Hal, 2008).

Cover crops are grown in the Pacific Northwest region to increase crop residue, improve water infiltration, retention and storage, enhance soil structure, promote microbial activities and increase crop yield. Examples of cover crops species that are common in this
region are; field pea (Austrian winter pea, trapper spring pea), sweet clover, rye, and sorghum-Sudan grass (Hal Collins, 2008).

Adoption of cover cropping in California has been very limited. Comprising less than 5% of California’s annual crop acreage. In addition conservation tillage practices are used on less than 2% of annual cropland in California (Jeffrey, 2008). Most cover crop use in conservation tillage systems in California has been for processing and fresh market commercial tomato production systems (Herrero et al., 2001). Research is ongoing on evaluating cover crops in CT corn and cotton systems (Mitchell et al., 2005).

The major factor limiting the adoption of cover crops in the Midwest are lack of familiarity (species selection, management requirement) and general perception of farmers that cover crops are costly. That why this research is very important, because any science–based information about the positive potential return on the investment to cover crops will increase the level of adoption.

**Factors Affecting Adoption of Cover Crop by Farmers**

Despite the obvious benefits of cover crops, including the potential improvements in cash crop, and livestock productivity, increase in yield, the rate of adoption of cover crops by farmer is very low in many places (Mallory et al., 1998).

The adoption of cover crop in Missouri in general and Northwest Missouri in particular is limited due to misconception that including cover crop in management system increases overall cost of farm operations (Franzluebbers, 2007) due to additional management (Kasper & Singer, 2011), and delayed spring planting (Snapp et al., 2005). This misunderstanding stems from information gap on cover crop management techniques (personal communication with NRCS, 2015; Kaspar & Singer, 2011) and the uncertainty
of the economic benefits of cover crops. The fact that cover crops are not harvested as cash crops adds to the economic uncertainty since the soil health benefits of cover crop establishment are not immediate and are also complex to quantify.

Nowak (1992) argues that growers fail to adopt cover crops either because they are unwilling or unable to do so. Unwillingness usually arises from the refusal to adopt the cover cropping system practice due risk of negative financial outcome. “Unable” arises from expenses and costs involved in adopting cover crop that the farmer cannot afford to incur. Despite the fact that is lack of information regarding the performance of cover crops, and most other hindrances to the adoption in the United State are likely to be surmountable. There may be a rationale for public subsidies to support continues provision of socially beneficial externalities, if cover crops offer net benefits that extend beyond the farm gate. A survey carried out in the Corn Belt found that 18 percent of farmer had used cover crops but only 8 percent had used them in multiply years (Singer et al., 2007). The main reason given by farmers relates to perceived cost and risk attached to cover crop production.

Similarly, the 2013-2014 SARE/CTIC Cover crop survey conducted across U.S. revealed that the perception that cover crops are costly was the main factor hindering the adoption of cover crops. In the survey 88% of respondents identified cost as always a limitation to adaptation, while 12% said cost is not the limitation. Similar figures- 84% always, and 16% does not limit (Rob 2014).

The 2010 farm poll survey conducted by the Iowa State University Extension and Outreach, found many farmer in Iowa indicated climate-related factors are major hindering to the use of cover crops. In the same survey 61% identifying inadequate time between harvest and winter as a key limitation to the use of cover crops. The results from this survey
suggested that lack of knowledge and equipment were additional barrier to the use of cover crop (J. Gordon Arbuckle, Jr., and John Ferrell, 2012).

A survey from four Corn-Belt states on the adoption of cover crops in Western U.S. (Iowa, Indiana, Illinois, and Minnesota) revealed comparatively lower use of cover crops in the farming system, despite the presence of knowledge about the benefits of cover crops (Singer et al., 2007).

In this survey (Singer et al., 2007) did four logistic regression. One for each state, using variables like number of acre farmed, importance of crops or livestock to farm, use of conservation practices, the number of crops farmed, and the farmer’s receipt of incentives, to explain the adoption of cover crops. The outcome from the analysis showed the number of crops grown on a farm was a significant factor affection the adoption of cover crop for all the states except Iowa. The other factors hindering the adoption of cover crops were perceived insufficient yield advantage or soil quality improvement; High cost of cover crop establishment; no significant runoff problem on their farm, additional time involved in establishing, maintain, and terminating cover crops, already adapted no-tillage system, and lack of adequate information about the cover crops.

**Economic Benefits of Cover Crops.**

Farmers often assume that cover crops are too expensive and are used only by farmer who get government subsidy to plant them or who primary focus is on conservation. In reality, less than 9% of farmers who planted cover crop received incentive payment or some kind of subsidy from government, according to the 2014-2015 cover crop survey. The cost of using cover crop may include increase direct cost for planting and management, loss in crop income if cover crops negatively affect cash crop production,
slow soil warming and difficult in predicting nitrogen (N) mineralization (Snapp et al., 2005). Essentially, many producers are finding cover crops can help boost their economic bottom line. Corn and soybean farmers have received yield benefits ranging from 4 to 10 percent in soybean and 2 to 9 percent in corn, according to 4 years national cover crop surveys by SARE/CTIC in 2012-2015. The recorded highest yield increases after cover crops came in the drought of 2012, which proves their value for risk management.

Although, not all the field have a yield benefit, especially in the first year, over the long-term the benefit tend to accumulate. A producer who uses cover crops consistently for 3-4 years often observe improvement in soil health and increase in yield over time. Cover crops can also effectively improve the economic bottom line by eventually making reductions in some input costs, such as a decrease in N fertilizer rate or less in pesticide or herbicide application.

Because we can’t always predict immediate benefits for all cover crops, the farmer should focus on the long term economic benefits. It is obvious that including cover crops annually in the crop rotation especially in Fall will improve soil health for crop production over time due to addition of carbon and nitrogen to the soil, reduced pest pressure resulting from diversifying crop rotation, reduction in soil erosion, and stimulation of soil microbes (Clay et al., 2014). In addition increased soil organic matter content due to cover crops can increase the water available to plants and provide resilience against extreme climatic conditions.

Grazing of cover crops is another effective way for boosting farm profits due to the potential of cover crops to extend the grazing season. Cover crops, such as forage turnips, cereal rye, triticale, winter wheat and annual ryegrass are cool-season crops that can grow
late into the fall and be grazed in November and December. The cereal grasses will overwinter in Missouri and can also be used for early spring grazing at a time when other forage and hay might be in short supply. Rate of cattle weight gain on wheat, cereal rye and annual ryegrass can exceed a pound of gain per day if sufficient fall growth has been achieved before grazing begins.

The main economic benefits of using cover crops are potential yield benefit and reduced production cost (Jaenicke, Frechette, and Larson, 2003; Larson et al., 2001; Roberts et al., 1998). These benefits of cover crops are determined by how the cover crop is managed. For example, Morton, Bergtold, and Price (2006) observed that maximizing cover crop biomass production may be a vital management consideration in boosting the economic benefit of winter grain cover crops for the following cash crop. The benefit can be achieved in cash crop and soil productivity. Farmers will adopt and continue to use cover crops in their production systems if the perceived net benefit is feasible. An important component of the perceived net benefit is the anticipated yield gain. Although this component alone does not act as a proxy for the net benefits from adopting cover crops, it can provide a measure of the direct revenue gains from a gain in the proceeding cash crop’s yields, which can play an important role in farmers’ choices to use a cover crop or not. The perceived yield benefit of a cover crop will be affected by economic, demographic, and management factors.

**Problem Statement and Motivation**

Despite obvious benefits associated with the use of cover crop in cropping system, most farmers are still reluctant to include cover crops in their farming systems. Generally the limited acceptance of cover crops relate to inadequate information and lack of
understanding about factors (cost versus economic benefits) associated with cover crop adoption. Therefore providing information on the economic benefits of incorporating cover crop and livestock grazing of these cover crops in corn–soybean cropping system may influence farmers to reconsider cover crops as a beneficial farming practice In addition information on the economic impact of cover crop and grazing can assist extension, conservation officer and agronomist to design programs that will encourage the use of cover crop in the future.

Reviewing the previous literatures revealed that limited research have been done in examining economic benefits of incorporating cover crops and livestock grazing in corn-soybean cropping system, especially in the Midwest. Almost all of the previous research literatures related to cover crops has identified many benefits including erosion control, minimizing nitrogen leaching, yield increase etc., but most researchers have concluded that cover crops are not economically beneficial for producers (Mallory, 1998). This research is intended to close the knowledge gap regarding the economic viability of including a combination of cover crops and livestock grazing in corn-soybean rotation farming systems. It is our contention that if cover cropping system is implemented and manage successfully, it will has immediate economic value to the farmer. Such immediate value could come from incorporating livestock into crop production system (Gardner & Faulkner, 1991).

Therefore, we hypothesize that including cover crops and livestock grazing in farming systems will not only improve soil health, but also increase farm profitability.
Objectives

The overall objective of this project is to demonstrate, livestock production, and economic benefits of including cover crop and grazing in a corn – soybean cropping system in Missouri. The specific objectives include:

a. Analyze economic benefits of including cover crops in the management of agronomic cropping systems.

b. Determine the economic benefits of using cover crops for livestock grazing.
CHAPTER 2: LITERATURE REVIEW

Introduction

In this chapter, we review existing literatures on the use of cover crops and livestock grazing in enhancing cropping systems. The chapter is comprised of four sections; a discussion on the economic benefits of cover-crops; an outline of concerns associated with the use of cover crops; an economic analysis of cover crop use; and finally a review of the adoption of innovation in agriculture.

Economic Benefits of Cover crops

Cover crops are generally included in a cropping system as ground cover in order to protect soil from erosion (Dabney et al., 2001) as well as for nutrient management (Fageria et al., 2005). There is an extensive range of literature discussing the agronomic importance of cover crops. For example Gardner and Faulkner (2009) noted increased interest from contemporary agriculturists on the potential of cover crops to offset and/or mitigate agronomic problems encountered on the farm. In their discussions Gardner and Faulkner (2009) listed among the advantages of cover crops reduction in erosion between monocultures, improving soil tilts, increased water infiltration rate, increased water holding capacity, and improved nutrient retention and cycling.

Sarrantonio and Gallandt (2003) in their work focused on the impact of cover crops on weed management, pest management, and yield improvement of subsequent crops. Similarly, Horman (2009) stated that cover crops protect water quality by reducing losses of nutrients, pesticides, and sediment form surrounding landscapes. Horman (2009) however observed that only a small percentage of farmers actually plant cover crops due
to farmers believe that the challenges of establishing cover crops outweigh the benefits gained from their use.

From the definition of cover crop, one of the purposes of using cover crops is for the soil protection. Erosion washes away the top soil layer, which contains a large proportion of soil organic matter and soil nutrients needed to achieve good crop yield (Fageria et al., 2005). Therefore, soil erosion can negatively impact soil profitability. When rain falls on fallow land, a seal or crust is formed on the soil surface which reduces water infiltration and increases runoff, thereby increasing the chances of soil erosion (Louw et al., 1991). It is practically impossible to prevent the contact of rain droplets with soil, however, vegetative cover can prevent crust formation on soil and reduce erosion. For example cover crops by preventing raindrops from directly striking the soil surface can reduce detachment, crusting, and erosion (Sarrantonio et al., 2003).

In addition, leaves and stems of cover crops slow the rate of water flow across the soil surface and the roots of the cover crop plants also hold soil particles together forming strong aggregates, thus reducing water erosion of the topsoil. Good water infiltration and reduction in runoff from rainfall significantly reduces soil erosion (Fageria et al., 2005). Studies involving conventionally tilled soybean conducted in Western Kentucky on a silt loam soil, fields planted to cover crops averaged an 88% reduction in soil erosion when compared to compare fields without cover crop (Langdale et al., 1991).

Another study showed that conservation-tilled cover crops reduced soil erosion 47% on a Providence silt loam soil in Mississippi when compare to fields on the same soil without cover crops (Langdale et al., 1991).
The choice of cover crops depends on the desired outcomes (e.g. controlling soil erosion, controlling pests, and increasing profit), the soil type, climatic conditions, and the crop preceding and following the cover crop. (Sarrantonio et al., 2003) concluded that cereal rye has potential to do well throughout the colder areas of North America as a winter annual cover crop for erosion protection because of its capacity to germinate and grow quickly in cool weather and its deep and fibrous root system. Soil erosion is controlled by cover crops because of the increasing soil organic matter in the soil which improves soil water infiltration and water holding capacity. Both cover crops and conservation tillage increase soil organic matter compared to conventional tillage without cover crops, but when combined, both practices of cover cropping and conservation tillage provide the best result (Frye et al., 1993).

The breakdown of plant residues by soil microorganisms produces compounds that are resistant to decomposition like gums and resins. These compounds help soil particles stick together and form granules. Granulated soil has greater soil permeability and aeration, and better water holding capacity, so that seeds germinate quicker and root growth is easier (Clark, 2007; Hartwig et al., 2002).

(Keisling et al., 1994) conducted cover crops experiments for 17 years on fine silty soil in Arkansas using hairy vetch, elbon rye, and crimson clover as their cover crops. A key deductions from the experiment by Keisling et al.,(1994) was that cover crops increased organic matter. Soils with high organic matter content generally have good water infiltration, less incidents of soil crusting, better ability to ameliorate and degrade herbicides, and better soil tilth. An increase in porosity was also observed by using cover crop (Keisling et al., 1994). Nutrient benefits associated with cover crops such as
conversion of atmospheric nitrogen to plant available N by legumes in association with rhizobium bacteria, and the uptake and retention of residual soil N from previous crops may justify the extra cost associated with the use of cover crops (Clark, 2007).

Proper growth of cover crops, good soil nutrient level, soil pH balance, adequate soil moisture, and proper nodulation are some of the factors that help cover crops to capture available nitrogen in soil and atmosphere (Sullivan, 2003). Dabney et al. (2001) noted that release of N from cover crops depended on species and growth stage of the crop and climatic condition, among other factors. Rapid mineralization of nitrogen by cover crops was advantageous in certain situations where crop nitrogen demand was high for early growth. On the other hand, slower release of nitrogen was beneficial for crops, like cotton, that have a relatively longer growing season and peak nitrogen demand occurs after mid-bloom. Hence, Dabney et al., (2001) emphasized the importance of synchronization of cover crop nitrogen release with the demand by the following crop.

Finally, they concluded that legume/grain bi-culture was a better combination compared to legume monocultures as the combination can scavenge more soil and atmospheric nitrogen from both soil and atmosphere. To observe the amount of nitrogen provided by different cover crops in soil, Ebelhar et al., (1984) conducted field experiments from 1977 through 1981 in Kentucky. They found that hairy vetch as a winter cover crop provided a significant amount of N regardless of applied N fertilizer rates.

Doran et al. (1991) showed that legume winter cover crops commonly accumulate from 60 to 150 lb/acre of nitrogen in the Eastern and Southeastern United States as compared to 30 to 40 lb/acre of nitrogen in the drier, cooler climates of the Corn-Belt area. (Daniel et al., 1999) conducted a study in Virginia on sandy loam soil from 1995 to 1997.
The cover crop treatments were crimson clover, hairy vetch, hairy vetch with rye, rye, wheat, and 11 white lupin. The cover crop providing the best cover also produced highest biomass. Results of the study showed that, on average, rye produced more biomass (2,721 lb/acre) than any other cover crop treatment.

The study also found out that cover crop biomass production was not affected by tillage treatment. Pathak and Diaz-Perez (2007) conducted a field experiment in Southwestern Georgia with a basic winter cover crop (rye, crimson clover, subterranean clover, or cahaba vetch) followed by summer cash crops (cotton, peanuts). They found that insecticides and herbicides were rarely necessary after the third or fourth year of a rotation. No-till plots with cover crops and long rotations had few problems with pests like thrips, aphids, bollworm, and budworm. In some instances, research plots were insecticide free for 6 to 12 years afterwards Pathak and Diaz-Perez (2007) claimed. Cover crops in conjunction with crop rotations increased the economic viability of producing vegetables like cucumbers, squash, peppers, eggplant, and cabbage, or row crops like peanuts, soybean, and cotton with only one or two applications of insecticides (Pathak and Diaz-Perez, 2007).

In addition to reducing the need for external inputs like fertilizers and pesticides, Pathak et al. (1991) showed that cover crops like blue lupin, vantage vetch, lentil, and crimson clover result in higher yields of marketable cucumbers when compared to no cover crop. Another study by Rothrock et al., (1991) demonstrated that, when planted as a winter cover crop, hairy vetch with or without rye increased cotton yields compared to cotton without a cover crop.
Concerns over the use of Cover Crops

Concerns that nutrients from farming are negatively impacting water quality have increased interest in cover crops in Illinois. For example, the Illinois Nitrogen Loss Reduction Strategy developed by a working group formed by the Illinois Water Resource Center-Illinois Indiana Sea Grant, the Illinois Environmental Protection Agency, and the Illinois Department of Agriculture, has established a goal of reducing nitrate loading in waters by 15% by 2025. Cover crops can scavenge non-organic nitrogen from soils, tying nitrogen up in the cover crop, thereby reducing the chances that those nitrates enter water bodies (Schnitkey et al., 2016).

Cover crops need proper management to prove beneficial to the cropping system. Proper management includes selecting the most suited cover crop according to the land, climate, and soil condition; planting cover crops in the fallow land or in between cash crops to protect soil and improve soil health; and timely termination of cover crops to avoid negatively impacting ensuing cash crop. Improper management of cover crops can negate the benefits of cover crops. Peet (1996) indicated that, excessive cover crop residues might interfere with the cash crop by producing unwanted allelopathic chemicals. Water use by cover crops and the cash crops is also one of the major challenges associated with using cover crops, because soil moisture maybe lower throughout the growing season when used some cover crops (Gardner et al., 1991).

Thelen (2004) observed that, where precipitation was insufficient inclusion of a rye cover crop reduced the yield of the cash crop, most likely due to competition for water. Ebelhar et al., (1984) showed that soil moisture was significantly less under hairy vetch compared to corn residue. They also concluded that careful timing of planting cover crops,
killing them, and planting corn was very important to prevent yield reduction of corn that might have caused by water used by cover crops. This might be because both corn and legumes require soil moisture for seed germination.

To avoid excessive winter-kill, legumes must become established before the severe winter weather and must be allowed to grow as late as is practical in the spring to provide maximum N. At the same time, attention must be given to the corn growing time to prevent corn yield reduction due to late planting. Tollenaar et al., (1993) show that corn growth and development was reduced when corn was preceded by a winter rye cover crop. After two years of field research, they concluded that cover crops can reduce the yield of the cash crop by reducing N uptake due to immobilization of N fertilizer in soil.

The result of Tollenaar et al., (1993), along with results from other studies and previous researchers strongly, suggested allelopathic effects of cereal cover crops on corn. Bruce et al. (1991) states that benefits from cover crops may not show over short time frames of one or two years. Nonetheless, he states that, in the long run, both economic and environmental benefits of cover crop are undeniable.

**Economic Analysis of Cover Crop Use**

A study done by Schlaapfer et al., (2001) examined the economic importance of biotic control in limiting nitrate leaching and conserving soil resources in agricultural ecosystems. The study concluded that extended use of cover crops may be highly desirable, assuming that groundwater contamination from nitrate leaching has high social cost. If the cost of planting mixtures of cover crop species is not prohibitively high, then increasing the functional diversity of cover crop species may also be cost-effective, although the optimal combination is yet to be found.
Hanson et al., (1993) studied the profitability of a hairy vetch system with no-till corn in comparison with winter wheat and winter fallow systems with no-till corn at two locations (Piedmont and Coastal Plain) in Maryland. A 3-year field study was conducted from 1986 to 1988 and four different nitrogen (N) fertilizer rates were applied for specific cover crops at each location at university recommended rates. The results of the study showed that, in both Piedmont and Coastal Plain soils, average no-till corn yield following hairy vetch was significantly higher than corn following winter fallow or winter wheat at comparable N rates. Among all combinations of N rates and cover crops, the highest corn yield in the Coastal Plain was after hairy vetch with 120lb N/acre; and in the Piedmont it was after hairy vetch with 40lb N/acre.

In the Coastal Plain, the yield advantages of corn following hairy vetch appear to more than compensate for the expense of establishing hairy vetch, but this was not the case in the Piedmont. Even the least profitable N rate for corn following hairy vetch (0lb N/acre) in the Coastal Plain was more profitable than the next best alternative, i.e., corn following winter fallow at 120lb N/acre. In both the locations, hairy vetch did not reduce profit maximizing N use, but increased the effectiveness of N. Thus, hairy vetch was more accurately a yield enhancer for no-till corn rather than an N substitute.

Hanson et al. (1993) also performed sensitivity analysis of the results with changes in the prices of hairy vetch seed, fertilizer, and herbicides. The result suggested that seed prices were unlikely to make the hairy vetch system economically unattractive. It also showed that, in both locations, the most profitable hairy vetch system would still be profitable even if N fertilizer were free. Finally, it showed that the hairy vetch system was
still profitable, even after including the extra cost for the additional herbicide application. Mallory et al., (1998) concluded that for cover crops, seed cost constituted almost three quarters of the total cost of using cover crops. A few other concerns regarding cover crop use were the possible need of extra machinery and labor. Most of these studies do not account for any long-term benefits, which is why most research related to cover crops concludes that cover crops are not economical.

**Adoption of Innovation in Agriculture**

Diffusion of innovation is the method by which an innovation is conversed through certain channels over time among the people of a social system (Roger, 2002, p.11). This underscores the fact that the four elements involved in the diffusion of innovation are: innovations, communication channels, time and the social system which will be discussed hereafter. Rogers (2002) defined innovation as any idea, practice or object that is either new, has never been applied, or has not yet been adopted or rejected. Technology is a tool to help achieve the expected results of the innovation. Technology adoption is as old as human history.

It was hypothesized that the process started from gaining knowledge about fire and using it for cooking or learning about plants and selecting edible, usable ones out of all the available plants. Primitive levels of technology and its adoption from the very early stage have now been studied in a systematic manner (Rogers, 2002). Research on the diffusion of innovations started during 1940s and 1950s in various disciplines outside agriculture such as technology adoption in the manufacturing industry (Bartolini et al., 2001). All innovations are not desirable to all the individuals in a social system. Some innovations, for example a mechanical tomato picker, may be desirable to one group of a social system,
like larger commercial tomato producers, while it may be harmful to the other potential adopters, such as small-scaled tomato producers. Most small-scaled tomato producers went out of business because a mechanical tomato picker was very expensive for them, given the size of their operations.

The rate of diffusion of an innovation differs from one innovation to another. The major characteristics of innovations that account for different rates of adoption are: relative advantage, compatibility, complexity and observability of the innovation compared to the existing knowledge. Another element of diffusion of innovation is communication channel. A communication channel is a means through which new ideas get from one individual or group to another. Mass media channels like radio, television, and newspaper are regarded as the most rapid means of informing others about the new idea. Interpersonal channel, on the other hand, is person to person communication of ideas between two or more individuals.

The interpersonal channel is more effective in persuading others to accept new ideas. Individuals generally do not evaluate innovations on the basis of results of scientific studies, but rather how effective it is for the first individuals who adopt. Basically, for most individuals, the decision of adopting a new innovation depends on the evaluation of the innovation by other individuals in similar conditions to theirs. A third element in the diffusion process is time. The “time” factor indicates the rate of adoption or the time an individual takes between knowing about an innovation for the first time to a point of adopting or rejecting it. Sometimes, the measurement of time gets criticized in research studies. The element, time, can be involved in a number of ways in the diffusion process, such as innovation-decision process, innovativeness and adopters category (e.g. innovator,
early adopter, late adopter, non-adopter), and rate of adoption. The fourth element in the diffusion of innovations is the social system. Social system is an interrelated group of individuals working on solving a common goal. Any individual, group, or organization could be considered a social system engaged to solve a common problem to reach a mutual goal. Innovation occurs within a social system and that innovation is either diffusing or is expected to diffuse within that social system.

Innovation-decision process is a five stage process through which an individual passes the first knowledge of an innovation, to the formation of an attitude towards that innovation, to a decision to adopt or reject the innovation, to implementation of the innovation, to the confirmation of that innovation. The first stage is called “knowledge” which is gained when someone learns about innovation and how it works. For example, use of cover crops; the first knowledge of what cover crops are and how to use cover crops in the cropping system can be considered as the first stage. The second stage is “persuasion”. This happens when a person forms a favorable or unfavorable attitude toward the technological innovation. In the example, when a person or a group starts to form an opinion about the usefulness of cover crops, this is the persuasion stage. The third stage is the “decision” stage when a person either adopts or rejects the innovation. When a person or a group decides to either use or not to use cover crops in their cropping system; this is the decision stage. The fourth stage is the “implementation” stage of the innovation, which is when an individual uses the innovation. The first time a farmer uses cover crops in the field shows implementation of an innovation. In some cases, during implementation, a user changes or modifies the innovation and that is called re-invention of the innovation. Not all innovations are re-invented.
The fifth stage is the “confirmation” of the innovation, which occurs when an individual rechecks the results of an innovation and approves it by continuing to use it. In this example, the farmer evaluates the results of using cover crops, considers the benefits and detriments provided by cover crops, determines it was worth using, and continues to incorporate cover crops into the cropping system. (Rogers, 2002). The rate of technology adoption can also be understood by studying why producers are rejecting the technology: either they are unable, or unwilling, or both (Nowak, 1992). Being unable to adopt new technology may be because of the lack of information, complexity of the system, limited availability of supporting recourses, excessive labor requirement, and so on. Unwillingness to adopt new technology could be due to conflicting information, poor applicability of the technology, the technology being inappropriate in their current system, chances of negative outcomes from using the technology, and so on (Nowak, 1992).

As in other fields, many researchers have been studying technology adoption and its consequences to agriculture. There are a number of studies done in different areas of agriculture to study the rate of technology adoption, to see effects of various technologies in the existing agricultural system, and to see the factors affecting the adoption rate of technology. Rahelizatovo and Gillespie (2004) investigated the economic and non-economic determinant factors of producers’ decisions to adopt twenty-one different best management practices (BMPs) by Louisiana dairy producers. Kim et al., (2006) analyzed the adoption of the use of Russian 18 varroa-resistant honey bees to deal with a parasitic mite (varroa), which is a very significant problem for beekeepers. Gillespie et al., (2004) focused on four different types of breeding technologies: weekly farrowing, intensive breeding, terminal crossbreeding, and artificial insemination in the U.S. hog production.
Each of these breeding technologies differs from one another in the capital investment and managerial skills requirement. Apart from these, the literature shows numerous studies based on technology adoption in crops, some of which are discussed below.

Griliches (1957) provided one of the seminal studies in the field of technology adoption. The study focused on different factors related to the use of hybrid corn in various parts of the United States. The study divided the logistic growth curves for the adoption of hybrid corn in each region into three parts: the origins, the slopes, and the ceilings, and examined each part separately. Griliches (1957) defines the origin as the development of hybrid corn varieties for a particular area (usually by a seed producing firm), slope as the rate of adoption of the hybrid corn varieties in the area, and ceiling as the equilibrium use of the varieties in the area.

The difference in development of hybrid corn varieties for different areas (the origins) was explained on the basis of how much the seed companies could profit by producing hybrid corn seeds for those areas. The results implied that development of hybrid corn varieties for a particular area depends upon the expected pay-off for the seed companies. If the seed companies perceive that producing hybrid corn varieties for that area is profitable for them, they will do so. The differences in rate of adoption (slope) and equilibrium use (ceiling) between various regions was explained by the profitability to farmers of shifting from non-hybrid to hybrid corn. It was found that the rate of adoption depended chiefly on the ‘profitability’ measures, i.e., average corn acreage per farm, average difference between yields from hybrid and open pollinated varieties, and the pre-hybrid yield. It was also found that the rate of adoption may also be affected by advertising carried on by private seed companies and outreach efforts by extension agents. In terms of
the ceiling (equilibrium use), it was found that the ‘profitability’ measures (i.e., average corn acres per farm and pre-hybrid yield, and capital per farm) had significant effects on the long run equilibrium use of hybrid corn. Griliches (1957) also concluded that in the long run, and cross-sectional, sociological variables, like income, education, standard of living, among others, tended not to have significant effects, leaving the economic variables as the major determinants of the adoption of technological change.

Frisvold et al., (2009) studied the frequency of use of ten best management practices by corn, cotton, and soybean producers to control weeds. Count data analysis was done to explain the total number of BMPs frequently practiced and ordered-probit regression was carried out to explain the frequency of individual weed-resistance BMP adoption. The result from the count data analysis indicated that the number of BMPs adopted increased with the education level of the producers. It also showed that producers who expected to have yields greater than the county average tended to adopt more BMPs. The number of BMPs adopted to control weed resistance was lower in areas reporting more resistance problems and in counties with variable yields.

The result of ordered-probit regressions showed less frequent use of multiple herbicides with different modes of action by soybean producers. It also showed that producers who expect yields higher than the county average were more likely to use multiple herbicides with different modes of action while producers in counties with greater yield variability less frequently used it. Overall, the study showed that cotton growers adopted BMPs more frequently compared to others. For all three crops, adoption of BMPs like cleaning equipment, using multiple herbicides with different modes of action, and
supplemental tillage, were low. The remaining seven BMPs were practiced frequently by all three crop producers i.e. corn, cotton and soybean producers.

Zilberman (1985) analyzed the factors affecting the adoption of alternative irrigation technologies by perennial crop growers in the San Joaquin Valley of California. The analysis shows the short-run estimates based on current behavioral patterns. Two equations were estimated using the maximum-likelihood estimation procedure, the first to estimate the odds of adopting sprinkler technology versus traditional technology and the second to estimate the odds of adopting drip technology versus traditional technology. They found that the farmers who used groundwater were more likely to adopt sprinkler and drip technologies than the farmers who used surface water. Also, the adoption of modern irrigation technologies depended on the types of crops grown.

Finally, the study shows that proper use of water-price policies can induce the use of modern irrigation technologies. Olive tree groves in mountainous regions are subject to a high risk of soil erosion and Calatrava-Leyva et al., (2005) examined factors that influenced adoption of soil conservation practices and the current level of adoption of such practices on olive tree farms in mountainous regions in Spain. For the analysis, three multivariate probit models using maximum likelihood estimation with three different soil conservation practices, namely tillage following contour lines, maintenance of terraces with stonewalls, and no-tillage with herbicides were used.

In general, the decision of farmers adopting soil conservation practices was governed by various circumstances like the cost of adopting conservation practices, farmers’ risk attitude, their perception of soil erosion, level of non-farm income, continuation of farming in the family, labor and machinery availability, and farm income.
The results of the study indicated that if the farmer was an early adopter of technological innovations, used local extension services, was younger than 60, had inherited the farm, and planned everything in advance, the probability of adoption of tillage following contour lines would increase. On the other hand, if the farmer used accounting only for tax purposes and not for managerial purposes, did not know about the existence of erosion agricultural-environmental schemes, and got technical information from professional organizations, the probability of adopting conservation practices would decrease.

Similarly for the case of farms maintaining stonewalls, the probability would increase if the farmer used his own machinery and did not rent it, and used accounting for taxation purposes only. The probability would decrease if farm profitability was lower and if it had relied on EU subsidies. The probability of farmers adopting no-tillage with herbicides would increase if the farmer had relied only on family labor, and had used accounting only for taxation. The probability would decrease if the farmer was older than 60.

Bultena et al., (1983) also compared some personal, attitudinal, and farm characteristics of farmers who adopted conservation tillage with those still practicing conventional tillage. The moldboard plow was very popular for seedbed preparation until the mid-1970s. After that, conservation tillage began to replace the moldboard plow system. The moldboard plow was criticized for wasting energy, reducing soil fertility, and contributing to soil erosion and the related problems of air and water pollution. Incorporating conservation tillage into one’s farming system required different management skills. Positive results of conservation tillage were slowly realized, so some producers had doubts about the positive outcomes and, furthermore, they had to change
various systems in their fields to incorporate a conservation tillage system. Researchers used analysis of variance and cross-tabulation to compare the three categories of adopters of conservation tillage. The results showed that the adopters of conservation tillage were younger, better educated, had larger farms, farms with greater potential for erosion, earned higher incomes, and were less risk-averse compared to non-adopters. The result also showed that adoption was implemented by producers who perceived widespread adoption of that technology in their community and the surroundings.

**Cover Crops as Technology Adoption**

Cover crop inclusion in the farming system is one of the various technologies whose adoption has been examined. In northern Honduras, with continuous development in agriculture systems, velvet bean (mucuna) was planted as part of the corn rotation. This boosted the corn yield along with biomass production, reduced labor use and the need for expensive fertilizers and herbicides compared to traditional corn system. The corn-mucuna system has therefore generated widespread interest in Honduras because it diffused rapidly and spontaneously among farmers with little or no intervention. In spite of this popularity, after a few years, the survey showed a sudden decline in the number of farmers adopting and continuing the corn-mucuna system.

Neill and Lee (1999) studied this and found four major factors that were affecting the adoption and abandonment of this technology: family and demographic attributes of the farm household like age or education; the physical characteristics of the farm, like soil, slope and farm size; economic factors such as input and output prices; and institutional factors, such as the land tenure regime and the availability of extension and information services. The survey results showed that three-quarters of the farmers who owned land
adopted the corn-mucuna system and later almost similar percentages of farmers abandoned it. It was found that, unexpectedly, the age of head of household and visitation by an extension agent were non-significant. According to the survey, the major reasons given for abandonment were problems with Rottboellia or other grasses, and reclamation of the plot by the landlord. The empirical results showed that the practice of annual reseeding of mucuna positively influenced adoption. On the other hand, the proportion of land sown to corn, cultivation of a high-value crop, farmers having problems with weeds and farmer having problems with rottboellia, had significant and negative influence on the continuation of the rotation.

The insignificance of the number of cattle owned by a farmer with corn-mucuna abandonment was surprising. In the case of corn-mucuna rotation abandonment, changes in variables like tenure security, shifting land markets, and the rise of extensive cattle were not statistically significant. As was seen, abandoners did not make more profit than adopters; a disutility associated with corn production in the steep hills of Honduras was thought to be the only reason.

Singer et al., (2007) used survey data from four Corn-Belt states: Illinois, Indiana, Iowa, and Minnesota, to study the use of cover crops in the central western U.S. Corn-Belt. They state that anecdotal evidence showed comparatively lower use of cover crops in the farming system, despite the presence of a wealth of knowledge about their benefits. Thus, this study was carried out to quantify the use of cover crops in the U.S. Corn-Belt and to identify the factors associated with their adoption. Singer et al., (2007) carried out four logistic regressions, one for each state, each trying to explain the adoption of cover crops with the help of variables like number of acres farmed, the number of crops farmed,
importance of crops or livestock, use of conservation practices, and the farmer’s receipt of incentives. The results of their analysis showed that the number of crops grown on a farm was a significant factor affecting cover crop use for all states except Iowa. Also, perceived yield advantage or soil quality improvement on the part of the producers had a positive effect on the adoption of cover crops. Producers quoted many reasons for not using cover crops, some of which included: too much time involved, too costly, no runoff problem, already using no-tillage practices, and lack of enough knowledge about cover crops. The producers also noted soil erosion, crop diversity, and adding soil organic matter as the most important reasons for using cover crops. Information on the cost of using cover crops was listed as an important factor. The study also observed that cost sharing could increase the use of cover crops among Corn-Belt farmers.

According to (Pannell et al., 2006), Adoption is a continual process, through which producers can evaluate the performance of adopted technologies, and modifying practice usage to suit their soil types and cropping systems. Farmers’ perceived performance of the economic benefits of cover crops can incentivize them to promote further adoption and help other farmers in their social networks (Pannell et al., 2006). Additionally, with the information provided in this study we estimate it will help farmers to gain more insight about the use of cover crops; most especially the economics benefits of including cover crops in corn-soybean cropping system and livestock grazing.
CHAPTER 3: METHODOLOGY

The cover crop economic tool designed by NRSC was used to assess affordability and profitability (economics analysis and financial analysis) of incorporating cover crops and livestock into soybean and corn rotation cropping systems. The cover crop economic tool is partial budgeting tool focuses on changes, in costs and benefits realized by the producer and on the benefits that can be easily monetized from the cropping system (Cartwright & Kirwan, 2014).

Cover Crop Economic Tool

This cover crop economic tool is partial budgeting tool based in a Microsoft excel spreadsheet. This tool only measures resources that will be changed, and estimating how the change increase or decrease income in the farm business. Therefore, the cover crop economic tool (CCET) provides producer a simple economic and financial evaluation that does not require any in-depth crop budget analysis. It also helps producers, and landowner to make decisions based on cost and benefits when considering incorporating cover crops to their cash crop rotation system.

The farm operations related to cover crop establishment and production is divided into two categories with this tool; cost and benefits. The cost categories includes; seed cost, planting cost, termination cost and management cost. The benefits categories include; direct nutrient credits benefits, such as reduction in fertilizer and chemical input and application; increased yield; and improved moisture retention and availability to the cash crop. Reductions in herbicide/insecticide/fungicide use occurs when cover crops outcompeting weeds for water and nutrient and reduce sunlight to the soil surface and
retard weed seed germination. Other soil benefits incorporated in the analysis relate to reduction in water runoff and soil erosion; and improve in water infiltration and retention (Natural Resources Conservation Service 2015).

Additionally, the tool provides both short-term and long-term costs and benefits analysis of including cover crops in cropping system. Economic benefits of cover crops increase significantly as the length of time of the cover crop use increases. Thus, CCET can enhance the producer ability to commit to using cover crops as a short-term and long-term conservation solution in their farm. When considering the short-term of including cover crops to operation, which is typically less than 10 years, the immediate benefits (like yield increase, input reduction, soil erosion control and grazing,) are mainly small depending on the type of crop, soil type and the producer management system. In long-term, over 10 years, economic benefits such as improved soil health and water storage benefit are to be more pronounced.
Model Parameters

The data used in this research was obtained from different sources of research on economic benefits of cover crops (meta-analysis). The main data used for the analysis was gathered from research carried out by USDA/NRSC to model cover crops partial budget analysis tool. So data obtained from NRCS cover crops economic decision support tool and other cover crops research (Ralph & Tom 2013, farmdocD. 2016, Lauren 2016) sources were used during the study period to obtain the overall costs and benefits of incorporating cover crops and livestock into the corn/soybean rotation system.
The data collected include cost of establishment and management of cover crops, direct nutrient credit, yield increase of corn and soybean based on type of cover crop used, erosion reduction, cow calf grazing benefit, grazing infrastructural cost, herbicides/insecticides/fungicides input reduction, over soil fertility benefit and water storage benefit.

The cash crops used in the study are corn and soybean, and the cover crops used in between soybean/corn rotation are cereal rye and hairy vetch (Table 1).

**Table 1. Cover Crops Species and Cash Crops used in Cropping System**

<table>
<thead>
<tr>
<th>Cover Crops Species</th>
<th>Seeding Rate (lb./acre)</th>
<th>Cash Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal rye</td>
<td>40</td>
<td>Soybean</td>
</tr>
<tr>
<td>Hairy vetch</td>
<td>15</td>
<td>Corn</td>
</tr>
</tbody>
</table>

Cereal rye and hairy vetch cover crops were used in this project because they are the most suited cover crops in the Midwest region (Clark, 2007). Rye as a non-legume grass it has great potential benefits for both soil health and livestock. Cereal rye is a good soil builder, top soil looser, nitrogen scavenger and suppressor of weeds due to its allopatic’s attributes. Cereal rye has also to found to inhibit insect infestation (Bugg, R. L., et al., 1990) and encourages increase of beneficial insect’s population such as lady beetle (Wingard, C. 1996). Additionally, cereal rye can also be considered for additional feed tonnage or grazing in cash crops rotational system with minimum effort (Ohio State University, 2013).

Hairy vetch as a leguminous cover crop fixes nitrogen and replenish the soil nitrogen for the following cash crop, corn. This nitrogen can partially replace nitrogen.
fertilizer for corn and increase nitrogen efficiency for higher corn yield (Sustainable Agricultural Research and Education, SARE, 2015). Hairy vetches are also good for livestock because they withstand trampling, provide forage during May and June and have good feeding value slightly closer to that of clover and alfalfa (Kaminski et al., 1990)
CHAPTER 4: RESULTS AND DISCUSSION

Short Term Potential Benefits

Direct nutrient credit- these are expected benefits or credits that producer will receive from the cash crops (soybean and corn) they plant after the cover crop. Nutrient credits usually reduces the cost of fertilizer, that producer would normally apply to his field. Legume cover crops are generally manage to supply nitrogen credit. For instance, hairy vetch is high in nitrogen, releases about half of the nitrogen because the vetch has more nitrogen than needed to “build up” soil organic matter (Andrews and Sullivan, 2010.)

Yield increases: cover crops provide yield increase by solving the yield limiting problem like N availability and soil compaction so that the growth of your subsequent cash crop can improve. Current research shows yield increases happen more often in soybeans than corn, especially in the short-term (Natural Resources Conservation Service 2015).

Herbicide/Insecticide/Fungicide Input Reductions: the mulching effect of cover crops residues reduces weeds growth, and subsurface microbial activities may result in reduced herbicides, insecticides and fungicide input.

Erosion reduction: cover crops serve as conservation tool by reducing soil fertility loss per ton to erosion, especially on-site erosion. According to recent research, U.S. has lost 30 percent of its topsoil to erosion in the last 200 years due to agricultural practices that leave soil bare, follow soil for most of the year (Tyler et al., 1994).

Grazing: most reliable way to benefit from incorporating cover crops in corn-soybean cropping system is by using cover crops for grazing livestock that are already part
of farming operation. So producer can integrating gazing and crop production to boost his or her production, thus increase farm income.

**Short Term Analysis Results**

From our analysis using cereal rye and hairy vetch cover crops for the overall economic benefits of corn/soybean rotation cropping system. We found that fall/spring grazing potential of the cover crop is highly dependent on proper management, timing of cover crop establishment, and good weather condition. The forage produced from cover crop to feed livestock was estimated to reduce feeding expenses by $33.20 and by $15.20 ($60-$26.80 is $33.20 and $42-26.80 is $15.20) respectively in years one and two of the rotation system (Tables 2 &3). Thus, livestock utilizing cover crops provide economic benefits both on the short and long-term scales (Table 3.)

Cereal rye add little or no direct nutrient credit to the soil, while hairy vetch added about 30lb N/acre to 40lb N/acre plant available nitrogen to the soil. In this study we assumed hairy vetch total nutrient benefits of $16.50/acre, based on nitrogen purchased reduction of 30lb N/acre (Natural Resources Conservation Service, 2015). Never-the-less cereal rye is known to its significant in fertility management based on its uptake of residual nutrient left over from the preceding crop (SARE, 2015). Rye have ability to prevent leaching and drainage losses of nitrate in corn/soybean rotation system by taking up 57lb.N/acre and convert it into immobile plant protein and thus sequester residual soil nitrogen within the soil nitrogen cycle (Brinsfield and Staver,1991; Staver and Brinsfield, 1998) (Kaspar et al., 2008).
Table 2. **Planting and Grazing Cereal Rye before Soybean in Short Term**

<table>
<thead>
<tr>
<th>Additional Costs :</th>
<th>Additional Revenue due to change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover crop seed ($/acre)-</td>
<td>Herbicides reduction ($/acre):</td>
</tr>
<tr>
<td>Cereal rye 40lb. /acre * $0.25/lb.</td>
<td>$20/acre reduced by 15%</td>
</tr>
<tr>
<td>Cover crop planting</td>
<td>Yield increase ($/acre)</td>
</tr>
<tr>
<td>$20</td>
<td></td>
</tr>
<tr>
<td>Termination ($/acre)</td>
<td>$50 bu/acre *2% increase @$10/bu</td>
</tr>
<tr>
<td>$10</td>
<td></td>
</tr>
<tr>
<td><strong>Grazing infrastructure :</strong></td>
<td>Erosion reduction ($/acre)-</td>
</tr>
<tr>
<td>Fence ($/acre)</td>
<td>$28.12</td>
</tr>
<tr>
<td>$3.3</td>
<td></td>
</tr>
<tr>
<td>Watering facilities ($/acre)</td>
<td>Grazing benefits</td>
</tr>
<tr>
<td>$7.50</td>
<td>$60</td>
</tr>
<tr>
<td>Added labor/management ($/acre)</td>
<td></td>
</tr>
<tr>
<td>$16.00</td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure cost subtotal</strong></td>
<td><strong>Subtotal</strong></td>
</tr>
<tr>
<td>$26.80</td>
<td>$101.12</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>$66.8</strong></td>
</tr>
</tbody>
</table>

**Net change in Benefits: $101.12 - $66.8 = $34.32**

**Note:** All cost listed reflects cost per acre of each operation. Subtotal cost (soybean) is the cost per acre to establish cereal rye in a field to be planted to soybean the spring following the cover crop establishment. Assuming a possibility in any given year of a 2% yield reduction due to a drought period. Soybeans at 45bu/acre x $10/bu x 2%=$10.00/acre/yr.
Table 3. Planting and Grazing Hairy Vetch before Corn in Short Term

<table>
<thead>
<tr>
<th>Additional Costs</th>
<th>Additional Revenue due to change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover crop seed ($/acre)</td>
<td>Herbicide reduction ($/acre)</td>
</tr>
<tr>
<td>Hairy vetch, 15lb./acre * $2.16/lb.</td>
<td>$30/acre reduced by 10%</td>
</tr>
<tr>
<td>$20</td>
<td>$3</td>
</tr>
<tr>
<td>$10</td>
<td>Yield increase ($/acre);</td>
</tr>
<tr>
<td>Termination cost ($/acre)</td>
<td>$150bu/ac*1.4% @ $5/bu</td>
</tr>
<tr>
<td>$16.00</td>
<td>$10.50</td>
</tr>
<tr>
<td>Infrastructure cost subtotal</td>
<td>Erosion reduction ($/acre)</td>
</tr>
<tr>
<td>Fence ($/acre)</td>
<td>$28.12</td>
</tr>
<tr>
<td>$3.30</td>
<td>Grazing benefits</td>
</tr>
<tr>
<td>Watering facilities ($/acre)</td>
<td>$42</td>
</tr>
<tr>
<td>$7.50</td>
<td>Nitrogen nutrient credit ($/acre)</td>
</tr>
<tr>
<td>Added labor/management ($/acre)</td>
<td>$30(lb/acre) * $0.55/lb.</td>
</tr>
<tr>
<td>$16.00</td>
<td>$16.5</td>
</tr>
<tr>
<td>Subtotal</td>
<td>Subtotal</td>
</tr>
<tr>
<td>$26.80</td>
<td>$100.12</td>
</tr>
</tbody>
</table>

Net Change in Benefits: $100.50 - $89.20 = $10.92

Note: All cost listed reflects cost per acre of each operation. Subtotal cost (corn) related to the cost of establishing.
The herbicides/insecticides/fungicides input reduction can be directly or indirectly. So we assume the use of cereal rye and hair vetch will reduced herbicide use by 15 percent and 10 percent respectively (NRSC’s ECCT, 2015).

The use of cover crops provide soil conservation benefits such as erosion reduction which can be estimated using two different variables; off-site water quality benefits and loss of fertility (NRSC, 2015). The USDA natural resources conservation service study estimates the cost to the producer in lost fertilizer value to be $2.10 per ton of soil loss and off-site water quality benefits of sediment not getting in water system value to be $4.93 per ton of soil (USDA/NRSC, 2010). The study assumed that 4ton/acre will be prevented from leaving the field by the addition of cover crops. So the total value of erosion reduction is $28.12/acre (USDA/NRSC, 2010)

Rye and hairy vetch (annul legume) in soybean–corn rotation suppress weed germination on no-till cropping system. When cereal rye residue covers more than 90% of soil it reduced total weed density by 78 % (Teasdale et al., 1991), and by 99% (University of California, SAREP Cover Crops Resource Page). The differences in weed density pressure among the two studies might be related to added parameters used in the studies.

When there is improvement reduction in soil compaction, combined with increase N and moisture availability due to the used of cover crop in a farm cropping system, growth of the next cash crop will also improve (Cartwright & Kirwan, 2014). In this analysis we found that soybean yield increase was higher than corn yield when grown following a cover crop. Soybean yield was estimated to increase by 2 percent, and corn yield was estimated to increase by 1.4 percent during the first two years of the rotation (NRSC/USAD 2015)
Grazing Benefits of Cover Crops

Grazing cover crops with livestock can provide economic benefits to farm operations in the short term and long term. However, establishing and grazing cover crops requires some economic inputs; these include grazing infrastructure costs such as fencing, watering facilities, and labor and management costs. Ralph & Olsen, (2013) estimate cost for portable temporary grazing fence to be $3.30/acre/year, water facilities cost $7.50/acre/year and added labor/management cost $16/acre/year; giving an estimated total grazing cost of $26.80/acre/year for each rotation. The total grazing cost in short term $53.6/acre (2 x $26.80) for corn/soybean rotation and the total grazing benefits in short term is $102/acre. So the grazing net benefits is short term is ($102 – $53.60) $48.40/acre

The overall immediate total costs and benefits of incorporate cereal rye and hairy vetch, cover crops, and livestock grazing in soybean/corn rotation system for each year per acre in short term (2 years) are $34.32 and $10.92, respectively, resulting in rotational net benefits per acre per year of $45.24 (Table 5).

Hairy vetch in the fall prior to planting corn in the following spring. Assuming a possibility in any given year of a 1.4% yield reduction due to a drought period. Corn at 150bu/acre x $5/bu x 1.4%=$10.00/acre/year.

Table 4. Short Term Analysis

<table>
<thead>
<tr>
<th>Cover Crops</th>
<th>Benefits ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal rye  Cover Crop before Soybean net benefit</td>
<td>$34.32</td>
</tr>
<tr>
<td>Hairy Vetch before Corn net benefit</td>
<td>$10.92</td>
</tr>
<tr>
<td>Rotational Net Benefit</td>
<td>$45.24</td>
</tr>
</tbody>
</table>
Long-Term Potential Benefits

Continued utilization of cover crops may lead to more economics benefits. The benefits that could be realized in long-term include:

**Improved Water Storage and Infiltration capacity:** when the soil organic matter increases, the soil ability to store water also increase. Thus, increase in water store ability will reduce the irrigation costs for irrigated land, or curb yield reduction due to drought stress in a dry land system. Using this tool we assume that for every 1 percent increase in soil organic matter the soil holds an additional 1 acre inch of water per week (Natural Resources Conservation Service 2015).

**Overall soil capacity improvement:** when including cover crops in corn-soybean rotation cover crops have ability to significantly improve chemical, physical and biological properties of the soil. This ability depends on the intrinsic condition of the soil and tillage practices of producer over the years. This soil improvement by cover crops may result to increase in some of soil nutrients; nitrogen, phosphorous and potassium, in plants (Natural Resources Conservation Service 2015).

Long Term Analysis Results

Long term analysis of implementing cover crop grazing in the farming system was based on the assumption that if the producer continues to utilize cover crops in his crop rotation and livestock production system for a period of 10 to 50 years. For this study, we conducted our analysis using 25 years for the long term projection (NRCS, 2015). Which means that, the producer will include cover crops into his production system for the next
25 years. In the long term analysis we used financial principle to estimate the present value of net benefits. According to default values of NRSC partial budgeting economic of cover crops tool, in the long term, we assumed that it will take 10 year to increase the soil organic matter by 1 percent and provide plant available N, P, K, Sulfur, and Carbon by cover crops.

There are two economic benefits categories that are exclusive to the long term analysis; over all soil fertility and water storage benefits. The values of this two categories depend on the maximum potential of the soil, the length of the analysis and estimated year to increase soil organic matter by 1 percent. The short term and amortized over long term analysis lifespan is $73.98 (show on Table 7.) The long term amortized benefits and total benefits are $20.47 acre per year and $90.88 acre per year, respectively. As a result, the total net benefits is $44.08 per year per acre.
Figure 2. This graph shows long term soil fertility and water storage benefits.

*The amortize soil fertility and water storage benefits are $12.27 and $8.20 acre per year, respectively.

Table 5. Long Term Amortized Benefits

<table>
<thead>
<tr>
<th>Long Term Benefits</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Fertility ($/ac/yr)</td>
<td>$12.27</td>
</tr>
<tr>
<td>Water Storage ($/ac/yr)</td>
<td>$8.20</td>
</tr>
<tr>
<td>Long Term Benefit($/ac/yr)</td>
<td>$20.47</td>
</tr>
</tbody>
</table>
Table 6. Short Term Benefits Analysis Amortized Over the Long Term Analysis Lifespan

<table>
<thead>
<tr>
<th>Short Term Benefits</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct nutrients credit ($/ac/yr)</td>
<td>$7.91</td>
</tr>
<tr>
<td>Herbicides /insecticides/fungicides input reduction ($/ac/yr)</td>
<td>$3.01</td>
</tr>
<tr>
<td>Yield increase ($/ac/yr)</td>
<td>$10.26</td>
</tr>
<tr>
<td>Erosion reduction ($/ac/yr)</td>
<td>$28.17</td>
</tr>
<tr>
<td>Grazing ($/ac/yr)</td>
<td>$24.63</td>
</tr>
<tr>
<td><strong>Total Short Term benefit ($/ac/yr)</strong></td>
<td><strong>$73.98</strong></td>
</tr>
</tbody>
</table>

Economic Analysis Results

The positive net benefits value ($44.08/acre/year) from the economic analysis in this study showed the profitability of management change is over the 25 years lifespan of this analysis (Table 7).

Table 7. 25 Years Economic Analysis results summary

<table>
<thead>
<tr>
<th>Summary</th>
<th>Values in dollar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short term benefits ($/ac/yr)</td>
<td>$73.97</td>
</tr>
<tr>
<td>Long Term benefits ($/ac/yr)</td>
<td>$20.92</td>
</tr>
<tr>
<td>Total cost ($/ac/yr)</td>
<td>$50.80</td>
</tr>
<tr>
<td>Total benefits ($/ac/yr)</td>
<td>$90.88</td>
</tr>
<tr>
<td><strong>Net benefits ($/ac/yr)</strong></td>
<td>**$44.08 * **</td>
</tr>
</tbody>
</table>

Note: * Net benefits is $90.88 - $50.80 = $44.08
Financial Analysis Results

The positive net benefits values we get from this financial analysis (table 8), even from first year over to the next 25 years, show that the producer can afford change in management system of this enterprise by including cover crops and livestock grazing in to his/her farm operation.

Table 8. Financial Analysis Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Costs ($/acre)</th>
<th>Benefits ($/acre)</th>
<th>Net benefits ($/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$40.00</td>
<td>$74.32</td>
<td>$34.32</td>
</tr>
<tr>
<td>2</td>
<td>$62.40</td>
<td>$73.32</td>
<td>$10.92</td>
</tr>
<tr>
<td>3</td>
<td>$62.40</td>
<td>$74.32</td>
<td>$34.32</td>
</tr>
<tr>
<td>4</td>
<td>$40.00</td>
<td>$73.32</td>
<td>$10.92</td>
</tr>
<tr>
<td>5</td>
<td>$62.40</td>
<td>$74.32</td>
<td>$34.32</td>
</tr>
<tr>
<td>6</td>
<td>$40.00</td>
<td>$73.32</td>
<td>$10.92</td>
</tr>
<tr>
<td>7</td>
<td>$62.40</td>
<td>$74.32</td>
<td>$34.32</td>
</tr>
<tr>
<td>8</td>
<td>$40.00</td>
<td>$73.32</td>
<td>$10.92</td>
</tr>
<tr>
<td>9</td>
<td>$62.40</td>
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<td>$40.00</td>
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</tr>
<tr>
<td>11</td>
<td>$62.40</td>
<td>$106.22</td>
<td>$62.22</td>
</tr>
<tr>
<td>12</td>
<td>$40.00</td>
<td>$105.22</td>
<td>$42.82</td>
</tr>
<tr>
<td>13</td>
<td>$62.40</td>
<td>$106.22</td>
<td>$62.22</td>
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<td>14</td>
<td>$40.00</td>
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</tr>
<tr>
<td>15</td>
<td>$62.40</td>
<td>$106.22</td>
<td>$62.22</td>
</tr>
<tr>
<td>16</td>
<td>$40.00</td>
<td>$105.22</td>
<td>$42.82</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>---</td>
<td>-----</td>
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</tr>
<tr>
<td>17</td>
<td>$62.40</td>
<td>$106.22</td>
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<td>18</td>
<td>$40.00</td>
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<td>$105.22</td>
<td>$42.82</td>
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<tr>
<td>21</td>
<td>$62.40</td>
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<td>22</td>
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<td>$62.40</td>
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</tr>
<tr>
<td>24</td>
<td>$40.00</td>
<td>$137.12</td>
<td>$74.72</td>
</tr>
<tr>
<td>25</td>
<td>$62.40</td>
<td>$138.12</td>
<td>$98.12</td>
</tr>
</tbody>
</table>
Financial Analysis Net Benefits Graph

The positive slope of financial analysis shows that as farmer continue using cover crop in his operation for long term, he will experience improvement on the soil health of his farm, and the net benefits will increase the profit of his farm operation over the years.

Figure 3. Financial Analysis Net Benefits Graph
CHAPTER 5: SUMMARY AND CONCLUSION

This chapter presents a synopsis of the findings in this study. Relevant conclusions derived from the analysis of results conducted, and recommendations are discussed in this chapter.

SUMMARY

The importance of cover crops in cropping systems cannot be overemphasized. As discussed throughout this project cover crops serve as ground cover protecting the soil from erosion, thereby enhancing soil quality, improving soil water quality, suppressing weed growth, conserving soil nutrients, and boosting crop yield. In this study we examined the economic benefits of including cover crops in corn-soybean cropping system in the Northwest Missouri region of the United States of America. A key benefit identified in this study is the economic benefits associated with a reduction in input cost such as nitrogen fertilizer and pesticide application. Other economic benefits of cover crop are increased soil organic matter and soil water, improved soil and plant resilience against extreme climatic conditions. Finally, the use of cover crops has often resulted in increased yield benefits and reduced production risks.

Reports from research indicate that a mixture of two or more cover crops are sometimes more effective in improving soil health than planting single species. For instance, a combination of rye and barley out-performed individually planted species in trapping surface water sediments and soil organic matter to the soil, enabling an increased uptake of water and soil nutrients by the economic crops. A model designed by NRCS was used in the comparison of the cover crop types planted in different regions of the United
States. Information in the literature suggest that rye, red clover, hairy vetch and sweet clovers are mostly planted in the Midwestern states. Wheat, oat, crimson clover, brassica and ryegrass are the commonly grown cover crops in the Northeast part of the U.S. In the Southeastern USA, field pea, sweet clover, rye and sorghum-Sudan grass are the dominant cover crops planted. The major factor influencing geographic distribution of cover crops was differences in soil types across the regions.

In spite of the aforementioned benefits of cover crops, the rate of adoption among farmers is still relatively low. Factors identified as preventing farmers from introducing cover crops in their farm operations included the misconceptions of farmers, especially those in Northwest Missouri that cover cropping increases farm operational costs and did not provide a net return on investment. Other factors include: lack of adequate information on cover cropping techniques, adoption of zero tillage system at the expense of cover cropping, and timeliness involved in planting cover crops.

The objectives of this study were to perform a benefit-cost analysis of including cover crops in the management of agronomic cropping systems as well as to determine the benefit-cost ratio of using cover crops for livestock grazing. Data used in this research were extracted from different sources including various publications on economic benefits of cover crops, which employ a meta-analysis. However, the main data employed in the analysis was gathered from cover crops economic decision support tool (Ralph & Tom, 2013; Lauren, 2016) as well as other research conducted by USDA/NRSC. From these sources were extracted data on cost of establishment and management of cover crops, direct nutrient credit, yield increase of corn and soybean base on type of cover crop used, erosion reduction, cow calf grazing benefit, grazing infrastructural cost, herbicides
insecticides/fungicides input reduction, over soil fertility benefit and water storage benefits. The cash crops use in the study were corn and soybean while cereal rye and hairy vetch were the cover crops used in between soybean/corn rotation.

The Cover Crop Economic Tool (CCET) was employed in analyzing the data collected. CCET provides producers with a simple economic and financial evaluation devoid of any in-depth crop budgeting technique. The analytical tool is built on the simple technique of cost and benefits analysis.

CONCLUSION

Results of analysis revealed that in the short-run, the most reliable way for farm producers to benefit from incorporating cover crops into corn-soybean cropping system is by using cover crops for livestock grazing. Integrating livestock grazing and crop production therefore help boost cash crop production, thus increasing farm income. In the long run, continual use of cover crops in corn-soybean rotation has the ability to significantly improve chemical, physical and biological properties of the soil. This ability however depends on the intrinsic condition of the soil and tillage practices of producer over the years. Similarly, soil organic matter also increases due to long-term use of cover crops, thus improving the ability of the soil to store. This increase in water storage ability will consequently reduce irrigation costs for irrigated land and also curb yield reduction due to drought stress in a dry land system.

A cost-benefit analysis of incorporating cereal rye and hairy vetch cover crops in corn-soybean rotation cropping system showed that cereal rye add little or no direct nutrient credit to the soil, while hairy vetch added an average of 35lb Nitrogen per acre to the soil.
However, other benefits associated with the inclusion of cereal rye were provision of considerable dry matter, an extensive soil-holding root system, reduction of nitrate leaching and weed suppression.

The forage provided from cover crop to feed livestock reduces feeding expenses by $33.20 and by $15.20 ($60-$26.80 is $33.20 and $42-26.80 is $15.20) respectively in years one and two of the short-term rotation system.

In addition, a total of $45.24/acre per year was obtained as total net benefit of incorporating cereal rye and hairy vetch cover crops in corn-soybean cropping system in the short run while in the long run, total net on a long term benefits is $44.08/acre per year (see Table 7). It is worthy of mentioning that for the purpose of this study, short term is defined as a period of time below two years while long term is defined as 25 years as adopted from NRCS (2015). From the economic analysis, the positive value of $44.08/acre per year obtained as long term net benefit is an indication that the management practice of incorporating cereal rye and hairy vetch as cover crops into corn-soybean system is profitable in the long run.

**Policy Recommendation**

Based on inference drawn from the study, the following recommendations are made for policy actions:

Cereal rye and hairy vetch are essential cover crops and should therefore be incorporated into cropping systems for more economic benefits.

Hairy vetch supplies more nutrient to the soil than cereal rye; it is therefore suggested that farmers in Midwest region should use more of hairy vetch in order to increase soil nutrient.
Cover crops especially, cereal rye and hairy vetch are profitable in the long run and should therefore be included in cropping systems.

**Research Limitations**

One of the major bottlenecks often encountered in research of this nature is non-availability of data. Consequently, this study was not an exception as relevant data which could have made the analysis more robust were not readily available. For example, information on the amount of cover crops as well as the environmental costs incurred by individual farmers could not be directly accessed. This therefore posed a major constraint to the type of methodology plausible for this study. Consequently, meta-analysis was adopted.

**Suggestions for further research**

It has been shown in this study that most of the economic benefits of cover crops are realized in the long run. It is therefore rational that studies like this be conducted over a period of time, employing primary data in order to capture the time variations in the economic benefits.


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The University of Missouri Extension Weed Science program's slideshow: The Effects of Herbicide Carryover on Cover Crops is available at http://weedscience.missouri.edu/extension/pdf/cover_cROP_cARRYOVER_slideshow.pdf.


Univ. of Calif. SAREP Cover Crops Resource Page. www.sarep.ucdavis.edu/ccrop


