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# Development and application of quantitative methods for ecosystem services

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Date



DEVELOPMENT AND APPLICATION OF QUANTITATIVE METHODS FOR  
ECOSYSTEM SERVICES

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Rebecca A. Logsdon

In Partial Fulfillment of the

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of

Doctor of Philosophy

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West Lafayette, Indiana

To Mike, Gus, Skeezi, Mikey, and PC.

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## LIST OF ABBREVIATIONS

AMALGAM .....	Multi ALgorithm Genetically Adaptive Method
ESS.....	Ecosystem Services
ERI .....	Erosion Regulation Index
FPI.....	Food Provision Index
FRI .....	Flood Regulation Index
FWPI.....	Freshwater Provision Index
HUC .....	Hydrologic Unit Code
MEA.....	Millennium Ecosystem Assessment
MRB.....	Mississippi River Basin
NASS .....	National Agricultural Statistics Service
SWAT .....	Soil and Water Assessment Tool
UMRB.....	Upper Mississippi River Basin
USGS .....	United States Geological Survey
UWRB.....	Upper Wabash River Basin
WQFS .....	Water Quality Field Station

## ABSTRACT

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Ecosystem services are benefits that people receive from the environment.

Despite recent exponential increases in ecosystem service research, the ecosystem service framework has made little impact on policy and land management decisions, especially in the United States. Two of the main limitations for a lack of ecosystem service considerations in both policy and land management decisions are a need for more advanced quantification methods and the lack of engagement of key stakeholders who are responsible for making land management decisions. This research seeks to address these two limitations by testing and improving quantification methods of ecosystem services and by evaluating agricultural managers' understanding and perceptions of ecosystem services. The main objectives of this research were to (1) test an existing ecosystem service evaluation method in the Upper Mississippi River Basin under current conditions and future climate change, (2) improve understanding of influences of aquatic genetic resource provisioning using the SWAT model, (3) improve quantification methods for climate regulation ecosystem services using the DayCent model; and (4) evaluate Indiana agricultural producers' and

conservationists' perceptions of ecosystem services in order to identify the best ways to improve inclusion of the ecosystem service considerations in making agricultural management decisions. For the first objective, previously developed quantification methods for freshwater provision, food provision, erosion regulation, and flood regulation were applied to a large 2-digit HUC watershed in the U.S. (the Upper Mississippi River Basin). The results show that these methods were able to capture tradeoffs between existing ecosystem services, specifically freshwater provision and food provision, in this watershed. Climate change and variability may have considerable impact on ecosystem services in this river basin. For the second objective of this research a Soil and Water Assessment Tool (SWAT) model was developed to evaluate the possible drivers of an observed change in fish regime the Wabash River that occurred around the 1990's. The results indicated that changing agricultural practices combined with increasing precipitation may have influenced the observed fish regime change. This link between agricultural management decisions and an historical fish regime change in the Wabash River can improve understanding of the link between management decisions and aquatic genetic resource provisioning. The third objective of this research applied a multi-objective genetic algorithm optimization tool (AMALGAM) to improve the performance of the DayCent model and then proposed a quantification method for climate regulation using DayCent. Although the DayCent calibration method was able to improve the performance of the model at the calibration plots for both yield and N<sub>2</sub>O flux, the N<sub>2</sub>O flux simulation of the validation plots were not improved due to the influence of two plots with high N<sub>2</sub>O emissions. This work suggests that although a multi-objective function can be used to calibrate DayCent, the method may work best within a treatment,

even if the plots are all at the same location. The climate regulation index that was developed under Objective 3 was able to capture the ability of a local, terrestrial ecosystem to regulate climate. For the last objective, surveys were conducted of Indiana farmers and conservationists, and interviews were held with Indiana farmers. The results indicated that Indiana farmers and conservationists understand ecosystem services, even if they do not use the terminology. It also shows that the existing conservation framework can be utilized to implement ecosystem service based management. By understanding the perceptions of these key stakeholders, the ecosystem service framework can be better implemented in developing management and policy strategies.



## 1 INTRODUCTION

### 1.1 Overview

Almost half of the world's terrestrial landscape is used for agriculture (Foley et al. 2005). Agricultural ecosystems provide more food than natural ecosystems, but usually at the expense of important services, such as maintaining biodiversity, water quality, and erosion control (Tilman et al. 2002; Rodriguez et al. 2006). Although these trade-offs may sustain human life in the short-term, it has been argued that the long-term effects of conventional agriculture can be unsustainable (Euliss et al. 2010). In order to develop more diversified agricultural systems that can provide more benefits to people (ecosystem services [MEA 2005]), a better understanding of the tradeoffs between ecosystem services is needed (Tscharntke et al. 2005; Swinton et al. 2007; Carpenter et al. 2009).

The Millennium Ecosystem Assessment (MEA) was commissioned by the United Nations in 2001 (completed in 2005), in order to assess the links between human health and well-being and the environment. The Millennium Ecosystem Assessment Report of 2005 documented a framework for understanding ecosystem services and strategies to quantify, assess, and restore them (MEA 2005). The MEA classifies ecosystem services into four broad categories: (1) provisioning – products derived from ecosystems such as food, fuel, and water; (2) regulating – services that help to create and maintain an environment suitable for human life, such as flood regulation and climate regulation; (3)

cultural – services specific to the human enjoyment and experience of nature, such as recreation, spirituality, and aesthetics; (4) supporting – services that support the other three categories but are not a direct service to people, such as nutrient cycling and soil formation (MEA 2005). Although alternative classification methods have been proposed (de Groot et al. 2002; Boyd and Banzhaf 2007; Fisher and Turner 2008), the MEA framework and definitions are the most commonly used. Despite the amount of research that has been completed on ecosystem services since the release of the MEA, ecosystem services still are not incorporated into many policy and management decisions (Seppelt et al. 2011). One reason for this is the lack of available quantification methods (Logsdon and Chaubey 2013; Portman 2013).

Included in the MEA synthesis reports is a chapter devoted entirely to describing the need for and possible approaches to developing analytical methods to assess ecosystem services (DeFries et al. 2005). Process-based models are specifically listed as an approach that can fill data gaps needed to evaluate ecosystem services, to quantify ecosystem service response to changes in management or other future scenarios, to assess species' status in the future under varying conditions, and, lastly, to understand the relationship between social drivers and the environment (DeFries et al. 2005). By utilizing process-based models to evaluate ecosystem services, the trade-offs between ecosystem services can be quantified and estimated under changing climate, land management, land use, and policy scenarios. Many studies have been published which aim to quantify ecosystem services using process-based models (Bekele and Nicklow 2005; Schroter et al. 2005; Sanchirico and Mumby 2009; Willarts et al. 2012) or land-use/proxy-based methods (Hein et al. 2006; Li et al. 2007; Egoh et al. 2008; Chen et al.

2009; Krishnaswamy et al. 2009; Raudsepp-Hearne et al. 2010; Lautenback et al. 2011; Frank et al. 2012; Goldstein et al. 2012; Koschke et al. 2012). Proxy based methods based on land use can be unreliable and lead to incorrect assessments (Eigenbrod et al. 2010). Of the existing ecosystem service assessments derived from process-based models, few have presented frameworks or methods to actually evaluate *final ecosystem services*; instead, they evaluate single indicators of ecosystem services, e.g., changes in stream nitrate or sediment, or changes in greenhouse gas emissions. The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model is one widely applied example of a model that estimates ecosystem service values, not just ecosystem health indicators (Daily et al. 2009; Tallis and Polasky 2009). However, the current version of InVEST has separate modeling components that estimate ecosystem services individually, so interactions and tradeoffs among services are not modeled. Some of its modeling components also rely on land use look-up tables, rather than process-based methods, which can lead to generalized assessments that may not be able to capture changes in specific ecosystem functions.

Logsdon and Chaubey (2013) developed mathematical representations of five final ecosystem services: freshwater provision, food provision, fuel provision, flood regulation, and erosion regulation. They then applied the methods in a watershed under three land use scenarios using the Soil and Water Assessment Tool (SWAT) to generate inputs for the ecosystem service calculations. Although this method is a step in the right direction towards utilizing existing process-based models to assess ecosystem services, not just functions, the methods do not quantify the full suite of ecosystem services and have not been tested in other watersheds. To incorporate ecosystem services in

management and policy scenarios, more quantification methods are needed so that scenarios can be evaluated for their impact on ecosystem services (Bennett et al. 2009; Caron-Lormier et al. 2009; de Groot et al. 2010; Power et al. 2010).

Another way to improve the adoption of the ecosystem service framework is to identify and engage key stakeholders in the process (Cowling et al. 2008). In the U.S., over 60% of the land is owned privately, and the majority of that land is agricultural (USDA-ERS, 2006). Engaging the agricultural producers in policy and management discussion to improve ecosystem services will be necessary. Existing conservation strategies and frameworks which have been shown to be effective at improving agricultural land management can be utilized to implement ecosystem-service based policy and management strategies (Carpenter et al. 2009).

The overall goal of this research was to contribute to the expansion of using process-based models and field data to evaluate ecosystem services (Objectives 1-3), and to evaluate the potential application of the ecosystem service framework in agricultural settings (Objective 4). The specific objectives were to:

- 1) Evaluate methods developed in Logsdon and Chaubey (2013) in the Upper Mississippi River Basin.
- 2) Evaluate possible environmental drivers of an historical fish regime change in the Wabash River using SWAT in order to examine the relationship between ecosystem functions and freshwater aquatic genetic resource provisioning.
- 3) Apply a multi-objective genetic algorithm optimization tool to improve the DayCent model to aid in the quantification of climate regulation ecosystem services.

- 4) Evaluate Indiana agricultural producer and conservationist understanding of ecosystem services to improve the adoption of the ecosystem service framework.

The specific hypotheses guiding this research, which match the aforementioned objectives, are:

- (1) Integrating physical process and statistical models, along with field data can improve the quantification of provisioning and regulatory ecosystem services, specifically helping to evaluate the impact of land use, land management, and climate change on ecosystem services.
- (2) Agricultural producers are a key stakeholder for the improvement and restoration of ecosystem services in the U.S., and understanding their perceptions of ecosystem services can help to engage them on discussions of ecosystem service-based management.

## 2 THE FUTURE OF ECOSYSTEM SERVICES IN THE UPPER MISSISSIPPI RIVER BASIN

### 2.1 Abstract

Ecosystem services provide people with products required for survival, as well as an inhabitable environment. Ecosystem services are inherently interdependent, therefore managing them requires an understanding of the trade-offs among them. By evaluating multiple ecosystem services simultaneously, we can improve strategies and programs to address environmental problems. The Upper Mississippi River Basin (UMRB) is a significant agricultural production area as well as a key contributor to the Gulf of Mexico hypoxia problem. The objectives for this research were to (1) evaluate current ecosystem services (specifically, freshwater provisioning, food provisioning, erosion regulation, and flood regulation) in the UMRB, and (2) assess trade-offs in ecosystem services under varying climate change uncertainty using Coupled Model Intercomparison Project Phase 5 (CMIP5) projected climate data simulated using the EC-EARTH RCA4 model. The Soil and Water Assessment Tool (SWAT) was used to model baseline and future ecosystem service provision. Currently, the UMRB is a good provider of food, while the freshwater provisioning is diminished due to the poor quality of the water. Under climate change all four ecosystem services may decrease. Drivers of these changes are increased annual precipitation and average temperatures. Specifically, food provisioning may decrease due to increased nutrient stress, assuming land management is held constant.

Understanding the potential impact of climate change on ecosystem service provisioning can help to improve land management strategies to improve ecosystem services.

## 2.2 Introduction

Agricultural ecosystems (agroecosystems) cover almost half of the world's terrestrial landscape (Foley et al. 2005; Smith et al. 2007). Compared to natural ecosystems, agroecosystems provide a different trade-off in ecosystem services (Rodriguez et al. 2006). Generally, most conversions from unmanaged ecosystems to managed agroecosystems cause the reduction of many regulatory ecosystem services in favor of food provisioning (Foley et al. 2005; Rodriguez et al. 2006). Evaluating ecosystem services under various land use/management and climate change scenarios is a necessary step to developing management and policy strategies which can sustain multiple ecosystem services, not just one (Bennett et al. 2009; Power 2010).

In the United States, one of the greatest challenges facing agriculture is the trade-off between freshwater provisioning and food provisioning. The most well-known example of this trade-off is the hypoxia in the Gulf of Mexico which has been linked to agricultural fertilizer applications in the Corn Belt region of the U.S. (Burkhart and James 1999; Rabalais et al. 1999; Scavia et al. 2004; Alexander et al. 2008). Fertilizers are applied by agricultural managers to maintain/increase crop productivity, but a large amount of these fertilizers leave agricultural fields via surface and subsurface pathways into nearby streams and ditches. Offsite losses of nutrients, specifically nitrogen and phosphorus, increase concentrations and loads in the receiving water bodies, and lead to hypoxia, loss of habitat, increased turbidity and decreased biodiversity (Diaz 2000; Rabalais et al. 2002). Such losses are also a monetary loss to the agricultural producers.

Multiple strategies have been proposed to decrease nutrients entering waterways throughout the entire Mississippi River Basin (MRB). These strategies include on and off-site management of agricultural drainage, as well as urban point source control, and restoration of wetlands and riparian buffers (Mitsch et al. 2001). Although urban sources do contribute nutrient inputs throughout the MRB, they are estimated to only contribute 9-12 percent of nitrogen and phosphorus delivered to the Gulf of Mexico, whereas agricultural sources have been estimated to contribute 70 percent (EPA, 2014). Therefore a lot of focus has been on both on and offsite agricultural management practices. On-site agricultural strategies include conservation tillage, nutrient planning, grassed water ways, and other in-field best management practices designed to prevent nutrients from leaving the field, or decrease the nutrients applied (Rabotyagov et al. 2010). Off-site agricultural strategies may include increasing wetlands and riparian zones (Mitsch et al. 2001).

The UMRB has been shown to be the primary contributor of nitrogen to the Gulf of Mexico (Burkhar and James 1999; David et al. 2010), therefore, it makes a study site for evaluating trade-offs in ecosystem services. Many Soil Water Assessment Tool (SWAT) models have been developed to examine hydrology, water quality, and biomass (crops and biofuels) in the UMRB. Srinivasan et al. (2010) developed a SWAT model to predict hydrology and crop yield. Secchi et al. (2011) evaluated water quality changes in the UMRB due to expansion of corn croplands, while White et al. (2014) evaluated nutrient loadings under cropland conservation scenarios. Jha et al. (2006) & (2013) and Panagopoulos et al. (2013) have even examined UMRB water quality and hydrology under the impacts of climate change. However, no studies have examined ecosystem services, rather than the ecosystem functions, provided in the UMRB under changing



climate regimes. The objective of this research was to evaluate potential changes in ecosystem services in the UMRB under a climate change scenario, in order to examine the trade-offs that may occur between ecosystem services, specifically food provision and freshwater provision.

## 2.3 Methods

### 2.3.1 Study Site

The study site for this research was the Upper Mississippi River Basin (UMRB); an approximately 490,000 km<sup>2</sup> 2-digit HUC watershed sprawled out across 8 Midwestern states (Figure 2.1). This large basin has over 60 percent of its land in cropland or pasture, and makes up a large portion of the Corn Belt Eco-region which is known for its high agricultural productivity (Guanter et al. 2014). This basin is a known contributor to the Gulf of Mexico hypoxia problems (Burkhar and James 1999; David et al. 2010), due to the large agricultural fertilizer inputs that have led to a tripling of nitrate levels in the Mississippi River since the 1950s (Donner and Kucharik, 2003). Although the benefits of the extra fertilizer applied in the UMRB are easily recognized in agricultural commodities (the five major states in the UMRB produced over 48% of corn and 44% of soybeans in the U.S. in 2012 [USDA-NASS 2013]), the loss of other ecosystem services, such as freshwater provision and biodiversity, may not be fully understood or realized. The hypoxic zone is only one consequence of excess nutrients in the UMRB. Over 15 million people directly utilize waters in the UMRB for a drinking water source, and the rivers of the UMRB also support commercial navigation, recreation, and commercial fisheries (Weitzell et al. 2003). Due to its economic and environmental importance, the UMRB was chosen as the study area for this research.

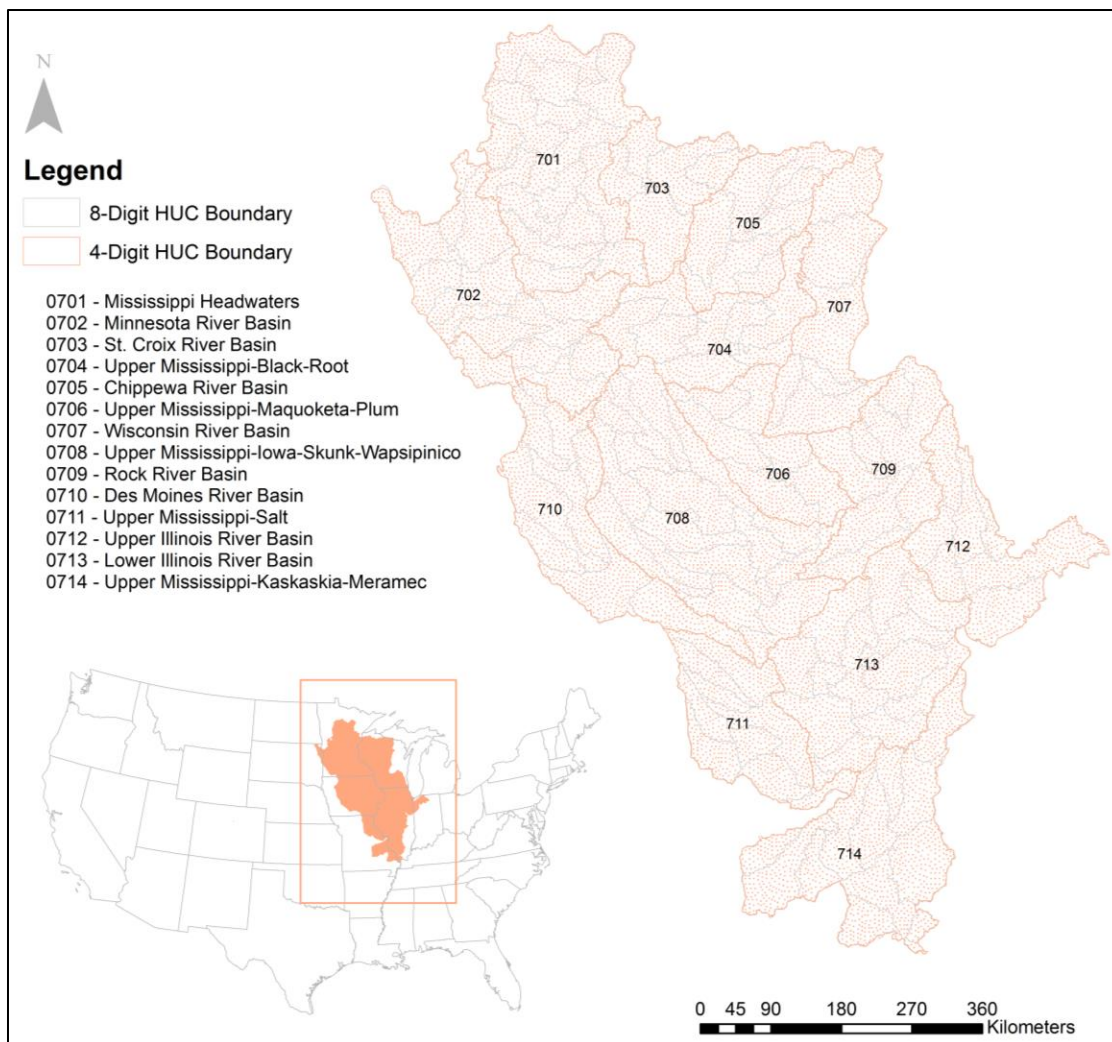


Figure 2.1 Location of the UMRB in the United States.

### 2.3.2 Model & Scenario Development

The Soil and Water Assessment Tool (SWAT) was used to evaluate ecosystem services in the UMRB. SWAT is a semi-distributed, process-based, hydrologic model which has been widely applied across a variety of landscapes and climates (Arnold et al. 1998; Vigerstol and Aukema 2011). A previously developed, uncalibrated SWAT model was utilized for this study, and details for the setup and validation of the model are provided in Appendix A, and further described in Srinivasan et al. (2010). Although uncalibrated, this model was validated for both crop yield (using NASS data) and streamflow (using USGS gage station data), which both showed good agreement between simulated and observed data. The original model was set up using SWAT 2005; for this study, the original model was re-run using SWAT version 2009 to evaluate ecosystem services.

Ecosystem services under current land use and climate were evaluated from 1992 – 2001 to create a baseline of ecosystem services in the watershed. Then, ecosystem services were evaluated under the Representative Concentration Pathways version 4.5 (RCP4.5) climate scenario that was developed using the ICHEC-EC-EARTH, RCA4 model (Smith and Wigley 2006; Clarke et al. 2007; Wise et al. 2009). The RCP4.5 model has medium-low radiative forcing with stabilization after 2150 and is further described in Meinhausen et al. (2011). The RCPs are greenhouse gas concentrations scenarios based on potential future greenhouse gas emissions. Specifically, the RCP4.5 scenario is a medium to low radiative forcing scenario which stabilizes after the year 2150. The RCP4.5 scenario was chosen as it is a mid-range scenario, which can enable possible discussion about ecosystem service response if the radiative forcing were in fact higher or lower than in this scenario. The RCP4.5 climate data was bias corrected using linear-

scaling with a factor term used to correct precipitation data, and an additive term to correct the temperature data using an overlapping period of historical and future climate data to calculate the factors (Teutschbein and Seibert 2012). The RCP4.5 scenario simulates an overall average difference of 100mm in precipitation in the UMRB between the baseline and future scenarios from an average of 846.3 mm/year in the baseline to 945.4 mm/ year in the future (Figure 2.2). An overall increase of 1°C in annual average temperatures between the baseline and future scenarios is simulated, with slight increases in average monthly temperatures (Figure 2.3). The bias-corrected climate data was used for the baseline run, to make ecosystem service calculations comparable.

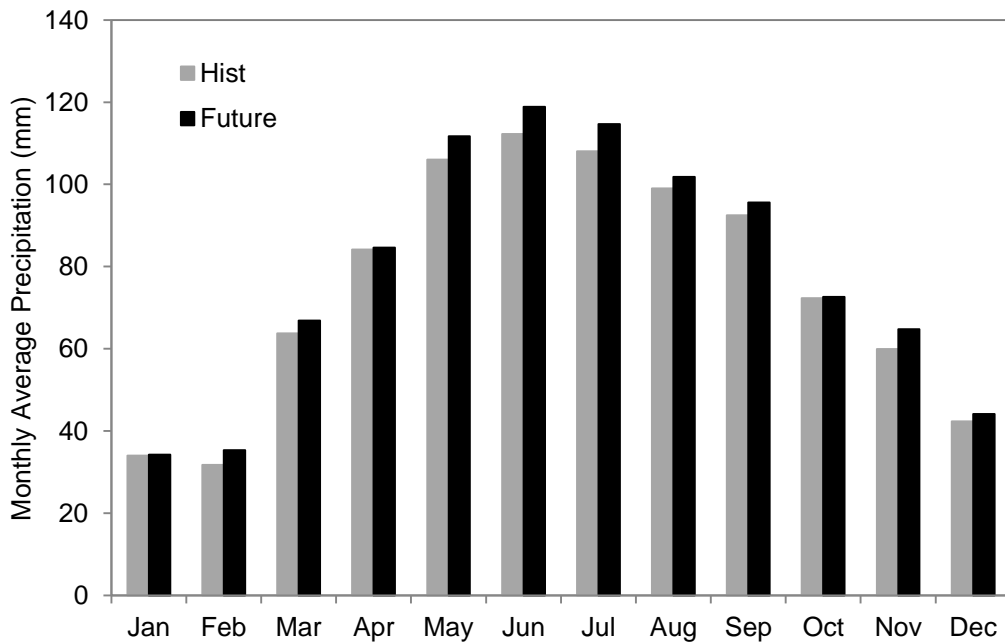
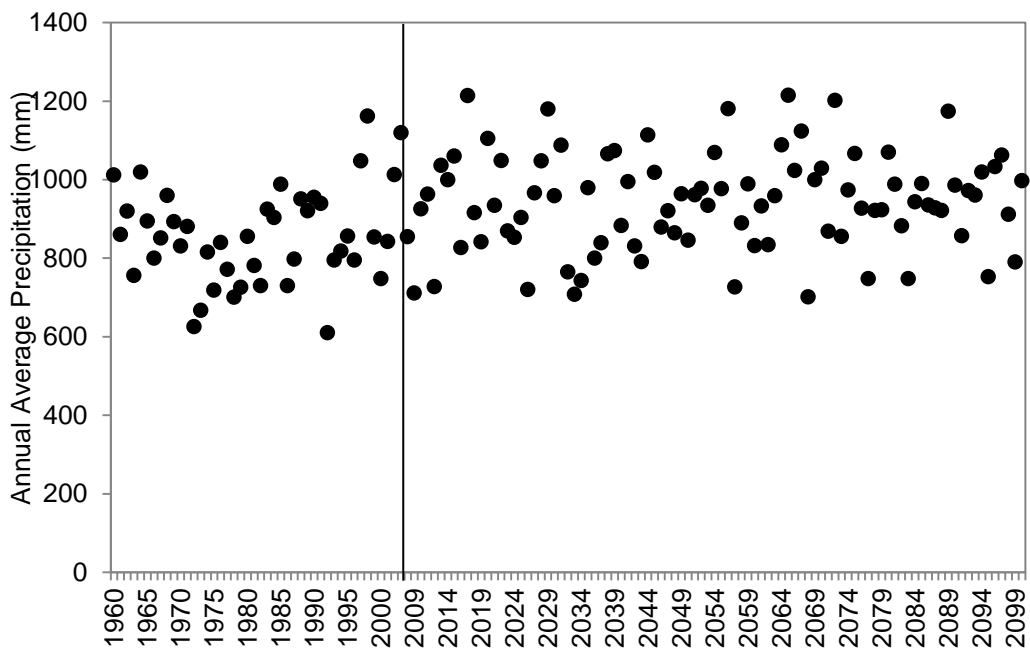
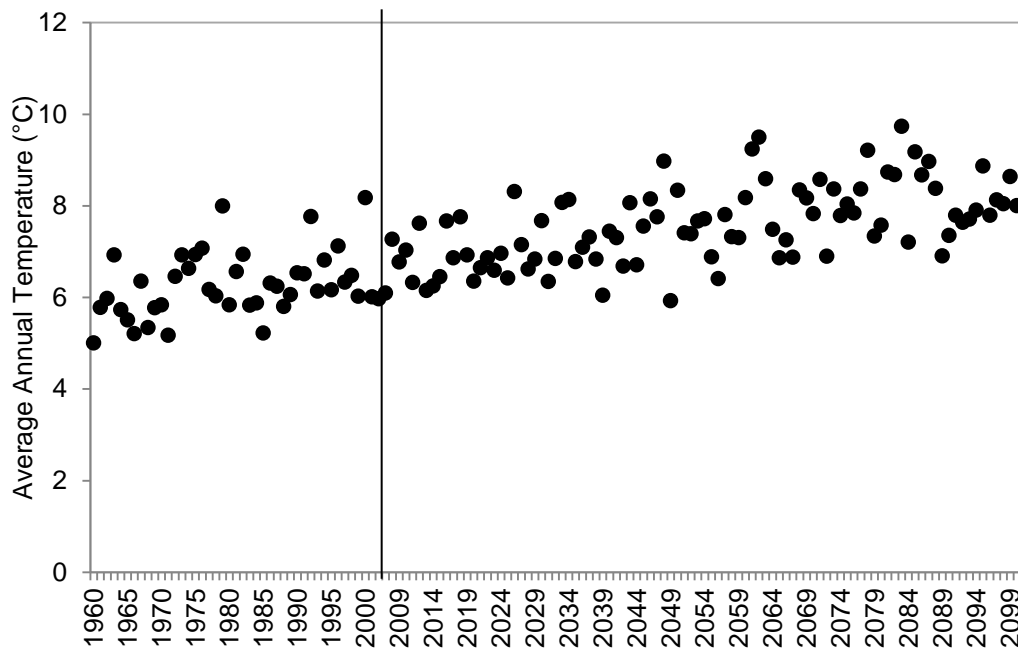
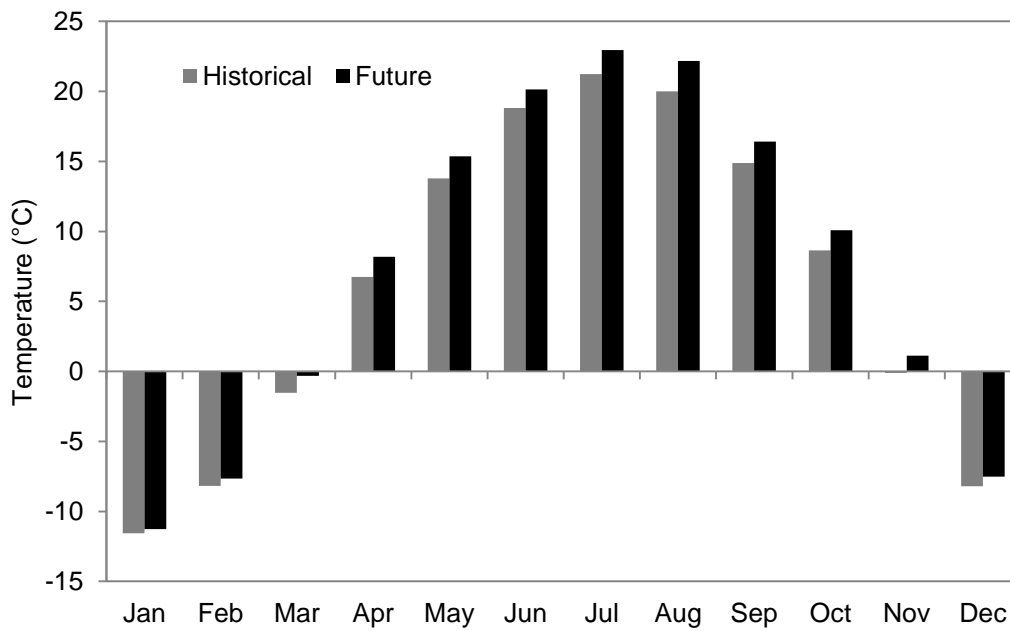


Figure 2.2 Average annual precipitation (a) across the UMRB sub-basins for the baseline to future scenario years (1960-2100); vertical line indicates break between baseline and future scenarios. Average monthly precipitation across baseline and future years shown in (b).



(a)



(b)

Figure 2.3 Average annual temperatures (a) and average monthly temperatures (b).

The existing SWAT model was developed using auto-fertilization routines in SWAT which apply a specified amount of nitrogen or phosphorus whenever it is calculated that nitrogen stress is occurring based on the amount needed for plant growth. Because of this implementation of auto-fertilization in the model, the future model had to be adjusted in order to make the two models comparable. To do this, the average annual nitrogen and phosphorus applied for each HRU through the auto-fertilization option of the SWAT model was determined over the entire baseline period. This average was set as the maximum auto fertilization allowed within each HRU. The annual average ecosystem services of all 4-digit HUCs were evaluated for the baseline (current climate, land use and management held constant, no technology adaptation considered) and future scenario (RCP4.5 climate, land use and management held constant, no technology adaptation considered) and then compared to evaluate how ecosystem services may change under a future climate.

### 2.3.3 Ecosystem Service Evaluation

The ecosystem service calculations were completed following methods described in Logsdon and Chaubey 2013 for each of the 14 4-digit HUC watersheds in the UMRB. Briefly, the erosion regulation index (*ERI*; Equation 2.1) was calculated for each 4-digit HUC using the area-weighted USDA ‘T’ factor for tolerable soil loss from STATSGO as the maximum allowable erosion and then determining the estimated soil erosion using SWAT.

$$\text{Equation 2.1} \quad ERI = \exp^{(1-(E_{Ann}/E_{max}))}$$

Equation 2.1 shows the erosion regulation index (*ERI*) which indicates how well a watershed is regulating erosion. In this equation,  $E_{Ann}$  is the annual erosion rate (T/ha)

and  $E_{max}$  is the maximum allowable (or natural) rate of erosion (T/ha). If annual erosion is equal to allowable erosion,  $ERI$  is 1. If erosion is less than maximum rate,  $ERI$  is greater than 1, indicating good erosion regulation. If erosion is greater than maximum rate, the  $ERI$  is less than 1, indicating decreased erosion regulation.

The food provisioning index ( $FPI$ ; Equation 2.2) was calculated for each 4-digit HUC using area-weighted state average yields from 1992-2001 (baseline modelling period) as the minimum required yield and SWAT yield output.

$$\text{Equation 2.2 } FPI = \frac{\left[ \left( TY_1 \cdot \frac{Y_1}{Y_{min,1}} \right) + \left( TY_2 \cdot \frac{Y_2}{Y_{min,2}} \right) + \dots + \left( TY_n \cdot \frac{Y_n}{Y_{min,n}} \right) \right]}{\sum_{i=1}^n TY_i}$$

Equation 2.2 is the food provisioning index ( $FPI$ ) which indicates how well a watershed is providing food compared to a ‘required yield’. In the equation,  $TY$  is the total biomass of grain harvested (tons),  $Y$  is the yield of the crop (tons/ha), and  $Y_{min}$  is a user determined minimum required yield (tons/ha). If required yields are exactly met, the  $FPI$  would be equal to 1. If minimum yields are not met, the  $FPI$  would be less than one. If minimum yields were exceeded the  $FPI$  will be greater than 1.

The freshwater provisioning index ( $FWPI$ ; Equation 2.3) was calculated using nitrate and total phosphorus as the water quality constituents for the water quality index ( $WQI$ ; Equation 2.4), with standards of 10mg/L and 0.1mg/L, respectively and SWAT estimated concentration data.

$$\text{Equation 2.3 } FWPI_t = \left( \frac{MF_t / MF_{EF}}{MF_t / MF_{EF} + (qne_t / n_t)} \right) \cdot \left( \frac{WQI_{avg,t}}{1 + (e_t / n_t)} \right)$$

In this equation,  $MF$  is the mean flow ( $m^3/s$ ),  $MF_{EF}$  is the long-term environmental flow requirement ( $m^3/s$ ),  $qne$  is the number of times the flow is less than environmental



flow requirements,  $WQI_{avg}$  is the average water quality index calculated using Equation 2.4,  $e$  is the number of times the  $WQI$  is less than one, and  $n$  is the number of units in the time step. If environmental flow requirements and water quality standards are met, the equation will be equal to one. If either flow requirements or quality standards are not met, the equation will be less than one. If water quality requirements are achieved better than standards (i.e., less than maximum standards) the equation can be greater than one.

$$\text{Equation 2.4 } WQI = \frac{\exp(w_1 + w_2 + \dots + w_n)}{\exp[(w_1 \times (C_1 / C_{1, std})) + (w_2 \times (C_2 / C_{2, std})) + \dots + (w_n \times (C_n / C_{n, std}))]}$$

In this equation,  $WQI$  is the water quality index,  $C_1, C_2, \dots, C_n$  are the observed concentrations of water quality constituents (mg/L),  $C_{1, std}, C_{2, std}, \dots, C_{n, std}$  are standard criteria for respective water quality constituents (mg/L), and  $w_1, w_2, \dots, w_n$  are weights for respective water quality constituents ( $\sum_{i=1}^n w_i$ ). The weights are user determined based on watershed priorities, where the standards may be specific water quality regulations or guidelines (e.g., 10ppm for nitrate).

The quantity portion of the  $FWPI$  and the flood regulation index ( $FRI$ ; Equation 2.5) were calculated using SWAT-simulated historical flow data from 1960-1991 for the quantity component of  $FWPI$ , and the long-term calculations for  $FRI$ , because 4-digit HUC outlets did not always match USGS gage stations and the simulated flow matched well with observed data (Srinivasan et al. 2010).

$$\text{Equation 2.5 } FRI = \frac{1}{\exp[w_1(DF/DF_{LT}) + w_2(QF/QF_{LT}) + w_3(FE/FE_{LT})]}$$

The  $FRI$  indicates how well a watershed is regulating floods (for the benefit of people). In the equation,  $DF$  is the duration of flood events (days),  $QF$  is the average magnitude of flood events ( $m^3/s$ ),  $FE$  is the number of flood events per year,  $w_1, w_2$ , and

$w_3$  are user determined weights for each respective component ( $\sum_{i=1}^3 w_i$ ), and the *LT* subscript indicates a calculation based on historical (long-term) data. If no flood events occur in a given year, the *FRI* will be equal to 1, indicating maximum flood regulation. If flooding events occur, the *FRI* can become less than one, indicating diminished flood regulation.

#### 2.3.4 Comparison of baseline and future scenarios

The four ecosystem services previously described were evaluated for the baseline scenario at the 4-digit HUC level (Figure 2.4) as well as for the climate change scenario, and then the 4-digit HUC values were averaged across the UMRB to create an annual average ecosystem service provision for the comparisons. Although the baseline model run went from 1960 – 2001, only the last ten years were used for comparison because the earlier data was used to calculate standards and long-term data for the ecosystem service indices. For the future scenario, although climate data was available from 2006-2100, the comparisons began at 2011 so that the SWAT model could have a warm-up period. The annual average values were then compared using Welch's 2-sample t-tests in *R* to look for differences in means between the two time periods (1990-2001 & 2011-2100). To evaluate the impact of capping the future scenario auto fertilization routine, the baseline scenario was also run with the same cap (see Section 2.3.2) as the future scenario. The capped baseline was then compared with the capped future scenario to evaluate if there would still be a significant difference in the annual means of ecosystem services.

To further investigate the impact of future climate on food provisioning, the baseline and future scenarios were run with auto fertilization routines on, without the caps, and the amount of nitrogen that was automatically applied for each HRU was compared to further evaluate the nitrogen stress.

## 2.4 Results & Discussion

For the baseline (current) scenario, the erosion regulation and food provisioning are high for most sub-basins (close to or greater than 1), whereas the freshwater provisioning is very low (less than 0.10), and the flood regulation is diminished compared to historical flood regulation (less than 0.50). The ecosystem services also varied spatially (Figure 2.4). For example, better erosion regulation was seen in upstream watersheds than in downstream locations.

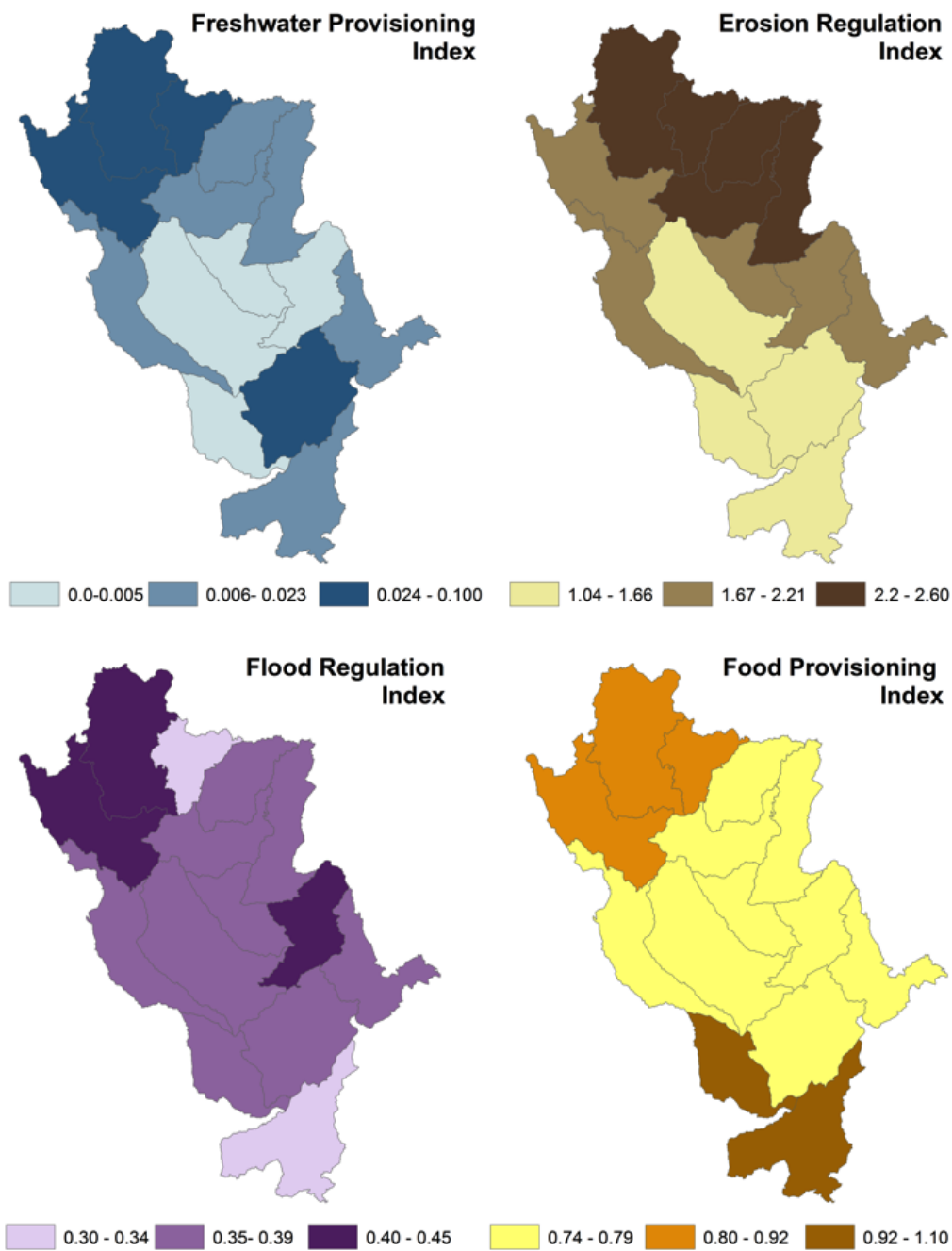


Figure 2.4 Baseline ecosystem services by 4-digit HUC in the UMRB.

#### 2.4.1 Baseline versus climate change under same management

Comparing ecosystem services under future climate change to the baseline shows that all ecosystem services, except food provisioning decrease over time under the RCP4.5 climate change scenario (Figure 2.5 & Figure 2.6). The means of the two time periods were compared using Welch's Two Sample t-test in *R* with a confidence level of 95% ( $\alpha = 0.05$ ) indicating significant difference in the means. For *FWPI* and *FRI*, there were no significant differences in the time periods ( $p = 0.15$ ,  $p = 0.11$ , respectively). For *ERI*, the future time period was providing significantly less erosion regulation than the baseline ( $p = 0.006$ ). This change is likely due to increased rainfall in the UMRB predicted by the RCP4.5 scenario. For *FPI*, the future time period is predicted to provide less food provisioning when compared with the baseline ( $p = 3.59e-10$ ). This approximately 40% decrease in food provisioning is likely due to the increase in nitrogen stress during the time period. By extracting the SWAT parameter "N\_STRS" –the number of nitrogen stress days- the amount of nitrogen stress experienced (days/year) can be evaluated. Although it is likely that land managers would apply more fertilizer under increased nitrogen stress, this comparison kept land management the same as baseline by capping the amount of auto fertilizer applied. The increase in nitrogen stress is due to the higher precipitation simulated in the RCP4.5 model, and thus higher runoff and leaching, resulting in more off-site losses of nitrogen. Although there wasn't a significant difference in *FWPI* between the two time periods, there was a slight decrease in the future which supports this idea that more nitrogen was leaving agricultural lands. Overall, the corn yields were most affected by this increased nitrogen stress rather than soybeans, due to the ability of soybeans to fix nitrogen.

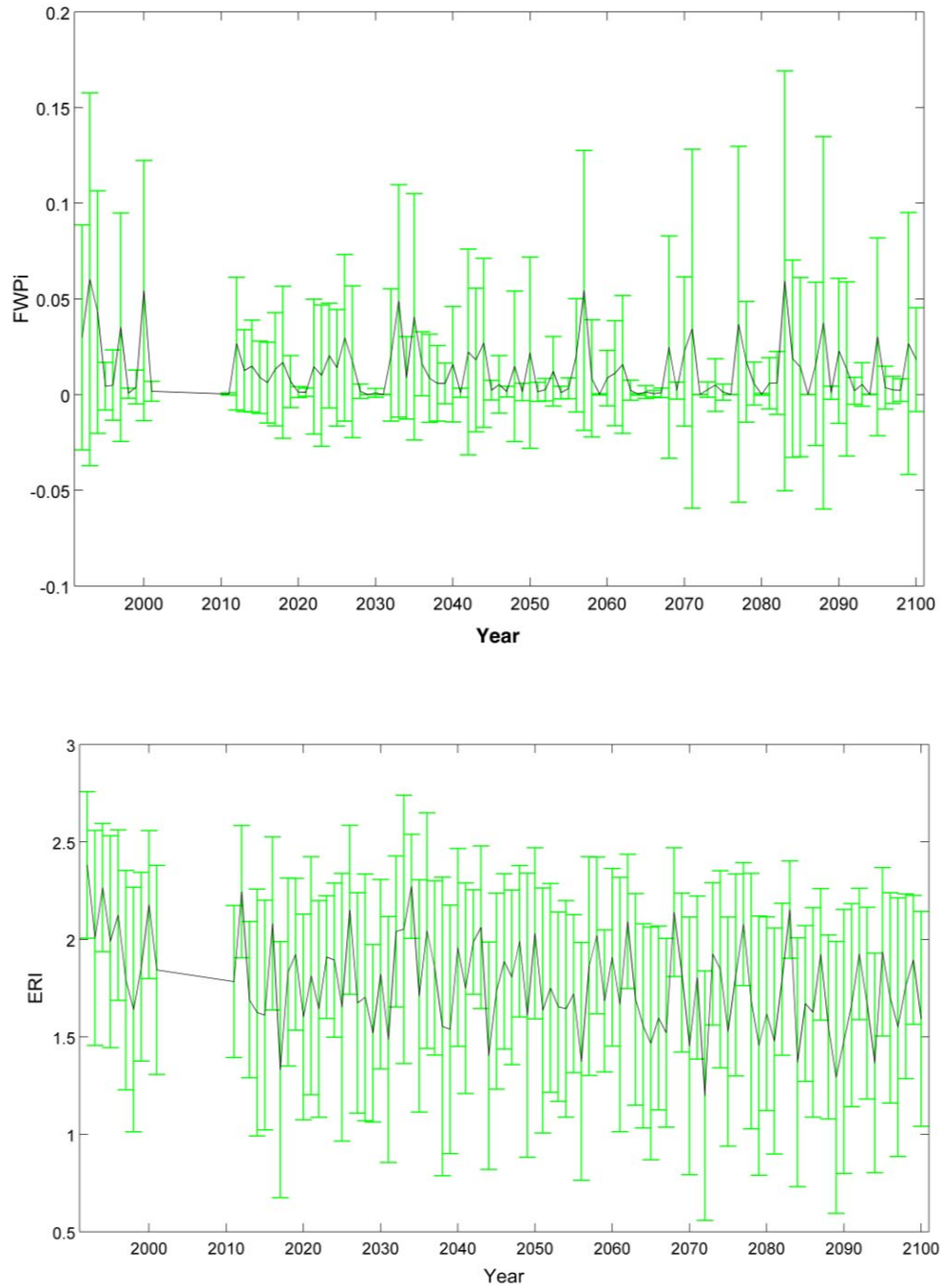


Figure 2.5 Freshwater provisioning index (*FWPI*), erosion regulation index (*ERI*), Flood regulation index (*FRI*), and food provisioning index (*FPI*) across baseline and future scenario, showing variability (green bars) among the 4-digit hydrologic units within the UMRB and annual average of 4-digit HUCs (black line).

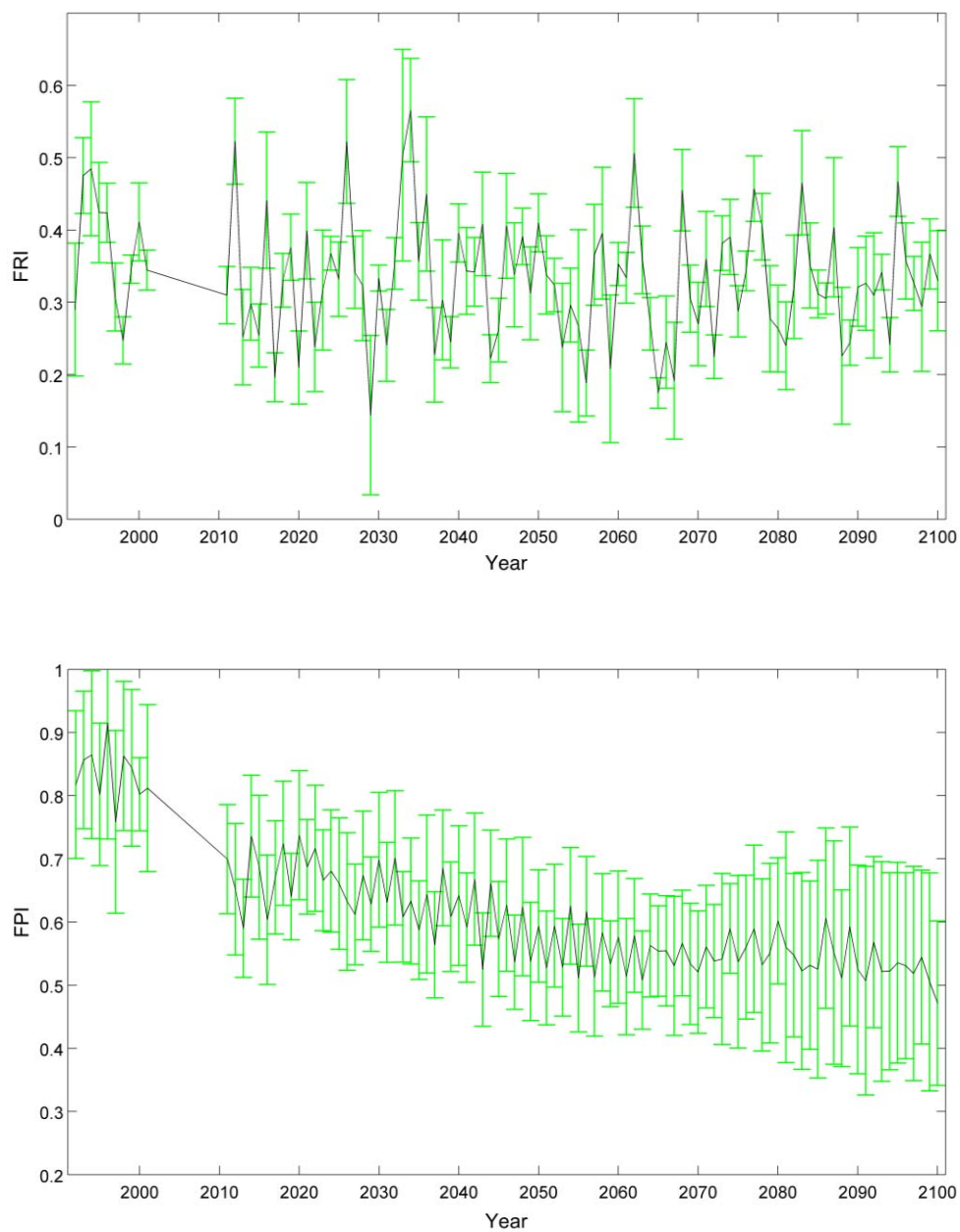


Figure 2.5 (Continued) Freshwater provisioning index (FWPI), erosion regulation index (ERI), Flood regulation index (FRI), and food provisioning index (FPI) across baseline and future scenario, showing variability (green bars) among the 4-digit hydrologic units within the UMRB and annual average of 4-digit HUCs (black line).

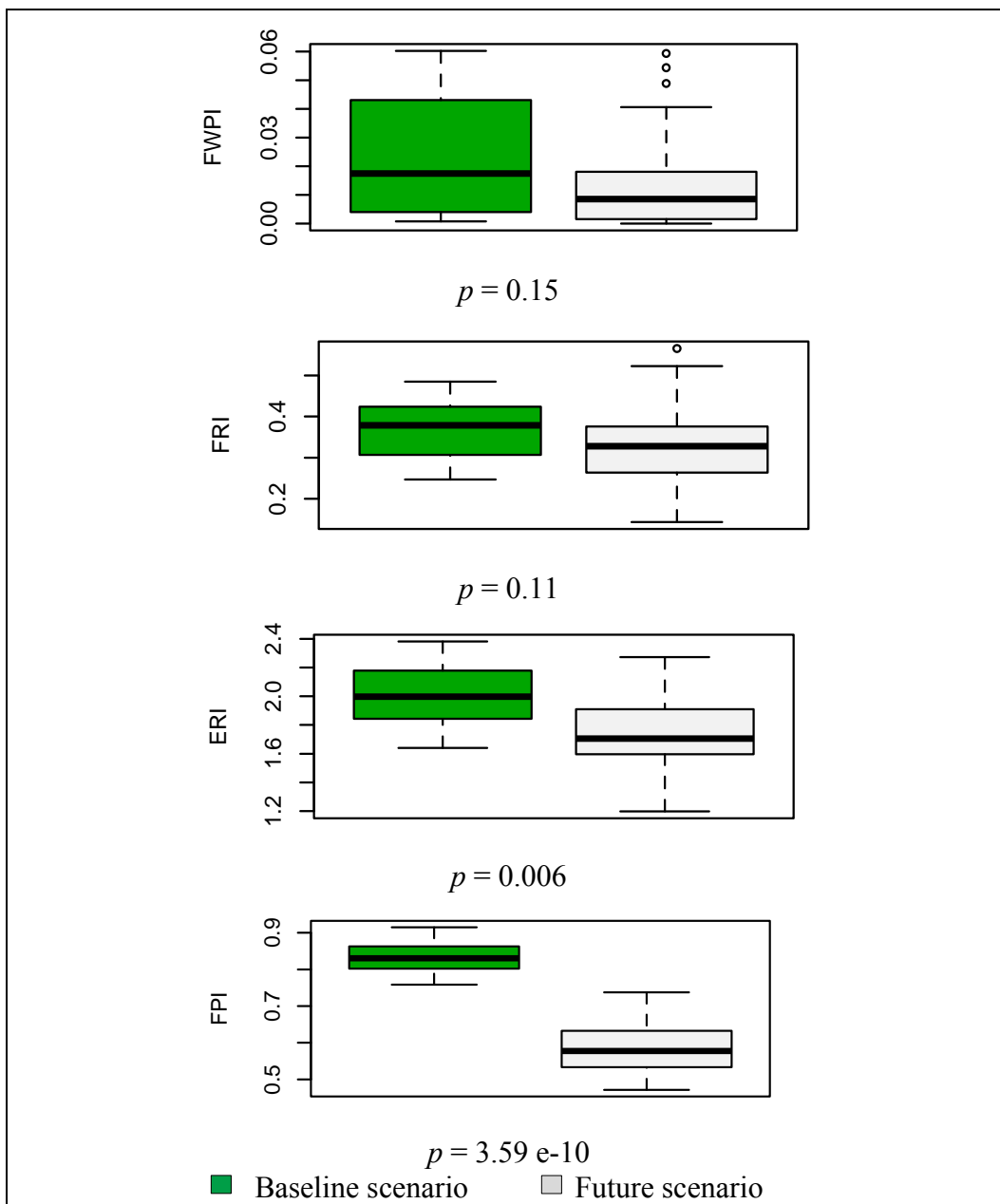


Figure 2.6 Average annual values for freshwater provisioning index (*FWPI*), flood regulation index (*FRI*), erosion regulation index (*ERI*), and food provisioning index (*FPI*) for the future scenario (gray) compared to the baseline (green).



The next step was to compare baseline and future scenarios with both of the auto-fertilization routines capped at the average value applied during the baseline scenario. This step was necessary to evaluate the influence of the cap in the future scenario. For food provisioning only there was a change in the significance; there no longer was a significant difference ( $p=0.24$ ; Figure 2.7) between the means of the current and future scenario, even though a decreasing trend over time was seen (Figure 2.7). Although the difference in the average FPI across the HUC4s was not significantly different when both scenarios had capped auto fertilization, a decreasing trend in FPI can be observed over time (Figure 2.7), indicating that food provisioning could be negatively affected under future climate change.

To further investigate the nitrogen stress, both the baseline and future scenarios were run without any cap on the auto-fertilization routines. When the SWAT auto fertilization routine is used, SWAT will apply nitrogen whenever there is nitrogen stress in the HRU. A comparison of average amount of nitrogen applied on each HRU during the baseline and future scenarios, shows that significantly more nitrogen ( $p = 1.12e-07$ ) had to be automatically applied during the future scenario due to increased nitrogen stress (Figure 2.8). This further shows that under a changing future climate, agricultural production will likely experience more stress, with a concomitant or possible decreases in ecosystem services.

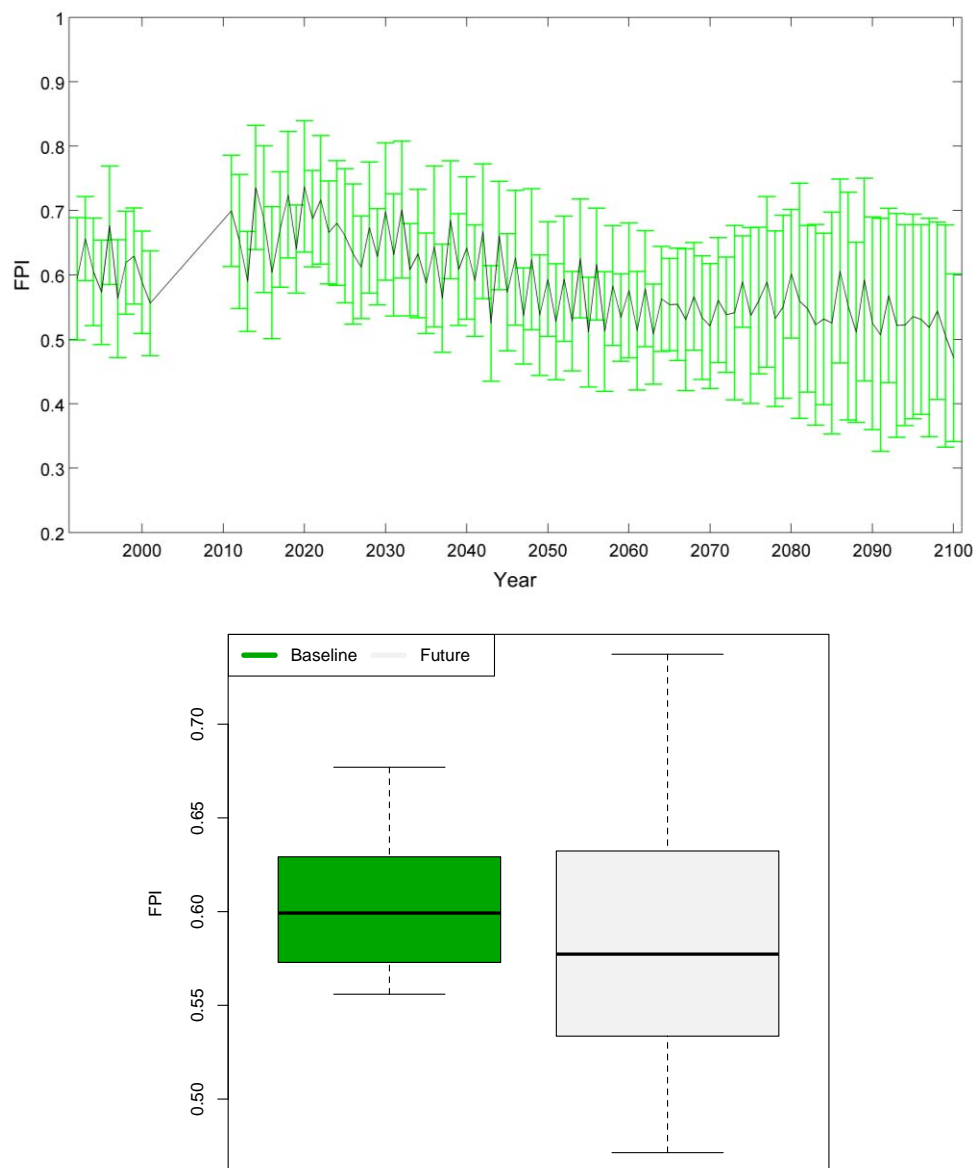


Figure 2.7 Food provisioning index (FPI) over time (top) and boxplot of annual average values (bottom) for future and baseline scenarios where the auto fertilization maximum is capped.

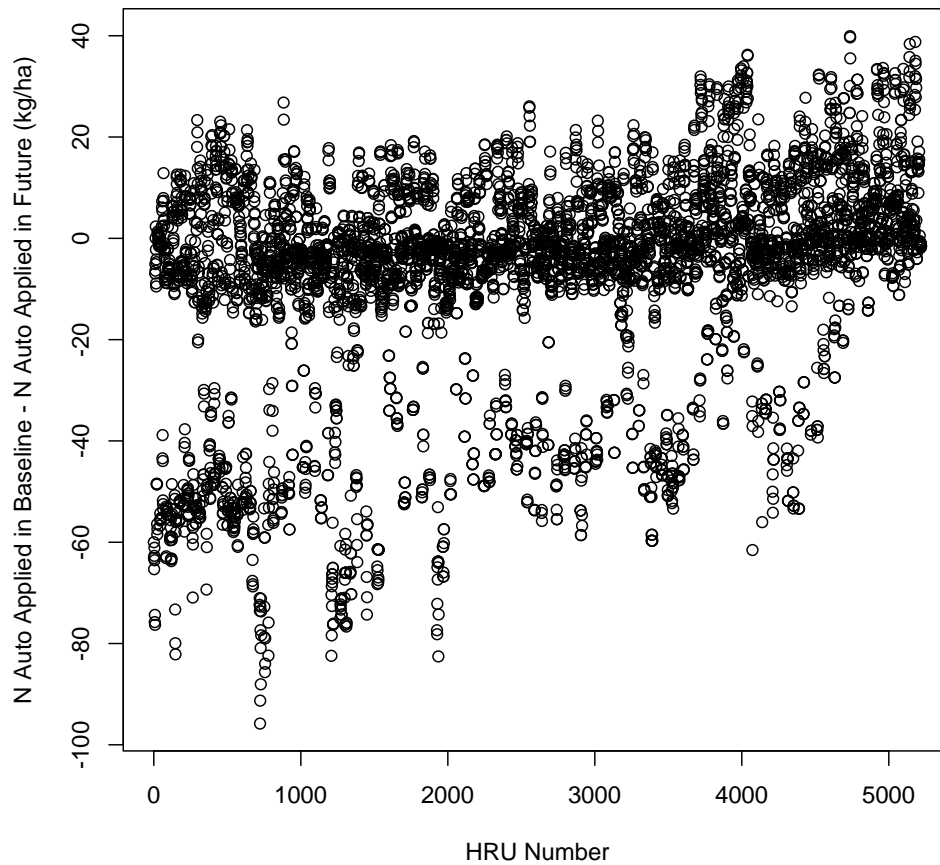


Figure 2.8 Difference in the amount of nitrogen automatically applied during the baseline time period and the future time period. A negative number indicates an increase in nitrogen that is automatically applied.

## 2.5 Conclusions

The objectives of this study were to evaluate current ecosystem service provisioning in the UMRB and determine the impact of future climate on those ecosystem services. The results suggest that under the future climate scenario RCP4.5, which is one of the mid-level RCP scenarios in terms of CO<sub>2</sub> concentration increases, ecosystem services of freshwater provisioning, erosion regulation, flood regulation and food provision will decrease over time in the UMRB due to increased precipitation and temperatures. Since one of the main trade-offs in ecosystem services in agricultural landscapes is food provisioning at the expense of freshwater provisioning, knowing that this tradeoff may worsen over time is important for land managers. More fertilizer may be needed, on average, to maintain food provisioning at current levels due to a projected increase in nitrogen stress due to losses from increased precipitation, which could further decrease freshwater provisioning. However, it is important to note that one assumption made for this study was that there were not technological yield improvements over time. This would likely occur, possibly lessening the severity of the yield changes. Also, only one global climate model was used in the future scenario. There is considerable variability between predictions from different climate models (Walsh, 2008) as evidenced by other UMRB SWAT climate change research (Jha et al. 2006). Other UMRB SWAT models have shown similar increases in precipitation and thus stream flow as well as variability of precipitation timing (Jha et al. 2006; Wu et al. 2012). However, Jha et al. (2013) found streamflow at the watershed outlet to decrease under climate change, with effects on nitrogen loading being variable throughout the watershed. Future work should therefore focus on calculating ecosystem services using multiple climate models. Overall,

however, this work has demonstrated that ecosystem services could be in decline in a future climate regime. Understanding how and why these declines may occur will be important for developing management strategies that can avoid or lessen the predicted decline in future ecosystem services in the UMRB.

### 3 EVALUATING POSSIBLE DRIVERS OF A FISH REGIME SHIFT USING THE SWAT MODEL: A CASE STUDY OF THE WABASH RIVER

#### 3.1 Abstract

Anthropogenic activities can have great effects on ecosystem stability. One such impact is a regime shift in the ecosystem community. Although these changes can occur naturally, many studies have shown that anthropogenic activities can also induce these changes. Some possible drivers of a freshwater fish regime shift in the Wabash River in the United States that occurred in the 1990's were investigated. Since the shift occurred over a time period of changing agricultural practices in an agriculturally-dominated watershed, we used the Soil and Water Assessment Tool (SWAT) to evaluate the possible influence that these management changes had on the observed regime shift. The results suggest that changing fertilizer management, tillage, and precipitation, may be associated with the fish regime shift. The increase in mineral phosphorus levels in the Wabash River at the watershed outlet correlated well with the corresponding increase in benthic invertivores. Although other changes, both natural and anthropogenic, could be drivers as well, we demonstrate that a combination of climate and agricultural management practices were likely influencing the observed fish regime shift.

#### 3.2 Introduction

Humans have been altering the landscape more rapidly than ever (Foley et al. 2005), and we are only beginning to understand some of the effects on the ecosystems.

Since over 40% of terrestrial biomes are now classified as agricultural (cropland/pasture), agricultural management practices can induce some of the greatest changes on ecosystems globally (Foley et al. 2005; Dale and Polasky 2007; Scanlon et al. 2007; Stoate et al. 2009). Agriculture can affect ecosystems by introducing typically limited resources in large quantities, including adding excess nutrients to fields and bringing groundwater to the surface faster than it would recharge. These types of changes alter hydrology as well as water and soil quality (McLauchlan 2006; Tilman et al. 2009). Agriculture practices can also alter species composition and the biodiversity of ecosystems (Allan 2004; Tschardt et al. 2005).

The relationships between land use, land management, environmental variables and freshwater ecosystems and fish communities has been evaluated in many research studies (Lenat and Crawford 1994; Guegan et al. 1998; Rathert et al. 1999; Koel and Peterka 2003; Allan 2004; Grubbs et al. 2007; Carlisle et al. 2008; Cookson and Schorr 2009; Helms et al. 2009). The influence of agriculture specifically on fish communities has also been examined (Walser and Bart 1999; Sutela and Vehanen 2010). From these studies it is clear that fish communities are explicitly linked to their local habitat, as well as regional environmental variables. Improving our understanding of exactly how fish communities respond to changes in these variables can help to improve how we manage our landscapes for aquatic biodiversity and ecosystem services.

Ecosystem regime changes have been demonstrated to occur by natural and anthropogenic influences, or a combination of both (Scheffer and Carpenter 2003; Folke et al. 2004; Kinzing et al. 2006), and are one possible consequence of human activities. Regime shifts are observable changes in the composition of species in an ecosystem

community. A previous study published by Broadway et al (*In Review*), demonstrated that the Wabash River in Indiana (Figure 3.1) experienced a fish regime shift that occurred during the 1990's. The early regime (1974-1993) was dominated by planktivores and omnivores, and the later regime (2001-2008) was dominated by benthic invertivores. Although the authors speculated as to the drivers of the regime change, they did not complete further investigation to determine possible causes for the shift. During this time period, tillage and fertilizer practices in conventional agriculture were changing in the U.S. Corn Belt (as shown in subsequent sections), so we hypothesize that these changes in agricultural management practices may have led to the observed fish regime change. The objective of this study was to investigate the impacts of agricultural management, specifically tillage and nutrient application, as one possible driver of the fish regime change in the Wabash River.

### 3.3 Methods

#### 3.3.1 Study Area

The study area for this research was the Upper Wabash River Basin (UWRB; 42,762km<sup>2</sup>) located mostly in Indiana, with relatively smaller areas in Illinois and Ohio (Figure 3.1). The UWRB is predominantly conventional corn-soybean rotation agriculture (~70%), with few large urban areas. The watershed is characterized by low slopes, and many of the agricultural lands are tile drained. The Wabash River is joined by the White River near the Illinois-Indiana Border before it flows into the Ohio River.



The Wabash River fish population has been sampled and described almost annually since 1974 (Figure 3.1; Gammond 1998; Pyron et al. 2006; Pyron et al. 2008). Although streamflow has been monitored since the same time period, water quality measurements have only been measured regularly in the recent past.

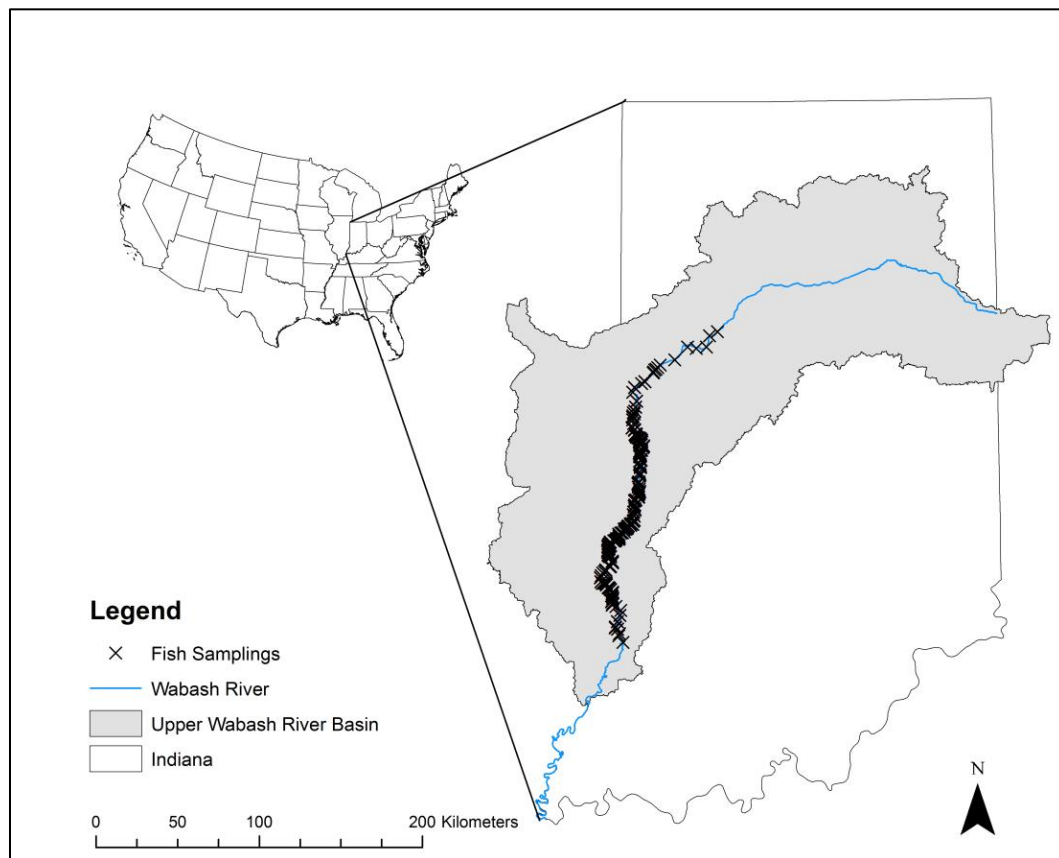


Figure 3.1 Location of the UWRB in the United States, along with fish sampling locations from 1974 – 2008.

### 3.3.2 Input Data

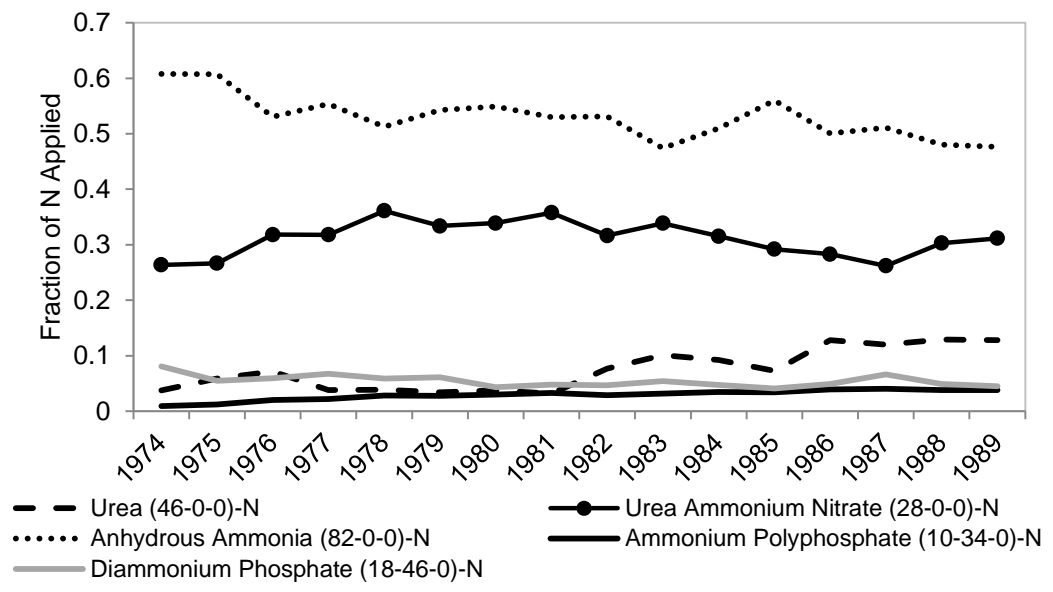
#### 3.3.2.1 Fish Sampling Data

The fish data used in this research are described in detail in Broadway et al. (*In Review*). Fishes were sampled annually from June to October using boat electrofishing along 500 meter segments of the main stem of the Wabash River (not in tributaries). The fish were identified to species level and released. They were then assigned to functional feeding groups (FFG; Frimpong and Angermeier, 2009). The data consists of the annual trophic compositions of all fish collected in the UWRB from 1974-2008. The three major trophic levels described in Broadway et al. (*In Review*) were used as independent variables for this research: benthic invertivores, planktivores, and omnivores. Before the regime shift, the assemblage was mostly planktivores (41.3%) and omnivores (31.7%); after the regime change benthic invertivores were the dominant FFG (55%).

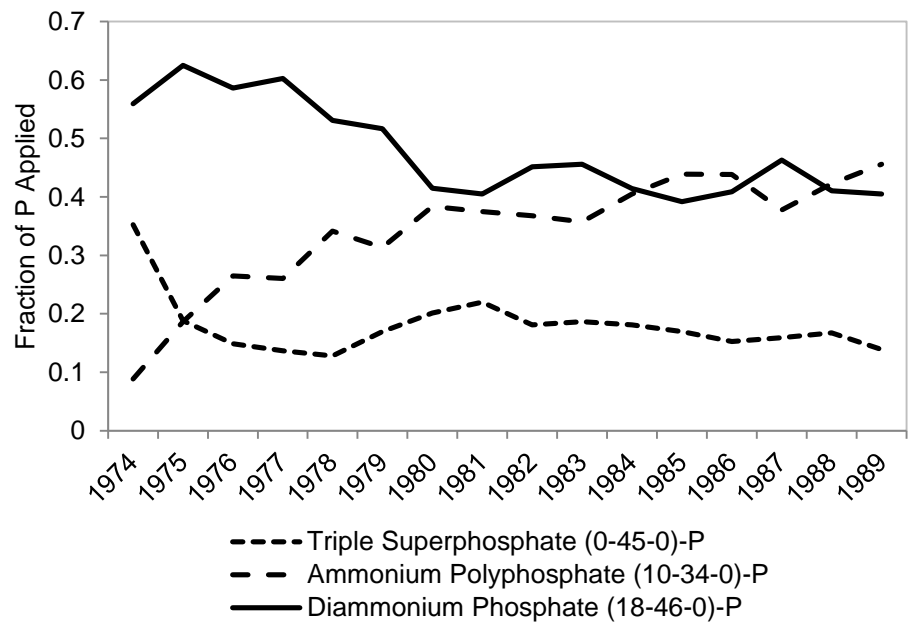
#### 3.3.2.2 Fertilizer Data (1974-1989)

Fertilizer data for the 1974-1989 time period was gathered from two resources. The fertilizer type and timing data were estimated from bi-annual Indiana Fertilizer Tonnage Reports that document the amount and type of fertilizers purchased in each county (Indiana State Chemist Office [1974:1989]). It was assumed that fertilizer bought within the season (fall/spring) was used in that season and not stored on site. A swath of counties in Indiana (Tippecanoe, Carroll, Cass, Miami, Wabash, Huntington) lying along the center of the UWRB were selected as representative of the conditions for the entire watershed. The fertilizer types were first narrowed down to fertilizers likely to be applied in corn and soybean fields only, as all fertilizers, including some turf and specialty crop

fertilizers, were included on the list. Next, only the top six fertilizers (Urea [46-0-0], Anhydrous Ammonia [82-0-0], 28% Urea Ammonium Nitrate [UAN; 28-0-0], Diammonium Phosphate [18-46-0], Ammonium Polyphosphate [10-34-0], Triple Superphosphate [0-45-0]) by weight across the time period were included (representing the majority of corn/soy fertilizers applied), and the percent of each type of fertilizer was adjusted accordingly. Although SWAT cannot model the potential differences in solubility of these fertilizers, it is an important management change to document. The final nitrogen and phosphorus fertilizer type percentages are provided in Figure 3.2.



(a)

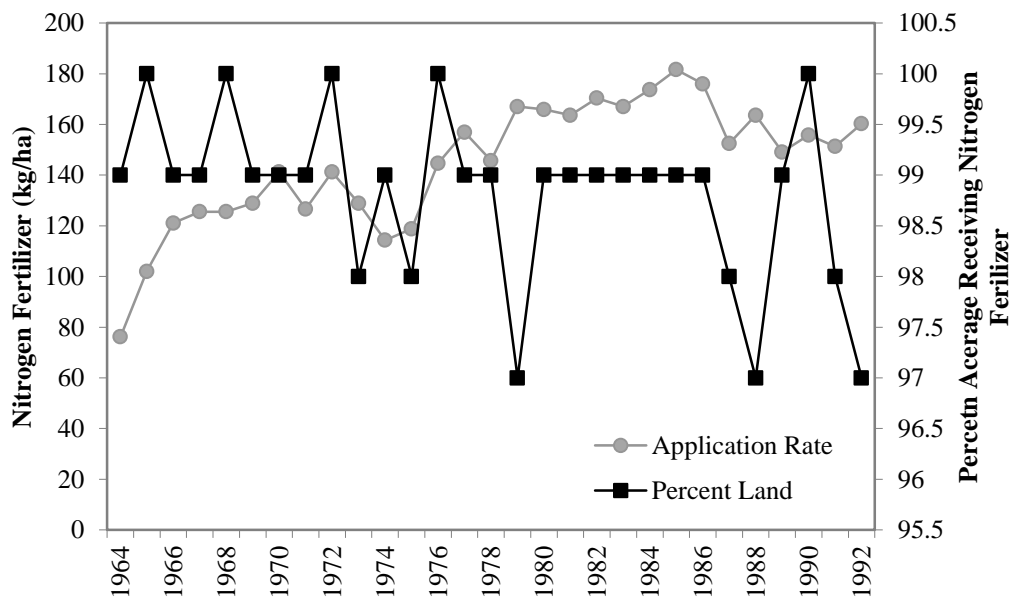


(b)

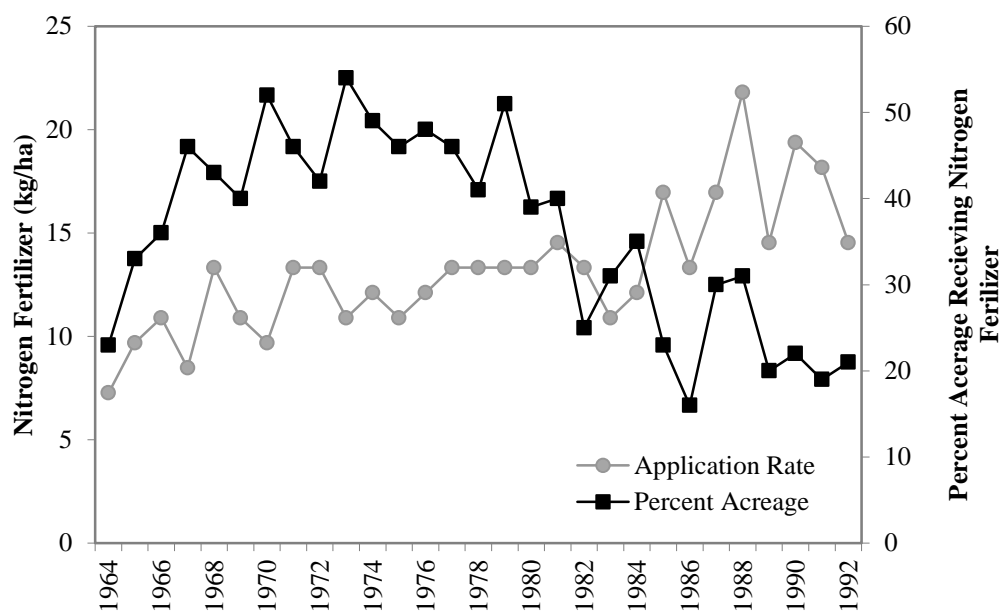
Figure 3.2 Fraction of major agricultural nitrogen (a) and phosphorus (b) fertilizer types applied in UWRB county swath from 1974 – 1990.

Fertilizer timing (fall versus spring) was also estimated using Indiana Fertilizer Tonnage Reports (Indiana State Chemist Office, 1974:1989) and evaluated using the same UWRB counties as before. The timing did not vary significantly over this time period, so the same values were used each year: 79% of nitrogen fertilizers were applied in the spring and 21% were applied in the fall; 65% of phosphorus fertilizers were applied in the spring and 35% in the fall.

The amount of fertilizer applied (kg/ha), as well as the percentage of areas that received nitrogen and phosphorus fertilizer (Figure 3.3 & Figure 3.4) were derived from United States Department of Agriculture Economic Research Service (USDA ERS) “Fertilizer Use and Price” reports (USDA ERS 2013). These data were generalized for all of Indiana (i.e., not available for a specific county), and specific to the crop. The date of the fertilizer application was randomized over three different weeks, assuming 1/3 of the HRUs were fertilized in each of three consecutive weeks.

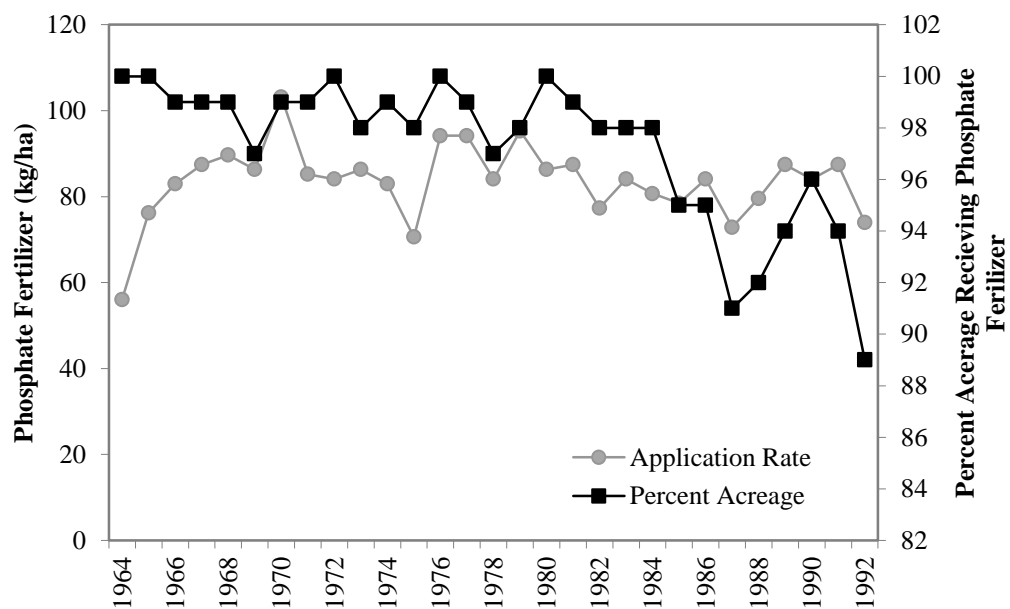


(a)

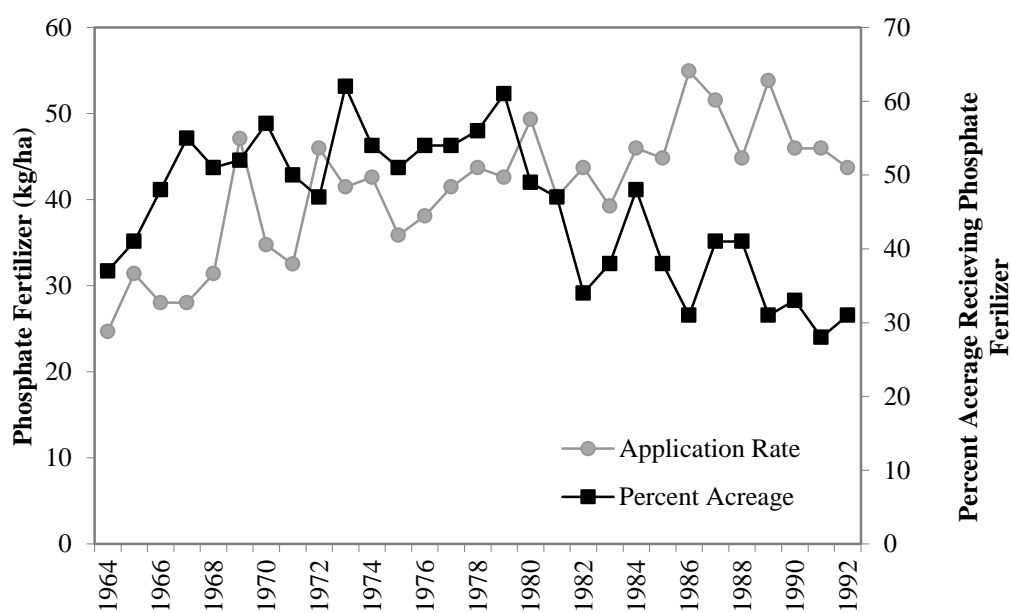


(b)

Figure 3.3 Amount of nitrogen fertilizer applied and percent of corn (a) and soybeans (b) in Indiana that received nitrogen fertilizer.



(a)



(b)

Figure 3.4 Amount of phosphorus fertilizer applied and percent of corn (a) and soybeans (b) in Indiana that received nitrogen fertilizer.



### 3.3.2.3 Manure Application Data

Manure application can affect the amount of nutrients entering streams, as well as the type of nutrients (organic versus inorganic). The amount of manure applied was estimated using NASS Census animal numbers for cattle and swine (Figure 3.5) from the UWRB swath of counties along with methods from Ruddy et al. (2006) to estimate nutrient generation from the animal manure. The total amount of nitrogen and phosphorus generated were divided by the total amount of harvested cropland to get an average application rate of manure. It was then assumed that half of this manure was applied in the spring, and half in the fall to corn and soybean HRUs. Manure calculations were also completed for the later time period (1990-2009) and an average amount of nitrogen and phosphorus applied as manure during this time period was used for all corn and soybean lands. During the earlier time period the number of cattle was declining while hogs and pigs were rising. Both swine and cattle numbers seemed to stabilize during the later time period. This change in the type of dominant animal in the UWRB created similar application rates of nitrogen and phosphorus as manure (kg/ha), however, each animal has a different proportion of their manure nitrogen and phosphorus as mineral versus organic. For example, in SWAT's fertilizer database, swine are estimated to have more mineral nitrogen than organic nitrogen in their manure whereas the opposite is true for cattle. This change in the form of nitrogen and phosphorus applied also can impact the nutrients seen in streams.

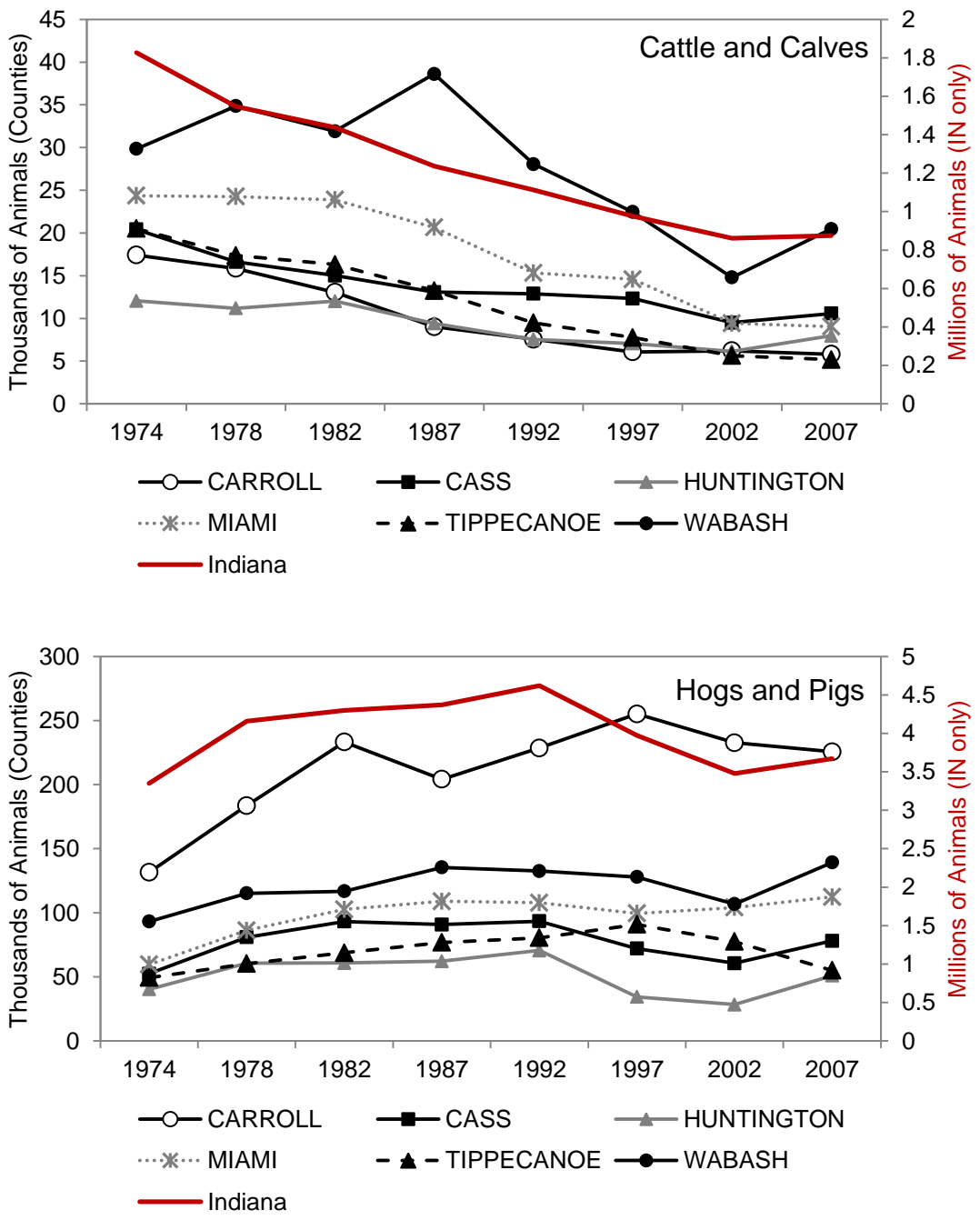


Figure 3.5 NASS Census animal numbers for cattle (top) and swine (bottom) across the swat of UWRB counties.

#### 3.3.2.4 Tillage Data (1974-1989)

Tillage data from this time period was determined based on estimates made in the magazine *No Till Farmer* which were derived from surveys of National Resource Conservation Service (formerly Soil Conservation Service) officials (Lessiter 1974:1990, Figure 3.6). The estimates of minimum tillage were ‘discounted’ based on Schertz (1998) to account for changes in tillage nomenclature. It was assumed that all corn and soybean acres were tilled in this earlier time period. Since tillage timing (fall versus spring) could not be determined from any data source, it was assumed that half of corn and soybean acres were tilled in the fall and half in the spring. In order to check the estimations of total land area in agriculture listed in *No Till Farmer*, their estimate was compared to USDA National Agricultural Statistic Service (USDA NASS) data for Indiana (Figure 3.7; USDA NASS 1999). Since the totals are similar, it was assumed that the estimates of tillage type areas were within reason. The date of the tillage was randomized over three weeks, assuming 1/3 of the hydrologic response units (HRUs – areas of unique land use, soils, and slope within a sub-basin at which base SWAT calculations are performed) were tilled in each of the weeks.

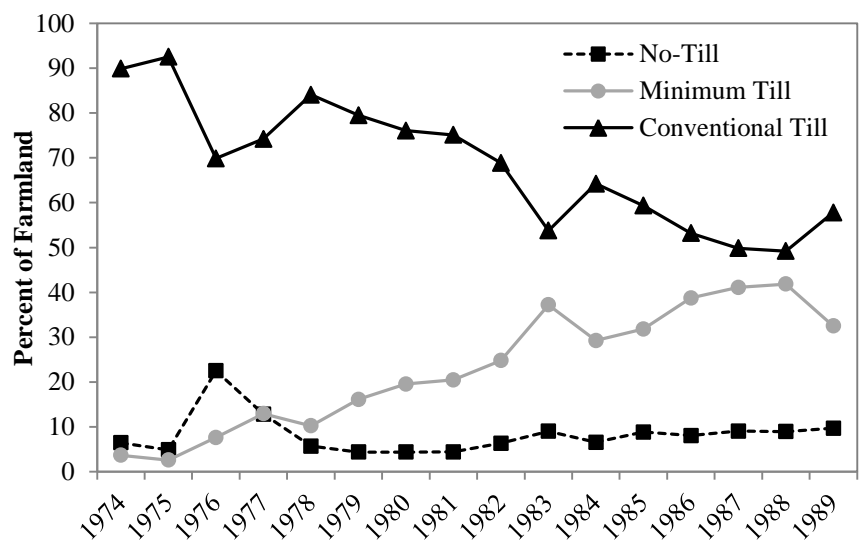


Figure 3.6 Estimations of Indiana tillage types from 1974-1990 from No-Till Farmer (Lessiter, 1974:1990).

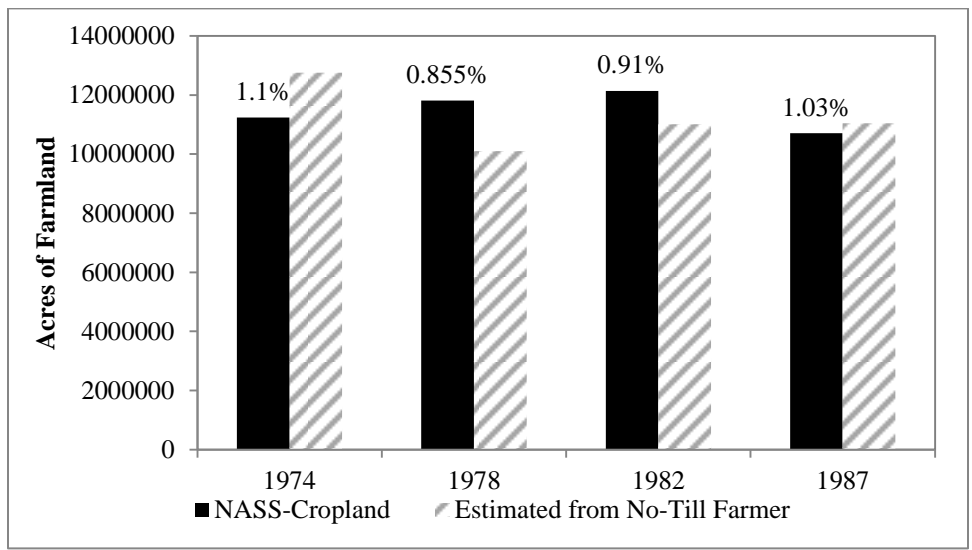


Figure 3.7 Comparison of acres of farmland listed in No Till Farmer compared with USDA NASS data, along with the percent difference between the two.

### 3.3.2.5 Land Use Changes

The USDA NASS Census data was mined to evaluate how agricultural land use was changing over time, if at all, across all of Indiana. The total amount of harvested cropland was extracted to see if the amount of land in agriculture was changing over time (Figure 3.8). The acreage of major crops harvested during the modelling period was also extracted to see if these values were changing over time (Figure 3.9). From the NASS Census data, it appears that the total amount of land harvested was not changing drastically over the time period. However, it appears that prior to 1987, there were a lot fewer soybeans planted than corn. Therefore, from 1974-1985 it was assumed that 60% of corn-soybean acreage was corn and 40% was soybean, and from 1986 on the corn-soybean acreage was approximately half corn and half soybean.

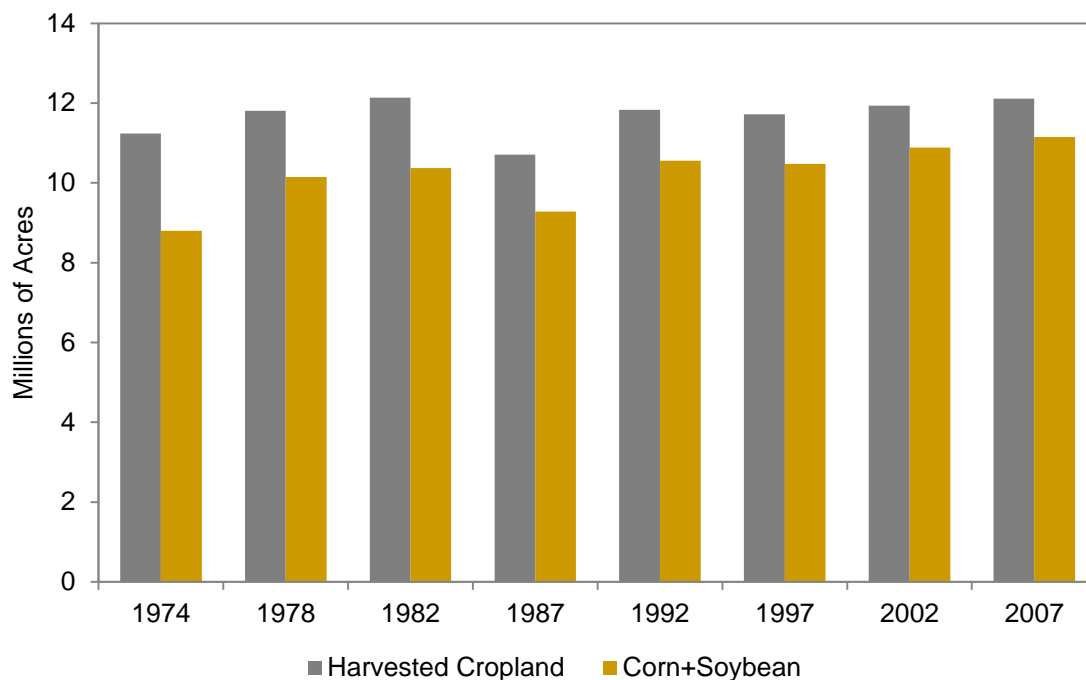


Figure 3.8 Amount of harvested cropland versus corn and soybean cropland from NASS Census data.

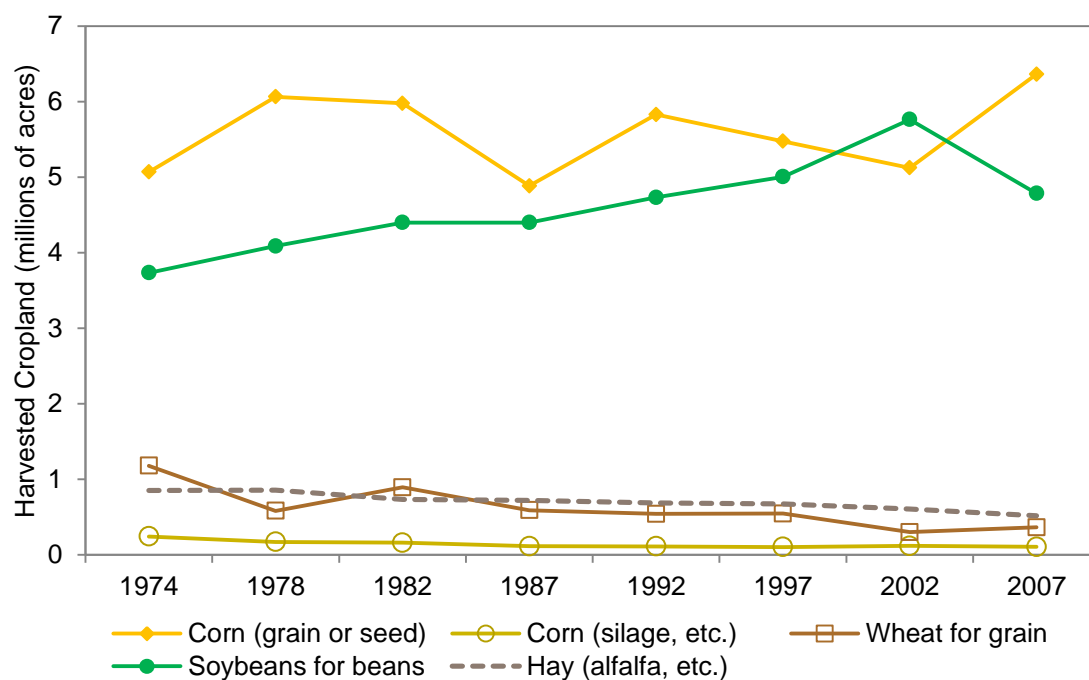


Figure 3.9 Amount of harvested cropland for major crops in Indiana.

### 3.3.3 SWAT Model Development

#### 3.3.3.1 Model Development

Given water quality data were not available consistently at or near the outlet of the UWRB, a watershed model, the Soil and Water Assessment Tool (SWAT) was used to estimate nutrient and sediment loadings during the 1974-2008 time period. SWAT is a semi-distributed, hydrologic model that has been widely applied and evaluated in many watersheds (Arnold et al. 1998; Jayakrishan et al. 2005; Douglas-Mankin et al. 2010). SWAT divides a basin into sub-watersheds, and sub-watersheds into hydrologic response units (HRUs) that are units of unique soil, land use, and slope combinations. Modeling occurs at the HRU scale; then water, sediment, and nutrients are routed through the sub-basins and then to the watershed outlet (Arnold et al. 1998). SWAT is an especially useful model for estimating watershed dynamics in agricultural ecosystems (Kalin and Hantush 2003).

A previously developed SWAT model for the UWRB was utilized in this study. The model was developed and calibrated for 1990-2012 and is further described in Sharma et al. (2013). The model consists of 481 sub-basins, and over 5,000 HRUs. To set up the model from 1974-1989, the previously developed model's corn and soybean management files were updated to account for the fertilizer, tillage, manure, and corn-soybean percentage data described above. Since the data above is generalized for either Indiana or a swath of counties in the UWRB, a Matlab® code was developed which randomly applied the management data to each of the corn and soybean HRUs, based on the land area percentages of the HRUs (Appendix B). The general management

information which was derived from the data described in the previous section is provided in Table 3.1. A subsequent Matlab® code was developed which converted the randomly assigned management information into SWAT formatted *.mgt* text files (Appendix C).

Because the land management information was randomly applied based on land area to individual HRUs, a Monte Carlo analyses was completed to evaluate the uncertainty in water quality outputs at the basin outlet. The model was run 100 times, each time with different, randomly applied management information using Purdue University's Carter supercomputer which has HP compute nodes with two 8-core Intel Xeon-E5 processors. The entire 100 runs took approximately 300 hours to complete. The average values and standard deviations of all runs were extracted using a Matlab® code (Appendix D), and average values were used in subsequent statistical analyses.

The final model was run from 1974-2009, using 4 years of warm-up (1974-1977). The averages of annual reach level data (sediment (tons), organic nitrogen (kg), organic phosphorus (kg), nitrate (kg), mineral phosphorus (kg), total nitrogen (kg), and total phosphorus (kg)) were extracted at the basin outlet for two reasons. First, the fish sampling data were available for the entire Wabash River, not individual sub-reaches, and the fish data were described on an annual basis. Second, examining sub-basin or HRU level results could prove to be less accurate due to the randomization of the fertilizer and tillage data. The same data were extracted at the daily scale to evaluate annual average concentrations.



Table 3.1 Overview of management operations implemented in SWAT UWRB model.

Year	Tillage Type (% land) [half tilled in fall, half spring]		Inorganic Fertilizer for Corn (% land receiving, amount)			Inorganic Fertilizer for Soybeans (% land receiving, amount)			Inorganic Fertilizer Application in Spring (% land)		Corn-Soyb LULC (%)		Amount of Manure Applied (kg/ha)	
	NoTill	Conv.	Min.	N (%)	P (%)	N lb/acre	P lb/acre	N (%)	P (%)	N	P	Soyb	Swine	Cattle
1974	6.4	89.9	3.7	99	102	99	74	49	10	54	38	40	17	17
1975	4.9	92.5	2.6	98	106	98	63	46	9	51	32	40	17	17
1976	22.5	69.9	7.6	100	129	100	84	48	10	54	34	40	19	15
1977	12.9	74.2	12.9	99	140	99	84	46	11	54	37	40	20	13
1978	5.7	84.0	10.2	99	130	97	75	41	11	56	39	40	20	13
1979	4.4	79.5	16.1	97	149	98	85	51	11	61	38	40	20	13
1980	4.4	76.1	19.5	99	148	100	77	39	11	49	44	40	21	12
1981	4.4	75.1	20.5	99	146	99	78	40	12	47	36	40	22	12
1982	6.4	68.8	24.8	99	152	98	69	25	11	34	39	40	22	12
1983	9.0	53.8	37.2	99	149	98	75	31	9	38	35	40	22	12
1984	6.6	64.2	29.2	99	155	98	72	35	10	48	41	40	22	11
1985	8.8	59.3	31.8	99	162	95	70	23	14	38	40	40	22	11
1986	8.1	53.2	38.7	99	157	95	75	16	11	31	49	40	22	11
1987	9.1	49.8	41.1	98	136	91	65	30	14	41	46	40	22	11
1988	8.9	49.2	41.9	97	146	92	71	31	18	41	40	40	22	11
1989	9.7	57.8	32.5	99	133	94	78	20	12	31	48	40	23	10
1990-2009	Chisel plow and disk plow in spring before corn; no-till soybeans			212 kg/ha of anhydrous ammonia in spring; 67 kg/ha P <sub>2</sub> O <sub>5</sub> in spring			No nitrogen; 56 kg/ha P <sub>2</sub> O <sub>5</sub> in spring			See previous		50	25	8

### 3.3.3.2 Model Assumptions

Due to the large spatial scale of this model, and the time period of analysis, some assumptions had to be made to set up the model. Although this earlier time period (1974-1989) follows the passing of the Clean Water Act of 1972, actual point source data were not included in this model because they were not available, outside of allowed (permitted) discharges. There are also only a couple of larger urban areas in the UWRB (Lafayette, IN, Kokomo, IN) that currently have less than 70,000 people each. Therefore, this study focused primarily on the changes induced by large-scale, conventional agriculture, rather than point source pollution control. Studies have also shown that urban point sources are typically much smaller contributors of nitrogen and phosphorus to surface waters (EPA, 2014). The second model assumption was that land use in the UWRB was not changing significantly, which is reasonable since the amount of harvested farmland stayed fairly constant during this time period (USDA NASS, 1999). Figure 3.8 also shows that corn and soybean acreage account for the majority of harvested cropland, therefore, only changing the management of these lands is a reasonable modeling decision.

### 3.3.3.3 Model Validation

The model was previously calibrated for streamflow and water quality for the 1990-2009 time period (Appendix E) showing good model performance. In order to check that the earlier outputs were reasonable, the simulated flow was compared to observed flow for the entire modelling period at the subbasin closest to the outlet that had available streamflow data (subbasin 428). The daily and yearly  $R^2$  values were calculated, as well as the Nash-Sutcliffe model efficiency (NSE) coefficient to ensure that the

streamflow was satisfactorily estimated by the SWAT model during the modeling period. Since water quality data during the earlier time period was not available near the outlet, a further comparison of the later time period water quality data was completed by comparing SWAT simulated water quality data to a recent USGS report on water quality in Indiana (Risch et al. 2014).

#### 3.3.4 Data Analysis

Statistical analyses completed in *R* were used to evaluate the relationship, if any, between the fish sampling data and the basin level water quality data. The annual load and the annual average concentrations of nutrients and sediment along with streamflow and precipitation were used in the analyses. Mann-Kendall trend tests were completed on each individual output data to test if there were any monotonic trends over the modelling period that might indicate a changing water quality regime. The second analysis was to evaluate the correlation between each variable and the percent of benthic invertivores. The time period for comparison was 1978-1999, 2002-2008, due to the availability of the fish data, as well as the exclusion of the modelling warm-up period. Finally, two linear regressions were performed on the annual load data and the annual average concentration data to see which model best predicted the benthic invertivore percentage. For each regression model, the correlation between the variables was determined, and the multicollinearity of the variables was evaluated using the variance inflation factor (VIF). The variable with the highest VIF was removed one at a time, until all VIFs for each variable were under five, ensuring that multicollinearity was not a problem. All dependent and independent variables were log transformed due to the differences in variance between many of the variables.

## 3.4 Results & Discussion

### 3.4.1 Modelling Results

The model streamflow validation statistics are provided in Table 3.2 and show that the model estimated streamflow well (Figure 3.10;  $R^2$  and NSE greater than 0.5) during both modelling periods, at both the daily and annual time scale (Moriassi et al. 2007). A comparison of estimated water quality data to Risch et al. (2014) showed comparable statistics for concentrations of nitrate, organic nitrogen, total phosphorus and suspended solids during 2000-2010 (Table 3.3).

The annual water quality loading averages from the 100 runs were graphed along with the standard deviation among the 100 runs (Figure 3.11) to ensure that the variation between runs was not significant. Since the variation was not large, it was assumed that the annual average values were reasonable to use in the statistical analyses. The annual concentration averages and standard deviations for each variable are plotted in Figure 3.12.

Table 3.2 Comparison of observed and simulated streamflow.

	Entire Modelling Period (1967-2009)	Calibrated Model Period (1990-2009)	Uncalibrated Model period (1967-1989)
R <sup>2</sup> Annual	0.83	0.87	0.77
R <sup>2</sup> Daily	0.62	0.64	0.59
NS Annual	0.78	0.80	0.67
NS Daily	0.61	0.63	0.57

Table 3.3 Comparison of SWAT estimated water quality and observed values reported by Risch et al. (2014) across the Wabash River Basin for 2000-2010. Values reported are **mean** [min, max].

Constituent	SWAT UWRB Outlet	Average of Wabash Basins from Risch et al. (2014)
Nitrate (mg/L)	<b>7.6</b> [0.2, 154]	<b>3.6</b> [0.1, 16.0]
Organic Nitrogen (mg/L)	<b>1.2</b> [0, 18.3]	<b>1.0</b> [0.1, 5.6]
Total Phosphorus (mg/L)	<b>0.2</b> [0, 2.7]	<b>0.19</b> [0.03, 2.10]
Suspended Solids (mg/L)	<b>38</b> [7, 719]	<b>55</b> [4, 1020]

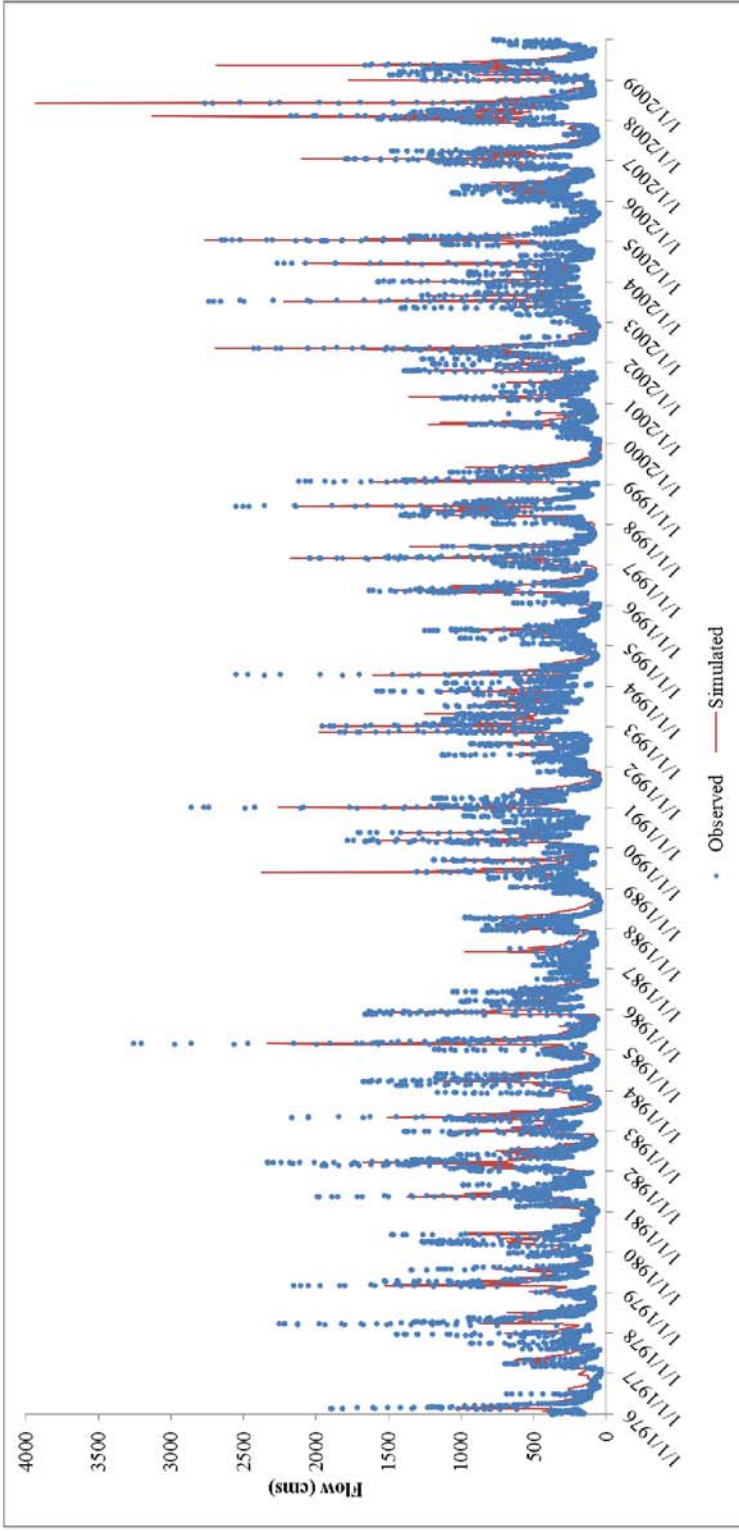


Figure 3.10 Hydrologic time series of observed vs. simulated streamflow values for the entire modelling period.

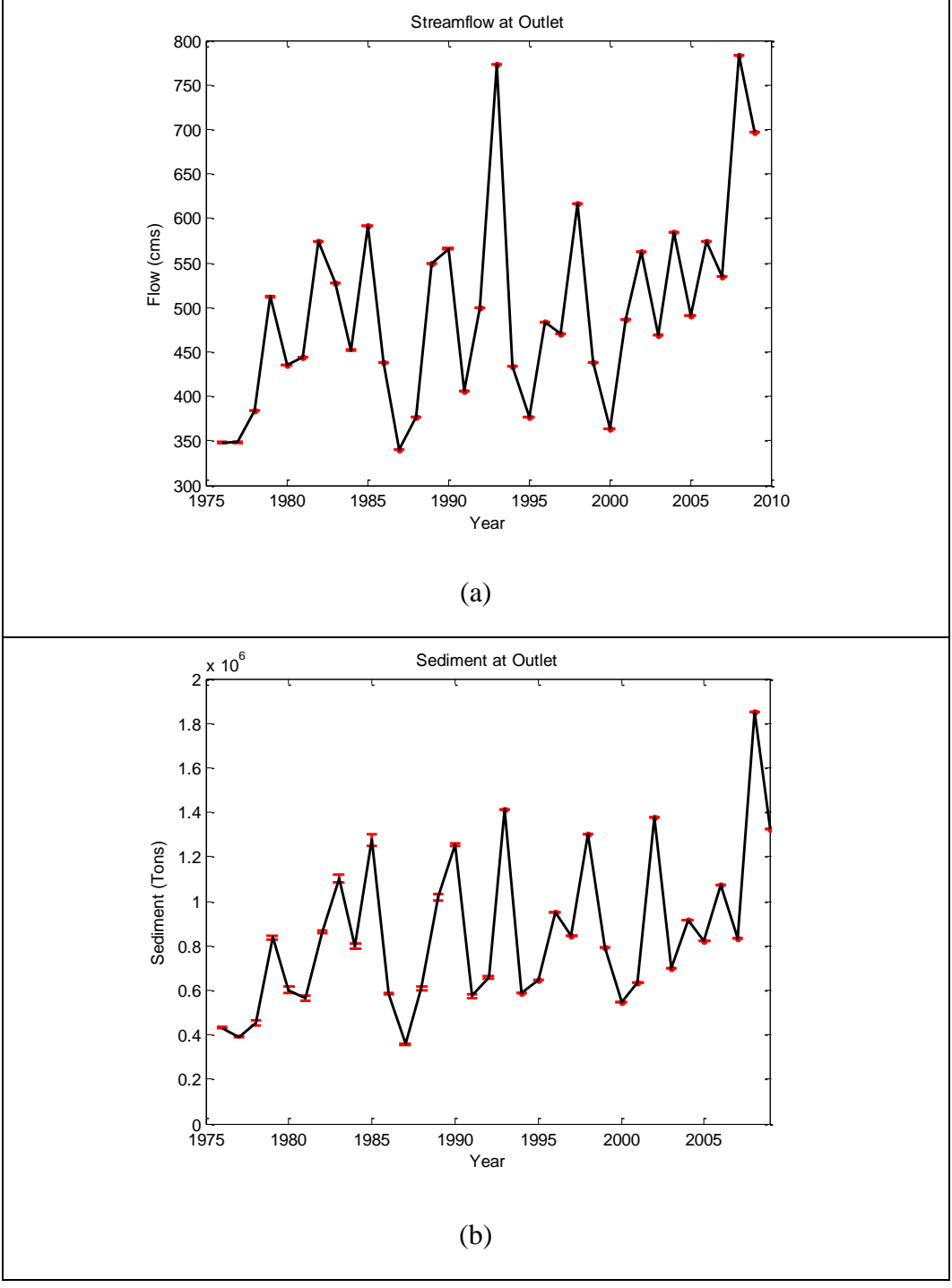


Figure 3.11 Average annual loadings from the 100 model runs plotted with standard deviation bands for streamflow (a), sediment (b), organic nitrogen (c), organic phosphorus (d), nitrate (e), mineral phosphorus (f), total nitrogen (g), total phosphorus (h), and the total nitrogen to total phosphorus ratio (i).

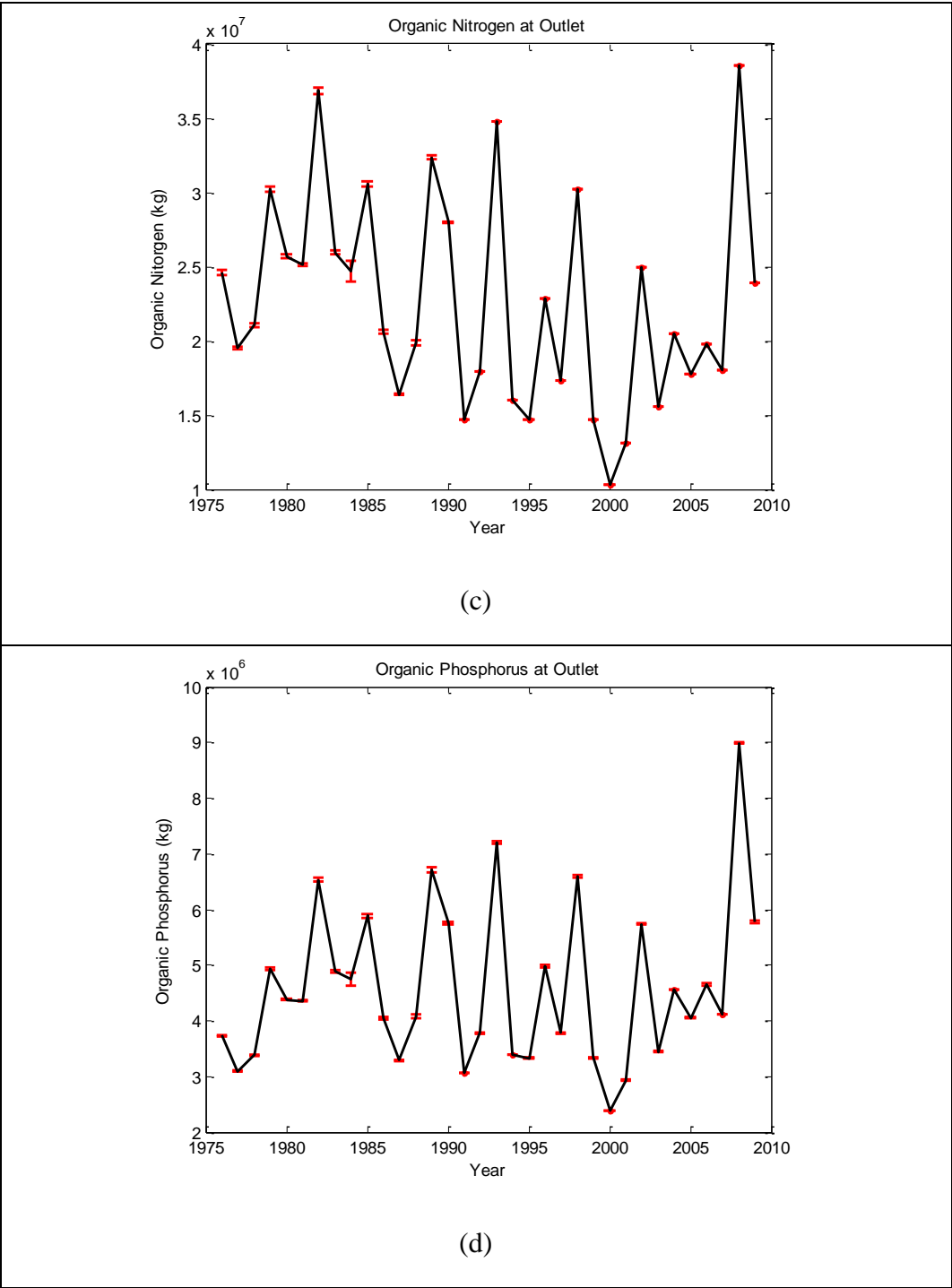


Figure 3.11 (Continued) Average annual loadings from the 100 model runs plotted with standard deviation bands for streamflow (a), sediment (b), organic nitrogen (c), organic phosphorus (d), nitrate (e), mineral phosphorus (f), total nitrogen (g), total phosphorus (h), and the total nitrogen to total phosphorus ratio (i).



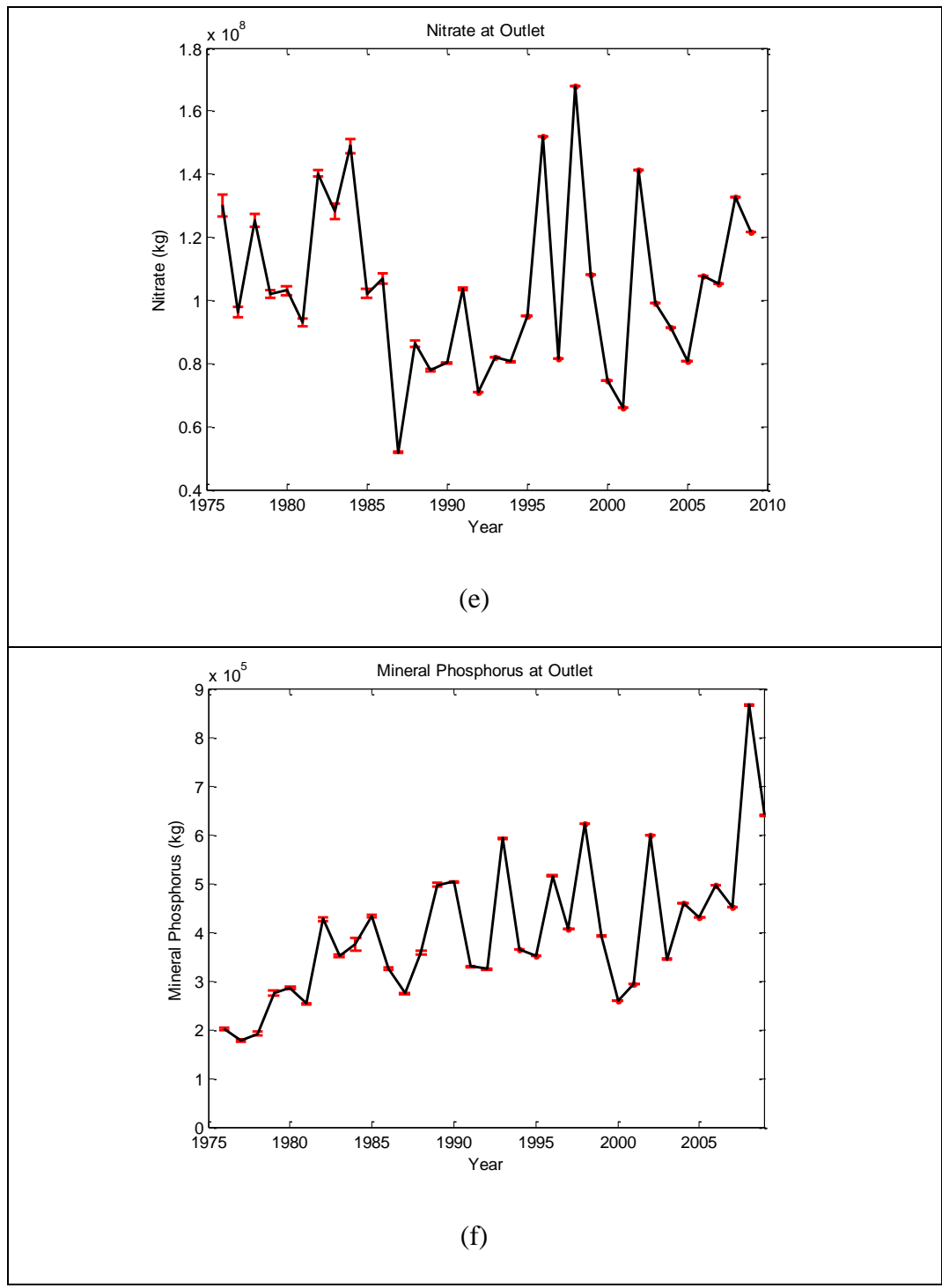


Figure 3.11 (Continued) Average annual loadings from the 100 model runs plotted with standard deviation bands for streamflow (a), sediment (b), organic nitrogen (c), organic phosphorus (d), nitrate (e), mineral phosphorus (f), total nitrogen (g), total phosphorus (h), and the total nitrogen to total phosphorus ratio (i).

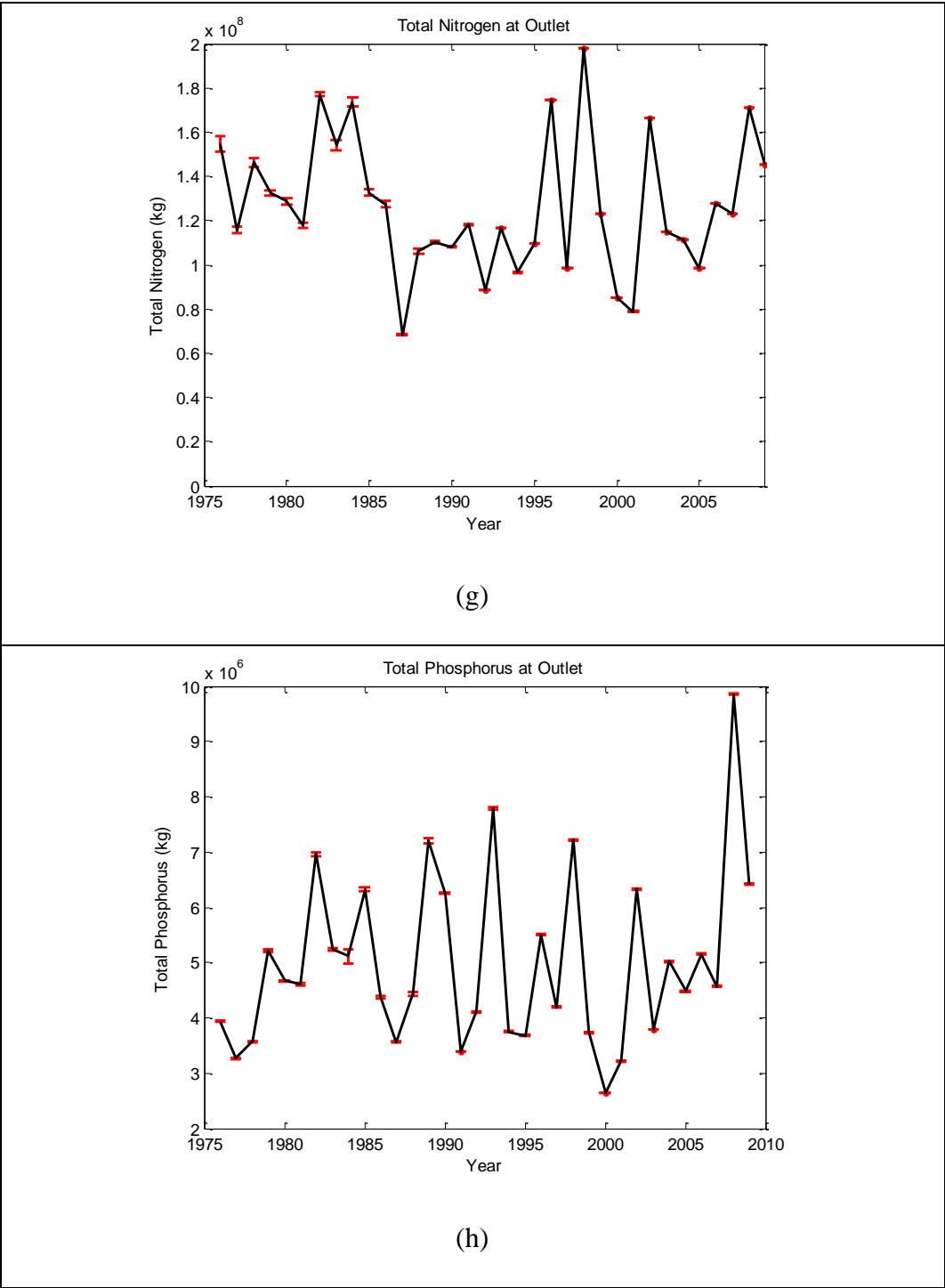


Figure 3.11 (Continued) Average annual loadings from the 100 model runs plotted with standard deviation bands for streamflow (a), sediment (b), organic nitrogen (c), organic phosphorus (d), nitrate (e), mineral phosphorus (f), total nitrogen (g), total phosphorus (h), and the total nitrogen to total phosphorus ratio (i).

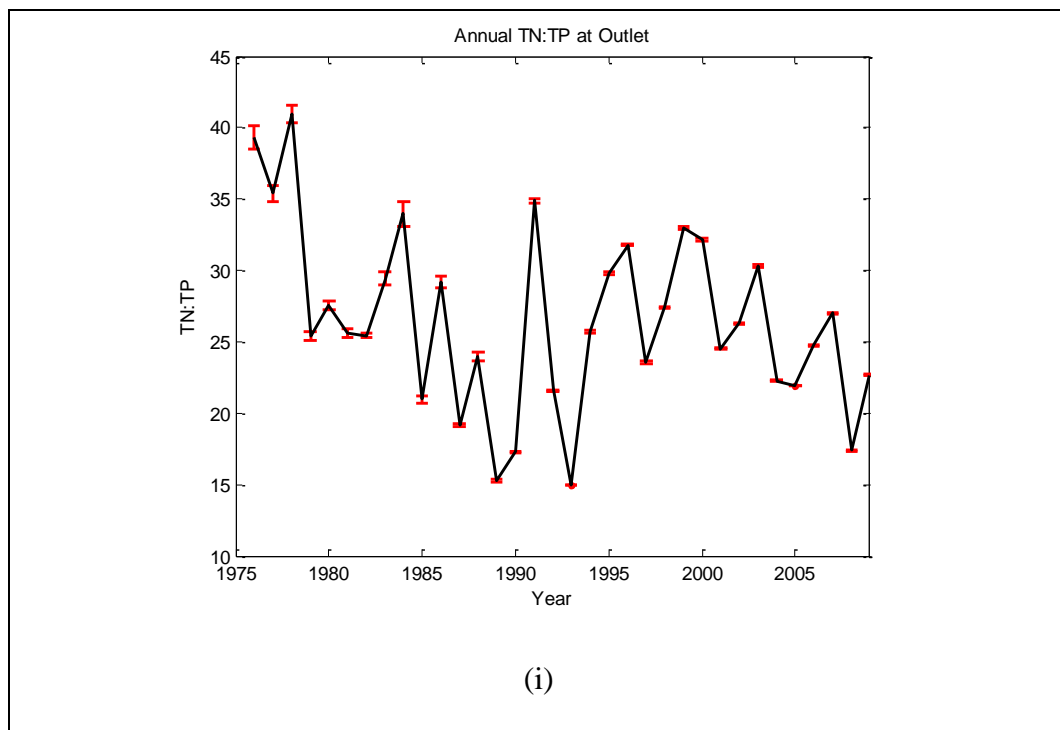


Figure 3.11 (Continued) Average annual loadings from the 100 model runs plotted with standard deviation bands for streamflow (a), sediment (b), organic nitrogen (c), organic phosphorus (d), nitrate (e), mineral phosphorus (f), total nitrogen (g), total phosphorus (h), and the total nitrogen to total phosphorus ratio (i).

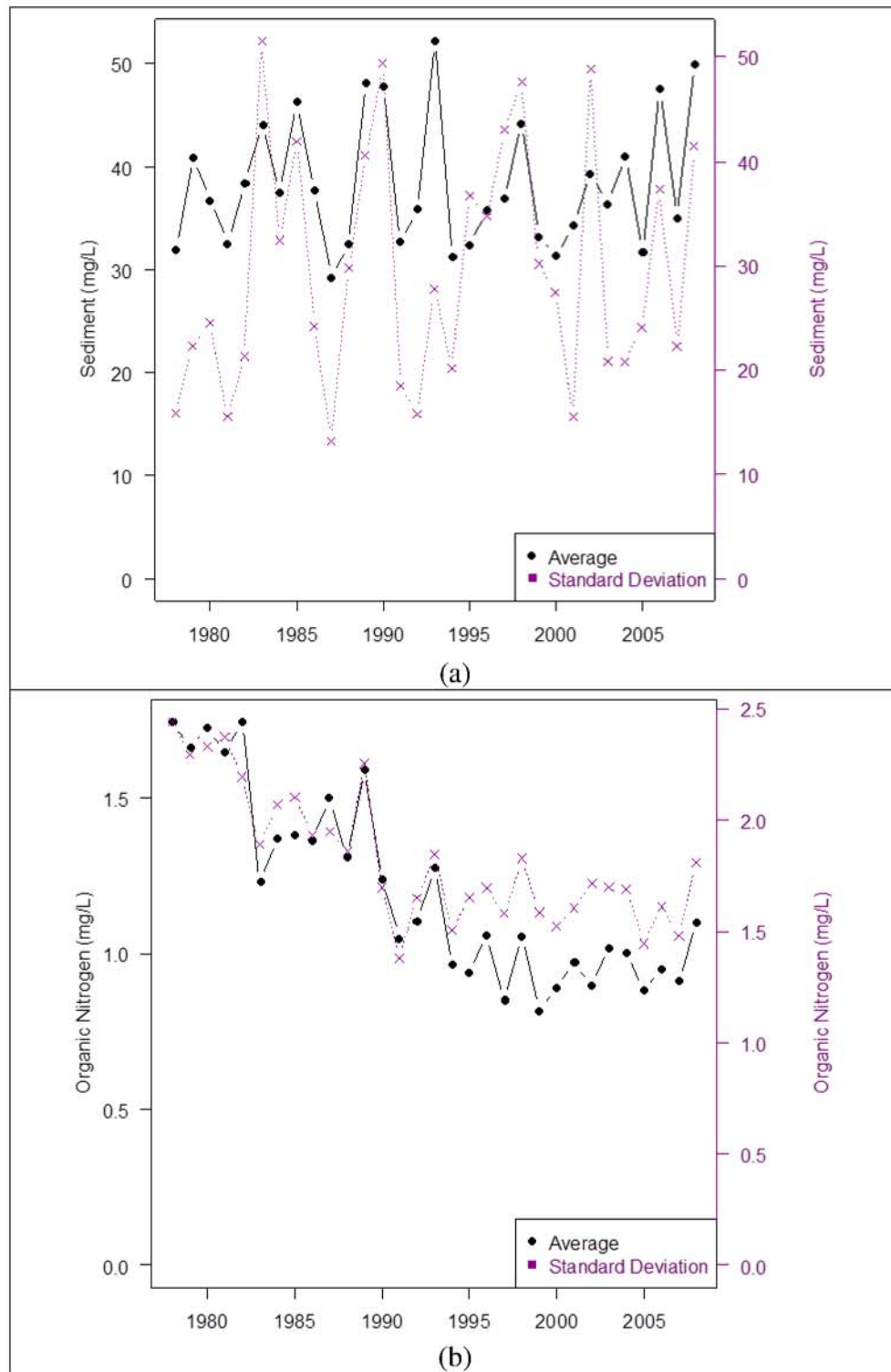


Figure 3.12 Annual average concentrations of sediment (a), organic nitrogen (b), organic phosphorus (c), nitrate (d), mineral phosphorus (e), total nitrogen (f), total phosphorus (g).

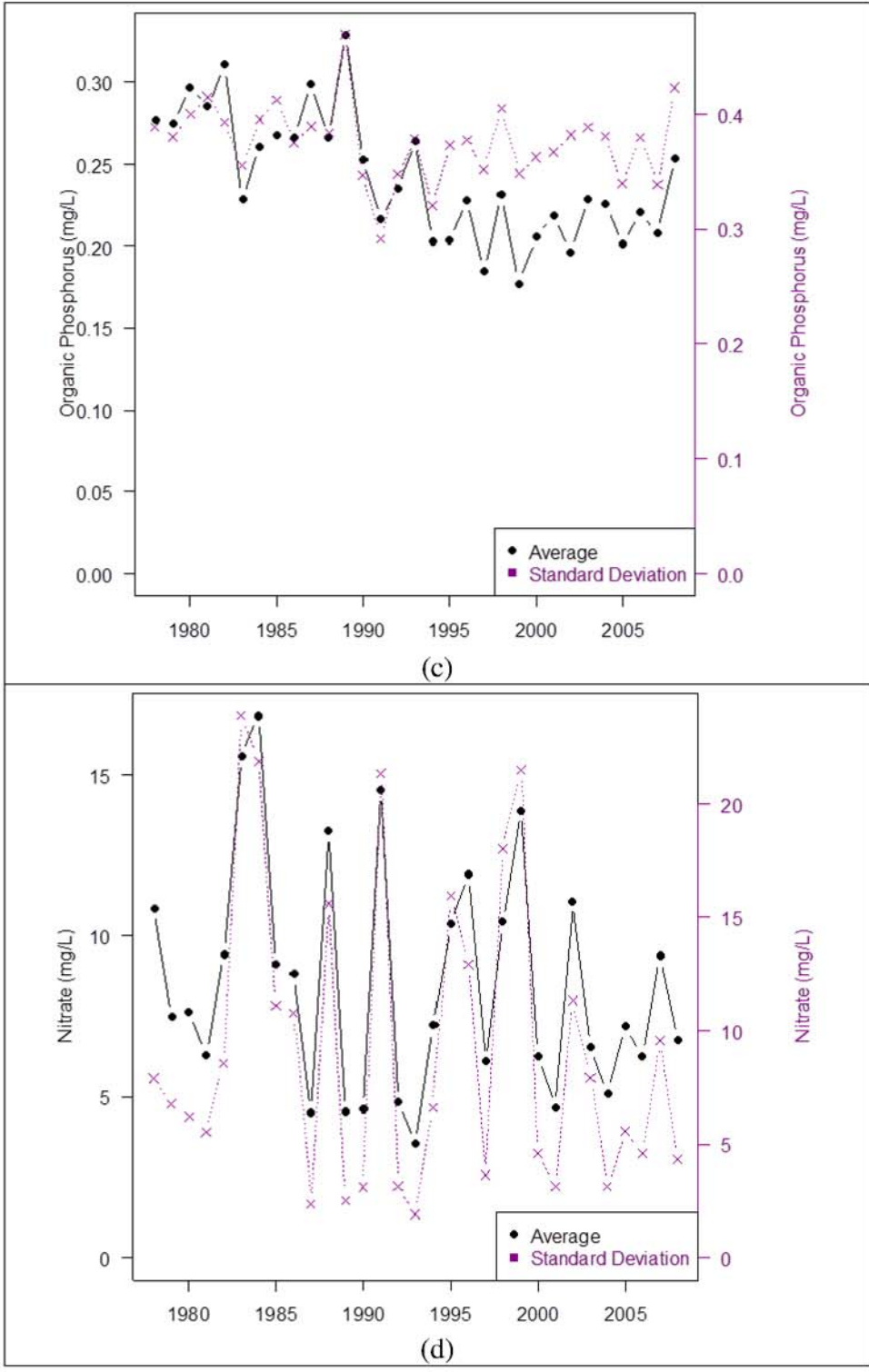


Figure 3.12 (Continued) Annual average concentrations of sediment (a), organic nitrogen (b), organic phosphorus (c), nitrate (d), mineral phosphorus (e), total nitrogen (f), total phosphorus (g).

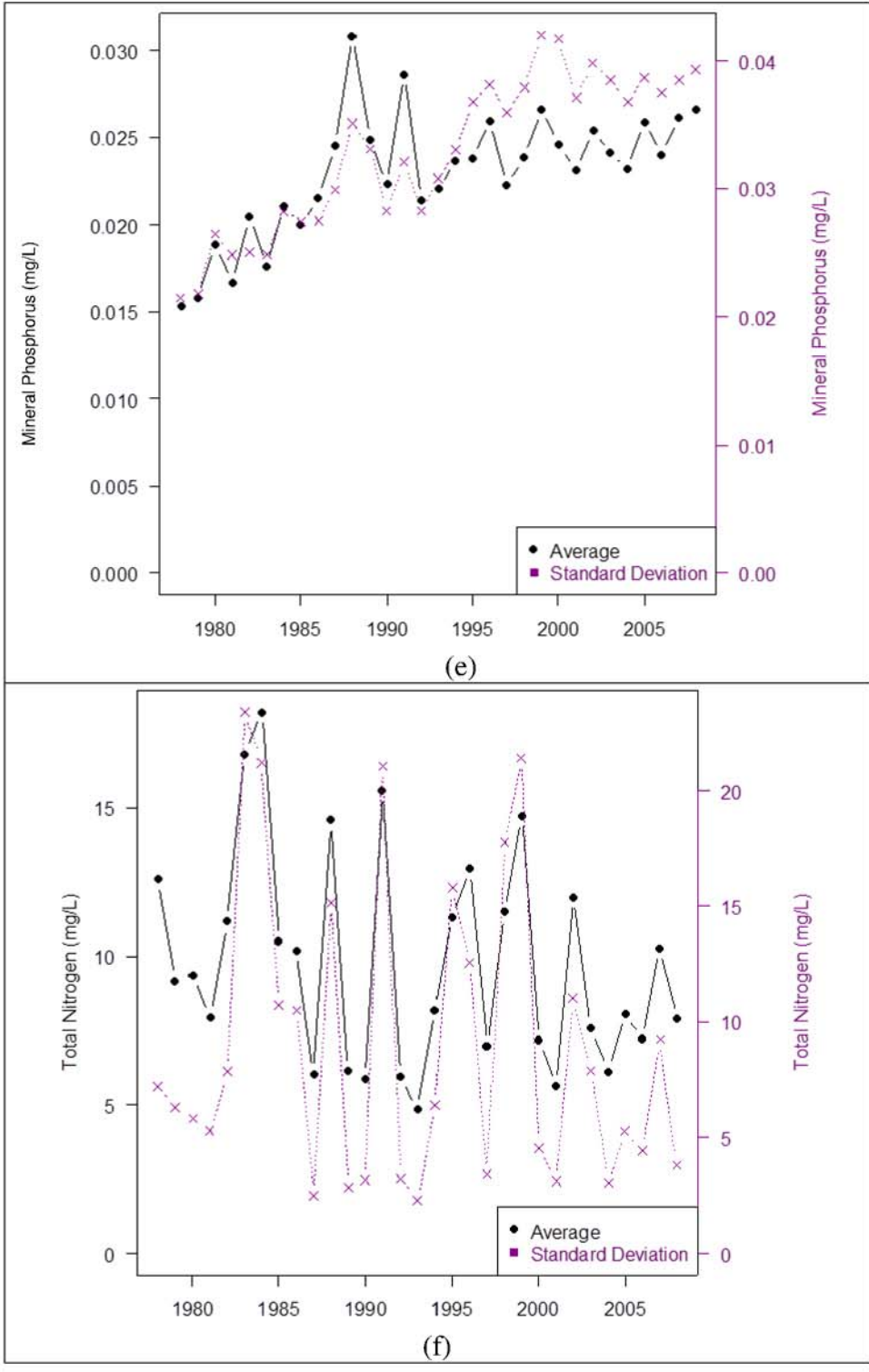


Figure 3.12 (Continued) Annual average concentrations of sediment (a), organic nitrogen (b), organic phosphorus (c), nitrate (d), mineral phosphorus (e), total nitrogen (f), total phosphorus (g).

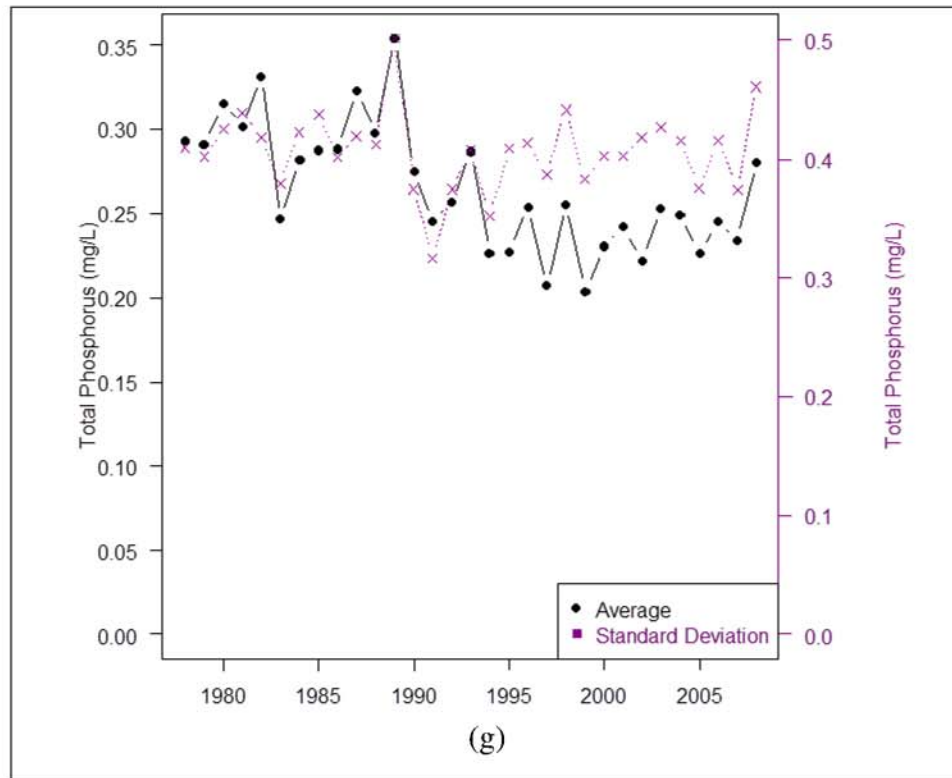


Figure 3.12 (Continued) Annual average concentrations of sediment (a), organic nitrogen (b), organic phosphorus (c), nitrate (d), mineral phosphorus (e), total nitrogen (f), total phosphorus (g).

### 3.4.2 Data Analysis

Mann-Kendall trend tests were performed on precipitation, streamflow, the annual sediment and nutrient loads, and the annual average sediment and nutrient concentrations. The Mann-Kendall test is utilized to test whether or not there is an upward or downward monotonic trend over time (Yue et al. 2002). Organic nitrogen and mineral phosphorus annual loads demonstrate significant ( $p < 0.05$ ) downward and upward monotonic trends, respectively (Table 3.4). Precipitation and streamflow exhibit somewhat significant ( $0.05 < p < 0.10$ ) upward trends during the time period. Four annual average concentration variables showed significant trends during the time period: organic nitrogen, organic phosphorus, mineral phosphorus, total phosphorus (Table 3.4). These trends identified during the modelling period do not necessarily inform what caused the fish regime change, but they do provide an overall assessment that water quality was changing during this time period.

The correlation coefficients and squared correlation coefficients ( $R^2$ ) were determined between all variables and the percent of benthic invertivores (Table 3.4). Since Broadway et al. (*In Review*) found a relationship between the three major fish trophic levels, only one trophic level percent was used as the independent variable. The benthic invertivores showed the most change during the time period so this was used as the independent variable. Mineral phosphorus annual load and annual average concentration showed high correlation to the percent of benthic invertivores ( $R^2 > 0.4$ ). Other variables with high correlation to the percent of benthic invertivores included annual average concentrations of organic nitrogen, organic phosphorus, and total phosphorus.



Table 3.4 Initial statistics for annual loads and daily concentration statistics.

Variable	Mann-Kendall Test on Variables			Correlation (Benthic Invertivores)	R <sup>2</sup> (Benthic Invertivores)	
	<i>tau</i>	<i>S</i>	<i>p</i>			
Annual Loads	Sediment (tons)	0.24	111	0.06	0.31	0.09
	Organic Nitrogen (kg)	-0.25	-117	0.05	-0.22	0.05
	Organic Phosphorus (kg)	-0.05	-23	0.71	0.06	0.003
	Nitrate (kg)	-0.03	-15	0.81	-0.04	0.002
	Mineral Phosphorus (kg)	0.38	175	0.003	0.47	0.22
	Total Nitrogen (kg)	-0.14	-67	0.26	-0.09	0.007
	Total Phosphorus (kg)	-0.02	-7	0.92	0.09	0.008
	TN:TP (ratio)	-0.09	-41	0.50	-0.21	0.04
	Precipitation (mm)	0.22	88	0.10	0.26	0.07
Annual Average	Sediment (mg/L)	0.05	25	0.68	0.04	0.002
	Organic Nitrogen (mg/L)	-0.63	-295	6e-07	-0.69	0.48
	Organic Phosphorus (mg/L)	-0.49	-229	1e-04	-0.57	0.32
	Nitrate (mg/L)	-0.11	-51	0.40	-0.27	0.08
	Mineral Phosphorus (mg/L)	0.55	255	2e-05	0.51	0.26
	Total Nitrogen (mg/L)	-0.16	-73	0.22	-0.33	0.11
	Total Phosphorus (mg/L)	-0.47	-217	2e-04	-0.54	0.29
	Flow (m <sup>3</sup> /s)	0.20	93	0.12	0.34	0.12

From the two regression models described in the methods, mineral phosphorus was a predictor for both models (Table 3.5). Other predictors included organic nitrogen, nitrate, and organic phosphorus. The annual concentration average model gave the highest  $R^2$  value, though the annual loads model performed similarly with fewer variables included.

The annual loads regression model included the consideration of precipitation, organic nitrogen, nitrate, and mineral phosphorus. All other variables were removed due to multicollinearity problems (Figure 3.13). The final selected model included two variables: organic nitrogen and mineral phosphorus. These two variables had opposite effects on the predicted percent of benthic invertivores. More organic nitrogen decreased the percent of benthic invertivores whereas more mineral phosphorus increased the percent of benthic invertivores.

The annual concentration average regression model included the consideration of precipitation, sediment, organic phosphorus, nitrate, and mineral phosphorus after variables causing multicollinearity problems were removed (Figure 3.14). Similarly to the annual loads model, increasing mineral phosphorus was predicted to increase the percent of benthic invertivores, whereas nitrate and organic phosphorus had the opposite effect.

Table 3.5 Best regression model results for benthic invertivores.

Model	Significant Variables	Coefficient Estimate	Pr(> t )	Model R <sup>2</sup>
Annual Loads	Organic Nitrogen	-2.1	2.2e-05	0.63
	Mineral Phosphorus	2.4	1.8e-06	
Annual daily concentration averages	Intercept	11.6	8e-04	0.69
	Organic Phosphorus	-2.6	0.002	
	Nitrate	-0.84	0.003	
	Mineral Phosphorus	-2.8	3e-04	



Figure 3.13 Correlation matrix for the annual loads regression model. The larger the circle the greater the correlation. Blue colors indicate positive correlation and red colors indicate negative correlation.

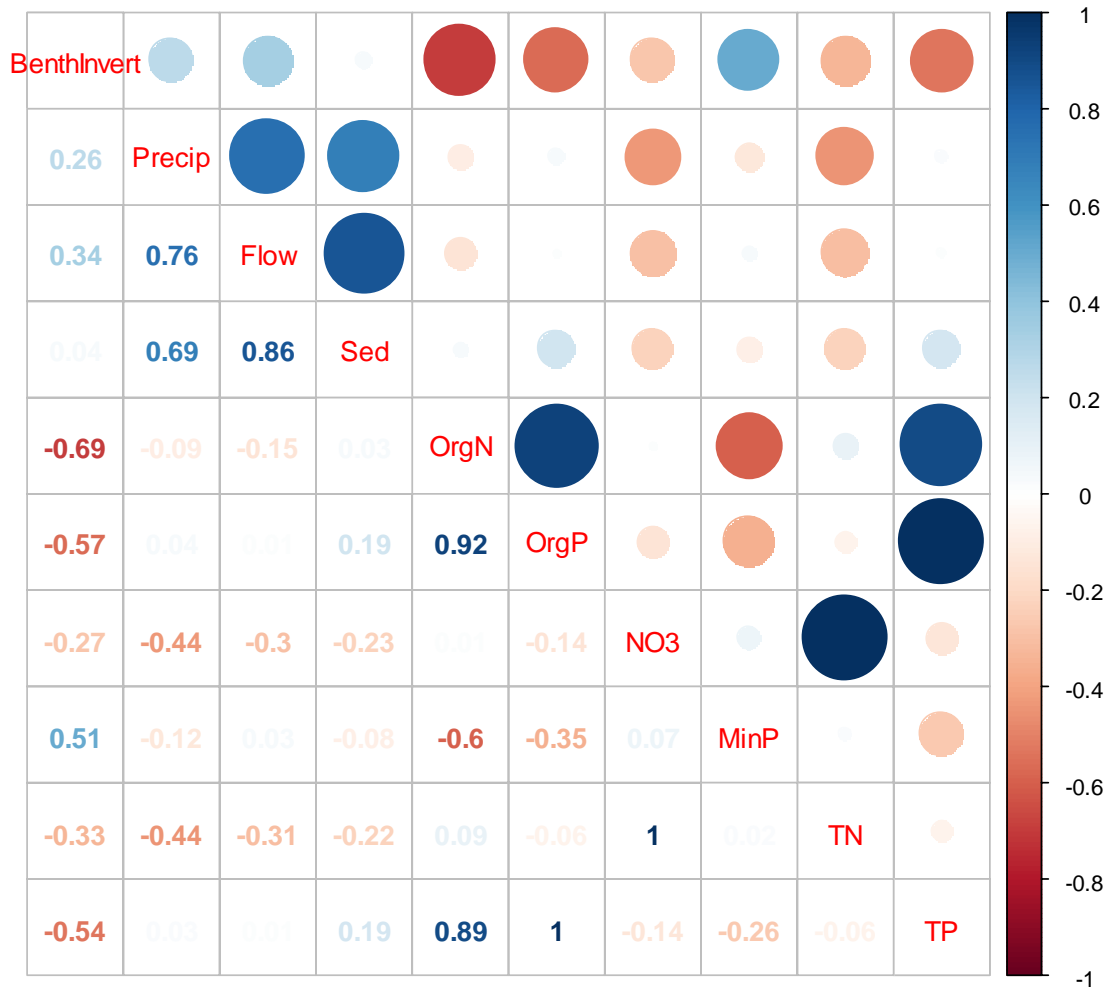


Figure 3.14 Correlation matrix for the annual average concentration model. The larger the circle the greater the correlation. Blue colors indicate positive correlation and red colors indicate negative correlation.

### 3.4.3 Relationship Between Fish Regime Change and Water Quality Changes

From the statistical analyses, it appears that there is an association between water quality changes due to changing agricultural practices and possibly increased precipitation and the identified change in the fish regime in the Wabash River. Over the modelling time period (1974-2009), conventional agricultural tillage and fertilization practices in Indiana were changing as shown from the USDA ERS data, the Indiana fertilizer sales data, and the *No-Till Farmer* tillage surveys. These changes combined with a slightly upward trend seen in precipitation appear to be associated with the fish regime change. The mineral phosphorus annual load and annual average concentration both were associated with an increase in benthic invertivores. During this time period the amount of phosphorus applied to soybeans increased from 40 kg/ha to 50 kg/ha (Figure 3.4), while slight increases in phosphorus fertilizer applications were also seen in corn. This relatively recent (last 50 years) observation of increased phosphorus loads to streams in the U.S. has also been documented in other research (David and Gentry 2000). There was also a change in the type of phosphorus fertilizer applied, mainly the substitution of 10-34-0 (Ammonium Polyphosphate/APP) for 0-45-0 (Triple Superphosphate/TSP) though the difference in the solubility seen in these two fertilizers cannot currently be modeled in SWAT. An association between organic nitrogen and benthic invertivores was also observed. The decline in conventional tillage, along with the observed decline in cattle numbers (which are higher producers of nitrogen than swine) are likely the major influencers of the decline of mineral nitrogen in UWRB. Average annual nitrate concentrations also showed an association with the percent of benthic invertivores.

During this time period, the amount of nitrogen applied to corn on average increased from approximately 120 kg/ha in the mid-1970s to 150 kg/ha in the early 1990s (Figure 3.3).

Although it appears that nitrogen and phosphorus in streams were associated with changing agricultural practices, it should be noted that precipitation and streamflow were also correlated with the percent of benthic invertivores and showed slightly significant ( $0.05 < p < 0.10$ ) upward trends during this time period. These variables are not seen in the final regression models because they were excluded due to multicollinearity problems, though it is likely that precipitation influenced nutrient concentrations (Jacobson et al. 2010). Generally, the observed regime change appeared to be most associated with the in-stream nutrients, which were likely changing based on a combination of changing agricultural practices and climate (Hatfield et al. 2013).

Overall, these findings suggest that changing nutrient regimes in the Wabash River were associated with the changing fish regime. Previous research has shown that nitrogen and phosphorus levels can impact freshwater fish community compositions in both lakes and rivers (Yurk and Ney 1989; Mitner and Rankin 1998; Bennett et al. 2001; Wang et al. 2007; Justus et al. 2009; Einheuser et al. 2013; Perkin and Bonner 2014). Bernot et al. (2006) even demonstrated that in streams in Indiana and Michigan, nitrate uptake was saturated, but phosphorus uptake increased with higher concentrations. This finding suggests that phosphorus may have the ability to influence stream ecosystems more than nitrogen in the Midwest, as they may be phosphorus limited (Ryden et al. 1974; Van Nieuwenhuysse and Jones 1994; Correll 1999; Hill and Fanta 2008). This potential phosphorus limitation may be further evidenced by the estimated change in the total

nitrogen to total phosphorus (TN:TP) annual loads ratio in the Wabash River which showed a slight negative correlation (-0.21) to the percent of benthic invertivores during the modeling period.

The connection between the nutrient levels and the fish community is likely due to the relationship between phosphorus and nitrogen and the algal communities, due to the link between algae and fish in the food chain. Many studies have shown that algal communities are influenced by the amount of phosphorus and nitrogen in a system (Biggs, 2000; Dodds et al. 2002; Rier and Stevenson 2006; Justus et al. 2009; Chambers et al. 2012; Stevenson et al. 2012; Suplee et al. 2012; Smucker et al. 2013). Although the form of nutrient (total, inorganic, organic, ratio of N:P, etc.), as well as which nutrient (nitrogen or phosphorus) had the greater impact varied, it is evident from the literature that nitrogen and phosphorus control the community structure and growth of algae in streams. Some studies have specifically shown that the algal community composition itself can change due to changing nutrient inputs (Stelzer and Lamberti 2001; Hill et al. 2009). In Midwestern streams specifically, the algal community has been shown to be extremely dependent on nutrient concentrations (Riseng et al. 2004; Bernot et al. 2006; Lowe et al. 2008; Andrus et al. 2015). Although this study can't demonstrate the direct connection between the changing nutrient regimes in the Wabash River and the fish regime change, it does establish that these two occurrences are correlated and previous research has shown that this association is probably due to the changes in algae communities and thus the larger stream ecosystem.

#### 3.4.4 Limitations of Study

The major limitations of this study include (1) model assumptions, (2) model limitations, and (3) lack of water quality data for validation. The major model assumption in this study was the exclusion of point source data. Although urban point sources have been shown to be smaller contributors of nutrients to streams (EPA, 2014), incorporating them into the model would improve the confidence of the results. Secondly, the model as setup is only able to evaluate entire UWRB water quality and fish regimes. This is partly due to the fact that the fish data were available as annual, reach-scale compositions. Also, because the management data were primarily available at the state level, the management information had to be randomized across the entire watershed. Because of this, no comparisons can be made between upper reaches water quality and fish capture data, as the model is not as reliable at smaller spatial scales due to the randomization of management practices. Lastly, although the model was validated for streamflow during the entire modeling period, it was only validated for water quality during the later time period due to the lack of water quality data available. Being able to validate the water quality estimates during the early time period would further improve the confidence of this model.

#### 3.5 Conclusion

Although ecosystem regime shifts can occur naturally, changes in land use and land management due to anthropogenic needs may alter species composition. This study demonstrated that a combination of increasing precipitation and changing agricultural management practices were associated with the increased percent of benthic invertivores in the Wabash River. Although nutrients in fertilizers are inherently linked to



productivity in water bodies, water quality data may not exist to examine the influence of these nutrients on aquatic regime changes. By utilizing a watershed model, the nitrogen and phosphorus loadings and concentrations in the Wabash River were estimated during a time period where only a limited water quality data are available. Through the use of this model, the association between the observed fish regime change in the Wabash River and the changing water quality regime in the Wabash River was identified.

## 4 EVALUATION OF CLIMATE REGULATION ECOSYSTEM SERVICES UTILIZING A MULTI-OBJECTIVE GENETIC ALGORITHM CALIBRATION AND VALIDATION PROCEDURE FOR DAYCENT

### 4.1 Abstract

Evaluating ecosystem services (benefits that people receive from the environment) is critical for ensuring that land management and policy decisions don't create feedback loops that may diminish ecosystem services and even human well-being. Climate regulation provides and maintains an environment in which humans can live. Ecosystems impact climate in many ways, such as being sources of greenhouse gas emissions, and sinks for carbon. Quantifying these ecosystem processes is a first step to evaluating climate regulation. DayCent is a biogeochemical model that has been widely applied to simulate ecosystem processes including carbon cycling and greenhouse gas emissions. Although the DayCent model has been used to simulate multiple ecosystem types with good results using no calibration or "trial-and-error" calibration, more recently advanced calibration techniques have been utilized to improve model performance. The objectives of this research were to calibrate the DayCent model for multiple plots at the Water Quality Field Station in West Lafayette, Indiana, United States using a multi-objective function genetic algorithm technique, and then propose and evaluate a method for quantifying climate regulation ecosystem services at the local scale considering carbon storage and greenhouse gas emissions. The calibration results showed that although the

model performance improved overall for both biomass yield and N<sub>2</sub>O emissions, the impact on plot level N<sub>2</sub>O emissions varied. Plots with higher N<sub>2</sub>O emissions (continuous corn) influenced the calibration more than plots with lower N<sub>2</sub>O emissions (corn-soybean, switchgrass). Calibrating within treatments may be preferable to improve plot-level performance. The method developed for quantifying climate regulation ecosystem services performed well when applied to one randomly selected plot; the index developed showed higher climate regulation for tall grass prairie and switchgrass plots, and low climate regulation for continuous corn and soybean plots. Overall this research contributes to the quantification of climate regulation ecosystem services by demonstrating a multi-objective function calibration of DayCent, and by proposing a method for quantifying climate regulation ecosystem services.

#### 4.2 Introduction

Ecosystem services provide people with more than just products from nature; they also maintain a safe, habitable environment by providing regulatory ecosystem services (MEA, 2005). One regulatory ecosystem service, climate regulation, helps to maintain an atmospheric chemistry that supports human life (MEA 2005). Although ecosystems can be both sources and sinks for many air quality components and greenhouse gases, anthropogenic forces have been shown to greatly influence the global biogeochemical cycle (Anderson-Teixeira et al. 2012; Hungate and Hampton 2012). Leading anthropogenic activities for changes in greenhouse gas concentrations are deforestation, biomass burning, burning of fossil fuels, and agricultural practices. Between 60-84% of global nitrous oxide (N<sub>2</sub>O) emissions come from agriculture (Smith et al. 2007; Smith et al. 2008), primarily due to fertilizer application to support agricultural production

(Robertson et al. 2000; MEA, 2005) and 10-30% of all anthropogenic greenhouse gas emissions come from agricultural activities (Del Grosso et al. 2009; Tubiello et al. 2012). Nitrous oxide also has a long lifespan in the atmosphere, with almost 300 times the 100-year global warming potential (amount of heat that can be trapped in the atmosphere) compared to carbon dioxide (MEA, 2005; Del Grosso et al. 2008a).

Quantifying the impact of agricultural management on greenhouse emissions is key to evaluating climate regulation and including this ecosystem service in management and policy decisions (de Groot et al. 2010). Since measuring greenhouse gas emissions from landscapes can be resource and time intensive (Del Grosso et al. 2008b), many biogeochemical models have been developed to estimate greenhouse gas emissions on various scales: CoupModel (Nylinder et al. 2011), DayCent (Parton et al. 1998), DNDC (Li 2000), EPIC (Williams 1990). These models use both empirical and physics-based equations to estimate the biogeochemical cycle. DayCent is a field-scale model that has been employed by a number of users to simulate the impacts of land use and land management on terrestrial ecosystem processes (Rafique et al. 2013). The model has been widely applied to agricultural fields with much success, making it a good model for estimating greenhouse gas flux from agricultural lands.

Although the DayCent model has been shown to simulate ecosystem processes well in some studies with little calibration effort (Del Grosso et al. 2005; Stehfest et al. 2007; Del Grosso et al. 2008b; Jarecki et al. 2008; Chamberlain et al. 2011; Lee et al. 2012), many users calibrate their models more intensely to improve model performance. Some studies use a 'trial and error' approach to calibration (De Gryze et al. 2010; Hartman et al. 2011; Scheer et al. 2014), while more recently, researchers have begun to

apply more advanced parameter calibration methods such as the Parameter Estimation Software Tool (PEST) and Bayesian techniques (van Oijen et al. 2011; Rafique et al. 2013; Rafique et a. 2014). Using the ‘trial and error’ method usually involves manually changing one parameter at a time, comparing the simulated output to observed data and then updating the model parameters as the user sees fit until a reasonable agreement between model predictions and observed data is obtained. This method can be somewhat subjective, and relies heavily upon the user’s understanding of model behavior. More recently, automated calibration methods have been spurred by the recent advancement in availability of computing resources and the development of algorithmic optimization programs (Rafique et al. 2013). The automated approaches generally utilize one objective function which compares model output to observed data, then change parameter sets aiming to minimize/maximize the objective function until a predefined criterion is reached. These algorithmic approaches can provide a method for calibrating models that is less influenced by user biases, as they utilize statistical methods and can examine multiple parameters simultaneously. Some subjectivity still exists in these approaches in selecting objective functions, as well as selection of the final parameter set, if equifinality is an issue (Beven 2006). Previous automated calibrations have been performed on DayCent (Rafique et al. 2013; Rafique et al. 2014) using the parameter estimation software (PEST; Doherty 1994), and computing one objective function for one plot. No studies, to our knowledge, have utilized the Multi ALgorithm Genetically Adaptive Method (AMALGAM) genetic algorithm- a genetic algorithm approach which utilizes the power of multiple algorithms and concepts from evolution to solve an optimization - or used more than one objective function to calibrate DayCent.

The first objective of this research was to calibrate the DayCent model using the AMALGAM genetic algorithm to improve estimations of yield and N<sub>2</sub>O emissions, using two objective functions (minimizing error between yield estimates and observations and minimizing error between N<sub>2</sub>O emissions estimates and observations). By first calibrating the N<sub>2</sub>O emissions and yield, other greenhouse gas emissions estimations by DayCent can be considered reasonable (Rafique et al. 2014). By utilizing two objective functions, this work will help demonstrate how effective a multi-objective genetic algorithm approach may be used to improving model parameter estimates. The second objective of this research was to use one of the calibrated models to evaluate climate regulation ecosystem services based on greenhouse gas emissions and belowground carbon storage.

### 4.3 Methods

#### 4.3.1 DayCent Model

The DayCent model is a field-scale, biogeochemical ecosystem model which simulates the partitioning of carbon and nitrogen between the atmosphere, plants/crops, and the soil (Parton et al. 1998; Shaffer et al. 2001; Del Grosso et al. 2008). The model requires inputs of weather (max/min temperature, precipitation), soils data (bulk density, texture, wilting point, field capacity, pH, etc.), crop/plant data, and site information (latitude, longitude, etc.). The DayCent model was developed as a daily version of the monthly CENTURY model (Parton et al. 1994), and therefore its subroutines are similar. The heart of the model is its soil carbon routine which simulates three pools of carbon: active, passive, and slow with respect to their turnover rate. Nitrogen in these pools follows carbon, and the flow of carbon and nitrogen between these pools is controlled by C/N ratios of plant materials, lignin content of plants, precipitation and temperature (Del

Grosso et al. 2008). The plant production subroutine determines a maximum growth rate based on genetic potential, and then decreases that production based on nutrient and water availability, temperature, and solar radiation. Plant management data, such as planting and harvesting dates, fertilizer application, tillage, grazing, and fires can also be included in the model. Nitrous oxide gas fluxes are driven by ammonia and nitrate concentrations in the soil, as well as soil properties such as temperature, texture, and water content (Del Grosso et al. 2000; Parton et al. 2001; Del Grosso et al. 2008; Rafique et al. 2013). Details of the DayCent modelling methodologies are described in Shaffer et al. 2001. DayCent model outputs include: greenhouse gas flux ( $N_2O$ ,  $NO_x$ ,  $N_2$ ,  $CO_2$ ,  $CH_4$ ), soil organic matter, soil water content, and yield (grain, above and belowground biomass) which can be extracted daily, or cumulatively over a month, year, or growing season.

#### 4.3.2 Study Site and Available Data

The study site for this research was the Water Quality Field Station (WQFS) located at Purdue University's Agronomy Center for Research & Education in Central Indiana ( $40^{\circ} 20' 55.20''$  N;  $86^{\circ} 59' 53.23''$  W; Figure 4.1). The WQFS sits on soil that is primarily a Drummer series, a very deep, poorly drained soil (fine-silty, mixed, superactive, mesic Typic Enoaquicoll), with a small percent of the plot areas on a Raub-Brenton complex which is a very deep, somewhat poorly drained soil (fine-silty, mixed, superactive, mesic Aquic Argiudoll). The plots are all entirely rain-fed and received an average of 977 mm of precipitation a year, with an annual mean temperature of  $11^{\circ}C$  based on observed data from 1997 to 2013 (Figure 4.2). Each plot has sub-surface tile drains that help to reduce the naturally high water table, typical of much of Indiana and used extensively in Indiana agricultural lands (Naz et al. 2009).

WQFS hosts 48 10m x 48.5m test plots which have 12 treatments in a randomized complete-block design with four replicates each (Brouder et al. 2014). For this study, however, only treatments 3, 4, 6/7, and 12 were used (Table 4.1) representing no-till continuous corn, switchgrass, corn and soybean rotation, and tilled continuous corn management practices, respectively. These treatments were selected to provide a variety of land use and management for modeling. Not all treatment replicates were used in this study either; only two plots for treatments 3 (no-till continuous corn), 4 (switchgrass), and 12 (tilled continuous corn) were used, and four plots from the paired treatments 6 and 7 (corn-soybean rotations) were used. A total of five calibration plots and five validation plots were randomly selected and utilized in this study.



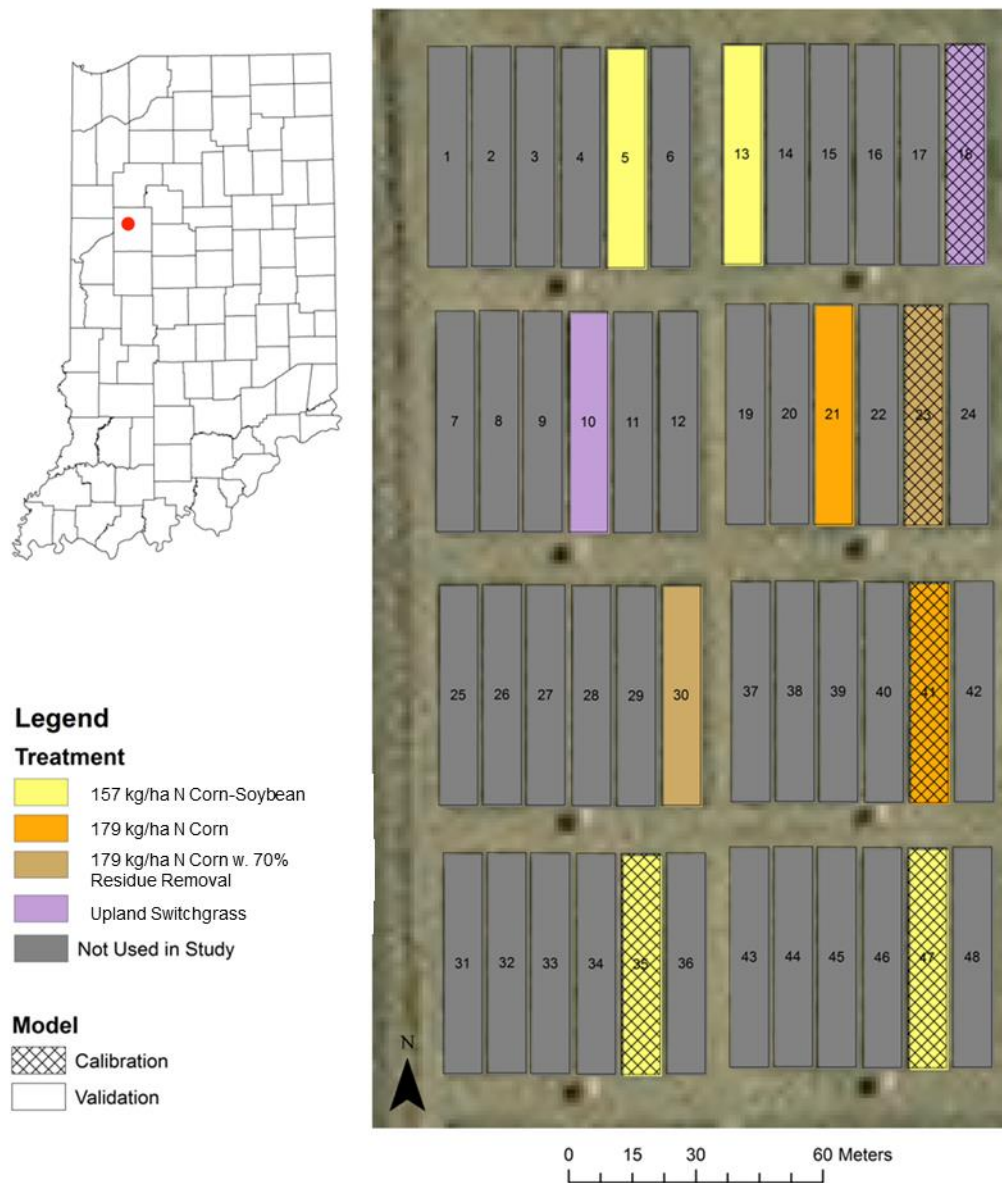


Figure 4.1 Location of WQFS, as well as plots included in this study and their treatment.

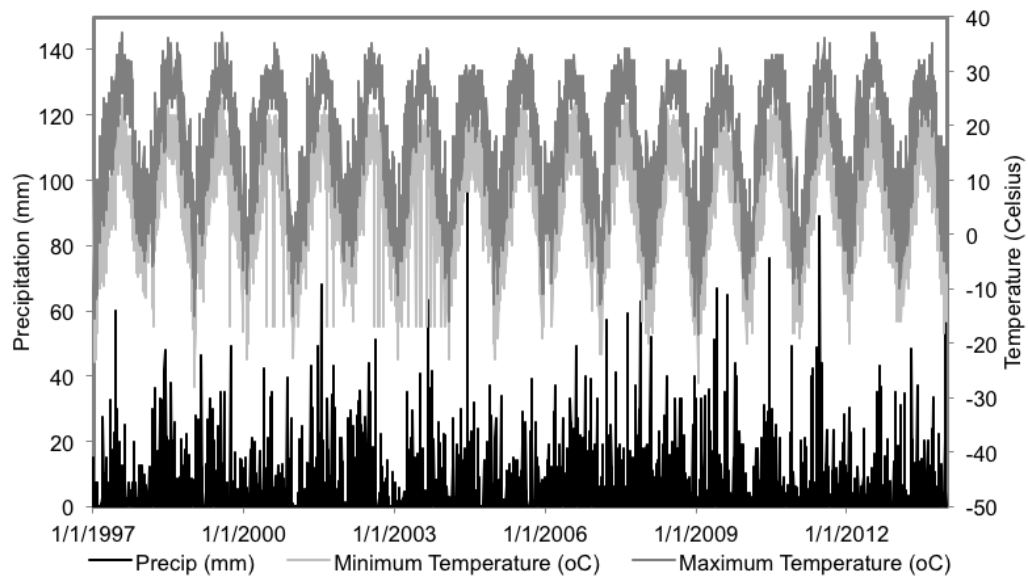


Figure 4.2 Climate data collected at WQFS from 1997-2013.

Table 4.1 Description of general plot management strategies for plots used in this research. Specific replicates used for calibration are bolded; plots used for validation are italicized. More detailed management data (including specific dates) are provided in Appendix F.

<b>Trt</b>	<b>Plots</b>	<b>Early Management</b>	<b>Current Management</b>
3	12, 23, <b>30, 46</b>	Years: 1995-2007 Plant: Continuous Corn Fertilizer: 201.6 kg/ha UAN 28% preplant; 19-17-0 starter Tillage: spring & fall Other: none	Years: 2008-present Plant: No-Till Continuous Corn Fertilizer: 179.2 kg/ha UAN 28% preplant; 19-17-0 starter Tillage: none Other: 80% residue removed
4	<b>10, 18,</b> 26, 44	Years: 1995-2006 Plant: Corn-Soybean Rotation Fertilizer: 179.2 kg/ha 28% UAN; 19-17-0 starter Tillage: spring & fall Other: none	Years: 2007-present Plant: Upland Switchgrass Fertilizer: 56-84 kg/ha urea coated w/agrotain Tillage: none Other: residue removed
6/7	<b>5, 8,</b> <b>13, 20,</b> 27, 35, 40, 47	Years: 1995-2006 Plant: Corn-Soybean Rotation Fertilizer: 156.8 kg/ha UAN 28%; 19-17-0 starter Tillage: spring & fall Other: none	Years: 2007-present <i>continued as previous</i>
12	3, <b>21,</b> 31, <i>41</i>	Years: 1995-2006 Plant: Continuous Corn Fertilizer: 179.2 kg/ha UAN 28%; 19-17-0 starter Tillage: spring & fall Other: none	Years: 2007-present <i>continued as previous</i>

UAN = urea-ammonium nitrate

WQFS plots are monitored for multiple research projects at Purdue University, therefore multiple datasets exist to parameterize and calibrate the DayCent model. Data specifically used in this study that were collected at WQFS included soils information, climate, total aboveground biomass, biomass of yield at harvest, and greenhouse gas emissions (Table 4.2). The greenhouse gas data were collected primarily during the growing season after major field activities or on a weekly basis. They were collected using an aluminum vent static rectangular chamber (0.40 m x 0.75m) following protocols in Reay et al. (2009). Further details of the chamber collection, measurement, analysis, and data calculations and adjustments are described in Hernandez-Ramirez et al. (2009).

Table 4.2 Summary of data available for use with DayCent model at all of the plots used in this research.

<b>Data Type</b>	<b>Variables</b>	<b>Year(s)</b>	<b>Used As</b>
Soils Data	bulk density at 0-10cm and 10-20cm	2013/2014	input/soils.in
	field capacity at 0-10cm and 10-20cm	2014	input/soils.in
	wilting point at 0-10cm and 10-20cm	2014	input/soils.in
	soil textural classification at 0-10cm and 10-20cm	2014	input/soils.in
	soil pH at 0-10cm and 10-20cm	2004	input/soils.in
	soil organic matter at 0-10cm and 10-20cm	2004	input/soils.in
Climate Data	minimum daily temperature	1997-2013	input/.wth
	maximum daily temperature	1997-2013	input/.wth
	precipitation	1997-2013	input/.wth
Biomass / Harvest Data	corn & soybean grain yield	1995-2012	calibration
	corn & soybean harvest indexes	1998-2002; 2011	calibration ( <i>himax</i> )
	biomass yield (switchgrass, corn stover)	2009-2012	calibration
	%C of grain and biomass for corn & switchgrass	2013	yield calculation
GHG Data	N <sub>2</sub> O emissions	2008-2013	calibration

### 4.3.3 DayCent Model Development

One DayCent model (DailyDayCent with daily plant production received from model developers on September 30, 2014) was developed for each of the ten plots used in this study. The same warm-up period (years 0000 – 1996) information was used for each of the models in order to establish reasonable soil carbon levels. The warm-up period consisted of four DayCent scheduling blocks: (1) warm up: 1-1899, tall grass prairie with four year burn; (2) Low intensity cropping: 1900-1968, three year rotation of corn, wheat, and soybean; (3) modern agriculture: 1969-1992, two year rotation of high yielding corn and soybean; (4) WQFS generic data: 1993-1996, although cropping systems were known for 1993-1995, specific dates of planting, fertilization, tillage, etc. had to be estimated using data from 1996. Details of these four warm-up blocks were derived from previous work at this site (Mohankumar 2012) and can be found in Appendix F. The long warm-up period was developed in order to establish soil carbon levels which were close to observed values of 4200 Mg/ha observed at the site (Hernandez-Ramirez et al. 2009).

The fifth scheduling block for each plot was a 17-year rotation which included actual data logged at the WQFS plots from 1997-2013. In general, most replicates of each treatment received the same management on the same day, so the fifth blocks within a given treatment are identical. Some abnormal deviation from this protocol was documented and was accounted for as needed in the scheduling files for individual blocks. Each model was run with default parameter values to create a baseline for calibration.

#### 4.3.4 Calibration & Validation of DayCent

Forty-six DayCent model parameters were calibrated by dynamically coupling DayCent with AMALGAM (Vrugt and Robinson 2007). The AMALGAM tool is a multi-algorithm, genetically adaptive multi-objective method which operates similar to evolutionary adaptation (Vrugt and Robinson 2007). The algorithm first initiates a random initial parameter set using Latin hypercube sampling. Next, each 'parent' or parameter set is ranked, and then a population of 'offspring' or new parameter sets are generated using a multimethod search to generate the most 'fit' offspring. The method employs four commonly used optimization algorithms: Non-dominated Sorted Genetic Algorithm II (Deb et al. 2002), adaptive metropolis search (Haario et al. 2001), particle swarm optimization (Kennedy and Eberhart 2001), and differential evolution (Storn and Price, 1997). Details of the AMALGAM methods are described in Vrugt and Robinson (2007).

Each of the five calibration plots was run as an independent DayCent model. The outputs of biomass yield and N<sub>2</sub>O emissions from all plots were combined into two vectors of observed and simulated values. The goal of the objective function was to simultaneously minimize the error in observed and simulated biomass yields and observed and simulated N<sub>2</sub>O emissions. Using two objective functions in the calibration leads to the development of an Pareto optimization front.

Figure 4.3 provides a general overview of the calibration tool and Matlab® codes developed to run AMALGAM coupled with DayCent. Codes developed specifically for this research are included in 0. The calibration was run on Purdue Community Cluster Carter which has HP compute nodes with two 8-core Intel Xeon-E5 processors. For each

iteration all five plots were run simultaneously using parallel computing, significantly reducing the run time. By running each of the five plot models at the same time, the run time of one iteration of AMALGAM was reduced from greater than 10 minutes to less than 2 minutes.



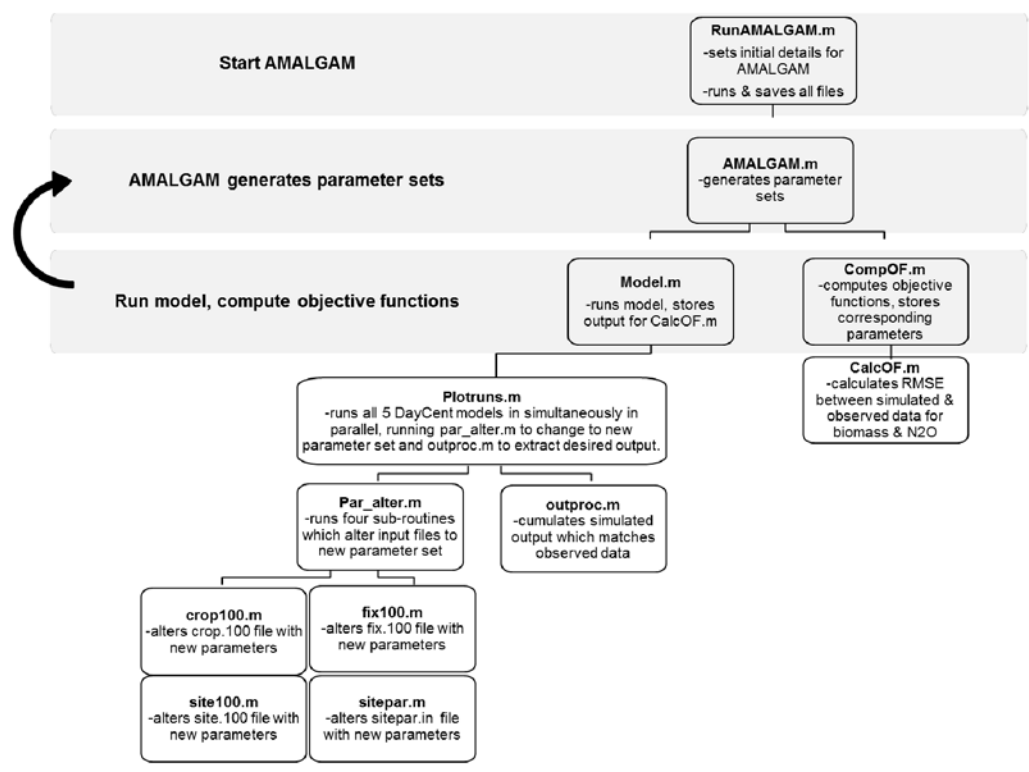


Figure 4.3 General overview of AMALGAM DayCent calibration tool & corresponding Matlab® codes.

The parameters selected for calibration as well as their upper and lower bounds were determined based on sensitive parameters reported by Rafique et al. 2013, Rafique et al. 2014, personal communication with model developers, or actual data measured on site. Descriptions of these parameters can be found in Appendix I. Default values were based on values set in files provided when downloading the model. Half of the plots were selected at random (at least one from each treatment: 5, 10, 13, 21, 30) to calibrate the model. The other half of the plots (18, 23, 35, 41, 47) were used to validate the calibrated parameters. A multi-objective function method was used to calibrate all five calibration plot models simultaneously to biomass yield and N<sub>2</sub>O emissions using the root mean square error as the objective function for both outputs (Equation 4.1). The biomass yield refers to the grain yield for corn and soybean, total harvested biomass for switchgrass, and stover plus grain for the corn with stover removal. The objective function tried to minimize the RMSE (Equation 4.2) between observed and simulated yield and N<sub>2</sub>O data, creating a Pareto optimization front from which a ‘best’ model could be selected that minimized both N<sub>2</sub>O emissions and yield for all five calibration plots. Nash-Sutcliff Efficiency (NSE; Equation 4.3) and RMSE-observations standard deviation ratio (RSR; Equation 4.4) were also determined for the final calibrated and validated models to provide a better evaluation of the model fit (Moriassi et al. 2007).

$$\text{Equation 4.1: } \text{OF} = \min (\text{RMSE}_{\text{BY}}, \text{RMSE}_{\text{N}_2\text{O}})$$

$$\text{Equation 4.2: } \text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i^{\text{obs}} - Y_i^{\text{sim}})^2}$$

$$\text{Equation 4.3: } \text{NSE} = 1 - \left[ \frac{\sum_{i=1}^n (Y_i^{\text{obs}} - Y_i^{\text{sim}})^2}{\sum_{i=1}^n (Y_i^{\text{obs}} - Y^{\text{mean}})^2} \right]$$

Equation 4.4: 
$$RSR = \frac{RMSE}{Y_{obs}^{stddev}} = \frac{\left[ \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i^{obs} - Y_i^{sim})^2} \right]}{\left[ \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i^{obs} - Y^{mean})^2} \right]}$$

#### 4.3.5 Development of Climate Regulation Quantification Method

According to the MEA, ecosystems can be both sources and sinks of chemicals, pollutants, and gases that influence our climate. At larger scales, ecosystems can also significantly influence the water cycle and the distribution of nutrients. For the purposes of this study, we focused on a more local, field scale, where an ecosystem can most strongly influence climate by storing carbon, or emitting greenhouse gases. The climate regulation index (CRI; Equation 4.5), indicates whether an ecosystem is contributing to, or mitigating climate change at the local, terrestrial level based on sources and sinks of greenhouse gases and user-applied weights which can add priority to certain sources and sinks (Figure 4.4). This approach is unique in that it allows users to assign weights to each climate regulation component. This is to be used as an indicator for climate regulation of local, terrestrial landscapes relative to required or desired standards. In this equation, sources and sinks have equal weight. If the landscape is storing more, relatively, than it is emitting, the equation will be greater than one. If it is emitting more, relatively, than it is storing, it will be less than one. If it is storing and emitting relatively equally, it is equal to one. The equation and details are provided below.

Equation 4.5:

$$CRI_t = \frac{w_1 \left( \frac{S_{std,1} + \Delta S_{1,t}}{S_{std,1}} \right) + w_2 \left( \frac{S_{std,2} + \Delta S_{2,t}}{S_{std,2}} \right) + \dots + w_n \left( \frac{S_{std,n} + \Delta S_{n,t}}{S_{std,n}} \right)}{wt_1 \left( \frac{GHG_{1,t}}{GHG_{std,1}} \right) + wt_2 \left( \frac{GHG_{2,t}}{GHG_{std,2}} \right) + \dots + wt_n \left( \frac{GHG_{n,t}}{GHG_{std,n}} \right)}$$

where:  $S$  = sink for greenhouse gas (mass carbon stored)

$GHG$  = greenhouse gas (flux of gas emission)

$std$  = standard

$w$  = weight for sink and  $\sum_1^n w_i = 1$

$wt$  = weight for GHG and  $\sum_1^n wt_i = 1$

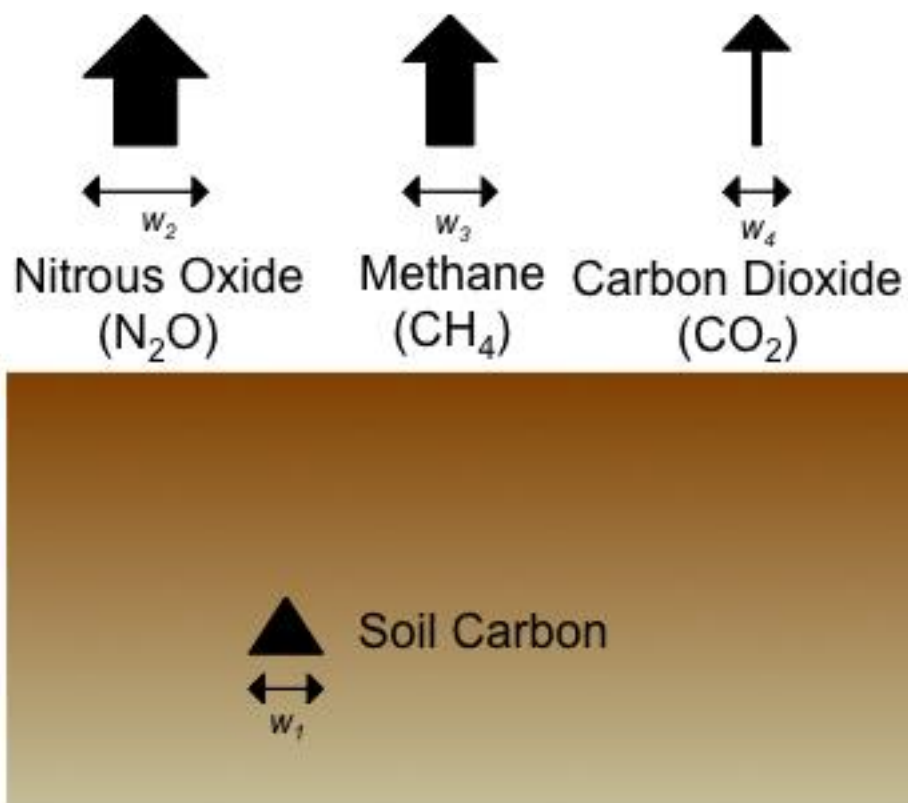


Figure 4.4 Diagram of the sources and sinks captured by the Climate Regulation Index.

To demonstrate how well the CRI captures the ecosystem service of climate regulation, the index was calculated for four scenarios using the one calibrated plot. The plot was set up with a warm-up period from 0000-1899 that was the same as the WQFS warm-up period: tall grass prairie with a burn every four years. Then, the model was run from 1900-2013 for four scenarios: (1) tall grass prairie with four year burn continued (assumed previous land use), (2) corn-soy rotation, (3) continuous tilled corn, and (4) switchgrass with biomass removal. The three cropping systems were modeled based on the latest years of WQFS data, i.e., the same management practices were used as in Table 4.1. The CRI was calculated on an annual basis from 2003-2013 for comparison purposes.

## 4.4 Results & Discussion

### 4.4.1 Calibration & Validation of DayCent

The calibrated parameter set is provided in Table 4.3. The Pareto optimization front is shown in Figure 4.5, with RMSE values divided by their default values to show the reduction compared to default models. The best parameter set was selected by finding the parameter set that minimized both objective functions almost equally, compared to their default values (Figure 4.5). This method was chosen so as to select a parameter set that does not decrease one objective function at the expense of the other. A majority of the parameters converged to a general value, meaning that after multiple iterations AMALGAM was selecting a similar value for that parameter each run (Appendix J). The sensitivity of parameters that did not converge was reviewed by graphing the parameter value versus the RMSE of yield and the RMSE of N<sub>2</sub>O (example in Figure 4.6). Only one non-converging parameter – *prdx(1)-corn*- showed some sensitivity to either of the calibration outputs. This coefficient for calculating potential aboveground monthly production of corn as a function of solar radiation appeared to influence the biomass yield RMSE values because the change in RMSE (the spread across the y-axis) was smaller with smaller values of *prdx(1)-corn* (Figure 4.6). This value could improve with later generations; however, it is important to note that the final parameter set included a *prdx(1)* value for corn that was close to the area where the yield RMSE was most reduced (*i.e.*, within the range that lead to smaller yield RMSE values).

Table 4.3 List of parameters changed, their default value, range, and calibrated value along with reported calibrated values from two other algorithmic optimization papers (NR = value not reported). The upper and lower limits for the parameter ranges came from 1-communication with model developers, 2-previous research (Rafique et al. 2013 & Rafique et al. 2014), 3-measured data from WQFS, and 4-DayCent manual. Parameter descriptions are provided in Appendix I.

Par #	Name	File	Default Value	Lower Limit	Upper Limit	Calibrated Value	Rafique et al. (2013)	Rafique et al. (2014)
1	<i>fligni(1,1)-corn</i>	crop.100	0.12	0.05	0.2	0.127	NR	0.19
2	<i>fligni(1,1)-soyb</i>	crop.100	0.12	0	1	0.246	NR	0.19
3	<i>himax-corn</i>	crop.100	0.6	0.49	0.75	0.626	NR	NR
4	<i>hiwsf-corn</i>	crop.100	0.5	0	1	0.012	NR	NR
5	<i>prdx(1)-corn</i>	crop.100	0.7	0.5	4	0.743	NR	NR
6	<i>prdx(1)-soyb</i>	crop.100	0.45	0.5	4	0.526	NR	NR
7	<i>prdx(1)-swg</i>	crop.100	0.35	0.5	4	0.590	NR	NR
8	<i>snfxmx-soyb</i>	crop.100	0.038	0	1	0.241	NR	NR
9	<i>dec4</i>	fix.100	.0045	0.0025	0.006	0.0037	NR	0.002
10	<i>aneref(2)</i>	fix.100	3	1	5	2.235	NR	2.0
11	<i>aneref(3)</i>	fix.100	1	0.2	2	1.416	0.50	0.51
12	<i>damr(2,1)</i>	fix.100	0.02	0.002	0.3	0.247	0.03	0.02
13	<i>damrmn(1)</i>	fix.100	15	5	30	12.95	5.00	7.11
14	<i>dec1(1)</i>	fix.100	3.9	2	8	4.481	NR	1.54
15	<i>dec1(2)</i>	fix.100	4.9	2	8	7.237	4.35	2.31
16	<i>dec2(1)</i>	fix.100	14.8	10	20	14.84	NR	12.60
17	<i>dec2(2)</i>	fix.100	18.5	10	25	15.84	NR	8.33



Table 4.3 (Continued) List of parameters changed, their default value, range, and calibrated value along with reported calibrated values from two other algorithmic optimization papers (NR = value not reported). The upper and lower limits for the parameter ranges came from 1-communication with model developers, 2-previous research (Rafique et al. 2013 & Rafique et al. 2014), 3-measured data from WQFS, and 4-DayCent manual. Parameter descriptions are provided in Appendix I.

18	<i>dec3(1)</i>	fix. 100	6	2	10	<sup>1</sup>	7.746	NR	7.28
19	<i>dec3(2)</i>	fix. 100	7.3	2	10	<sup>1</sup>	9.140	NR	12.55
20	<i>dec5(2)</i>	fix. 100	0.2	0.03	0.2	<sup>1</sup>	0.092	0.19	0.17
21	<i>fleach(3)</i>	fix. 100	1	0.2	1	<sup>2</sup>	0.914	0.24	0.22
22	<i>fwloss(4)</i>	fix. 100	0.7	0.6	1.2	<sup>1</sup>	0.599	NR	NR
23	<i>omlech(3)</i>	fix. 100	0.1	0.05	0.15	<sup>1</sup>	0.118	NR	NR
24	<i>peftxa</i>	fix. 100	0.25	0.1	0.7	<sup>2</sup>	0.617	0.70	0.20
25	<i>teff(1)</i>	fix. 100	15.4	5	15	<sup>2</sup>	11.99	8.65	15.0
26	<i>teff(2)</i>	fix. 100	11.75	2	20	<sup>2</sup>	3.454	3.47	3.50
27	<i>teff(3)</i>	fix. 100	29.7	10	40	<sup>2</sup>	36.41	29.56	12.98
28	<i>teff(4)</i>	fix. 100	0.031	0.01	0.04	<sup>2</sup>	0.0392	0.03	0.02
29	<i>varat11(1, 1)</i>	fix. 100	16	5	30	<sup>2</sup>	26.18	10.00	16.57
30	<i>varat11(2, 1)</i>	fix. 100	8	4	15	<sup>2</sup>	4	NR	6.50
31	<i>varat12(1, 1)</i>	fix. 100	16	5	30	<sup>2</sup>	28.30	27.70	6.57
32	<i>varat12(2, 1)</i>	fix. 100	8	4	15	<sup>2</sup>	5.10	8.60	6.50
33	<i>basef</i>	site. 100	0.9	0.1	0.9	<sup>2</sup>	0.897	NR	0.35
34	<i>epnfa(1)</i>	site. 100	0.05	0.02	0.5	<sup>2</sup>	0.5	0.06	0.06
35	<i>epnfa(2)</i>	site. 100	0.01	0.002	0.5	<sup>2</sup>	0.002	0.09	0.03
36	<i>epnfs(1)</i>	site. 100	30	10	40	<sup>2</sup>	28.65	21.93	16.41

Table 4.3 (Continued) List of parameters changed, their default value, range, and calibrated value along with reported calibrated values from two other algorithmic optimization papers (NR = value not reported). The upper and lower limits for the parameter ranges came from 1-communication with model developers, 2-previous research (Rafique et al. 2013 & Rafique et al. 2014), 3-measured data from WQFS, and 4-DayCent manual. Parameter descriptions are provided in Appendix I.

37	<i>epnfs(2)</i>	site. 100	0.009	0.001	0.1	<sup>2</sup>	0.0142	0.01	0.01
38	<i>adwpfs</i>	sitep ar.in	1	0.8	1.5	<sup>1</sup>	0.869	NR	NR
39	<i>dmpfact</i>	sitep ar.in	0.003	0.0025	0.0045	<sup>1</sup>	0.0036	NR	NR
40	<i>dmpflux</i>	sitep ar.in	8e-06	0.0000 01	0.0001	<sup>4</sup>	9.80e- 05	NR	NR
41	<i>nitmax</i>	sitep ar.in	0.4	0.2	0.6	<sup>1</sup>	0.2	0.28	0.15
42	<i>nitN_fc</i>	sitep ar.in	0.015	0.01	0.03	<sup>1</sup>	0.0161	NR	NR
43	<i>nitN_wp</i>	sitep ar.in	0.002	0.001	0.005	<sup>1</sup>	0.0049	NR	NR
44	<i>nratadj</i>	sitep ar.in	1	0.8	1.5	<sup>1</sup>	1.353	NR	NR
45	<i>timlag</i>	sitep ar.in	30	30	100	<sup>1</sup>	45.39	NR	NR
46	<i>waterlimit</i>	sitep ar.in	0.03	0	0.5	<sup>1</sup>	0.0455	0.03	0.04

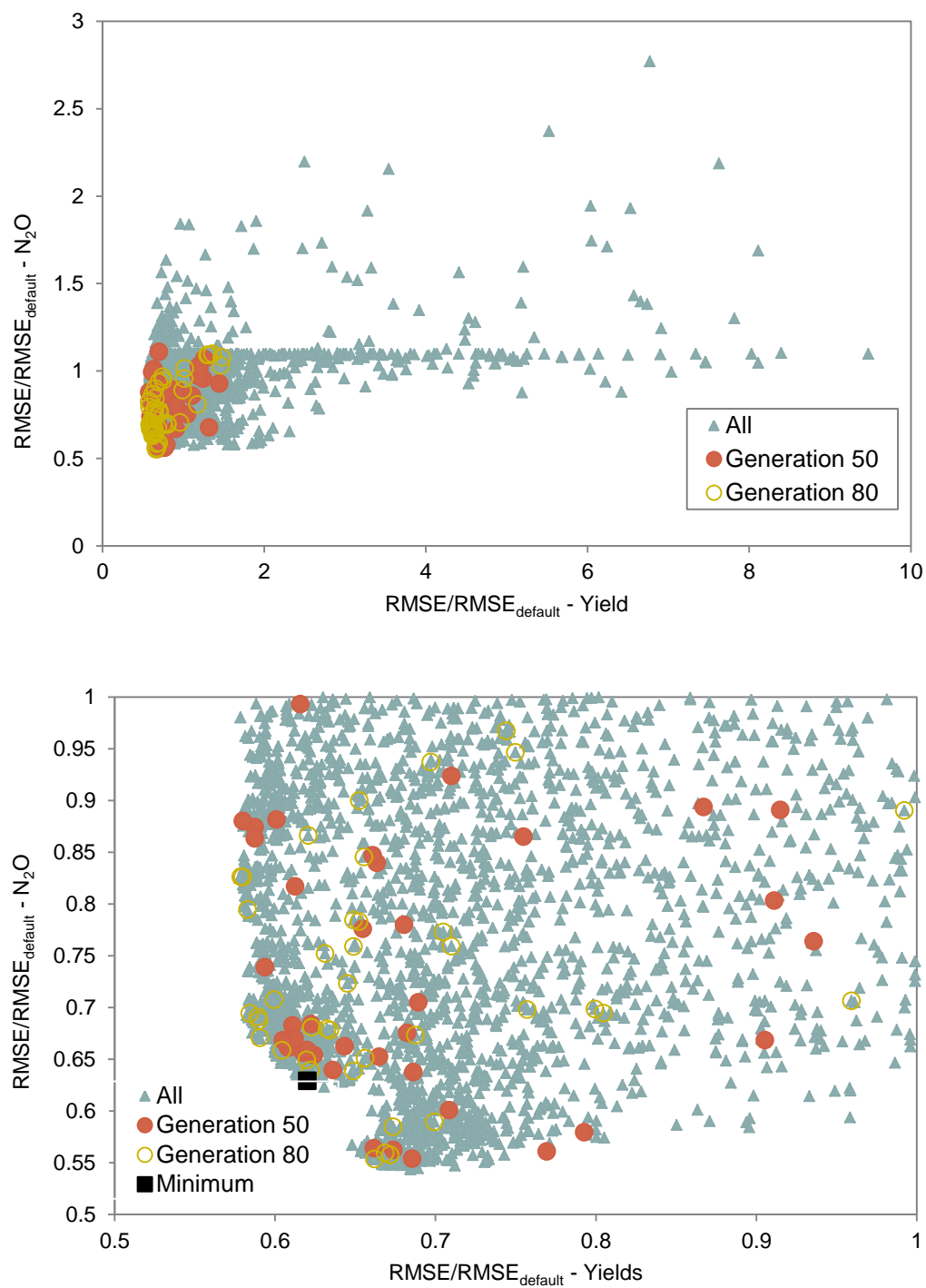


Figure 4.5 Pareto-optimization front for all runs (top) and zoomed in to lower edge of the front which also shows final parameter set location as the black square (bottom).

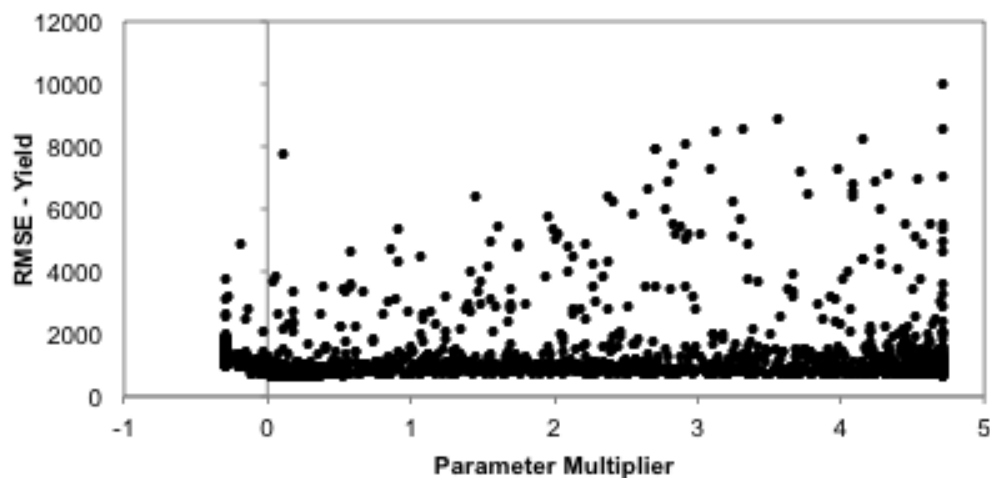


Figure 4.6 Yield RMSE versus  $prdx(I)$  for corn (coefficient for calculating potential aboveground monthly production of corn as a function of solar radiation outside the atmosphere). The  $prdx(I)$  values shown are multiplicative changes from the default value, e.g., 1 = 1 times the default value.

The most changed model parameters (doubled, or decreased by at least half) were the maximum harvest index of corn (*hiwsf*), the symbiotic nitrogen fixation maximum for soybeans (*snfxmx*), the intercept for the equation to predict lignin content fraction based on annual rainfall for aboveground material for soybeans (*flignin(1,1)*), the fraction of surface nitrogen absorbed by residue (*damr(2,1)*), the maximum decomposition rate of soil organic matter with intermediate turnover (*dec5(2)*), the intercept parameter for the regression equation to compute the effect of soil texture on microbe decomposition rate (*peftxa*), the “y” location of the inflection point for determining the temperature component of the decomposition factor (*teff(2)*), the intercept and slope values for determining the effect of annual precipitation on atmospheric nitrogen fixation (*epnfa(1)*, *epnfa(2)*), the damping factor for soil water flux (*dmpflux*), and the minimum proportion of nitrified nitrogen lost as N<sub>2</sub>O at wilting point (*nitN\_wp*). However, yield and N<sub>2</sub>O RMSE showed little sensitivity to most of these parameters except *flignin(1,1)* for soybeans, *teff(2)*, and *epnfa(2)*, suggesting that most of these parameters were not influencing these two outputs, and did not need to be changed. The parameter *teff(2)* is important for estimating the decomposition factor (*DEFAC*) which helps control the flow of carbon based on water and temperature. Even though this value was decreased from 11.75 to 3.45, the final value was similar to values reported by Rafique et al. (2013) and Rafique et al. (2014). Three studies finding similar values for the same parameter that is largely different from the model default may suggest that a change is necessary in the default value for this parameter, especially in agricultural landscapes. The *flignin(1,1)* parameter for soybeans was also sensitive and was significantly changed from default. This parameter determines the “y” intercept for the equation that predicts the lignin

content fraction of soybeans based on annual rainfall for aboveground material. This value (0.25) also differed from the Rafique et al. 2014 value of 0.19, however this value may be different due to the different annual rainfall between the site in Iowa (890.6mm) and at WQFS in Indiana (977mm). The third sensitive parameter that changed significantly was *epnfa(2)*, which sets the slope value for determining the effect of annual precipitation on atmospheric nitrogen fixation. This value indicates the rate of nitrogen fixation per centimeter of precipitation. Again, this value was different from reported values in Rafique et al. 2014, but this could also be due to the differences in site and climate.

Comparing the rest of the parameters to previously published values (Table 4.3) shows that six additional parameters [*aneref(3)*, *damr(2,1)*, *dec1(1)*, *fleach(3)*, *basef*, *epnfa(2)*] calibrated at WQFS were very different (more than doubled, or less than half) from other studies. The two previous studies were conducted in Iowa where soil conditions, weather and management differed from WQFS, so a difference in site characteristics can lead to different parameter values. These results indicate that these six parameters may be sensitive to the site and need to be calibrated using local data. For example, *basef*, controls the amount of soil water content that is lost via base flow. The WQFS plots are all tile-drained, whereas the plot used in Rafique et al. 2014 was not. This difference in drainage characteristics lead to the *basef* parameter for the WQFS tile-drained plots being 0.89, versus 0.35 in the Iowa plot with no tile drains, indicating more water being lost via sub-surface pathways. This parameter specifically will be useful to calibrate in tile-drained landscapes. Similarly, the *fleach(3)* parameter was higher at WQFS than the studies in Iowa. This parameter controls the fraction of mineral nitrogen

lost to deeper soil layers when there is saturation excess flow. Tile-drained systems have been shown to increase nitrogen leaching from the landscape (Gentry et al. 1998) so the change in this parameter compared to a non-tile drained landscape is reasonable, though future work should compare these values to measured data as nitrate leaching in DayCent has been shown to be overestimated (Del Grosso et al. 2006).

The overall RMSE for yield and for N<sub>2</sub>O emissions was reduced by almost half compared with default runs for the calibration plots (Table 4.4). The validation plots were improved overall compared with default for yield, but not for N<sub>2</sub>O emissions. The impact on individual plots varied for N<sub>2</sub>O, but yield RMSE values were improved for all plots (Table 4.5 & Table 4.6). When examining the plot by plot final and default models (Table 4.6), it is clear that the model had more difficulty predicting the N<sub>2</sub>O emissions for the corn-soy rotation and switchgrass plots, compared with the continuous corn plots. One possible reason for the discrepancies is that the two continuous corn treatments had higher overall N<sub>2</sub>O emissions than the corn-soy and switchgrass plots (Figure 4.7). When AMALGAM was trying to minimize the overall RMSE across all plots, these data points likely had more influence on the RMSE than the plots with smaller N<sub>2</sub>O emissions. Therefore, the final calibrated parameter sets are better fit to the continuous corn plots, rather than the corn-soybean and switchgrass plots.

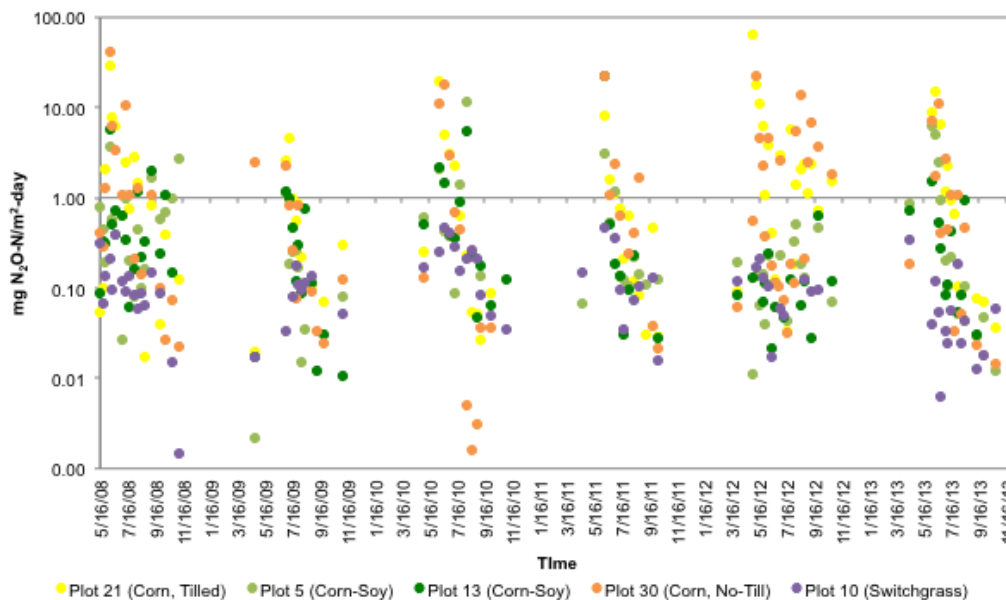


Figure 4.7 Comparison of  $N_2O$  emissions for the five calibration plots, shown on log scale so the peaks and the daily dynamics are visible.

Table 4.4 Calibration and validation statistics for all plots combined

		<i>Calibration Plots</i>		<i>Validation Plots</i>	
		Default Model	Final Model	Default Model	Final Model
Yield (kg/ha)	RMSE	115.37	72.08	126.11	91.34
	RSR	7.92	4.94	7.44	5.39
	NSE	0.24	0.71	0.33	0.65
Mg $N_2O$ - N/m <sup>2</sup> -d	RMSE	4.54	3.04	5.95	6.54
	RSR	20.26	13.57	20.70	22.76
	NSE	0.10	0.60	0.058	-0.14



Table 4.5 Yield statistics for individual plots.

	Plot	Treatment	<i>Default Model</i>			<i>Final Model</i>		
			RMSE	RSR	NSE	RMSE	RSR	NSE
Calibration Plots	5	Corn-Soy	94.94	3.46	0.25	28.57	1.04	0.93
	10	Switchgrass	96.72	2.88	0.45	59.36	1.78	0.79
	13	Corn-Soy	108.59	3.64	0.17	39.73	1.33	0.90
	21	Corn, Tilled	103.88	6.61	-1.57	59.43	3.78	0.16
	30	Corn, No-Till	162.11	3.89	-0.01	131.28	3.13	0.33
Validation Plots	18	Switchgrass	90.74	2.57	0.56	73.31	2.08	0.71
	23	Corn, No-Till	227.69	4.46	-0.33	164.68	3.22	0.31
	35	Corn-Soy	57.44	2.29	0.67	38.44	1.54	0.85
	41	Corn, Tilled	99.14	7.05	-1.92	58.65	4.17	-0.02
	47	Corn-Soy	91.28	3.14	0.38	74.42	2.56	0.59

Table 4.6 N<sub>2</sub>O-N statistics for individual plots.

	Plot	Treatment	<i>Default Model</i>			<i>Final Model</i>		
			RMSE	RSR	NSE	RMSE	RSR	NSE
Calibration Plots	5	Corn-Soy	1.488	9.17	0.19	1.59	9.79	0.07
	10	Switchgrass	0.982	9.71	-0.02	1.77	12.07	-0.58
	13	Corn-Soy	2.43	9.27	0.10	2.18	8.35	0.26
	21	Corn, Tilled	7.39	8.92	0.13	3.78	4.56	0.77
	30	Corn, No-Till	6.27	9.94	0.06	4.82	7.65	0.44
Validation Plots	18	Switchgrass	0.26	14.73	-0.85	1.15	11.97	- 35.69
	23	Corn, No-Till	2.64	9.47	0.17	2.56	9.18	0.22
	35	Corn-Soy	2.23	8.70	0.24	3.33	12.99	-0.68
	41	Corn, Tilled	12.05	9.47	- 0.007	11.69	9.18	0.05
	47	Corn-Soy	4.65	8.94	0.15	7.76	14.9	-1.35

#### 4.4.2 Climate Regulation Index Testing

Ten years of CRI was determined for each of the four scenarios using the calibrated model for Plot 13: (1) tall grass prairie, (2) corn-soybean rotation, (3) continuous tilled corn, and (4) switchgrass with biomass removal. One sink was used – total belowground carbon, so the weight ( $w_1$ ) was one. Three GHG sources were used: nitrous oxide, carbon dioxide, and methane. The weights used for the GHGs were based on the 100-year global warming potential of the greenhouse gases. Weight 1 ( $w_{t1}$ ) for carbon storage in the soil was  $1/333$ , weight 2 ( $w_{t2}$ ) for nitrous oxide emissions was  $298/333$ , and weight 3 ( $w_{t3}$ ) for methane was  $34/333$ . The standards used for the four CRI constituents were the values at the end of the warm-up period simulation, i.e., the amount of soil carbon in the model during year 1899, and the annual amounts of nitrous oxide, methane, and carbon dioxide released in year 1899. The results indicate that the climate regulation provided by corn-soybean rotation and continuous corn is much lower than that provided by switchgrass and tall grass prairie (Figure 4.8). It is also noticeable that the climate regulation provided during the corn years of the corn-soybean rotations is nearly identical to the continuous corn. The soybean years of the corn-soybean rotation are higher as the soybeans are not as intensively tilled. The switchgrass provided higher or nearly similar climate regulation compared with tall grass prairie, mostly due to lower  $N_2O$  emissions from switchgrass when compared to prairie.

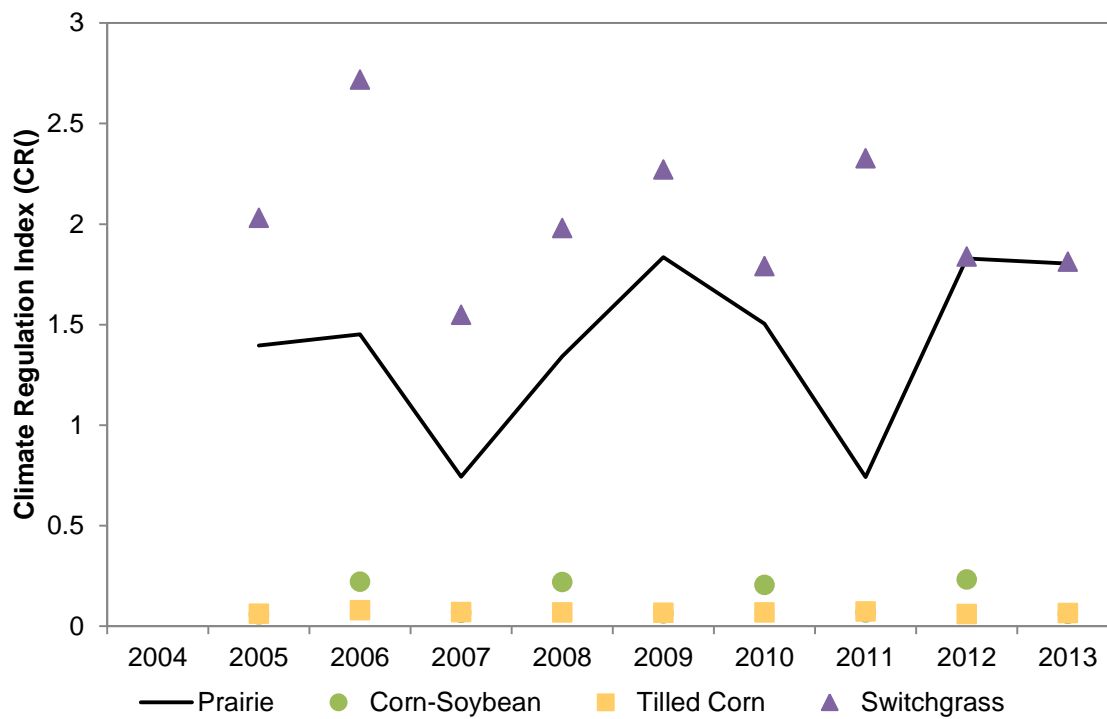


Figure 4.8 Climate regulation index from 2004-2013 for prairie, corn-soybean, no-till corn, and switchgrass scenarios.

#### 4.5 Conclusion

Although previous research has demonstrated the effectiveness of DayCent at estimating yearly greenhouse gas emissions, previous studies have also shown that it is difficult to develop a calibrated model that can predict daily N<sub>2</sub>O emissions well. Calibrating DayCent across different treatments at the same site worked well for estimating biomass, but the same was not true for N<sub>2</sub>O. Other studies have used the same plot to both calibrate and validate model parameters, using different time periods for calibration and validation. This method may prove to be better for small-scale studies, however for larger spatial scale simulations, a multi-plot method may be more effective to create general parameter estimates.

This research demonstrates an alternative multi-objective DayCent calibration method that utilizes the AMALGAM method to generate a parameter set useful for plots located at the Water Quality Field Station in West Lafayette, Indiana. The results show that the AMALGAM method was useful for generating a parameter set that could reduce RMSE of yield and N<sub>2</sub>O emissions for the calibration plots. However, when this parameter set was tested for a second set of plots (validation plots) at the same site, the parameter set was able to improve RMSE of yield, but not N<sub>2</sub>O. The most influential reason that the calibrated parameter set could not predict N<sub>2</sub>O well at the validation plots is that the continuous corn plots in the calibration plots had the highest N<sub>2</sub>O emissions, which likely influenced the calibration more than the plots with lower N<sub>2</sub>O emissions. Future work may require calibrating models within a site separately for different treatments. This research shows that a multi-objective function genetic algorithm calibration is a useful method for calibrating the DayCent model.

This work also demonstrates parameters that may be useful to calibrate for DayCent, as well as parameters that do not need to be calibrated.

The second objective of this research introduces a method to evaluate climate regulation ecosystem services on a local level by comparing the amount of carbon stored in the soil and the amount of greenhouse gases emitted to values of the native ecosystem. The results indicate that the climate regulation index captures the known loss of climate regulation when changing the landscape from the natural native prairie to conventional corn and soybean agriculture. The results also supports previous research which has shown that switchgrass may be able to improve climate regulation ecosystem services relative to the native prairie by storing more belowground carbon and emitting fewer greenhouse gases (Liebig et al. 2005; McLaughlin and Kszos 2005). This method for evaluating climate regulation is highly dependent on the weights selected for each constituent. For this study the 100-year global warming potential was used as the basis of the weights. It should also be noted that for this study, emissions from farming equipment were not included in the climate regulation calculations, and these emissions would further decrease the climate regulation provided.

Overall, this research utilized a multi-objective function genetic algorithm tool (AMALGAM) to calibrate and validate the DayCent model in order to calculate climate regulation ecosystem services. The methods demonstrated provide insight for the calibration of DayCent for both N<sub>2</sub>O emissions and biomass yields. The climate regulation index also offers a way to evaluate the climate regulation ecosystem services provided by an ecosystem using output from the DayCent model.

Future work may include both further evaluation of the impact of different objective functions on the final calibration of DayCent, and the evaluation of climate regulation on larger scales.

## 5 ECOSYSTEM SERVICES AND INDIANA AGRICULTURE: FARMERS' AND CONSERVATIONISTS' PERCEPTIONS<sup>1</sup>

### 5.1 Abstract

The fate of ecosystem services (ESS) in the United States (U.S.) depends on the actions of private landowners and operators (“farmers”). This work uses a mixed qualitative and quantitative method to understand farmer knowledge of ESS and willingness to manage lands from an ESS perspective. Fourteen interviews were conducted to analyze farmer understanding of ESS within the context of conservation management. Two hundred surveys of Indiana farmers and 33 surveys of Indiana U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) conservationists (“conservationists”) were analyzed in order to assess ESS knowledge derived from varied land types. Though most farmers and conservationists were unfamiliar with ESS, both groups consistently recognized environmental benefits from land types and conservation practices. They were also able to identify trade-offs in ESS when managing lands for maximum food production. Farmers and conservationists differed in their views of the beneficiaries and stewards of ESS, which also varied by land type.

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<sup>1</sup> This work is part of a combined research project developed and conducted by the author (Rebecca Logsdon), and two other graduate students at Purdue: Margaret Kalcic and Elizabeth Trybula. Each of their percent contributions to various aspects of the project have been detailed in Appendix K.

Overall, this study shows that while Indiana farmers and conservationists are aware of ESS concepts, some ecosystem services are more easily recognized and understood than others. By understanding how farmers view and describe ESS, we can start applying the ESS concept to agricultural management in the U.S.

## 5.2 Introduction

Ecosystem services (ESS) are defined as benefits the natural environment provides to humans, and are divided into four categories: provisional, regulatory, cultural, and supporting (MEA 2005). The ESS concept provides a holistic framework for understanding links between human actions on the natural environment and human well-being, which makes it practical for land management decision-making. Human-altered landscapes have existed for thousands of years; however, in the past century, rates of land conversion have accelerated (Foley et al. 2005). Specifically, natural landscapes have been increasingly converted to agriculture; over 40% of the world's terrestrial ecosystems are now agriculturally managed (Foley et al. 2005). In this type of land conversion, ESS are often diminished or lost in order to increase food provision (Foley et al. 2005; Rodriguez et al. 2006; Wratten et al. 2013). However, this loss can create a negative feedback loop that may unintentionally undermine food provisioning (Rodriguez et al. 2006). The ESS concept can aid in evaluation of these trade-offs and development of sustainable management strategies.

Although the ESS concept is not new, its popularity as a management tool is growing (Seppelt et al. 2011; Von Haaren and Albert 2011; Sandhu et al. 2012; Logsdon and Chaubey 2013). The U.S. Department of Agriculture (USDA) established an Office



of Environmental Markets (OEM) in 2008 (USDA 2010), and in 2011, the Presidents' Council of Advisors on Science and Technology released a report on ESS for protecting society and the economy (Holdren and Lander 2011). This coincides with the fact that approximately 60% of land in the U.S. is owned by private landowners, the majority of which is cropland or pasture/rangeland (USDA-ERS 2006). In the U.S. Corn Belt, which includes Indiana, 95% of the land is privately owned (USDA-ERS 2006). This suggests that if U.S. lands are to be managed for multiple ESS, cooperation from private land managers is needed.

USDA Natural Resource Conservation Service (NRCS) programming and accompanying state agricultural conservation programs have long established a culture and system of delivery for agricultural conservation (referred to simply as "conservation" throughout). While original design of structural and management-based conservation practices in agriculture was intended to target specific improvements in environmental quality, practice implementation inherently enhances multiple ESS.

Private landowners, farm owners, and farm operators can be considered key stakeholders in managing ESS, and their knowledge and perceptions of ESS are relevant (Purushothaman et al. 2013). Farmers generally view themselves as good stewards and land managers (Ahnstrom et al. 2008; McGuire et al. 2013). Despite this sentiment, managing lands for restoration of multiple ESS could be more complicated and require significant farmer training and involvement (Benayas and Bullock 2012).

Multiple studies have examined the effect of farmers' perceptions on conservation efforts (Ryan et al. 2003; Pannell et al. 2006; Ahnstrom et al. 2008; Prokopy et al. 2008; Greiner et al. 2009; Greiner and Gregg 2011; Reimer et al. 2011; Arbuckle 2012;

Arbuckle 2013), how payments for ESS to farmers could be implemented (Powlson et al. 2011; Hayes 2012), and ESS assessment in agriculture (Wratten et al. 2013). More recently, studies outside the U.S. have focused on understanding farmers' perceptions of ESS (Sandhu et al. 2007; Sandhu et al. 2012; Smith and Sullivan 2014). This study, however, is a first step in exploring the extent of U.S. farmer knowledge of the terms and meanings within the MEA ESS framework. We also aim to demonstrate the opportunity to engage U.S. farmers to improve and restore ESS.

The overall goal of this work was to evaluate awareness and perceptions of ESS among Indiana farmers (owners and operators) and NRCS conservationists. Four research questions motivated this work:

- (3) Have farmers (or conservationists) heard of the term "ecosystem services," and do they know its MEA meaning?
- (4) Do farmers (or conservationists) recognize the ESS provided by landscapes, and do they value these services?
- (5) Who do farmers (or conservationists) consider to benefit directly from ecosystem services, and who do they believe is responsible for maintaining ESS?
- (6) If U.S. farmers are decision-makers for restoring and improving ESS in their lands, what are effective methods of engaging them in policy discussions?

This research aimed to gain a baseline perception of ESS through in-depth interviews and statewide surveying of Indiana farmers and conservationists. Interviews provided qualitative data needed to contextualized farmers' perceptions of ESS (Kaplowitz and Hoehn 2001; Prokopy 2011). Farmers' responses, language they used, and concepts they were familiar with in the interviews aided creation of the survey.

### 5.3 Materials and Methods

#### 5.3.1 Study Area

Indiana was chosen as the study area because it is located in the Corn Belt ecoregion of the Midwestern United States (Figure 5.1 Location of Indiana in the U.S., along with number of farmer responses per county (indicated by number in county) and number of NRCS responses by district (indicated by color of district).). This region of the U.S. produces over 40% of the global corn and soybean crops and is one of the most productive regions in the world (Guanter et al. 2014). Indiana can serve as a microcosm for Midwestern agriculture and help to better understand the views of private owners and operators who control a large portion of U.S. agriculture.

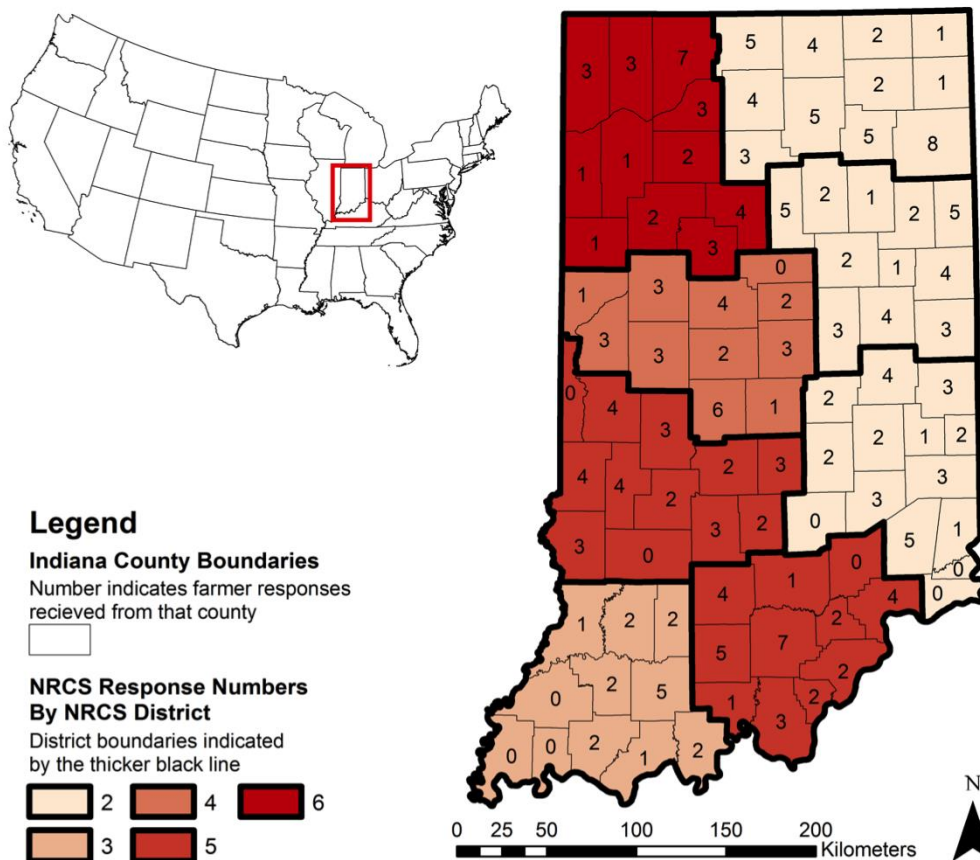


Figure 5.1 Location of Indiana in the U.S., along with number of farmer responses per county (indicated by number in county) and number of NRCS responses by district (indicated by color of district).

### 5.3.2 Sampling Tools and Methods

#### 5.3.2.1 In-depth Interviews

Individual interviews with Indiana farmers were conducted to explore knowledge and perceptions surrounding ESS within the context of agricultural conservation practices. Two questions were included to define and describe ESS: (1) “Are you familiar with the term ‘ecosystem services?’” and (2) “How would you describe ecosystem services?” In addition, farmers were asked to describe benefits of eleven conservation practices. These questions were included in a longer interview script as part of a broader study designed to evaluate an adaptive targeting approach to conservation (Kalcic et al. 2013).

Interview participants were targeted in two small watersheds in Tippecanoe County, Indiana. Fourteen farmers were interviewed, containing twelve actively farming and two retired farmers. Participating farmers were identified using publicly available parcel ownership data, and while total land area farmed by interviewees accounted for approximately 33% of study watershed land area, the response rate was nearly 100% from farmers contacted by mail and phone. Farmers who operated in the remaining 67% of the watershed land couldn’t be identified.

#### 5.3.2.2 Farmer Survey

Indiana farm owners and operators were the target study group. A sample of this population was obtained using the USDA Farm Service Agency (FSA) payment records, accessed using a Freedom of Information Act request. After removing duplicates and entries with non-Indiana mailing addresses, there were 66,051 producers who received a USDA FSA payment in 2011. This modified database was then sub-sampled using a

randomized algorithm, weighted by county farmland percentage. One of the three hardcopy surveys was then randomly distributed to the resulting 1,000-person mailing list. Three rounds of hard-copy surveys were sent based on a modified Dillman method (Dillman 2000).

The survey was developed and reviewed in multiple stages to ensure it would address the objectives of this study through a method that was quick and easy for participants to complete. Initial questions were developed using qualitative results from the interviews. The survey was pretested in focus groups with undergraduate students with agricultural backgrounds. These focus groups helped examine and improve wording and formatting that might be confusing, misleading, or off-putting for participants. The final survey is provided in Appendix K. The survey consisted of question types described in Table 5.1.

Table 5.1 Specific questions and categories of questions asked on the farmer survey.

Category	Questions Asked
Ecosystem Service Questions	<ul style="list-style-type: none"> <li>• Do you know what an “ecosystem” is?</li> <li>• Have you heard of the term “ecosystem services”?</li> <li>• What would you guess that “ecosystem services” means?</li> </ul>
Conservation Questions	<ul style="list-style-type: none"> <li>• What conservation practices do you implement on your farm?</li> <li>• What federal or state conservation programs have you participated in?</li> <li>• Do you consider yourself to be conservation-minded in your views of agricultural production?</li> </ul>
Information and Willingness to Change Farm Practices	<ul style="list-style-type: none"> <li>• Where do you get information when making farm management decisions?</li> <li>• Would you be more willing to implement conservation practices if you knew how they benefited your farm’s ecosystems?</li> <li>• What resources would you consult for information about the environmental benefits on your farm?</li> </ul>
Value, Beneficiaries, and Stewards of Environmental Benefits	<ul style="list-style-type: none"> <li>• How often do <i>[land type]</i> provide the following benefits to society? <i>benefits provided in Table 5.3</i></li> <li>• If you checked that one of the benefits was provided by <i>[land type]</i>, how valuable is this benefit to you?</li> <li>• Who benefits from <i>[land type]</i>?</li> <li>• Who should be responsible for maintaining <i>[land type]</i> benefits?</li> <li>• Of those responsible, who do you believe is most responsible for maintaining benefits from <i>[land type]</i>?</li> </ul>
Personal and Farm Demographics	<ul style="list-style-type: none"> <li>• What counties do you farm in Indiana?</li> <li>• How many acres do you farm?</li> <li>• What types of crops do you produce?</li> <li>• What livestock do you have on your farm?</li> <li>• How many years have you farmed in the area?</li> <li>• Did you grow up on a farm?</li> <li>• What is your gender?</li> <li>• What is your age?</li> <li>• What best describes your work?</li> <li>• Do you identify as a racial minority?</li> </ul>

Each participant received one of three versions of the survey, each focusing on a different ecosystem or “land type”: croplands, forestlands, and reservoirs, to assess whether or not farmers would recognize differences in ESS provided by different ecosystems. Questions about the given land type included the environmental benefits it provided, associated value of those benefits to society, and who they think are the primary beneficiaries and stewards of those benefits. This was not intended to be a valuation study; therefore, the valuation questions focused broadly on what ESS were most important for society. Based on the interviews, we did not anticipate farmers would know the term “ecosystem services,” and determined that using this term in the survey would likely cause confusion, so in most cases we used the term “environmental benefits” instead. Some MEA definitions were reworded to aid comprehension (Table 5.2). In addition, we found that farmers shied away from the term regulation during interviews, so we asked about erosion regulation twice in different ways in the environmental benefits section: using MEA-based language “regulate erosion” as well as “reduce soil loss” so we could test the influence of the word “regulation” in ESS language, though no significant difference was determined.



Table 5.2 Wording changes to convey ecosystem service as a benefit provided by ecosystems.

<b>Category</b>	<b>Ecosystem Service (Type of Service)</b>	<b>Survey Wording – Environmental Benefits</b>
Provisioning	fiber provision	provide plant fibers
	food provision	provide food
	fresh water provision	provide fresh water
	fuel provision	provide fuel
	genetic resource provision	provide genetic resources
	medicine provision	provide medicines
Regulatory	air quality regulation	provide clean air
	climate regulation	regulate local climate
	erosion regulation	regulate erosion/reduce soil loss
	flood regulation	reduce flooding
Cultural	aesthetic values	are aesthetically pleasing
	recreation	provide opportunities for recreation
	sense of place	provide a sense of place
	spiritual and religious values	inspire spiritual connection
Supporting	biodiversity	maintain species diversity

### 5.3.2.3 Conservationist Survey

An almost identical survey was sent to Indiana NRCS conservationists via email by the Indiana State NRCS Office using Qualtrics; participation in the survey was voluntary. Conservationists were randomly assigned a survey land type. The three ESS questions were identical to the farmer survey, with an added question of, “Have ecosystem services ever come up in discussions with farmers?” The “Information and willingness to change practices” category of questions were asked about farmers instead of themselves. Instead of asking farming demographic questions, we asked how long they have been with NRCS, the district they serve, and the type of work they do for NRCS.

## 5.3.3 Data Analysis

### 5.3.3.1 In-depth Interviews

Interviews were transcribed verbatim and coded using a grounded theory approach as detailed in Miles and Huberman (1994) for a number of themes related to ESS and conservation. The final set of codes (Table 5.3) was developed based on commonly used ESS definitions (MEA 2005). Coding was performed by one researcher and cross-checked for reliability by other members of the research team.

Table 5.3 Final set of 19 codes used to categorize statements related to ecosystem services.

<b>Codes</b>	<b>Description</b>
Aesthetics	Farmer mentions aesthetic benefits of conservation. For example, enjoying the sight of quail or watching hawks nesting in fencerows.
Biodiversity <sup>(s)</sup>	Farmer mentions biodiversity benefits of conservation. Must specifically comment on diversity beyond statements related only to creation of wildlife habitat.
Climate regulation	Farmer mentions climate regulation benefits of conservation.
Crop pollination <sup>(s)</sup>	Farmer mentions the importance of crop pollination.
Disaster regulation	Farmer mentions the importance of natural disaster regulation. This would include drought mitigation/regulation, but not flooding regulation, as it has its own category.
Disease regulation	Farmer mentions disease regulation benefits of conservation.
Education	Farmer mentions the education value of ecosystems or cropping systems. For example, noting that Purdue University has test plots that will show how cover crops can be used to improve farmland.
Erosion regulation	Farmer mentions soil erosion benefits of conservation. The farmer may mention both soil and surface water flow related to soil erosion, or wind erosion.
Flood regulation	Farmer mentions the importance of flood regulation. For example, commenting on how a practice might mitigate flooding, or talking about how flooding is a problem in the landscape.
Food provisioning	Farmer mentions the importance of food provisioning.
Fresh water provisioning	Farmer mentions the importance of fresh water provisioning, and any water quality benefits of conservation.
Genetic resources	Farmer mentions the importance of genetic resources on the farm or elsewhere. For example, a farmer emphasizes the difficulties that come with a lack of genetic diversity in the crops he grows.
Habitat <sup>(s)</sup>	Farmer mentions wildlife habitat benefits of conservation. Coded any time a farmer mentions that a practice provides wildlife habitat, or statements that reveal a more general value of wildlife.

Table 5.3 (Continued) Final set of 19 codes used to categorize statements related to ecosystem services.

Nutrient cycling <sup>(s)</sup>	Farmer mentions nutrient cycling benefits of conservation. For example, water quality concerns in the streams could be addressed by a practice (e.g. nutrient "filtering" by wetlands or grassed waterways), and soil nutrient cycling (e.g. cover crops or legumes improving nutrient composition of the soil).
Pest regulation	Farmer mentions pest regulation, and benefits of conservation.
Recreation	Farmer mentions recreational activities, and the benefits of conservation, such as hunting, fishing, trapping and walking trails.
Sense of place	Farmer mentions a "sense of place" felt when in a natural or conserved area. This can be hard to determine, but examples include simply loving to visit the restored wetland on his property.
Soil formation <sup>(s)</sup>	Farmer mentions soil formation benefits to conservation. Soil tilth, reducing soil compaction, and improving infiltration/drainage are included. Could be in the context of better plant growth, and since soil tilth is in the eye of the beholder, and our beholders are farmers, they're considering soil health for the purpose of growing crops.
Spiritual connection	Farmer mentions a spiritual connection to nature or the land. For example, any time a farmer mentions God in relation to preserving the environment, such as "That's how the good Lord intended it to be" when talking about a more pristine landscape.
<sup>(f)</sup> denotes a supporting ecosystem service.	

### 5.3.3.2 Farmer Surveys

Early in the survey participants were asked to define ESS. In order to better understand what the term could mean to producers upon first hearing it, responses to this question were grouped according to a number of common themes that emerged, similar to those identified in the in-depth farmer interviews.

The majority of data collected, other than demographics, were categorical. In order to analyse differences in farmer responses to the three survey types, chi-squared tests were used. Chi-squared tests were used to examine the differences in responses among the survey types for (1) what benefits participants felt that land type provided, (2) of the benefits that land provides, how valuable the benefits were to society, and (3) who participants felt was most responsible for maintaining those benefits.

### 5.3.3.3 Conservationists Surveys

The same chi-squared analyses were completed for the NRCS data as for the farmer data. However, for some tests with low sample sizes, the chi-squared tests results were compared with Fisher's Exact Test as well as Chi-squared tests using Monte Carlo simulation to estimate p-values to confirm the interpretation. Conservationist results were also compared with farmer survey results using similar techniques to examine similarities and differences between the two stakeholders.

## 5.4 Results and Discussion

### 5.4.1 In-depth Interviews

Of the 14 farmers interviewed, none produced the MEA definition of “ecosystem services”, and only two had heard of the term. However, they identified a variety of ESS in the context of agricultural conservation, and particularly the benefits received from conservation practices explicitly discussed (Figure 5.2). Some farmers focused almost exclusively on one or two ESS (e.g. erosion regulation), while others discussed an assortment of ESS. All farmers recognized freshwater provisioning and erosion regulation. Most ESS were only recognized by some of the farmers, although failing to mention a service does not indicate that the farmer does not recognize that service on their lands – instead, it may indicate that they don’t believe the specific conservation practices discussed provide that particular service.

Provisioning and regulating services were emphasized more frequently than cultural services. Soil erosion regulation was the most discussed service at over 100 references in fourteen interviews, with food provisioning and freshwater provisioning ranking second and third. It’s possible that farmers referred to services they thought the researcher wanted to hear, as the context of the interview was on targeting conservation practices to locations where they would do the most good, and NRCS conservation practice standards were shown to the farmers on sheets of paper during the conversation. In most cases, however, farmers answered the question with their own opinion, as evidenced by frequently neglecting to provide answers available on the NRCS practice standard sheets.

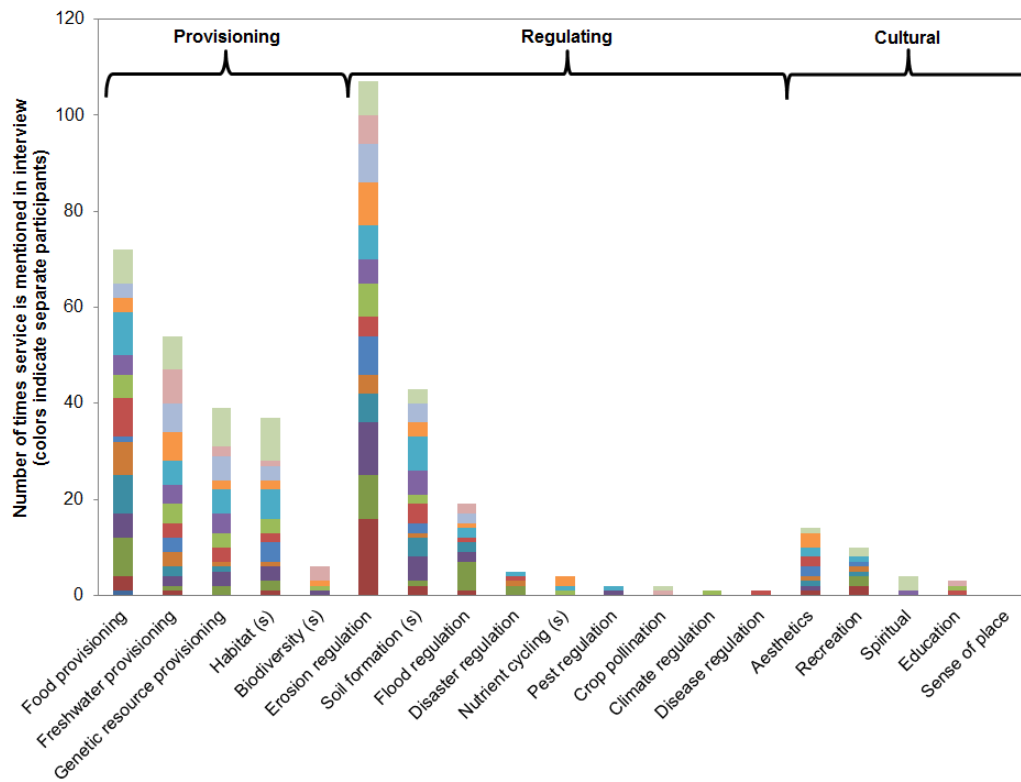


Figure 5.2 Total number of references to ecosystem services over fourteen interviews. Each interview is given a particular color across all bars. Services are arranged by prevalence within service type (provisioning, regulating, and cultural services). Supporting ecosystem services are denoted with an (s).

The emphasis on freshwater provisioning and erosion regulation may also be an outcome of long-term, targeted education and outreach activities to farmers by federal and state conservation agencies such as the NRCS “T-by-2000” campaign. Simultaneously, Indiana has also focused efforts on nonpoint source reduction campaigns, such as the Indiana Department of Environmental Management (IDEM) Section 319 Grant-Funded Watershed Management and the Indiana Department of Agriculture’s Clean Water Indiana (CWI) Initiative. The water quality emphasis of these programs may have increased farmer awareness and recognition of freshwater provisioning as a key benefit. Understanding the institutions that already influence farmers can help reveal preferences for ESS provision (Spangenberg et al. 2014).

The following sections detail how farmers perceived the major provisioning, regulating, and cultural services to be relevant to their work and agricultural conservation. Actual quotations are provided in Table 5.4.



Table 5.4 Actual quotes from farmer interviews.

FP-1	“That was nature’s way of taking care of us, so we’ve modified it, and made it, you know, more specialized and more productive. Because how many people can we feed off of these acres today, versus what we did fifty years ago? And that’s what your goal is, to make this whole thing more efficient.”
FP-2	“I guess it just goes back to the soil is the basis for the productivity and we are...producers of products that sustain people.”
FP-3	“we’re all about yield out here, so the more we can grow out here off of an acre, then hopefully that will give us more money to operate on.”
FWP -1	“[Water protection] is more important to me as a secondary. Obviously economic survival is first. But [it is] secondary to not contribute my nitrogen, phosphorus and potassium to the water supply.”
FWP -2	“Keeping those soluble nutrients out of drainage water is very big. We don’t want them to go anyplace else, they’re ours. We don’t want to give them away down the creek. We don’t want the guys in New Orleans and on south to have to deal with it. We want to keep them.”
FWP -3	“I was always very conscientious when we pumped our pits out of our hog barns, tried not to do it where it could run off, potentially get into a stream.”
FWP -4	“I think the previous year, where the big issue was basically nutrient leaching, you couldn’t get rid of enough water. I hate to say it, that’s why we leach nutrient. And it really wasn’t a surface drain problem, it was basically going out the tile [subsurface drain].”
GRP -1	it’s kind of nice, it’s an ecosystem, you know, and you’ve got to protect ecosystems. So, [there are] some benefits of it, even though there’s no practical agricultural benefit.”
GRP -2	“there is some habitat there for types of birds that like to live in the grass.”
GRP -3	“just for habitat, homes for wildlife.”
GRP -4	“The DNR [Department of Natural Resources] guys used to come up and check this about every year, walk it with you, and every once in a while they’d say ‘well there’s something’ that had gotten established that was lost to the area. They were tickled to death, you never see [these species], so [conservation] works. Like I said, build it and they will come.”
GRP -5	“It would be helpful [to do so, but] whether I can justify taking land out of production, that’s another story.”
GRP -6	“This bench here is a big area for invasive species to get started in.”

Table 5.4 (Continued) Actual quotes from farmer interviews.

ER-1	“I will do virtually whatever I can, to a point, to limit the amount of soil leaving our property.”
ER-2	“Basically the soil is the most important thing...without soil you don't have anything else.”
ER-3	“I think everybody ought to have an idea of what their soil losses are, where they occur, and how to control that.”
ER-4	“there's a fine line of being able to keep the dirt where it belongs and keep everything usable,”
ER-5	“Yeah, it's just a problem. The tiles drain into this area, and they're all plugged, so it erodes the top of the ground and starts huge erosion ditches, I'm almost at wits ends. So I need to...whatever programs are available I'll line up for that one. And like I said, there's more erosion on this 78 acres of farm ground than on all the other acres I have.”
ER-6	“Again, the biggest deal, it helps control water movement. It keeps the soil much more in place, controls erosion, depending again on the topography.”
ER-7	“Slowing the water down, having an access for rain, runoff, to escape without carrying with it much topsoil.”
ER-8	“And I can see, this one particular farm we have, it's got a lot of hills, sloping land, and if you get a big rain, there'll be areas, there will be silt, top soil, this deep, that's just washed off of these hills. It can only last so long.”
ER-9	“I guess, if it was something that makes the soil, preserves it in some way, I mean I certainly look forward to taking care of the next generation. Someone took care of it for me.”
FR-1	“drainage was a religion, it was very rigid – you have to drain.”
FR-2	“When it rains, anything more than an inch and three quarters to two inches...if we have had some rain prior too...I lose up to 65 acres of that 150 acres. That has happened about one in three years.”
A-1	“Biodiversity. And even landscape diversity. Just the way the landscape looks,” or “Well, it's just kind of nice to see the wildlife, I kind of like to see it, diversity of the environment.”
A-2	“I think probably we did it more for aesthetic purposes than for anything.”
A-3	“It's fun, it's just a fun place to go out to if you like that kind of stuff, go out and walk. We mow the edges [of the wildlife area] and mow through it a little so I can just...when I lived on the farm I'd just go out there and spend an evening, go out after supper and just walk, and it was always fresh out there, cooler, seemed like.”

#### 5.4.1.1 Food Provisioning

Many farmers stated clearly that food provisioning was their primary goal. One farmer emphasized that the goal of farming in general is to increase crop yields (FP-1). Another suggested that food provisioning is at the core of the identity of his profession (FP-2). The importance of crop yields went beyond the satisfaction of sustaining human life on earth – sustaining high crop yields is necessary for farm profitability. Some made direct references to food provisioning as a factor in economic sustainability (FP-3).

Farmers' statements displayed an understanding of the interconnectedness between food provisioning and several supporting services, particularly soil formation and nutrient cycling. While direct references to food provisioning services were common, farmers frequently focused on related supporting services. Soil compaction, soil tilth, nutrient and organic matter content of soils, as well as water availability were emphasized because of their importance to crop growth.

#### 5.4.1.2 Freshwater Provisioning

Freshwater provisioning was highlighted as another primary benefit of conservation practices, and was also acknowledged as a challenge for intensive agriculture. Most farmers expressed a desire not to pollute waters with fertilizer runoff for two main reasons: fertilizer loss impacts their economic bottom line and it causes harm to humans and the environment downstream. While loss of nutrients to surface waters is a cost to the farmer, some farmers believed water quality consequences of farming were assumed by neighbouring lands or society at large (FWP-1, FWP-2).

Farmers primarily emphasized the water quality aspect of freshwater provisioning rather than quantity. Many farmers used conservation practices intended to reduce the impact of nutrient leaching (FWP-3). However, one farmer highlighted the inherent difficulty of keeping nutrients out of surface waters, especially under the Indiana climate and subsurface drainage conditions (FWP-4). Overall, most farmers cared about freshwater provisioning primarily for practical (lost fertilizer value) and ethical (not wanting to contribute to problems downstream) reasons. Some farmers showed heightened awareness of water quality concerns related to subsurface tile drainage, while others presumed that water quality protection only need occur along open waterways.

#### 5.4.1.3 Genetic Resource Provisioning

Genetic resource provisioning was viewed as less synergistic with food provisioning – the main goal of most farmers – leading to discussion of ESS trade-offs. Farmers primarily discussed the benefits of species diversity in the context of habitat restoration conservation practices. Many farmers suggested that diversity is important for sentimental or ideological reasons rather than practical ones. One farmer spoke about a five acre “lake” in his field that he chose not to drain because of “other” benefits it provided, despite its lack of agricultural benefit (GRP-1). Another farmer chose not to mow grass areas on his farm until after wildlife breeding periods so that there was habitat for certain types of birds (GRP-2). One farmer converted a large piece of farmland to wetland, native prairie, and food plots for wildlife. His sole justification was habitat benefits for wildlife (GRP-3).

He went on to share how endangered sparrows had inhabited the conservation land (GRP-4). This is also an example of how state and federal agency conservation outreach and encouragement can support and influence farmer priorities.

Ideological reasons, however, are not always sufficiently compelling in the face of practical constraints, such as economics, invasive species, and inconvenience. One farmer brought up the declining bird populations due to decreased habitat, but stated that he may not be comfortable creating habitat from good farmland (GRP-5). Still others brought up difficulties of keeping invasive species out of conservation lands such as filter strips (GRP-6). Between the economic bottom line of intensive agricultural production and the inconveniences of managing diverse lands on the farm, many were not able to justify conservation measures intended to increase genetic resources.

#### 5.4.1.4 Erosion Regulation

Soil erosion regulation was the ESS stressed most by farmers regarding conservation, sustainability, and personal farm management goals. One farmer expressed the importance of soil conservation as a priority for his management strategies (ER-1). Another suggested that soil conservation is the most basic need of farming (ER-2). Another farmer suggested that soil conservation is a responsibility all farmers share (ER-3). Yet many farmers mentioned the difficulty of balancing soil erosion and other farm goals. One noted that it is difficult to maintain topsoil, in the context of the practicality and inconvenience of using conservation practices in his farm management (ER-4). Another lamented the difficulty of controlling soil erosion when other management practices fail (ER-5).

Soil erosion regulation was often connected to freshwater provisioning, and farmers generally expressed greater concern over erosion by surface runoff than wind erosion (ER-6). Another farmer suggested that the goal of conservation was to slow runoff so that it could not carry away topsoil (ER-7). Soil erosion was tied to long-term sustainability of farming more than any other service in the interviews. One farmer even expressed a sense of urgency over soil erosion occurring on one sloped farm field (ER-8). Another more directly expressed a desire to sustain the farm for future generations, and that doing so requires soil preservation (ER-9).

#### 5.4.1.5 Flood Regulation

The importance of flood regulation emerged repeatedly in the need for subsurface drainage in the fairly flat, poorly-drained agricultural fields that are characteristic of west central Indiana. Farmers generally did not discuss the environment as providing flood regulation, but rather as being the cause of the problem. While tile drainage may not be a natural ESS provided by the land, a preoccupation with drainage revealed farmer knowledge of its importance to their operations. All farmers had extensive tile drainage on at least some of their fields, and many had plans to increase the number of tile drains in the wettest fields they worked. One farmer spoke of a mentality where drainage was equivalent to religion (FR-1). Another farmer's story demonstrated how maintaining farm productivity depends on tile drainage, and poor drainage can result in considerable yield losses. In his case, a main tile drain had broken, leaving his land susceptible to ponding (FR-2).

It is notable that while farmers viewed freshwater provisioning and nutrient cycling services as beneficial to humans and the environment downstream, they did not connect the problem of downstream flooding to their tile drainage management. Were the landscape to return to pre-settlement conditions, where extensive poorly-drained soils were wetlands, downstream lands would benefit from reduced flooding in the Wabash River and its tributaries. Yet in this condition, un-drained farmlands would not be nearly as productive for crops.

#### 5.4.1.6 Aesthetics

Aesthetics was the cultural ESS most frequently mentioned, and was generally introduced in the context of wildlife and restoring diverse landscapes. When asked the benefits of conservation intended to create wildlife habitat, farmers might say how “nice” it was view the diversity and wildlife of the landscape (A-1). When asked why they used these practices, one commented that aesthetics was a main influence (A-2). When farmers had installed a conservation practice for wildlife, they often told stories of the cultural services provided, such as spending an evening walking around and enjoying the landscape (A-3).

### 5.4.2 Farmer and Conservationist Surveys

#### 5.4.2.1 Sample Characteristics

The response rate for the farmer survey was 20% (N = 200), including 71 cropland surveys, 61 forestland surveys, and 68 reservoir surveys. The responses were spatially distributed across Indiana, with 82 of the 92 counties having at least one response (Figure 5.1). The majority of respondents were male (75%), 55 or older (75%)

and either the farm owner (45%) or farm owner and operator (42%). These demographics correspond to National Agricultural Statistics Service (NASS) statistics from Indiana in 2007 which report that Indiana farmers are 90% male and the average age is 55 (USDA 2011). Corn, soybean, hay, and wheat were farmed by 80%, 83%, 34%, and 26%, respectively, with 16% of the respondents growing something other than these crops, and 4% growing no crops (most indicated they were retired). Respondents generally implemented conservation practices, participated in conservation programs, and farmed hundreds to thousands of acres (Table 5.5).

The response rate for the conservationists survey was 16% (N=33) with 10 cropland responses, 8 forestland responses, and 15 reservoir responses. There were at least two responses from each of the NRCS conservation districts in Indiana (Figure 5.1). The majority of respondents who chose to indicate their gender were male (64%) and most respondents were under the age of 55. This is significantly different from the farmer responses, as the majority of respondents were over the age of 55 ( $p < 0.05$ ). The most common positions held by participants were District Conservationists (35%), Soil Conservationists (18%) and Engineers (12%).



Table 5.5 Minimum, maximum and mean conservation participation and farm size of farmers.

<b>Farm Demographics</b>	<b>Min</b>	<b>Mean</b>	<b>Max</b>
Conservation practices (no.)	0	2.8	7
Conservation programs (no.)	0	1.2	4
Land farmed (acres)	0*	405	3,000
*Reasons farmers marked “no” land as farmed included they were renting their land, they retired recently, or they had fruit or nut trees, not farmland.			

#### 5.4.2.2 Baseline Knowledge of Ecosystem Services

Most of the farmer participants (72%) were unfamiliar with “ecosystem services.” Of the 55% of surveys that provided a definition, only 11 respondents (6%) gave definitions consistent with MEA (Table 5.6). Farmers who had heard of the term were not significantly more likely to provide the correct definition than farmers who hadn’t heard of the term. The most common (and incorrect) definition provided by respondents was a category of responses we refer to as “conservation consultant,” where participants defined ESS as services provided by an outside group to assess and improve their farm’s ecosystem (Table 5.7). This definition is similar to the idea of crop or soil and water conservation service consultants, and the similarity of language is likely one reason they commonly provided this definition. Other categories included “land management,” where participants gave a definition which involved humans generally managing the landscape for the benefit of the ecosystem (not humans), “general environment,” where participants provided a general statement about protecting the environment, and “ecosystem,” where participants gave the definition of an ecosystem (Table 5.7).

Although the percent of conservationists who had heard of the term “ecosystem services” did not differ significantly than the percent of farmers who had heard of the term, a significantly larger percentage (30%,  $\alpha=0.05$ ) of conservationists were able to provide the MEA definition. The conservationist responses were readily grouped in the same categories as the farmers’ responses (Table 5.7). Three conservationists who provided a correct definition of ESS also said the term had come up in conversations with farmers.

Table 5.6 Results of baseline assessment of participant ecosystem service knowledge

	Heard of Term	Not Heard of Term
Definition Right	6	5
Definition Wrong	24	65

Table 5.7 Qualitative coding of farmer and landowner responses to the question “What would you guess that ‘ecosystem services’ means?” Descriptions of each code, along with representative definitions in that code group, are provided.

<b>ES definition group</b>	<b>Group description</b>
No response	The definition is left blank.
Vague	Cannot be grouped because it is too vague.
Irrelevant	Response is irrelevant to the question.
Not sure	Participant states they are not sure what the definition is and does not guess a definition.
Ecosystem	Definition is that of "ecosystem"
General environment	Only a general understanding that ecosystem services relate to the environment in some way.
Land management	Focus is on humans managing the land in ecologically relevant ways, without the mention of an external consultant educating or helping the farmer or landowner. Humans are providing a service to the land.
Conservation consultant	Emphasis is on an outside consultant from government, private industry, academia, etc. helping farmers and landowners manage land in "environmentally friendly" ways. Focuses on external consultants providing a service to the land or landowner.
Correct definition	Definition is in line with the ecosystem service concept. Focus is on the environment providing benefits to humans.

Table 5.7 (Continued) Qualitative coding of farmer and landowner responses to the question “What would you guess that ‘ecosystem services’ means?” Descriptions of each code, along with representative definitions in that code group, are provided.

ES definition group	Response % (number)		Representative definitions
	Farmers	NRCS	
No response	45% (90)	18% (6)	N/A
Vague	1% (1)	0% (0)	<i>“Management, information”</i>
Irrelevant	4% (8)	3% (1)	<i>“You want to control what I do on my land. Tax me or penalize me for not doing it your way.”</i>
Not sure	5% (9)	3% (1)	<i>“Don't know”</i> <i>“?”</i>
Ecosystem	3% (5)	3% (1)	<i>“A system formed by the interaction of a community of organisms with its environment”</i> <i>“full habitat system”</i>
General environment	4% (8)	0% (0)	<i>“Something to do with conservation practices”</i> <i>“Balance of soil and nature”</i> <i>“Method of protecting the environment”</i>
Land management	10% (20)	26% (9)	<i>“A plan that would create a positive, productive ecosystem”</i> <i>“How to maintain farm land and protect the environment”</i>
Conservation consultant	24% (47)	15% (5)	<i>“Somebody who helps design ecosystems”</i> <i>“Help from a Government agency or Group to assist farmer to improve their farm and in turn improve the ecosystem”</i> <i>“Consulting to help people maintain the ecology of their lands”</i>
Correct definition	6% (11)	30% (10)	<i>“The benefits we get from an ecosystem”</i> <i>“Services provided by nature that would otherwise be necessary for humans to perform”</i>

### 5.4.2.3 Recognition and Value of Ecosystem Services

#### 5.4.2.3.1 Farmers

Although many farmers had not heard of “ecosystem services” and even fewer could correctly define it, it was clear that farmers recognized benefits that different kinds of landscapes provided (Figure 5.3). By indicating the presence (always, sometimes, or never) of a “benefit to society” provided by a land type, the farmers demonstrated their recognition of ESS – even though they may not use the term ESS. Based on the responses from the three different survey types, it was also clear that farmers recognized that different landscapes provide different benefits (or ESS) with some trade-offs (Figure 5.3).

When comparing responses of the forestland and cropland surveys, there was a significant difference in recognized benefits for all services except fiber provision. Moreover, all ESS except food provision were chosen as being provided significantly more often by forestlands than croplands. This shows a trade-off of ESS between these two land types consistent with ESS literature (Groffman et al. 2007) and notably depicted in conceptual trade-offs identified by Foley et al. (2005), where an intensively managed agroecosystem has increased food provision at the expense of other ESS.

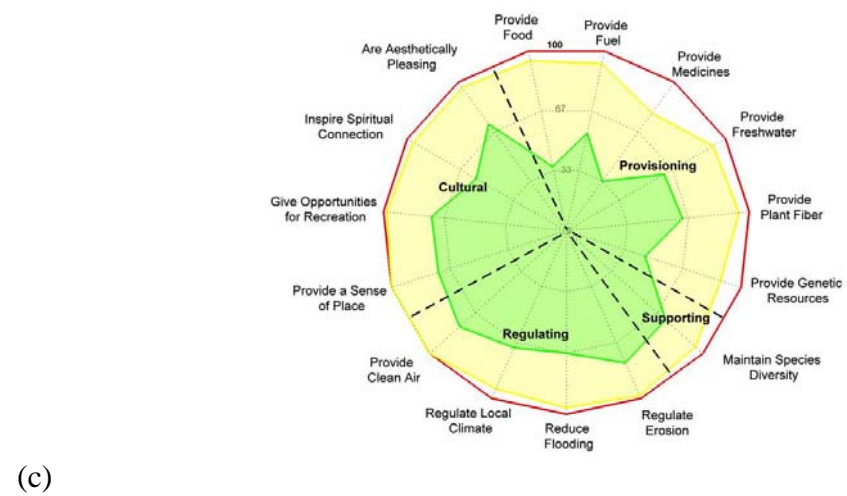
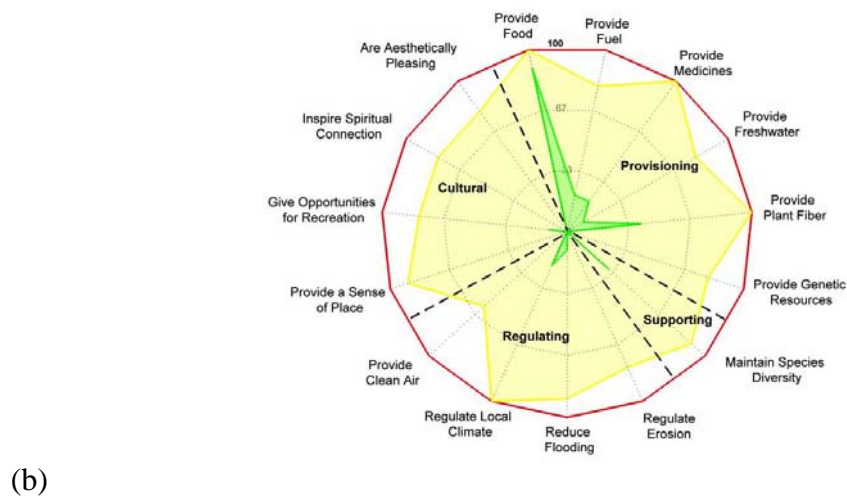
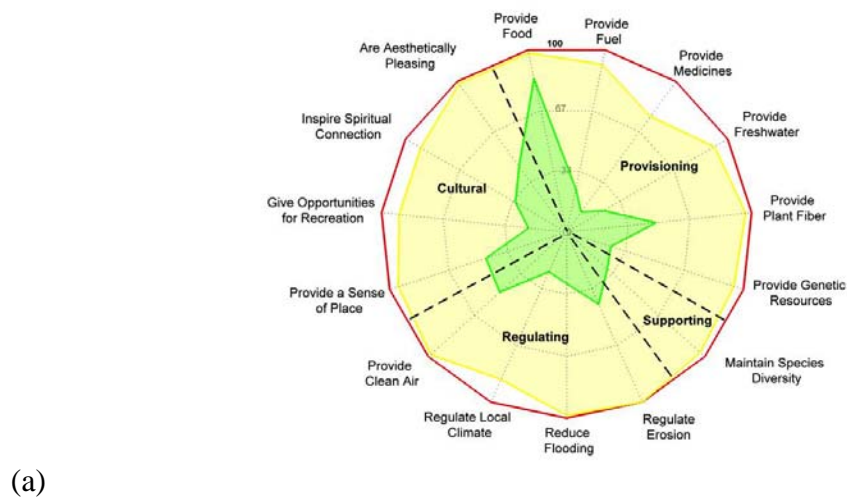


Figure 5.3 Farmer (a) and conservationist (b) recognition of Indiana cropland benefits. Farmer (c) and conservationist (d) recognition of Indiana forestland benefits. Farmer (e) and conservationist (f) recognition of Indiana reservoir benefits.

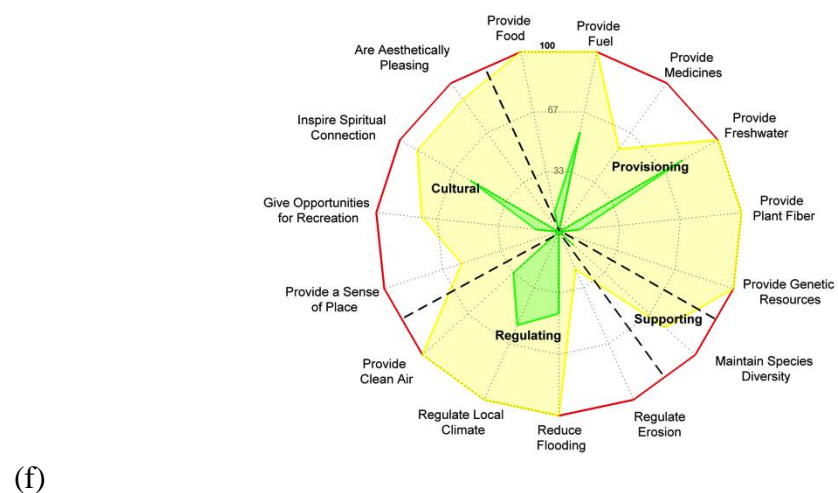
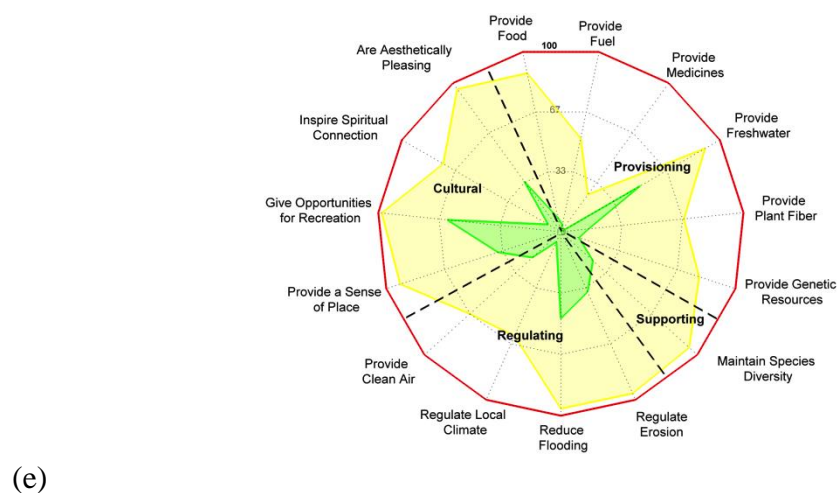
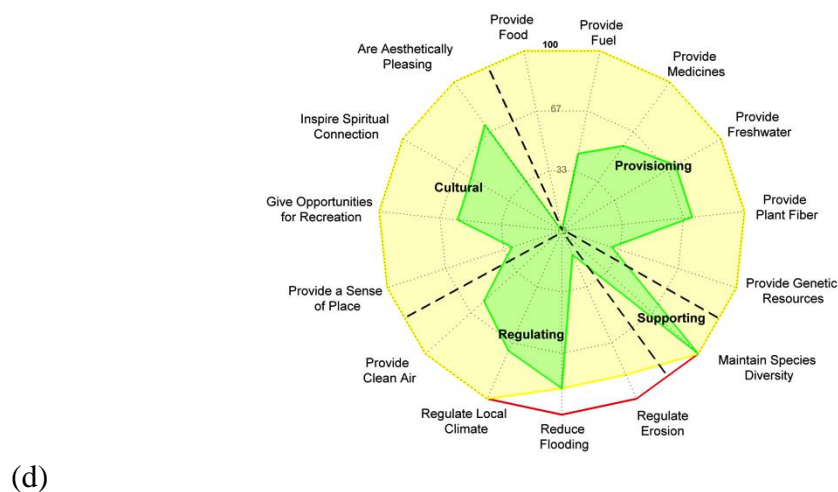


Figure 5.3 (Continued) Farmer (a) and conservationist (b) recognition of Indiana cropland benefits. Farmer (c) and conservationist (d) recognition of Indiana forestland benefits.

Farmer (e) and conservationist (f) recognition of Indiana reservoir benefits.

In comparing the cropland and forestland survey responses to the reservoir responses (Figure 5.3), it is clear that farmers felt reservoirs provided significantly less ESS. Between forestlands and reservoirs, only freshwater provision, flood regulation and recreation services provided by both land types were not significantly different. Between croplands and reservoirs, only erosion regulation, sense of place, aesthetics, and habitat for species were not significantly different. The fact that farmers felt reservoirs provide significantly less benefits than forests and croplands could be due to a perception of reservoirs as man-made rather than natural systems.

Farmers were also asked to choose whether ESS they selected as “always” or “sometimes” being provided were “always”, “sometimes”, or “never” valuable to society (Figure 5.4). Between the cropland and forestland survey responses, the valuation of the benefits recognized by farmers was not significantly different for the majority of services listed. Only valuations of food provision, climate regulation, recreation, and aesthetics were significantly different ( $\alpha=0.05$ ). Food provisioning from croplands was valued higher than food provisioning from forestlands, whereas recreation, climate regulation, and aesthetics benefits from forestlands were valued higher than croplands. The higher valuation of food from croplands by farmers is expected as those lands are typically managed primarily for providing food.



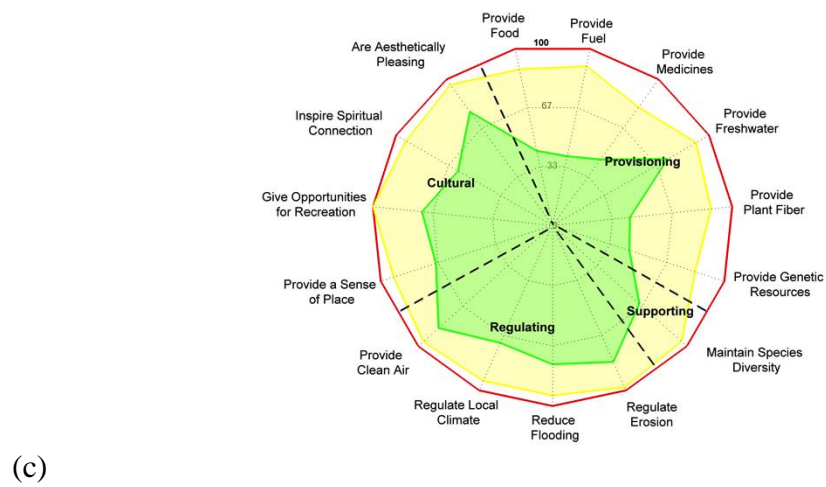
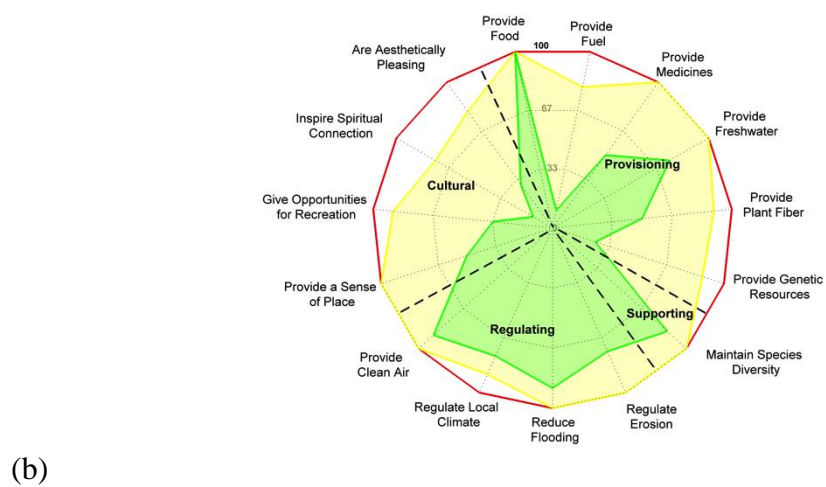
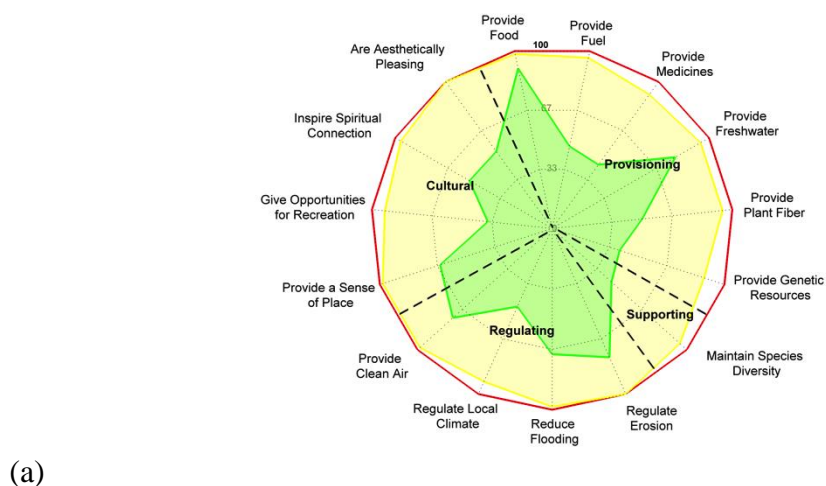


Figure 5.4 Farmer (a) and conservationist (b) valuation of recognized Indiana cropland benefits. Farmer (c) and conservationist (d) valuation of recognized of Indiana forestland benefits. Farmer (e) and conservationist (f) valuation of recognized Indiana reservoir benefits.

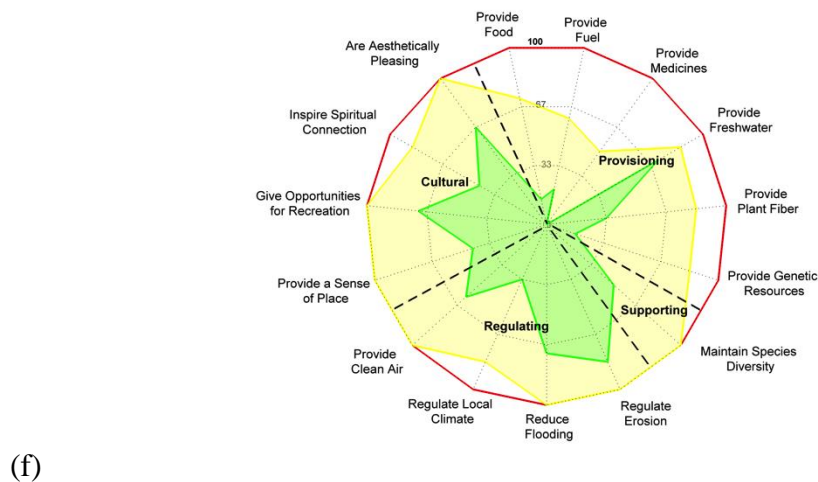
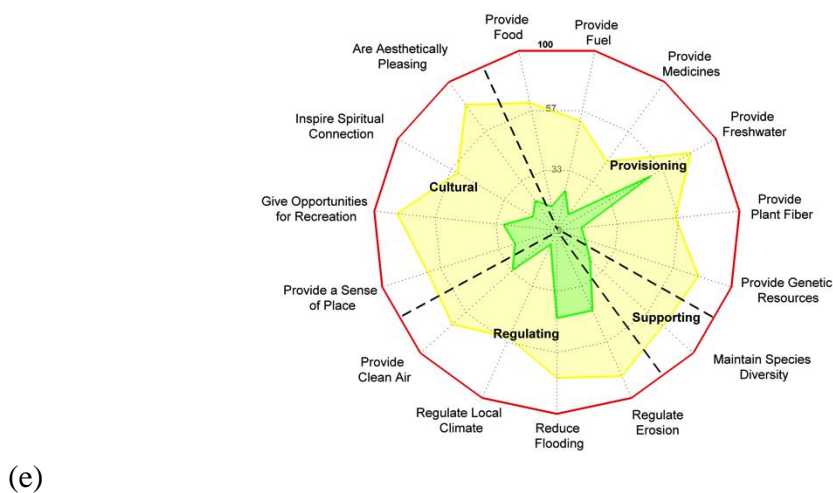
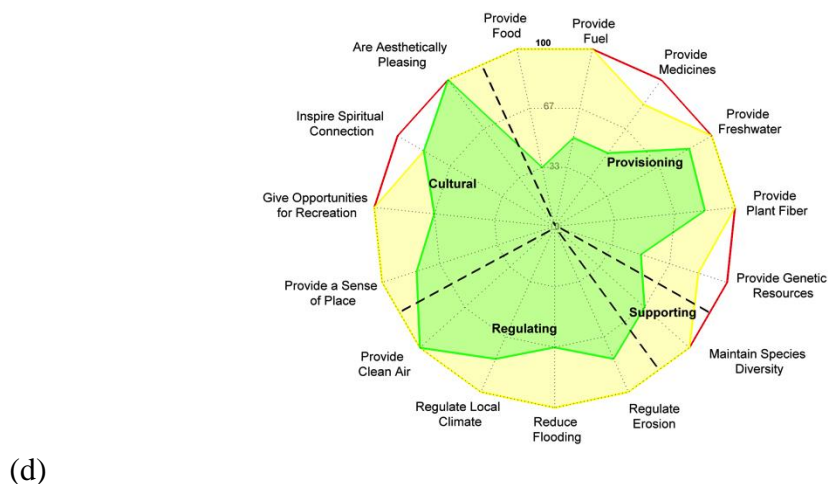


Figure 5.4 (Continued) Farmer (a) and conservationist (b) valuation of recognized Indiana cropland benefits. Farmer (c) and conservationist (d) valuation of recognized of Indiana forestland benefits. Farmer (e) and conservationist (f) valuation of recognized Indiana reservoir benefits.

Benefits provided by reservoirs were typically valued lower than benefits provided by forestlands and croplands. Comparing forestlands and reservoirs, only the valuation of freshwater provision was not significantly different (Figure 5.4). For all other services, the valuation of benefits provided by forestlands was higher than those provided by reservoirs. Between croplands and reservoirs only the valuation of recreation was not significantly different. For all other services, farmers valued the benefits provided by croplands higher than the benefits provided by reservoirs.

#### 5.4.2.3.2 NRCS Conservationists

Similar to the farmers, conservationist responses showed the recognition of trade-offs between different land types (Figure 5.3). Comparing the forestland responses to the cropland responses showed that food provision, freshwater provision, flood regulation, air quality regulation, spirituality, aesthetics, and habitat benefits provided were significantly different. Of these benefits, only food provision was selected as being more often provided by croplands, whereas the rest were chosen as being more often provided by forestlands. The trade-off in services from a natural system to an intensively managed agricultural landscape is clearly shown in the conservationists' response.

The comparison between croplands and forests to reservoirs (Figure 5.3) shows that similar to farmers, conservationists felt reservoirs provided less benefits overall. Between forestlands and reservoirs medicine provision, fiber provision, erosion regulation, aesthetics, and habitat were the only benefits shown as being provided differently between the two land types. The responses indicated that forestlands were providing these benefits more often than reservoirs. Comparing cropland and reservoir

responses showed that food provision, medicine provision, freshwater provision, erosion regulation, air quality regulation, and spirituality were significantly different. Food provision, medicine provision, and erosion regulation were seen as being more often provided by croplands, whereas freshwater provision, air quality regulation, and spirituality were seen as being more often provided by reservoirs.

Conservationists were also asked to value the benefits they selected as being “always” or “sometimes” provided by the land (Figure 5.4). The valuations of forestlands and croplands showed that only food provision, spirituality, and aesthetics were valued differently between the two land types. Food provision was valued higher for croplands, whereas spirituality and aesthetics were valued higher for forestlands. This suggests that, like farmers, conservationists think the food grown on croplands is more valuable, perhaps because croplands are primarily managed for food. Comparing the valuation of benefits provided by forestlands and reservoirs, all benefits were valued the same. This may suggest that conservationists think that ESS, despite the land type they were provided from, have similar value. Yet, in comparing croplands and reservoirs, food provision was valued differently, indicating that conservationists valued food provisioning higher on croplands.

#### 5.4.2.3.3 Comparing Farmers and NRCS Conservationists

We compared the responses of farmers and conservationists for benefits provided by each land type and the valuation of those benefits. In general we found that valuation of services did not differ considerably, but recognition of services derived from croplands and reservoirs did vary.

While farmers and conservationists thought food provisioning was the dominant service provided by croplands, they differed widely in their views of other ESS (Figure 5.3). Farmers and conservationists who took the cropland surveys differed in how often croplands provide erosion regulation, air quality regulation, sense of place, and aesthetics ( $p < 0.05$ ). Farmers identified these benefits as being provided more often than did conservationists. Valuation of these benefits differed only in fuel provisioning, spiritual connection, and aesthetics, and again farmers valued these higher on croplands than did conservationists. The divergence in the valuation of cultural services derived from cropland is notable. Farmers' higher valuation of aesthetics of croplands agrees with findings that Midwest farmers value an aesthetically pleasing, tidy landscape (Ryan et al. 2003; Ahnstrom et al. 2008). It is unclear from this survey why farmers would view croplands as more spiritually inspiring than conservationists, although it may pertain to attachment many farmers feel to their land (Ryan et al. 2003). The discrepancy between farmer and conservationist views of benefits provided by croplands might come from true differences or sampling bias. Farmers may have a more positive view of croplands because they own and/or work on them. Alternatively, the sample of farmers may be biased towards conservation-mindedness and these farmers may be thinking of their own specific farm, whereas conservationists may be generalizing across multiple farms.

When responses were compared for the forestland surveys, only erosion regulation and sense of place were recognized at significantly different levels ( $p < 0.05$ ) and no services were given different values (Figure 5.3).

Most farmers thought forests always regulated erosion while most conservationists thought forests sometimes regulate erosion. Again, farmers rated sense of place and erosion regulation from forestlands higher than conservationists, and the difference is considerable.

Farmers and conservationists exhibited differing views of ecosystem benefits from reservoirs yet no significant difference in valuation ( $\alpha = 0.05$ ) (Figure 5.3 & Figure 5.4). Recognition of fuel provision, erosion regulation, climate regulation, sense of place, recreation, and spirituality benefits differed significantly between farmer and conservationist responses ( $p < 0.05$ ). Fuel provision, climate regulation, and spirituality were chosen by conservationists as being more often provided by reservoirs, whereas erosion regulation, sense of place, and recreation were seen by farmers as being more often provided. These differences between farmer and conservationist recognition of ESS from reservoirs may be partially due to variation in the particular “reservoir” each participant was thinking of when asked to “think of the reservoirs in your town and in the state of Indiana.”

#### 5.4.2.4 Beneficiaries and Stewards of Ecosystem Services

Both farmer and conservationist responses show slight differences in who they perceived to benefit from ESS provided by different land types (Figure 5.5). For croplands, respondents identified owners and operators as benefiting the most, with society and local community just behind. Similarly for forestlands, both conservationists and farmers felt owner/operators and society/community benefited the most.

Fewer beneficiaries were chosen for the benefits provided by reservoirs, which may be due to the lower amount and value of the benefits that farmers and conservationists felt reservoirs provided.

There was a significant difference overall ( $p = 0.02$ ) in who respondents believed was most responsible for maintaining benefits provided by the three land types (Figure 5.6). However, comparing farmer and conservationist responses within each land type showed that for croplands and forestlands there was no significant difference in who they believed were primary stewards, but there was a significant difference ( $p = 0.003$ ) for primary stewards of reservoir benefits. For croplands, both conservationists and farmers overwhelmingly felt farm owner and/or operators were responsible for maintaining benefits they identified as being provided to society. The majority of farmer responses that fell into the combination category chose both farm owner and operator. There were more farmer respondents that felt forestland benefits were the responsibility of various levels of government. For reservoirs, farmer respondents felt government was the major entity that should be responsible for maintaining these benefits, whereas conservationists felt this to be primarily society's responsibility.

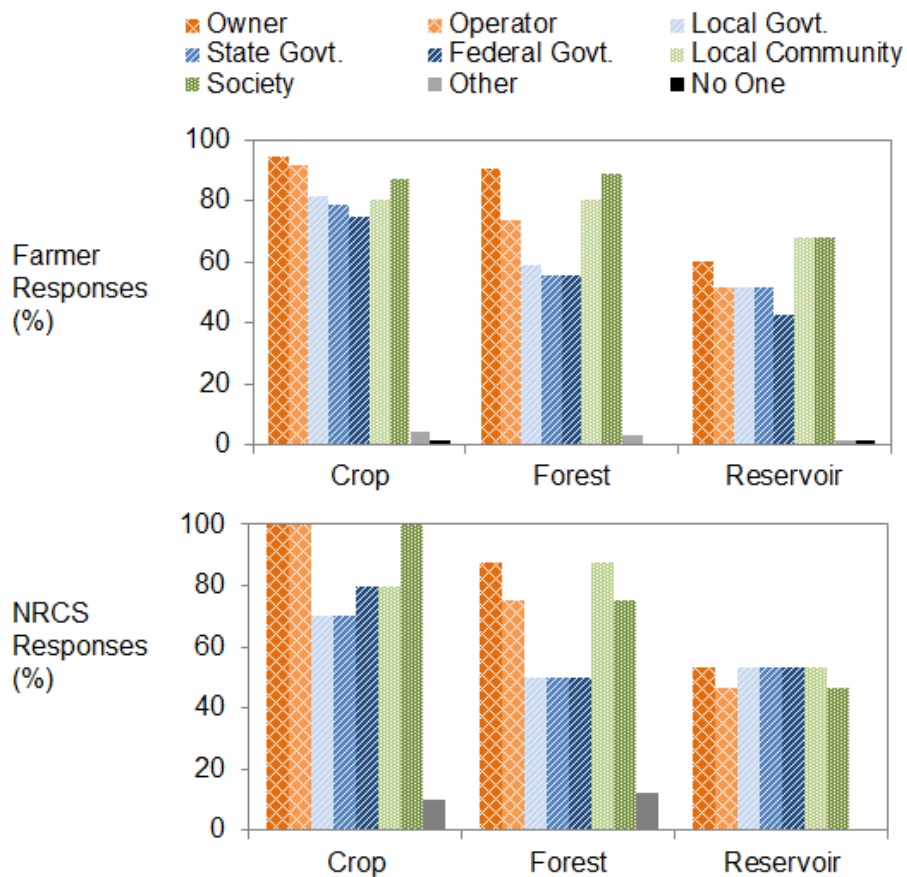


Figure 5.5 Farmers' and conservationists' perceptions of those benefiting from ecosystem services derived from each land type. Respondents were permitted to select as many beneficiaries as desired, and the unit shown is the percentage of respondents selecting a given beneficiary.



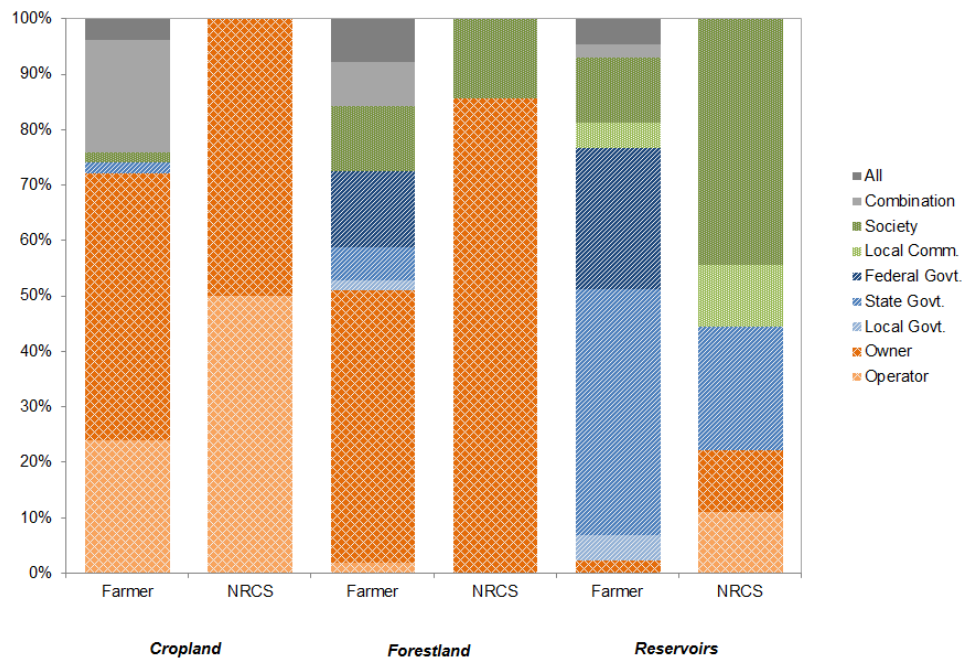


Figure 5.6 Participant response for who was most responsible for maintaining benefits provided to society by the different land types.

Overall, results show that both farmers and conservationists recognize that ecosystem benefits from these three land types are important to a wide range of stakeholders, including society at large. Understanding the breadth of beneficiaries likely corresponds with knowledge that management of these private croplands and forestlands has widespread impacts in our society, and indicates that it may not be a stretch for farmers to think about how management of their farm is relevant to society. It's interesting to note that farmers tended to view the government as having a greater responsibility than did the conservationists, although the distinction between "government" and "society" may be a matter of preferred language (since government funds come from society). These findings generally demonstrate that Indiana farmers believe they are primarily responsible for maintaining benefits (ESS) on their lands.

#### 5.4.2.5 Engaging Farmers in Policy Discussions

Knowledge about issues on hand is a prerequisite to engage any stakeholder on a policy discussion. This study evaluated farmers' awareness of ecosystem services. Results from this study indicated that an overwhelming majority of the farmers participated in conservation programs or were willing to participate making them ideal participants in policy discussions related to ESS. What may be needed is increased outreach to educate them about how conservation practices relate to ESS derived from their farmland. From the 200 responses, only three indicated they didn't have any conservation practices on their farm (five left this question blank), which demonstrates that many farmers are already participating in conservation on their farm. Farmers also indicated what kinds of conservation practices they used on their farm: No-tillage (70%),

grassed waterways (60%), nutrient management (43.5%), cover crops (39%), filter strips (28.5%), wetlands (20.5%), riparian buffers (12.5%), two-stage ditch (3.5%), and other (7%). Sixty-three percent of respondents participated in at least one federal conservation program, with 21% participating in more than one. Despite this prevalence of conservation participation, there were no statistically significant connections ( $\alpha=0.05$ ) between the number or type of conservation practices implemented and farmer knowledge or valuation of ESS. This suggests that most farmers were knowledgeable about and valued ESS provided by conservation practices, but their participation in conservation practices may have been influenced by other factors such as cost.

We also asked farmers directly if they would “be more willing to implement conservation practices if [they] knew how they benefited [their] farm’s ecosystems.” Thirty-seven percent responded “yes” and 49% responded with “potentially”. Only 4% responded “no”, and the remaining 10% left the question blank. Similarly, we asked farmers to evaluate their level of conservation-mindedness to better understand their view of their own attitude towards conservation. Sixty-four percent said they were conservation-minded, 25% said they were mostly conservation-minded, and 9% said they were somewhat conservation-minded. None responded that they weren’t conservation-minded and the rest (2%) left the question blank. Farmers’ self-assessments indicated a general interest in conservation and a willingness to manage their lands to improve their farm’s ecosystems, suggesting that they will be a cooperative and active stakeholder in ESS policy discussions.

When conservationists were asked to assess farmers' willingness to implement practices that benefit their farms' ecosystems, they gave a less optimistic assessment. They responded that "yes" farmers would be willing only 21% of the time, "no" 18% of the time, and "potentially" 53% of the time (9% left blank). This inconsistency in view of farmer willingness to change practices may be because of the survey pool – it's possible that farmers who responded were more open to change. However, it agrees with previous work showing that farmers generally view themselves as good stewards and land managers (Ahnstrom et al. 2008; McGuire et al. 2013), and that farmers often view themselves to be conservation-minded, though conservationists may not agree (Carr and Tait 1991). This slight discrepancy between farmers and conservationists may need to be considered before initiating ESS policy discussions.

Lastly, to understand how best to begin involving farmers on discussions of managing multiple ESS, we asked where farmers preferred to get information when making management decisions on their farm, as well as what resources they would consult for information about their farm's environmental benefits. Most farmers preferred consulting other farmers or publicly funded professionals such as the FSA, Extension Officers, and NRCS. To get more information about environmental benefits on their farm, respondents indicated they would consult mostly with publicly-funded professionals or learn from articles in farm or other magazines they read. The results of these two questions show the greatest potential for engaging farmers in ESS policy discussions may involve outreach through publicly-funded professionals as well as farm magazines, as these sources seem to be more trustworthy to farmers.

### 5.4.3 Joint Discussion of All Three Studies

All study results support a central theme of current farmer knowledge of ESS and the potential for ESS-based farm management. Farmer interviews focused mainly on conservation practices within croplands, while farmer and conservationist surveys focused on cropland in general, along with forestlands and reservoirs. The qualitative work was exploratory, informing the primarily quantitative survey that followed. Interviews were also able to support findings from surveys, particularly farmer knowledge of ESS.

Both farmer interviews and surveys demonstrate recognition of many ESS derived from natural and managed landscapes, and the services emphasized provide an understanding of how farmers view ecosystems. While farmers recognized a wide variety of ESS in interviews, they emphasized services that impact them economically – food provisioning is their source of income, and soil formation and erosion regulation sustain food provisioning long-term. Freshwater provisioning and genetic resource provisioning were well known benefits to conservation efforts, yet under current management and policy directives these services have a less direct impact on them. Utilizing this knowledge of farmers' perceptions towards ESS will aid in creating policies that help improve ESS on farms.

The trade-off between food provisioning and other ESS was evident in both interviews and surveys, where farmers and conservationists consistently felt that croplands provided less ESS than forestlands, except for food provision. This is unsurprising, as others have shown such as that when agricultural lands are managed to maximize production, other ESS suffer (Groffman et al. 2007; Pilgrim et al. 2010). Our

results demonstrate that Indiana croplands are currently managed mainly for food provisioning rather than for multiple ESS. Policies and programs which promote multi-objective farm management may be required to help change this specific management behaviour.

Interestingly, farmers and conservationists rated reservoirs as providing fewer benefits than forestlands, and reservoir benefits were considered less valuable to society. We have realized the term “reservoir” may have been perceived as an engineered system, rather than a natural one. Originally, we had planned to use “wetland” to represent an aquatic ecosystem, but interviews suggested the word “wetland” had negative connotations to farmers. Farmers are known to have negative attitudes toward federal regulation in the Midwest (Arbuckle 2012) and in the region where interviews took place (Reimer et al. 2011; Kalcic et al. 2014). This concern about government intrusion was confirmed to exist in the surveyed population through multiple survey comments. If further studies were conducted we suggest using a term such as “pond” or “lake” that could be viewed as a natural ecosystem while avoiding contentious ecosystems like wetlands.

All studies indicate inherent understanding of ESS concepts for major provisioning and regulating services by farmers and conservationists. However, the ESS framework was unfamiliar to the majority of all three study groups. While conservationists were better able to define ESS, farmer views of specific ESS were often similar to conservationists’, indicating a shared understanding of environmental benefits. If farmers receive information from conservationists, education of conservation professionals may be an effective way to transfer knowledge. If conservation policy were

to incorporate ESS in its goals, the framework appears to already exist to translate this knowledge into factors that may affect farm-level management. Understanding the language farmers already use to explain ESS can also provide a pathway for further ESS management education. Our results can begin to lay the foundation to develop a shared language and understanding of ESS between farmers, conservation professionals, and policy-makers, which may be a useful next step that will move the science of ESS into practice in U.S. agricultural landscapes.

### 5.5 Conclusions

This research demonstrates that Indiana farmers recognize benefits that their land (and other ecosystems) provides to people. Despite this general understanding of benefits, they were unfamiliar with the term “ecosystem services”, which suggests that more education is needed to develop policies that support ESS-based agricultural management. The majority of farmers surveyed were already implementing conservation practices or programs, and stated that they were interested in learning more about how they can improve ESS on their farm. They saw themselves as the primary stewards of the benefits provided by their croplands to society, which suggests an opportunity to engage farmers in ESS-based policy discussions. Their recognition and valuation of ESS generally aligned with conservationists, which was not surprising since the study also showed that farmers preferred to get information from publicly-funded professionals. Expanding existing conservation programming in the U.S. is an approach that does not require a major shift in national policy, but instead, an expansion of current systems of delivery.

This study supports the idea that dissemination of ESS research at the levels of administrative and program-development as well as through Extension Service partnerships could leverage current farmer interest in and knowledge of conservation management to promote ESS-based management.

One of the primary obstacles to integrating ESS in program decisions may be the ongoing gaps between data producers and data users. Since Zhang et al. (2007) called for research that quantifies the flows of ES to and from agricultural lands, the number of ESS publications has expanded (Rodriguez et al. 2006) and the ability to quantify flows continues to improve. Translating such knowledge into program-based metrics while establishing a language that is simultaneously consistent with ESS concepts and approachable for conservationists and farmers may be an important step for administrative-level implementation.

There is a specific opportunity for extension specialists, government agencies, and private companies to work with farmers to develop strategies and programs to improve and restore ESS in the U.S. This work offers some insight into which ESS are currently well understood and valued by farmers, and which may require more education and programming to manage. Wratten et al. (2013) note that because of the large land area of agricultural landscapes, these managed ecosystems offer the greatest opportunity to increase global ESS. Our research demonstrates that Indiana farmers are knowledgeable about the ESS benefits provided by conservation practices on their farm and can be easily engaged in discussions to restore and increase ESS in the U.S. Since private stakeholders own and manage a large portion of U.S. agricultural lands, and as we have shown that they not only recognize benefits ecosystems provide but also work to conserve them and



are willing to improve their farm's ecosystems, U.S. farmers are key stakeholders that should be engaged in discussions about improving and restoring ESS. If we are not engaging U.S. farmers in ESS discussions, then we cannot expect that policies created will (1) be well understood by the farmers who are making decisions at the field-level, and (2) make the kind of impact required to improve and restore ESS from intensively managed landscapes.

## 6 CONCLUSION

### 6.1 Summary

Overall, this research contributes to the broader adaptation of the ecosystem service framework for policy and management decisions. The MEA (2005) identifies quantitative methods as a need to evaluate and assess ecosystem services; yet, improved quantitative methods have been identified as a need to move the concept of ecosystem services into practice (de Groot et al. 2010). Better engagement of key stakeholders is also needed to apply ecosystem service concepts to management and policy decision. The goals of this research were to improve quantification methods for ecosystem services, as well as evaluate the applicability of the ecosystem service framework in agricultural management. An existing ecosystem service quantification method (Logsdon and Chaubey 2013) was evaluated in the Upper Mississippi River Basin (UMRB) under current conditions and under future climate change and variability using the Soil & Water Assessment Tool (SWAT). Next, to look at aquatic genetic resource provisioning, a SWAT model was developed for the Upper Wabash River Basin (UWRB) in order to determine the possible influences of agricultural management on an observed fish regime change in the Wabash River. To improve quantification methods for climate regulation, a multi-objective genetic algorithm calibration of DayCent was completed.

Lastly, to evaluate the potential application of the ecosystem service framework in land management, surveys were completed with Indiana farmers to evaluate how they view and understand ecosystem services on their farm, and in other ecosystems.

## 6.2 Major Research Findings

The major research findings are summarized below:

### Objective 1 / Hypothesis 1

- The ecosystem service methods developed by Logsdon and Chaubey (2013) were able to capture the known trade-off between food provisioning and freshwater provisioning in the UMRB.
- Under a future climate change scenario, freshwater provision, erosion regulation, flood regulation, and food provisioning in the UMRB may decline over time.

### Objective 2 / Hypothesis 2

- Changes in agricultural management in the UWRB along with increased precipitation could be associated with the observed fish regime change in the Wabash River.
- This observed connection is likely due to the link between nutrients in the stream and algal biomass, i.e., changes in food sources lead to changes in dominant fish trophic levels.

### Objective 3/ Hypothesis 3

- A multi-objective AMALGAM method *was* able to improve model performance, relative to default, for the five calibration plots at WQFS for both yield and daily N<sub>2</sub>O flux.

- The resulting parameter set compared well with previous studies, or matched site characteristics.
- The validation plots, however, only showed improvement for yield, not N<sub>2</sub>O flux. This lack of improvement is likely due to the fact that the two plots that had the highest N<sub>2</sub>O emissions influenced model parameterization more than the other plots.
- DayCent site parameters may not apply well across all possible treatment types in terms of predicting N<sub>2</sub>O emissions, and calibration may need to be done for one treatment at a time, even if the plots are in the same location.

#### Objective 4 /Hypothesis 4

- Survey results of Indiana agricultural producers indicated that even though most Indiana farmers had not heard of the term 'ecosystem services', they easily recognized the benefits that multiple ecosystems provided to people.
- Indiana farmers were also able to identify tradeoffs among ecosystem services provided by different landscapes; similarly to theoretical tradeoffs identified by Foley et al. 2005.
- The conservationist surveys showed similar recognition of ecosystem services, though the value of many ecosystem services differed between them and farmers, especially for many of the cultural ecosystem services.

- Although both Indiana farmers and conservationists were able to recognize many ecosystem services, some ecosystem services were more understood than others, as indicated in both surveys and focus groups. By understanding how key stakeholders view and describe ecosystem services, we can improve the implementation of the ecosystem service framework in agricultural policy and management in the U.S.

### 6.3 Limitation of Current Study and Recommendations for Future Research

#### Study 1

- This research was completed using an existing SWAT model for the UMRB. Although this model has been shown to perform well for estimating crop yield and hydrology, the water quality estimates have not been validated. Future work should include validating, and if needed, calibrating the model to estimate water quality constituents.
- The existing SWAT model was developed using auto fertilization routines in SWAT. This made the comparison of future scenarios to baseline scenario difficult; future research should include a SWAT model setup that does not utilize the auto fertilization routine.
- This research used previously developed methods to quantify ecosystem services. The methods only quantify four ecosystem services, not the entire suite of ecosystem services, so future work should include more ecosystem services in order to truly understand all of the ecosystem service tradeoffs.

- The application of the ecosystem service quantification methods is user-driven in that the user specifies water quality standards, yield requirements, etc., in order to estimate ecosystem services. Future work may include an analysis on the impacts of changing these user-defined inputs.
- Only one climate model was used to model future climate. Future work should include the evaluation of climate using multiple climate models.

### Study 2

- The SWAT model used for this study has been calibrated and validated for flow and for water quality under present conditions (1990-2009). However, only the flow was calibrated for the historical model (1975-1989) due to a lack of available flow data. Future work may include validation methods for water quality.
- Urban point sources were not included in the model due to the unavailability of the data. Future work could improve the confidence of the model by including these data.
- This research kept land use constant for the historical model, and did not estimate changes in cropland outside of corn and soybean lands. Future work may compare land use during the historical time period as well as crop rotations and include these as needed in the historical model.
- Future work may include calibration and validation of the algal biomass output in SWAT to see how estimate algal biomass changes compares with the observed fish regime change.

### Study 3

- This study utilized five plots of varying crop type and treatments to calibrate and validate the DayCent model. Because the objective function for calibration was the RMSE, the plots with the highest N<sub>2</sub>O emissions were weighted higher during the calibration process, leading to validation results that were not as good as calibration. Future work should compare the effects of varying objective functions on calibration.
- This work was also limited to the chosen parameter set and parameter ranges. Future work may include more, sensitive parameters, and less of the parameters which were shown to be not sensitive.
- Future work should also compare parameter sets estimated by calibrating for one plot versus multiple plots in the same location.
- Future work may also compare how calibration and validation of the DayCent model compares when using the same plot for calibration and validation, versus using one plot for calibration, and another plot (same treatment, same site) for validation.

### Study 4

- The survey results of this study could be influenced by the response group. Those farmers, who responded to the survey on environmental benefits of ecosystems, may be already biased towards implementing conservation practices on their farm.
- This study was also limited by a limited sample size; future work may want to include more surveys and perhaps from different states in the Midwest.

- Future work could also engage a ‘trusted’ agent to assist with the survey, such as the Farm Bureau.
- Although this study was focused on agricultural managers and ecosystem services, future work could easily expand to urban and suburban decision-makers.



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## APPENDICES

Appendix A Set up details for the previously developed SWAT model. Further details can be found in Srinivasan et al. (2010).

<b>Data Input/Model Detail</b>	<b>Source/Method</b>
Digital Elevation Model	90-m (3 arc second) digital elevation model
Watershed delineation	Boundaries defined by United States Geological Survey 8-digit hydrologic unit codes
Stream definition	National Hydrography Dataset (NHD) stream dataset
Sub-basin detail	131 sub-basins;
Reservoirs	15 major reservoirs on main stream were included
Land use	Cropland data layer (CDL) and 2001 National Land Cover Data
Crop rotations	Derived from overlaying multiple years of CDL information
Soils	United States Department of Agriculture (USDA) National Resource Conservation Service (NRCS) State Soil Geographic (STATSGO) database
HRU detail	Used thresholds of 5%, 10%, and 5% for land use, soils, and slope, respectively. Resulted in 14,568 HRUs.
Tile Drainage	Very poorly drained to poorly drained soils identified, combined with slopes of less than 1% and land use of agriculture were considered as tile drained.
Tillage	Estimated from county level Conservation Technology Information Center (CTIC) data
Fertilizer & Manure	2002 county Census of Agriculture statistics used to estimate number of animals & manure rates. Auto-fertilization using chemical fertilizers were used to supplement manure operations as well as in non-manure management.
Weather	National Climactic Data Center (NCDC) and Parameter-Elevation Regressions on Independent Slopes Model (PRISM)
Stream flow	USGS stream flow observation gages
Crop yield	USDA National Agricultural Statistics Data

Appendix B Matlab® code (yearloop.m) which randomly applies land management information to all corn and soybean watersheds.

```

%clear all
clc
global sim %sim is the folder that contains the SWAT input files from which
           % input management files will be modified
sim = 'input';%name of the folder where all the input files are located
fid1 = fopen('SubHruAreaLulc.dat','r');
data = textscan(fid1,'%d%d%f%s','HeaderLines',1);
sub = data{1};
hru = data{2};
area = data{3};
lulc = data{4};

nsub = max(sub);
%% Calculating Corn & Soybean Area
k = 1;
Carea=0; % Carea will be total amount of corn area in watershed
for isub = 1:nsub
    hruinsub = size(find(sub == isub),1); %finding number of HRUs in sub-basin
    for ihru = 1:hruinsub %for all hrus within subbasin
        if size(findstr(lulc{k},'CORN'),1)>0 %if corn/soy, calculate total area of C/S
            Carea=Carea + area(k);
        end
        k = k + 1;
    end
end

j = 1;
Sarea=0; % Sarea will be total amount of soybean area in watershed
for isub = 1:nsub
    hruinsub = size(find(sub == isub),1); %finding number of HRUs in sub-basin
    for ihru = 1:hruinsub %for all hrus within subbasin
        if size(findstr(lulc{j},'SOYB'),1)>0 %if corn/soy, calculate total area of C/S
            Sarea=Sarea + area(j);
        end
    end
end

```



```

    end
    j = j + 1;
end
end
TotArea=Carea+Sarea;
%%
if exist([sim 'new'],'dir') == 0 %creating new sim directory if it doesn't exist already
    mkdir([sim 'new']); %adds on a new directory that is named 'currdirnew'
end

%% Load Land Management Files
till=xlsread('TillType.xlsx'); %tillage percentages
cfert=xlsread('CORN_fert.xlsx'); %Corn fertilizer percentages (what % land gets N&P)
Nfertappl=xlsread('Napp.xlsx'); % N fertilizer amounts (lb/ac)
Ntype=xlsread('NType.xlsx'); % N fertilizer types by percent
Pfertappl=xlsread('Papp.xlsx'); % P fertilizer amounts (lb/ac)
Ptype=xlsread('PType.xlsx'); % P fertilizer types by percent
sfert=xlsread('SOYB_fert.xlsx'); %SOYB fertilizer percentages (what % land gets N&P)
manure=xlsread('ManureApp.xlsx'); %Manure applied to all corn and soybean lands.

%% Creating alternate column in lulc which can be used for earlier years (i.e., soybean only 40%
of C/S area)
LULC={};
TotArea=Carea+Sarea;

for j=1:length(lulc) %adding soybean HRUs to file.
    if size(findstr(lulc{j},'SOYB')),1>0;
        LULC{j,1}=lulc(j);
        LULC{j,2}=sub(j);
        LULC{j,3}=hru(j);
        LULC{j,4}=area(j);
    else
        LULC{j,1}=[];
        LULC{j,2}=sub(j);
        LULC{j,3}=hru(j);
        LULC{j,4}=area(j);
    end
end

```

```

    j=j+1;
end

LULC=LULC(randperm(size(LULC,1)),:);

y=.6;
nsarea=0;
ncarea=Carea;
for j=1:size(LULC,1) %loop adds tillage type to hruinfoin column 3
    if isempty(LULC{j,1})
        LULC{j,5}=[];
    else
        if ncare < (y*TotArea)
            LULC{j,5}='CORN'; %adding SOYB to CORN lulc
            ncare=ncare+LULC{j,4};
        else
            LULC{j,5}='SOYB'; % Conventional Till
            nsarea=nsarea+LULC{j,4};
        end
    end
end
end

LULC=sortrows(LULC,3);
LULC3=LULC(:,5);

for i=1:size(lulc,1)
    if isequal(lulc{i},'SOYB')==1
        if isequal(LULC3{i},'SOYB')==1
            lulc(i,2)={'SOYB'};
        else
            lulc(i,2)={'CORN'};
        end
    else
        lulc(i,2)=lulc(i,1);
    end
end
end

```

```

%%% Creating "odd year" lulc code for early time period since can't just
%%% flip land use because C/S are not 50/50.

%Getting what next years lulc would be if 50/50 C/S adding as column 3 of
%lulc
for i=1:length(lulc)
    if isequal(lulc{i,2},'SOYB')==1
        lulc(i,3)={'CORN'};
    elseif isequal(lulc{i,2},'CORN')==1
        lulc(i,3)={'SOYB'};
    else
        lulc(i,3)=lulc(i,2);
    end
end

%setting up new column to extract soybean data only
LULC2={};
for j=1:length(lulc) %adding soybean HRUs to file.
    if size(findstr(lulc{j,3},'SOYB'),1)>0;
        LULC2{j,1}=lulc(j,3);
        LULC2{j,2}=sub(j);
        LULC2{j,3}=hru(j);
        LULC2{j,4}=area(j);
    else
        LULC2{j,1}=[];
        LULC2{j,2}=sub(j);
        LULC2{j,3}=hru(j);
        LULC2{j,4}=area(j);
    end
    j=j+1;
end

%%%calculate c/s area for second year (assumming 50/50 C/S)
k = 1;
Carea2=0; % Carea will be total amount of corn area in watershed
for isub = 1:nsub
    hrainsub = size(find(sub == isub),1); %finding number of HRUs in sub-basin

```

```

for ihru = 1:hruinsub %for all hrus within subbasin
    if size(findstr(lulc{k,3},'CORN'),1)>0 %if corn/soyb, calculate total area of C/S
        Carea2=Carea2 + area(k);
    end
    k = k + 1;
end
end
end

j = 1;
Sarea2=0; % Sarea will be total amount of soybean area in watershed
for isub = 1:nsub
    hruinsub = size(find(sub == isub),1); %finding number of HRUs in sub-basin
    for ihru = 1:hruinsub %for all hrus within subbasin
        if size(findstr(lulc{j,3},'SOYB'),1)>0 %if corn/soyb, calculate total area of C/S
            Sarea2=Sarea2 + area(j);
        end
        j = j + 1;
    end
end
end

TotArea2=Carea2+Sarea2;

LULC2=LULC2(randperm(size(LULC2,1)),:); %randomly sorting LULC2 (so not assigning same
HRUs to soybeans everytime)

y=6;
nsarea2=0;
ncarea2=Carea2;
for j=1:size(LULC2,1) %loop adds tillage type to hruinfoin column 3
    if isempty(LULC2{j,1})
        LULC2{j,5}=[];
    else
        if ncare2 < (y*TotArea2)
            LULC2{j,5}='CORN'; %adding SOYB to CORN lulc
            ncare2=ncarea2+LULC2{j,4};
        else
            LULC2{j,5}='SOYB'; % Conventional Till
        end
    end
end

```

```

        nsarea2=nsarea2+LULC2{j,4};
    end
end
end

LULC2=sortrows(LULC2,3);
LULC4=LULC2(:,5);

for i=1:size(lulc,1)
    if isequal(lulc{i,3},'SOYB')==1
        if isequal(LULC4{i},'SOYB')==1
            lulc(i,4)={'SOYB'};
        else
            lulc(i,4)={'CORN'};
        end
    else
        lulc(i,4)=lulc(i,3);
    end
end

%% Calculating Corn & Soybean Area (for 4th lulc column)
k = 1;
Carea3=0; % Carea will be total amount of corn area in watershed
for isub = 1:nsub
    hruisub = size(find(sub == isub),1); %finding number of HRUs in sub-basin
    for ihru = 1:hruisub %for all hrus within subbasin
        if size(findstr(lulc{k,4},'SOYB'),1)>0 %if corn/soyb, calculate total area of C/S
            Carea3=Carea3 + area(k);
        end
        k = k + 1;
    end
end

j = 1;
Sarea3=0; % Sarea will be total amount of soybean area in watershed
for isub = 1:nsub
    hruisub = size(find(sub == isub),1); %finding number of HRUs in sub-basin

```



```

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(a,2)/100;
y=till(a,3)/100;
c=till(a,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfo in column 3
    if ntarea < (x*Sarea2)
        tilltype(j)=1; %No Till
        ntarea=ntarea+hruinfo(j,3);
    elseif mtarea < (y*Sarea2)
        tilltype(j)=2; % Minimum Till
        mtarea=mtarea+hruinfo(j,3);
    else
        tilltype(j)=3; % Conventional Till
        ctarea=ctarea+hruinfo(j,3);
    end
end
tilltype=tilltype';
hruinfo=[hruinfo tilltype];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,4),'rows');
tillarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfo,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Sarea2)

```

```

    tilltim(j)=1; %fall
    falltillar=falltillar+hruinfo(j,3);
else
    tilltim(j)=2; %spring
    sptillar=sptillar+hruinfo(j,3);
end
end
tilltim=tilltim';
hruinfo=[hruinfo tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,5),'rows');
tilltimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertapp=[];
d=cfert(a,2)/100;
Nnofertar=0;
Nfertar=0;

for j=1:size(hruinfo,1) %loop adds whether or not N was applied to column 5
    if Nfertar < (d*Sarea2)
        Nfertapp(j)=1; %Fertilizer applied
        Nfertar=Nfertar+hruinfo(j,3);
    else
        Nfertapp(j)=2; %fertilizer not applied
        Nnofertar=Nnofertar+hruinfo(j,3);
    end
end
Nfertapp=Nfertapp';
hruinfo=[hruinfo Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,6),'rows');
```



```

Nfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertim=[];
Nfallfentar=0;
Nspfentar=0;
for j=1:size(hruinfo,1) % loop adds when N was applied to column 6
    if hruinfo(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfentar < (.21*Nfentar)
            Nfertim(j)=1; %fall
            Nfallfentar=Nfallfentar+hruinfo(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfentar=Nspfentar+hruinfo(j,3);
        end
    end
end
Nfertim=Nfertim';
hruinfo=[hruinfo Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,7),'rows');
Nfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(a,2);

for j=1:size(hruinfo,1) %loop adds amount applied (lb/ac) to column 7
    if hruinfo(j,6)==2
        hruinfo(j,8)=0;
    else
        hruinfo(j,8)=Nlbac;
    end
end

```

```

end
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assiging N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Ntypes=[];
x=Ntype(a,2);
y=Ntype(a,3);
c=Ntype(a,4);
d=Ntype(a,5);
e=Ntype(a,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfo,1) %loop adds N fertilizer type to column 8
    if hruinfo(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*Nfertar)
            Ntypes(j)=1; %urea
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Nfertar)
            Ntypes(j)=2; %28% UAN
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Nfertar)
            Ntypes(j)=3; %Anhydrous Ammonia
            carea=carea+hruinfo(j,3);
        elseif darea < (d*Nfertar)
            Ntypes(j)=4; %10-34-0 (N only)
            darea=darea+hruinfo(j,3);
        else
            Ntypes(j)=5; %18-46-0 (N only)
            earea=earea+hruinfo(j,3);
        end
    end
end

```

```

        end
    end
end
Ntypes=Ntypes';
hruinfo=[hruinfo Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfo(:,9),'rows');
Nfertypearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Pfertapp=[];
d=cfert(a,4)/100;
Pnofertar=0;
Pfertar=0;

for j=1:size(hruinfo,1) %loop adds if P was applied to column 9
    if Pfertar < (d*Sarea2)
        Pfertapp(j)=1; %Fertilizer applied
        Pfertar=Pfertar+hruinfo(j,3);
    else
        Pfertapp(j)=2; %fertilizer not applied
        Pnofertar=Pnofertar+hruinfo(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfo=[hruinfo Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,10),'rows');
Pfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data

```

```

    hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
    Pfertim=[];
    Pfallfertar=0;
    Pspfertar=0;
    for j=1:size(hruinfo,1) %loop adds timing of fertilizer app to column 10
        if hruinfo(j,10)==2
            Pfertim(j)=999;
        else
            if Pfallfertar < (.36*Pfertar)
                Pfertim(j)=1; %fall
                Pfallfertar=Pfallfertar+hruinfo(j,3);
            else
                Pfertim(j)=2; %spring
                Pspfertar=Pspfertar+hruinfo(j,3);
            end
        end
    end
    Pfertim=Pfertim';
    hruinfo=[hruinfo Pfertim];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
    %checking tillage area
    [unX,~,subs]=unique(hruinfo(:,11),'rows');
    pfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

    %% assigning Phosphorus fertilizer amount applied
    Plbac=Pfertappl(a,2);

    for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
        if hruinfo(j,10)==2
            hruinfo(j,12)=0;
        else
            hruinfo(j,12)=Plbac;
        end
    end
    hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

```

```

%% Randomly assigning P fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Ptypes=[];
x=Ptype(a,2);
y=Ptype(a,3);
c=Ptype(a,4);
d=Ptype(a,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfo,1) %loop adds type of P fertilizer applied to column 12
    if hruinfo(j,10)==2
        Ptypes(j)=0;
    else
        if aarea < (x*Pfertar)
            Ptypes(j)=1; %Triple superphosphate
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Pfertar)
            Ptypes(j)=2; %10-34-0 P only
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Pfertar)
            Ptypes(j)=3; %18-46-0 P only
            carea=carea+hruinfo(j,3);
        else
            Ptypes(j)=4; %0-15-40 P only
            darea=darea+hruinfo(j,3);
        end
    end
end
Ptypes=Ptypes';
hruinfo=[hruinfo Ptypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area

```

```

[unX,~,subs]=unique(hruinfo(:,13),'rows');
Pfertypearea=[unX accumarray(subs,hruinfo(:,3),[],@nansum)];

%% Adding LULC code to column 14
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,14)=1; %1 is CORN
    else
        hruinfo(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 15
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,15)=p; %year is p
    else
        hruinfo(j,15)=-999; % just to error check
    end
end

%%Adding N fertilizer date to column 16
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfo(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfo(j,3)
    end
end

```

```

elseif hruinfo(j,7)==2 && Esfertdate < (x*Nspfertar)
    Nfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==2
    Nfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Nffertdate < (x*Nfallfertar)
    Nfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Effertdate < (x*Nfallfertar)
    Nfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Nfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Nfertdate=Nfertdate';
hruinfo=[hruinfo Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfo=hruinfo(randperm(size(hruinfo,1),:)); %radomly sorting the rows of the main data
matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3

```

```

if hruinfo(j,11)==999
    Pfertdate(j)=999;
elseif hruinfo(j,11)==2 && Nsfertdate < (x*Pspfertar)
    Pfertdate(j)=1; %Normal spring fertilizer date
    Nsfertdate=Nsfertdate+hruinfo(j,3)
elseif hruinfo(j,11)==2 && Esfertdate < (x*Pspfertar)
    Pfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==2
    Pfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Nffertdate < (x*Pfallfertar)
    Pfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Effertdate < (x*Pfallfertar)
    Pfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Pfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Pfertdate=Pfertdate';
hruinfo=[hruinfo Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding tillage timing to column 18
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;

```



```

Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfo(j,3)
    elseif hruinfo(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfo(j,3);
    elseif hruinfo(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfo(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfo(j,3);
    end
end

tilldate=tilldate';
hruinfo=[hruinfo tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Manure (Pig & Cow) Applied
manP=manure(a,2); %getting amount of manure applied as pig
manC=manure(a,3); %getting amount of manure applied as cow (beef

```



```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Set up Soybean Master file (hruinfoSB)
hruinfoSB=[];
for i=1:length(lulc) %creates a file with only Soybean HRUs.
    if size(findstr(lulc{i,2},'SOYB'),1)>0;
        hruinfoSB=[hruinfoSB; sub(i) hru(i) area(i)];
    end
    i=i+1;
end

%% randomly assigning tillage type data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1),:));
tilltype=[];
x=till(a,2)/100;
y=till(a,3)/100;
c=till(a,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to column 3
    if ntarea < (x*Carea2)
        tilltype(j)=1; %No till
        ntarea=ntarea+hruinfoSB(j,3);
    elseif mtarea < (y*Carea2)
        tilltype(j)=2; % Minimum till
        mtarea=mtarea+hruinfoSB(j,3);
    else
        tilltype(j)=3; %Conventional till
        ctarea=ctarea+hruinfoSB(j,3);
    end
end
tilltype=tilltype';
hruinfoSB=[hruinfoSB tilltype];
%hruinfo=[HRU, area, tilltype]
```

```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,4),'rows');
tillareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfoSB,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Carea2)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfoSB(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfoSB(j,3);
    end
end
tilltim=tilltim';
hruinfoSB=[hruinfoSB tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,5),'rows');
tilltimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Nfertapp=[];
d=sfert(a,2)/100;
NnofertarSB=0;
NfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds whether or not N was applied to column 5
    if NfertarSB < (d*Carea2)

```

```

    Nfertapp(j)=1; %Fertilizer applied
    NfertarSB=NfertarSB+hruinfoSB(j,3);
else
    Nfertapp(j)=2; %fertilizer not applied
    NnofertarSB=NnofertarSB+hruinfoSB(j,3);
end
end
end

Nfertapp=Nfertapp';
hruinfoSB=[hruinfoSB Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,6),'rows');
NfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertim=[];
Nfallfertar=0;
Nspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of N fertilizer to column 6
    if hruinfoSB(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfertar < (.21*NfertarSB)
            Nfertim(j)=1; %fall
            Nfallfertar=Nfallfertar+hruinfoSB(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfertar=Nspfertar+hruinfoSB(j,3);
        end
    end
end
end
Nfertim=Nfertim';
hruinfoSB=[hruinfoSB Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]

```

```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,7),'rows');
NfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of N fertilizer added to column 7
    if hruinfoSB(j,6)==2
        hruinfoSB(j,8)=0;
    else
        hruinfoSB(j,8)=Nlbac;
    end
end
%hruinfoSB=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assigning N fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Ntypes=[];
x=Ntype(a,2);
y=Ntype(a,3);
c=Ntype(a,4);
d=Ntype(a,5);
e=Ntype(a,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfoSB,1) %loop adds fertilizer type information to column 8
    if hruinfoSB(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*NfentarSB)
            Ntypes(j)=1; %urea
        end
    end
end

```

```

        aarea=aarea+hruinfoSB(j,3);
elseif barea < (y*NfertarSB)
    Ntypes(j)=2; %28% UAN
    barea=barea+hruinfoSB(j,3);
elseif carea < (c*NfertarSB)
    Ntypes(j)=3; %Anyhdrous Ammonia
    carea=carea+hruinfoSB(j,3);
elseif darea < (d*NfertarSB)
    Ntypes(j)=4; %10-34-0 only
    darea=darea+hruinfoSB(j,3);
else
    Ntypes(j)=5; %18-46-0 N only
    earea=earea+hruinfoSB(j,3);
end
end
end
Ntypes=Ntypes';
hruinfoSB=[hruinfoSB Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAm, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,9),'rows');
NfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1),:)); %radomly sorting the rows of the main
data matrix
Pfertapp=[];
d=sfert(a,4)/100;
PnofertarSB=0;
PfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds if P was applied to column 9
    if PfertarSB < (d*Carea2)
        Pfertapp(j)=1; %Fertilizer applied
        PfertarSB=PfertarSB+hruinfoSB(j,3);
    else

```

```

        Pfertapp(j)=2; %fertilizer not applied
        PnofertarSB=PnofertarSB+hruinfoSB(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfoSB=[hruinfoSB Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,10),'rows');
PfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertim=[];
Pfallfertar=0;
Pspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of P application to column 10
    if hruinfoSB(j,10)==2
        Pfertim(j)=999;
    else
        if Pfallfertar < (.36*PfertarSB)
            Pfertim(j)=1; %fall
            Pfallfertar=Pfallfertar+hruinfoSB(j,3);
        else
            Pfertim(j)=2; %spring
            Pspfertar=Pspfertar+hruinfoSB(j,3);
        end
    end
end
Pfertim=Pfertim';
hruinfoSB=[hruinfoSB Pfertim];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,11),'rows');
pfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

```



```

%% assigning Phosphorus fertilizer amount applied
Plbac=Pfertappl(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    if hruinfoSB(j,10)==2
        hruinfoSB(j,12)=0;
    else
        hruinfoSB(j,12)=Plbac;
    end
end
end
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

%% Randomly assigning p fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
PtypesSB=[];
x=Ptype(a,2);
y=Ptype(a,3);
c=Ptype(a,4);
d=Ptype(a,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfoSB,1) %loop adds type of P fertilizer applied to column 12
    if hruinfoSB(j,10)==2
        PtypesSB(j)=0;
    else
        if aarea < (x*PfertarSB)
            PtypesSB(j)=1;
            aarea=aarea+hruinfoSB(j,3);
        elseif barea < (y*PfertarSB)
            PtypesSB(j)=2;
            barea=barea+hruinfoSB(j,3);
        elseif carea < (c*PfertarSB)
            PtypesSB(j)=3;
        end
    end
end

```

```

        carea=carea+hruinfoSB(j,3);
    else
        PtypesSB(j)=4;
        darea=darea+hruinfoSB(j,3);
    end
end
end
PtypesSB=PtypesSB';
hruinfoSB=[hruinfoSB PtypesSB];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,13),'rows');
PfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,14)=2; %2 is SOYB
    else
        hruinfoSB(j,14)=-999; % just to error check
    end
end
end
%% Adding Year to column 14
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,15)=p; %2 is SOYB
    else
        hruinfoSB(j,15)=-999; % just to error check
    end
end
end

%%Adding N fertilizer date to column 16
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Nfertdate=[];

```

```

x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfoSB(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,7)==2 && Esfertdate < (x*Nspfertar)
        Nfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==2
        Nfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Nffertdate < (x*Nfallfertar)
        Nfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Effertdate < (x*Nfallfertar)
        Nfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Nfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Nfertdate=Nfertdate';
hruinfoSB=[hruinfoSB Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[],@nansum)];

```

```

%%Adding P fertilizer date to column 17
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,11)==999
        Pfertdate(j)=999;
    elseif hruinfoSB(j,11)==2 && Nsfertdate < (x*Pspfertar)
        Pfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,11)==2 && Esfertdate < (x*Pspfertar)
        Pfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==2
        Pfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Nffertdate < (x*Pfallfertar)
        Pfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Effertdate < (x*Pfallfertar)
        Pfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Pfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Pfertdate=Pfertdate';

```

```

hruinfoSB=[hruinfoSB Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

    %%Adding tillage timing to column 18
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;
Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfoSB(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfoSB(j,3);

```

```

    end
end

tilldate=tilldate';
hruinfoSB=[hruinfoSB tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfoSB(:,3),[],@nansum)];

%% assigning manurea pplied
manP=manure(a,2);
manC=manure(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    hruinfoSB(j,19)=manP;
    hruinfoSB(j,20)=manC;
end

%% randomly assigning manure application timing
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:);
mantime=[];
x=1/3;
y=1/3;
c=1/3;
manEarea=0;
manNarea=0;
manLarea=0;
for j=1:size(hruinfoSB,1) %loop adds manure timing to column 21
    if manEarea < (x*Carea2)
        mantime(j)=1; % Early time
        manEarea=manEarea+hruinfoSB(j,3);
    elseif manNarea < (y*Carea2)
        mantime(j)=2; % Normal time
        manNarea=manNarea+hruinfoSB(j,3);
    else
        mantime(j)=3; %Late time
    end
end

```

```

        manLarea=manLarea+hruinfoSB(j,3);
    end
end
mantime=mantime';
hruinfoSB=[hruinfoSB mantime];
[unX,~,subs]=unique(hruinfoSB(:,21),'rows');
manurearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%hruinfo=[Sub,HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,Ptype,LULC, Yr,Ndate,Pdate,TillDate,PigMan,CowMan,manure timing]

%%Creating one file for hrumgtinfo for one year
hrumgt=[hrumgt; hruinfo; hruinfoSB];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Other year
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
b=a+1
%% Set up Corn Master file (hruinfo) which was originally SOYB
hruinfo=[];
for i=1:length(lulc) %creates a file with only Corn HRUs.
    if size(findstr(lulc{i,4},'CORN'),1)>0;
        hruinfo=[hruinfo; sub(i) hru(i) area(i)];
    end
    i=i+1;
end
end

```

```

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(b,2)/100;
y=till(b,3)/100;
c=till(b,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfo in column 3
    if ntarea < (x*Carea3)
        tilltype(j)=1; %No Till
        ntarea=ntarea+hruinfo(j,3);
    elseif mtarea < (y*Carea3)
        tilltype(j)=2; % Minimum Till
        mtarea=mtarea+hruinfo(j,3);
    else
        tilltype(j)=3; % Conventional Till
        ctarea=ctarea+hruinfo(j,3);
    end
end
tilltype=tilltype';
hruinfo=[hruinfo tilltype];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,4),'rows');
tillarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfo,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Carea3)

```



```

    tilltim(j)=1; %fall
    falltillar=falltillar+hruinfo(j,3);
else
    tilltim(j)=2; %spring
    sptillar=sptillar+hruinfo(j,3);
end
end
tilltim=tilltim';
hruinfo=[hruinfo tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,5),'rows');
tilltimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertapp=[];
d=cfert(b,2)/100;
Nnofertar=0;
Nfertar=0;

for j=1:size(hruinfo,1) %loop adds whether or not N was applied to column 5
    if Nfertar < (d*Carea3)
        Nfertapp(j)=1; %Fertilizer applied
        Nfertar=Nfertar+hruinfo(j,3);
    else
        Nfertapp(j)=2; %fertilizer not applied
        Nnofertar=Nnofertar+hruinfo(j,3);
    end
end
Nfertapp=Nfertapp';
hruinfo=[hruinfo Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,6),'rows');
```

```

Nfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Nfertim=[];
Nfallfentar=0;
Nspfentar=0;
for j=1:size(hruinfo,1) % loop adds when N was applied to column 6
    if hruinfo(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfentar < (.21*Nfentar)
            Nfertim(j)=1; %fall
            Nfallfentar=Nfallfentar+hruinfo(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfentar=Nspfentar+hruinfo(j,3);
        end
    end
end
Nfertim=Nfertim';
hruinfo=[hruinfo Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,7),'rows');
Nfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(b,2);

for j=1:size(hruinfo,1) %loop adds amount applied (lb/ac) to column 7
    if hruinfo(j,6)==2
        hruinfo(j,8)=0;
    else
        hruinfo(j,8)=Nlbac;
    end
end

```

```

end
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assiging N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Ntypes=[];
x=Ntype(b,2);
y=Ntype(b,3);
c=Ntype(b,4);
d=Ntype(b,5);
e=Ntype(b,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfo,1) %loop adds N fertilizer type to column 8
    if hruinfo(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*Nfertar)
            Ntypes(j)=1; %urea
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Nfertar)
            Ntypes(j)=2; %28% UAN
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Nfertar)
            Ntypes(j)=3; %Anhydrous Ammonia
            carea=carea+hruinfo(j,3);
        elseif darea < (d*Nfertar)
            Ntypes(j)=4; %10-34-0 (N only)
            darea=darea+hruinfo(j,3);
        else
            Ntypes(j)=5; %18-46-0 (N only)
            earea=earea+hruinfo(j,3);
        end
    end
end

```

```

        end
    end
end
Ntypes=Ntypes';
hruinfo=[hruinfo Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfo(:,9),'rows');
Nfertypearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Pfertapp=[];
d=cfert(b,4)/100;
Pnofertar=0;
Pfertar=0;

for j=1:size(hruinfo,1) %loop adds if P was applied to column 9
    if Pfertar < (d*Carea3)
        Pfertapp(j)=1; %Fertilizer applied
        Pfertar=Pfertar+hruinfo(j,3);
    else
        Pfertapp(j)=2; %fertilizer not applied
        Pnofertar=Pnofertar+hruinfo(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfo=[hruinfo Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,10),'rows');
Pfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data

```

```

    hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
    Pfertim=[];
    Pfallfertar=0;
    Pspfertar=0;
    for j=1:size(hruinfo,1) %loop adds timing of fertilizer app to column 10
        if hruinfo(j,10)==2
            Pfertim(j)=999;
        else
            if Pfallfertar < (.36*Pfertar)
                Pfertim(j)=1; %fall
                Pfallfertar=Pfallfertar+hruinfo(j,3);
            else
                Pfertim(j)=2; %spring
                Pspfertar=Pspfertar+hruinfo(j,3);
            end
        end
    end
    Pfertim=Pfertim';
    hruinfo=[hruinfo Pfertim];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
    %checking tillage area
    [unX,~,subs]=unique(hruinfo(:,11),'rows');
    pfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

    %% assigning Phosphorus fertilizer amount applied
    Plbac=Pfertappl(b,2);

    for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
        if hruinfo(j,10)==2
            hruinfo(j,12)=0;
        else
            hruinfo(j,12)=Plbac;
        end
    end
    hruinfo=[hruinfo,Plbac];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

```

```

%% Randomly assigning N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Ptypes=[];
x=Ptype(b,2);
y=Ptype(b,3);
c=Ptype(b,4);
d=Ptype(b,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfo,1) %loop adds type of P fertilizer applied to column 12
    if hruinfo(j,10)==2
        Ptypes(j)=0;
    else
        if aarea < (x*Pfertar)
            Ptypes(j)=1; %Triple superphosphate
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Pfertar)
            Ptypes(j)=2; %10-34-0 P only
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Pfertar)
            Ptypes(j)=3; %18-46-0 P only
            carea=carea+hruinfo(j,3);
        else
            Ptypes(j)=4; %0-15-40 P only
            darea=darea+hruinfo(j,3);
        end
    end
end
Ptypes=Ptypes';
hruinfo=[hruinfo Ptypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area

```

```

[unX,~,subs]=unique(hruinfo(:,13),'rows');
Pfertypearea=[unX accumarray(subs,hruinfo(:,3),[],@nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,14)=1; %1 is CORN
    else
        hruinfo(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 14
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,15)=p+1; %year is p
    else
        hruinfo(j,15)=-999; % just to error check
    end
end

%%Adding N fertilizer date to column 16
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfo(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfo(j,3)
    end
end

```

```

elseif hruinfo(j,7)==2 && Esfertdate < (x*Nspfertar)
    Nfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==2
    Nfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Nffertdate < (x*Nfallfertar)
    Nfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Effertdate < (x*Nfallfertar)
    Nfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Nfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Nfertdate=Nfertdate';
hruinfo=[hruinfo Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfo=hruinfo(randperm(size(hruinfo,1),:)); %radomly sorting the rows of the main data
matrix

Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3

```



```

if hruinfo(j,11)==999
    Pfertdate(j)=999;
elseif hruinfo(j,11)==2 && Nsfertdate < (x*Pspfertar)
    Pfertdate(j)=1; %Normal spring fertilizer date
    Nsfertdate=Nsfertdate+hruinfo(j,3)
elseif hruinfo(j,11)==2 && Esfertdate < (x*Pspfertar)
    Pfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==2
    Pfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Nffertdate < (x*Pfallfertar)
    Pfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Effertdate < (x*Pfallfertar)
    Pfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Pfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Pfertdate=Pfertdate';
hruinfo=[hruinfo Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding tillage timing to column 18
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;

```

```

Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfo in column 3
    if hruinfo(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfo(j,3)
    elseif hruinfo(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfo(j,3);
    elseif hruinfo(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfo(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfo(j,3);
    end
end

tilldate=tilldate';
hruinfo=[hruinfo tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Phosphorus fertilizer amount applied
manP=manure(b,2);
manC=manure(b,3);

```

```

for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    hruinfo(j,19)=manP;
    hruinfo(j,20)=manC;
end

%% randomly assigning manure timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
mantime=[];
x=1/3;
y=1/3;
c=1/3;
manEarea=0;
manNarea=0;
manLarea=0;
for j=1:size(hruinfo,1) %loop adds manure timing to column 21
    if manEarea < (x*Carea3)
        mantime(j)=1; % Early time
        manEarea=manEarea+hruinfo(j,3);
    elseif manNarea < (y*Carea3)
        mantime(j)=2; % Normal time
        manNarea=manNarea+hruinfo(j,3);
    else
        mantime(j)=3; % Late Time
        manLarea=manLarea+hruinfo(j,3);
    end
end
mantime=mantime';
hruinfo=[hruinfo mantime];
%checking manure area
[unX,~,subs]=unique(hruinfo(:,21),'rows');
manurearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%hruinfo=[Sub,HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,Ptype,LULC, YR,Ndate,Pdate,Tilldate,PigMan,CowMan,ManureTime]

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Set up Soybean Master file (hruinfoSB) for HRUs that were originally SOYB
hruinfoSB=[];
for i=1:length(lulc) %creates a file with only Soybean HRUs.
    if size(findstr(lulc{i,4},'SOYB'),1)>0;
        hruinfoSB=[hruinfoSB; sub(i) hru(i) area(i)];
    end
    i=i+1;
end

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(b,2)/100;
y=till(b,3)/100;
c=till(b,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to column 3
    if ntarea < (x*Sarea3)
        tilltype(j)=1; %No till
        ntarea=ntarea+hruinfoSB(j,3);
    elseif mtarea < (y*Sarea3)
        tilltype(j)=2; % Minimum till
        mtarea=mtarea+hruinfoSB(j,3);
    else
        tilltype(j)=3; %Conventional till
        ctarea=ctarea+hruinfoSB(j,3);
    end
end
end
tilltype=tilltype';

```

```

hruinfoSB=[hruinfoSB tilltype];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,4),'rows');
tillareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfoSB,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Sarea3)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfoSB(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfoSB(j,3);
    end
end
tilltim=tilltim';
hruinfoSB=[hruinfoSB tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,5),'rows');
tilltimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertapp=[];
d=sfert(b,2)/100;
NnofertarSB=0;
NfertarSB=0;

```

```

for j=1:size(hruinfoSB,1) %loop adds whether or not N was applied to column 5
    if NfertarSB < (d*Sarea3)
        Nfertapp(j)=1; %Fertilizer applied
        NfertarSB=NfertarSB+hruinfoSB(j,3);
    else
        Nfertapp(j)=2; %fertilizer not applied
        NnofertarSB=NnofertarSB+hruinfoSB(j,3);
    end
end

Nfertapp=Nfertapp';
hruinfoSB=[hruinfoSB Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,6),'rows');
NfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1),:)); %radomly sorting the rows of the main
data matrix
Nfertim=[];
Nfallfertar=0;
Nspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of N fertilizer to column 6
    if hruinfoSB(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfertar < (.21*NfertarSB)
            Nfertim(j)=1; %fall
            Nfallfertar=Nfallfertar+hruinfoSB(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfertar=Nspfertar+hruinfoSB(j,3);
        end
    end
end
Nfertim=Nfertim';

```

```

hruinfoSB=[hruinfoSB Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,7),'rows');
NfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of N fertilizer added to column 7
    if hruinfoSB(j,6)==2
        hruinfoSB(j,8)=0;
    else
        hruinfoSB(j,8)=Nlbac;
    end
end
%hruinfoSB=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assigning N fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Ntypes=[];
x=Ntype(b,2);
y=Ntype(b,3);
c=Ntype(b,4);
d=Ntype(b,5);
e=Ntype(b,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfoSB,1) %loop adds fertilizer type information to column 8
    if hruinfoSB(j,6)==2
        Ntypes(j)=0;
    else

```

```

if aarea < (x*NfertarSB)
    Ntypes(j)=1; %urea
    aarea=aarea+hruinfoSB(j,3);
elseif barea < (y*NfertarSB)
    Ntypes(j)=2; %28% UAN
    barea=barea+hruinfoSB(j,3);
elseif carea < (c*NfertarSB)
    Ntypes(j)=3; %Anyhdrous Ammonia
    carea=carea+hruinfoSB(j,3);
elseif darea < (d*NfertarSB)
    Ntypes(j)=4; %10-34-0 only
    darea=darea+hruinfoSB(j,3);
else
    Ntypes(j)=5; %18-46-0 N only
    earea=earea+hruinfoSB(j,3);
end
end
end
Ntypes=Ntypes';
hruinfoSB=[hruinfoSB Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,9),'rows');
NfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertapp=[];
d=sfert(b,4)/100;
PnofertarSB=0;
PfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds if P was applied to column 9
    if PfertarSB < (d*Sarea)
        Pfertapp(j)=1; %Fertilizer applied
    end
end

```



```

        PfertarSB=PfertarSB+hruinfoSB(j,3);
    else
        Pfertapp(j)=2; %fertilizer not applied
        PnofertarSB=PnofertarSB+hruinfoSB(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfoSB=[hruinfoSB Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,10),'rows');
PfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertim=[];
Pfallfertar=0;
Pspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of P application to column 10
    if hruinfoSB(j,10)==2
        Pfertim(j)=999;
    else
        if Pfallfertar < (.36*PfertarSB)
            Pfertim(j)=1; %fall
            Pfallfertar=Pfallfertar+hruinfoSB(j,3);
        else
            Pfertim(j)=2; %spring
            Pspfertar=Pspfertar+hruinfoSB(j,3);
        end
    end
end
Pfertim=Pfertim';
hruinfoSB=[hruinfoSB Pfertim];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,11),'rows');

```

```

pfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning Phosphorus fertilizer amount applied
Plbac=Pfertappl(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    if hruinfoSB(j,10)==2
        hruinfoSB(j,12)=0;
    else
        hruinfoSB(j,12)=Plbac;
    end
end
end
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

%% Randomly assigning p fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
PtypesSB=[];
x=Ptype(b,2);
y=Ptype(b,3);
c=Ptype(b,4);
d=Ptype(b,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfoSB,1) %loop adds type of P fertilizer applied to column 12
    if hruinfoSB(j,10)==2
        PtypesSB(j)=0;
    else
        if aarea < (x*PfertarSB)
            PtypesSB(j)=1;
            aarea=aarea+hruinfoSB(j,3);
        elseif barea < (y*PfertarSB)
            PtypesSB(j)=2;
            barea=barea+hruinfoSB(j,3);
        end
    end
end

```

```

elseif carea < (c*PfertarSB)
    PtypesSB(j)=3;
    carea=carea+hruinfoSB(j,3);
else
    PtypesSB(j)=4;
    darea=darea+hruinfoSB(j,3);
end
end
end
PtypesSB=PtypesSB';
hruinfoSB=[hruinfoSB PtypesSB];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,13),'rows');
PfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,14)=2; %2 is SOYB
    else
        hruinfoSB(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 14
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,15)=p+1; %2 is SOYB
    else
        hruinfoSB(j,15)=-999; % just to error check
    end
end

p=p+2;

```

```

a=a+1;

%%Adding N fertilizer date to column 16
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfoSB(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,7)==2 && Esfertdate < (x*Nspfertar)
        Nfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==2
        Nfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Nffertdate < (x*Nfallfertar)
        Nfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Effertdate < (x*Nfallfertar)
        Nfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Nfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end
end

```

```

Nfertdate=Nfertdate';
hruinfoSB=[hruinfoSB Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,11)==999
        Pfertdate(j)=999;
    elseif hruinfoSB(j,11)==2 && Nsfertdate < (x*Pspfertar)
        Pfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,11)==2 && Esfertdate < (x*Pspfertar)
        Pfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==2
        Pfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Nffertdate < (x*Pfallfertar)
        Pfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Effertdate < (x*Pfallfertar)
        Pfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else

```

```

        Pfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Pfertdate=Pfertdate';
hruinfoSB=[hruinfoSB Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[],@nansum)];

%%Adding tillage timing to column 18
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;
Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Eftilldate < (x*falltillar)

```

```

    tilldate(j)=5; % Early spring fertilizer date
    Eftilldate=Eftilldate+hruinfoSB(j,3);
else
    tilldate(j)=6; % Late spring fertilizer date
    Lftilldate=Lftilldate+hruinfoSB(j,3);
end
end

tilldate=tilldate';
hruinfoSB=[hruinfoSB tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning manure applied
manP=manure(b,2);
manC=manure(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    hruinfoSB(j,19)=manP;
    hruinfoSB(j,20)=manC;
end

%% randomly assigning manure timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
mantime=[];
x=1/3;
y=1/3;
c=1/3;
manEarea=0;
manNarea=0;
manLarea=0;
for j=1:size(hruinfoSB,1) %loop adds manure timing to column 21
    if manEarea < (x*Sarea3)
        mantime(j)=1; %early time
        manEarea=manEarea+hruinfoSB(j,3);
    end
end

```

```

elseif manNarea < (y*Sarea3)
    mantime(j)=2; %normal time
    manNarea=manNarea+hruinfoSB(j,3);
else
    mantime(j)=3; %late time
    manLarea=manLarea+hruinfoSB(j,3);
end
end
mantime=mantime';
hruinfoSB=[hruinfoSB mantime];
%checking manure area
[unX,~,subs]=unique(hruinfoSB(:,21),'rows');
manurearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%hruinfo=[SUB,HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType,LULC,Yr,Ndate,Pdate,TillDate,PigMan,CowMan,ManTime]

%%Creating one file for hrumgtinfo for one year
hrumgt=[hrumgt; hruinfo; hruinfoSB];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
else %%% Later years %%%
a=a+1
%% Set up Corn Master file (hruinfo)
hruinfo=[];
for i=1:length(lulc) %creates a file with only Corn HRUs.
    if size(findstr(lulc{i},'CORN')),1>0;
        hruinfo=[hruinfo; sub(i) hru(i) area(i)];
    end
    i=i+1;

```



```

end

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(a,2)/100;
y=till(a,3)/100;
c=till(a,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if ntarea < (x*Carea)
        tilltype(j)=1; %No Till
        ntarea=ntarea+hruinfo(j,3);
    elseif mtarea < (y*Carea)
        tilltype(j)=2; % Minimum Till
        mtarea=mtarea+hruinfo(j,3);
    else
        tilltype(j)=3; % Conventional Till
        ctarea=ctarea+hruinfo(j,3);
    end
end
tilltype=tilltype';
hruinfo=[hruinfo tilltype];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,4),'rows');
tillarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfo,1) %loop adds tillage timing to column 4

```

```

    if falltillar < (.5*Carea)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfo(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfo(j,3);
    end
end
tilltim=tilltim';
hruinfo=[hruinfo tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,5),'rows');
tilltimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertapp=[];
d=cfert(a,2)/100;
Nnofertar=0;
Nfertar=0;

for j=1:size(hruinfo,1) %loop adds whether or not N was applied to column 5
    if Nfertar < (d*Carea)
        Nfertapp(j)=1; %Fertilizer applied
        Nfertar=Nfertar+hruinfo(j,3);
    else
        Nfertapp(j)=2; %fertilizer not applied
        Nnofertar=Nnofertar+hruinfo(j,3);
    end
end
Nfertapp=Nfertapp';
hruinfo=[hruinfo Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas

```

```

[unX,~,subs]=unique(hruinfo(:,6),'rows');
Nfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Nfertim=[];
Nfallfertar=0;
Nspfertar=0;
for j=1:size(hruinfo,1) % loop adds when N was applied to column 6
    if hruinfo(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfertar < (.21*Nfertar)
            Nfertim(j)=1; %fall
            Nfallfertar=Nfallfertar+hruinfo(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfertar=Nspfertar+hruinfo(j,3);
        end
    end
end
Nfertim=Nfertim';
hruinfo=[hruinfo Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,7),'rows');
Nfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(a,2);

for j=1:size(hruinfo,1) %loop adds amount applied (lb/ac) to column 7
    if hruinfo(j,6)==2
        hruinfo(j,8)=0;
    else
        hruinfo(j,8)=Nlbac;
    end
end

```

```

    end
end
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assiging N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Ntypes=[];
x=Ntype(a,2);
y=Ntype(a,3);
c=Ntype(a,4);
d=Ntype(a,5);
e=Ntype(a,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfo,1) %loop adds N fertilizer type to column 8
    if hruinfo(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*Nfertar)
            Ntypes(j)=1; %urea
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Nfertar)
            Ntypes(j)=2; %28% UAN
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Nfertar)
            Ntypes(j)=3; %Anhydrous Ammonia
            carea=carea+hruinfo(j,3);
        elseif darea < (d*Nfertar)
            Ntypes(j)=4; %10-34-0 (N only)
            darea=darea+hruinfo(j,3);
        else
            Ntypes(j)=5; %18-46-0 (N only)
        end
    end
end

```

```

        earea=earea+hruinfo(j,3);
    end
end
end
Ntypes=Ntypes';
hruinfo=[hruinfo Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfo(:,9),'rows');
Nfertypearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Pfertapp=[];
d=cfert(a,4)/100;
Pnofertar=0;
Pfertar=0;

for j=1:size(hruinfo,1) %loop adds if P was applied to column 9
    if Pfertar < (d*Carea)
        Pfertapp(j)=1; %Fertilizer applied
        Pfertar=Pfertar+hruinfo(j,3);
    else
        Pfertapp(j)=2; %fertilizer not applied
        Pnofertar=Pnofertar+hruinfo(j,3);
    end
end
end
Pfertapp=Pfertapp';
hruinfo=[hruinfo Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,10),'rows');
Pfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data

```

```

    hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
    Pfertim=[];
    Pfallfertar=0;
    Pspfertar=0;
    for j=1:size(hruinfo,1) %loop adds timing of fertilizer app to column 10
        if hruinfo(j,10)==2
            Pfertim(j)=999;
        else
            if Pfallfertar < (.36*Pfertar)
                Pfertim(j)=1; %fall
                Pfallfertar=Pfallfertar+hruinfo(j,3);
            else
                Pfertim(j)=2; %spring
                Pspfertar=Pspfertar+hruinfo(j,3);
            end
        end
    end
    Pfertim=Pfertim';
    hruinfo=[hruinfo Pfertim];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
    %checking tillage area
    [unX,~,subs]=unique(hruinfo(:,11),'rows');
    pfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

    %% assigning Phosphorus fertilizer amount applied
    Plbac=Pfertappl(a,2);

    for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
        if hruinfo(j,10)==2
            hruinfo(j,12)=0;
        else
            hruinfo(j,12)=Plbac;
        end
    end
    hruinfo=[hruinfo, Plbac];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

```

```

%% Randomly assigning P fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Ptypes=[];
x=Ptype(a,2);
y=Ptype(a,3);
c=Ptype(a,4);
d=Ptype(a,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfo,1) %loop adds type of P fertilizer applied to column 12
    if hruinfo(j,10)==2
        Ptypes(j)=0;
    else
        if aarea < (x*Pfertar)
            Ptypes(j)=1; %Triple superphosphate
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Pfertar)
            Ptypes(j)=2; %10-34-0 P only
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Pfertar)
            Ptypes(j)=3; %18-46-0 P only
            carea=carea+hruinfo(j,3);
        else
            Ptypes(j)=4; %0-15-40 P only
            darea=darea+hruinfo(j,3);
        end
    end
end
Ptypes=Ptypes';
hruinfo=[hruinfo Ptypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAm, NType, Papp,
PTime,PAmt,PType]
%checking fert type area

```

```

[unX,~,subs]=unique(hruinfo(:,13),'rows');
Pfertypearea=[unX accumarray(subs,hruinfo(:,3),[],@nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,14)=1; %1 is CORN
    else
        hruinfo(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 14
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,15)=p; %year is p
    else
        hruinfo(j,15)=-999; % just to error check
    end
end

%%Adding N fertilizer date to column 16
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix

Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;

for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfo(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfo(j,3)
    end
end

```



```

elseif hruinfo(j,7)==2 && Esfertdate < (x*Nspfertar)
    Nfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==2
    Nfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Nffertdate < (x*Nfallfertar)
    Nfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Effertdate < (x*Nfallfertar)
    Nfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Nfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Nfertdate=Nfertdate';
hruinfo=[hruinfo Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfo=hruinfo(randperm(size(hruinfo,1),:)); %radomly sorting the rows of the main data
matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3

```

```

if hruinfo(j,11)==999
    Pfertdate(j)=999;
elseif hruinfo(j,11)==2 && Nsfertdate < (x*Pspfertar)
    Pfertdate(j)=1; %Normal spring fertilizer date
    Nsfertdate=Nsfertdate+hruinfo(j,3)
elseif hruinfo(j,11)==2 && Esfertdate < (x*Pspfertar)
    Pfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==2
    Pfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Nffertdate < (x*Pfallfertar)
    Pfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Effertdate < (x*Pfallfertar)
    Pfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Pfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Pfertdate=Pfertdate';
hruinfo=[hruinfo Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding tillage timing to column 18
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;

```

```

Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfo in column 3
    if hruinfo(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfo(j,3)
    elseif hruinfo(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfo(j,3);
    elseif hruinfo(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfo(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfo(j,3);
    end
end

tilldate=tilldate';
hruinfo=[hruinfo tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning manure applied
manP=manure(a,2);
manC=manure(a,3);

```



```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Set up Soybean Master file (hruinfoSB)
hruinfoSB=[];
for i=1:length(lulc) %creates a file with only Soybean HRUs.
    if size(findstr(lulc{i},'SOYB')),1>0;
        hruinfoSB=[hruinfoSB; sub(i) hru(i) area(i)];
    end
    i=i+1;
end

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(a,2)/100;
y=till(a,3)/100;
c=till(a,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to column 3
    if ntarea < (x*Sarea)
        tilltype(j)=1; %No till
        ntarea=ntarea+hruinfoSB(j,3);
    elseif mtarea < (y*Sarea)
        tilltype(j)=2; % Minimum till
        mtarea=mtarea+hruinfoSB(j,3);
    else
        tilltype(j)=3; %Conventional till
        ctarea=ctarea+hruinfoSB(j,3);
    end
end
tilltype=tilltype';
hruinfoSB=[hruinfoSB tilltype];
%hruinfo=[HRU, area, tilltype]

```

```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,4),'rows');
tillareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfoSB,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Sarea)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfoSB(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfoSB(j,3);
    end
end
tilltim=tilltim';
hruinfoSB=[hruinfoSB tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,5),'rows');
tilltimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertapp=[];
d=sfert(a,2)/100;
NnofertarSB=0;
NfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds whether or not N was applied to column 5
    if NfertarSB < (d*Sarea)

```

```

    Nfertapp(j)=1; %Fertilizer applied
    NfertarSB=NfertarSB+hruinfoSB(j,3);
else
    Nfertapp(j)=2; %fertilizer not applied
    NnofertarSB=NnofertarSB+hruinfoSB(j,3);
end
end
end

Nfertapp=Nfertapp';
hruinfoSB=[hruinfoSB Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,6),'rows');
NfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertim=[];
Nfallfentar=0;
Nspfentar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of N fertilizer to column 6
    if hruinfoSB(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfentar < (.21*NfertarSB)
            Nfertim(j)=1; %fall
            Nfallfentar=Nfallfentar+hruinfoSB(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfentar=Nspfentar+hruinfoSB(j,3);
        end
    end
end
end
Nfertim=Nfertim';
hruinfoSB=[hruinfoSB Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]

```

```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,7),'rows');
NfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of N fertilizer added to column 7
    if hruinfoSB(j,6)==2
        hruinfoSB(j,8)=0;
    else
        hruinfoSB(j,8)=Nlbac;
    end
end
%hruinfoSB=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assigning N fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Ntypes=[];
x=Ntype(a,2);
y=Ntype(a,3);
c=Ntype(a,4);
d=Ntype(a,5);
e=Ntype(a,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfoSB,1) %loop adds fertilizer type information to column 8
    if hruinfoSB(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*NfentarSB)
            Ntypes(j)=1; %urea
        end
    end
end

```



```

        aarea=aarea+hruinfoSB(j,3);
elseif barea < (y*NfertarSB)
    Ntypes(j)=2; %28% UAN
    barea=barea+hruinfoSB(j,3);
elseif carea < (c*NfertarSB)
    Ntypes(j)=3; %Anyhdrous Ammonia
    carea=carea+hruinfoSB(j,3);
elseif darea < (d*NfertarSB)
    Ntypes(j)=4; %10-34-0 only
    darea=darea+hruinfoSB(j,3);
else
    Ntypes(j)=5; %18-46-0 N only
    earea=earea+hruinfoSB(j,3);
end
end
end
Ntypes=Ntypes';
hruinfoSB=[hruinfoSB Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAm, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,9),'rows');
NfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertapp=[];
d=sfert(a,4)/100;
PnofertarSB=0;
PfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds if P was applied to column 9
    if PfertarSB < (d*Sarea)
        Pfertapp(j)=1; %Fertilizer applied
        PfertarSB=PfertarSB+hruinfoSB(j,3);
    else

```

```

        Pfertapp(j)=2; %fertilizer not applied
        PnofertarSB=PnofertarSB+hruinfoSB(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfoSB=[hruinfoSB Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,10),'rows');
PfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertim=[];
Pfallfertar=0;
Pspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of P application to column 10
    if hruinfoSB(j,10)==2
        Pfertim(j)=999;
    else
        if Pfallfertar < (.36*PfertarSB)
            Pfertim(j)=1; %fall
            Pfallfertar=Pfallfertar+hruinfoSB(j,3);
        else
            Pfertim(j)=2; %spring
            Pspfertar=Pspfertar+hruinfoSB(j,3);
        end
    end
end
Pfertim=Pfertim';
hruinfoSB=[hruinfoSB Pfertim];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,11),'rows');
pfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

```

```

%% assigning Phosphorus fertilizer amount applied
Plbac=Pfertappl(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    if hruinfoSB(j,10)==2
        hruinfoSB(j,12)=0;
    else
        hruinfoSB(j,12)=Plbac;
    end
end
end
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

%% Randomly assiging p fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
PtypesSB=[];
x=Ptype(a,2);
y=Ptype(a,3);
c=Ptype(a,4);
d=Ptype(a,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfoSB,1) %loop adds type of P fertilizer applied to column 12
    if hruinfoSB(j,10)==2
        PtypesSB(j)=0;
    else
        if aarea < (x*PfertarSB)
            PtypesSB(j)=1;
            aarea=aarea+hruinfoSB(j,3);
        elseif barea < (y*PfertarSB)
            PtypesSB(j)=2;
            barea=barea+hruinfoSB(j,3);
        elseif carea < (c*PfertarSB)
            PtypesSB(j)=3;
        end
    end
end

```

```

        carea=carea+hruinfoSB(j,3);
    else
        PtypesSB(j)=4;
        darea=darea+hruinfoSB(j,3);
    end
end
end
PtypesSB=PtypesSB';
hruinfoSB=[hruinfoSB PtypesSB];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,13),'rows');
PfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,14)=2; %2 is SOYB
    else
        hruinfoSB(j,14)=-999; % just to error check
    end
end
%% Adding Year to column 14
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,15)=p; %2 is SOYB
    else
        hruinfoSB(j,15)=-999; % just to error check
    end
end

%%Adding N fertilizer date to column 16
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Nfertdate=[];

```

```

x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfoSB(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,7)==2 && Esfertdate < (x*Nspfertar)
        Nfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==2
        Nfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Nffertdate < (x*Nfallfertar)
        Nfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Effertdate < (x*Nfallfertar)
        Nfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Nfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Nfertdate=Nfertdate';
hruinfoSB=[hruinfoSB Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[],@nansum)];

```

```

%%Adding P fertilizer date to column 17
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,11)==999
        Pfertdate(j)=999;
    elseif hruinfoSB(j,11)==2 && Nsfertdate < (x*Pspfertar)
        Pfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,11)==2 && Esfertdate < (x*Pspfertar)
        Pfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==2
        Pfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Nffertdate < (x*Pfallfertar)
        Pfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Effertdate < (x*Pfallfertar)
        Pfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Pfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Pfertdate=Pfertdate';

```

```

hruinfoSB=[hruinfoSB Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

    %%Adding tillage timing to column 18
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;
Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfoSB(j,3);
    elseif hruinfoSB(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfoSB(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfoSB(j,3);

```

```

    end
end

tilldate=tilldate';
hruinfoSB=[hruinfoSB tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning manure applied
manP=manure(a,2);
manC=manure(a,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    hruinfoSB(j,19)=manP;
    hruinfoSB(j,20)=manC;
end

%% randomly assigning manure timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
mantime=[];
x=1/3;
y=1/3;
c=1/3;
manEarea=0;
manNarea=0;
manLarea=0;
for j=1:size(hruinfoSB,1) %loop adds manure timing to column 21
    if manEarea < (x*Sarea)
        mantime(j)=1; %Early time
        manEarea=manEarea+hruinfoSB(j,3);
    elseif manNarea < (y*Sarea)
        mantime(j)=2; % Normal time
        manNarea=manNarea+hruinfoSB(j,3);
    else
        mantime(j)=3; %Late time
    end
end

```





```

end

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(b,2)/100;
y=till(b,3)/100;
c=till(b,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfo in column 3
    if ntarea < (x*Carea)
        tilltype(j)=1; %No Till
        ntarea=ntarea+hruinfo(j,3);
    elseif mtarea < (y*Carea)
        tilltype(j)=2; % Minimum Till
        mtarea=mtarea+hruinfo(j,3);
    else
        tilltype(j)=3; % Conventional Till
        ctarea=ctarea+hruinfo(j,3);
    end
end
tilltype=tilltype';
hruinfo=[hruinfo tilltype];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,4),'rows');
tillarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfo,1) %loop adds tillage timing to column 4

```

```

    if falltillar < (.5*Carea)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfo(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfo(j,3);
    end
end
tilltim=tilltim';
hruinfo=[hruinfo tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,5),'rows');
tilltimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Nfertapp=[];
d=cfert(b,2)/100;
Nnofertar=0;
Nfertar=0;

for j=1:size(hruinfo,1) %loop adds whether or not N was applied to column 5
    if Nfertar < (d*Carea)
        Nfertapp(j)=1; %Fertilizer applied
        Nfertar=Nfertar+hruinfo(j,3);
    else
        Nfertapp(j)=2; %fertilizer not applied
        Nnofertar=Nnofertar+hruinfo(j,3);
    end
end
Nfertapp=Nfertapp';
hruinfo=[hruinfo Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas

```

```

[unX,~,subs]=unique(hruinfo(:,6),'rows');
Nfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Nfertim=[];
Nfallfentar=0;
Nspfentar=0;
for j=1:size(hruinfo,1) % loop adds when N was applied to column 6
    if hruinfo(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfentar < (.21*Nfentar)
            Nfertim(j)=1; %fall
            Nfallfentar=Nfallfentar+hruinfo(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfentar=Nspfentar+hruinfo(j,3);
        end
    end
end
Nfertim=Nfertim';
hruinfo=[hruinfo Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,7),'rows');
Nfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(b,2);

for j=1:size(hruinfo,1) %loop adds amount applied (lb/ac) to column 7
    if hruinfo(j,6)==2
        hruinfo(j,8)=0;
    else
        hruinfo(j,8)=Nlbac;
    end
end

```

```

    end
end
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assiging N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Ntypes=[];
x=Ntype(b,2);
y=Ntype(b,3);
c=Ntype(b,4);
d=Ntype(b,5);
e=Ntype(b,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfo,1) %loop adds N fertilizer type to column 8
    if hruinfo(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*Nfertar)
            Ntypes(j)=1; %urea
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Nfertar)
            Ntypes(j)=2; %28% UAN
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Nfertar)
            Ntypes(j)=3; %Anhydrous Ammonia
            carea=carea+hruinfo(j,3);
        elseif darea < (d*Nfertar)
            Ntypes(j)=4; %10-34-0 (N only)
            darea=darea+hruinfo(j,3);
        else
            Ntypes(j)=5; %18-46-0 (N only)
        end
    end
end

```

```

        earea=earea+hruinfo(j,3);
    end
end
end
Ntypes=Ntypes';
hruinfo=[hruinfo Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfo(:,9),'rows');
Nfertypearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Pfertapp=[];
d=cfert(b,4)/100;
Pnofertar=0;
Pfertar=0;

for j=1:size(hruinfo,1) %loop adds if P was applied to column 9
    if Pfertar < (d*Carea)
        Pfertapp(j)=1; %Fertilizer applied
        Pfertar=Pfertar+hruinfo(j,3);
    else
        Pfertapp(j)=2; %fertilizer not applied
        Pnofertar=Pnofertar+hruinfo(j,3);
    end
end
end
Pfertapp=Pfertapp';
hruinfo=[hruinfo Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfo(:,10),'rows');
Pfertarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data

```

```

    hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
    Pfertim=[];
    Pfallfertar=0;
    Pspfertar=0;
    for j=1:size(hruinfo,1) %loop adds timing of fertilizer app to column 10
        if hruinfo(j,10)==2
            Pfertim(j)=999;
        else
            if Pfallfertar < (.36*Pfertar)
                Pfertim(j)=1; %fall
                Pfallfertar=Pfallfertar+hruinfo(j,3);
            else
                Pfertim(j)=2; %spring
                Pspfertar=Pspfertar+hruinfo(j,3);
            end
        end
    end
    Pfertim=Pfertim';
    hruinfo=[hruinfo Pfertim];
    %hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
    %checking tillage area
    [unX,~,subs]=unique(hruinfo(:,11),'rows');
    pfertimar=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

    %% assigning Phosphorus fertilizer amount applied
    Plbac=Pfertappl(b,2);

    for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
        if hruinfo(j,10)==2
            hruinfo(j,12)=0;
        else
            hruinfo(j,12)=Plbac;
        end
    end
    hruinfo=[hruinfo, PTime, PAmt]

```

```

%% Randomly assigning N fertilizer type
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Ptypes=[];
x=Ptype(b,2);
y=Ptype(b,3);
c=Ptype(b,4);
d=Ptype(b,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfo,1) %loop adds type of P fertilizer applied to column 12
    if hruinfo(j,10)==2
        Ptypes(j)=0;
    else
        if aarea < (x*Pfertar)
            Ptypes(j)=1; %Triple superphosphate
            aarea=aarea+hruinfo(j,3);
        elseif barea < (y*Pfertar)
            Ptypes(j)=2; %10-34-0 P only
            barea=barea+hruinfo(j,3);
        elseif carea < (c*Pfertar)
            Ptypes(j)=3; %18-46-0 P only
            carea=carea+hruinfo(j,3);
        else
            Ptypes(j)=4; %0-15-40 P only
            darea=darea+hruinfo(j,3);
        end
    end
end
Ptypes=Ptypes';
hruinfo=[hruinfo Ptypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area

```



```

[unX,~,subs]=unique(hruinfo(:,13),'rows');
Pfertypearea=[unX accumarray(subs,hruinfo(:,3),[],@nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,14)=1; %1 is CORN
    else
        hruinfo(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 14
for j=1:size(hruinfo,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfo(j,2)> 0
        hruinfo(j,15)=p+1; %year is p
    else
        hruinfo(j,15)=-999; % just to error check
    end
end

%%Adding N fertilizer date to column 16
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %randomly sorting the rows of the main data
matrix
Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfo(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfo(j,3)
    end
end

```

```

elseif hruinfo(j,7)==2 && Esfertdate < (x*Nspfertar)
    Nfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==2
    Nfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Nffertdate < (x*Nfallfertar)
    Nfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,7)==1 && Effertdate < (x*Nfallfertar)
    Nfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Nfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Nfertdate=Nfertdate';
hruinfo=[hruinfo Nfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3

```

```

if hruinfo(j,11)==999
    Pfertdate(j)=999;
elseif hruinfo(j,11)==2 && Nsfertdate < (x*Pspfertar)
    Pfertdate(j)=1; %Normal spring fertilizer date
    Nsfertdate=Nsfertdate+hruinfo(j,3)
elseif hruinfo(j,11)==2 && Esfertdate < (x*Pspfertar)
    Pfertdate(j)=2; % Early spring fertilizer date
    Esfertdate=Esfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==2
    Pfertdate(j)=3; % Late spring fertilizer date
    Lsfertdate=Lsfertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Nffertdate < (x*Pfallfertar)
    Pfertdate(j)=4; %Normal spring fertilizer date
    Nffertdate=Nffertdate+hruinfo(j,3);
elseif hruinfo(j,11)==1 && Effertdate < (x*Pfallfertar)
    Pfertdate(j)=5; % Early spring fertilizer date
    Effertdate=Effertdate+hruinfo(j,3);
else
    Pfertdate(j)=6; % Late spring fertilizer date
    Lffertdate=Lffertdate+hruinfo(j,3);
end
end

Pfertdate=Pfertdate';
hruinfo=[hruinfo Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%%Adding tillage timing to column 18
hruinfo=hruinfo(randperm(size(hruinfo,1)),:); %radomly sorting the rows of the main data
matrix
tilldate=[];
x=1/3;
Nstilldate=0;
Estilldate=0;

```

```

Lstilldate=0;
Nftilldate=0;
Eftilldate=0;
Lftilldate=0;
for j=1:size(hruinfo,1) %loop adds tillage type to hruinfoin column 3
    if hruinfo(j,5)==2 && Nstilldate < (x*sptillar)
        tilldate(j)=1; %Normal spring fertilizer date
        Nstilldate=Nsfertdate+hruinfo(j,3)
    elseif hruinfo(j,5)==2 && Estilldate < (x*sptillar)
        tilldate(j)=2; % Early spring fertilizer date
        Estilldate=Esfertdate+hruinfo(j,3);
    elseif hruinfo(j,5)==2
        tilldate(j)=3; % Late spring fertilizer date
        Lstilldate=Lstilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Nftilldate < (x*falltillar)
        tilldate(j)=4; %Normal spring fertilizer date
        Nftilldate=Nftilldate+hruinfo(j,3);
    elseif hruinfo(j,5)==1 && Eftilldate < (x*falltillar)
        tilldate(j)=5; % Early spring fertilizer date
        Eftilldate=Eftilldate+hruinfo(j,3);
    else
        tilldate(j)=6; % Late spring fertilizer date
        Lftilldate=Lftilldate+hruinfo(j,3);
    end
end

tilldate=tilldate';
hruinfo=[hruinfo tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfo(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% assigning manure applied
manP=manure(b,2);
manC=manure(b,3);

```



```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Set up Soybean Master file (hruinfoSB) for HRUs that were originally SOYB
hruinfoSB=[];
for i=1:length(lulc) %creates a file with only Soybean HRUs.
    if size(findstr(lulc{i},'CORN'),1)>0;
        hruinfoSB=[hruinfoSB; sub(i) hru(i) area(i)];
    end
    i=i+1;
end

%% randomly assigning tillage type data
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
tilltype=[];
x=till(b,2)/100;
y=till(b,3)/100;
c=till(b,4)/100;
ntarea=0;
mtarea=0;
ctarea=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to column 3
    if ntarea < (x*Sarea)
        tilltype(j)=1; %No till
        ntarea=ntarea+hruinfoSB(j,3);
    elseif mtarea < (y*Sarea)
        tilltype(j)=2; % Minimum till
        mtarea=mtarea+hruinfoSB(j,3);
    else
        tilltype(j)=3; %Conventional till
        ctarea=ctarea+hruinfoSB(j,3);
    end
end
tilltype=tilltype';
hruinfoSB=[hruinfoSB tilltype];
%hruinfo=[HRU, area, tilltype]

```

```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,4),'rows');
tillareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning tillage timing
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
tilltim=[];
falltillar=0;
sptillar=0;
for j=1:size(hruinfoSB,1) %loop adds tillage timing to column 4
    if falltillar < (.5*Sarea)
        tilltim(j)=1; %fall
        falltillar=falltillar+hruinfoSB(j,3);
    else
        tilltim(j)=2; %spring
        sptillar=sptillar+hruinfoSB(j,3);
    end
end
tilltim=tilltim';
hruinfoSB=[hruinfoSB tilltim];
%hruinfo=[HRU, area, tilltype, tilltime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,5),'rows');
tilltimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% NITROGEN FERTILIZER APPLICAION %%%
%% Randomly assigning if Nitrogen fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertapp=[];
d=sfert(b,2)/100;
NnofertarSB=0;
NfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds whether or not N was applied to column 5
    if NfertarSB < (d*Sarea)

```

```

    Nfertapp(j)=1; %Fertilizer applied
    NfertarSB=NfertarSB+hruinfoSB(j,3);
else
    Nfertapp(j)=2; %fertilizer not applied
    NnofertarSB=NnofertarSB+hruinfoSB(j,3);
end
end
end

Nfertapp=Nfertapp';
hruinfoSB=[hruinfoSB Nfertapp];
%hruinfo=[HRU, area, tilltype, tilltime,Napp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,6),'rows');
NfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Nitrogen fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Nfertim=[];
Nfallfentar=0;
Nspfentar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of N fertilizer to column 6
    if hruinfoSB(j,6)==2
        Nfertim(j)=999;
    else
        if Nfallfentar < (.21*NfertarSB)
            Nfertim(j)=1; %fall
            Nfallfentar=Nfallfentar+hruinfoSB(j,3);
        else
            Nfertim(j)=2; %spring
            Nspfentar=Nspfentar+hruinfoSB(j,3);
        end
    end
end
end
Nfertim=Nfertim';
hruinfoSB=[hruinfoSB Nfertim];
%hruinfo=[HRU, area, tilltype, tilltime,Napp,Ntime]

```



```

%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,7),'rows');
NfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning Nitrogen fertilizer amount applied
Nlbac=Nfertappl(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of N fertilizer added to column 7
    if hruinfoSB(j,6)==2
        hruinfoSB(j,8)=0;
    else
        hruinfoSB(j,8)=Nlbac;
    end
end
%hruinfoSB=[HRU, area, tilltype, tilltime,Napp,Ntime,Nfertamt(lb/ac)]

%% assigning N fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Ntypes=[];
x=Ntype(b,2);
y=Ntype(b,3);
c=Ntype(b,4);
d=Ntype(b,5);
e=Ntype(b,6);
aarea=0;
barea=0;
carea=0;
darea=0;
earea=0;

for j=1:size(hruinfoSB,1) %loop adds fertilizer type information to column 8
    if hruinfoSB(j,6)==2
        Ntypes(j)=0;
    else
        if aarea < (x*NfentarSB)
            Ntypes(j)=1; %urea
        end
    end
end

```

```

        aarea=aarea+hruinfoSB(j,3);
elseif barea < (y*NfertarSB)
    Ntypes(j)=2; %28% UAN
    barea=barea+hruinfoSB(j,3);
elseif carea < (c*NfertarSB)
    Ntypes(j)=3; %Anyhdrous Ammonia
    carea=carea+hruinfoSB(j,3);
elseif darea < (d*NfertarSB)
    Ntypes(j)=4; %10-34-0 only
    darea=darea+hruinfoSB(j,3);
else
    Ntypes(j)=5; %18-46-0 N only
    earea=earea+hruinfoSB(j,3);
end
end
end
Ntypes=Ntypes';
hruinfoSB=[hruinfoSB Ntypes];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAm, NType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,9),'rows');
NfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% PHOSPHORUS FERTILIZER APPLICAION %%%
%% Randomly assigning if Phosphorus fertilizer was applied
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertapp=[];
d=sfert(b,4)/100;
PnofertarSB=0;
PfertarSB=0;

for j=1:size(hruinfoSB,1) %loop adds if P was applied to column 9
    if PfertarSB < (d*Sarea)
        Pfertapp(j)=1; %Fertilizer applied
        PfertarSB=PfertarSB+hruinfoSB(j,3);
    else

```

```

        Pfertapp(j)=2; %fertilizer not applied
        PnofertarSB=PnofertarSB+hruinfoSB(j,3);
    end
end
Pfertapp=Pfertapp';
hruinfoSB=[hruinfoSB Pfertapp];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp]
%checking fertilizer applied areas
[unX,~,subs]=unique(hruinfoSB(:,10),'rows');
PfertareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Randomly assigning Phosphorus fertilizer timing data
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %radomly sorting the rows of the main
data matrix
Pfertim=[];
Pfallfertar=0;
Pspfertar=0;
for j=1:size(hruinfoSB,1) %loop adds timing of P application to column 10
    if hruinfoSB(j,10)==2
        Pfertim(j)=999;
    else
        if Pfallfertar < (.36*PfertarSB)
            Pfertim(j)=1; %fall
            Pfallfertar=Pfallfertar+hruinfoSB(j,3);
        else
            Pfertim(j)=2; %spring
            Pspfertar=Pspfertar+hruinfoSB(j,3);
        end
    end
end
Pfertim=Pfertim';
hruinfoSB=[hruinfoSB Pfertim];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,11),'rows');
pfertimarSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

```

```

%% assigning Phosphorus fertilizer amount applied
Plbac=Pfertappl(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    if hruinfoSB(j,10)==2
        hruinfoSB(j,12)=0;
    else
        hruinfoSB(j,12)=Plbac;
    end
end
end
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp, PTime,PAmt]

%% Randomly assigning p fertilizer type
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
PtypesSB=[];
x=Ptype(b,2);
y=Ptype(b,3);
c=Ptype(b,4);
d=Ptype(b,5);
aarea=0;
barea=0;
carea=0;
darea=0;

for j=1:size(hruinfoSB,1) %loop adds type of P fertilizer applied to column 12
    if hruinfoSB(j,10)==2
        PtypesSB(j)=0;
    else
        if aarea < (x*PfertarSB)
            PtypesSB(j)=1;
            aarea=aarea+hruinfoSB(j,3);
        elseif barea < (y*PfertarSB)
            PtypesSB(j)=2;
            barea=barea+hruinfoSB(j,3);
        elseif carea < (c*PfertarSB)
            PtypesSB(j)=3;
        end
    end
end

```

```

        carea=carea+hruinfoSB(j,3);
    else
        PtypesSB(j)=4;
        darea=darea+hruinfoSB(j,3);
    end
end
end
PtypesSB=PtypesSB';
hruinfoSB=[hruinfoSB PtypesSB];
%hruinfo=[HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType]
%checking fert type area
[unX,~,subs]=unique(hruinfoSB(:,13),'rows');
PfertypeareaSB=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% Adding LULC code to column 13
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,14)=2; %2 is SOYB
    else
        hruinfoSB(j,14)=-999; % just to error check
    end
end

%% Adding Year to column 14
for j=1:size(hruinfoSB,1) %loop adds amount of P applied (lb/ac) to column 11
    if hruinfoSB(j,2)> 0
        hruinfoSB(j,15)=p+1; %2 is SOYB
    else
        hruinfoSB(j,15)=-999; % just to error check
    end
end

p=p+2;
a=a+1;

```

```

%%Adding N fertilizer date to column 16
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Nfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,7)==999
        Nfertdate(j)=999;
    elseif hruinfoSB(j,7)==2 && Nsfertdate < (x*Nspfertar)
        Nfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,7)==2 && Esfertdate < (x*Nspfertar)
        Nfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==2
        Nfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Nffertdate < (x*Nfallfertar)
        Nfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,7)==1 && Effertdate < (x*Nfallfertar)
        Nfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Nfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

Nfertdate=Nfertdate';
hruinfoSB=[hruinfoSB Nfertdate];

```

```

%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,16),'rows');
Nfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%%Adding P fertilizer date to column 17
hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
Pfertdate=[];
x=1/3;
Nsfertdate=0;
Esfertdate=0;
Lsfertdate=0;
Nffertdate=0;
Effertdate=0;
Lffertdate=0;
for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
    if hruinfoSB(j,11)==999
        Pfertdate(j)=999;
    elseif hruinfoSB(j,11)==2 && Nsfertdate < (x*Pspfertar)
        Pfertdate(j)=1; %Normal spring fertilizer date
        Nsfertdate=Nsfertdate+hruinfoSB(j,3)
    elseif hruinfoSB(j,11)==2 && Esfertdate < (x*Pspfertar)
        Pfertdate(j)=2; % Early spring fertilizer date
        Esfertdate=Esfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==2
        Pfertdate(j)=3; % Late spring fertilizer date
        Lsfertdate=Lsfertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Nffertdate < (x*Pfallfertar)
        Pfertdate(j)=4; %Normal spring fertilizer date
        Nffertdate=Nffertdate+hruinfoSB(j,3);
    elseif hruinfoSB(j,11)==1 && Effertdate < (x*Pfallfertar)
        Pfertdate(j)=5; % Early spring fertilizer date
        Effertdate=Effertdate+hruinfoSB(j,3);
    else
        Pfertdate(j)=6; % Late spring fertilizer date
        Lffertdate=Lffertdate+hruinfoSB(j,3);
    end
end

```

```

    end
end

Pfertdate=Pfertdate';
hruinfoSB=[hruinfoSB Pfertdate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:, 17),'rows');
Pfertdataarea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

    %%Adding tillage timing to column 18
    hruinfoSB=hruinfoSB(randperm(size(hruinfoSB,1)),:); %randomly sorting the rows of the main
data matrix
    tilldate=[];
    x=1/3;
    Nstilldate=0;
    Estilldate=0;
    Lstilldate=0;
    Nftilldate=0;
    Eftilldate=0;
    Lftilldate=0;
    for j=1:size(hruinfoSB,1) %loop adds tillage type to hruinfoin column 3
        if hruinfoSB(j,5)==2 && Nstilldate < (x*sptillar)
            tilldate(j)=1; %Normal spring fertilizer date
            Nstilldate=Nsfertdate+hruinfoSB(j,3)
        elseif hruinfoSB(j,5)==2 && Estilldate < (x*sptillar)
            tilldate(j)=2; % Early spring fertilizer date
            Estilldate=Esfertdate+hruinfoSB(j,3);
        elseif hruinfoSB(j,5)==2
            tilldate(j)=3; % Late spring fertilizer date
            Lstilldate=Lstilldate+hruinfoSB(j,3);
        elseif hruinfoSB(j,5)==1 && Nftilldate < (x*falltillar)
            tilldate(j)=4; %Normal spring fertilizer date
            Nftilldate=Nftilldate+hruinfoSB(j,3);
        elseif hruinfoSB(j,5)==1 && Eftilldate < (x*falltillar)
            tilldate(j)=5; % Early spring fertilizer date
            Eftilldate=Eftilldate+hruinfoSB(j,3);
    end

```



```

else
    tilldate(j)=6; % Late spring fertilizer date
    Lftilldate=Lftilldate+hruinfoSB(j,3);
end
end

tilldate=tilldate';
hruinfoSB=[hruinfoSB tilldate];
%hruinfo=[HRU, area, tilltype]
%checking tillage area
[unX,~,subs]=unique(hruinfoSB(:,18),'rows');
tilldatearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%% assigning manure applied
manP=manure(b,2);
manC=manure(b,3);

for j=1:size(hruinfoSB,1) %loop adds amount of P applied to column 11
    hruinfoSB(j,19)=manP;
    hruinfoSB(j,20)=manC;
end

%% randomly assigning manure timing
hruinfo=hruinfo(randperm(size(hruinfo,1)),:);
mantime=[];
x=1/3;
y=1/3;
c=1/3;
manEarea=0;
manNarea=0;
manLarea=0;
for j=1:size(hruinfoSB,1) %loop adds manure timing to column 21
    if manEarea < (x*Sarea)
        mantime(j)=1; % Early time
        manEarea=manEarea+hruinfoSB(j,3);
    elseif manNarea < (y*Sarea)
        mantime(j)=2; % Normal time
    end
end

```

```

        manNarea=manNarea+hruinfoSB(j,3);
    else
        mantime(j)=3; % Late time
        manLarea=manLarea+hruinfoSB(j,3);
    end
end
mantime=mantime';
hruinfoSB=[hruinfoSB mantime];
%checking manure area
[unX,~,subs]=unique(hruinfoSB(:,21),'rows');
manurearea=[unX accumarray(subs,hruinfoSB(:,3),[], @nansum)];

%hruinfo=[SUB,HRU, area, tilltype, TillTim, Napp, NTime, NAmt, NType, Papp,
PTime,PAmt,PType,LULC, YR,Ndate,Pdate,TillDate,PigMan,CowMan,ManTime]

%%Creating one file for hrumgtinfo for one year
hrumgt=[hrumgt; hruinfo; hruinfoSB];
end
end

hrumgtnew=sortrows(hrumgt,[1,2,15]); %sorts by sub,hru #, then year.
% Can use the code below to check if getting the correct amount of soybean
% and corn each year (should be ~40% SOYB up to 1985 and then 50/50 after)
% [unX,~,subs]=unique(hrumgtnew(:,[14,15]),'rows');
% lulccheck=[unX accumarray(subs,hrumgtnew(:,3),[], @nansum)];

```

Appendix C Matlab ® code (hruwrite.m) which creates the SWAT HRU management (.mgt) files using the randomly assigned management data from the yearloop code.

```

%k=1;
%for isub = 1:nsub %for each sub-basin
%  hruinsub = size(find(sub == isub),1); %for all HRUs in sub-basin
%  for ihru = 1:hruinsub
%    if size(findstr(lulc{k},'CORN'),1)>0 | size(findstr(lulc{k},'SOYB'),1)>0 %if C|S
%clear all
%clc
global sim %sim is the folder that contains the SWAT input files from which
        % input management files will be modified
sim = 'input';

if exist([sim 'new'],'dir') == 0 %creating new sim directory if it doesn't exist already
    mkdir([sim 'new']);
end

fid1 = fopen('SubHruAreaLulc.dat','r');
data = textscan(fid1,'%d%d%f%S','HeaderLines',1);
sub = data{1};
hru = data{2};
lulc = data{4};
nsub = max(sub);

%isub=1;
%ihru=1;
k=1;
hruprev=0;
for isub = 1:nsub %for each sub-basin
    hruinsub = size(find(sub == isub),1); %for all HRUs in sub-basin
    for ihru = 1:hruinsub
        %ihru
        if isub < 10
            szeros = '0000';
        elseif isub >=10 & isub < 100

```

```

    szeros = '000';
elseif isub >= 100 & isub < 1000
    szeros = '00';
elseif isub >= 1000
    szeros = '0';
end

if ihru < 10
    hzeros = '000';
elseif ihru >=10 & ihru < 100
    hzeros = '00';
elseif ihru >= 100 & ihru < 1000
    hzeros = '0';
elseif ihru >= 1000
    hzeros = "";
end

hrustr = [szeros num2str(isub) hzeros num2str(ihru) '.mgt']
if isequal(lulc{(ihru+hruprev)},'CORN')==1
    %hrunum=ihru+hruprev
    hrutemp=[];
    for i=1:size(hrumgtnew,1)%Creating matrix with every year for only one HRU
        if hrumgtnew(i,1)==isub && hrumgtnew(i,2)==(ihru+hruprev)
            hrutemp=[hrutemp; hrumgtnew(i,:)];
        end
    end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Planting Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
planttemp={};%creating a temporary matrix which stores planting line information
plantiltmp={};
for i=1:size(hrutemp,1)
    if hrutemp(i,14)==1
        %planttemp{i,1}='Plant Corn';
    end
end

```

```

    planttemp{i,1}=sprintf(' 5 6      1 19      1550.00000 0.00  0.00000 0.00
0.00 0.00');
    planttemp{i,2}=hrutemp(i,15);
    planttemp{i,3}=5;
    planttemp{i,4}=6;
    if hrutemp(i,4)==1
        %planttiltmp{i,1}='No Till at planting';
        planttiltmp{i,1}=sprintf(' 5 6      6 4      0.00000');
        planttiltmp{i,2}=hrutemp(i,15);
        planttiltmp{i,3}=5;
        planttiltmp{i,4}=6;
    else
        %planttiltmp{i,1}='Till 88 at planting';
        planttiltmp{i,1}=sprintf(' 5 6      6 88      0.00000');
        planttiltmp{i,2}=hrutemp(i,15);
        planttiltmp{i,3}=5;
        planttiltmp{i,4}=6;
    end
else
    %planttemp{i,1}='Plant Soybeans';
    planttemp{i,1}=sprintf(' 5 24      1 56      1250.00000 0.00  0.00000 0.00
0.00 0.00');
    planttemp{i,2}=hrutemp(i,15);
    planttemp{i,3}=5;
    planttemp{i,4}=24;
    %planttiltmp{i,1}='Tillage 4';
    planttiltmp{i,1}=sprintf(' 5 24      6 4      0.00000');
    planttiltmp{i,2}=hrutemp(i,15);
    planttiltmp{i,3}=5;
    planttiltmp{i,4}=24;
end
end

planttemps=sortrows(planttemp,[2,3,4]);
planttiltmps=sortrows(planttiltmp,[2,3,4]);

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Tillage Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
tilltemp={}; %creating a temporary matrix which stores tillage line information
for i=1:size(hrutemp,1)
    if hrutemp(i,14)==1
        if hrutemp(i,4)==1
            tilltemp{i,1}={};
            tilltemp{i,2}={};
            tilltemp{i,3}={};
            tilltemp{i,4}={};
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==4
            %tilltemp{i,1}='Min Till, fall, normal date';
            tilltemp{i,1}=sprintf(' 11 1      6 3');
            tilltemp{i,2}=hrutemp(i,15)-1;
            tilltemp{i,3}=11;
            tilltemp{i,4}=1;
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==5
            %tilltemp{i,1}='Min Till, fall, early date';
            tilltemp{i,1}=sprintf(' 10 25     6 3');
            tilltemp{i,2}=hrutemp(i,15)-1;
            tilltemp{i,3}=10;
            tilltemp{i,4}=25;
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==6
            %tilltemp{i,1}='Min Till, fall, late date';
            tilltemp{i,1}=sprintf(' 11 8      6 3');
            tilltemp{i,2}=hrutemp(i,15)-1;
            tilltemp{i,3}=11;
            tilltemp{i,4}=8;
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==1
            %tilltemp{i,1}='Min Till, spring, normal date';
            tilltemp{i,1}=sprintf(' 4 15     6 3');
            tilltemp{i,2}=hrutemp(i,15);
            tilltemp{i,3}=4;
            tilltemp{i,4}=15;
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==2
            %tilltemp{i,1}='Min Till, spring, early date';

```

```

tilltemp{i,1}=sprintf(' 4 8      6 3');
tilltemp{i,2}=hrutemp(i,15);
tilltemp{i,3}=4;
tilltemp{i,4}=8;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='Min Till, spring, late date';
    tilltemp{i,1}=sprintf(' 4 22      6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=22;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==4
    %tilltemp{i,1}='Conven Till, fall, normal date';
    tilltemp{i,1}=sprintf(' 11 1      6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=1;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==5
    %tilltemp{i,1}='Conven Till, fall, early date';
    tilltemp{i,1}=sprintf(' 10 25      6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=10;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==6
    %tilltemp{i,1}='Conven Till, fall, late date';
    tilltemp{i,1}=sprintf(' 11 8      6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==1
    %tilltemp{i,1}='Conven Till, spring, normal date';
    tilltemp{i,1}=sprintf(' 4 15      6 2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=15;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='Conven Till, spring, early date';
    tilltemp{i,1}=sprintf(' 4 8      6 2');

```

```

    tilltemp{i,2}=hrutemp(i, 15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='Conven Till, spring, late date';
    tilltemp{i,1}=sprintf(' 4 22      6  2');
    tilltemp{i,2}=hrutemp(i, 15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=22;
end
else
    if hrutemp(i,4)==1
        tilltemp{i,1}={};
        tilltemp{i,2}={};
        tilltemp{i,3}={};
        tilltemp{i,4}={};
    elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==4
        %tilltemp{i,1}='SBMin Till, fall, normal date';
        tilltemp{i,1}=sprintf(' 11 1      6  3');
        tilltemp{i,2}=hrutemp(i, 15)-1;
        tilltemp{i,3}=11;
        tilltemp{i,4}=1;
    elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==5
        %tilltemp{i,1}='SBMin Till, fall, early date';
        tilltemp{i,1}=sprintf(' 10 25     6  3');
        tilltemp{i,2}=hrutemp(i, 15)-1;
        tilltemp{i,3}=10;
        tilltemp{i,4}=25;
    elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==6
        %tilltemp{i,1}='SBMin Till, fall, late date';
        tilltemp{i,1}=sprintf(' 11 8      6  3');
        tilltemp{i,2}=hrutemp(i, 15)-1;
        tilltemp{i,3}=11;
        tilltemp{i,4}=8;
    elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==1
        %tilltemp{i,1}='SBMin Till, spring, normal date';
        tilltemp{i,1}=sprintf(' 4 25      6  3');

```



```

    tilltemp{i,2}=hrutemp(i, 15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='SBMin Till, spring, early date';
    tilltemp{i,1}=sprintf(' 4 18      6 3');
    tilltemp{i,2}=hrutemp(i, 15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=18;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='SBMin Till, spring, late date';
    tilltemp{i,1}=sprintf(' 5 2      6 3');
    tilltemp{i,2}=hrutemp(i, 15);
    tilltemp{i,3}=5;
    tilltemp{i,4}=2;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==4
    %tilltemp{i,1}='SBConven Till, fall, normal date';
    tilltemp{i,1}=sprintf(' 11 1      6 1');
    tilltemp{i,2}=hrutemp(i, 15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=1;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==5
    %tilltemp{i,1}='SBConven Till, fall, early date';
    tilltemp{i,1}=sprintf(' 10 25      6 1');
    tilltemp{i,2}=hrutemp(i, 15)-1;
    tilltemp{i,3}=10;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==6
    %tilltemp{i,1}='SBConven Till, fall, late date';
    tilltemp{i,1}=sprintf(' 11 8      6 1');
    tilltemp{i,2}=hrutemp(i, 15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==1
    %tilltemp{i,1}='SbConven Till, spring, normal date';
    tilltemp{i,1}=sprintf(' 4 25      6 2');
    tilltemp{i,2}=hrutemp(i, 15);

```

```

    tilltemp{i,3}=4;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='SbConven Till, spring, early date';
    tilltemp{i,1}=sprintf(' 4 18      6 2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=18;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='SBConven Till, spring, late date';
    tilltemp{i,1}=sprintf(' 5 2      6 2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=5;
    tilltemp{i,4}=2;
end
end
end
tilltemp(find(all(cellfun(@isempty,tilltemp),2)),:)=[];
tilltemp=sortrows(tilltemp,[2,3,4]);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning P Fert Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Pferttemp={}; %creating a temporary matrix which stores P fertilizer line information
for i=1:size(hrutemp,1)
    f=hrutemp(i,12)*1.12; %converting to kg/ha from lb/ac
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,10)==2
            Pferttemp{i,1}={};
            Pferttemp{i,2}={};
            Pferttemp{i,3}={};
            Pferttemp{i,4}={};
        elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==1
            %Pferttemp{i,1}='Fall P, normal date, Triple Super';

```

```

    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Fall P, normal date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Fall P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Fall P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Fall P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Fall P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;

```

```

    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==3
        %Pferttemp{i,1}='Fall P, early date, 18-46-0';
        Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=10;
        Pferttemp{i,4}=25;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==4
        %Pferttemp{i,1}='Fall P, early date, 0-15-40';
        Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=10;
        Pferttemp{i,4}=25;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==1
        %Pferttemp{i,1}='Fall P, late date, Triple Super';
        Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=8;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==2
        %Pferttemp{i,1}='Fall P, late date, 10-34-0';
        Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=8;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==3
        %Pferttemp{i,1}='Fall P, late date, 18-46-0';
        Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=8;

```

```

elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Fall P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Spring P, normal date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, normal date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Spring P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==1

```

```

    %Pferttemp{i,1}='Spring P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Spring P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Spring P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);

```

```

    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Spring P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
end
else
    if hrutemp(i,10)==2
        Pferttemp{i,1}={};
        Pferttemp{i,2}={};
        Pferttemp{i,3}={};
        Pferttemp{i,4}={};
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==1
        %Pferttemp{i,1}='SBFall P, normal date, Triple Super';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=1;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==2
        %Pferttemp{i,1}='SBFall P, normal date, 10-34-0';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;

```

```

    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBFall P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBFall P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBFall P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBFall P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBFall P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;

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elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBFall P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBFall P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBFall P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBFall P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBFall P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==1

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```

    %Pferttemp{i,1}='SBSpring P, normal date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, normal date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBSpring P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBSpring P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);

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```

    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBSpring P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBSpring P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;

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```

        Pferttemp{i,4}=17;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==4
        %Pferttemp{i,1}='SBSpring P, late date, 0-15-40';
        Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15);
        Pferttemp{i,3}=5;
        Pferttemp{i,4}=17;
    end
end
end

Pferttemp(find(all(cellfun(@isempty,Pferttemp),2),:)==[]); %deleting empty rows (i.e., no P
fertilizer)
Pferttemp=sortrows(Pferttemp,[2,3,4]); %Sorting by date

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning N Fert Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Nferttemp={}; %creating a temporary matrix which stores N fertilizer line information
for i=1:size(hrutemp,1)
    f=hrutemp(i,8)*1.12; %converting to kg/ha from lb/ac
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,6)==2
            Nferttemp{i,1}={};
            Nferttemp{i,2}={};
            Nferttemp{i,3}={};
            Nferttemp{i,4}={};
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==1
            %Nferttemp{i,1}='Fall N, normal date, Urea';
            Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
            Nferttemp{i,4}=1;
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==2
            %Nferttemp{i,1}='Fall N, normal date, 28% UAN';

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Nferttemp{i,1}=sprintf(' 11 1      3 57    %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Fall N, normal date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 11 1      3 1    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Fall N, normal date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 11 1      3 58    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Fall N, normal date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 11 1      3 59    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==1
    %Nferttemp{i,1}='Fall N, early date, Urea';
    Nferttemp{i,1}=sprintf(' 10 25      3 1    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Fall N, early date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 10 25      3 57    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Fall N, early date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 10 25      3 1    %12.5f 0.20',f);

```

```

Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=10;
Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Fall N, early date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 10 25      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Fall N, early date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 10 25      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==1
    %Nferttemp{i,1}='Fall N, late date, Urea';
    Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Fall N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 11 8      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Fall N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Fall N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 11 8      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;

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Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Fall N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 11 8      3 59    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==1
    %Nferttemp{i,1}='Spring N, normal date, Urea';
    Nferttemp{i,1}=sprintf(' 4 22      3 1     %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Spring N, normal date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 4 22      3 57    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Spring N, normal date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 4 22      3 1     %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Spring N, normal date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 4 22      3 58    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Spring N, normal date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 4 22      3 59    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;

```

```

Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==1
  %Nferttemp{i,1}='Spring N, early date, Urea';
  Nferttemp{i,1}=sprintf(' 4 15      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==2
  %Nferttemp{i,1}='Spring N, early date, 28% UAN';
  Nferttemp{i,1}=sprintf(' 4 15      3 57      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==3
  %Nferttemp{i,1}='Spring N, early date, Anyhondrous Ammonia';
  Nferttemp{i,1}=sprintf(' 4 15      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==4
  %Nferttemp{i,1}='Spring N, early date, 10-34-0';
  Nferttemp{i,1}=sprintf(' 4 15      3 58      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==5
  %Nferttemp{i,1}='Spring N, early date, 18-46-0';
  Nferttemp{i,1}=sprintf(' 4 15      3 59      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==1
  %Nferttemp{i,1}='Spring N, late date, Urea';
  Nferttemp{i,1}=sprintf(' 4 29      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=4;
  Nferttemp{i,4}=29;

```



```

elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Spring N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 4 29      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Spring N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 4 29      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Spring N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 4 29      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Spring N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 4 29      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
end
else
    if hrutemp(i,6)==2
        Nferttemp{i,1}={};
        Nferttemp{i,2}={};
        Nferttemp{i,3}={};
        Nferttemp{i,4}={};
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==1
        %Nferttemp{i,1}='SBFall N, normal date, Urea';
        Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
        Nferttemp{i,2}=hrutemp(i,15)-1;
        Nferttemp{i,3}=11;
        Nferttemp{i,4}=1;
    end
end

```

```

elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBFall N, normal date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 11 1      3 57    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBFall N, normal date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 11 1      3 1    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBFall N, normal date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 11 1      3 58    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBFall N, normal date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 11 1      3 59    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBFall N, early date, Urea';
    Nferttemp{i,1}=sprintf(' 10 25      3 1    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBFall N, early date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 10 25      3 57    %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==3

```

```

%Nferttemp{i,1}='SBFall N, early date, Anyhodrous Ammonia';
Nferttemp{i,1}=sprintf(' 10 25      3 1      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=10;
Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==4
%Nferttemp{i,1}='SBFall N, early date, 10-34-0';
Nferttemp{i,1}=sprintf(' 10 25      3 58      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=10;
Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==5
%Nferttemp{i,1}='SBFall N, early date, 18-46-0';
Nferttemp{i,1}=sprintf(' 10 25      3 59      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=10;
Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==1
%Nferttemp{i,1}='SBFall N, late date, Urea';
Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==2
%Nferttemp{i,1}='Fall N, late date, 28% UAN';
Nferttemp{i,1}=sprintf(' 11 8      3 57      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==3
%Nferttemp{i,1}='SBFall N, late date, Anyhodrous Ammonia';
Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==4
%Nferttemp{i,1}='SBFall N, late date, 10-34-0';

```

```

Nferttemp{i,1}=sprintf(' 11 8      3 58      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBFall N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 11 8      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBSpring N, normal date, Urea';
    Nferttemp{i,1}=sprintf(' 5 10      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBSpring N, normal date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 5 10      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBSpring N, normal date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 5 10      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBSpring N, normal date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 5 10      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBSpring N, normal date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 5 10      3 59      %12.5f 0.20',f);

```

```

Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=5;
Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBSpring N, early date, Urea';
    Nferttemp{i,1}=sprintf(' 5 3      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBSpring N, early date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 5 3      3 57     %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBSpring N, early date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 5 3      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBSpring N, early date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 5 3      3 58     %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBSpring N, early date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 5 3      3 59     %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBSpring N, late date, Urea';
    Nferttemp{i,1}=sprintf(' 5 17     3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);

```

```

Nferttemp{i,3}=5;
Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBSpring N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 5 17      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBSpring N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 5 17      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBSpring N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 5 17      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBSpring N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 5 17      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
end
end
end

Nferttemp(find(all(cellfun(@isempty,Nferttemp),2)),:)==[]; %deleting empty rows (i.e., no N
fertilizer)
Nferttemp=sortrows(Nferttemp,[2,3,4]); %Sorting by date

```



```

eoytemp={};%creating a temporary matrix which stores end of year line information
for i=1:size(hrutemp,1)
    if hrutemp(i,14)==1
        %eoytemp{i,1}='End of year Corn';
        eoytemp{i,1}=sprintf('          0');
        eoytemp{i,2}=hrutemp(i,15);
        eoytemp{i,3}=12;
        eoytemp{i,4}=1;
    else
        %eoytemp{i,1}='End of year Soybeans';
        eoytemp{i,1}=sprintf('          0');
        eoytemp{i,2}=hrutemp(i,15);
        eoytemp{i,3}=12;
        eoytemp{i,4}=1;
    end
end

eoytemps=sortrows(eoytemp,[2,3,4]);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Manure Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

pmansp={};
cmansp={};
pmanfa={};
cmanfa={};
for i=1:size(hrutemp,1)
    p=hrutemp(i,19)*.5;%amount of pig manure applied (halved so that half is applied in
spring and half in fall)
    c=hrutemp(i,20)*.5;%amount of cow manure applied
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,21)==1
            %early applicaiton corn
            pmansp{i,1}=sprintf(' 4 15      3 47      %12.5f 0.20',p);
            pmansp{i,2}=hrutemp(i,15);

```



```

    pmansp{i,3}=4;
    pmansp{i,4}=15;
    cmansp{i,1}=sprintf(' 4 15      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=4;
    cmansp{i,4}=15;
    pmanfa{i,1}=sprintf(' 10 25      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=10;
    pmanfa{i,4}=25;
    cmanfa{i,1}=sprintf(' 10 25      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=10;
    cmanfa{i,4}=25;
elseif hrutemp(i,21)==2
    %normal application corn
    pmansp{i,1}=sprintf(' 4 22      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i,15);
    pmansp{i,3}=4;
    pmansp{i,4}=22;
    cmansp{i,1}=sprintf(' 4 22      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=4;
    cmansp{i,4}=22;
    pmanfa{i,1}=sprintf(' 11 1      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=1;
    cmanfa{i,1}=sprintf(' 11 1      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=1;
elseif hrutemp(i,21)==3
    %late application corn
    pmansp{i,1}=sprintf(' 4 29      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i,15);
    pmansp{i,3}=4;

```

```

    pmansp{i,4}=29;
    cmansp{i,1}=sprintf(' 4 29      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=4;
    cmansp{i,4}=29;
    pmanfa{i,1}=sprintf(' 11 8      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=8;
    cmanfa{i,1}=sprintf(' 11 8      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=8;
end
elseif hrutemp(i,14)==2 %LULC is SOYB
    if hrutemp(i,21)==1
        %early applicaiton soyb
        pmansp{i,1}=sprintf(' 5 3      3 47      %12.5f 0.20',p);
        pmansp{i,2}=hrutemp(i,15);
        pmansp{i,3}=5;
        pmansp{i,4}=23;
        cmansp{i,1}=sprintf(' 5 3      3 45      %12.5f 0.20',c);
        cmansp{i,2}=hrutemp(i,15);
        cmansp{i,3}=5;
        cmansp{i,4}=23;
        pmanfa{i,1}=sprintf(' 10 25      3 47      %12.5f 0.20',p);
        pmanfa{i,2}=hrutemp(i,15);
        pmanfa{i,3}=10;
        pmanfa{i,4}=25;
        cmanfa{i,1}=sprintf(' 10 25      3 45      %12.5f 0.20',c);
        cmanfa{i,2}=hrutemp(i,15);
        cmanfa{i,3}=10;
        cmanfa{i,4}=25;
    elseif hrutemp(i,21)==2
        %normal application soyb
        pmansp{i,1}=sprintf(' 5 10      3 47      %12.5f 0.20',p);
        pmansp{i,2}=hrutemp(i,15);

```

```

    pmansp{i,3}=5;
    pmansp{i,4}=10;
    cmansp{i,1}=sprintf(' 5 10      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=5;
    cmansp{i,4}=10;
    pmanfa{i,1}=sprintf(' 11 1      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=1;
    cmanfa{i,1}=sprintf(' 11 1      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=1;
elseif hrutemp(i,21)==3
    %late application soyb
    pmansp{i,1}=sprintf(' 5 17      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i,15);
    pmansp{i,3}=5;
    pmansp{i,4}=17;
    cmansp{i,1}=sprintf(' 4 17      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=5;
    cmansp{i,4}=17;
    pmanfa{i,1}=sprintf(' 11 8      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=8;
    cmanfa{i,1}=sprintf(' 11 8      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=8;
end
end
end

pmansps=sortrows(pmansp,[2,3,4]);

```

```

cmansps=sortrows(cmansp,[2,3,4]);
pmanfas=sortrows(pmanfa,[2,3,4]);
cmanfas=sortrows(cmanfa,[2,3,4]);

```

```

%% Combining all MGT information into one cell array %%

```

```

hrumgttmp={};
corrtemp={};
corrtemp{1}=sprintf('          0');
corrtemp{2}=int32(1973);
corrtemp{3}=12;
corrtemp{4}=1;
%corrmt={'          0',1973,12,1};

```

```

hrumgttmp=[hrumgttmp;planttemps;corrtemp;tilltempst;Pfertempst;Nfertempst;plantiltmps;h
arvtempst;killtempst;eoytempst;pmansps;cmansps;pmanfas;cmanfas];

```

```

%hrumgttmp=[hrumgttmp;planttemps;Pfertempst;Nfertempst;plantiltmps;harvtempst;ki
lltempst;eoytempst];

```

```

hrumgt75={}; %accounting for only greater than 1975 land mangement
for u=1:size(hrumgttmp,1)
    if hrumgttmp{u,2}>1974
        hrumgt75=[hrumgt75; hrumgttmp(u,:)];
    end
end

```

```

hrumgtmps=sortrows(hrumgt75,[2,3,4]);

```

```

%% Importing current mgt info as hruold %%
hruold=textread(hrustr,'%s','delimiter','\n','whitespace','');
top=hruold(1:28); %saving only the top of the file
% Creating text lines needed
Nrot={'          35 | NROT: number of years of rotation'};
OpSchtxt={'Operation Schedule:'};
% Collecting current managemtn operation schedule
t=size(hruold,1);
currot=hruold(31:t);

```

```

for i=1:length(currot)
    eops{i}=strsplit(currot{i});
end

g=0; %loop to add year, month, and day to each entry of the hru mgt file
monvec={};
dayvec={};
yearvec={};
for i=1:length(eops)
    if str2num(eops{1,i}{1,2})==0
        monvec{i}=12;
        dayvec{i}=31;
        yearvec{i}=g;
        g=g+1;
    else
        monvec{i}=str2num(eops{1,i}{1,2});
        dayvec{i}=str2num(eops{1,i}{1,3});
        yearvec{i}=g;
    end
end

monvec=monvec';
dayvec=dayvec';
yearvec=yearvec';

currot2=[currot yearvec monvec dayvec];
nyr=max([currot2{:,2}])+1; %getting number of years in currunt rotation
%Adding half of the manure in spring and half in fall
for i=1:nyr
    p=13; c=4;
    pmansp1{i,1}=sprintf(' 4 15      3 47      %12.5f 0.20',p);
    pmansp1{i,2}=i-1;
    pmansp1{i,3}=4;
    pmansp1{i,4}=15;
    cmansp1{i,1}=sprintf(' 4 15      3 45      %12.5f 0.20',c);
    cmansp1{i,2}=i-1;
    cmansp1{i,3}=4;

```

```

cmansp1{i,4}=15;
pmanfa1{i,1}=sprintf(' 10 31      3 47      %12.5f 0.20',p);
pmanfa1{i,2}=i-1;
pmanfa1{i,3}=10;
pmanfa1{i,4}=31;
cmanfa1{i,1}=sprintf(' 10 31      3 45      %12.5f 0.20',c);
cmanfa1{i,2}=i-1;
cmanfa1{i,3}=10;
cmanfa1{i,4}=31;
end

```

```

currot3=[currot2; pmansp1; cmansp1; pmanfa1; cmanfa1];
currot3=sortrows(currot3,[2,3,4]);
% Creating cell array with all management information

```

```

hrunew=[top;Nrot;OpSchtxt;hrumgttmps(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot
3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1)];

```

```

%% Creating new hrumgt text file %%
fid = fopen([sim 'new' hrustr],'w');
%fid=fopen('testtest.txt','wt'); %creating new hru text file NEED TO FIGURE OUT HOW
TO SAVE AS HRUSTR IN NEW FOLDER
formatSpec='%s\n'; %s is for text %d is for integers.
for row=1:size(hrunew,1)
    fprintf(fid,formatSpec,hrunew{row,:});
end

```

```

hrutemp=[];
for i=1:size(hrumgtnew,1)%Creating matrix with every year for only one HRU
    if hrumgtnew(i,1)==isub && hrumgtnew(i,2)==ihru
        hrutemp=[hrutemp; hrumgtnew(i,:)];
    end
end
end

```

```

%fid2 = fopen([input 'newmgt' hrustr],'w'); %open new mgt file
elseif isequal(lulc{(ihru+hruprev)},'SOYB')==1

```

```

%hrunum=ihru+hruprev
hrutemp=[];
for i=1:size(hrumgtnew,1)%Creating matrix with every year for only one HRU
    if hrumgtnew(i,1)==isub && hrumgtnew(i,2)==(ihru+hruprev)
        hrutemp=[hrutemp; hrumgtnew(i,:)];
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Planting Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
planttemp={};%creating a temporary matrix which stores planting line information
planttiltmp={};
for i=1:size(hrutemp,1)
    if hrutemp(i,14)==1
        %planttemp{i,1}='Plant Corn';
        planttemp{i,1}=sprintf(' 5 6      1 19      1550.00000 0.00  0.00000 0.00
0.00 0.00');
        planttemp{i,2}=hrutemp(i,15);
        planttemp{i,3}=5;
        planttemp{i,4}=6;
        if hrutemp(i,4)==1
            %planttiltmp{i,1}='No Till at planting';
            planttiltmp{i,1}=sprintf(' 5 6      6 4      0.00000');
            planttiltmp{i,2}=hrutemp(i,15);
            planttiltmp{i,3}=5;
            planttiltmp{i,4}=6;
        else
            %planttiltmp{i,1}='Till 88 at planting';
            planttiltmp{i,1}=sprintf(' 5 6      6 88      0.00000');
            planttiltmp{i,2}=hrutemp(i,15);
            planttiltmp{i,3}=5;
            planttiltmp{i,4}=6;
        end
    else
        %planttemp{i,1}='Plant Soybeans';
        planttemp{i,1}=sprintf(' 5 24      1 56      1250.00000 0.00  0.00000 0.00
0.00 0.00');
    end
end

```

```

    planttemp{i,2}=hrutemp(i, 15);
    planttemp{i,3}=5;
    planttemp{i,4}=24;
    %planttiltmp{i,1}='Tillage 4';
    planttiltmp{i,1}=sprintf(' 5 24      6 4      0.00000');
    planttiltmp{i,2}=hrutemp(i, 15);
    planttiltmp{i,3}=5;
    planttiltmp{i,4}=24;
end
end

planttemps=sortrows(planttemp,[2,3,4]);
planttiltmps=sortrows(planttiltmp,[2,3,4]);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Tillage Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
tilltemp={}; %creating a temporary matrix which stores tillage line information
for i=1:size(hrutemp,1)
    if hrutemp(i,14)==1
        if hrutemp(i,4)==1
            tilltemp{i,1}={};
            tilltemp{i,2}={};
            tilltemp{i,3}={};
            tilltemp{i,4}={};
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==4
            %tilltemp{i,1}='Min Till, fall, normal date';
            tilltemp{i,1}=sprintf(' 11 1      6 3');
            tilltemp{i,2}=hrutemp(i,15)-1;
            tilltemp{i,3}=11;
            tilltemp{i,4}=1;
        elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==5
            %tilltemp{i,1}='Min Till, fall, early date';
            tilltemp{i,1}=sprintf(' 10 25      6 3');
            tilltemp{i,2}=hrutemp(i,15)-1;
            tilltemp{i,3}=10;
        end
    end
end

```



```

    tilltemp{i,4}=25;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==6
    %tilltemp{i,1}='Min Till, fall, late date';
    tilltemp{i,1}=sprintf(' 11 8      6 3');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==1
    %tilltemp{i,1}='Min Till, spring, normal date';
    tilltemp{i,1}=sprintf(' 4 15     6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=15;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='Min Till, spring, early date';
    tilltemp{i,1}=sprintf(' 4 8      6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='Min Till, spring, late date';
    tilltemp{i,1}=sprintf(' 4 22     6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=22;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==4
    %tilltemp{i,1}='Conven Till, fall, normal date';
    tilltemp{i,1}=sprintf(' 11 1      6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=1;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==5
    %tilltemp{i,1}='Conven Till, fall, early date';
    tilltemp{i,1}=sprintf(' 10 25     6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=10;
    tilltemp{i,4}=25;

```

```

elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==6
    %tilltemp{i,1}='Conven Till, fall, late date';
    tilltemp{i,1}=sprintf(' 11 8      6  1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==1
    %tilltemp{i,1}='Conven Till, spring, normal date';
    tilltemp{i,1}=sprintf('  4 15      6  2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=15;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='Conven Till, spring, early date';
    tilltemp{i,1}=sprintf('  4  8      6  2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='Conven Till, spring, late date';
    tilltemp{i,1}=sprintf('  4 22      6  2');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=22;
end
else
    if hrutemp(i,4)==1
        tilltemp{i,1}={};
        tilltemp{i,2}={};
        tilltemp{i,3}={};
        tilltemp{i,4}={};
    elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==4
        %tilltemp{i,1}='SBMin Till, fall, normal date';
        tilltemp{i,1}=sprintf(' 11 1      6  3');
        tilltemp{i,2}=hrutemp(i,15)-1;
        tilltemp{i,3}=11;
        tilltemp{i,4}=1;
    end
end

```

```

elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==5
    %tilltemp{i,1}='SBMin Till, fall, early date';
    tilltemp{i,1}=sprintf(' 10 25      6 3');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=10;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==1 && hrutemp(i,18)==6
    %tilltemp{i,1}='SBMin Till, fall, late date';
    tilltemp{i,1}=sprintf(' 11 8      6 3');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=8;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==1
    %tilltemp{i,1}='SBMin Till, spring, normal date';
    tilltemp{i,1}=sprintf(' 4 25      6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=25;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==2
    %tilltemp{i,1}='SBMin Till, spring, early date';
    tilltemp{i,1}=sprintf(' 4 18      6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=4;
    tilltemp{i,4}=18;
elseif hrutemp(i,4)==2 && hrutemp(i,5)==2 && hrutemp(i,18)==3
    %tilltemp{i,1}='SBMin Till, spring, late date';
    tilltemp{i,1}=sprintf(' 5 2      6 3');
    tilltemp{i,2}=hrutemp(i,15);
    tilltemp{i,3}=5;
    tilltemp{i,4}=2;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==4
    %tilltemp{i,1}='SBConven Till, fall, normal date';
    tilltemp{i,1}=sprintf(' 11 1      6 1');
    tilltemp{i,2}=hrutemp(i,15)-1;
    tilltemp{i,3}=11;
    tilltemp{i,4}=1;
elseif hrutemp(i,4)==3 && hrutemp(i,5)==1 && hrutemp(i,18)==5

```



```

%% Assigning P Fert Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Pferttemp={}; %creating a temporary matrix which stores P fertilizer line information
for i=1:size(hrutemp,1)
    f=hrutemp(i,12)*1.12; %converting to kg/ha from lb/ac
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,10)==2
            Pferttemp{i,1}={};
            Pferttemp{i,2}={};
            Pferttemp{i,3}={};
            Pferttemp{i,4}={};
        elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==1
            %Pferttemp{i,1}='Fall P, normal date, Triple Super';
            Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
            Pferttemp{i,2}=hrutemp(i,15)-1;
            Pferttemp{i,3}=11;
            Pferttemp{i,4}=1;
        elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==2
            %Pferttemp{i,1}='Fall P, normal date, 10-34-0';
            Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
            Pferttemp{i,2}=hrutemp(i,15)-1;
            Pferttemp{i,3}=11;
            Pferttemp{i,4}=1;
        elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==3
            %Pferttemp{i,1}='Fall P, normal date, 18-46-0';
            Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
            Pferttemp{i,2}=hrutemp(i,15)-1;
            Pferttemp{i,3}=11;
            Pferttemp{i,4}=1;
        elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==4
            %Pferttemp{i,1}='Fall P, normal date, 0-15-40';
            Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);

```

```

    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=1;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Fall P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Fall P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Fall P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Fall P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Fall P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;

```

```

    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Fall P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Fall P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Fall P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Spring P, normal date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, normal date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;

```

```

elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Spring P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 22      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=22;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Spring P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==4

```



```

    %Pferttemp{i,1}='Spring P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 15      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=15;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='Spring P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='Spring P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='Spring P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='Spring P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 4 29      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=4;
    Pferttemp{i,4}=29;
end
else
    if hrutemp(i,10)==2
        Pferttemp{i,1}={};

```

```

    Pferttemp{i,2}={};
    Pferttemp{i,3}={};
    Pferttemp{i,4}={};
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==1
        %Pferttemp{i,1}='SBFall P, normal date, Triple Super';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=1;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==2
        %Pferttemp{i,1}='SBFall P, normal date, 10-34-0';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=1;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==3
        %Pferttemp{i,1}='SBFall P, normal date, 18-46-0';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=1;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==4 &&
hrutemp(i,13)==4
        %Pferttemp{i,1}='SBFall P, normal date, 0-15-40';
        Pferttemp{i,1}=sprintf(' 11 1      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=11;
        Pferttemp{i,4}=1;
    elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==1
        %Pferttemp{i,1}='SBFall P, early date, Triple Super';
        Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
        Pferttemp{i,2}=hrutemp(i,15)-1;
        Pferttemp{i,3}=10;

```

```

    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBFall P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBFall P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==5 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBFall P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 10 25      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=10;
    Pferttemp{i,4}=25;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBFall P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBFall P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;

```

```

elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBFall P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==1 && hrutemp(i,17)==6 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBFall P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 11 8      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15)-1;
    Pferttemp{i,3}=11;
    Pferttemp{i,4}=8;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBSpring P, normal date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, normal date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, normal date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==1 &&
hrutemp(i,13)==4

```

```

    %Pferttemp{i,1}='SBSpring P, normal date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 5 10      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=10;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBSpring P, early date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, early date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, early date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==2 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBSpring P, early date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 5 3      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i,15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=3;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==1
    %Pferttemp{i,1}='SBSpring P, late date, Triple Super';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);

```

```

    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==2
    %Pferttemp{i,1}='SBSpring P, late date, 10-34-0';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==3
    %Pferttemp{i,1}='SBSpring P, late date, 18-46-0';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
elseif hrutemp(i,10)==1 && hrutemp(i,11)==2 && hrutemp(i,17)==3 &&
hrutemp(i,13)==4
    %Pferttemp{i,1}='SBSpring P, late date, 0-15-40';
    Pferttemp{i,1}=sprintf(' 5 17      3 2      %12.5f 0.20',f);
    Pferttemp{i,2}=hrutemp(i, 15);
    Pferttemp{i,3}=5;
    Pferttemp{i,4}=17;
end
end
end

Pferttemp(find(all(cellfun(@isempty,Pferttemp),2)),:)=[]; %deleting empty rows (i.e., no P
fertilizer)
Pferttemp=sortrows(Pferttemp,[2,3,4]); %Sorting by date

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning N Fert Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Nferttemp={}; %creating a temporary matrix which stores N fertilizer line information

```

```

for i=1:size(hrutemp,1)
    f=hrutemp(i,8)*1.12; %converting to kg/ha from lb/ac
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,6)==2
            Nferttemp{i,1}={};
            Nferttemp{i,2}={};
            Nferttemp{i,3}={};
            Nferttemp{i,4}={};
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==1
            %Nferttemp{i,1}='Fall N, normal date, Urea';
            Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
            Nferttemp{i,4}=1;
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==2
            %Nferttemp{i,1}='Fall N, normal date, 28% UAN';
            Nferttemp{i,1}=sprintf(' 11 1      3 57      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
            Nferttemp{i,4}=1;
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==3
            %Nferttemp{i,1}='Fall N, normal date, Anyhodrous Ammonia';
            Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
            Nferttemp{i,4}=1;
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==4
            %Nferttemp{i,1}='Fall N, normal date, 10-34-0';
            Nferttemp{i,1}=sprintf(' 11 1      3 58      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
            Nferttemp{i,4}=1;
        elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==5
            %Nferttemp{i,1}='Fall N, normal date, 18-46-0';
            Nferttemp{i,1}=sprintf(' 11 1      3 59      %12.5f 0.20',f);
            Nferttemp{i,2}=hrutemp(i,15)-1;
            Nferttemp{i,3}=11;
    
```

```

Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==1
  %Nferttemp{i,1}='Fall N, early date, Urea';
  Nferttemp{i,1}=sprintf(' 10 25      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=10;
  Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==2
  %Nferttemp{i,1}='Fall N, early date, 28% UAN';
  Nferttemp{i,1}=sprintf(' 10 25      3 57      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=10;
  Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==3
  %Nferttemp{i,1}='Fall N, early date, Anyhodrous Ammonia';
  Nferttemp{i,1}=sprintf(' 10 25      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=10;
  Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==4
  %Nferttemp{i,1}='Fall N, early date, 10-34-0';
  Nferttemp{i,1}=sprintf(' 10 25      3 58      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=10;
  Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==5
  %Nferttemp{i,1}='Fall N, early date, 18-46-0';
  Nferttemp{i,1}=sprintf(' 10 25      3 59      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=10;
  Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==1
  %Nferttemp{i,1}='Fall N, late date, Urea';
  Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=11;
  Nferttemp{i,4}=8;

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elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Fall N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 11 8      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Fall N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Fall N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 11 8      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Fall N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 11 8      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=11;
    Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==1
    %Nferttemp{i,1}='Spring N, normal date, Urea';
    Nferttemp{i,1}=sprintf(' 4 22      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Spring N, normal date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 4 22      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==3

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%Nferttemp{i,1}='Spring N, normal date, Anyhodrous Ammonia';
Nferttemp{i,1}=sprintf(' 4 22      3  1      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==4
%Nferttemp{i,1}='Spring N, normal date, 10-34-0';
Nferttemp{i,1}=sprintf(' 4 22      3  58      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==5
%Nferttemp{i,1}='Spring N, normal date, 18-46-0';
Nferttemp{i,1}=sprintf(' 4 22      3  59      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=22;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==1
%Nferttemp{i,1}='Spring N, early date, Urea';
Nferttemp{i,1}=sprintf(' 4 15      3  1      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==2
%Nferttemp{i,1}='Spring N, early date, 28% UAN';
Nferttemp{i,1}=sprintf(' 4 15      3  57      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==3
%Nferttemp{i,1}='Spring N, early date, Anyhodrous Ammonia';
Nferttemp{i,1}=sprintf(' 4 15      3  1      %12.5f  0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==4
%Nferttemp{i,1}='Spring N, early date, 10-34-0';

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Nferttemp{i,1}=sprintf(' 4 15      3 58      %12.5f 0.20',f);
Nferttemp{i,2}=hrutemp(i,15);
Nferttemp{i,3}=4;
Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Spring N, early date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 4 15      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=15;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==1
    %Nferttemp{i,1}='Spring N, late date, Urea';
    Nferttemp{i,1}=sprintf(' 4 29      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==2
    %Nferttemp{i,1}='Spring N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 4 29      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==3
    %Nferttemp{i,1}='Spring N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 4 29      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==4
    %Nferttemp{i,1}='Spring N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 4 29      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==5
    %Nferttemp{i,1}='Spring N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 4 29      3 59      %12.5f 0.20',f);

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```

    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=4;
    Nferttemp{i,4}=29;
end
else
    if hrutemp(i,6)==2
        Nferttemp{i,1}={};
        Nferttemp{i,2}={};
        Nferttemp{i,3}={};
        Nferttemp{i,4}={};
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==1
        %Nferttemp{i,1}='SBFall N, normal date, Urea';
        Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
        Nferttemp{i,2}=hrutemp(i,15)-1;
        Nferttemp{i,3}=11;
        Nferttemp{i,4}=1;
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==2
        %Nferttemp{i,1}='SBFall N, normal date, 28% UAN';
        Nferttemp{i,1}=sprintf(' 11 1      3 57      %12.5f 0.20',f);
        Nferttemp{i,2}=hrutemp(i,15)-1;
        Nferttemp{i,3}=11;
        Nferttemp{i,4}=1;
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==3
        %Nferttemp{i,1}='SBFall N, normal date, Anyhodrous Ammonia';
        Nferttemp{i,1}=sprintf(' 11 1      3 1      %12.5f 0.20',f);
        Nferttemp{i,2}=hrutemp(i,15)-1;
        Nferttemp{i,3}=11;
        Nferttemp{i,4}=1;
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==4
        %Nferttemp{i,1}='SBFall N, normal date, 10-34-0';
        Nferttemp{i,1}=sprintf(' 11 1      3 58      %12.5f 0.20',f);
        Nferttemp{i,2}=hrutemp(i,15)-1;
        Nferttemp{i,3}=11;
        Nferttemp{i,4}=1;
    elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==4 && hrutemp(i,9)==5
        %Nferttemp{i,1}='SBFall N, normal date, 18-46-0';
        Nferttemp{i,1}=sprintf(' 11 1      3 59      %12.5f 0.20',f);

```

```

Nferttemp{i,2}=hrutemp(i,15)-1;
Nferttemp{i,3}=11;
Nferttemp{i,4}=1;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBFall N, early date, Urea';
    Nferttemp{i,1}=sprintf(' 10 25      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBFall N, early date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 10 25      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBFall N, early date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 10 25      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBFall N, early date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 10 25      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==5 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBFall N, early date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 10 25      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;
    Nferttemp{i,3}=10;
    Nferttemp{i,4}=25;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBFall N, late date, Urea';
    Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15)-1;

```

```

Nferttemp{i,3}=11;
Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==2
  %Nferttemp{i,1}='Fall N, late date, 28% UAN';
  Nferttemp{i,1}=sprintf(' 11 8      3 57      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=11;
  Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==3
  %Nferttemp{i,1}='SBFall N, late date, Anyhodrous Ammonia';
  Nferttemp{i,1}=sprintf(' 11 8      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=11;
  Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==4
  %Nferttemp{i,1}='SBFall N, late date, 10-34-0';
  Nferttemp{i,1}=sprintf(' 11 8      3 58      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=11;
  Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==1 && hrutemp(i,16)==6 && hrutemp(i,9)==5
  %Nferttemp{i,1}='SBFall N, late date, 18-46-0';
  Nferttemp{i,1}=sprintf(' 11 8      3 59      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15)-1;
  Nferttemp{i,3}=11;
  Nferttemp{i,4}=8;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==1
  %Nferttemp{i,1}='SBSpring N, normal date, Urea';
  Nferttemp{i,1}=sprintf(' 5 10      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==2
  %Nferttemp{i,1}='SBSpring N, normal date, 28% UAN';
  Nferttemp{i,1}=sprintf(' 5 10      3 57      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;

```

```

Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==3
  %Nferttemp{i,1}='SBSpring N, normal date, Anyhodrous Ammonia';
  Nferttemp{i,1}=sprintf(' 5 10      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==4
  %Nferttemp{i,1}='SBSpring N, normal date, 10-34-0';
  Nferttemp{i,1}=sprintf(' 5 10      3 58      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==1 && hrutemp(i,9)==5
  %Nferttemp{i,1}='SBSpring N, normal date, 18-46-0';
  Nferttemp{i,1}=sprintf(' 5 10      3 59      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=10;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==1
  %Nferttemp{i,1}='SBSpring N, early date, Urea';
  Nferttemp{i,1}=sprintf(' 5 3      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==2
  %Nferttemp{i,1}='SBSpring N, early date, 28% UAN';
  Nferttemp{i,1}=sprintf(' 5 3      3 57      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==3
  %Nferttemp{i,1}='SBSpring N, early date, Anyhodrous Ammonia';
  Nferttemp{i,1}=sprintf(' 5 3      3 1      %12.5f 0.20',f);
  Nferttemp{i,2}=hrutemp(i,15);
  Nferttemp{i,3}=5;
  Nferttemp{i,4}=3;

```

```

elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBSpring N, early date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 5 3      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==2 && hrutemp(i,9)==5
    %Nferttemp{i,1}='SBSpring N, early date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 5 3      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=3;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==1
    %Nferttemp{i,1}='SBSpring N, late date, Urea';
    Nferttemp{i,1}=sprintf(' 5 17      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==2
    %Nferttemp{i,1}='SBSpring N, late date, 28% UAN';
    Nferttemp{i,1}=sprintf(' 5 17      3 57      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==3
    %Nferttemp{i,1}='SBSpring N, late date, Anyhodrous Ammonia';
    Nferttemp{i,1}=sprintf(' 5 17      3 1      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==4
    %Nferttemp{i,1}='SBSpring N, late date, 10-34-0';
    Nferttemp{i,1}=sprintf(' 5 17      3 58      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
elseif hrutemp(i,6)==1 && hrutemp(i,7)==2 && hrutemp(i,16)==3 && hrutemp(i,9)==5

```



```

    %Nferttemp{i,1}='SBSpring N, late date, 18-46-0';
    Nferttemp{i,1}=sprintf(' 5 17      3 59      %12.5f 0.20',f);
    Nferttemp{i,2}=hrutemp(i,15);
    Nferttemp{i,3}=5;
    Nferttemp{i,4}=17;
  end
end
end

Nferttemp(find(all(cellfun(@isempty,Nferttemp),2)),:)=[]; %deleting empty rows (i.e., no N
fertilizer)
Nferttemp=sortrows(Nferttemp,[2,3,4]); %Sorting by date

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% Assigning Harvest Data %%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
harvtemp={};%creating a temporary matrix which stores harvesting line information
killtemp={};
for i=1:size(hrutemp,1)
  if hrutemp(i,14)==1
    %harvtemp{i,1}='Harvest Corn';
    harvtemp{i,1}=sprintf(' 10 14      7      1');
    harvtemp{i,2}=hrutemp(i,15);
    harvtemp{i,3}=10;
    harvtemp{i,4}=14;
    %killtemp{i,1}='Kill Corn';
    killtemp{i,1}=sprintf(' 10 14      8      0.00000');
    killtemp{i,2}=hrutemp(i,15);
    killtemp{i,3}=10;
    killtemp{i,4}=14;
  else
    %harvtemp{i,1}='Harvest Soybeans';
    harvtemp{i,1}=sprintf(' 10 7      7      1');
    harvtemp{i,2}=hrutemp(i,15);

```



```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```

pmanfsp={};
cmansp={};
pmanfa={};
cmanfa={};
for i=1:size(hrutemp,1)
    p=hrutemp(i,19)*.5;%amount of pig manure applied (halved so that half is applied in
spring and half in fall)
    c=hrutemp(i,20)*.5;%amount of cow manure applied
    if hrutemp(i,14)==1 %LULC is CORN
        if hrutemp(i,21)==1
            %early applicaiton corn
            pmanfsp{i,1}=sprintf(' 4 15      3 47      %12.5f 0.20',p);
            pmanfsp{i,2}=hrutemp(i,15);
            pmanfsp{i,3}=4;
            pmanfsp{i,4}=15;
            cmansp{i,1}=sprintf(' 4 15      3 45      %12.5f 0.20',c);
            cmansp{i,2}=hrutemp(i,15);
            cmansp{i,3}=4;
            cmansp{i,4}=15;
            pmanfa{i,1}=sprintf(' 10 25      3 47      %12.5f 0.20',p);
            pmanfa{i,2}=hrutemp(i,15);
            pmanfa{i,3}=10;
            pmanfa{i,4}=25;
            cmanfa{i,1}=sprintf(' 10 25      3 45      %12.5f 0.20',c);
            cmanfa{i,2}=hrutemp(i,15);
            cmanfa{i,3}=10;
            cmanfa{i,4}=25;
        elseif hrutemp(i,21)==2
            %normal application corn
            pmanfsp{i,1}=sprintf(' 4 22      3 47      %12.5f 0.20',p);
            pmanfsp{i,2}=hrutemp(i,15);
            pmanfsp{i,3}=4;
            pmanfsp{i,4}=22;
            cmansp{i,1}=sprintf(' 4 22      3 45      %12.5f 0.20',c);
            cmansp{i,2}=hrutemp(i,15);

```

```

    cmansp{i,3}=4;
    cmansp{i,4}=22;
    pmanfa{i,1}=sprintf(' 11 1      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=1;
    cmanfa{i,1}=sprintf(' 11 1      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=1;
elseif hrutemp(i,21)==3
    %late application corn
    pmansp{i,1}=sprintf(' 4 29      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i,15);
    pmansp{i,3}=4;
    pmansp{i,4}=29;
    cmansp{i,1}=sprintf(' 4 29      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i,15);
    cmansp{i,3}=4;
    cmansp{i,4}=29;
    pmanfa{i,1}=sprintf(' 11 8      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=8;
    cmanfa{i,1}=sprintf(' 11 8      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=8;
end
elseif hrutemp(i,14)==2 %LULC is SOYB
    if hrutemp(i,21)==1
        %early applicaiton soyb
        pmansp{i,1}=sprintf(' 5 3      3 47      %12.5f 0.20',p);
        pmansp{i,2}=hrutemp(i,15);
        pmansp{i,3}=5;
        pmansp{i,4}=23;
        cmansp{i,1}=sprintf(' 5 3      3 45      %12.5f 0.20',c);

```

```

cmansp{i,2}=hrutemp(i, 15);
cmansp{i,3}=5;
cmansp{i,4}=23;
pmanfa{i,1}=sprintf(' 10 25      3 47      %12.5f 0.20',p);
pmanfa{i,2}=hrutemp(i, 15);
pmanfa{i,3}=10;
pmanfa{i,4}=25;
cmanfa{i,1}=sprintf(' 10 25      3 45      %12.5f 0.20',c);
cmanfa{i,2}=hrutemp(i, 15);
cmanfa{i,3}=10;
cmanfa{i,4}=25;
elseif hrutemp(i,21)==2
    %normal application soyb
    pmansp{i,1}=sprintf(' 5 10      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i, 15);
    pmansp{i,3}=5;
    pmansp{i,4}=10;
    cmansp{i,1}=sprintf(' 5 10      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i, 15);
    cmansp{i,3}=5;
    cmansp{i,4}=10;
    pmanfa{i,1}=sprintf(' 11 1      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i, 15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=1;
    cmanfa{i,1}=sprintf(' 11 1      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i, 15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=1;
elseif hrutemp(i,21)==3
    %late application soyb
    pmansp{i,1}=sprintf(' 5 17      3 47      %12.5f 0.20',p);
    pmansp{i,2}=hrutemp(i, 15);
    pmansp{i,3}=5;
    pmansp{i,4}=17;
    cmansp{i,1}=sprintf(' 4 17      3 45      %12.5f 0.20',c);
    cmansp{i,2}=hrutemp(i, 15);

```

```

    cmansp{i,3}=5;
    cmansp{i,4}=17;
    pmanfa{i,1}=sprintf(' 11 8      3 47      %12.5f 0.20',p);
    pmanfa{i,2}=hrutemp(i,15);
    pmanfa{i,3}=11;
    pmanfa{i,4}=8;
    cmanfa{i,1}=sprintf(' 11 8      3 45      %12.5f 0.20',c);
    cmanfa{i,2}=hrutemp(i,15);
    cmanfa{i,3}=11;
    cmanfa{i,4}=8;
    end
  end
end

```

```

pmansps=sortrows(pmansp,[2,3,4]);
cmansps=sortrows(cmansp,[2,3,4]);
pmanfas=sortrows(pmanfa,[2,3,4]);
cmanfas=sortrows(cmanfa,[2,3,4]);

```

```

%% Combining all MGT information into one cell array %%
hrumgttmp={};
corrtemp={};
corrtemp{1}=sprintf('      0');
corrtemp{2}=int32(1973);
corrtemp{3}=12;
corrtemp{4}=1;
%corrmt={'      0',1973,12,1};

```

```

hrumgttmp=[hrumgttmp;planttemps;corrtemp;tilltempst;Pfertempst;Nfertempst;plantiltmps;h
arvtemps;killtemps;eoytemps;pmansps;cmansps;pmanfas;cmanfas];

```

```

%hrumgttmp=[hrumgttmp;planttemps;Pfertempst;Nfertempst;plantiltmps;harvtemps;ki
lltemps;eoytemps];

```

```

hrumgt75={}; %accounting for only greater than 1975 land mangement
for u=1:size(hrumgttmp,1)
    if hrumgttmp{u,2}>1974

```

```

        hrumgt75=[hrumgt75; hrumgttmp(u,:)];
    end
end

hrumgttmps=sortrows(hrumgt75,[2,3,4]);

%hrumgttmps(:,2)=cell2mat(hrumgttmps(:,2));
%[unX,~,subs]=unique(hruinfo(:,4),'rows');
%tillarea=[unX accumarray(subs,hruinfo(:,3),[], @nansum)];

%% Importing current mgt info as hruold %%
hruold=textread(hrustr, '%s','delimiter','\n','whitespace','');
top=hruold(1:28); %saving only the top of the file
% Creating text lines needed
Nrot={'          35 | NROT: number of years of rotation'};
OpSchtxt={'Operation Schedule.'};
% Collecting current managemtn operation schedule
t=size(hruold,1);
currot=hruold(31:t);
for i=1:length(currot)
    eops{i}=strsplit(currot{i});
end

g=0; %adding year, month, day to current operations
monvec={};
dayvec={};
yearvec={};
for i=1:length(eops)
    if str2num(eops{1,i}{1,2})==0
        monvec{i}=12;
        dayvec{i}=31;
        yearvec{i}=g;
        g=g+1;
    else

```

```

        monvec{i}=str2num(eops{1,i}{1,2});
        dayvec{i}=str2num(eops{1,i}{1,3});
        yearvec{i}=g;
    end
end

monvec=monvec';
dayvec=dayvec';
yearvec=yearvec';

currot2=[currot yearvec monvec dayvec];
nyr=max([currot2{:,2}])+1; %getting number of years of current management operations
%Adding half of manure every spring and fall
for i=1:nyr
    p=13; c=4;
    pmansp1{i,1}=sprintf(' 4 15      3 47      %12.5f 0.20',p);
    pmansp1{i,2}=i-1;
    pmansp1{i,3}=4;
    pmansp1{i,4}=15;
    cmansp1{i,1}=sprintf(' 4 15      3 45      %12.5f 0.20',c);
    cmansp1{i,2}=i-1;
    cmansp1{i,3}=4;
    cmansp1{i,4}=15;
    pmanfa1{i,1}=sprintf(' 10 31      3 47      %12.5f 0.20',p);
    pmanfa1{i,2}=i-1;
    pmanfa1{i,3}=10;
    pmanfa1{i,4}=31;
    cmanfa1{i,1}=sprintf(' 10 31      3 45      %12.5f 0.20',c);
    cmanfa1{i,2}=i-1;
    cmanfa1{i,3}=10;
    cmanfa1{i,4}=31;
end

currot3=[currot2; pmansp1; cmansp1; pmanfa1; cmanfa1];
currot3=sortrows(currot3,[2,3,4]);
% Creating cell array with all management information

```



```
hrunew=[top;Nrot;OpSchtxt;hrumgtmps(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot
3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1);currot3(:,1)];
```

```
    %% Creating new hrumgt text file %%
    fid = fopen([sim 'new' hrustr], 'w');
    %fid=fopen('testtest.txt', 'wt'); %creating new hru text file NEED TO FIGURE OUT HOW
TO SAVE AS HRUSTR IN NEW FOLDER
    formatSpec='%s\n'; %s is for text %d is for integers.
    for row=1:size(hrunew,1)
        fprintf(fid,formatSpec,hrunew{row,:});
    end
else
    hruold=textread(hrustr, '%s', 'delimiter', '\n', 'whitespace', '');
    fid = fopen([sim 'new' hrustr], 'w');
    %fid=fopen('testtest.txt', 'wt'); %creating new hru text file NEED TO FIGURE OUT HOW
TO SAVE AS HRUSTR IN NEW FOLDER
    formatSpec='%s\n'; %s is for text %d is for integers.
    for row=1:size(hruold,1)
        fprintf(fid,formatSpec,hruold{row,:});
    end
end
end
k=k+1;
end
hruprev=hruprev+hruinsub;
end
```

## Appendix D Matlab® code (multirun.m) which runs both the yearloop.m and

hruwrite.m code 100 times.

```

clear all
clc
for irun=1:100 %runs 100 loops, though this number can be changed
    yearloop % run yearloop_rev.m
    hruwrite % run hruwrite.m

    close all
    fclose all
    clc
    % copy old managment files into working folder

copyfile('\scratch\lustreC\r\rlogsdo\wabasmanul\input\inputnew\*.mgt', '\
scratch\lustreC\r\rlogsdo\wabasmanul\sensin\');
    % change to the working directory
    cd(['\scratch\lustreC\r\rlogsdo\wabasmanul\sensin'])

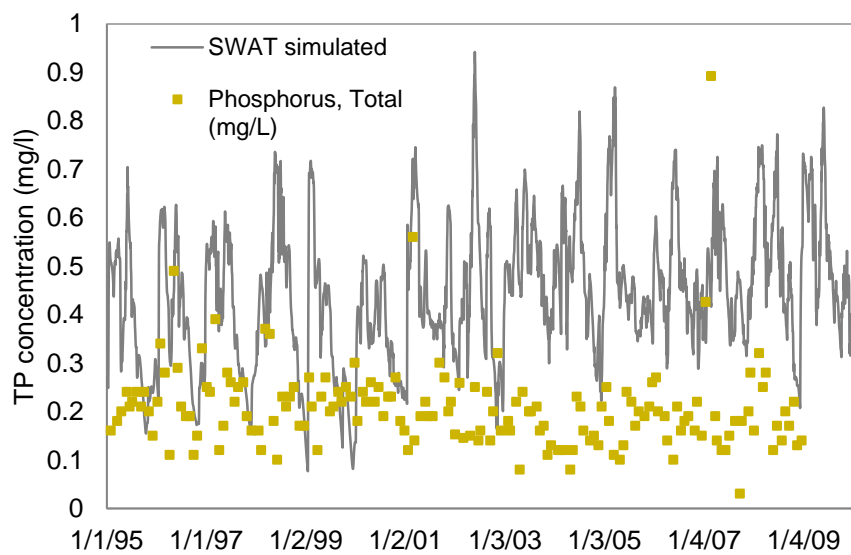
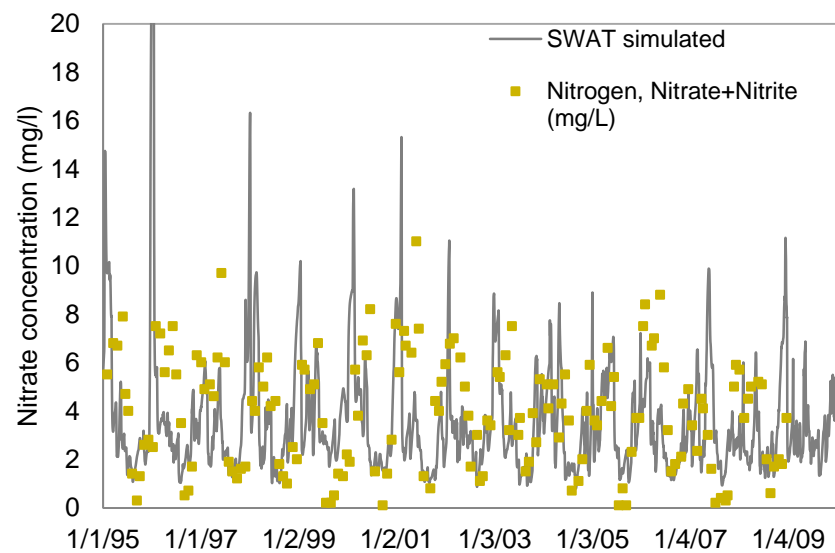
    % run SWAT
    !./swat488Original

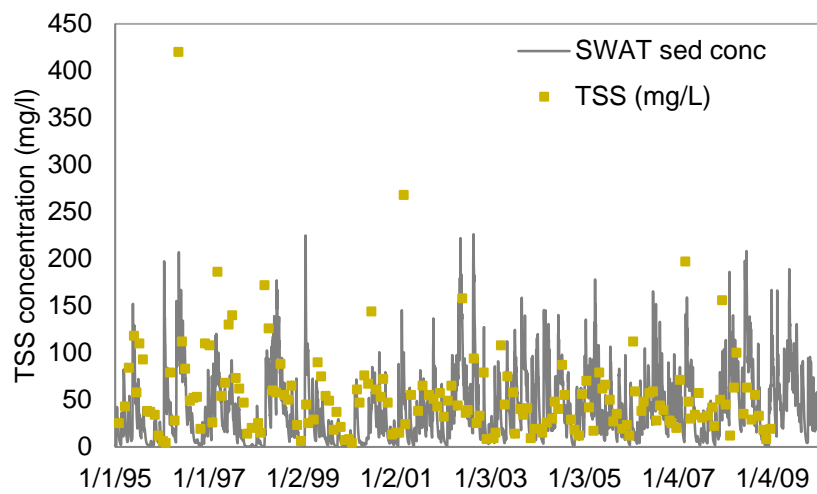
    runstr=num2str(irun) %convert run number to string
    %copy output.rch file to new file named 'irun'.rch in output folder
    copyfile('output.rch', ['output\' runstr '.rch']);
    %change back to original directory
    cd(['\scratch\lustreC\r\rlogsdo\wabasmanul\input'])

end

```

## Appendix E Calibration results for water quality from original model





## Appendix F Detailed management information for treatments used in analysis. Values

highlighted in grey are estimated.

Treatment 3												
Year	Crop	Description	Plant	Harv	Field Cultivated (spring)	Disk (spring)	Chisel Plow (fall)	Fertilizer	Fert Date	Starter (at Planting)	Start Fert gal/ac	Start Fert Date
1996	Corn	Corn in a Corn/Soybean/Wheat rotation	5-Jun	26-Oct	4-Jun	15-Apr	12-Nov	190 lbs N/acre	28-May	19-17-0	10	5-Jun
1997	Corn	Corn in a continuous corn rotation	30-Apr	15-Oct	29-Apr	25-Apr	28-Nov	190 lbs N/acre	26-Apr	19-17-0	9.5	30-Apr
1998	Corn	Corn in a continuous corn rotation	22-May	10-Oct	21-May	21-May	15-Nov	180 lbs N/acre	18-May	19-17-0	8	22-May
1999	Corn	Corn in a continuous corn rotation	29-May	14-Oct	28-May	15-Apr	1-Nov	180 lbs N/acre	21-Jun	19-17-0	9	29-May
2000	Corn	Corn in a continuous corn rotation	24-May	19-Oct	23-May	16-May	1-Nov	180 lbs N/acre	8-May	19-17-0	9	24-May
2001	Corn	Corn in a continuous corn rotation	2-May	29-Oct	1-May	30-Apr	9-Nov	180 lbs N/acre	20-Apr	19-17-0	10	2-May
2002	Corn	Corn in a continuous corn rotation	4-Jun	15-Oct	4-Jun	No	8-Nov	180 lbs N/acre	1-Jun	19-17-0	10	4-Jun
2003	Corn	Corn in a continuous corn rotation	28-Apr	21-Oct	28-Apr	15-Apr	31-Oct	180 lbs N/acre	14-Apr	19-17-0	10	28-Apr
2004	Corn	Corn in a continuous corn rotation	5-May	5-Oct	29-Apr	20-Apr	22-Oct	180 lbs N/acre	19-Apr	19-17-0	10	5-May
2005	Corn	Corn in a continuous corn rotation	5-May	13-Oct	19-Apr	19-Apr	18-Oct	180 lbs N/acre	5-Apr	19-17-0	15	5-May
2006	Corn	Corn in a continuous corn rotation	9-May	3-Nov	No	8-May	28-Nov	180 lbs N/acre	21-Apr	19-17-0	10	9-May
2007	Corn	Corn in a continuous corn rotation, with residue removal	15-May	5-Nov	14-May	No	No	160 lbs N/acre	14-May	19-17-0	10	15-May
2008	Corn	Corn in a continuous corn rotation, with residue removal	28-May	29-Oct	No	No	No	160 lbs N/acre	27-May	19-17-0	10	28-May
2009	Corn	Corn in a continuous corn rotation, with residue removal	24-May	1-Oct	No	No	No	160 lbs N/acre	21-May	19-17-0	7	21-May
2010	Corn	Corn in a continuous corn rotation, with residue removal	26-May	23-Sep	No	No	No	160 lbs N/acre	25-May	19-17-0	10	26-May
2011	Corn	Corn in a continuous corn rotation, with residue removal	3-Jun	6-Oct	No	No	No	160 lbs N/acre	13-May	19-17-0	10	3-Jun
2012	Corn	Corn in a continuous corn rotation, with residue removal	25-Apr	11-Sep	No	No	No	160 lbs N/acre	18-Apr	19-17-0	10	25-Apr
2013	Corn	Corn in a continuous corn rotation, with residue removal	20-May	11-Oct	No	No	No	160 lbs N/acre	18-May	19-17-0	No	No

Treatment 4												
Year	Crop	Description	Plant Date	Harv Date	Field Cultivated (spring)	Disk (spring)	Chisel Plow (fall)	Fertilizer	Fert Date	Starter (at Planting)	Start Fert gal/ac	Start Fert Date
1996	Soybean	Soybean in a Corn/Soybean/Wheat rotation	17-Jun	28-Oct	4-Jun	15-Apr	No	None	--	None	--	--
1997	Corn	Corn in a corn/soybean rotation	30-Apr	15-Oct	9-Apr	25-Apr	28-Nov	160 lbs N/acre Preplant	26-Apr	19-17-0	9.5	30-Apr
1998	Soybean	Corn in a corn/soybean rotation	22-May	10-Oct	21-May	21-May	No	None	--	None	--	--
1999	Corn	Corn in a corn/soybean rotation	29-May	14-Oct	28-May	15-Apr	1-Nov	160 lbs N/acre Preplant	21-Jun	19-17-0	9	29-May
2000	Soybean	Corn in a corn/soybean rotation	24-May	20-Oct	23-May	16-May	No	None	--	None	--	--
2001	Corn	Corn in a corn/soybean rotation	2-May	29-Oct	2-May	30-Apr	9-Nov	160 lbs N/acre Preplant	20-Apr	19-17-0	10	2-May
2002	Soybean	Corn in a corn/soybean rotation	4-Jun	15-Oct	4-Jun	No	No	None	--	None	--	--
2003	Corn	Corn in a corn/soybean rotation	28-Apr	21-Oct	28-Apr	15-Apr	31-Oct	160 lbs N/acre Preplant	14-Apr	19-17-0	10	28-Apr
2004	Soybean	Corn in a corn/soybean rotation	18-May	7-Oct	29-Apr	20-Apr	No	None	--	None	--	--
2005	Corn	Corn in a corn/soybean rotation	5-May	13-Oct	19-Apr	19-Apr	18-Oct	160 lbs N/acre Preplant	5-Apr	19-17-0	15	5-May
2006	Soybean	Soybean in a corn/soybean rotation	9-May	1-Nov	No	8-May	No	None	--	None	--	--
2007	Switchgrass	Switchgrass established with spring seeding	15-May	NA	15-May	No	No	None	--	None	--	--
2008	Switchgrass	Switchgrass with residue removal	NA	NA	No	No	No	75 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	1-May	None	--	--
2009	Switchgrass	Switchgrass with residue removal	NA	29-Oct	No	No	No	50 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	11-May	None	--	--
2010	Switchgrass	Switchgrass with residue removal	NA	27-Oct	No	No	No	50 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	4-May	None	--	--
2011	Switchgrass	Switchgrass with residue removal	NA	28-Oct	No	No	No	50 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	4-May	None	--	--
2012	Switchgrass	Switchgrass with residue removal	NA	30-Oct	No	No	No	50 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	3-Apr	None	--	--
2013	Switchgrass	Switchgrass with residue removal	NA	15-Nov	No	No	No	50 lbs acre Urea + Agrotain Broadcast with Gandy airflow fertilizer	13-May	None	--	--

Treatment 6												
Year	Crop	Description	Plant Date	Harv Date	Field Cultivated (spring)	Disk (spring)	Chisel Plow (fall)	Fertilizer	Fert Date	Starter (at Planting)	Start Fert gal/ac	Start Fert Date
1996	Soybean	Soybeans in Corn/Soybean rotation	17-Jun	28-Oct	4-Jun	15-Apr	No	None	--	None	--	--
1997	Corn	Corn in a corn/soybean rotation	30-Apr	15-Oct	29-Apr	25-Apr	28-Nov	140 lbs N/acre Preplant	26-Apr	19-17-0	9.5	30-Apr
1998	Soybean	Corn in a corn/soybean rotation	22-May	10-Oct	21-May	21-May	No	None	--	None	--	--
1999	Corn	Corn in a corn/soybean rotation	29-May	14-Oct	28-May	15-Apr	1-Nov	140 lbs N/acre Preplant	21-Jun	19-17-0	9	29-May
2000	Soybean	Corn in a corn/soybean rotation	24-May	20-Oct	23-May	16-May	No	None	--	None	--	--
2001	Corn	Corn in a corn/soybean rotation	2-May	29-Oct	2-May	30-Apr	9-Nov	140 lbs N/acre Preplant	20-Apr	19-17-0	10	2-May
2002	Soybean	Corn in a corn/soybean rotation	4-Jun	15-Oct	4-Jun	No	No	None	--	None	--	--
2003	Corn	Corn in a corn/soybean rotation	7-Jun	23-Oct	28-Apr & 6-Jun	15-Apr	No	140 lbs N/acre Preplant	28-May	19-17-0	10	7-Jun
2004	Soybean	Corn in a corn/soybean rotation	18-May	7-Oct	29-Apr	20-Apr	No	None	--	None	--	--
2005	Corn	Corn in a corn/soybean rotation	5-May	13-Oct	19-Apr	19-Apr	18-Oct	140 lbs N/acre Preplant	5-Apr	19-17-0	15	5-May
2006	Soybean	Soybean in a corn/soybean rotation	9-May	1-Nov	No	8-May	No	None	--	None	--	--
2007	Corn	Corn in a corn/soybean rotation	15-May	5-Nov	14-May	No	No	140 lbs N/acre Preplant	14-May	19-17-0	10	15-May
2008	Soybean	Soybean in a corn/soybean rotation	30-May	23-Oct	No	24-Apr	No	None	--	None	--	--
2009	Corn	Corn in a corn/soybean rotation	24-May	13-Nov	No	22-May	No	140 lbs N/acre Preplant	21-May	19-17-0	7	24-May
2010	Soybean	Soybean in a corn/soybean rotation	26-May	19-Oct	No	16-Apr	4-Nov	None	--	None	--	--
2011	Corn	Corn in a corn/soybean rotation	3-Jun	28-Oct	No	13-May	22-Nov	140 lbs N/acre Preplant	13-May	19-17-0	10	3-Jun
2012	Soybean	Soybean in a corn/soybean rotation	4-May	11-Oct	No	10-Apr	16-Nov	None	--	None	--	--
2013	Corn	Corn in a corn/soybean rotation	20-May	8-Nov	20-May	17-May	No	140 lbs N/acre Preplant	18-May	19-17-0	10	20-May

Treatment 7												
Year	Crop	Description	Plant Date	Harv Date	Field Cultivated (spring)	Disk (spring)	Chisel Plow (fall)	Fertilizer	Fert Date	Starter (at Planting)	Start Fert gal/ac	Start Fert Date
1996	Corn	Corn in a Corn/Soybean rotation	5-Jun	26-Oct	4-Jun	15-Apr	12-Nov	140 lbs N/acre	28-May	19-17-0	10	5-Jun
1997	Soybean	Soybean in a Corn/Soybean rotation	17-May	15-Oct	29-Apr	25-Apr	No	None	--	None	--	--
1998	Corn	Soybean in a Corn/Soybean rotation	22-May	10-Oct	21-May	21-May	15-Nov	140 lbs N/acre	18-May	19-17-0	8	22-May
1999	Soybean	Soybean in a Corn/Soybean rotation	29-May	28-Oct	28-May	15-Apr	No	None	--	None	--	--
2000	Corn	Soybean in a Corn/Soybean rotation	24-May	19-Oct	23-May	16-May	1-Nov	140 lbs N/acre	8-May	19-17-0	9	24-May
2001	Soybean	Soybean in a Corn/Soybean rotation	8-May	30-Oct	2-May	30-Apr	No	None	--	None	--	--
2002	Corn	Soybean in a Corn/Soybean rotation	4-Jun	15-Oct	4-Jun	No	8-Nov	140 lbs N/acre	1-Jun	19-17-0	10	4-Jun
2003	Soybean	Soybean in a Corn/Soybean rotation	7-Jun	23-Oct	28-Apr & 6-Jun	15-Apr	No	None	--	None	--	--
2004	Corn	Soybean in a Corn/Soybean rotation	5-May	5-Oct	29-Apr	20-Apr	22-Oct	140 lbs N/acre	19-Apr	19-17-0	10	5-May
2005	Soybean	Soybean in a Corn/Soybean rotation	9-May	13-Oct	19-Apr	19-Apr	No	None	--	None	--	--
2006	Corn	Corn in a Corn/Soybean rotation	9-May	3-Nov	No	8-May	28-Nov	140 lbs N/acre	21-Apr	19-17-0	10	9-May
2007	Soybean	Soybean in a Corn/Soybean rotation	15-May	6-Nov	14-May	No	No	None	--	None	--	--
2008	Corn	Corn in a Corn/Soybean rotation	28-May	3-Nov	No	24-Apr	No	140 lbs N/acre	27-May	19-17-0	10	28-May
2009	Soybean	Soybean in a Corn/Soybean rotation	24-May	20-Oct	No	22-May	No	None	--	None	--	--
2010	Corn	Corn in a Corn/Soybean rotation	26-May	11-Oct	No	4-Apr & 16-Apr	4-Nov	140 lbs N/acre	25-May	19-17-0	10	26-May
2011	Soybean	Soybean in a Corn/Soybean rotation	8-Jun	24-Oct	No	13-May	22-Nov	None	--	None	--	--
2012	Corn	Corn in a Corn/Soybean rotation	25-May	4-Oct	No	10-Apr	16-Nov	140 lbs N/acre	18-Apr	19-17-0	10	25-Apr
2013	Soybean	Soybean in a Corn/Soybean rotation	20-May	11-Nov	20-May	17-May	No	None	--	None	--	--



Treatment 12												
Year	Crop	Description	Plant Date	Harv Date	Field Cultivated (spring)	Disk (spring)	Chisel Plow (fall)	Fertilizer	Fert Date	Starter (at Planting)	Start Fert gal/ac	Start Fert Date
1996	Corn	Corn in a continuous corn rotation	5-Jun	26-Oct	4-Jun	15-Apr	12-Nov	160 lbs N/acre	28-May	19-17-0	10	5-Jun
1997	Corn	Corn in a continuous corn rotation	30-Apr	15-Oct	29-Apr	25-Apr	28-Nov	160 lbs N/acre	26-Apr	19-17-0	9.5	30-Apr
1998	Corn	Corn in a continuous corn rotation	22-May	10-Oct	21-May	21-May	15-Nov	160 lbs N/acre	18-May	19-17-0	8	22-May
1999	Corn	Corn in a continuous corn rotation	29-May	14-Oct	28-May	15-Apr	1-Nov	160 lbs N/acre	21-Jun	19-17-0	9	29-May
2000	Corn	Corn in a continuous corn rotation	24-May	19-Oct	23-May	16-May	1-Nov	160 lbs N/acre	8-May	19-17-0	9	24-May
2001	Corn	Corn in a continuous corn rotation	2-May	29-Oct	2-May	30-Apr	9-Nov	160 lbs N/acre	20-Apr	19-17-0	10	2-May
2002	Corn	Corn in a continuous corn rotation	4-Jun	15-Oct	4-Jun	No	8-Nov	160 lbs N/acre	1-Jun	19-17-0	10	4-Jun
2003	Corn	Corn in a continuous corn rotation	28-Apr	21-Oct	28-Apr	15-Apr	31-Oct	160 lbs N/acre	14-Apr	19-17-0	10	28-Apr
2004	Corn	Corn in a continuous corn rotation	5-May	5-Oct	29-Apr	20-Apr	22-Oct	160 lbs N/acre	19-Apr	19-17-0	10	5-May
2005	Corn	Corn in a continuous corn rotation	5-May	13-Oct	19-Apr	19-Apr	18-Oct	160 lbs N/acre	5-Apr	19-17-0	15	5-May
2006	Corn	Corn in a continuous corn rotation	9-May	3-Nov	No	8-May	28-Nov	160 lbs N/acre	21-Apr	19-17-0	10	9-May
2007	Corn	Corn in a continuous corn rotation	15-May	5-Nov	14-May	No	No	160 lbs N/acre	14-May	19-17-0	10	15-May
2008	Corn	Corn in a continuous corn rotation	28-May	3-Nov	No	24-Apr	No	160 lbs N/acre	27-May	19-17-0	10	28-May
2009	Corn	Corn in a continuous corn rotation	24-May	13-Nov	No	22-May	No	160 lbs N/acre	21-May	19-17-0	7	24-May
2010	Corn	Corn in a continuous corn rotation	26-May	11-Oct	No	4-Apr & 16-Apr	4-Nov	160 lbs N/acre	25-May	19-17-0	10	26-May
2011	Corn	Corn in a continuous corn rotation	3-Jun	28-Oct	No	13-May	22-Nov	160 lbs N/acre	13-May	19-17-0	10	3-Jun
2012	Corn	Corn in a continuous corn rotation	25-Apr	4-Oct	No	10-Apr	16-Nov	160 lbs N/acre	18-Apr	19-17-0	10	25-Apr
2013	Corn	Corn in a continuous corn rotation	20-May	8-Nov	No	17-May	No	160 lbs N/acre	18-May	None	--	--

## Appendix G DayCent model warm-up block details

<b>Block 1 – Warm up</b>						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
0	1899	4	1700	12	1	F-wqfs
<u>Year 1</u> <ul style="list-style-type: none"> <li>Grow KNZ (April 15–November 15)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>Grow KNZ (April 15–November 15)</li> </ul>						
<u>Year 3</u> <ul style="list-style-type: none"> <li>Grow KNZ (April 15–November 15)</li> </ul>						
<u>Year 4</u> <ul style="list-style-type: none"> <li>Grow KNZ (April 15 –November 15)</li> <li>Fire (August 15)</li> </ul>						
<b>Block 2 – Low intensity cropping</b>						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1900	1968	3	1900	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>Plow (April 15)</li> <li>Grow low yield corn (May 5– October 15)</li> <li>Plow (P) Oct 16</li> <li>Plant low yielding winter wheat (October 25)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>Harvest wheat (May 15)</li> <li>Plow (September 15)</li> </ul>						
<u>Year 3</u> <ul style="list-style-type: none"> <li>Plow (April 15)</li> <li>Grow low yield soybeans (May 15 – October 15)</li> <li>Plow (November 15)</li> </ul>						
<b>Block 3 – Modern agriculture</b>						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1969	1992	2	1969	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>Plow (April 15)</li> <li>Field cultivate (May 3)</li> <li>Fertilize pre-plant (May 4) w.120lbs N/acre 28% UAN</li> <li>Grow corn (May 5 - October 15)</li> <li>Plow (November 15)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>Plow (April 15)</li> <li>Field Cultivate (May 14)</li> <li>Grow soybeans (May– October 15)</li> <li>Plow (p) (November 15)</li> </ul>						

Block 4 – WQFS Generic data - Trt 3						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1993	1996	1	1993	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Fertilize pre-plant (May 28) w.190lbs N/acre 28% UAN</li> <li>• Field Cultivate (June 4)</li> <li>• Grow corn (June 5– October 26)</li> <li>• Plow (November 12)</li> </ul>						

Block 4 – WQFS Generic data - Trt 4						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1993	1996	1	1993	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Fertilize pre-plant (May 4) w.160lbs N/acre 28% UAN</li> <li>• Field Cultivate (May 3)</li> <li>• Grow corn (May 5– October15)</li> <li>• Plow (November 15)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Field cultivate (June 4)</li> <li>• Grow soybeans (June 17– October 28)</li> </ul>						

Block 4 – WQFS Generic data - Trt 6						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1993	1996	1	1993	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Fertilize pre-plant (May 4) w.140lbs N/acre 28% UAN</li> <li>• Field cultivate May 3</li> <li>• Grow corn (C-HI) (May 5– October15)</li> <li>• Plow (November 15)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Field cultivate (June 4)</li> <li>• Grow soybeans (June 17– October 28)</li> </ul>						

<b>Block 4 – WQFS Generic data - Trt 7</b>						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1993	1996	2	1993	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Field cultivate(June 4)</li> <li>• Grow soybeans (June 17– October 28)</li> </ul>						
<u>Year 2</u> <ul style="list-style-type: none"> <li>• Plow (April 15)</li> <li>• Fertilize pre-plant (May 28) w.140lbs N/acre 28% UAN</li> <li>• Field cultivate (June 4)</li> <li>• Grow corn (June 6– October 26)</li> <li>• Plow (November 12)</li> </ul>						

<b>Block 4 – WQFS Generic data - Trt 12</b>						
Start Year	Last year	Repeating yr	Output yr	Output month	Output interval	Weather choice
1993	1996	1	1993	12	1	C
<u>Year 1</u> <ul style="list-style-type: none"> <li>• Plow (April 24)</li> <li>• Field cultivate May 3</li> <li>• Fertilize pre-plant (May 4) w.180lbs N/acre 28% UAN</li> <li>• Grow corn (May 5– October 15)</li> <li>• Plow (November 15)</li> </ul>						

## Appendix H AMALGAM Codes to Run DayCent

**Model.m**

```
%% Model.m is a function which calls plotruns.m to run all five models simultaneously on  
parallel  
%% computing system
```

```
function [ModPred1, ModPred2] = cedar(Pars,Extra);  
    outlet=21; % arbitrary, but needed to name output files  
    x = (Pars); % calling the parameters from AMALGAM  
    simdataB=[]; % this will be simulated biomass  
    simdataN=[]; % this will be simulated N2O  
    parfor iRun=1:5 % runs all five plots in parallel  
        [simdataB(:,iRun),simdataN(:,iRun)]=plotruns(x,Extra,iRun);  
    end  
    ModPred1 = simdataB; % saves biomass output to go into CalcOF.m  
    ModPred2 = simdataN; % saves N2O output to go into CalcOF.m
```

**plotruns.m**

```

%% plotruns.m is a function which runs each plot in different folders so that the matlabpool
workers
%% can run them simultaneously. Each worker alters the parameters generated by AMALGAM
using %%par_alteramalgam.m and then runs DayCent and retrieves the output using outproc.m
function [simdataB,simdataN]=plotruns(x,Extra,iRun)
i=iRun;
n_sub=1; % arbitrary, not used, but will not work without
outlet=21; % arbitrary, will use to name files
if i==1
    %% Run for plot 21 (in plot 21 folder)
    cd <Location of Plot 21 files>
    plot=21;
    par_alteramalgam(Extra.par_n,Extra.par_f,x,plot);
    delete('plot21.bin');
    disp(' Running DayCent Plot 21 ')
    !./DailyDayCent -s trt12 -n plot21
    iVars = [1];
    start_year = 1995;
    n_years = 18;
    nPars = 72;
    outproc(iVars,n_sub,outlet,start_year,n_years,plot);
    %saving biomass output
    filename='sim_daily21.dat';delimiter = ',';formatSpec = '%*s%f%[\n\r]';fileID =
fopen(filename,'r');
    dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError',
false);fclose(fileID);
    simdataB= [dataArray{1:end-1}];
    clearvars filename delimiter formatSpec fileID dataArray ans;
    %saving N2O output
    filename = 'sim_dailyN21.dat';delimiter = ";formatSpec = '%f%[\n\r]'; fileID =
fopen(filename,'r');
    dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError', false);
    fclose(fileID);
    simdataN = [dataArray{1:end-1};0]; clearvars filename delimiter formatSpec fileID
dataArray ans;
    cd <Start location>

elseif i==2 %% Run for plot 5 (in Plot5 folder)
    cd <Location of Plot 5 files>
    plot=5;
    par_alteramalgam(Extra.par_n,Extra.par_f,x,plot);
    delete('plot5.bin');
    disp(' Running DayCent Plot 5 ')
    !./DailyDayCent -s trt6 -n plot5
    iVars = [1];
    start_year = 1995;
    n_years = 18;
    nPars = 72;

```

```

outlet=21;
outproc(iVars,n_sub,outlet,start_year,n_years,plot);
%saving biomass output
filename='sim_daily21.dat';delimiter = ',';formatSpec = '% *s%f%[\n\r]';fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError',
false);fclose(fileID);
simdataB= [dataArray{1:end-1};0];
clearvars filename delimiter formatSpec fileID dataArray ans;
%saving N2O output
filename = 'sim_dailyN21.dat';delimiter = ";formatSpec = '%f%[\n\r]'; fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError', false);
fclose(fileID);
simdataN = [dataArray{1:end-1};0;0]; clearvars filename delimiter formatSpec fileID
dataArray ans;
cd <Start location>
elseif i==3 %% Run for plot 13 (in Plot13 folder)
cd <Location of Plot 13 files>
plot=13;
par_alteramalgam(Extra.par_n,Extra.par_f,x,plot);
delete('plot13.bin');
disp(' Running DayCent Plot 13 ')
!./DailyDayCent -s trt6 -n plot13
iVars = [1];
start_year = 1995;
n_years = 18;
nPars = 72;
outlet=21;
outproc(iVars,n_sub,outlet,start_year,n_years,plot);
%saving biomass output
filename='sim_daily21.dat';delimiter = ',';formatSpec = '% *s%f%[\n\r]';fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError',
false);fclose(fileID);
simdataB= [dataArray{1:end-1};0];
clearvars filename delimiter formatSpec fileID dataArray ans;
%saving N2O output
filename = 'sim_dailyN21.dat';delimiter = ";formatSpec = '%f%[\n\r]'; fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError', false);
fclose(fileID);
simdataN = [dataArray{1:end-1};0;0]; clearvars filename delimiter formatSpec fileID
dataArray ans;
cd <Start location>

elseif i==4 %% Run for plot 30 (in Plot30 folder)
cd <Location of Plot 30 files>
plot=30;

```

```

par_alteramalgam(Extra.par_n,Extra.par_f,x,plot);
delete('plot30.bin');
disp(' Running DayCent Plot 30 ')
!./DailyDayCent -s trt3 -n plot30
iVars = [1];
start_year = 1995;
n_years = 18;
nPars = 72;
outlet=21;
outproc(iVars,n_sub,outlet,start_year,n_years,plot);
%saving biomass output
filename='sim_daily21.dat';delimiter = ',';formatSpec = '% *s%f%[\n\r]';fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError',
false);fclose(fileID);
simdataB = [dataArray{1:end-1};0;0];
clearvars filename delimiter formatSpec fileID dataArray ans;
%saving N2O output
filename = 'sim_dailyN21.dat';delimiter = ";formatSpec = '%f%[\n\r]'; fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError', false);
fclose(fileID);
simdataN = [dataArray{1:end-1};0;0]; clearvars filename delimiter formatSpec fileID
dataArray ans;
cd <Start location>
else %% Run for plot 10 (in Plot10 folder)
cd <Location of plot 10 files>
plot=10;
par_alteramalgam(Extra.par_n,Extra.par_f,x,plot);
delete('plot10.bin');
disp(' Running DayCent Plot 10 ')
!./DailyDayCent -s trt4 -n plot10
iVars = [1];
start_year = 1995;
n_years = 18;
nPars = 72;
outlet=21;
outproc(iVars,n_sub,outlet,start_year,n_years,plot);
%saving biomass output
filename='sim_daily21.dat';delimiter = ',';formatSpec = '% *s%f%[\n\r]';fileID =
fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError',
false);fclose(fileID);
simdataB = [dataArray{1:end-1};0;0];
clearvars filename delimiter formatSpec fileID dataArray ans;
%saving N2O output
filename = 'sim_dailyN21.dat';delimiter = ";formatSpec = '%f%[\n\r]'; fileID =
fopen(filename,'r');

```



```
dataArray = textscan(fileID, formatSpec, 'Delimiter', delimiter, 'ReturnOnError', false);
fclose(fileID);
simdataN = [dataArray{1:end-1}]; clearvars filename delimiter formatSpec fileID dataArray
ans;
cd <Start location>
end

simdataB=simdataB;
simdataN=simdataN;
```

**par\_alteramalgam.m**

%% par\_alteramalgam.m (par\_alter.m for short), is the code which alters parameters in input files based

%% on which parameters you ask to change, and the parameters generated by AMALGAM

function par\_alteramalgam(par\_nold,par\_f,xold,plot)

x = zeros(72,1);%creates column vector of zeros

for i =1:length(x) %if parameter is flagged, zero is replaced with the new parameter

    if par\_f(i)==1

        x(i)=xold(i);

    end

end

% x(par\_f==1) = xold;

par\_n = (1:72)';

% Change site.100 parameters

ibsn=max(par\_f(par\_n==18)==1 || par\_f(par\_n==19)==1 || par\_f(par\_n==20)==1 || ...

    par\_f(par\_n==21)==1 || par\_f(par\_n==22)==1 || par\_f(par\_n==23)==1 || ...

    par\_f(par\_n==24)==1 || par\_f(par\_n==62)==1);

disp(' writing site.100 files ')

if ibsn==1; site100(par\_n,par\_f,x,plot); end %If at least one site100 params is flagged, run site100

% Change sitepar.in/

isitepar=max(par\_f(par\_n==12)==1 || par\_f(par\_n==13)==1 || par\_f(par\_n==14)==1 || ...

    par\_f(par\_n==15)==1 || par\_f(par\_n==16)==1 || par\_f(par\_n==17)==1 || ...

    par\_f(par\_n==68)==1 || par\_f(par\_n==69)==1 || par\_f(par\_n==70)==1 || ...

    par\_f(par\_n==71)==1 || par\_f(par\_n==72)==1);

disp(' writing sitepar.in files ')

if isitepar==1; sitepar(par\_n,par\_f,x); end

% Change fix.100 parameters

ifix100=max(par\_f(par\_n==25)==1 || par\_f(par\_n==26)==1 || par\_f(par\_n==27)==1 || ...

    par\_f(par\_n==28)==1 || par\_f(par\_n==29)==1 || par\_f(par\_n==30)==1 ||...

    par\_f(par\_n==31)==1 || par\_f(par\_n==32)==1 || par\_f(par\_n==33)==1 ||...

    par\_f(par\_n==34)==1 || par\_f(par\_n==35)==1 || par\_f(par\_n==36)==1 ||...

    par\_f(par\_n==37)==1 || par\_f(par\_n==38)==1 || par\_f(par\_n==39)==1 ||...

    par\_f(par\_n==40)==1 || par\_f(par\_n==41)==1 || par\_f(par\_n==42)==1 ||...

    par\_f(par\_n==43)==1 || par\_f(par\_n==44)==1 || par\_f(par\_n==45)==1 ||...

    par\_f(par\_n==46)==1 || par\_f(par\_n==47)==1 || par\_f(par\_n==48)==1 ||...

    par\_f(par\_n==49)==1 || par\_f(par\_n==50)==1 || par\_f(par\_n==51)==1 ||...

    par\_f(par\_n==52)==1 || par\_f(par\_n==53)==1 || par\_f(par\_n==54)==1 ||...

    par\_f(par\_n==55)==1 || par\_f(par\_n==56)==1 || par\_f(par\_n==57)==1 ||...

    par\_f(par\_n==58)==1 || par\_f(par\_n==59)==1 || par\_f(par\_n==60)==1);

disp(' writing fix.100 files ')

if ifix100==1; fix100(par\_n,par\_f,x); end

% Change crop.100 parameters

```
icrop100=max(par_f(par_n==1)==1 || par_f(par_n==2)==1 || par_f(par_n==3)==1 || ...
  par_f(par_n==4)==1 || par_f(par_n==5)==1 || par_f(par_n==6)==1 ||...
  par_f(par_n==7)==1 || par_f(par_n==8)==1 || par_f(par_n==9)==1 ||...
  par_f(par_n==10)==1 || par_f(par_n==11)==1 || par_f(par_n==63)==1 ||...
  par_f(par_n==64)==1 || par_f(par_n==65)==1 || par_f(par_n==66)==1 ||...
  par_f(par_n==67)==1);

disp(' writing crop.100 files ')
if icrop100==1; crop100(par_n,par_f,x); end

disp(' finished parameter alter ')
return;
```

**outproc.m**

%% outproc.m is the code which extracts biomass harvest data and N2O flux data based on plot number

%% this code reads in the harvest.csv and nflux.out files from DayCent and only gets data for which there %% is an observation

```
function outproc(iVars,nsubs,outlet,start_year,n_years,plot)
global n_sub file_id outlet
VarName = {'BiomassHarvested_kg_ha','N2O'};
if plot==21
    %Importing simulated harvest data
    tempout=csvread('harvest.csv',1);
    %Importing simulated nflux data
    filename = 'nflux.out'; formatSpec = '% 8f% 6f% 12f% 14f% [\n\r]';
    startRow = 2; fileID = fopen(filename,'r');
    dataArray = textscan(fileID, formatSpec, 'Delimiter', ',', 'WhiteSpace', ' ', 'EmptyValue',
NaN,'HeaderLines',startRow-1, 'ReturnOnError', false); fclose(fileID);
    nflux = [dataArray{1:end-1}]; clearvars filename startRow formatSpec fileID dataArray ans;
    for n=1:length(nflux) %cumulative N2O
        nflux(n,5)= (nflux(n,3)+nflux(n,4))/10; % converting to mg/m2-d
    end
    %Importing rows for nflux data
    p21rows=textread('p21NobsRows.txt');
    nfluxsim = nflux([p21rows],5); %n20flux for only observed data points
    % Years of yield
    years=[1995:2012]';
    yeild=tempout(96:113,7); %extracting biomass yield for only observed years
    tempsim=[years yeild];
    names={'Year',VarName{iVars}};
    dlmwrite(['sim_daily' num2str(outlet) '.dat'],tempsim); % writing simulated biomass to file
    clear tempout tempsim names years
    dlmwrite(['sim_dailyN' num2str(outlet) '.dat'],nfluxsim); %writing simulated n2o flux to file
elseif plot==5
    %Importing simulated harvest data
    tempout=csvread('harvest.csv',1);
    %Importing simulated nflux data
    filename = 'nflux.out'; formatSpec = '% 8f% 6f% 12f% 14f% [\n\r]';
    startRow = 2; fileID = fopen(filename,'r');
    dataArray = textscan(fileID, formatSpec, 'Delimiter', ',', 'WhiteSpace', ' ', 'EmptyValue',
NaN,'HeaderLines',startRow-1, 'ReturnOnError', false); fclose(fileID);
    nflux = [dataArray{1:end-1}]; clearvars filename startRow formatSpec fileID dataArray ans;
    for n=1:length(nflux) %cumulative N2O
        nflux(n,5)= (nflux(n,3)+nflux(n,4))/10; % converting to mg/m2-d
    end
    %Importing rows for nflux data
    p21rows=textread('p5NobsRows.txt');
    nfluxsim = nflux([p21rows],5); %n20flux for only observed data points
    % Years of yield
    years=[1995:2011]';
```

```

yeild=tempout(96:112,7); %extracting biomass yield for only observed years
tempsim=[years yeild];
names={'Year',VarName{iVars}};
dlmwrite(['sim_daily' num2str(outlet) '.dat'],tempsim); %writing simulated biomass to file
clear tempout tempsim names years
dlmwrite(['sim_dailyN' num2str(outlet) '.dat'],nfluxsim); %writing simulated n2o flux to file
elseif plot==13
%Importing simulated harvest data
tempout=csvread('harvest.csv',1);
%Importing simulated nflux data
filename = 'nflux.out'; formatSpec = '% 8f% 6f% 12f% 14f% [\n\r]';
startRow = 2; fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', ', ', 'WhiteSpace', ' ', 'EmptyValue',
NaN,'HeaderLines',startRow-1, 'ReturnOnError', false); fclose(fileID);
nflux = [dataArray{1:end-1}]; clearvars filename startRow formatSpec fileID dataArray ans;
for n=1:length(nflux) %cumulative N2O
    nflux(n,5)= (nflux(n,3)+nflux(n,4))/10; % converting to mg/m2-d
end
%Importing rows for nflux data
p21rows=textread('p13NobsRows.txt');
nfluxsim = nflux([p21rows],5); %n2o flux for only observed data points
% Years of yield
years=[1995:2011];
yeild=tempout(96:112,7); %extracting biomass yield for only observed years
tempsim=[years yeild];
names={'Year',VarName{iVars}};
dlmwrite(['sim_daily' num2str(outlet) '.dat'],tempsim); %writing simulated biomass to file
clear tempout tempsim names years
dlmwrite(['sim_dailyN' num2str(outlet) '.dat'],nfluxsim); %writing simulated n2o flux to file
elseif plot==30
%Importing simulated harvest data
tempout=csvread('harvest.csv',1);
%Importing simulated nflux data
filename = 'nflux.out'; formatSpec = '% 8f% 6f% 12f% 14f% [\n\r]';
startRow = 2; fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', ', ', 'WhiteSpace', ' ', 'EmptyValue',
NaN,'HeaderLines',startRow-1, 'ReturnOnError', false); fclose(fileID);
nflux = [dataArray{1:end-1}]; clearvars filename startRow formatSpec fileID dataArray ans;
for n=1:length(nflux) %cumulative N2O
    nflux(n,5)= (nflux(n,3)+nflux(n,4))/10; % converting to mg/m2-d
end
%Importing rows for nflux data
p21rows=textread('p30NobsRows.txt');
nfluxsim = nflux([p21rows],5); %n2o flux for only observed data points
% Years of yield
years=[1996:2007];
years=[2009:2012];
years=[years;years];
yeildg=tempout(97:108,7);%extracting biomass yield for only observed years

```

```

yeilds=[tempout(110:113,7)+tempout(110:113,11)];
yeild=[yeildg;yeilds];
tempsim=[years yeild];
names={'Year',VarName{iVars}};
dlmwrite(['sim_daily' num2str(outlet) '.dat'],tempsim); % writing simulated biomass to file
clear tempout tempsim names years
dlmwrite(['sim_dailyN' num2str(outlet) '.dat'],nfluxsim); % writing simulated n2o flux to file
else
%Importing simulated harvest data
tempout=csvread('harvest.csv',1);
%Importing simulated nflux data
filename = 'nflux.out'; formatSpec = '% 8f% 6f% 12f% 14f% [^\n\r]';
startRow = 2; fileID = fopen(filename,'r');
dataArray = textscan(fileID, formatSpec, 'Delimiter', ',', 'WhiteSpace', '\s+', 'EmptyValue',
NaN,'HeaderLines', startRow-1, 'ReturnOnError', false); fclose(fileID);
nflux = [dataArray{1:end-1}]; clearvars filename startRow formatSpec fileID dataArray ans;
for n=1:length(nflux) %cumulative N2O
    nflux(n,5)= (nflux(n,3)+nflux(n,4))/10; % converting to mg/m2-d
end
%Importing rows for nflux data
p21rows=textread('p10NobsRows.txt');
nfluxsim = nflux([p21rows],5); %n2o flux for only observed data points
% Years of yield
years=[1995:2006];
yearss=[2009:2012];
years=[years;yearss];
yeildg=tempout(96:107,7);%extracting biomass yield for only observed years
yeilds=tempout(108:111,11);
yeild=[yeildg;yeilds];
tempsim=[years yeild];
names={'Year',VarName{iVars}};
dlmwrite(['sim_daily' num2str(outlet) '.dat'],tempsim); % writing simulated biomass to file
clear tempout tempsim names years
dlmwrite(['sim_dailyN' num2str(outlet) '.dat'],nfluxsim); % writing simulated n2o flux to file
end

fclose all;

```

## Appendix I Description of DayCent parameters calibrated

<b>Par #</b>	<b>Name</b>	<b>File</b>	<b>Description</b>
1	fligni(1,1)-corn	crop.10 0	Intercept for equation to predict lignin content fraction based on annual rainfall for aboveground material - corn
2	fligni(1,1)-soyb	crop.10 0	Intercept for equation to predict lignin content fraction based on annual rainfall for aboveground material - soybean
3	himax-corn	crop.10 0	Harvest index maximum (fraction of aboveground live C in grain) - corn
4	hiwsf-corn	crop.10 0	Harvest index water stress factor: 0 = no effect of water stress; 1 = no grain yield with maximum water stress - corn
5	prdx(1)-corn	crop.10 0	Coefficient for calculating potential aboveground monthly production as a function of solar radiation outside the atmosphere - corn
6	prdx(1)-soyb	crop.10 0	Coefficient for calculating potential aboveground monthly production as a function of solar radiation outside the atmosphere - soybean
7	prdx(1)-swg	crop.10 0	Coefficient for calculating potential aboveground monthly production as a function of solar radiation outside the atmosphere -switchgrass
8	snfxmx-soyb	crop.10 0	Symbiotic N fixation maximum - soybean
9	dec4	fix.100	Maximum decomposition rate of soil organic matter with slow turnover, the fraction of the pool that turns over each year
10	aneref(2)	fix.100	Ratio of rain/potential evapotranspiration above which there is maximum negative impact of soil anaerobic conditions on decomposition
11	aneref(3)	fix.100	Minimum value of the impact of soil anaerobic conditions on decomposition; functions as a multiplier for the maximum decomposition rate
12	damr(2,1)	fix.100	Fraction of surface N absorbed by residue
13	damrmn(1)	fix.100	Minimum C/N ratio allowed in residue after direct absorption
14	dec1(1)	fix.100	Maximum surface structural decomposition rate, the fraction of the pool that turns over each year
15	dec1(2)	fix.100	Maximum soil structural decomposition rate, the fraction of the pool that turns over each year
16	dec2(1)	fix.100	Maximum surface metabolic decomposition rate, the fraction of the pool that turns over each year

17	dec2(2)	fix.100	Maximum soil metabolic decomposition rate, the fraction of the pool that turns over each year
18	dec3(1)	fix.100	Maximum decomposition rate of surface organic matter with active turnover, the fraction of the pool that turns over each year
19	dec3(2)	fix.100	Maximum decomposition rate of soil organic matter with active turnover, the fraction of the pool that turns over each year
20	dec5(2)	fix.100	Maximum decomposition rate of soil organic matter with intermediate turnover, the fraction of the pool that turns over each year
21	fleach(3)	fix.100	Leaching fraction multiplier for N to compute the fraction of mineral N which will leach to the next layer when there is a saturated water flow; normal leaching is a function of sand content
22	fwloss(4)	fix.100	Scaling factor for potential evapotranspiration
23	omlech(3)	fix.100	The amount of water that needs to flow out of water layer 2 to leach organic C at the maximum rate
24	peftxa	fix.100	Intercept parameter for regression equation to compute the effect of soil texture on the microbe decomposition rate (the effect of texture when there is no sand in the soil)
25	teff(1)	fix.100	"x" location of inflection point for determining the temperature component of DEFAC, the decomposition factor
26	teff(2)	fix.100	"y" location of inflection point for determining the temperature component of DEFAC, the decomposition factor
27	teff(3)	fix.100	Step size (distance from the maximum point to the minimum point), for determining the temperature component of DEFAC, the decomposition factor
28	teff(4)	fix.100	Slope of line at inflection point, for determining the temperature component of DEFAC, the decomposition factor
29	varat11(1, 1)	fix.100	Maximum C/N ratio for material entering surface som1
30	varat11(2, 1)	fix.100	Minimum C/N ratio for material entering surface som1
31	varat12(1, 1)	fix.100	Maximum C/N ratio for material entering soil som1
32	varat12(2, 1)	fix.100	Minimum C/N ratio for material entering soil som1
33	basef	site.100	The fraction of the soil water content of layer N LAYER+1 which is lost via base flow

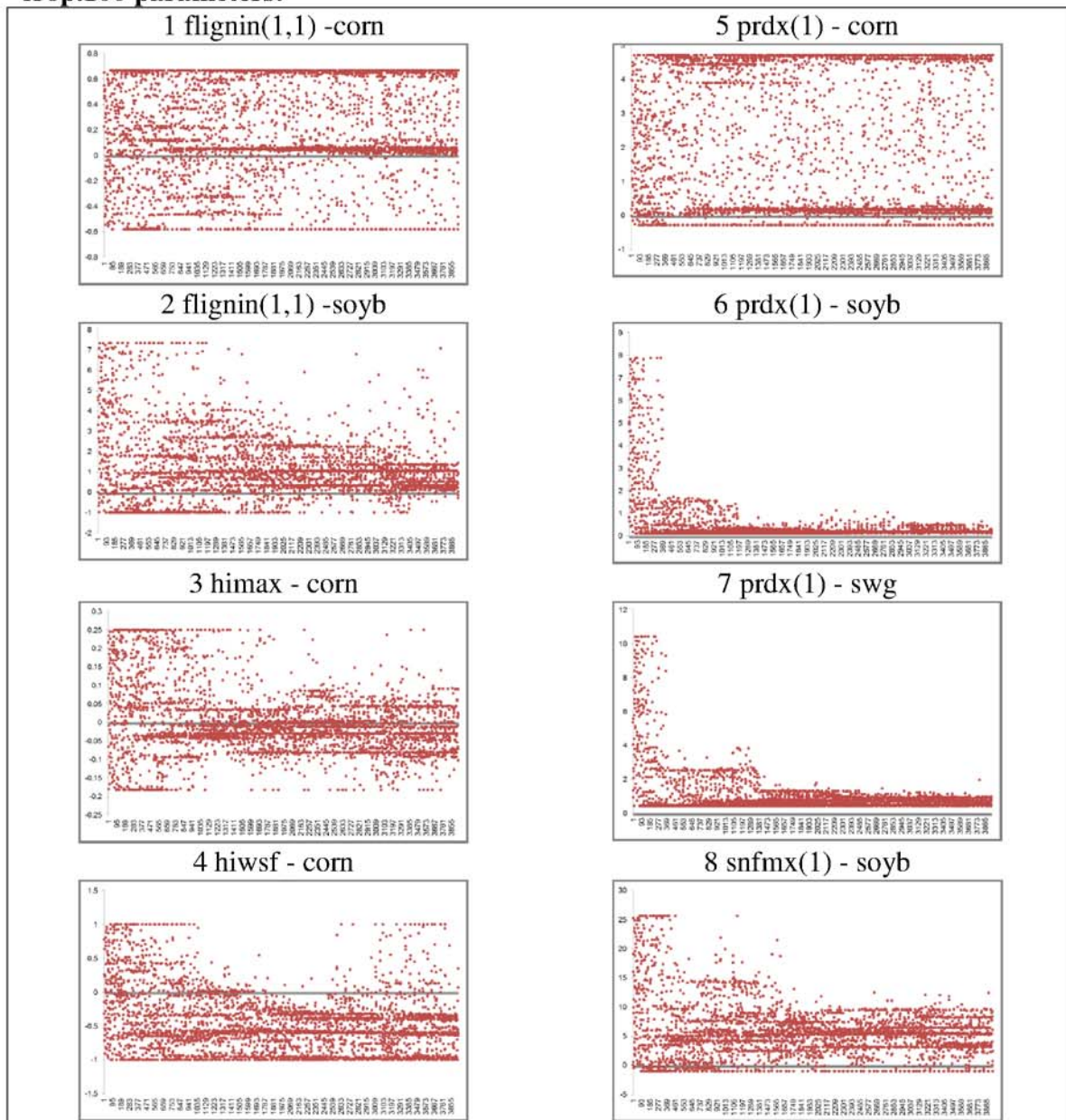


34	epnfa(1)	site.100	Intercept value for determining the effect of annual precipitation on atmospheric N fixation (wet and dry deposition)
35	epnfa(2)	site.100	Slope value for determining the effect of annual precipitation on atmospheric N fixation (wet and dry deposition)
36	epnfs(1)	site.100	Minimum AET value used for determining the effect of annual evapotranspiration on non-symbiotic soil N fixation; not used if nsnfix=1
37	epnfs(2)	site.100	Intercept value used for determining the effect of annual evapotranspiration on non-symbiotic soil N fixation; not used if nsnfix=1
38	adwpfs	sitepar.in	Adjustment on inflection point for WFPS effect on denitrification
39	dmpfact	sitepar.in	Damping factor for calculating soil temperature by layer
40	dmpflux	sitepar.in	In H <sub>2</sub> O flux routine
41	nitmax	sitepar.in	Maximum daily nitrification amount
42	nitN_fc	sitepar.in	Maximum proportion of nitrified N lost as N <sub>2</sub> O @ field capacity
43	nitN_wp	sitepar.in	Minimum proportion of nitrified N lost as N <sub>2</sub> O @ wilting point
44	nratadj	sitepar.in	N <sub>2</sub> /N <sub>2</sub> O ratio adjustment coefficient
45	timlag	sitepar.in	Days from Jan 1 to coolest temp at bottom of soil (days)
46	waterlimit	sitepar.in	Min water/temperature limitation coefficient for nitrify

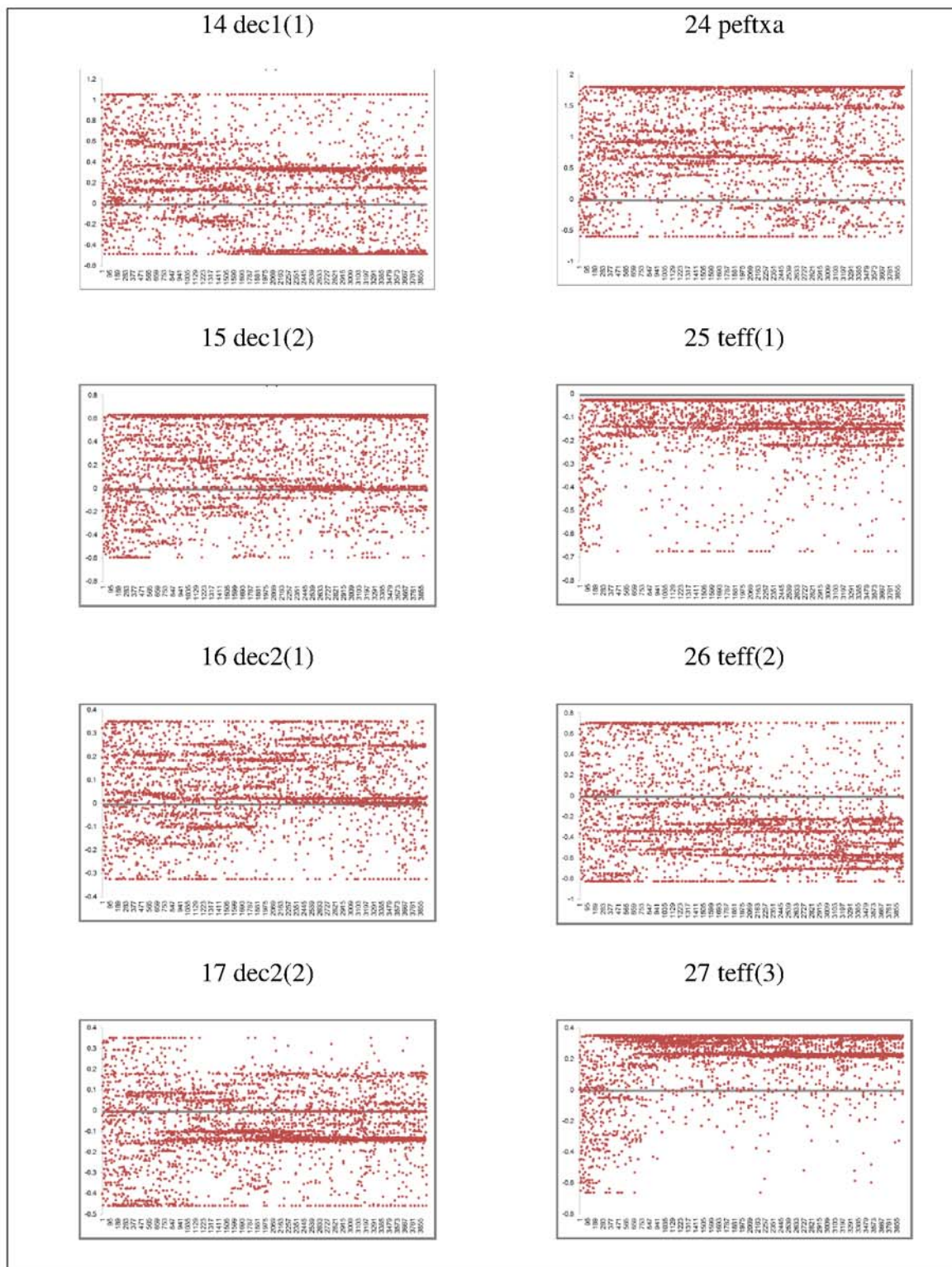
Appendix J DayCent parameter\* Sampling by AMALGAM

\*Parameter values shown are percent changes from default value.

**crop.100 parameters:**

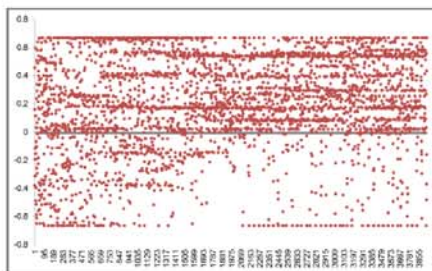


## fix.100 parameters:

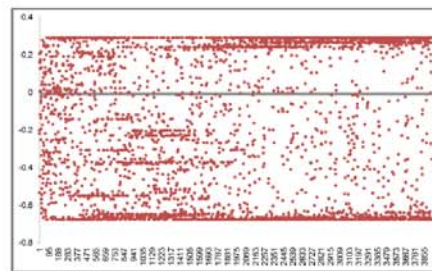




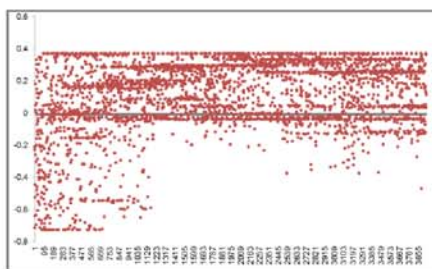
18 dec3(1)



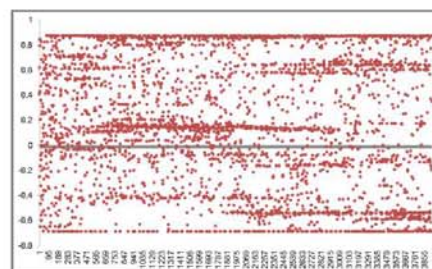
28 teff(4)



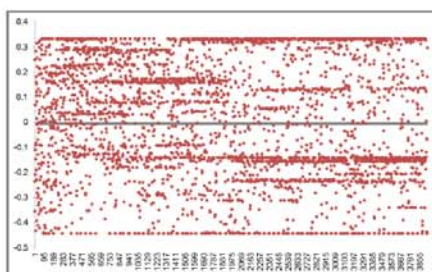
19 dec3(2)



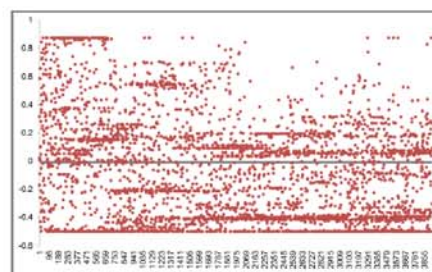
29 varat11(1,1)



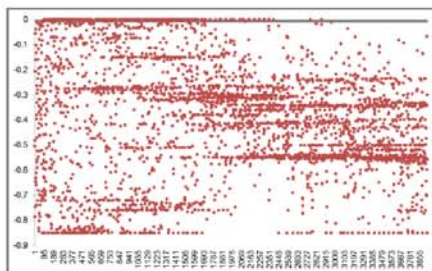
9 dec4



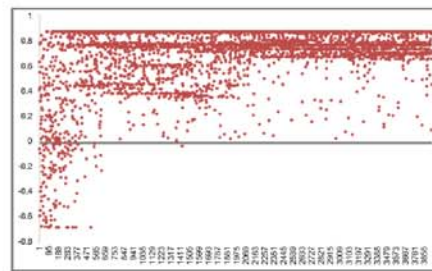
30 varat11(2,1)



20 dec5(2)



31 varat12(1,1)

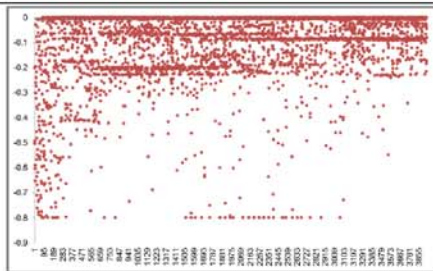


21 fleach(3)

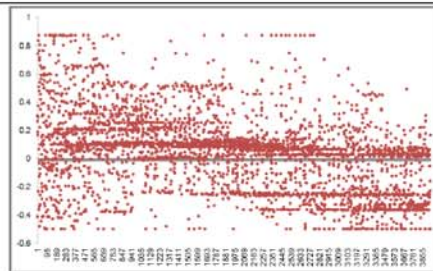


32 varat12(2,1)

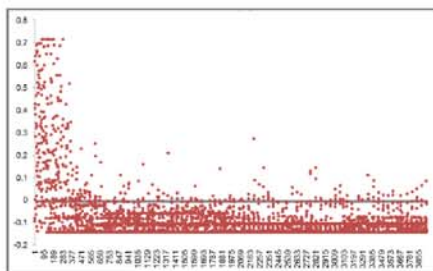




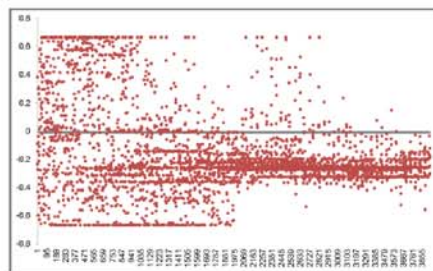
22 fwloss(4)



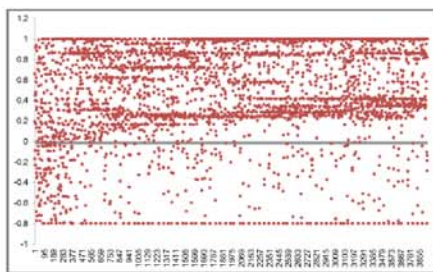
10 aneref(2)



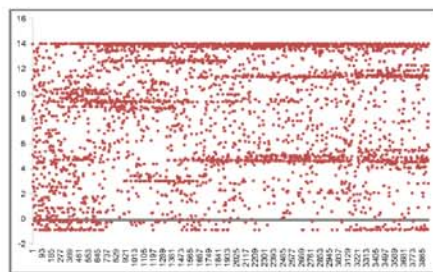
11 aneref(3)



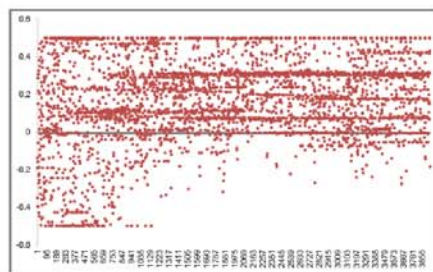
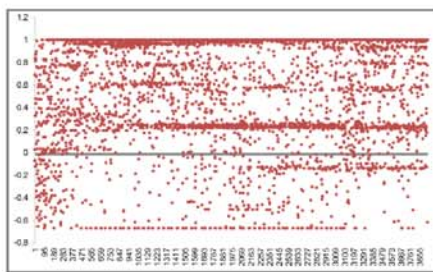
12 damr(2,1)



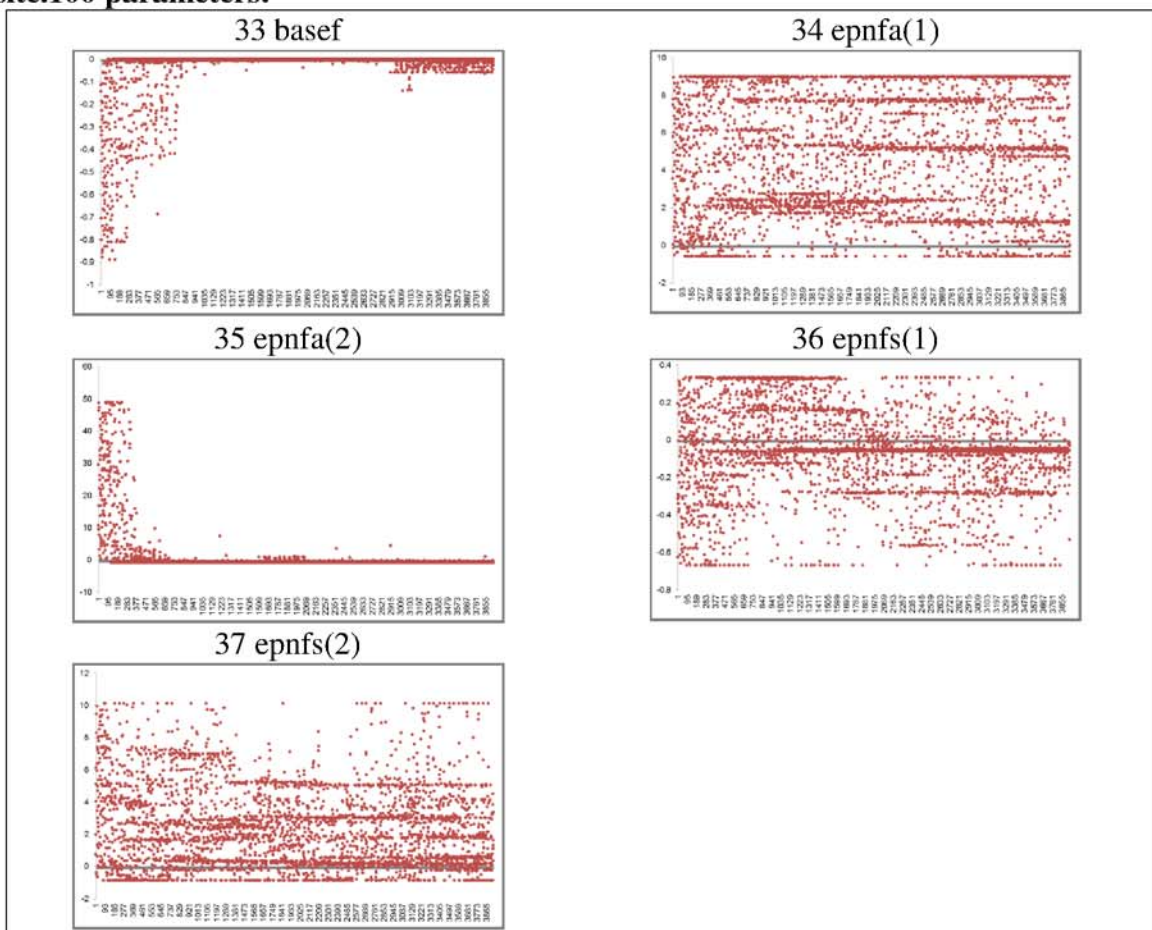
13 damrmn(1)



23

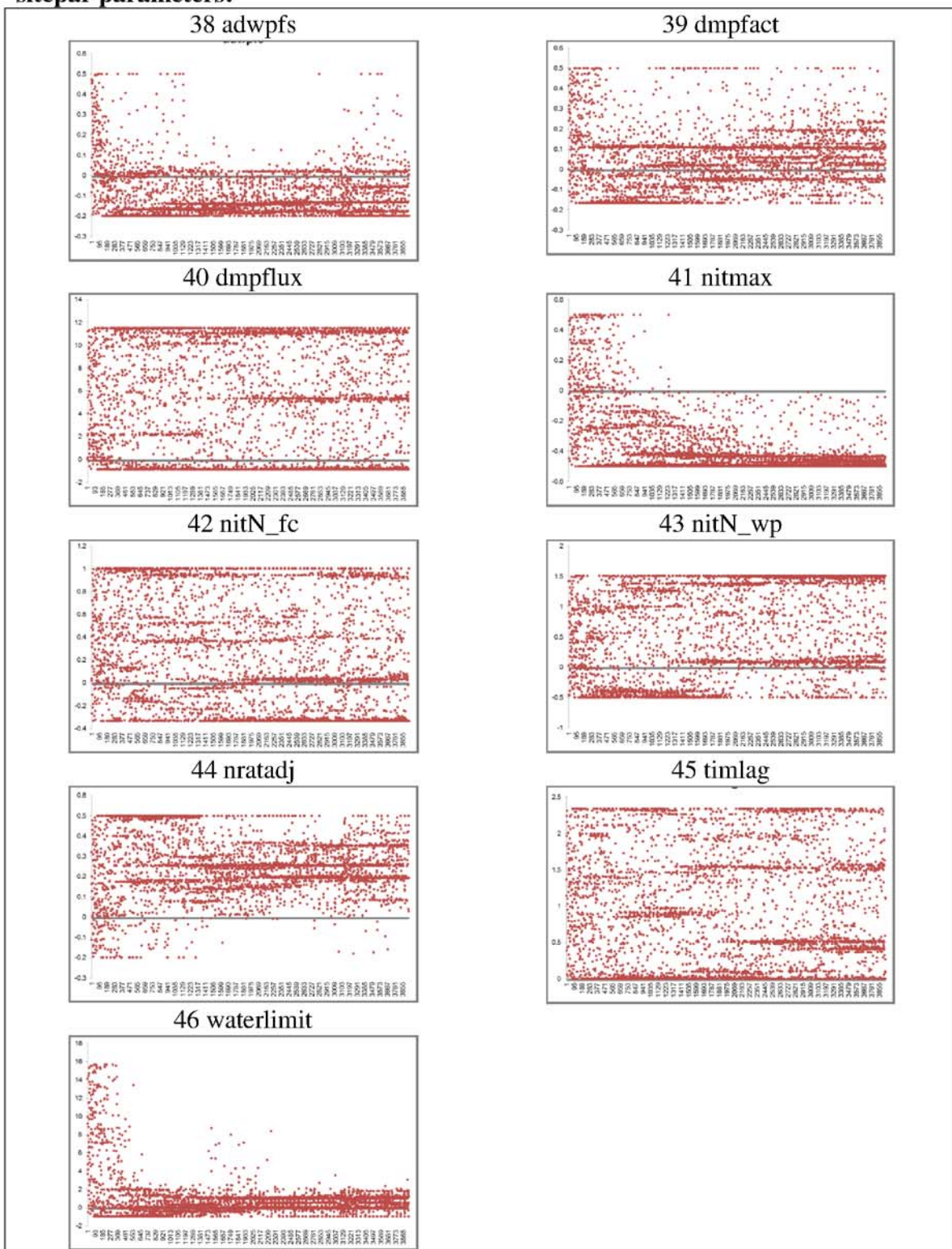


## site.100 parameters:





## sitepar parameters:



Appendix K Table of individual author contributions to Chapter 5 work.

Individual author percent contribution		Rebecca Logsdon	Margaret Kalcic	Elizabeth Trybula
Overall Project	Project Component			
	Study Design & Coordination	33	33	33
	Final Paper on Interviews & Surveys	50	30	20
Interviews	Data Collection & Entry	0	100	0
	Data Synthesis & Analysis	5	90	5
	Write-Up & Ending	10	80	10
Surveys	Data Collection & Entry	40	30	30
	Data Synthesis & Analysis	60	20	20
	Write-Up & Ending	40	35	25



## Appendix L Farmer survey

**Appendix L. Farmer survey**

1. Do you know what an "ecosystem" is?  Yes  No

2. Have you heard of the term "ecosystem services"?  Yes  No

3. What would you guess that "ecosystem services" means?  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

4. Please check the conservation practices on your farm: (check all that apply)

<input type="checkbox"/> Riparian buffer	<input type="checkbox"/> Filter strips	<input type="checkbox"/> Wetland
<input type="checkbox"/> Grassed waterways	<input type="checkbox"/> Two-stage ditch	<input type="checkbox"/> No-till
<input type="checkbox"/> Nutrient management	<input type="checkbox"/> Cover Crops	<input type="checkbox"/> None
<input type="checkbox"/> Others _____		

5. Please check all federal or state conservation programs you have participated in: (check all that apply)

<input type="checkbox"/> Environmental Quality Incentives Program (EQIP)
<input type="checkbox"/> Conservation Reserve Program (CRP)
<input type="checkbox"/> Conservation Reserve Enhancement Program (CREP)
<input type="checkbox"/> Wetlands Reserve Program (WRP)
<input type="checkbox"/> Wildlife Habitat Incentives Program (WHIP)
<input type="checkbox"/> None of the above <input type="checkbox"/> Others _____

6. Where do you get information when making farm management decisions? (check all that apply)

<input type="checkbox"/> Extension	<input type="checkbox"/> Other farmers	<input type="checkbox"/> Farm Service Agency
<input type="checkbox"/> Internet	<input type="checkbox"/> Newspapers	<input type="checkbox"/> Private crop advisor
<input type="checkbox"/> Radio	<input type="checkbox"/> Soil and Water Conservation District	
<input type="checkbox"/> NRCS (Soil or District Conservationist)		
<input type="checkbox"/> Other: _____	<input type="checkbox"/> None of the above	

7. Do you consider yourself to be conservation-minded in your views of agricultural production?  
 Yes  No  Mostly  Somewhat  Unsure

8. What county/counties do you farm in Indiana?  
 \_\_\_\_\_

9. Approximately how many acres do you farm?  
 \_\_\_\_\_

10. Please check the crops you produce: (check all that apply)

<input type="checkbox"/> Corn	<input type="checkbox"/> Soybeans	<input type="checkbox"/> Wheat	<input type="checkbox"/> Hay	<input type="checkbox"/> No crops
<input type="checkbox"/> Specialty crop: _____	<input type="checkbox"/> Other: _____			

11. Do you have any livestock on your farm? (check all that apply)

<input type="checkbox"/> Dairy cattle	<input type="checkbox"/> Beef cattle	<input type="checkbox"/> Hogs	<input type="checkbox"/> Poultry
<input type="checkbox"/> Sheep	<input type="checkbox"/> Goats	<input type="checkbox"/> None	
<input type="checkbox"/> Other _____			

12. How many years have you farmed officially in the area?  
 \_\_\_\_\_

13. Did you grow up on a farm?  Yes  No  Prefer not to answer

14. Would you be more willing to implement conservation practices if you knew how they benefited your farm's ecosystems?  
 Yes  No  Potentially

15. What resources would you consult for information about the environmental benefits on your farm? (check all that apply)

<input type="checkbox"/> Articles in farm or other magazines that I read
<input type="checkbox"/> Online or farm-specific calculators
<input type="checkbox"/> Conversations with publicly funded professionals (e.g., Extension services, NRCS conservationists, SWCD technical staff)
<input type="checkbox"/> Conversations with private/industry professionals (e.g., crop advisors)
<input type="checkbox"/> Other: _____ <input type="checkbox"/> None

16. Gender:  M  F  Prefer not to answer

17. Age:  < 25  25-34  35-44  45-54  55-65  65+  Prefer not to answer

18. Which best describes your work?  Farm owner  Farm operator  Owner & operator  Other: \_\_\_\_\_

19. Do you identify as a racial minority?  
 Yes  No  Prefer not to answer

0 CROPLANDS – think of the croplands in your town and in the state of Indiana, and answer the following questions

1

CROPLANDS...	20. How often do croplands provide the following benefits to society?			21. If you just checked always or sometimes, how valuable is this benefit (from croplands) to you?			22. Check each box for those who benefit from croplands	23. Check each box for those who should be responsible for maintaining cropland benefits
	Always	Sometimes	Never	Very Valuable	Somewhat Valuable	Not Valuable		
...provide food	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Society	<input type="checkbox"/>
...provide a "sense of place"	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Local gov't	<input type="checkbox"/>
...regulate erosion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	State gov't	<input type="checkbox"/>
...provide fuel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Fed. gov't	<input type="checkbox"/>
...provide medicines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Local community	<input type="checkbox"/>
...give opportunities for recreation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Farm operator	<input type="checkbox"/>
...inspire spiritual connection	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	No one	<input type="checkbox"/>
...provide fresh water	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Other (fill in blank)	<input type="checkbox"/>
...reduce flooding	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	24. Of the list above, who is most responsible for maintaining benefits from croplands?	<input type="checkbox"/>
...are aesthetically pleasing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...maintain species diversity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...provide plant fibers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...reduce soil loss	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...provide genetic resources	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...regulate local climate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
...provide clean air	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

Please provide us with any comments, questions, or suggestions you have in the blank space below!

**THANK YOU!!**

VITA

## VITA

**EDUCATION**

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Ph.D., Agricultural & Biological Engineering, Purdue University, 2015  
GPA: 3.9/4.0  
M.S., Agricultural & Biological Engineering, Purdue University, 2011  
GPA: 4.0/4.0  
B.S., Biological Engineering, University of Arkansas, 2009  
GPA: 3.9/4.0; minors in geology and mathematics

**EMPLOYMENT HISTORY**

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*Postdoctoral Fellow*, University of Michigan, 2015-present  
*National Science Foundation Graduate Research Fellow/Research Assistant*,  
Agricultural & Biological Engineering, Purdue University, 2009-2014  
*Engineering Intern*, Ecological Design Group, Little Rock, Arkansas, 2009  
*GIS Assistant*, Center for Advanced Spatial Technologies, University of Arkansas,  
2008-2009  
*Undergraduate Researcher*, Biological Engineering, University of Arkansas, 2006-  
2009

**EXPERTISE**

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Logsdon's primary research focus is on developing quantitative methods to assess ecosystem services. She utilizes environmental models such as the Soil and Water Assessment Tool and the DayCent carbon model, when necessary to enable scenario and trade-off analyses. She also utilizes field and lab data, along with statistical methods to improve ecosystem service quantification. Secondary research interests for Logsdon include the assessment of the applicability of the ecosystem service framework and the incorporation of citizen science data in ecosystem service assessments. Her dissertation research was interdisciplinary including studies related to the assessment of aquatic genetic resource provisioning (fish populations), climate regulation/change, and assessing farmers' perceptions of ecosystem surveys through surveys and focus groups.

## PUBLICATIONS

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- Logsdon RA**, Kalcic MM, Trybula EM, Chaubey I, Frankenberger J. 2015. Ecosystem services and Indiana agriculture: Farmers' and conservationists' perceptions. *International Journal of Biodiversity Science, Ecosystem Services & Management*. *In press*. doi: 10.1080/21513732.2014.998711.
- Logsdon RA** 2015. Development and application of quantitative methods for ecosystem services. Ph.D. dissertation, Purdue University, West Lafayette, IN.
- Logsdon RA**, Chaubey I. 2013. A quantitative approach to evaluating ecosystem services. *Ecological Modelling*, 257, p. 57-65.
- Logsdon RA**, Chaubey I. 2012. Ecosystem services: A need to move from concept to application. *Resource*, Vol. 19, No. 3, p. 31.
- Logsdon RA**. 2011. Development of quantification methods for ecosystem services. M.S. thesis. Purdue University, West Lafayette, IN.
- Logsdon RA**, Bajwa, S.G. 2009. Development of a distributed artificial neural network for hydrologic modeling. *Inquiry Undergraduate Research Journal*, Vol 10, p. 49-54.

## MANUSCRIPTS IN REVIEW OR PREPARATION

---

- Grady C, **Logsdon RA**, Groh JL, Kahn J, Wiesner V, Oogebule S. (*In Review*). Mentoring strategies to promote student retention and support of graduate women engineering students: Assessment of a model program. *Advances in Engineering Education*.
- Logsdon RA**, Bowling LC, Peel S, Turco RF, Haas MH. (*In prep*). The Wabash Sampling Blitz: A Case Study of the Effectiveness of Citizen Science. *Citizen Science Theory and Practice*.
- Goforth RR, **Logsdon RA**, Keitzer SC, Raj C, Beugly J, Chaubey I. (*In prep*). From Microcosms to Landscapes: Predicting Stream Fish Site Occupancy Based on Soil and Water Assessment Tool (SWAT) Suspended Sediment Estimates. *Ecological Applications*.
- Dennedy-Frank PJ, **Logsdon RA**, Chaubey I, Ziv G. (*In prep*). Ecosystem service assessments for water resources decisions: A comparison of two tools. *Journal of Environmental Management*.
- Logsdon RA**, Omani N, Srinivasan R, Chaubey I. (*In prep*). The future of ecosystem services in the Upper Mississippi River Basin. *Transactions of the ASABE*.
- Logsdon RA**, Pyron M, Sharma S, Chaubey I. (*In prep*). Evaluating possible drivers of a fish regime shift using the SWAT model: A case study of the Wabash River. *Freshwater Biology*
- Logsdon RA**, Brouder S, Gramig B, Chaubey I. (*In prep*). Evaluation of climate regulation ecosystem services utilizing a multi-objective genetic algorithm calibration. *Ecological Modelling*.

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**PRESENTATIONS AT NATIONAL CONFERENCES**


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- Logsdon RA**, Denedy-Frank PJ, Chaubey I, Ziv G. Ecosystem service assessments for water resources management: A comparison of two tools. A Community on Ecosystem Services. Washington, D.C. Dec. 8-12, 2014.
- Logsdon RA**, Chaubey I, Zhang Y. Evaluation of ecosystem services under varying climate and grazing scenarios: Three Rivers Source Region, China. A Community on Ecosystem Services. Washington, D.C. Dec. 8-12, 2014.
- Logsdon RA**, Kalcic MM, Trybula EM, Chaubey I, Frankenberger JR. Assessing farmer understanding of agricultural ecosystem services. A Community on Ecosystem Services. Ft. Lauderdale, Fl. Dec.10-12, 2012.
- Logsdon RA**, Chaubey I. A quantitative approach to evaluating ecosystem services. A Community on Ecosystem Services. Ft. Lauderdale, Fl. Dec. 10-12, 2012.
- Logsdon RA**, Payne LB, Peel S, Heller MH, Turco RF. The Wabash sampling blitz: Engaging over 600 volunteers in water quality sampling. Public Participation in Scientific Research. Portland, OR. Aug. 4-5, 2012.
- Logsdon RA**, Faust KM, Wiener MJ, Groh JL. Engineering global solutions to water scarcity: A model outreach program for middle school students. WEPAN Annual Meeting, Columbus, OH, Jun. 25-27, 2012.
- Logsdon RA**, Raj C, Maringanti C, Chaubey I, Engel, B. Development of a quantification method for ecosystem services using landscape models. ASABE Annual International Meeting. Pittsburgh, PA. Jun. 20-23, 2010.
- Logsdon RA**, Chaubey I, Gramig B. Development of a methodology to quantify ecosystem services using landscape models. A Community on Ecosystem Services. Gila River Indian Community near Phoenix, AZ. Dec. 6-9, 2010.
- Logsdon RA**, Bajwa SG, Vibhava V. Development of a distributed artificial neural network for hydrologic modeling. 7th World Congress on Computers in Agriculture. Reno, NV. Jun.21-24, 2009.

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**SELECTED PRESENTATIONS AT REGIONAL & LOCAL CONFERENCES**


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- Logsdon RA**, Payne LB, Peel S, Heller MH, Turco RF. 2013. Evaluation of volunteer-collected water quality data to target management strategies. Wabash River Conference. Indiana University-Purdue University, Indianapolis, IN. Dec. 13, 2013.
- Logsdon RA**, Payne LB, Peel S, Haas MH, Bowling LC, Turco RF. The Wabash sampling blitz: Engaging the local community around the Wabash River. The 34th Annual Indiana Water Resources Association Spring Symposium, "The State of the State's Waters". Ball State University, Muncie, IN. Jun. 19-21, 2013.
- Logsdon RA**, Fitzpatrick V, Arentson E, Davis Z, Hands M, Kahn J, Weeks F, Young K, Groh JL. Introducing engineering through the food life cycle to middle school students. P-12 Engagement Summit. Purdue University, West Lafayette, IN. Mar. 1, 2011.

### **SELECTED COMMUNITY TEACHING & OUTREACH EXPERIENCE**

---

- *Education Committee Member*, Wabash River Enhancement Corporation, IN. 2010-2014  
I helped plan and organize community outreach programming, materials, and events including Paint the Rain and the Wabash Sampling Blitz.
- *Introduce a Girl to Engineering Day*, Women in Engineering, Purdue Univ., 2011-2014  
Developed a presentation as well as hands-on activity to introduce high school girls to environmental and ecological engineering.
- *Access Engineering*, Women in Engineering, Purdue University, 2013  
I helped teach K-12 students about engineering through hands-on activities during summer camps.
- *4H Career Day Round-Up & National 4H Engineering Workshop*, Purdue University. 2013. Designed a hands-on activity related to engineering, water quality, and agriculture to help introduce high school students to agricultural and biological engineering. 2013
- *Innovation to Reality*, Women in Engineering, Purdue University, 2009-2013  
Curriculum planner, organizer and volunteer for program that was an introduction to engineering for local 6-8th graders. Designed hands on activities to introduce engineering through themes such as water, food, and natural disasters.

### **SELECTED CAMPUS & COMMUNITY LEADERSHIP ACTIVITIES**

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- Chair-Elect and Reviewer, ASABE Robert E. Stewart Engineering Humanities Award Selection Committee, 2012-present
- Leadership Team Member, Women in Engineering Graduate Mentoring Program, Women in Engineering Program, Purdue University, 2010-2013
- President, Purdue Graduate Student Government (served on University Senate, Graduate Council, University Resource Policy Committee, Library Dean's Advisory Council, Purdue-West Lafayette Community Partnership Team), Purdue University, 2011-2012
- Graduate Student Liaison, City of West Lafayette, IN, 2010-2012

## SELECTED GRANTS, HONORS, AND AWARDS

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- *National Science Foundation Graduate Research Fellowship* (\$90,000+) 2009
- *Robert E. Stewart Engineering and Humanities Award*, American Society of Agricultural and Biological Engineers, 2011
- **Logsdon, R.A.**, Kalcic, M.M., Trybula, E.M.. 2011. “Engaging farmers to improve communication and model representation of agricultural ecosystem services.” *North Central Region Sustainable Agriculture Research & Education (NCR-SARE), Graduate Student Grant*. (\$10,000)
- *France A. Córdova Leadership in Action Award*, Purdue University, 2014
- *ABE Outstanding Service Award*, Purdue University College of Engineering, 2014
- *Emily M. Wadsworth Graduate Mentoring Award*, Women in Engineering Program, Purdue University, 2012
- *D. Woods Thomas Memorial International Support Fund* (\$1,000), College of Agriculture, Purdue University, 2014
- *Travel Award* (\$750), 2012 Public Participation in Scientific Research conference in Portland, OR, August 4-5, 2012
- *Frederick Andrews Environmental Travel Grant*, Purdue University (\$1,500), 2010 & 2014
- *Travel Grant*, Purdue Graduate Student Government (\$1,000), 2012

## PROFESSIONAL DEVELOPMENT & CERTIFICATIONS

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- Catalyzing Advocacy in Science & Engineering (workshop). American Association for the Advancement of Science (AAAS), Washington, D.C., March 31-April 2, 2014.
- Demonstration of InVEST: A Decision Support Tool for Valuing Nature (workshop). A Community on Ecosystem Services, Ft. Lauderdale, FL, December 10, 2012.
- Foundations of Organizational Ombudsman Practice, International Ombudsman Association. Lake Buena Vista, FL, July 16-20, 2012. Received Certificate of Foundations of Organization Ombudsman Practice.
- Century/DayCent Training Workshop, National Resource Ecology Laboratory. Colorado State University, Ft. Collins, CO, December 12-16, 2012

## COMPUTER PROGRAM EXPERIENCE

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ArcGIS, Soil and Water Assessment Tool (SWAT), DayCent/Century, R, InVEST, Python, FRAGSTATS, SAS, Microsoft Office Suite