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Long term effect of poultry manure application on water quality, yield under a corn-corn system in Iowa

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Long term effect of poultry manure application on water quality, yield under a corn-corn system in Iowa

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Agricultural and Biosystems Engineering

Program of Study Committee:
Michelle Soupir, Major Professor
Rameshwar Kanwar
Huaiqing Wu

Iowa State University

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NOMENCLATURE

ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
EPA	Environmental Protection Agency
GDD	Growing Degree Day
IEM	IOWA Environmental Mesonet
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MLR	Multiple Linear Regression
NPS	Non-point Source
NUE	Nitrogen Use Efficiency
PM	Poultry Manure
TAN	Total Ammonia Nitrogen
TMDL	Total Maximum Daily Load
UAN	Urea Ammonia Nitrogen
WSS	Web Soil Survey

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ABSTRACT

Nitrogen (N) and Phosphorus (P) are primary nutrients required for plant growth, but agricultural nitrogen and phosphorous losses through tile drainage systems pollute downstream waters. The objectives of this study were to assess the effects of poultry manure (PM) application to continuous-corn cropping system on nitrogen and phosphorous losses and crop yields from 2010 to 2014. Soil test sampling at 0 – 15 cm and 15 – 30 cm depth were collected each spring, prior to fertilizer application which included poultry manure at 112 kg · ha^{-1} (PM), poultry manure at 224 kg · ha^{-1} (PM2), and urea ammonia nitrogen at 224 kg · ha^{-1} (UAN). Water samples were collected from drainage tiles weekly and following precipitation during the research period (2010-2014) with tile drainage flow recorded by Neptune T-10 meters. PM (7879 kg · ha^{-1}) and PM2 (8756 kg · ha^{-1}) application rates resulted in significantly greater yields, without considering the impacts of phosphorous and other micro nutrients. PM2 applications rate resulted in greater corn yield while at the same time contributing similar NO_3-N load (43.4 kg · ha^{-1}) and concentration (38.7 mg · L^{-1}) to tile waters in comparison with UAN (51.9 kg · ha^{-1}, 43.5 mg · L^{-1}). The PM application resulted in lower NO_3-N load (13.8 kg · ha^{-1}) and concentration (13.5 mg · L^{-1}) and larger crop yield than UAN. UAN treatment had lower PO_4-P load (0.017 kg · ha^{-1}) and concentrations (0.004 mg · L^{-1}) when compared to the PM (0.027 kg · ha^{-1}, 0.01 mg · L^{-1}) and PM2 (0.029 kg · ha^{-1}, 0.019 mg · L^{-1}) treatments. PM was found to be the best treatment for both acceptable crop yields and the lowest nutrient losses with the NO_3-N concentration closest to the 10 mg • L^{-1} NO_3-N MCL of drink water set by the U.S. EPA.

CHAPTER I: GENERAL INTRODUCTION

1.1 Introduction

Iowa, U.S. leads national agricultural production of commodities including corn, soybeans, and eggs (USDA-NASS, 2015). Approximately 1.2 billion pounds of poultry manure was generated every year from 2010 to 2014, with an average 2.5% annual increase. Due to the increase in poultry production in recent years, great opportunities as well as big challenges accompany the fast expansion of the poultry industry. Land application of manure is regarded as a good solution to reuse the manures generated each year (Moore et al., 1995). Poultry manure, though, is thought to be valuable and economical as an organic fertilizer from poultry industry in Iowa and other regions in the U.S. Poultry manure application may also contribute to non-point source pollution (NPS). Risks of water body impairments do exist, especially when over-application of fertilizer occurs frequently due to the desire to ensure sufficient fertilizer for increased crop yields (Power et al., 2000).

Nitrogen and phosphorous are important for plant growth but also recognized as important NPS pollutants. In the Upper Midwestern U.S., nitrate primarily enters waters through subsurface leaching while the majority of phosphorous export is thought to be associated with surface runoff and sediment. Bundy and Andraski (2005) found that about half of the Nitrogen applied to the soil is subject to leaching into groundwater. Studies have been conducted to determine the environmental mechanism affecting the N leaching, such as cropping systems, hydrology, or fertilization rate (Hansen and Djurhuus, 1996; Morecroft et al., 2000; Bakhsh et al., 2002). Indicators such as Nitrogen Use Efficiency (NUE) are used to determine whether fertilizer is applied efficiently (Duan et al., 2011). Phosphorous is the primary cause of eutrophication in freshwaters. Except for sediment movement, Madison et al. (2014) revealed the variability on a watershed-by-watershed basis of phosphorous contribution from tile drainage. For Iowa, a state where subsurface drainage systems are widely implemented on farm land aiming for better yields, the risk of nitrate and phosphorous leaching to tile drainage systems is high. Studies have revealed nutrient losses from agricultural land through the drainage systems. Among them the nitrate concentrations measured are reported in the range of 10 mg • L^{-1} to 70 mg • L^{-1} (Hansen and Djurhuus, 1996; De Vos et al., 2000; Dinnes et al., 2002; Kladivko et al., 2004). Effort to restrain the nitrogen and phosphorous losses which is excessively entering the waterbodies, water quality criteria such as Maximum Contaminant Level (MCL) and Total Maximum Daily Load (TMDL) are under development, especially for specific water bodies in specific areas of the country. In the U.S., the MCL for nitrate nitrogen in drinking water is set at 10 mg • L^{-1} (EPA, 2015).

Crop rotation is also an important factor related to nutrient losses. Dinnes et al. (2002) pointed out that decreasing the diversity in crop rotations is one of the primary management strategies leading to increased nitrate leaching. Randall et al. (1997) found that corn-soybean rotation systems leach smaller amounts of nitrate than a corn-on-corn system; however, the amount of reduction depends on climate. None-controllable factors such as weather conditions, known to affect flow, has a profound influence on nitrate N concentration and loads in subsurface drainage systems (Randall and Mulla, 2001). Different nitrate concentrations are found between wet years and dry years (Morecroft et al., 2000). As hydrology varies greatly from year to year, long term studies are needed to better understand these trends. Further, much of previous work on this topic is typically completed within a three year period, while a limited number of studies consider the long-term effect of hydrology (Benbi and Biswas, 1996; Hansen and Djurhuus, 1996; Kladivko et al., 2004; Zhang et al., 2009). Considering the many factors which influence nutrient fate and transport, the goal of this study is to define the effect of poultry manure application and hydrology on water quality and yield under a corn-corn cropping system.

1.2 Objectives

Considering the many factors which influence nutrient fate and transport, the goal of this study is to define the effect of poultry manure application and hydrology on water quality and yield under a corn-corn cropping system. The specific objectives are:

1. To determine how different application rates of poultry manure affect crop yield in comparison to commercial fertilizer.

2. To determine how different application rates of poultry manure affect tile drainage NO_3-N and PO_4-P load in comparison to commercial fertilizer.

3 To determine how different application rate of poultry manure affect tile drainage NO_3-N and PO_4-P concentration in comparison to commercial fertilizer

CHAPTER II: LITERATURE REVIEW

For decades, humans have dedicated research to manure, from subjects covering both economic and environmental aspects, including increasing the crop yield, decreasing the cost of fertilization from the economic aspects, and decreasing NPS pollution from the environmental aspect. This section is a review of work done in recent decades about manure, with an emphasis on poultry manure, guided by the research objectives.

2.1 Economic Considerations of Manure Utilization

Iowa leads the nation in the agricultural production of corn, soybeans, and eggs (UADA-NASS, 2014). About 1.2 billion pounds of poultry manure were generated every year during 2010 to 2014, with an average 2.5% annual increase (USDA-NASS, 2015). About 2.3 million Mg poultry manure were generated in Iowa poultry production area in 2007 (Nguyen et al., 2013). Due to the increases poultry production in recent years, opportunities and big challenges are developing along with the fast expansion of the poultry industry.

2.1.1 Solution of poultry manure disposal

Land application is regarded as a good solution to process the manures generated each year (Moore et al., 1995; Edwards and Daniel, 1992). Compared with traditional synthesis of fertilizer, manure is rich in many of the necessary nutrients for crop production (N, P and K).

2.1.2 Crop yields improvement

Improvements in crop yields under manure application is the goal of both farmers and researchers. Studies have reported a yield increase in many different crops, including Bermuda grass, corn, fescue, orchard-grass, rice, and wheat under application of poultry litter (Edwards and Daniel, 1992; Wood, 1992). This increase of yield is attribute to the rich nutrients, especially N and P in poultry manure. Though positive effects on farming were found, researches comparing yields under applying manure and applying traditional synthetic fertilizer are limited. A farming system with nutrient sources from synthetic fertilizers limited is known as organic farming system. An organic farming system with manure application reported an average of 27% decrease in yield under 47% less N application rates compared with the inorganic farming system (Kirchmann and Bergström, 2001). In China, manure with additional P application was reported to be the most efficient nutrient management on corn wheat rotation system, compared with other combinations of different synthetic or organic fertilization (Duan et al., 2011). A 12 year long term research (1998-2009) found that corn yields under corn-soybean rotation system under application of poultry manure was much higher than yields of field applied with urea ammonia nitrogen (Nguyen et al., 2013). However, yield is usually a difficult indicator of comparison. As none of controlling circumstances of the experiments mentioned above were set consistently, conclusions between these studies are incomparable.

2.1.3 Fertilizer efficiency

From the economic perspective, farmers would like to see their fertilizer applied effectively. In other words, producers prefer to pay less for the fertilizer while benefiting from higher yields. When it comes to scientists, the word “efficiency” as used in the literature usually refers to producing similar crop yields when applying smaller amount of fertilizer, where nutrient or element economic is considered. Although it is mentioned quite frequently, this concept is quite obscure, as it is not a model or a physical variable that can be calculated. Indicators are necessary to interpret the efficiency of a specific fertilizer or a method of fertilization management. Nitrogen Use Efficiency (NUE) and nitrogen availability are two parameters often referred to in the literature when selecting fertilizer or working on management comparison ((Iowa State University Extension, 2008; Duan et al., 2011).

Many factors can affect the fertilizer efficiency, including manure quality, land application management, soil conditions, and environmental factors like weather. Manure quality, the composition of manure, is further affected by several variables, including the type and amount of bedding material used, accumulation time, feed, amount and quality of water used to flush the house, location in a storage pit at which the manure is removed, and length of storage before land application (Edwards and Daniel, 1992). In order to regular the amount of nutrient applied, a rough manure analysis is generally done for manure quality on its moisture content, total nitrogen, ammonium nitrogen and total phosphorous for an estimate of application rate. Researchers have found that a higher dry matter (DM), higher soil initial pH and higher per unit of TAN (Total Ammonia Nitrogen) applied, tend to positively affect ammonia volatilization (Sommer and Christensen, 1991; Sommer and Olesen, 1991; Menzi et al., 1997), a step of nitrogen emission which would indirectly negatively affect the manure efficiency. However, neither DM (Dry Matter) nor initial pH is regularly measured. Because of the huge variability of nutrient content in manure, manure analysis should be used as a guideline only (Moore et al., 1995).

Land application management is also well researched because of its importance in affecting the fertilizer efficiency. Researches have covered manure application timing and field earth work like tillage. Early spring manure application was reported to lead to nitrogen release in advance of crop uptake (Durieux et al., 1995). Higher nitrogen efficiency was found from spring manure slurry fertilizer application than from fall applied slurry (Smith and Chambers, 1995). Timing is also considered to affect ammonia volatilization (Meisinger and Jokela, 2000), which will affect the manure efficiency as well. Broadcasting is thought to be the simplest method in manure application. However, application manure before or during the tillage would promote the crop utilization of nutrient and benefit the fertilizer efficiency. Meisinger and Jokela (2000), also mentioned a merely small percentage of nitrogen loss through volatilization when manure is injected or incorporated immediately into the soil as it’s applied.

Soil chemical properties like pH can affect fertilizer efficiency. In order to avoid over application of phosphorous, a soil test P based might be done. Soil and soil test research is usually comparable and valid within a single state. Comparison of three different methods of soil phosphorous test was done, reporting the most frequent choice in Iowa that the Bray test for all samples and the Olsen only for samples with high pH (Sawyer and Mallarino, 1999), so that the accuracy of soil test is improved resulting in an avoidance of over-application of nutrients. Besides, soil tests recommend the residual effect of nutrient applied and may lead to a decreasing initial fertilizer application in the following years (Moore et al., 1995). However, though it adds efficiency for fertilization, soil test may add a burden to the farmers.

Environmental factors as well are reported to relate to the fertilizer efficiency. Sommer et al. (1991) found that increased temperature, higher wind speed and rainfall soon after manure application would respectively increase, increase and decrease the volatilization of manure.

2.2 Environmental Consideration of Manure Utilization

Though poultry manure is thought to be valuable and economical as an organic fertilizer as well as a solution for the poultry industry in Iowa and other regions in the U.S., potential negative impacts of poultry waste disposal related to non-point source (NPS) pollution must be addressed. Risk of water quality impairment exist especially when over application of fertilizer occurrs frequently due to the eagerness of applying sufficient fertilizer for higher yield to all crop fields (Power et al., 2000).

One of the cardinal problems with manure over application is nitrate leaching into the water. In 1974, the US Congress passed the Safe Drinking Water Act Law which requires EPA to determine the level of nitrate in drinking water at which no adverse health effects such as shortness of breath and blue baby syndrome are likely to occur. The non-enforceable maximum contaminant level goal (MCLG) was set at 10 mg/L or 10 ppm for nitrate under that situation based on the health concern. Maximum contaminant level (MCL), which is 10 mg/L, is set to be as close to the maximum contaminant level goal as possible considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies, became effective in 1992 (US EPA). As for the other nutrient losses in water, phosphorous, there is no uniform standard of drinking water phosphorous at the state or national level. Instead of the uniform MCL, total maximum daily loads (TMDL) of phosphorous, which have higher flexibility and variability, are set on an individual watershed basis for streams, rivers and lakes.

2.2.1 Effect of manure application on nitrate leaching

The process of land management usually affects the manure application on its efficiency as well as the nutrient losses. Van Es et al. (2006) found that most of the urea and NH_4 would convert to NO_3-N under circumstance of sufficient incorporation, which makes nitrogen source plant available or subject to leaching. Early spring manure application was found to lead to an early timing of NO_3-N release in advance of crop uptake (Durieux et al., 1995), which may lead to leaching. A 3-year study on how manure application timing as well as cropping systems affect N losses was conducted on 2 soils, a Muskellunge clay loam and a Stafford loamy sand. The results showed that NO_3-N concentrations measured from different treatments (application varied among different timings) follow the application timing order: early fall> late fall> early spring=both early spring and late spring (Van Es et al., 2006).

2.2.2 Effect of other factors on nitrate leaching

In addition to manure application, other factors may affect the nitrate leaching. Similar to manure application, soil management (e.g. tillage) affect the nitrate leaching from fields receiving commercial fertilizer application. A randomized complete design within chisel plow vs. no tillage under two different treatments, pre-plant injected urea ammonium nitrate solution (UAN) at 110 kg · ha^{-1} and late–spring N application at 179 and 156 kg · ha^{-1} respectively found that nitrogen loss from chisel plow plots were 16% less, and late–spring N application leaches 25% lower nitrate nitrogen (Bakhsh et al., 2002), which is a similar finding as nitrate leaching affected by manure application timing and incorporation. However, Weed and Kanwar (1996) found that nitrate leaching can be most effectively minimized by decreasing the amount of N fertilizer applied, regardless of tillage.

Crop rotation is also one of the most effective factors that would significantly affect nitrate leaching. Many studies of the effect of crop rotation on nitrate leaching have been conducted (Kanwar et al., 1993; Weed and Kanwar, 1996; Randall et al., 1997; Randall and Mulla, 2001), with all showing a significant decrease of nitrate leaching from rotation cropping systems when compared to a continuous corn cropping system.

Yearly variation of nitrate leaching is usually explained by yearly uncontrollable variables. Non-controllable factors such as climate and soil organic matter are found to have a profound influence on nitrate N concentrations and loadings in subsurface drainage water (Randall and Mulla, 2001). Hydrology in the prior year is found to affect the nitrate leaching in the coming year. After 3 years (1995-1997) research at Oxfordshire in southern England, leaching nitrate concentration of all sites was found to rise dramatically following a drought year (Morecroft et al., 2000). Accumulated nutrient in the prior year is found to affect the nitrogen loss in the following year. Baker and Johnson (1981) found that, although NO_3-N concentrations for the higher fertility plot decreased as time went by after the last fertilization, it still took about 3 years until the samples showed no effect of the higher level of fertilization.

2.2.3 Phosphorous loss

Agricultural phosphorus loss is known as the primary reason causing eutrophication in fresh waters ((Sharpley et al., 1994; Carpenter et al., 1998)). Manure application rates are regularly designed based primarily on the management of N to minimize nitrate losses by leaching, under that circumstance, it results in an excessive increase in soil P levels because of the limited N availability (Moore et al., 1995). Manure application based on phosphorous is suggested to mitigate the impairment caused by phosphorous over-application (Wood, 1992); however, additional nitrogen from commercial fertilizer might be required.

Whether phosphorous leaching through tile drainage is the major reason affecting the water area impairment is still under research. Sprague and Gronberg (2012) have concluded that tile drains are not main contributors to watershed P fluxes. A compromised conclusion is given as phosphorous contribution from tiles varies from case to case (Madison et al., 2014).

2.3 Summary

Producers prefer an outcome from manure application that results in both improvement of nutrient efficiency as well as decrease of nutrient losses (or both in opposite way), when compared with traditional commercial synthetic fertilizer application. Because it’s easier to make a decision when advantages (or disadvantage) are shown in both economic and environmental perspectives. Thus, researchers not only focus on the fertilizer efficiency, but also consider nutrient loss when designing the experiments.

It is true that nitrogen loss is somehow correlated with nutrient efficiency, from the angle of mechanism nitrogen transport in soil. The N mechanisms occurring in the soil include mineralization, volatilization, denitrification, and immobilization (Edwards and Daniel, 1992). Once volatilization is reduced by on time tillage or significant rainfall, the part of nitrogen kept from emission will carry on to mineralization and then be utilized by crops or leach, of which the ratio is difficult tell. That is why it is difficult to get both economic and environmental benefits when designing the application rate and management.

Because of the huge variability of manure quality and limitation of parameters in manure tests, experimental circumstances vary from case to case. Although researchers reported their results and values, conclusion are likely to vary from different experimental circumstances. Additionally, the results might be highly affected by those uncontrollable factors such as soil content and climate. In order to avoid the influence of hydrology, there’s a case that an impermeable polyvinyl chloride (PVC) geomembrane was applied surrounding the field plots to make them hydrologically independent (Van Es et al., 2006). This is going to be a challenge as well as a chance. Researches of effects from uncontrollable factors like climate and soil type require long term research period. Comparison between commercial fertilizers and organic fertilizer like manure is under great expectation.

CHAPTER III: Materials and Methods

3.1 Study Site

From 2010 to 2014, field experiments were conducted at field 5 A of the Iowa State University's Agronomy Farm located on US highway 30 between Ames and Boone, Iowa. Components of soil type and slope details are listed below (Figure 3.1, web soil survey). The research plots are located on soils with a Canisteo-Clarion-Nicollet association (Chinkuyu, 2000; Chinkuyu et al., 2002), with 44.4% area Nicollet loam, 45.1% area Clarion loam and the rest the combine of Canisteo silty clay loam and Harps clay loam (Table 3.1), with drainage classifications ranging from well-drained to poorly drained (Web Soil Survey, 2013). The 0 – 30 cm soil for all research plots during the research period range from 1.8 – 4.5% organic matter content. Plot slopes range from 0–6 percent, which roughly supports the assumption of the hydrologic independency of all plots.

A long-term study of the effects of poultry manure on water quality was initiated in 1998, with 11 chisel-plowed plots under a corn-soy rotation (Nygen et al, 2013; Hoover et al., 2015). For 12 years, fertilizers were applied in the spring, only to the half of each plot planted in corn. The center tile drain was taken as a dividing line for planting, with corn planted in the north half part and soybeans in south half part of each plot in even years, while the opposite planting of corn and soybean in odd years (Cheatham, 2003; Nguyen et al., 2013; Hruby, 2014; Hoover et al., 2015). In 2010, all plots were converted to a corn on corn rotation.

Table 0.1 Soil components of field 5 A (WSS, 2015)

Soil type	Area (ha)	Area (%)
Canisteo silty clay loam	0.08	2.5%
Nicollet loam	1.66	44.4%
Harps clay loam	0.28	8.0%
Clarion loam	1.66	45.1%
Total	3.68	100.0%

Figure 0.1 Location of field 5A (in green) and climate station AMES 8 WSW (in red, Lat. 42.0211, Log. -93.7742) at the Iowa State University's Agronomy Farm, Boone, IA.

3.2 Tile Flow Measurement and Precipitation

Subsurface drainage tiles with 10 centimeter diameter were installed 1.2 meters underground through the central of each plot, spaced about 34 meters (Figure 3.2). Sumps with effluent pumps were installed as the outlets at the downstream end of each plot (in red circle). Once the sump is filled by the drainage flow to a specific level, the flow is pumped out to the main tile. The Neptune T-10 flowmeter furnished on the pump take a record in the Hobo Pendant Event Data logger every time there is 14.16 liter (0.5 cubic feet) flow passing through the pump for instantaneous tile flow rates. Flow meters were read roughly weekly from May to August every year. A small fraction of flow is stored in a 20 liter plastic jar for flow-weighted as drainage samples for water quality measurements. More details of the sump construction were given by Kanwar et al. (1988). Precipitation data were gathered from climate station AMES 8 WSW, with latitude and longitude 42.0211, -93.7742 (Figure 3.1), Iowa Environmental Mesonet (IEM) located 0.5 km from field 5 A.

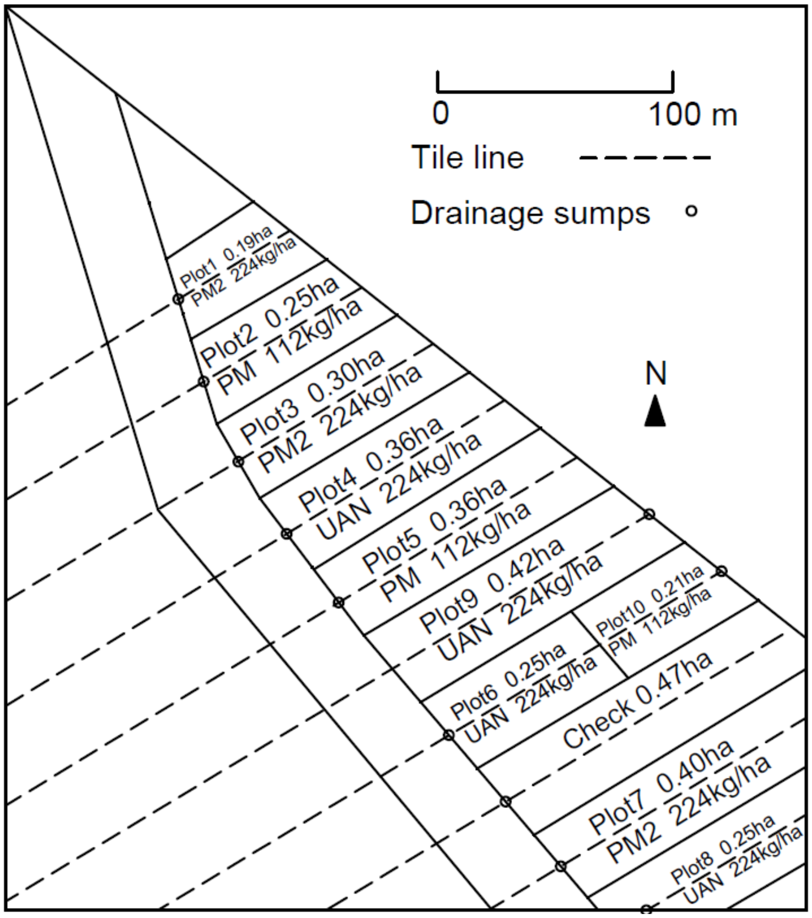

Figure 0.2 Field 5A research site at Iowa State University Agronomy Research Farm. Each plot is labeled with area and fertilizer or manure application rate. Plots 6, 9, and Check were excluded from data analysis.

3.3 Experimental Method

Within the 8 field plots (plot 1, plot 2, plot 3, plot 4, plot 5, plot 7, plot 8, and plot 10 (Figure 3.2), area ranging from 0.19 ha to 0.40 ha) in the experiment, three treatments, including two applications of poultry manure (PM and PM2) and one application of urea ammonia nitrate (UAN) laid out in a split plot design with a target N-basis application rates for PM of 112 $kg \cdot ha^{-1}$; PM2 of 224 $kg \cdot ha^{-1}$; and UAN of 224 $kg \cdot ha^{-1}$ (Figure 3.3, Table 3.2). Flow is no longer present from plot 6 or plot 9 since 2010 and the check plot lacks replicates. Therefore, these three plots were no longer offering any flow data since 2010. The application rates were based on N-basis poultry manure application rates assuming a 60% availability of N in poultry manure (Iowa State University Extension, 2008).

Soil tests were conducted from 2010 to 2014 several weeks before spring manure application. In 2012, soil tests were done twice at different dates, once for the nutrient study and secondly for a study of pathogen fate and transport (Hruby, 2014). 0-15 cm depth and 15-30 cm depth soil samples were collected separately from each plot. Soil sample analysis was conducted at Iowa State University Agronomy Department's Soil and Plant Analysis Laboratory, with colorimetric method for soil NO_3-N concentration and Bray's 1-P test for soil plant available phosphorous.

Table 0.2 Annual N-basis application rates for all treatment plots and target manure rates

Year	**PM (kg · ha^{-1})**	**PM2 (kg · ha^{-1})**	**UAN (kg · ha^{-1})**
2010	115	296	224
2011	125	257	224
2012	137	236	224
2013	114	241	224
2014	116	183	224
Mean	121	242	224
Target	112	224	224

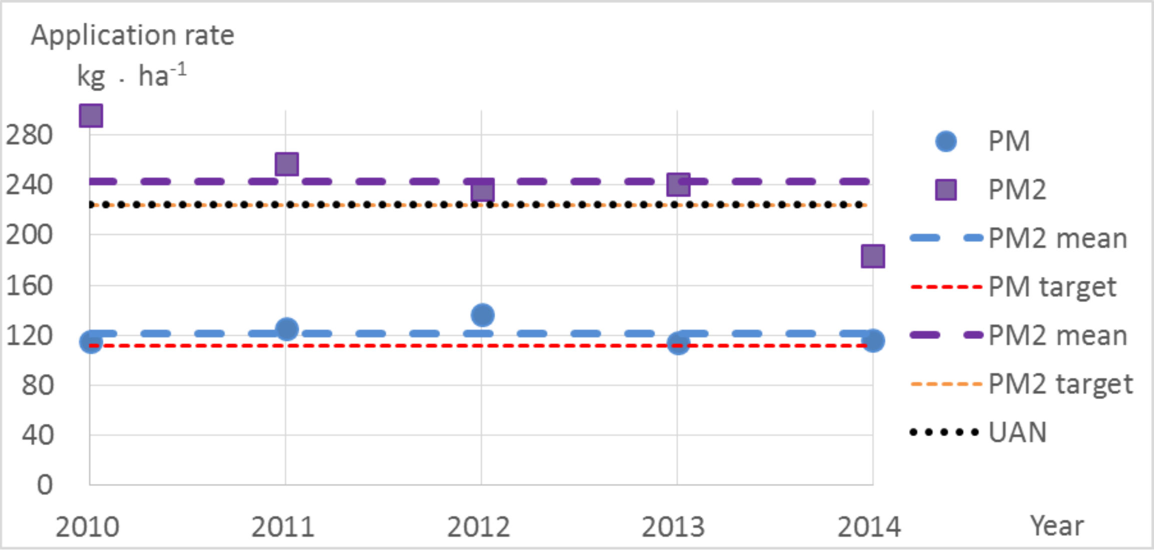

Figure 0.3 Annual PM, PM2 and UAN achieved application rate, mean application rate and target application rate

3.4 Treatment Application

Manure for this study was donated by a commercial poultry farm located in Humboldt, Iowa. Poultry manure samples were collected at the time of field application, started each year in May or June, and analyzed by Minnesota Valley Testing Laboratories Inc. in Nevada, IA for nutrient content (N, P and K). Samples were collected before application to estimate the poultry manure application rate according to the study design. Poultry manure samples were also collected during application so that the actual amount of nutrient applied could be calculated. All treatments (PM, PM2, and UAN) were applied to field plots by surface broadcast and then incorporated into the soil within 24 hours by chisel plow tillage to minimize nitrogen loss via volatilization.

Table 3.3 presents the schedule of major farming activities including planting date, fertilizer application date, and, harvesting date as well as the corn seed company, seed type, and, relative maturity for the study period. Growing date and fertilizer application date are typically in late May or early June when manure was available and field conditions were acceptable for application and tillage. It takes one day or two to apply and incorporate manure and UAN and then, right after fertilizer application, the crop was planted. The harvest date is based on corn seed type as well as the growing days, usually around late October. Pesticide and herbicide application are applied as needed each year and are not shown. Every other year the field is tilled after harvesting.

Table 0.3a Planting and fertilizer schedule

Year	Apply Manure	Apply UAN	Planting date	Harvest date	Growing days
2010	25-May	25-May	25-May	22-Oct	150
2011	2-Jun	2-Jun	3-Jun	25-Oct	144
2012	15-May	16-May	21-May	17-Oct	149
2013	21-Jun	20-Jun	27-Jun	12-Nov	138
2014	16-Jun	16-Jun	25-Jun	3-Nov	131

Table 3.3b Seed Company, seed type and relative maturity

Year	Company	Seed	Relative maturity
2010	Fontanelle	No record	No record
2011	Fontanelle	5T128	100-102
2012	Fontanelle	6T510	105-107
2013	Fontanelle	5V137	No record
2014	Kruger	9703	103

** corn seed were selected according to the estimated planting dates.*

*** corn seed with a lower relative maturity (not recorded) which is not hybrid was selected for 2013 because of the late planting.*

3.5 Sample Collection, Variable Calculation and Statistical Analysis

Subsurface drainage water data including flow volume and sample water quality were collected approximately weekly after major rainfall events. Samples were acidified with sulfuric acid and stored at 4 degrees Celsius. Water samples were analyzed using a Seal Analytical AQ2 discrete auto-analyzer in the Water Quality Research Laboratory (WQRL) for the combine of nitrate-nitrite concentration and reactive orthophosphate concentration. As is required by the US EPA drinking water standard, no filter is used before sampling analysis.

The EPA-approved method for measuring nitrate-nitrite concentration, the cadmium reduction method, measures both nitrate and nitrite concentration for filtered water samples. Nitrate is reduced by copperized cadmium to nitrite, which reacts with sulfanilamide to form a diazonium compound which, in dilute phosphoric acid, couples with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a reddish-purple azo dye. This is measured spectrophotometrically at 520 nm with method detection limit (MDL) 0.03 $mg \cdot L^{-1}$. Separate concentrations for nitrate and nitrite can be obtained by running the sample on a separate test without copperized cadmium.

The EPA-approved method for measuring total orthophosphate, the ascorbic acid method, measures both dissolved and suspended orthophosphate, because the sample is not filtered. A reagent (either liquid or powder) containing ascorbic acid and ammonium molybdate reacts with orthophosphate in the sample to form a blue compound which could be measured photometrically at 880 nm with method detection limit (MDL) 0.002 $mg \cdot L^{-1}$.

Corn was harvested using a combine with 3.05 meter (10 feet) or 3.81 meter (12.5 feet) in length. Yield calculation averaged combine passes excluding those passes from the edge of each plot to avoid the mixing of yields from two adjunct plots under different treatments. Weekly volume basis flow was calculated from weekly flow meter reading. Weekly drainage on a depth basis was calculated by dividing flow by plot area. Nutrient load (NO_3-N and PO_4-P) were calculated by drainage volume multiplied by nutrient (nitrate-nitrite and reactive orthophosphate) concentrations. Instead of annual mean temperature, total precipitation and total solar radiation, growing degree days (GDD) (Schneider and Gupta, 1985; McMaster and Wilhelm, 1997), effective precipitation and effective solar radiation, which are accumulation of annual heat, precipitation and solar radiation from planting date to harvest date, were calculated to interpret the actual amount of heat, precipitation and solar radiation that crops received at the same time considering the effect of growing days. (Schneider and Gupta (1985)) defined GDD

$$GDD = \Sigma \; (T_{min} + T_{max}) / 2 - T_{base} \tag{1}$$

Where,

GDD are the growing degree days

T_{min} is the minimum daily temperature, if temperature is less than 10 °C, use 10 °C.

T_{max} is the maximum daily temperature, if temperature is greater than 30 °C, use 30 °C.

T_{base} is the base temperature (10 °C for maize).

All the experimental data were processed and statistically analyzed using R software (R 3.1.2). Statistical methods include multiple linear regression (MLR), ANOVA, Tukey pairwise comparison and Wilcoxon rank sum. Models with continuous variables were analyzed by MLR. Models with discrete variables only were analyzed with ANOVA and Tukey pairwise comparison. Models which violated assumptions of MLR, ANOVA and Tukey including independence of observation, normality of distribution and equality of variance, were analyzed by Wilcoxon rank sum test. Bayesian information criterion (BIC) was used to select the best fit MLR model. A significant level $\alpha = 0.05$ was used in all statistical testing.

CHAPTER IV: RESULTS AND DISCUSSION

For this study, 5 years (2010-2014) of data was collected from eight field plots (1, 2, 3, 4, 5, 7, 8, and 10; Fig 3.2) amended with three different treatments-PM, PM2 and UAN under corn-on-corn management. Data included yearly crop yields, weekly nutrient concentrations and tile flow, and spring soil test nutrient concentrations. Annual nutrient load was calculated to assess the contribution of these three different treatments on crop production and environmental nutrient export. Soil tests were conducted in each of the research years. Statistics models with responses including weekly nitrogen concentration and phosphorous concentration, yearly corn yield, nitrogen load and phosphorous load were built. Multiple linear regression (MLR), ANOVA, Tukey pairwise comparison and Wilcoxon ranked sum test were used for statistical analysis.

4.1 Climate, Planting Date and Hydrology Differences during the Study Period

When year is considered as a variable, it indirectly affects the responses because the variable "year" is not a numerical variable, and therefore, it does not directly affect the response. Factors included in the year variable that directly impact responses are those annually changing variables that may include but are not limited to climate factors such as precipitation, temperature, solar radiation; and planting factors such as cultivar, growing days, and growing degree days. Temperature and precipitation data during the study period as well as the most recent 60 and 30-year periods are shown in Table 4.1.

Table 0.1 Precipitation and temperature from the IEM climate station AMES 8 WSW (Lat. 42.0211, Log. -93.7742)

Year	**Daily Temperature (°C)**			**Daily Precipitation (mm)**		
	average	max	min	average	max	annual total
2010	9.6	33.3	-29.4	3.5	126.5	1287.2
2011	10.0	35.6	-24.4	2.2	43.7	816.0
2012	12.0	37.8	-21.1	1.7	61.2	637.3
2013	8.9	36.1	-26.1	1.9	55.4	695.2
2014	8.0	32.8	-28.3	3.0	45.2	1076.8
Recent 60-year[1]	9.0	40.0	-34.4	2.3	142.0	840.5
Recent 30-year[1]	8.9	38.9	-33.3	2.4	142.0	866.0

[1] *recent 60-year and recent 30-year climate data is the max, min, mean temperature and precipitation data for the recent 60 and 30 years collected at this climate site. There is slight change in heat and precipitation conditions for the recent 30 years compared with the recent 60 years.*

Precipitation varies by year (Table 4.1), with annual total precipitation in 2010, 1287mm, 2011 816 mm, 2012 637.3 mm, 2013 695.2 mm, and 2014 1076.8 mm. In comparison of the 60-year average annual precipitation, 840.5 mm, 2012 and 2013 are dry years, 2011 is a normal year, and 2010 and 2014 are wet years. Flooding occurred in 2010 with an extreme precipitation event; the maximum daily precipitation recorded was 126.5 mm on 2010/08/09, which is more than double the maximum daily precipitation of the other four years.

Temperature also contributes to crop growth, which directly affects crop yield, drainage flow, and crop evapotranspiration. According to the 60-year average daily temperature of 9.0 °C, 2010, 2011, and 2012 can be classified as warm years while 2013 and 2014 can be considered cooler years.

Table 0.2 Growing days, GDD, effective solar radiation and effective precipitation from 2010 to 2014

Year	**Growing Days**[1]	**GDD**	**Effective Solar Radiation (MJ/m^2)**[2]	**Effective Precipitation (mm)**[2]
2010	150	1710.0	3683.6	918.2
2011	144	1533.9	3471.2	390.7
2012	149	1640.1	3846.8	290.3
2013	138	1277.9	2907.3	203.7
2014	131	1076.6	2750.8	630.7

[1] growing degree day (GDD) is an indicator of crop yield calculated with the method described in part 3.4
[2] both effective solar radiation and effective precipitation are accumulation of values during the growing seasons for the specific year.

As crop planting dates and harvesting dates vary, growing days is not a consistent variable. GDD, effective solar radiation, and effective precipitation are variables that describe the growing season for each year, and are a better description than the growing day. However, the effect of growing time on responses cannot be eliminated. Warm years 2010, 2011 and 2012 also have good effective solar radiation and sufficient GDD because there were plenty of growing days, while, years 2013 and 2014 have much lower GDD and effective solar radiation. When growing season is considered for precipitation, effective precipitation of wet year 2010 (918.2 mm) is 3-4 times the effective precipitation of dry years of 2012 (290.3 mm) and 2013 (203.7 mm).

Hydrology is important for concentration measurement and load calculations. Hydrology independency is assumed in part 3.1 (Table 3.1), which is to say that a similar amount of drainage is assumed from any treatment within each year (Table 4.3). Although, no significance is found from either ANOVA or Wilcoxon test for the mean (ANOVA) or median (Wilcoxon) drainage of different treatment for the overall research years (Table 4.3), different of mean (median) drainage by treatment is shown within years (Figure 4.1). For example, in 2010, the mean drainage in UAN plots is 334 mm, larger than the amount of mean drainage in PM2 plots, 205 mm, far larger than the amount drainage in PM plots, 187 mm. However, there is no consistent pattern showing a drainage trend for all treatments over all research years. In order to realize hydrological independency, Van Es et al. (2006) applied a 0.8-mm-thick impermeable PVC (polyvinyl chloride) geomembrane to a depth of 1.8m surrounding each plots; however, this is not the case at this research site. Therefore, drainage difference plays an important role in the modeling and analysis.

Table 0.3 Tile drainage by treatment from 2010 to 2014

Year	**PM (mm)**	**PM2 (mm)**	**UAN (mm)**	**Mean (mm)**
2010	187 ± (93)[1]	205 ± (119)	334 ± (32)	230 ± (104)a
2012[2]	70 ± (60)	45 ± (18)	63 ± (1)	59 ± (35)b
2013	100 ± (43)	85 ± (22)	95 ± (5)	93 ± (27)bc
2014	79 ± (27)	145 ± (28)	119 ± (56)	114 ± (43)c
Mean	109 ± (71)a[3]	120 ± (83)a	153 ± (116)a	

[1] *the mean annual drainage of all research plots by treatment with standard deviation in parentheses*

[2] *very little drainage in 2011 resulted in no sample collection in 2011*

[3] *Tukey pairwise comparison test shows no significant difference of mean annual drainage for all treatments In each row, values with the same letter are not significantly different at the p=0.05 level.*

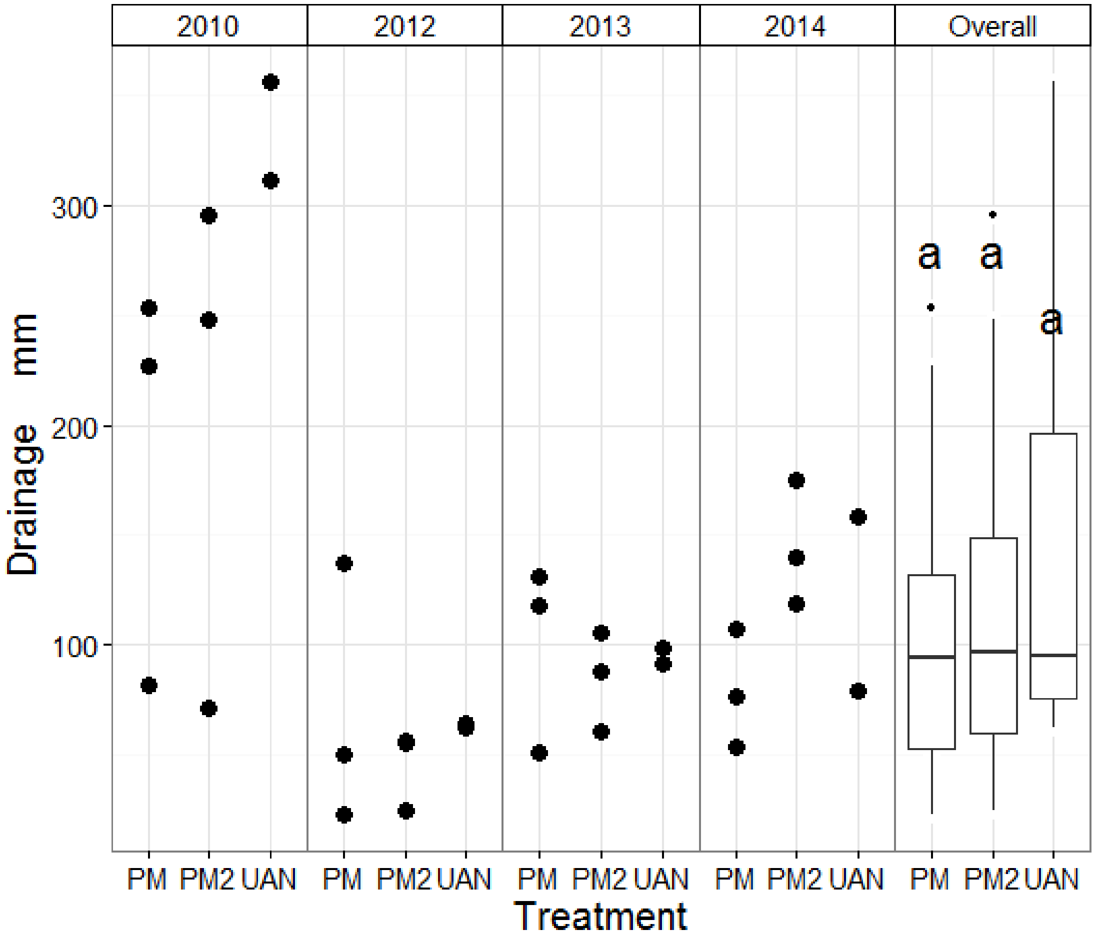

Figure 0.1 Annual drainage for all research plots by treatment by year

4.2 Poultry Manure Attributes and Application Rate

Average total moisture content of poultry manure at the time of application varies by year with average moisture of 26.8% in 2010, 60.6% in 2011, 29.7% in 2012 and 52.7% in 2014 year (moisture data in year 2013 was not recorded). Average total nutrient content of poultry manure varies, ranging from 1.58%-3.7% average total nitrogen, 2.1%-4.7% average phosphorous as P_2O_5, and 1.6%-2.9% potassium as K_2O.

Table 0.4 Annual achieved nitrogen, phosphorus and potassium application rates for poultry manure treatments.

Year	**PM (kg · ha^{-1})**			**PM2 (kg · ha^{-1})**		
	N	P	K	N	P	K
2010	115(±27)[1,2]	207(±49)	241(±57)	296(±21)	535(±38)	621(±44)
2011	125(±7)	156(±8)	265(±14)	257(±36)	319(±44)	544(±75)
2012	137(±1)	88(±1)	85(±1)	236(±18)	151(±11)	147(±11)
2013	114(±15)	81(±11)	99(±13)	241(±51)	171(±36)	207(±44)
2014	116(±15)	115(±21)	145(±33)	183(±39)	174(±21)	232(±29)
Mean	121(±16)[3]	129(±53)	167(±80)	242(±48)	270(±153)	350(±204)

[1] average nitrogen and phosphorous application rates for replicate plots for both PM and PM2 treatments are displayed with standard deviations in parentheses

[2] nitrogen application rate shown has already considered the assumption of 60% availability of N for all research years suggested by the Iowa State University Extension (2008)

[3] target N-basis manure application rates designed for PM and PM2 are 112 kg · ha^{-1} and 224 kg · ha^{-1} (Table 3.2)

Despite of the high variation of poultry manure moisture content which may result in high variability in N and P content and therefore highly variable manure application rates in the poultry manure by year (Harmel et al., 2011), there is no significant evidence that the N application rates differ by year (p=0.08153, ANOVA). Although, due to wide variation in nutrient concentrations between production facilities, nutrient application rates cannot be determined as specific and accurate as designed (Iowa State University Extension, 2008), it is able to conclude that all plots are applied fertilizer on an N-basis that is similar to the designed application rates (112 kg · ha^{-1} for PM and 224 kg · ha^{-1} for PM2, Table 3.2). However, high variation of phosphorous and other poultry manure nutrient content application still exists. There is significant evidence that P application rates vary by year (p=0, ANOVA).

Availability is assumed to compensate the N lost during N cycling including volatilization and leaching. Because of lower availability, a greater amount of N is applied as to reach the target application rate. The Iowa State University Extension (2008) suggests the estimation methods of up to 60% N available during the first year of poultry manure application only, while with 10% of the previous year's N applied available for all following years. That is to say, starting from the second year, not only additional N application rate is waived because of the 100% availability assumed, but also a reduction of application rate equals to 10% the previous year's N applied should be considered. This suggested setting is different than the setting in this research, where, 60% availability of N were assumed not only for the first year, but also for remaining research years (Table 4.4). Therefore, except year 2010, plant available nutrients may be high for PM and PM2 plots.

4.3 Spring Soil Test Results

Result of spring soil test phosphorous are shown in Figure 4.2 by treatment and year with markers distinguishing between soil sampling depth 0-15 cm and 15-30 cm. Increased poultry manure application resulted in a higher soil test phosphorous concentration, with all three treatments statistically different from each other. Both the interaction of year and treatment ($p<0.001$, ANOVA), as well as the interaction of soil sampling depth and treatment ($p<0.001$, ANOVA) are significantly affecting the soil test phosphorous (Figure 4.2).

Although there is a tile drainage system in the field, phosphorous is easily absorbed and accumulates in the soil. As long as manure is applied, soil test phosphorous concentration for both treatments PM and PM2 are increasing annually. For the UAN control treatment which has not received phosphorous for over 5 years, soil test phosphorous changes only slightly. PM and PM2 have higher soil test phosphorous for 0-15 cm soil than 15-30 cm soil. This is consistent with the finding from long-term soil sampling at the same site under a corn-soy rotation from 1998-2009 (Hoover et al., 2015). For UAN treated plots, different soil sampling depths have similarly low soil test phosphorous concentrations.

For the 0-15 cm soil, the mean soil test phosphorous are 252 ppm for PM2, 113 ppm for PM and 15 ppm for UAN over the study period. For the 0-15 cm soil, all soil test phosphorous concentrations from PM and PM2 are classified as “very high” (>30 ppm) for corn growth as defined by Sawyer (2002). Based on this classification, no additional poultry manure is recommended for PM and PM2 treated soils. Soil test phosphorous concentrations of the 0-15 cm soil for UAN has a suitable amount of phosphorous (classified “optimum”), except in year 2012, the phosphorous concentration of which is classified as “low” (9~15 ppm) defined by (Sawyer, 2002).

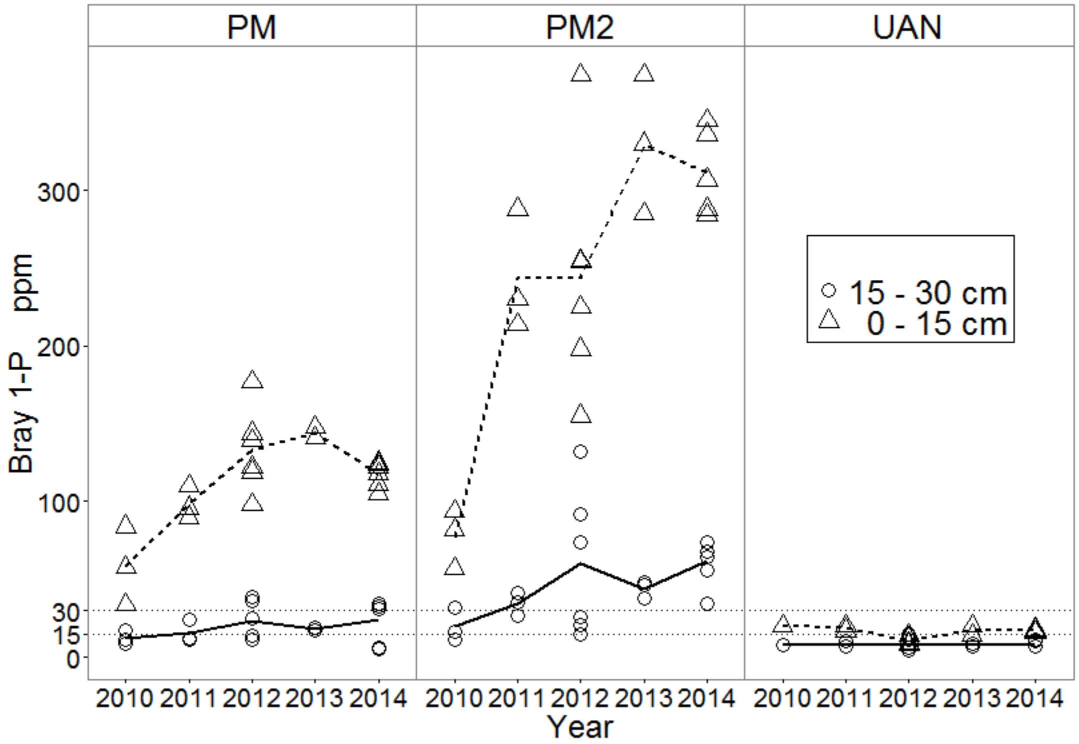

Figure 0.2 0-15 cm and 15-30 cm soil test phosphorus concentrations for all treatments from 2010 to 2014

The Bray 1-P test, the soil test used in this research, is targeted for non-calcareous because it often underestimate the plant available phosphorous in soil with pH> 7.3 compared with Olsen P test and Mehlich-3 P test (Mallarino, 2013). According to the soil test pH, most (103 out of 110) soil test samples from poultry manured plots and all samples from UAN plots have pH lower than 7.3 (Figure 4.3). Seven samples from PM and PM2 had higher pH. treatments are from calcareous soil, of which the soil phosphorous may be underestimated. Thus, there may exist an opportunity that over application of poultry manure may result in higher soil test phosphorous concentration than what is measured by Bray 1-P test. No soil samples from UAN plots have pH larger than 7.3, which shows no underestimation. Therefore, whatever the soil test method is, UAN plots have significant lower soil phosphorous than poultry manure applied plots. Mehlich-3 test, which is suitable for all soils is suggested for the study of those calcareous soil samples with pH above 7.3. From 2012 to 2014, Mehlich-3 test, as well was used for soil phosphorous test. For the 2 soil samples tested in 2013 from calcareous soil (soil pH > 7.3), higher soil phosphorous concentrations (420 ppm P for the soil sample from plot 1; 200 ppm P for the soil sample from plot 2) were tested by Mehlich-3 test than those (300 ppm P for the soil sample from plot 1, PM; 148 ppm P for the soil sample from plot 2, PM2) tested by Bray 1-P for samples from both PM and PM2 treatments 0-15 cm soil.

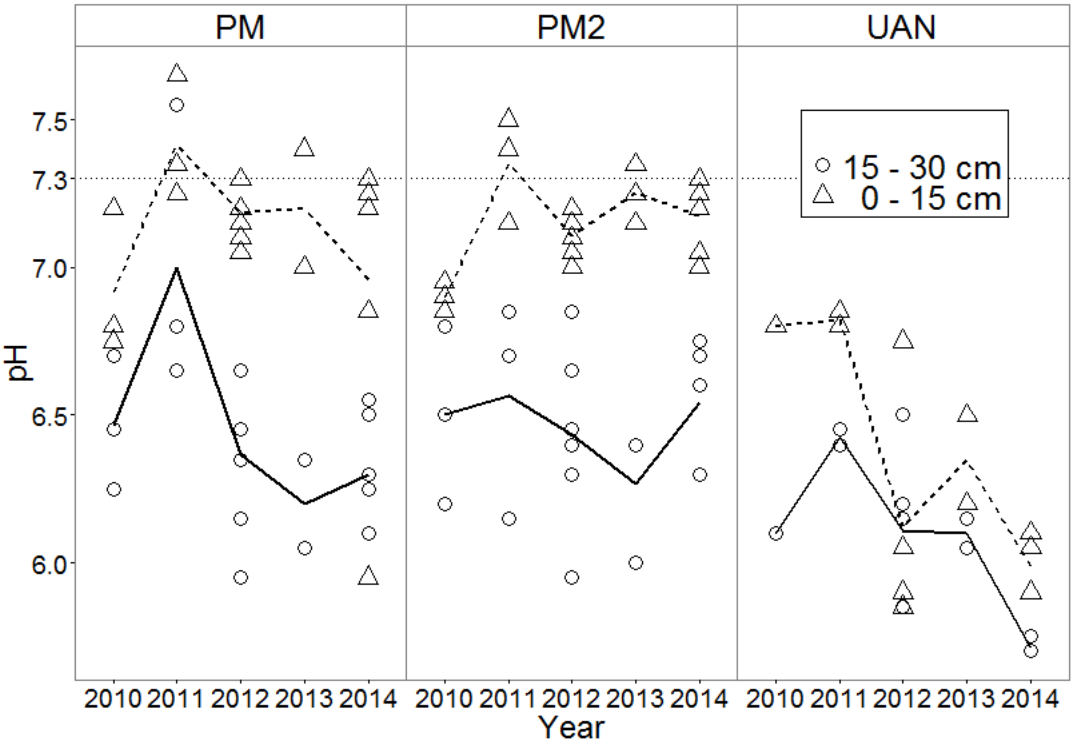

Figure 0.3 Soil test pH from 2010 to 2014

The 0-15 cm and 15-30 cm soil NO_3-N concentrations are shown in Figure 4.4. Unlike soil test phosphorous, an increasing trend of annual NO_3-N concentration is found for all three treatments (Figure 4.4) except 2013. The late manure application date in 2013

(Table 3.3) might explain this observation. As soil test was conducted several days before the manure application, the soil drained for months longer in 2013 than in other years. Large variation of soil NO_3-N was reported (the same with soil test phosphorous) in 2012. The soil test data in 2012 was a combination of two soil tests that might have been processed at different times which may explain the large variation of soil test data (both soil test phosphorous and NO_3-N concentration) in 2012.

When considering the effect of soil depth, none of the main variables year (p=0.11, ANOVA), treatment (p=0.76, ANOVA) or soil sampling depth (p=0.84, ANOVA) significantly affected the soil NO_3-N concentration. This finding is different from the result of (Cheatham, 2003), who found that PM2 and UAN (both with N application rates 336 $kg \cdot ha^{-1}$) treatments applied over 1998-2003 resulted in increase of soil NO_3-N concentration soil nitrogen, while, PM (with N application rates 168 $kg \cdot ha^{-1}$) had a lower likelihood of increase of soil NO_3-N concentration with both spring and fall soil test data. Soil NO_3-N concentration build up by year at the corn-on-corn field during the research study can be found from the trend shown (Figure 4.4), though statistical trends do not exist. This is different from the soil NO_3-N concentration build up trend of previous research (Cheatham, 2003), where no increase of either soil NO_3-N concentration or soil phosphorous could be found at the corn-soybean rotation field by year.

Therefore, compared with corn-soybean rotation, soil NO_3-N concentration under corn-on-corn planting get easier built up not only for UAN and PM2 treatment, but also for PM treatment, and soil phosphorous get easier built up for poultry manure plots as well.

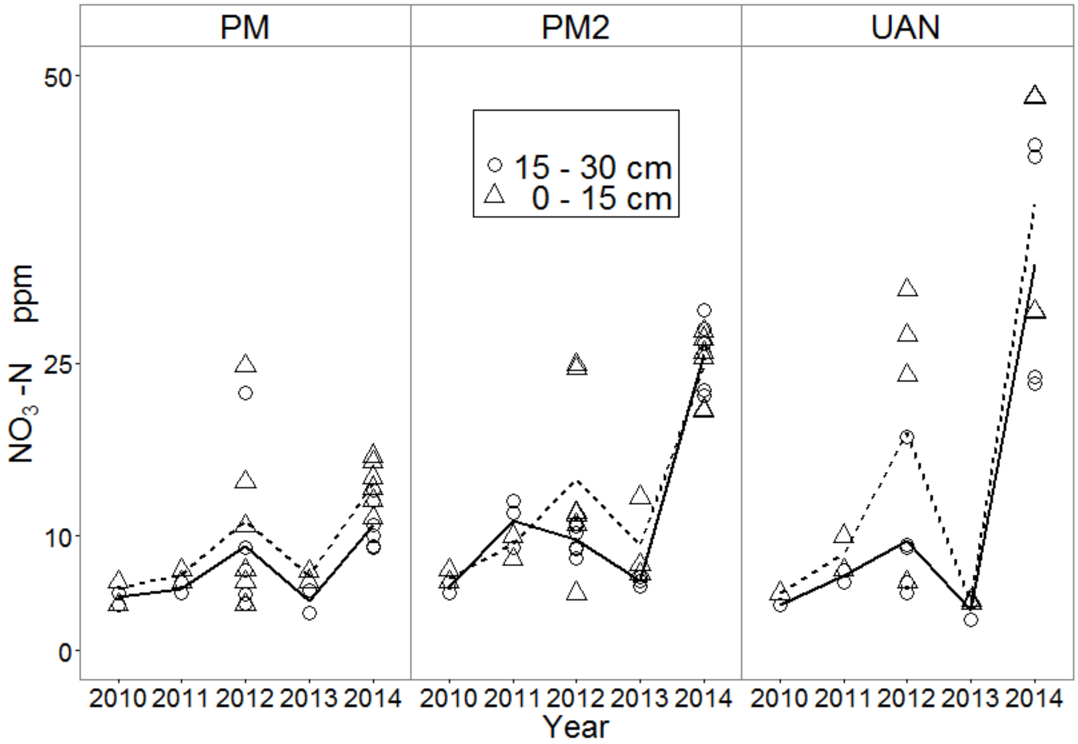

Figure 0.4 0-15 cm and 15-30 cm soil test NO_3-N concentrations for all treatments from 2010 to 2014

** different shape of points are used for different depth soil*
*** line through the mean value of each year are shown for each treatment*

4.4. Effect of Multiple Variables on Crop Yield

The overall mean yields (Table 4.5) during the study period (2010-2014) for each treatment are PM2 8756 kg · ha^{-1}, PM 7879 kg · ha^{-1}, and UAN 6967 kg · ha^{-1}. For different treatments for each year (Figure 4.5), the yields follow the order of PM2>PM>UAN. Although UAN plots are applied double the N rate than PM plots and similar N rate of the PM2 plots, the significant lower amount of soil phosphorous (section 4.3) likely explains the lower yield production for UAN plots in comparison with poultry manure plots. Mean yields for different treatments ($p=0.0004$) as well as different years ($p<0.0001$) and their interaction ($p=0.0005$) are all significantly different, according to ANOVA with year, treatment and the interactions as variables. Tukey pairwise comparison test also shows that mean yields for all three treatments are significantly different from each other, which is to say that the three treatments designed for the research contribute significantly differently to the crop yield. Multiple linear regression (MLR) model (BIC=-104.37, R^2= 9648) with effective precipitation, effective solar radiation, GDD, treatment and the interaction of treatment and effective solar radiation, and the interaction of effective solar radiation and effective precipitation was developed to further explain the significance effect of variable year and the interaction of year and treatment (Table 4.6).

Table 0.5 Mean crop yields by treatment for years 2010 to 2014

Year	**PM (kg · ha^{-1})**	**PM2 (kg · ha^{-1})**	**UAN (kg · ha^{-1})**	**Mean (kg · ha^{-1})**
2010	8983(±441)[1]	10130(±243)	8684(±377)	9338(±733)a
2011	9001(±116)	10218(±180)	8511(±314)	9335(±776)a
2012	9060(±441)	9329(±282)	8998(±551)	9145(±381)a
2013	5353(±686)	6468(±456)	3904(±337)	5408(±1157)b
2014	6999(±309)	7636(±142)	4737(±492)	6672(±1258)c
Mean	7879(±1582)a[2]	8756(±1543)b	6967(±2322)c	

[1] *the mean yearly yield is an average of all plots for each treatment with standard deviation in parentheses.*

[2] *Mean yields by treatment for all years follow the order PM2>PM>UAN. Tukey pairwise comparison test shows that mean yearly crop yields for all treatments are significantly different from each other. In each row, values with the same letter are not significantly different at the p=0.05 level.*

Table 0.6 Best estimate MLR model of crop yield by BIC (BIC=-104.37, R^2=0.9648)

Variables	**Estimate**	**p-value**
Intercept	-3.04×104	<0.0001
GDD	35.5	<0.0001
Effective solar radiation	-4.14	0.0008
Effective precipitation	84.3	<0.0001
Treatment PM2	1.36×103	0.2347
Treatment UAN	-7.12×103	<0.0001
Effective solar radiation * Treatment PM2	-0.144	0.6691
Effective solar radiation * Treatment UAN	1.86	<0.0001
Effective solar radiation * Effective precipitation	-2.46×10-2	<0.0001

Crop yields for all research plots by treatment and year are shown in Figure 4.5. Tukey pairwise comparison shows that over the study period, 2010 (9338 kg · ha^{-1}), 2011 (9335 kg · ha^{-1}), and 2012 (9145 kg · ha^{-1}) have similarly high mean crop yields, different from 2013 (5408 kg · ha^{-1}) and 2014 (6672 kg · ha^{-1}). The reason for lower yields from 2013 and 2014 is likely because of the variation of annual effective solar radiation (Table 4.2). Effective solar radiation is found to significantly ($p=0.0008$) affect the crop yield (Table 4.6). Further, the late planting date (Table 3.3) meant insufficient days 2013 and 2014. Yield in 2014 is higher than 2013 because the farm manager selected a corn seed (Table 3.3) with a lower relative maturity for year 2013, which is not a hybrid. Additionally, in 2014 there was sufficient precipitation (Table 4.1) and effective precipitation (Table 4.2), which is also a variable that significantly ($p<0.0001$) affects the yield (Table 4.6) Significant effect to crop yield is also found on GDD ($p<0.0001$, Table 4.6).

Higher yields from treatment PM2 than the other two treatments were found in all years except 2012. In 2012, PM plots were applied the largest N application rates (Table 4.4), which resulted in the smallest N source difference between PM and UAN plots. Compared with the other effective solar radiation sufficient years 2010 and 2011 (Table 4.2), 2012 had the smallest N source difference between PM2 and PM (Table 4.4). These might explain the small yield difference over PM PM2 and UAN in 2012. Heat parameters are highly correlated to the solar radiation. Effective solar radiation seems to affect yields differently for UAN ($p<0.0001$, Table 4.6). As yields increase by solar radiation, steeper slope is found from UAN than poultry manure treatments (Figure 4.6). However, it is not logical in reality. In fact, the lower increase of yields for poultry manure treatment resulted from the small yield differences in 2012 (with the largest effective solar radiation). Effective solar radiation is also found to negatively affect the effect of the effective precipitation to crop yield ($p<0.0001$, Table 4.6). For years with low effective solar radiation (< 3000 MJ $\cdot$ m^{-2}), greater effective precipitation significantly increases the crop yield; while for years with high effective solar radiation (> 3400 MJ $\cdot$ m^{-2}), the effective of effective precipitation on yield is diminished (Figure 4.7). Similar but detailed results were found by Boyer (1970), who reported the inhibition of photosynthesis in field grown maize in low leaf water potentials (< -0.35 MPa).

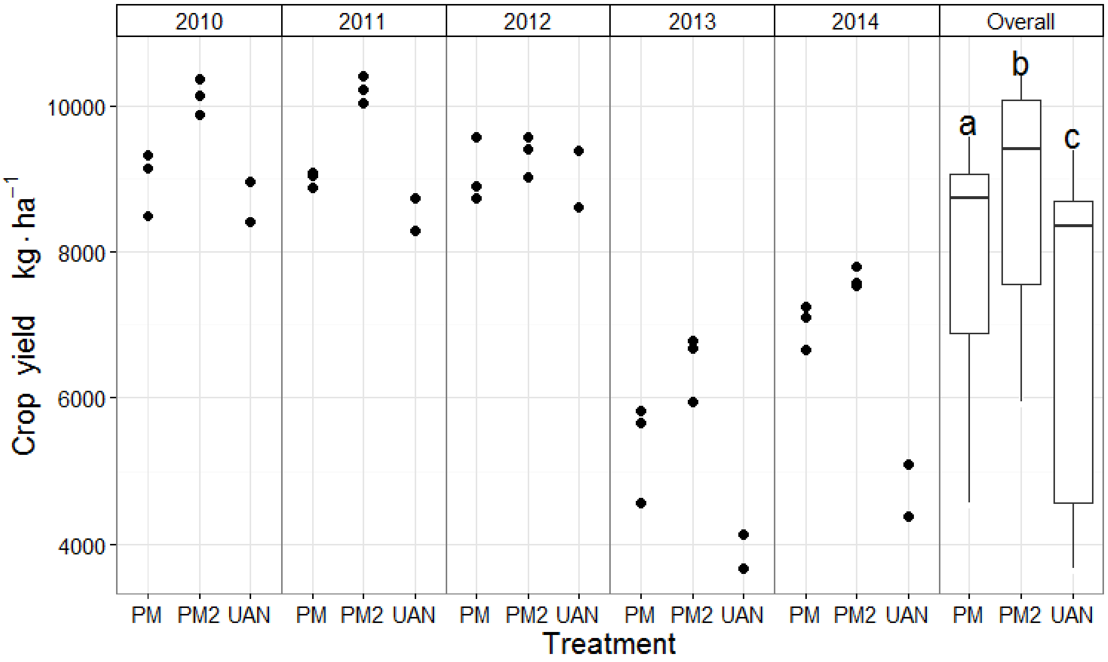

Figure 0.5 Crop yields for all treatments all plots from 2010 to 2014

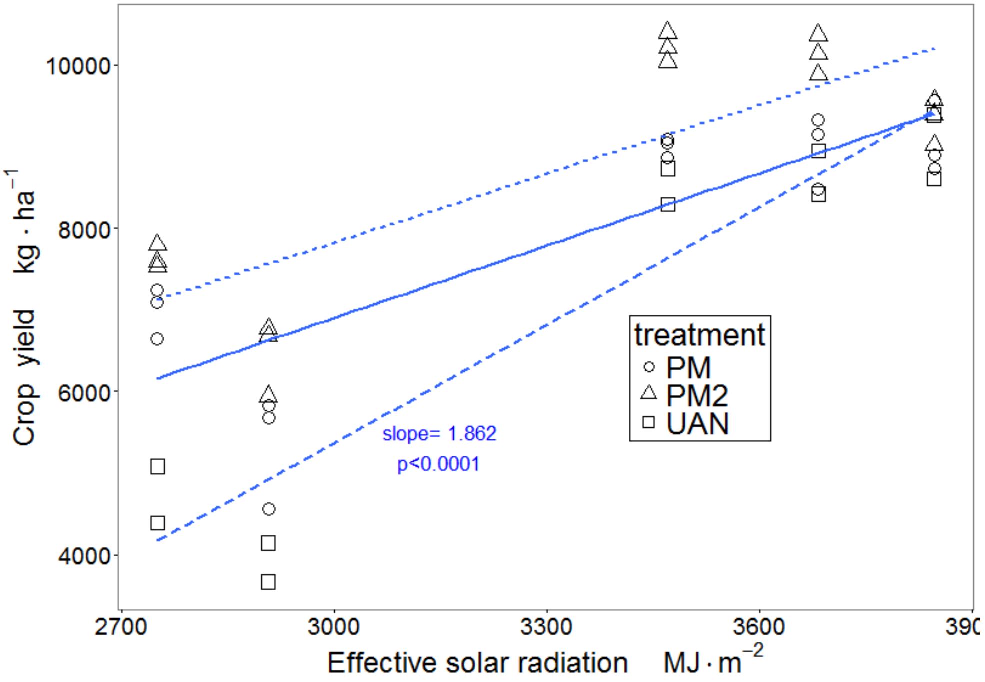

Figure 0.6 Effect of effective solar radiation on crop yield by treatment

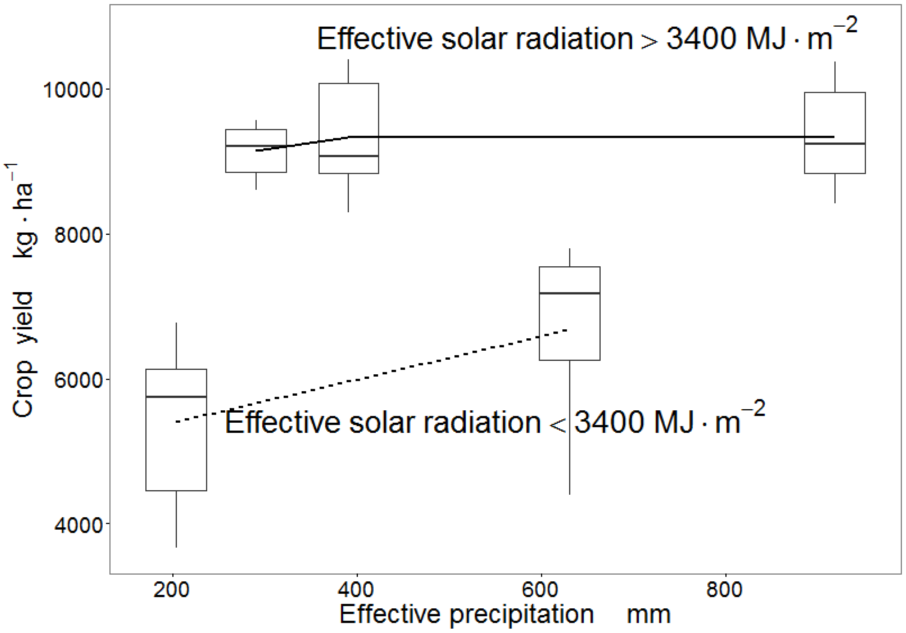

Figure 0.7 Effect of the interaction of effective precipitation and effective solar radiation on crop yield

Therefore, we are able to conclude that under the same (224 kg · ha^{-1}) or half (112 kg · ha^{-1}) amount of nitrogen application rate with UAN (224 kg · ha^{-1}), PM2 and PM have greater yields, without considering the impact of significant different levels of soil phosphorous (section 4.3). Effective solar radiation is the dominant factor that increases the crop yield in comparison with effective precipitation, which would benefit the yield when lacking effective solar radiation.

4.5 Effects of Year and Treatment on Nutrient Loads from Drainage Flow

4.5.1 Effects of year and treatment on NO_3-N load from drainage flow

The treatment mean flow weighted NO_3-N load (Table 4.7) during the research years (2010-2014) are 43.4 kg · ha^{-1} for PM2, 13.8 kg · ha^{-1} for PM, and 51.9 kg · ha^{-1} for UAN. For different treatments, flow weighted NO_3-N loads follow the order UAN>PM2>PM in 2010, 2012 and 2013. Though plots from both UAN and PM2 treatments are applied under similar N application rate (about 224 kg · ha^{-1}, Table 4.4) in 2010, 2012 and 2013, mean yearly drainage is 164 mm for UAN, 1.47 times the drainage of PM2, which is 112mm (Table 4.3). The flow weighted NO_3-N load from UAN in 2010, 2012 and 2013 is 44.8 kg · ha^{-1}, 1.5 (similar to 1.47) times the flow weighted NO_3-N load from PM2, which is 29.8 kg · ha^{-1}.

Differences were observed in 2014 when the flow weighted NO_3-N loads follow the order PM2> UAN >PM. This is because in 2014, UAN plots gathered about 119 mm tile drainage, 0.82 times of the amount of drainage PM2 plots gathered (145 mm, Table 4.3). This ratio is close to the ratio of mean flow weighted NO_3-N load for UAN (73.2 kg · ha^{-1}, Table 4.7) over mean flow weighted NO_3-N load for PM2 (83.8 kg · ha^{-1}) in 2014, which is 0.87. Therefore, the variation of treatment mean flow weighted NO_3-N load can be best explained by the variation of yearly tile drainage.

Statistical differences between NO_3-N load in different treatments is found according to ANOVA (p=0.0226). Tukey pairwise comparison test also shows that the mean NO_3-N load for treatment PM plots is significantly different from the other two treatments (Figure 4.8). There is no significant difference between the NO_3-N load for treatment PM2 and UAN, although it is reported that the mean NO_3-N load for UAN is larger than that of PM2. The lower application rate of NO_3-N for PM plots (Table 4.4) may best explain the significant lower NO_3-N load from PM plot tile drainage.

Table 0.7 Yearly nitrogen load by treatment from 2010 to 2014

Year	**PM (kg · ha^{-1})**	**PM2 (kg · ha^{-1})**	**UAN (kg · ha^{-1})**	**Mean (kg · ha^{-1})**
2010	16.6(±8.4)1	32.8(±20.2)	51.3(±3.6)	33.6(±18.6)a
2012[2]	11.8(±13.3)	16.5(±8.2)	25.6(±2.7)	18(±10.2)a
2013	12.3(±4.4)	40.2(±11.6)	57.4(±3.2)	36.6(±20.5)a
2014	13.9(±3.2)	83.8(±18.1)	73.2(±26.3)	56.9(±37)b
Mean	13.6(±7.4)a[3]	43.4(±29.1)b	51.9(±20.9)b	

[1] the mean yearly nitrogen load is an average of all plots for each treatment with standard deviation in parentheses

[2] little drainage in 2011, no sample were collected in 2011

[3] mean NO_3-N loads by treatment for all years follow the order UAN>PM2>PM. Tukey pairwise comparison test shows that mean yearly N loads of treatment PM is significantly lower than that of the other two treatments, there is no significant difference between N loads for PM2 and UAN. In each row, values with the same letter are not significantly different at the p=0.05 level.

Tukey pairwise comparison (Table 4.7) shows that over all the study years, 2010 (33.6 kg · ha^{-1}), 2012 (18 kg · ha^{-1}) and 2013 (36.6 kg · ha^{-1}) have similarly lower mean NO_3-N loads, when compared to 2014 (56.9 kg · ha^{-1}). However suitable drainage is used to explain the NO_3-N load, as both drainage and concentration are directly affecting the load in the formula of calculation, statistic explanation by these two factors makes no sense. Instead, other related factors, such as the greater precipitation (Table 4.1) with lower yield (Table 4.5) occurred in 2014, may explain high NO_3-N load in that year. However, no significant evidence is found for different annual mean NO_3-N load by ANOVA (p=0.9653). The interaction of year and treatment is significantly affecting the mean NO_3-N load (p=0.0069, ANOVA). MLR model (BIC=-82.83, R^2= 0.9716) with variables yield, NO_3-N concentration by plot, drainage, and the interaction of treatment and drainage, the interaction of treatment and temperature and treatment and the interaction of yield and drainage was developed to further explain the significant effect of the interaction of year and treatment (Table 4.8).

Table 0.8 Best estimates MLR model of NO_3-N load by BIC (BIC=-82.83, R^2=0.9716)

Variables	Estimate	p-value
Intercept	-73	<0.0001
Crop yield	8.28×10-3	0.0012
NO3-N concentration	1.10	<0.0001
Drainage	0.702	<0.0001
Treatment PM2 * Drainage	0.162	0.0006
Treatment UAN * Drainage	8.44×10-2	0.0136
Treatment PM2 * Yield	1.07×10-3	0.6608
Treatment UAN * Yield	-2.96×-3	0.1838
Treatment PM * Temperature	-0.880	0.529
Treatment PM2 * Temperature	-3.84	0.02
Treatment UAN * Temperature	-0.262	0.8495
Crop yield * Drainage	-6.88×10-5	<0.0001

Mean NO_3-N concentration (p<0.0001), drainage (p<0.0001) and crop yield (p=0.0012) are found to affect NO_3-N load significantly (Table 4.8). Drainage as well as mean NO_3-N concentration are used as parameters of load calculation shown in part 3.5, which are obviously highly related to nutrient load. Considering the nitrogen cycle in the soil, generally, the larger yield results in a greater nitrogen utilization, which leads to lower nitrate leaching under the same nitrogen source application. Thus, increased yield is related to lower nitrate leaching. The interaction of drainage and crop yield also significantly affects NO_3-N load (p<0.0001, Table 4.8), which means, the amount of drainage affect the NO_3-N load differently in terms of different crop yields. For years with low crop yield (< 8000 kg · ha^{-1}), the NO_3-N loads increases as drainage increases, when compared to years with high crop yield (> 8000 kg · ha^{-1}).

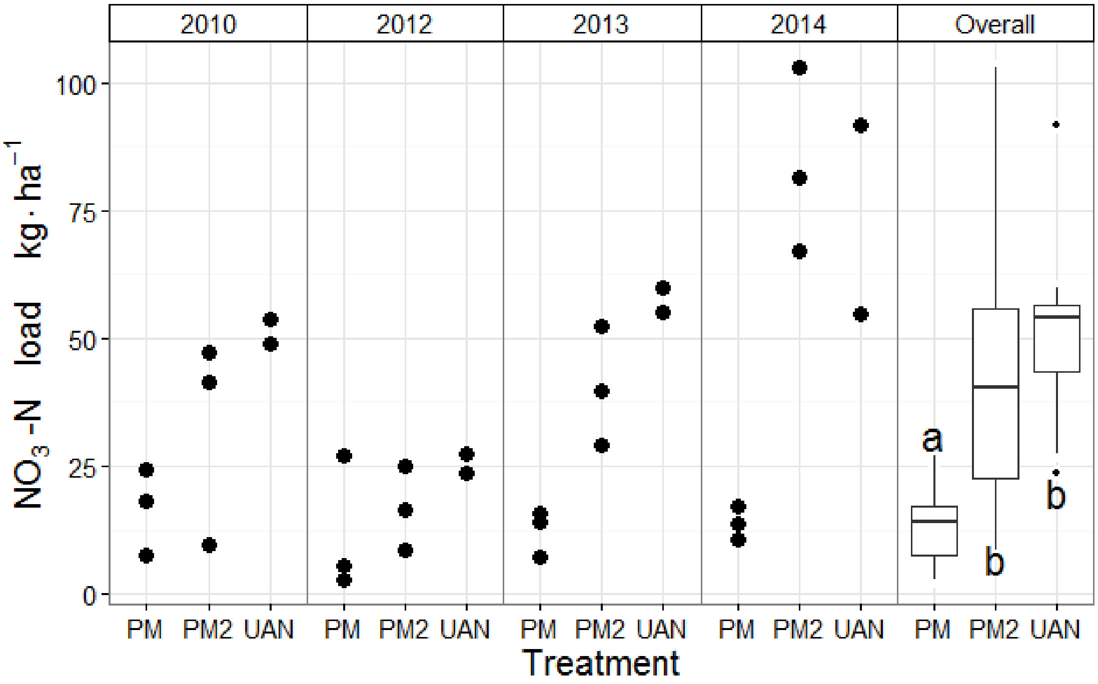

Figure 0.8 NO_3-N load for each treatment each plot from 2010 to 2014

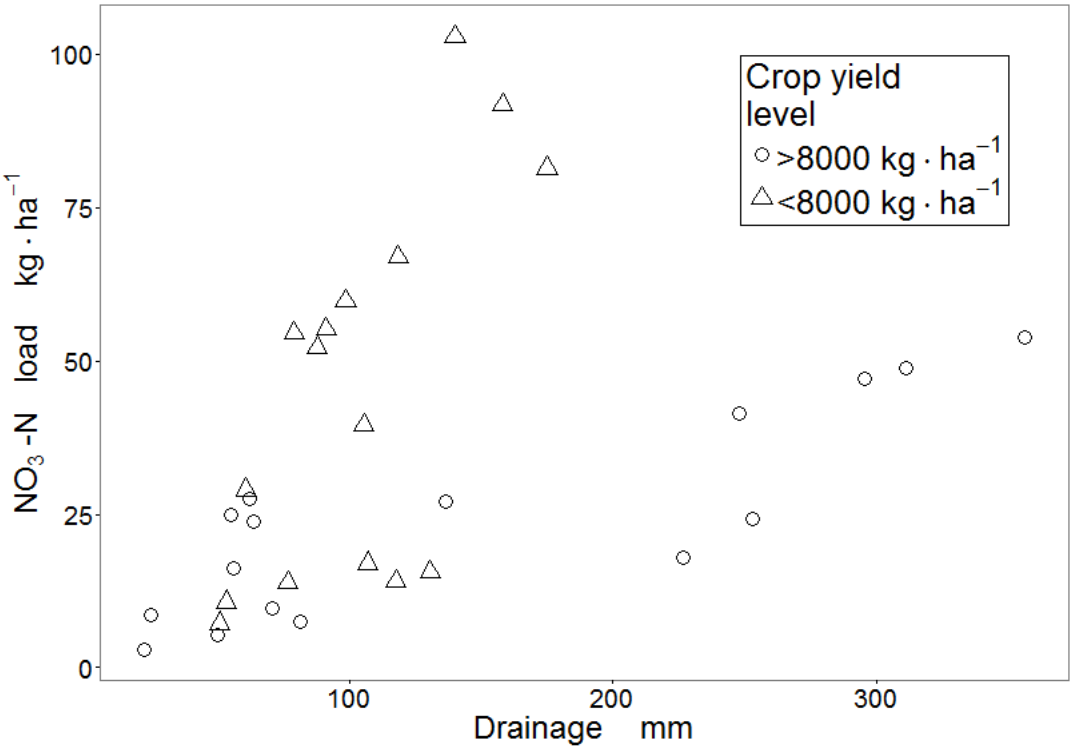

Figure 0.9. Effect of the interaction of yield and drainage on NO_3-N yield

Therefore, we are able to conclude that applying treatment PM leads to a lower NO_3-N load than applying the other two treatments. There is no difference of NO_3-N load by applying PM2 or UAN. A larger crop yield would diminish the increasing trend of NO_3-N load by drainage. In part 4.4, it shows that PM2 contributes to the largest yield, while applying UAN, which is of the same NO_3-N application rate with PM2, has the lowest yield. However, when it comes to NO_3-N load, UAN contributes similar NO_3-N load as PM2 does. Additionally, PM leads to larger yield but lower NO_3-N load relative to UAN. Therefore, when applying at the same N rate (224 kg · ha^{-1}), PM2 is more efficient for corn yield while at the same time contributes to similar amount of NO_3-N load in comparison with UAN.

When applying at about half the N rate (112 kg ⋅ ha^{-1}), PM is more NO_3-N load friendly and crop yield efficient than UAN.

4.5.2 Effects of year and treatment on PO_4-P load from drainage flow

The treatment mean flow weighted PO_4-P load (Table 4.9) during the research years (2010-2014) are 0.029 kg ⋅ ha^{-1} for PM2, 0.027 kg ⋅ ha^{-1} for PM, and 0.017 kg ⋅ ha^{-1} for UAN. For different treatments, overall flow weighted PO_4-P loads follow the order PM2>PM>UAN. This is also the order of P application rate (Table 4.4), soil test phosphorous (Figure 4.2) and PO_4-P concentration (Table 4.11). UAN plots are assumed to leach little phosphorous as they have not received phosphorous application for over 5 years. In 2012 and 2013, the two dry years (Table 4.1), the water samples collected from the UAN plots had little PO_4-P load measured. However, in the wet years (2010 and 2014), high PO_4-P loads and high variation are found from all treatment plots likely because of the soil phosphorous movement through macropores under the impact of frequent precipitation. Geohring et al. (2001) also pointed out the important impact of phosphorus losses in subsurface runoff when weather conditions favor rapid flow through cracks or macropores. No significant difference among the median PO_4-P loads of all three treatments is found according to Wilcoxon rank sum test (Table 4.9, Figure 4.10). Significant difference of median PO_4-P loads are found between 2010 and 2012, 2010 and 2013, and 2013 and 2014 (Table 4.9).

Table 0.9 Yearly PO_4-P load for each treatment from 2010 to 2014

Year	**PM (kg · ha^{-1})**	**PM2 (kg · ha^{-1})**	**UAN (kg · ha^{-1})**	**Mean (kg · ha^{-1})**
2010	0.04(±0.018)[1]	0.061(±0.025)	0.061(±0)	0.054(±0.008)a
2012[2]	0.029(±0.051)	0.007(±0.01)	0(±0)	0.012(±0.011)bc
2013	0.004(±0.006)	0.003(±0.002)	0.001(±0)	0.002(±0.001)b
2014	0.036(±0.05)	0.045(±0.06)	0.003(±0.005)	0.028(±0.009)ac
Mean	0.027(±0.01)a[3]	0.029(±0.01)a	0.017(±0.009)a	

1. the mean yearly phosphorous loads by treatment with standard deviation in parentheses

2. there's little drainage in 2011, no sample were collected in 2011

3. mean PO_4-P loads by treatment for all years are close. Wilcoxon rank sum non-parametric test shows that there is no significant difference among the median PO_4-P loads of all three treatments. In each row, values with the same letter are not significantly different at the p=0.05 level.

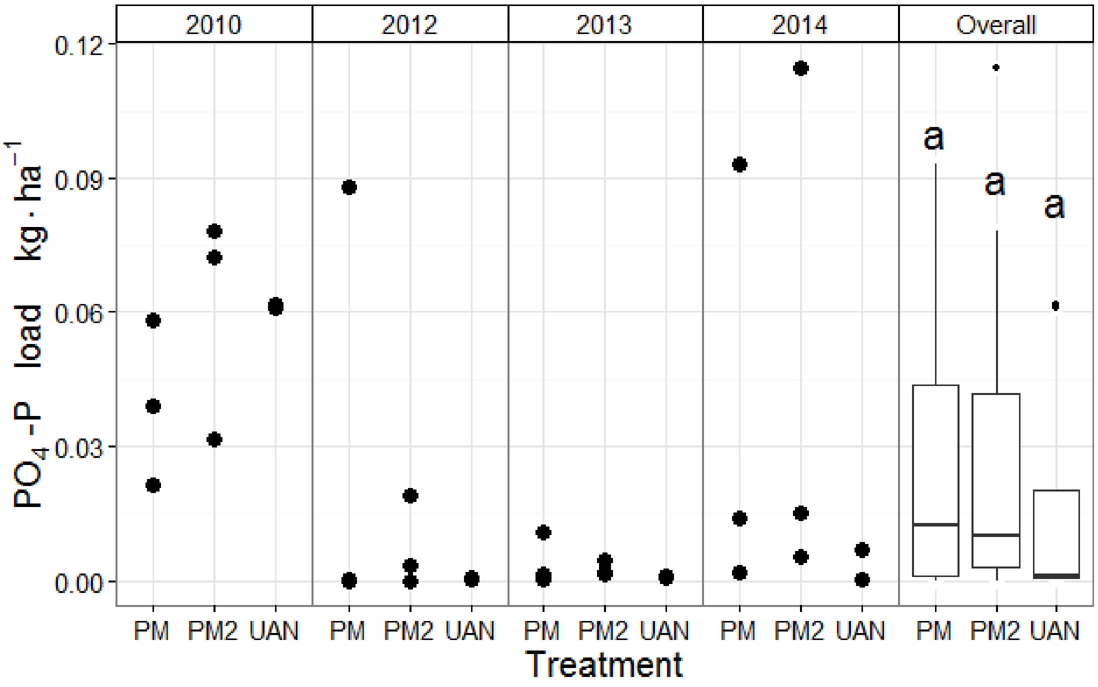

Figure 0.10 PO_4-P load for each treatment each plot from 2010 to 2014

Therefore, we are only able to conclude that UAN is more PO_4-P load friendly in dry years. It is difficult to tell the difference between PM and PM2 for the contribution of PO_4-P load as they both have relatively high PO_4-P loads.

4.6 Effects of Year and Treatment on Nutrient Concentrations in Drainage Tile Water

4.6.1 Effects of year, treatment and water event on nitrate-nitrite concentrations in drainage tile water

The overall mean nitrate-nitrite concentrations (Table 4.10) during the research years (2010-2014) for each treatment are 38.7 mg · L^{-1} for PM2, 13.5 mg · L^{-1} for PM, and 43.5 mg · L^{-1} for UAN. For different treatments each year, the nitrate-nitrite concentrations follow the order UAN>PM2>PM. Due to the lower N application rate (Table 3.1), during the study period, PM has the lowest NO_3-N concentration and the smallest variation, which is the most likely to meet the 10 mg · L^{-1} NO_3-N MCL of drink water, set by the U.S. EPA. Treatment ($p<0.0001$), year ($p<0.0001$) and their interaction ($p<0.0001$) are found to significantly affect the mean NO_3-N concentrations according to ANOVA. Tukey pairwise comparison test also shows that NO_3-N concentrations for all three treatments (Table 4.10, Figure 4.11) and for all research years (Table 4.10) are significantly different from each other. The annual NO_3-N concentrations during the research years are 13.2 mg · L^{-1} for 2010, 29.4 mg · L^{-1} for 2012, 38.6 mg · L^{-1} for 2013, and, 46.5 mg · L^{-1} for 2014. An increasing NO_3-N concentration trend by year is found as fertilizers are applied, which is consistent with the soil N source accumulation discussed in section 4.3. Therefore, we are able to conclude that among all three treatments, PM with lower N application rate has the lowest NO3-N concentration, 13.5 mg · L^{-1} that is closest to the 10 mg · L^{-1} NO_3-N MCL of drink water, EPA. PM is also more NO_3-N concentration friendly and crop yield efficient than UAN.

Table 0.10 Mean NO_3-N concentration by treatment from year 2010 to year 2014

Year	PM (mg · L^{-1})	PM2 (mg · L^{-1})	UAN (mg · L^{-1})	Mean (mg · L^{-1})
2010	9.1(±0.5)[1]	15.3(±0.3)	15.2(±0.6)	13.2(±3.2)a
2012[2]	14.3(±3.6)	35.3(±9.6)	38.5(±4)	29.4(±12.9)b
2013	12.8(±1.7)	47.3(±12.6)	55.8(±1.6)	38.6(±21.1)c
2014	17.9(±1.8)	56.9(±14.2)	64.6(±8.8)	46.5(±23.6)d
Mean	13.5(±3.8)a[3]	38.7(±20.5)b	43.5(±18.6)c	

[1] mean yearly sample NO_3-N concentration by treatment with standard deviation in parentheses

[2] there's little drainage in 2011, thus no sample were collected in 2011

[3] mean sample nitrate-nitrite concentration by treatment for all years follow the order UAN>PM2>PM . Tukey pairwise comparison test shows significant difference of the mean sample NO_3-N concentrations for all treatments In each row, values with the same letter are not significantly different at the p=0.05 level.

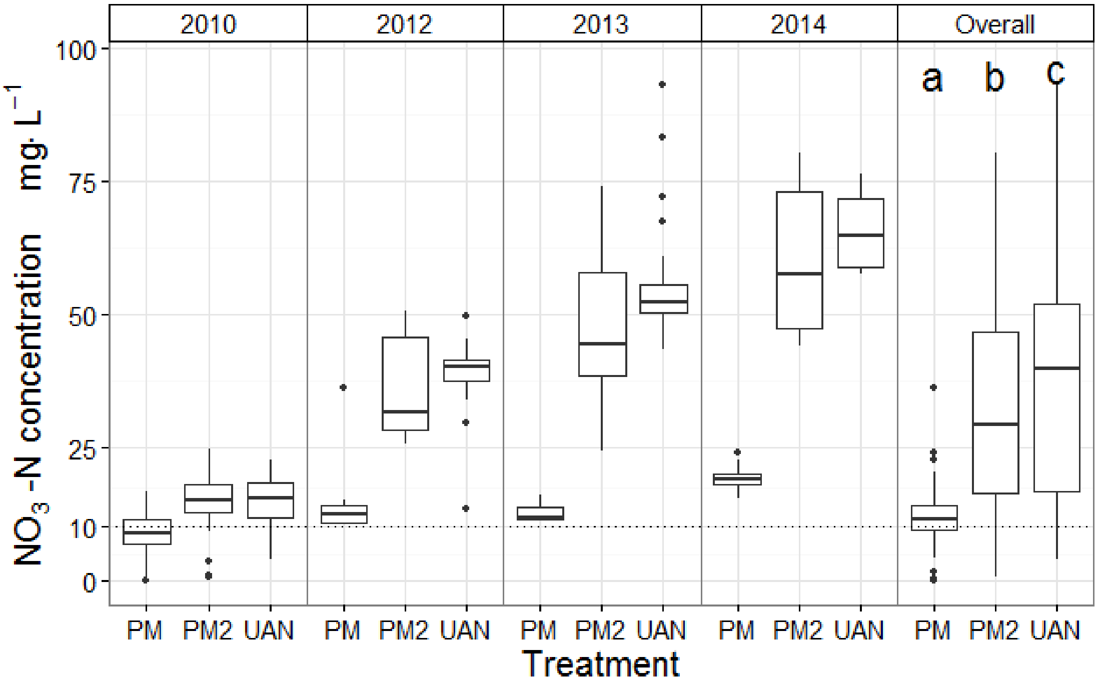

Figure 0.11 Tile drainage NO_3-N concentration for all research plots by treatment and year

4.6.2 Effects of year, treatment on orthophosphate concentrations in drainage tile water

Table 0.11 Median orthophosphate concentration by year from year 2010 to year 2014

Year	**PM (mg · L^{-1})**	**PM2 (mg · L^{-1})**	**UAN (mg · L^{-1})**	**Mean (mg · L^{-1})**
2010	0.016(±0.012)[1]	0.029(±0.006)	0.013(±0.003)	0.02(±0.01)a
2012[2]	0(±0)	0.006(±0.011)	0(±0)	0.002(±0.007)b
2013	0.001(±0.001)	0.005(±0.005)	0.001(±0.001)	0.002(±0.004)c
2014	0.023(±0.036)	0.036(±0.055)	0.001(±0)	0.02(±0.038)d
Mean	0.01(±0.019)ab[3]	0.019(±0.028)a	0.004(±0.006)b	

[1] *median orthophosphate concentration, a median of all samples by treatment for each year with standard deviation in parentheses*

[2] *there's little drainage in 2011, no sample were collected in 2011*

[3] ***median** sample phosphate concentration by treatment for all years follow the order that PM2>PM>UAN. Wilcoxon rand sum non-parametric test only shows significant difference between the median PO_4-P concentration of UAN and PM2. In each row, values with the same letter are not significantly different at the p=0.05 level.*

The median phosphate concentrations (Table 4.11) for each treatment are 0.019 mg · L^{-1} for PM2, 0.01 mg · L^{-1} for PM, and 0.004 mg · L^{-1} for UAN. For different treatments for each year, the phosphate concentrations follow the order PM2>PM>UAN. This is also the order of P application rate (Table 4.4), soil test phosphorous (Figure 4.2) and PO4-P load (Table 4.9). Median is reported instead of mean is because of huge variation and the none-normal distribution of concentration data, where mean value is not as suitable as median value to reveal the whole PO_4-P concentration data under the effect of huge data variation because of the soil phosphorous movement in precipitation.

Tile drainage PO_4-P concentration for all research plots by treatment and year are shown in Figure 4.12 with 6 samples which have extremely high PO_4-P concentrations (>0.25 mg · L^{-1}) excluded in the figure (they were included in the statistical analysis). In 2012 and 2013, the two dry years, the water sample in all treatment plots had limited PO_4-P concentration measured with medians close to 0.001, the detection level of PO_4-P. In wet years, 2010 and 2014, higher PO_4-P concentrations are found from all treatment except UAN in 2014. Median PO_4-P concentrations in wet year with low yield (2014) is lower than the median concentration in wet year with high yield (2010). Wilcoxon rank sum test only shows significant difference between the median PO_4-P concentrations of UAN and PM2. (Table 4.11, Figure 4.12). Significant different median PO_4-P concentrations are found for all research years (Table 4.11).

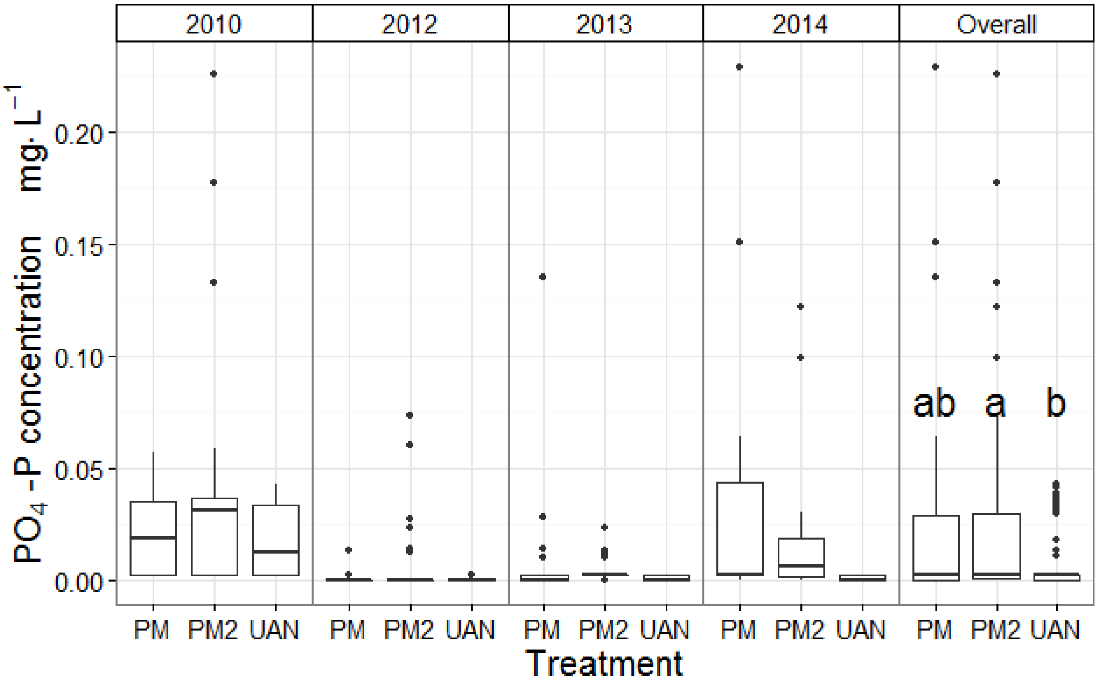

Figure 0.12 Tile drainage PO_4-P concentration for all research plots by treatment and year

∗ 6 samples which have extreme high PO_4-P concentrations (>0.25 mg · L^{-1}) are excluded in the figure (they are included in statistical analysis)

Therefore, we are able to conclude that UAN is more PO_4-P concentration friendly in comparison of PM2 There tends to be higher PO_4-P concentrations in wet years than dry years.

4.7 Seasonal patterns of drainage NO_3-N

Significant decreasing trend of monthly NO_3-N loads can be found from both dry years, 2012 and 2013 (Figure 4.13). As for dry years (2012 and 2013), the majority of the load occurs before June when the amount of water the crop needs is limited, temperature is lower and tile drains are flowing. This observation was different for wet years, in wet years (2010 and 2014), NO_3-N loads in 2010 fluctuate, while, NO_3-N loads in 2014 increase by month. There exists a possibility that nitrate is stored in the soil in dry year (2012 and 2013) and then lost with drainage in the following wet years (2014); A dry year followed by a wet year may result in leaching of unused nitrogen.

Similar trends are found between monthly NO_3-N loads and monthly drainage (Figure 4.14). As described, variation of drainage can best explain the variation of treatment mean flow weighted NO_3-N loads. It seems as if NO_3-N loads are linear related to drainage only, although, in fact NO_3-N concentration also follows this pattern.

The fluctuation of NO_3-N concentration in 2010 (APPENDIX C1 a) looks similar as the trend Nguyen (2013) recorded from 1998 to 2009, with increase before June and decrease after July, indicating the usage of nitrogen for crop growth. This is a proof of the transfer year 2010, when before, corn-soybean rotation is applied on field 5 A. However, starting from 2010 the cropping system was changed to a corn on corn system. Similarly, the field is fertilized every year. An increasing amount of soil NO_3-N is observed (section 4.3). Soil NO_3-N build up is so serious that even crop usage does not affect the drainage NO_3-N concentration much for the following years. Actually, except 2010, the series drainage NO_3-N concentration keeps increasing annually but shows no similar trend (APPENDIX C1). And it seems as if NO_3-N loads are linear related to drainage only, although, in fact NO_3-N concentration follows similar trends. We can infer that not only during the last year, but also during the two dry years, the field is leaching NO_3-N that is stored during the previous year. Regarding 2014, it is difficult to know that if the high NO_3-N leaching is because 2014 is following by a dry year or because of continuous fertilizer application.

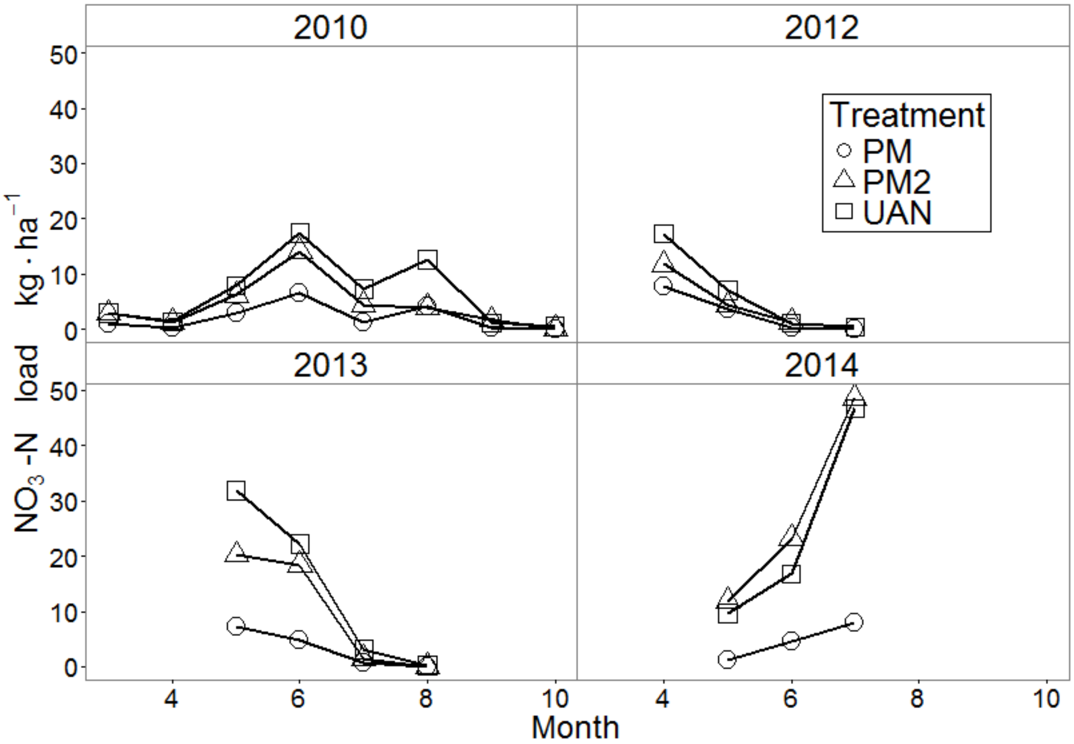

Figure 0.13 Monthly NO_3-N loads for all treatments by year

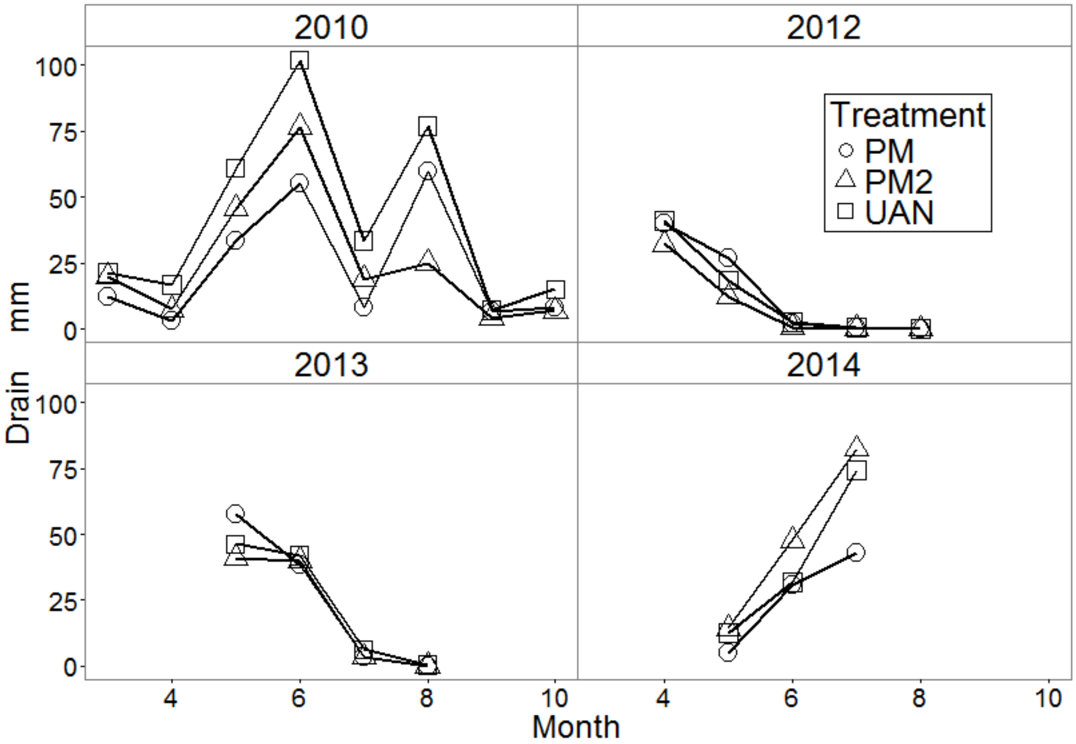

Figure 0.14 Monthly drainage for all treatments by year

CHAPTER V: CONCLUSIONS

With the experiment designed, the research covers the comparison of manure application, soil nutrients, crop yields, NO_3-N and PO_4-P loads, and NO_3-N and PO_4-P concentrations between treatments (PM, PM2 and UAN) and years (2010-2014). Major findings are listed below:

- All plots are applied fertilizer on an N-basis that is similar to the designed application rates (112 kg · ha-1 for PM and 224 kg · ha-1 for PM2, Table 3.2).
- Potential lack of soil phosphorous is significant on UAN plots
- Mehlich 3-P test are suggested for calcareous soil with pH larger than 7.3 to avoid underestimated of soil nitrate by Bray 1-P test.
- Instead of corn-soybean rotation, soil NO_3-N concentration under corn-on-corn planting builds up for all treatments. Soil phosphorous builds up for poultry manure applied plots
- Under half (112 kg · ha^{-1}) or the same (224 kg · ha^{-1}) amount of nitrogen application rate with UAN (224 kg · ha^{-1}), PM and PM2 result in greater yield production, without considering the nutrient control of phosphorous and other micro nutrient sources. Effective solar radiation dominants the advantage of crop yield in comparison with effective precipitation, which would benefit the yield when lacking effective solar radiation.
- PM2 is more efficient on producing corn yield while at the same time contributes similar NO_3-N load and concentration in comparison with UAN. PM is more NO_3-N load and concentration friendly and produces larger crop yields than UAN. UAN has significantly

lower PO_4-P concentrations than PM2 and is more PO_4-P loads friendly than the other two treatments.

CHAPTER VI: SUGGESTION AND FUTURE EXPECTION

Manure nitrogen is suggested to diminish the accumulation of nutrients in the soil of poultry manure plots. Applying additional phosphorous, potassium and micro nutrient source to UAN plots to a level that is similar to the amount of P as applied in PM or PM2 plots to reduce variables that would affect crop yield, which also better control the variables affect nutrient losses. Instead of requiring manure early in spring right before the planting, store manure on the field after stalk chopping before the winter in the prior year. This diminishes the possibility of late planting and results in sufficient time for plant growth, which leads to a consistent growing days and a consistent seed type each year during the research period, which further control the variables affect the crop yield and nitrogen and phosphorous losses.

Possible future research could be focused on further developing the P index. Make modular to model the drainage and tile P movement with monitored data support. Also effect of manure application on nutrient losses with a P-basis manure application design.

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APPENDIX A. SPRING SOIL TEST

year	treatment	plot	depth	pH	Ompct	B-P(ppm)	NO3-N(ppm)
2010	PM2	1	0-15 cm	6.9	3.4	57	6
2010	PM2	1	15-30 cm	6.5	2.7	11	6
2010	PM2	3	0-15 cm	6.85	3.3	82	7
2010	PM2	3	15-30 cm	6.8	2.8	32	6
2010	PM2	7	0-15 cm	6.95	3.9	94	6
2010	PM2	7	15-30 cm	6.2	3.3	16	5
2010	PM	2	0-15 cm	6.8	2.9	34	4
2010	PM	2	15-30 cm	6.7	2	9	4
2010	PM	5	0-15 cm	6.75	3.6	58	6
2010	PM	5	15-30 cm	6.25	3.2	17	5
2010	PM	10	0-15 cm	7.2	3.4	84	6
2010	PM	10	15-30 cm	6.45	3.1	11	5
2010	UAN	8	0-15 cm	6.8	3.9	20	5
2010	UAN	8	15-30 cm	6.1	3.7	8	4
2011	PM2	1	0-15 cm	7.5	3.9	288	10
2011	PM2	1	15-30 cm	6.7	2.9	41	13
2011	PM2	3	0-15 cm	7.4	3.1	214	8
2011	PM2	3	15-30 cm	6.85	2.1	35	9
2011	PM2	7	0-15 cm	7.15	4.1	230	10
2011	PM2	7	15-30 cm	6.15	3.4	27	12
2011	PM	2	0-15 cm	7.35	2.9	90	6
2011	PM	2	15-30 cm	6.8	1.8	24	5
2011	PM	5	0-15 cm	7.65	3.7	96	7
2011	PM	5	15-30 cm	7.55	3	12	6
2011	PM	10	0-15 cm	7.25	3.6	110	7
2011	PM	10	15-30 cm	6.65	2.8	11	5
2011	UAN	4	0-15 cm	6.8	3.8	20	10
2011	UAN	4	15-30 cm	6.45	3.4	10	7
2011	UAN	8	0-15 cm	6.85	3.4	17	7
2011	UAN	8	15-30 cm	6.4	2.9	7	6
2012	PM2	1	0-15 cm	7.15	4	374	12
2012	PM2	1	15-30 cm	6.65	2.6	92	9
2012	PM2	3	0-15 cm	7.15	3.1	254	11
2012	PM2	3	15-30 cm	6.85	2.4	132	11
2012	PM2	7	0-15 cm	7.1	3.5	155	5
2012	PM2	7	15-30 cm	6.45	3.1	74	8
2012	PM	2	0-15 cm	7.3	2.6	98	4
2012	PM	2	15-30 cm	6.65	2.1	25	7
2012	PM	5	0-15 cm	7.15	3.2	144	7

2012	PM	5	15-30 cm	6.35	2.7	39	7
2012	PM	10	0-15 cm	7.1	3.6	139	6
2012	PM	10	15-30 cm	6.65	3	36	9
2012	UAN	4	0-15 cm	6.05	2.9	8	6
2012	UAN	4	15-30 cm	6.2	3.2	11	5
2012	UAN	8	0-15 cm	6.05	2.8	12	6
2012	UAN	8	15-30 cm	6.5	3.4	15	6
2012	PM2	1	0-15 cm	7.2	4.076	255	24.55
2012	PM2	1	15-30 cm	6.4	3.066	15	8.8
2012	PM	2	0-15 cm	7.2	3.586	122	10.9
2012	PM	2	15-30 cm	6.15	2.691	14	4.92
2012	PM2	3	0-15 cm	7	3.446	198	24.85
2012	PM2	3	15-30 cm	6.3	2.56	21	10.85
2012	UAN	4	0-15 cm	5.85	4.167	9	23.95
2012	UAN	4	15-30 cm	5.85	3.383	4	9.15
2012	PM	5	0-15 cm	7.05	4.475	177	24.8
2012	PM	5	15-30 cm	5.95	3.861	14	22.45
2012	PM2	7	0-15 cm	7.05	4.522	225	11.85
2012	PM2	7	15-30 cm	5.95	4.298	26	10.25
2012	UAN	8	0-15 cm	6.75	3.776	14	31.4
2012	UAN	8	15-30 cm	6.15	3.25	6	18.6
2012	PM	10	0-15 cm	7.3	3.622	119	14.7
2012	PM	10	15-30 cm	6.45	3.052	11	4.045
2012	UAN	6	0-15 cm	5.9	3.931	9	27.45
2012	UAN	6	15-30 cm	5.85	3.351	4	8.95
2013	PM2	1	0-15 cm	7.35	3.913	330	13.35
2013	PM	2	0-15 cm	7.4	2.819	148	6.95
2013	PM2	3	0-15 cm	7.25	3.796	374	7.5
2013	UAN	4	0-15 cm	6.2	3.637	14	4.385
2013	PM	5	0-15 cm	7	3.616	141	6.05
2013	PM2	7	0-15 cm	7.15	3.754	285	6.65
2013	UAN	8	0-15 cm	6.5	3.583	20	4.16
2013	PM2	1	15-30 cm	6.4	2.563	46	6.45
2013	PM	2	15-30 cm	6.35	2.125	19	3.265
2013	PM2	3	15-30 cm	6.4	2.614	48	6.1
2013	UAN	4	15-30 cm	6.05	3.014	7	4.255
2013	PM	5	15-30 cm	6.05	3.163	17	5.3
2013	PM2	7	15-30 cm	6	2.905	38	5.65
2013	UAN	8	15-30 cm	6.15	3.091	9	2.76
2014	PM2	1	0-15 cm	7.25		307	25.95
2014	PM2	1	0-15 cm	7.3		307	27.8
2014	PM	2	0-15 cm	7.25		111	11.55

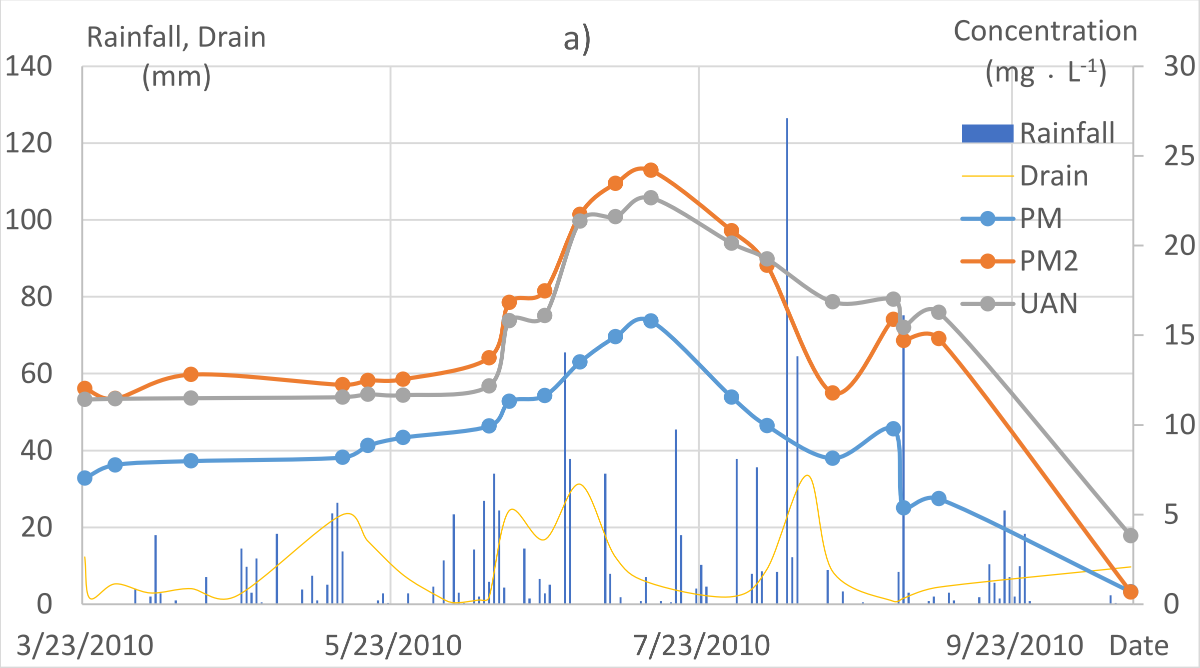
2014	PM	2	0-15 cm	7.3		105	14.15
2014	PM2	3	0-15 cm	7		284	27.15
2014	PM2	3	0-15 cm	7.05		288	25.45
2014	UAN	4	0-15 cm	5.9		18	29.5
2014	UAN	4	0-15 cm	5.9		16	29.45
2014	PM	5	0-15 cm	6.85		125	16.95
2014	PM	5	0-15 cm	5.95		118	16.45
2014	PM2	7	0-15 cm	7.2		345	20.95
2014	PM2	7	0-15 cm	7.25		336	20.8
2014	UAN	8	0-15 cm	6.05		18	48.2
2014	UAN	8	0-15 cm	6.1		17	48.1
2014	PM	10	0-15 cm	7.2		122	13.1
2014	PM	10	0-15 cm	7.2		124	15.1
2014	PM2	1	15-30 cm	6.7		74	25.9
2014	PM2	1	15-30 cm	6.75		74	28
2014	PM	2	15-30 cm	6.5		34	10.95
2014	PM	2	15-30 cm	6.55		31	10
2014	PM2	3	15-30 cm	6.6		64	29.6
2014	PM2	3	15-30 cm	6.6		68	26.65
2014	UAN	4	15-30 cm	5.7		7	23.2
2014	UAN	4	15-30 cm	5.75		7	23.85
2014	PM	5	15-30 cm	6.1		33	13.95
2014	PM	5	15-30 cm	6.1		34	13
2014	PM2	7	15-30 cm	6.3		56	22.2
2014	PM2	7	15-30 cm	6.3		34	22.65
2014	UAN	8	15-30 cm	5.7		11	42.95
2014	UAN	8	15-30 cm	5.7		10	44
2014	PM	10	15-30 cm	6.3		6	8.95
2014	PM	10	15-30 cm	6.25		5	9.1

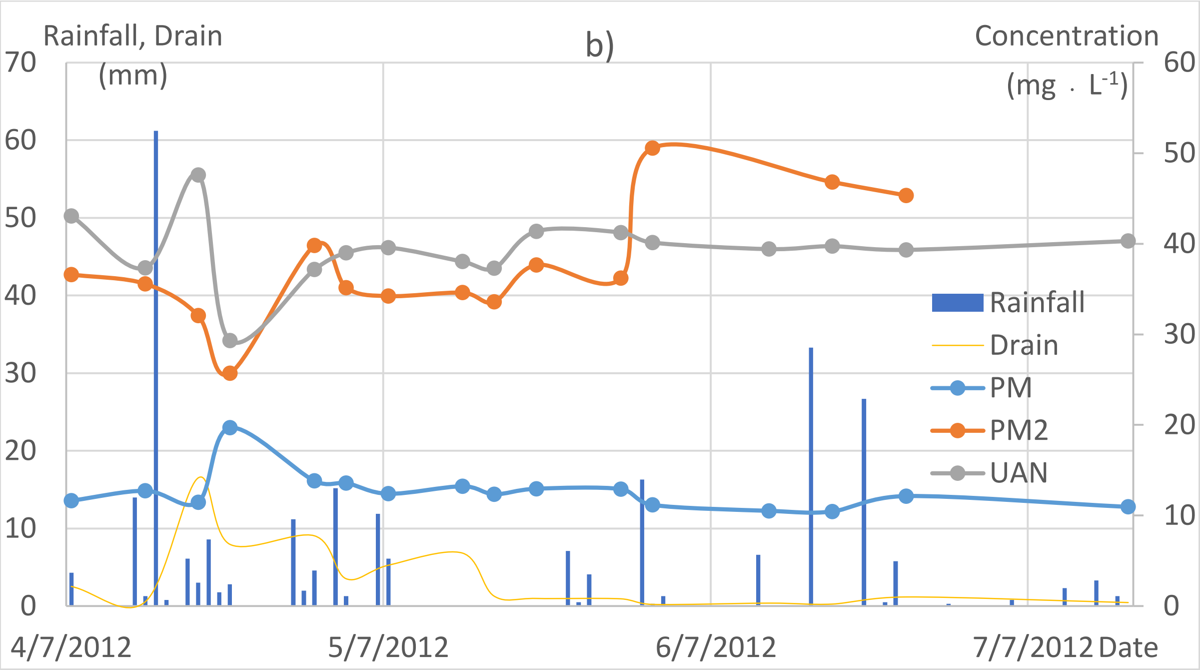
APPENDIX B. CROP YIELDS

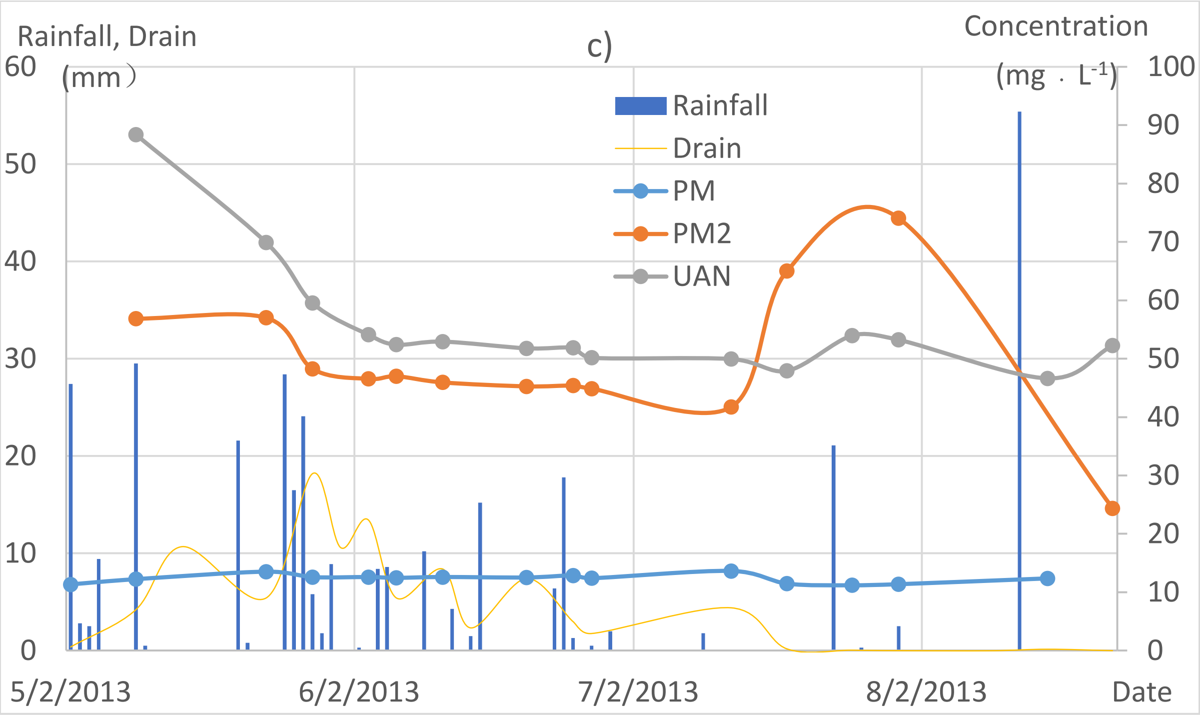
Year	Treatment	Plot	Yield (kg/ha)	Area (ha)
2010	PM	2	8484.415	0.234013
2010	PM	5	9142.604	0.357862
2010	PM	10	9321.557	0.202287
2010	PM2	1	9883.047	0.161521
2010	PM2	3	10136.16	0.288473
2010	PM2	7	10369.44	0.376415
2010	UAN	4	8950.802	0.327251
2010	UAN	8	8417.112	0.231059
2011	PM	2	9089.58	0.249129
2011	PM	5	8869.334	0.385492
2011	PM	10	9045.01	0.211728
2011	PM2	1	10399.56	0.174017
2011	PM2	3	10213.43	0.315071
2011	PM2	7	10040.02	0.405261
2011	UAN	4	8289.149	0.353737
2011	UAN	8	8732.609	0.249621
2012	PM	2	8894.546	0.273599
2012	PM	5	8725.552	0.414928
2012	PM	10	9560.087	0.236299
2012	PM2	1	9018.36	0.193563
2012	PM2	3	9568.693	0.33545
2012	PM2	7	9399.308	0.425565
2012	UAN	4	8608.596	0.376304
2012	UAN	8	9387.763	0.266562
2013	PM	2	5820.498	0.085471
2013	PM	5	5671.746	0.145114
2013	PM	10	4565.658	0.084913
2013	PM2	1	6774.457	0.051654
2013	PM2	3	6684.456	0.116779
2013	PM2	7	5943.88	0.151525
2013	UAN	4	4141.673	0.132387
2013	UAN	8	3665.596	0.094854
2014	PM	2	6652.866	0.104423
2014	PM	5	7245.7	0.163881
2014	PM	10	7097.923	0.081104
2014	PM2	1	7584.741	0.070142
2014	PM2	3	7796.52	0.104609
2014	PM2	7	7527.999	0.171592
2014	UAN	4	5084.623	0.149481
2014	UAN	8	4388.775	0.090488

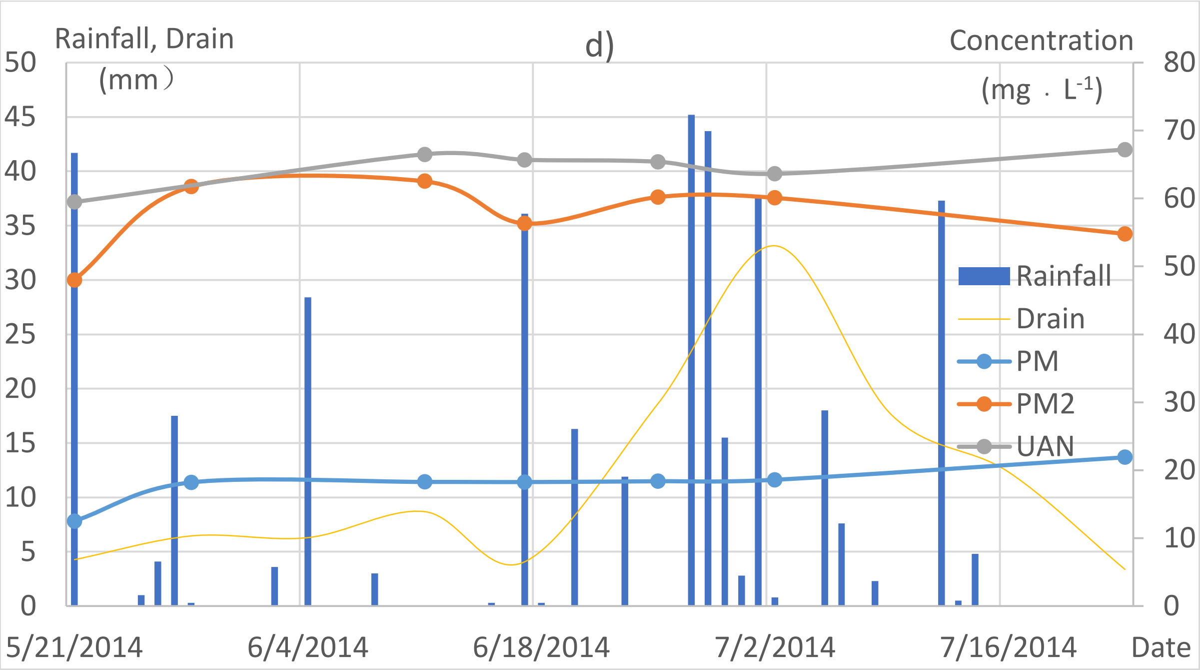
APPENDIX C. DRAINAGE EVEN AND WATER QUALITY UP ON PRECIPITATION

APPENDIX C1. NO3-N concentration with drainage event and precipitation from 2010 to 2014

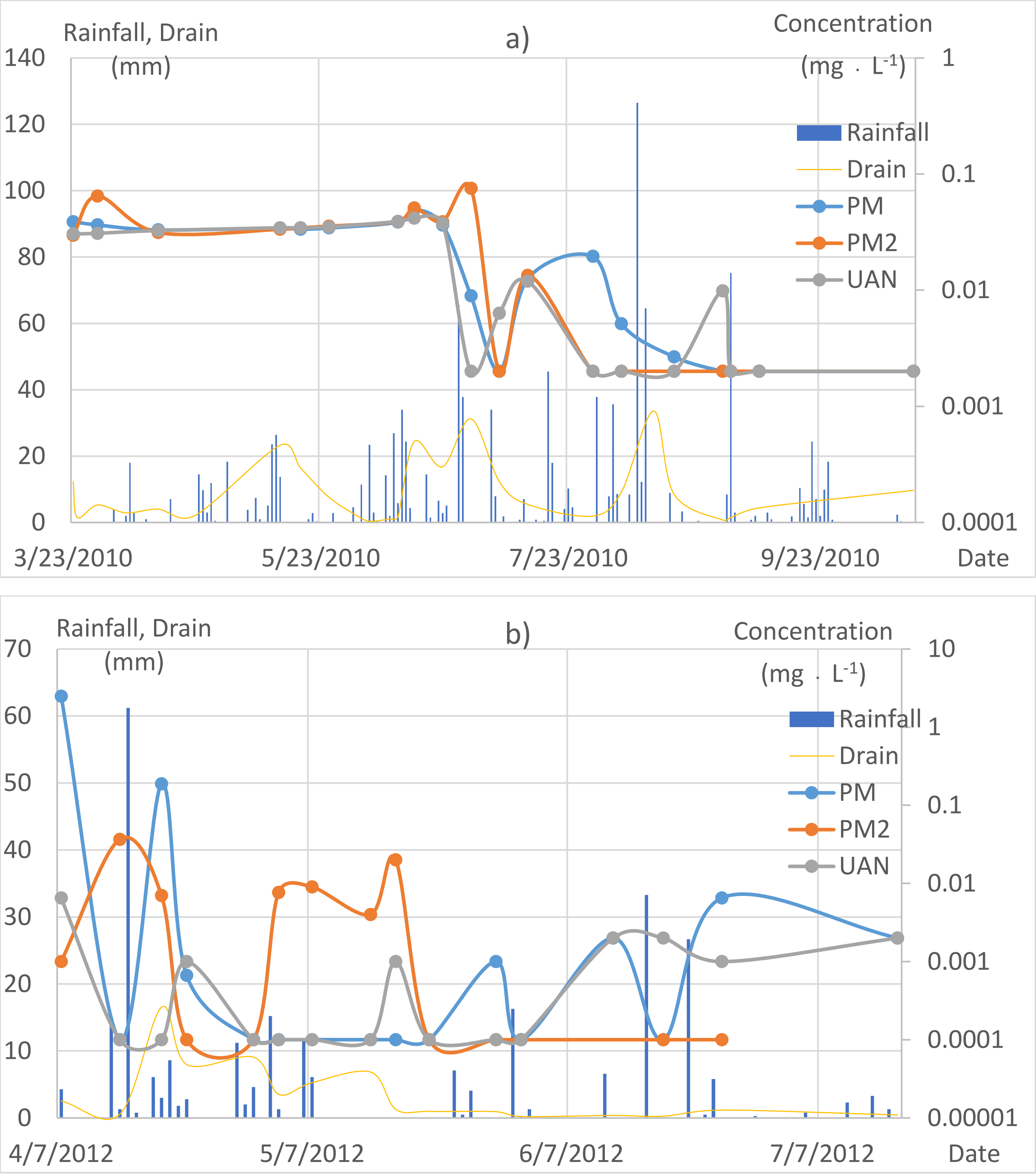


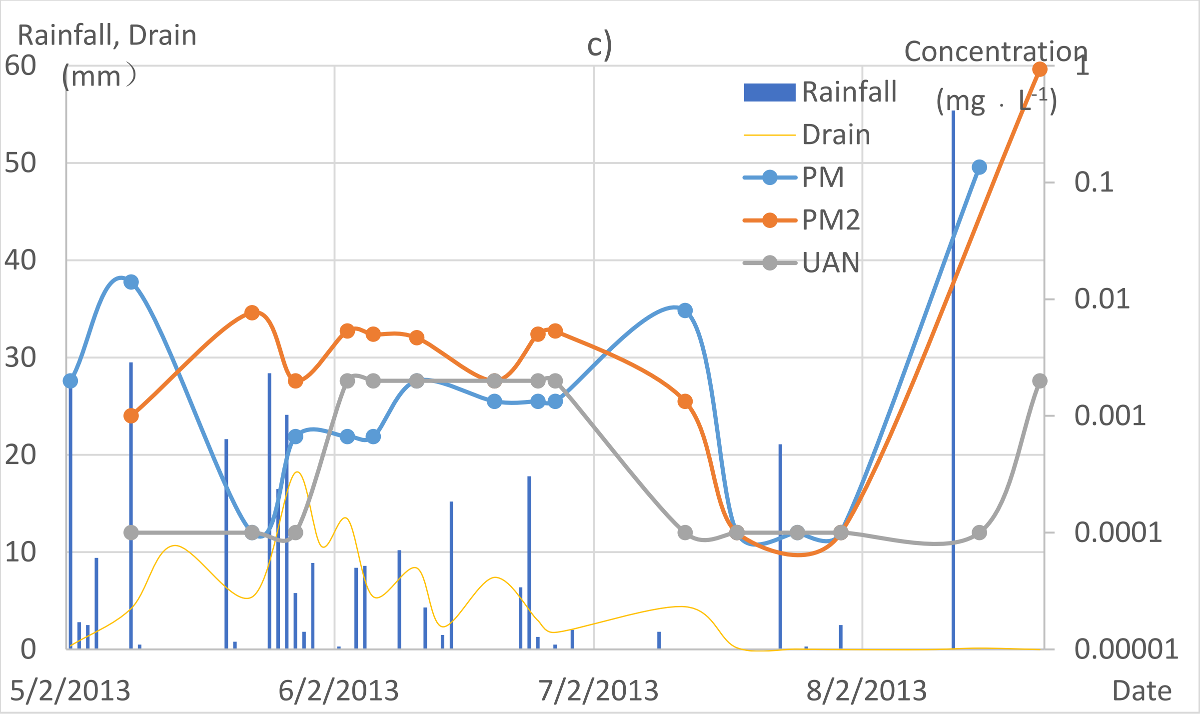

b)
Rainfall, Drain
(mm)
Concentration
(mg . L-1)
70
60
50
40
30
20
10
0
60
50
40
30
20
10
0
4/7/2012
5/7/2012
6/7/2012
7/7/2012
Date
Rainfall
Drain
PM
PM2
UAN

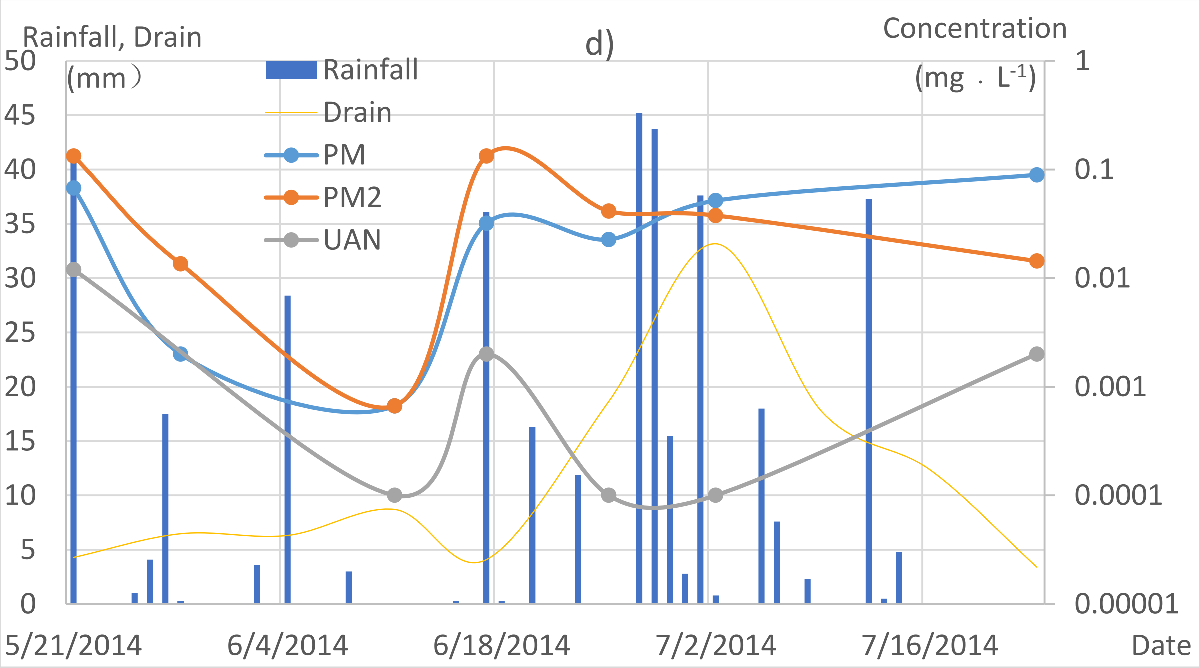

c)
Rainfall, Drain
(mm)
Concentration
(mg . L-1)
60
50
40
30
20
10
0
100
90
80
70
60
50
40
30
20
10
0
5/2/2013
6/2/2013
7/2/2013
8/2/2013
Date
Rainfall
Drain
PM
PM2
UAN


d)
Rainfall, Drain
(mm）
Concentration
(mg . L-1)
50
45
40
35
30
25
20
15
10
5
0
80
70
60
50
40
30
20
10
0
5/21/2014
6/4/2014
6/18/2014
7/2/2014
7/16/2014
Date
Rainfall
Drain
PM
PM2
UAN

APPENDIX C2. PO4-P concentration with drainage event and precipitation from 2010 to 2014




c)
Rainfall, Drain
(mm）
60
50
40
30
20
10
0
Concentration
(mg . L-1)
1
0.1
0.01
0.001
0.0001
0.00001
Rainfall
Drain
PM
PM2
UAN
5/2/2013
6/2/2013
7/2/2013
8/2/2013
Date


d)
Rainfall, Drain
(mm）
50
45
40
35
30
25
20
15
10
5
0
Concentration
(mg . L-1)
1
0.1
0.01
0.001
0.0001
0.00001
Rainfall
Drain
PM
PM2
UAN
5/21/2014
6/4/2014
6/18/2014
7/2/2014
7/16/2014
Date

APPENDIX C3. Event water quality from 2010 to 2014

Date	Plot	Treatment	meter reading (cubit feet)	segment flow (L)	tile flow (mm)	Nitrate+nitrite (mg/L)	Phosphate (mg/L)
5/7/2014	1	PM2	35320.6		0.0		
5/21/2014	1	PM2	35505.8	5242.3	2.8	46.4	0.394
5/28/2014	1	PM2	35893.5	10979.0	5.8	57.6	0.002
6/4/2014	1	PM2	36347.1	12843.9	6.8		0.146
6/11/2014	1	PM2	36980.9	17947.8	9.4	59.9	0.000
6/17/2014	1	PM2	37220.2	6776.8	3.6	46.8	0.372
6/25/2014	1	PM2	38337.5	31638.6	16.7	50.9	0.122
7/2/2014	1	PM2	40652.5	65552.0	34.5	58.9	0.099
7/9/2014	1	PM2	41995.7	38034.8	20.0		0.015
7/16/2014	1	PM2	42991.4	28196.2	14.8		
7/23/2014	1	PM2	43274.1	8004.3	4.2	44.1	0.030
5/7/2014	2	PM	41659		0.0		
5/21/2014	2	PM	41678.1	543.4	0.2	17.9	0.031
5/28/2014	2	PM	42042.1	10306.7	4.1	18.2	0.002
6/4/2014	2	PM	42370.6	9300.4	3.7		0.000
6/11/2014	2	PM	42362.6	0.0	0.0	19.0	0.002
6/17/2014	2	PM	42354.5	0.0	0.0	19.9	0.014
6/25/2014	2	PM	42824.3	13303.5	5.3	19.3	0.002
7/2/2014	2	PM	44501.3	47487.8	19.0	20.3	0.002
7/9/2014	2	PM	45601.7	31160.1	12.5		0.000
7/16/2014	2	PM	46240.9	18098.4	7.2		
7/23/2014	2	PM	46360.1	3377.1	1.4	24.1	0.037
5/7/2014	3	PM2	111337		0.0		
5/21/2014	3	PM2	111730	11124.8	3.7	58.6	0.002
5/28/2014	3	PM2	112661	26360.7	8.8	65.9	0.025
6/4/2014	3	PM2	113630	27441.2	9.1		0.026
6/11/2014	3	PM2	115113	42013.6	14.0	80.4	0.002
6/17/2014	3	PM2	115622	14392.0	4.8	77.8	0.010
6/25/2014	3	PM2	117711	59153.8	19.7	79.2	0.000
7/2/2014	3	PM2	121887	118248.1	39.4	73.0	0.000
7/9/2014	3	PM2	124427	71924.4	24.0		0.000
7/16/2014	3	PM2	126136	48396.0	16.1		
7/23/2014	3	PM2	126179	1231.2	0.4	75.1	0.002
5/7/2014	4	UAN	125217		0.0	62.4	0.015
5/21/2014	4	UAN	125560	9722.3	2.7	63.7	0.002

5/28/2014	4	UAN	125797	6722.4	1.9		0.000
6/4/2014	4	UAN	125797	0.8	0.0		0.030
6/11/2014	4	UAN	125983	5263.5	1.5	71.8	0.000
6/17/2014	4	UAN	125991	221.7	0.1	71.6	0.002
6/25/2014	4	UAN	127108	31620.2	8.8	73.3	0.000
7/2/2014	4	UAN	130546	97346.9	27.0	68.7	0.000
7/9/2014	4	UAN	133430	81686.9	22.7		0.000
7/16/2014	4	UAN	135168	49197.3	13.7		
7/23/2014	4	UAN	135266	2786.4	0.8	76.2	0.002
5/7/2014	5	PM	119388		0.0		
5/21/2014	5	PM	119475	2475.5	0.7	8.8	0.172
5/28/2014	5	PM	119868	11115.5	3.1		0.016
6/4/2014	5	PM	120072	5779.2	1.6		0.002
6/11/2014	5	PM	120487	11751.2	3.3	16.2	0.000
6/17/2014	5	PM	121333	23954.9	6.7	16.7	0.050
6/25/2014	5	PM	124082	77837.5	21.6	18.0	0.002
7/2/2014	5	PM	126166	59026.4	16.4	19.9	0.002
7/9/2014	5	PM	126934	21731.7	6.0		0.000
7/16/2014	5	PM	128197	35765.0	9.9		
7/23/2014	5	PM	129138	26640.2	7.4	18.9	0.002
5/7/2014	7	PM2	124666		0.0	30.8	0.054
5/21/2014	7	PM2	125812	32453.9	8.1	39.0	0.002
5/28/2014	7	PM2	127807	56503.3	14.1		0.105
6/4/2014	7	PM2	129475	47213.5	11.8		0.012
6/11/2014	7	PM2	131768	64948.3	16.2	47.3	0.000
6/17/2014	7	PM2	132593	23346.6	5.8	44.3	0.016
6/25/2014	7	PM2	136185	101734.3	25.4	50.6	0.002
7/2/2014	7	PM2	142692	184241.3	46.1	48.4	0.014
7/9/2014	7	PM2	146165	98356.7	24.6		0.000
7/16/2014	7	PM2	148624	69623.6	17.4		
7/23/2014	7	PM2	149386	21589.0	5.4	45.1	0.011
5/7/2014	8	UAN	97848.1		0.0	58.3	0.002
5/21/2014	8	UAN	98683.1	23644.2	9.5	55.2	0.022
5/28/2014	8	UAN	99674.4	28070.7	11.2		0.000
6/4/2014	8	UAN	100471	22552.9	9.0		0.000
6/11/2014	8	UAN	101679	34204.1	13.7	61.2	0.000
6/17/2014	8	UAN	102303	17664.0	7.1	59.8	0.002
6/25/2014	8	UAN	104368	58487.8	23.4	57.5	0.000
7/2/2014	8	UAN	108200	108496.1	43.4	58.6	0.000
7/9/2014	8	UAN	109955	49696.0	19.9		0.000
7/16/2014	8	UAN	111279	37504.5	15.0		

7/23/2014	8	UAN	111812	15090.6	6.0	58.1	0.002
5/7/2014	10	PM	54351.3		0.0		
5/21/2014	10	PM	54857.4	14328.6	6.8	10.9	0.000
5/28/2014	10	PM	54859.5	59.5	0.0		
6/4/2014	10	PM	55613.4	21350.3	10.2		0.002
6/11/2014	10	PM	56523.4	25766.0	12.3	19.7	0.000
6/25/2014	10	PM	58599.6	58792.2	28.0	17.9	0.064
7/2/2014	10	PM	61733.9	88753.1	42.3	15.5	0.151
7/9/2014	10	PM	62290.7	15766.2	7.5		0.056
7/16/2014	10	PM	62290.7	0.0	0.0		
7/23/2014	10	PM	62290.7	0.0	0.0	22.7	0.229
4/19/2013	1	PM2	31251		0.0		
5/2/2013	1	PM2	31251	0.0	0.0		
5/9/2013	1	PM2	31251	0.0	0.0		
5/14/2013	1	PM2	31288	1047.7	0.6		
5/23/2013	1	PM2	31427	3936.0	2.1	58.8	0.023
5/28/2013	1	PM2	32394	27382.3	14.4	53.3	0.002
5/31/2013	1	PM2	32980	16593.6	8.7		
6/3/2013	1	PM2	33714	20784.5	10.9	45.5	0.012
6/6/2013	1	PM2	34019	8636.6	4.5	44.7	0.011
6/11/2013	1	PM2	34465	12629.3	6.6	43.7	0.010
6/14/2013	1	PM2	34584	3369.7	1.8		
6/20/2013	1	PM2	34975	11071.9	5.8	42.2	0.002
6/25/2013	1	PM2	35109	3794.5	2.0	39.7	0.013
6/27/2013	1	PM2	35195	2435.2	1.3	39.8	0.012
7/12/2013	1	PM2	35329	3794.5	2.0	31.9	0.002
7/18/2013	1	PM2	35329	0.0	0.0		
7/25/2013	1	PM2	35329	0.0	0.0		
7/30/2013	1	PM2	35329	0.0	0.0		
8/9/2013	1	PM2	35329	0.0	0.0		
8/15/2013	1	PM2	35329	0.0	0.0		
8/22/2013	1	PM2	35332	85.0	0.0	24.4	0.933
4/19/2013	2	PM	37188		0.0		
5/2/2013	2	PM	37188	0.0	0.0		
5/9/2013	2	PM	37188	0.0	0.0		
5/14/2013	2	PM	37476	8155.2	3.3		
5/23/2013	2	PM	37598	3454.6	1.4	15.7	0.000
5/28/2013	2	PM	38833	34971.2	14.0	13.8	0.000
5/31/2013	2	PM	39642	22908.3	9.2		
6/3/2013	2	PM	40659	28798.2	11.5	14.5	0.000
6/6/2013	2	PM	40992	9429.5	3.8	13.8	0.000

6/11/2013	2	PM	41529	15206.1	6.1	14.7	0.002
6/14/2013	2	PM	41673	4077.6	1.6		
6/20/2013	2	PM	41666	0.0	0.0	14.6	0.002
6/25/2013	2	PM	41663	0.0	0.0	15.0	0.002
6/27/2013	2	PM	41660	0.0	0.0	14.2	0.002
7/12/2013	2	PM	41658	0.0	0.0	16.1	0.014
7/18/2013	2	PM	41658	0.0	0.0		
7/25/2013	2	PM	41658	0.0	0.0		
7/30/2013	2	PM	41658	0.0	0.0		
8/9/2013	2	PM	41658	0.0	0.0		
8/15/2013	2	PM	41658	0.0	0.0		
8/22/2013	2	PM	41658	0.0	0.0		
4/19/2013	3	PM2	102004		0.0		
5/2/2013	3	PM2	102005	28.3	0.0		
5/9/2013	3	PM2	102262	7277.4	2.4	69.9	0.002
5/14/2013	3	PM2	103070	22880.0	7.6		
5/23/2013	3	PM2	103540	13308.9	4.4	73.5	0.000
5/28/2013	3	PM2	105314	50234.0	16.7	57.9	0.002
5/31/2013	3	PM2	106453	32252.8	10.8		
6/3/2013	3	PM2	107897	40889.5	13.6	56.7	0.002
6/6/2013	3	PM2	108461	15970.7	5.3	57.9	0.002
6/11/2013	3	PM2	109338	24833.8	8.3	55.6	0.002
6/14/2013	3	PM2	109572	6626.1	2.2		
6/20/2013	3	PM2	110355	22172.1	7.4	55.1	0.002
6/25/2013	3	PM2	110660	8636.6	2.9	58.3	0.000
6/27/2013	3	PM2	110848	5323.6	1.8	56.3	0.002
7/12/2013	3	PM2	111281	12261.2	4.1	59.8	0.000
7/18/2013	3	PM2	111295	396.4	0.1	65.0	0.000
7/25/2013	3	PM2	111301	169.9	0.1		
7/30/2013	3	PM2	111302	28.3	0.0	74.1	0.000
8/9/2013	3	PM2	111302	0.0	0.0		
8/15/2013	3	PM2	111302	0.0	0.0		
8/22/2013	3	PM2	111302	0.0	0.0		
4/19/2013	4	UAN	112688		0.0		
5/2/2013	4	UAN	112688	0.0	0.0		
5/9/2013	4	UAN	112689	28.3	0.0	93.3	0.000
5/14/2013	4	UAN	114013	37491.4	10.4		
5/23/2013	4	UAN	114602	16678.6	4.6	72.2	0.000
5/28/2013	4	UAN	116707	59606.9	16.6	60.9	0.000
5/31/2013	4	UAN	118108	39671.8	11.0		
6/3/2013	4	UAN	119986	53179.0	14.8	55.9	0.002

6/6/2013	4	UAN	120757	21832.3	6.1	55.6	0.002
6/11/2013	4	UAN	121884	31913.0	8.9	53.9	0.002
6/14/2013	4	UAN	122240	10080.8	2.8		
6/20/2013	4	UAN	123428	33640.4	9.3	52.0	0.002
6/25/2013	4	UAN	123919	13903.5	3.9	52.6	0.002
6/27/2013	4	UAN	124192	7730.5	2.1	51.9	0.002
7/12/2013	4	UAN	125030	23729.5	6.6	48.8	0.000
7/18/2013	4	UAN	125123	2633.5	0.7	47.7	0.000
7/25/2013	4	UAN	125136	368.1	0.1	54.0	0.000
7/30/2013	4	UAN	125138	56.6	0.0	53.2	0.000
8/9/2013	4	UAN	125138	0.0	0.0		
8/15/2013	4	UAN	125214	2152.1	0.6	49.8	0.000
8/22/2013	4	UAN	125216	56.6	0.0	52.2	0.002
4/19/2013	5	PM	102772		0.0		
5/2/2013	5	PM	102772	0.0	0.0		
5/9/2013	5	PM	103854	30638.8	8.5	11.7	0.000
5/14/2013	5	PM	105887	57568.1	16.0		
5/23/2013	5	PM	106937	29732.6	8.3	12.4	0.000
5/28/2013	5	PM	109492	72349.4	20.1	12.4	0.000
5/31/2013	5	PM	111055	44259.2	12.3		
6/3/2013	5	PM	113188	60399.7	16.8	11.9	0.002
6/6/2013	5	PM	114078	25202.0	7.0	12.0	0.002
6/11/2013	5	PM	115484	39813.4	11.1	11.5	0.002
6/14/2013	5	PM	115890	11496.6	3.2		
6/20/2013	5	PM	117274	39190.5	10.9	11.8	0.002
6/25/2013	5	PM	117863	16678.6	4.6	12.2	0.002
6/27/2013	5	PM	118185	9118.0	2.5	11.7	0.002
7/12/2013	5	PM	119315	31998.0	8.9	11.4	0.000
7/18/2013	5	PM	119349	962.8	0.3	11.5	0.000
7/25/2013	5	PM	119373	679.6	0.2	11.2	0.000
7/30/2013	5	PM	119377	113.3	0.0	11.4	0.000
8/9/2013	5	PM	119377	0.0	0.0		
8/15/2013	5	PM	119388	311.5	0.1	12.3	0.135
8/22/2013	5	PM	119388	0.0	0.0		
4/19/2013	7	PM2	109739		0.0		
5/2/2013	7	PM2	109739	0.0	0.0		
5/9/2013	7	PM2	110084	9769.3	2.4	43.8	0.000
5/14/2013	7	PM2	112037	55302.7	13.8		
5/23/2013	7	PM2	113090	29817.6	7.5	38.8	0.000
5/28/2013	7	PM2	115958	81212.6	20.3	33.5	0.002
5/31/2013	7	PM2	117590	46213.0	11.6		

6/3/2013	7	PM2	119620	57483.1	14.4	37.4	0.002
6/6/2013	7	PM2	120462	23842.7	6.0	38.3	0.002
6/11/2013	7	PM2	121759	36726.9	9.2	38.5	0.002
6/14/2013	7	PM2	122110	9939.2	2.5		
6/20/2013	7	PM2	123305	33838.6	8.5	38.5	0.002
6/25/2013	7	PM2	123794	13846.9	3.5	38.1	0.002
6/27/2013	7	PM2	124085	8240.2	2.1	38.5	0.002
7/12/2013	7	PM2	124634	15545.9	3.9	33.5	0.002
7/18/2013	7	PM2	124634	0.0	0.0		
7/25/2013	7	PM2	124634	0.0	0.0		
7/30/2013	7	PM2	124634	0.0	0.0		
8/9/2013	7	PM2	124634	0.0	0.0		
8/15/2013	7	PM2	124634	0.0	0.0		
8/22/2013	7	PM2	124634	0.0	0.0		
4/19/2013	8	UAN	89700		0.0		
5/2/2013	8	UAN	89700	0.0	0.0		
5/9/2013	8	UAN	90082	10817.0	4.3	83.5	0.000
5/14/2013	8	UAN	91227	32422.7	13.0		
5/23/2013	8	UAN	91736	14413.3	5.8	67.6	0.000
5/28/2013	8	UAN	93314	44683.9	17.9	58.2	0.000
5/31/2013	8	UAN	94107	22455.2	9.0		
6/3/2013	8	UAN	95050	26702.7	10.7	52.3	0.002
6/6/2013	8	UAN	95421	10505.5	4.2	49.2	0.002
6/11/2013	8	UAN	96037	17443.1	7.0	51.9	0.002
6/14/2013	8	UAN	96214	5012.1	2.0		
6/20/2013	8	UAN	96844	17839.6	7.1	51.6	0.002
6/25/2013	8	UAN	97115	7673.9	3.1	51.1	0.002
6/27/2013	8	UAN	97270	4389.1	1.8	48.4	0.002
7/12/2013	8	UAN	97716	12629.3	5.1	51.1	0.000
7/18/2013	8	UAN	97730	396.4	0.2	48.2	0.000
7/25/2013	8	UAN	97730	0.0	0.0		
7/30/2013	8	UAN	97730	0.0	0.0		
8/9/2013	8	UAN	97730	0.0	0.0		
8/15/2013	8	UAN	97755	707.9	0.3	43.5	0.000
8/22/2013	8	UAN	97755	0.0	0.0		
4/19/2013	10	PM	45619		0.0		
5/2/2013	10	PM	45935	8948.1	4.3	11.3	0.002
5/9/2013	10	PM	47312	38992.2	18.6	12.8	0.028
5/14/2013	10	PM	48479	33045.7	15.7		
5/23/2013	10	PM	48977	14101.8	6.7	12.4	0.000
5/28/2013	10	PM	50788	51281.7	24.4	11.5	0.002

5/31/2013	10	PM	51554	21690.7	10.3		
6/3/2013	10	PM	52376	23276.4	11.1	11.4	0.000
6/6/2013	10	PM	52743	10392.3	4.9	11.6	0.000
6/11/2013	10	PM	53305	15914.0	7.6	11.5	0.002
6/14/2013	10	PM	53439	3794.5	1.8		
6/20/2013	10	PM	53943	14271.7	6.8	11.1	0.000
6/25/2013	10	PM	54117	4927.1	2.3	11.4	0.000
6/27/2013	10	PM	54249	3737.8	1.8	11.2	0.000
7/12/2013	10	PM	54329	2265.3	1.1	13.3	0.010
7/18/2013	10	PM	54329	0.0	0.0		
7/25/2013	10	PM	54329	0.0	0.0		
7/30/2013	10	PM	54329	0.0	0.0		
8/9/2013	10	PM	54329	0.0	0.0		
8/15/2013	10	PM	54341	339.8	0.2		
8/22/2013	10	PM	54341	0.0	0.0		
4/19/2013	Check	None	364321		0.0		
5/2/2013	Check	None	367607	93049.0	19.8	6.1	0.000
5/9/2013	Check	None	375177	214358.2	45.6	14.4	0.032
5/14/2013	Check	None	382071	195216.0	41.5		
5/23/2013	Check	None	385244	89849.2	19.1	11.0	0.000
5/28/2013	Check	None	392254	198500.8	42.2	12.7	0.026
5/31/2013	Check	None	394569	65553.4	13.9		
6/3/2013	Check	None	401946	208893.0	44.4	16.1	0.002
6/6/2013	Check	None	404308	66884.3	14.2	15.9	0.002
6/11/2013	Check	None	408062	106301.3	22.6	16.0	0.002
6/14/2013	Check	None	409098	29336.2	6.2		
6/20/2013	Check	None	412647	100496.3	21.4	15.4	0.002
6/25/2013	Check	None	414071	40323.1	8.6	12.9	0.002
6/27/2013	Check	None	414853	22143.7	4.7	15.3	0.002
7/12/2013	Check	None	416993	60598.0	12.9	2.8	0.000
7/18/2013	Check	None	417486	13960.2	3.0	2.8	0.002
7/25/2013	Check	None	417887	11355.0	2.4	3.0	0.002
7/30/2013	Check	None	418108	6258.0	1.3	3.0	0.000
8/9/2013	Check	None	418405	8410.1	1.8	3.6	0.011
8/15/2013	Check	None	418756	9939.2	2.1	4.1	0.014
8/22/2013	Check	None	418965	5918.2	1.3	0.3	0.738
3/29/2012	1	PM2	29611.7		0.0		
4/7/2012	1	PM2	29611.7	0.0	0.0		
4/14/2012	1	PM2	29611.7	0.0	0.0		
4/19/2012	1	PM2	30468.6	24264.1	12.8	37.3	0.014
4/22/2012	1	PM2	30673	5786.5	3.0		

4/30/2012	1	PM2	30944.1	7677.5	4.0	31.5	0.000
5/3/2012	1	PM2	31003.3	1675.5	0.9	30.1	0.023
5/7/2012	1	PM2	31109.8	3016.0	1.6	28.9	0.027
5/14/2012	1	PM2	31241.4	3728.2	2.0	29.9	0.012
5/17/2012	1	PM2	31251	272.1	0.1	26.1	0.060
5/21/2012	1	PM2	31251.4	9.1	0.0		
5/29/2012	1	PM2	31251.4	0.8	0.0		
6/1/2012	1	PM2	31251.4	0.0	0.0		
6/12/2012	1	PM2	31251.4	0.0	0.0		
6/18/2012	1	PM2	31251.4	0.0	0.0		
6/25/2012	1	PM2	31251.7	7.6	0.0		
7/16/2012	1	PM2	31251.6	0.0	0.0		
8/6/2012	1	PM2	31251.6	0.0	0.0		
3/29/2012	2	PM	35221.8		0.0		
4/7/2012	2	PM	35250.7	817.2	0.3	11.5	0.000
4/14/2012	2	PM	35261.7	311.2	0.1	12.7	0.000
4/19/2012	2	PM	36156.1	25325.4	10.1	12.4	0.000
4/22/2012	2	PM	36382.6	6414.0	2.6	12.3	0.002
4/30/2012	2	PM	36689.8	8698.9	3.5	14.4	0.000
5/3/2012	2	PM	36774.6	2401.0	1.0	14.0	0.000
5/7/2012	2	PM	36904.3	3673.5	1.5	13.6	0.000
5/14/2012	2	PM	37099.4	5524.9	2.2	14.1	0.000
5/17/2012	2	PM	37133.6	967.3	0.4	14.2	0.000
5/21/2012	2	PM	37169.2	1008.1	0.4	15.0	0.000
5/29/2012	2	PM	37184.5	435.2	0.2	15.1	0.002
6/1/2012	2	PM	37184.5	0.0	0.0		
6/12/2012	2	PM	37184.5	0.0	0.0		
6/18/2012	2	PM	37184.5	0.0	0.0		
6/25/2012	2	PM	37188.7	119.5	0.0	13.5	0.013
7/16/2012	2	PM	37188.7	0.0	0.0		
8/6/2012	2	PM	37188.7	0.0	0.0		
3/29/2012	3	PM2	96186.3		0.0		
4/7/2012	3	PM2	96405.1	6196.3	2.1	43.6	0.002
4/14/2012	3	PM2	96488.3	2354.5	0.8	43.0	0.073
4/19/2012	3	PM2	98574.8	59083.0	19.7		
4/22/2012	3	PM2	99155.9	16456.0	5.5		
4/30/2012	3	PM2	100067	25785.6	8.6	50.2	0.000
5/3/2012	3	PM2	100339	7729.9	2.6	47.3	0.000
5/7/2012	3	PM2	100765	12052.8	4.0	45.5	0.000
5/14/2012	3	PM2	101386	17578.8	5.9	45.9	0.000
5/17/2012	3	PM2	101534	4193.7	1.4	46.0	0.000

5/21/2012	3	PM2	101664	3687.7	1.2	46.6	0.000
5/29/2012	3	PM2	101716	1470.2	0.5	44.5	0.000
6/1/2012	3	PM2	101734	497.5	0.2	50.6	0.000
6/12/2012	3	PM2	101767	955.7	0.3		
6/18/2012	3	PM2	101818	1422.9	0.5	46.8	0.000
6/25/2012	3	PM2	101977	4502.1	1.5	45.3	0.000
7/16/2012	3	PM2	102004	783.5	0.3		
8/6/2012	3	PM2	102004	0.0	0.0		
3/29/2012	4	UAN	104787		0.0	42.5	0.000
4/7/2012	4	UAN	105142	10040.0	2.8	39.0	0.000
4/14/2012	4	UAN	105319	5018.6	1.4	36.7	0.000
4/19/2012	4	UAN	107670	66583.0	18.5	49.7	0.000
4/22/2012	4	UAN	108397	20591.4	5.7	45.1	0.000
4/30/2012	4	UAN	109644	35304.3	9.8	44.7	0.000
5/3/2012	4	UAN	109979	9469.7	2.6	43.3	0.000
5/7/2012	4	UAN	110528	15555.8	4.3	39.6	0.000
5/14/2012	4	UAN	111365	23695.2	6.6	41.3	0.000
5/17/2012	4	UAN	111601	6693.0	1.9	40.5	0.002
5/21/2012	4	UAN	111829	6454.5	1.8	41.4	0.000
5/29/2012	4	UAN	112098	7608.7	2.1	40.6	0.000
6/1/2012	4	UAN	112148	1428.6	0.4	40.1	0.000
6/12/2012	4	UAN	112216	1933.5	0.5	39.4	0.002
6/18/2012	4	UAN	112261	1263.2	0.4	39.7	0.002
6/25/2012	4	UAN	112559	8441.5	2.3	40.7	0.000
7/16/2012	4	UAN	112688	3652.6	1.0	40.3	0.002
8/6/2012	4	UAN	112688	0.0	0.0		
3/29/2012	5	PM	96444.3		0.0		
4/7/2012	5	PM	96498.4	1529.7	0.4	13.1	7.441
4/14/2012	5	PM	96498.4	0.3	0.0		
4/19/2012	5	PM	98405.5	54004.4	15.0	10.6	0.375
4/22/2012	5	PM	99279.3	24742.7	6.9	10.5	0.000
4/30/2012	5	PM	99281.7	69.1	0.0	12.0	0.000
5/3/2012	5	PM	99657.3	10634.1	3.0	11.8	0.000
5/7/2012	5	PM	100265	17217.5	4.8	11.2	0.000
5/14/2012	5	PM	101212	26816.9	7.4	11.0	0.000
5/17/2012	5	PM	101488	7805.8	2.2	10.5	0.000
5/21/2012	5	PM	101628	3975.4	1.1	10.9	0.000
5/29/2012	5	PM	101835	5849.7	1.6	10.7	0.000
6/1/2012	5	PM	101932	2754.4	0.8	11.2	0.000
6/12/2012	5	PM	102134	5710.1	1.6	10.5	0.002
6/18/2012	5	PM	102240	2993.9	0.8	10.4	0.000

6/25/2012	5	PM	102593	10001.2	2.8	10.8	0.000
7/16/2012	5	PM	102773	5094.8	1.4	11.0	0.002
8/6/2012	5	PM	102773	0.0	0.0		
3/29/2012	7	PM2	101839		0.0		
4/7/2012	7	PM2	101984	4102.5	1.0	29.6	0.000
4/14/2012	7	PM2	102009	686.4	0.2	28.1	0.000
4/19/2012	7	PM2	105354	94744.6	23.7	26.8	0.000
4/22/2012	7	PM2	106205	24088.0	6.0	25.7	0.000
4/30/2012	7	PM2	107511	36978.9	9.2	37.7	0.000
5/3/2012	7	PM2	107897	10933.4	2.7	28.1	0.000
5/7/2012	7	PM2	108506	17244.1	4.3	28.3	0.000
5/14/2012	7	PM2	109377	24666.5	6.2	28.0	0.000
5/17/2012	7	PM2	109569	5422.4	1.4	28.7	0.000
5/21/2012	7	PM2	109695	3584.9	0.9	28.7	0.000
5/29/2012	7	PM2	109789	2661.5	0.7	27.9	0.000
6/1/2012	7	PM2	109789	0.0	0.0		
6/12/2012	7	PM2	109789	0.0	0.0		
6/18/2012	7	PM2	109789	0.0	0.0		
6/25/2012	7	PM2	109789	0.0	0.0		
7/16/2012	7	PM2	109789	0.0	0.0		
8/6/2012	7	PM2	109789	0.0	0.0		
3/29/2012	8	UAN	84075.8		0.0		
4/7/2012	8	UAN	84446.7	10500.7	4.2	47.1	0.013
4/14/2012	8	UAN	84600.8	4363.6	1.7	37.9	0.000
4/19/2012	8	UAN	86692.9	59243.3	23.7	45.5	0.000
4/22/2012	8	UAN	87191.4	14116.2	5.6	13.5	0.002
4/30/2012	8	UAN	87969.3	22027.1	8.8	29.6	0.000
5/3/2012	8	UAN	88190.6	6265.9	2.5	34.7	0.000
5/7/2012	8	UAN	88520.5	9342.0	3.7		
5/14/2012	8	UAN	89125.8	17139.3	6.9	34.8	0.000
5/17/2012	8	UAN	89279.2	4344.6	1.7	34.0	0.000
5/21/2012	8	UAN	89414	3816.8	1.5		
5/29/2012	8	UAN	89533.6	3386.7	1.4	41.8	0.000
6/1/2012	8	UAN	89534.3	21.5	0.0		
6/12/2012	8	UAN	89534.3	0.0	0.0		
6/18/2012	8	UAN	89535.1	20.4	0.0		
6/25/2012	8	UAN	89675.7	3983.3	1.6	37.9	0.002
7/16/2012	8	UAN	89700.6	705.1	0.3		
8/6/2012	8	UAN	89700.6	0.0	0.0		
3/29/2012	10	PM	16268.9		0.0		
4/7/2012	10	PM	17160.9	25258.6	12.0	10.3	0.000

4/14/2012	10	PM	17160.9	0.0	0.0		
4/19/2012	10	PM	17160.9	0.0	0.0		
4/22/2012	10	PM	19717.1	72383.4	34.5	36.2	0.000
4/30/2012	10	PM	22315.1	73567.0	35.0	15.0	0.000
5/3/2012	10	PM	23461.5	32462.4	15.5	14.9	0.000
5/7/2012	10	PM	25012.6	43922.2	20.9		
5/14/2012	10	PM	26400.5	39299.5	18.7	14.6	0.000
5/17/2012	10	PM	0	0.0	0.0		
5/21/2012	10	PM	0	0.0	0.0		
5/29/2012	10	PM	0	0.0	0.0		
6/1/2012	10	PM	0	0.0	0.0		
6/12/2012	10	PM	0	0.0	0.0		
6/18/2012	10	PM	0	0.0	0.0		
6/25/2012	10	PM	0	0.0	0.0		
7/16/2012	10	PM	0	0.0	0.0		
8/6/2012	10	PM	0	0.0	0.0		
3/29/2012	check	None	338136		0.0	5.9	0.000
4/7/2012	check	None	339985	52370.8	11.1	7.8	0.000
4/14/2012	check	None	340550	15986.2	3.4	4.9	0.000
4/19/2012	check	None	348343	220691.8	47.0	15.2	0.000
4/22/2012	check	None	350800	69563.6	14.8	14.3	0.002
4/30/2012	check	None	354328	99915.3	21.3	14.4	0.000
5/3/2012	check	None	355544	34420.5	7.3	13.4	0.000
5/7/2012	check	None	357302	49778.4	10.6		
5/14/2012	check	None	359643	66299.8	14.1	13.4	0.000
5/17/2012	check	None	360162	14688.2	3.1	6.2	0.000
5/21/2012	check	None	360705	15376.6	3.3	5.3	0.000
5/29/2012	check	None	361524	23188.9	4.9	5.2	0.000
6/1/2012	check	None	361748	6340.7	1.3	5.3	0.000
6/12/2012	check	None	362370	17609.7	3.7	5.1	0.000
6/18/2012	check	None	362674	8625.3	1.8	5.1	0.002
6/25/2012	check	None	363453	22061.9	4.7	5.3	0.000
7/16/2012	check	None	364321	24574.5	5.2	4.9	0.002
8/6/2012	check	None	364321	0.0	0.0		
3/15/2010	1	PM2	22562		0.0		
3/18/2010	1	PM2	22562	0.0	0.0		
3/23/2010	1	PM2	22562	0.0	0.0		
3/24/2010	1	PM2	22755	5465.1	2.9		
3/29/2010	1	PM2	22789	962.8	0.5	9.2	0.133
4/5/2010	1	PM2	22789	0.0	0.0		
4/13/2010	1	PM2	22800	311.5	0.2		

4/22/2010	1	PM2	22800	0.0	0.0		
5/13/2010	1	PM2	23357	15772.5	8.3	10.6	0.034
5/18/2010	1	PM2	24050	19623.5	10.3	10.2	0.035
5/25/2010	1	PM2	24233	5182.0	2.7	10.2	0.036
6/1/2010	1	PM2	24233	0.0	0.0		
6/4/2010	1	PM2	24233	0.0	0.0		
6/9/2010	1	PM2	24233	0.0	0.0		
6/11/2010	1	PM2	24300	1897.2	1.0	12.2	0.041
6/15/2010	1	PM2	25588	36472.0	19.2	16.1	0.051
6/22/2010	1	PM2	26242	18519.2	9.7	16.5	0.039
6/29/2010	1	PM2	26446	5776.6	3.0	20.7	0.177
7/6/2010	1	PM2	26901	12884.1	6.8	22.9	0.002
7/13/2010	1	PM2	26902	28.3	0.0	24.7	0.012
7/29/2010	1	PM2	26902	0.0	0.0	18.8	0.002
8/5/2010	1	PM2	26905	85.0	0.0	20.4	0.002
8/13/2010	1	PM2	26906	28.3	0.0	14.3	0.226
8/18/2010	1	PM2	27137	6541.2	3.4	3.6	0.002
8/30/2010	1	PM2	27150	368.1	0.2		
9/1/2010	1	PM2	27159	254.9	0.1		
9/8/2010	1	PM2	27171	339.8	0.2		
10/16/2010	1	PM2	27306	3822.8	2.0		
3/15/2010	2	PM	23809		0.0		
3/18/2010	2	PM	23809	0.0	0.0		
3/23/2010	2	PM	23811	56.6	0.0	5.8	0.054
3/24/2010	2	PM	23813	56.6	0.0		
3/29/2010	2	PM	23854	1152.5	0.5	7.7	0.041
4/5/2010	2	PM	24020	4709.1	1.9		
4/13/2010	2	PM	24100	2265.3	0.9	8.3	0.032
4/22/2010	2	PM	24153	1500.8	0.6		
5/13/2010	2	PM	24214	1727.3	0.7		
5/18/2010	2	PM	25273	29987.5	12.0	8.8	0.032
5/25/2010	2	PM	25796	14809.7	5.9	9.7	0.033
6/1/2010	2	PM	25951	4389.1	1.8		
6/4/2010	2	PM	25970	538.0	0.2		
6/9/2010	2	PM	26083	3199.8	1.3		
6/11/2010	2	PM	26218	3822.8	1.5	9.9	0.036
6/15/2010	2	PM	27975	49752.6	19.9	11.4	0.037
6/22/2010	2	PM	29175	33980.2	13.6	12.5	0.034
6/29/2010	2	PM	29583	11553.3	4.6	13.9	0.002
7/6/2010	2	PM	29595	339.8	0.1	15.6	0.002
7/13/2010	2	PM	29598	85.0	0.0	16.7	0.010

7/29/2010	2	PM	29598	0.0	0.0		
8/5/2010	2	PM	29598	0.0	0.0	9.6	0.002
8/13/2010	2	PM	29599	28.3	0.0		
8/18/2010	2	PM	30035	12346.1	4.9	4.1	0.002
8/30/2010	2	PM	30065	849.5	0.3	14.2	0.002
9/1/2010	2	PM	30134	1953.9	0.8	4.1	0.002
9/8/2010	2	PM	30436	8551.7	3.4	4.6	0.002
10/16/2010	2	PM	30980	15404.3	6.2	0.1	0.002
3/15/2010	3	PM2	52941		0.0		
3/18/2010	3	PM2	52941	0.0	0.0		
3/23/2010	3	PM2	54317	38963.9	13.0	11.8	0.031
3/24/2010	3	PM2	54528	5974.8	2.0		
3/29/2010	3	PM2	55453	26181.7	8.7	12.5	0.032
4/5/2010	3	PM2	55713	7373.7	2.5		
4/13/2010	3	PM2	55713	0.0	0.0	12.8	0.032
4/22/2010	3	PM2	56077	10307.3	3.4		
5/13/2010	3	PM2	59440	95229.4	31.7	13.1	0.034
5/18/2010	3	PM2	61339	53773.6	17.9	13.7	0.036
5/25/2010	3	PM2	62381	29506.1	9.8	13.7	0.037
6/1/2010	3	PM2	62770	11015.2	3.7		
6/4/2010	3	PM2	62865	2690.1	0.9		
6/9/2010	3	PM2	63136	7673.9	2.6		
6/11/2010	3	PM2	63456	9061.4	3.0	14.5	0.039
6/15/2010	3	PM2	66453	84865.4	28.3	17.8	0.045
6/22/2010	3	PM2	68537	59012.2	19.7	17.9	0.041
6/29/2010	3	PM2	73219	132579.3	44.2	23.6	0.017
7/6/2010	3	PM2	74515	36698.6	12.2	23.2	0.002
7/13/2010	3	PM2	75340	23361.4	7.8	23.7	0.015
7/29/2010	3	PM2	75785	12601.0	4.2	22.8	0.002
8/5/2010	3	PM2	77327	43664.5	14.6	16.7	0.002
8/13/2010	3	PM2	79713	67563.9	22.5	15.4	0.058
8/18/2010	3	PM2	80833	31714.8	10.6	15.3	0.002
8/30/2010	3	PM2	80976	4049.3	1.3	14.1	0.002
9/1/2010	3	PM2	81361	10902.0	3.6	13.3	0.002
9/8/2010	3	PM2	82272	25796.6	8.6	14.1	0.002
10/16/2010	3	PM2	84281	56888.5	19.0	0.8	0.002
3/15/2010	4	UAN	49794		0.0		
3/18/2010	4	UAN	49794	0.0	0.0		
3/23/2010	4	UAN	51560	50007.5	13.9	11.8	0.032
3/24/2010	4	UAN	51730	4813.9	1.3		
3/29/2010	4	UAN	51732	59.5	0.0	11.8	0.031

4/5/2010	4	UAN	52290.8	15820.6	4.4		
4/13/2010	4	UAN	53283	28095.9	7.8	11.9	0.035
4/22/2010	4	UAN	53888	17131.7	4.8		
5/13/2010	4	UAN	57728	108736.5	30.2	11.9	0.037
5/18/2010	4	UAN	60226	70735.4	19.6	11.7	0.036
5/25/2010	4	UAN	61671	40917.8	11.4	11.8	0.037
6/1/2010	4	UAN	62283	17329.9	4.8		
6/4/2010	4	UAN	62427	4077.6	1.1		
6/9/2010	4	UAN	62746	9033.1	2.5		
6/11/2010	4	UAN	63013	7560.6	2.1	12.2	0.041
6/15/2010	4	UAN	66394	95739.1	26.6	15.0	0.041
6/22/2010	4	UAN	69074	75889.0	21.1	15.6	0.039
6/29/2010	4	UAN	74509	153901.8	42.8	21.3	0.002
7/6/2010	4	UAN	77290	78749.0	21.9	21.6	0.011
7/13/2010	4	UAN	78503	34348.3	9.5	22.7	0.011
7/29/2010	4	UAN	78933	12176.2	3.4	20.4	0.002
8/5/2010	4	UAN	80263	37661.3	10.5	19.8	0.002
8/13/2010	4	UAN	84617	123291.3	34.2	17.9	0.002
8/18/2010	4	UAN	86159	43664.5	12.1	17.7	0.002
8/30/2010	4	UAN	86359	5663.4	1.6	18.3	0.002
9/1/2010	4	UAN	86371	339.8	0.1	17.4	0.002
9/8/2010	4	UAN	87229	24295.8	6.7	17.9	0.002
10/16/2010	4	UAN	89381	60937.8	16.9	3.8	0.002
3/15/2010	5	PM	50297		0.0		
3/18/2010	5	PM	50297	0.0	0.0		
3/23/2010	5	PM	51941	46552.8	12.9	7.0	0.032
3/24/2010	5	PM	52325	10873.7	3.0		
3/29/2010	5	PM	53074	21209.3	5.9	7.3	0.032
4/5/2010	5	PM	53185.4	3154.5	0.9		
4/13/2010	5	PM	53422	6699.8	1.9	7.5	0.033
4/22/2010	5	PM	53422	0.0	0.0		
5/13/2010	5	PM	55878	69546.1	19.3	7.9	0.035
5/18/2010	5	PM	58047	61419.1	17.1	8.4	0.035
5/25/2010	5	PM	58903	24239.2	6.7	8.6	0.036
6/1/2010	5	PM	58913	283.2	0.1		
6/4/2010	5	PM	58913	0.0	0.0		
6/9/2010	5	PM	58913	0.0	0.0		
6/11/2010	5	PM	58936	651.3	0.2	9.4	0.042
6/15/2010	5	PM	60312	38963.9	10.8	10.6	0.057
6/22/2010	5	PM	62487	61589.0	17.1	11.4	0.038
6/29/2010	5	PM	64401	54198.4	15.1	12.7	0.002

7/6/2010	5	PM	64421	566.3	0.2	13.9	0.002
7/13/2010	5	PM	65051	17839.6	5.0	14.0	0.015
7/29/2010	5	PM	65303	7135.8	2.0	11.4	0.002
8/5/2010	5	PM	66725	40266.5	11.2	10.4	0.002
8/13/2010	5	PM	74973	233557.0	64.9	6.5	0.002
8/18/2010	5	PM	76676	48223.5	13.4	5.9	0.002
8/30/2010	5	PM	76783	3029.9	0.8	5.3	0.002
9/1/2010	5	PM	77075	8268.5	2.3	5.9	0.002
9/8/2010	5	PM	77868	22455.2	6.2	5.9	0.002
10/16/2010	5	PM	79139	35990.7	10.0	0.4	0.002
3/15/2010	7	PM2	61129		0.0		
3/18/2010	7	PM2	61129	0.0	0.0		
3/23/2010	7	PM2	64164	85941.5	21.5	12.3	0.028
3/24/2010	7	PM2	64164	0.0	0.0		
3/29/2010	7	PM2	65754	45012.4	11.3	12.7	0.029
4/5/2010	7	PM2	66577.7	23335.9	5.8		
4/13/2010	7	PM2	67752	33252.4	8.3	12.8	0.030
4/22/2010	7	PM2	68056	8608.3	2.2		
5/13/2010	7	PM2	72268	119270.4	29.8	13.0	0.032
5/18/2010	7	PM2	74854	73227.2	18.3	13.6	0.032
5/25/2010	7	PM2	75963	31403.3	7.9	13.7	0.034
6/1/2010	7	PM2	76107	4077.6	1.0		
6/4/2010	7	PM2	76107	0.0	0.0		
6/9/2010	7	PM2	76112	141.6	0.0		
6/11/2010	7	PM2	76375	7447.3	1.9	14.5	0.038
6/15/2010	7	PM2	80703	122555.1	30.6	16.6	0.058
6/22/2010	7	PM2	83319	74076.7	18.5	18.0	0.037
6/29/2010	7	PM2	89360	171061.8	42.8	20.9	0.032
7/6/2010	7	PM2	92209	80674.6	20.2	24.3	0.002
7/13/2010	7	PM2	93026	23134.8	5.8		
7/29/2010	7	PM2	93026	0.0	0.0		
8/5/2010	7	PM2	94191	32989.1	8.2	19.6	0.002
8/13/2010	7	PM2	95510	37349.9	9.3	16.4	0.002
8/18/2010	7	PM2	96148	18066.1	4.5	16.4	0.002
8/30/2010	7	PM2	96149	28.3	0.0	17.7	0.002
9/1/2010	7	PM2	96149	0.0	0.0	16.1	0.002
9/8/2010	7	PM2	96149	0.0	0.0	15.5	0.002
10/16/2010	7	PM2	96149	0.0	0.0	0.5	0.002
3/15/2010	8	UAN	39440		0.0		
3/18/2010	8	UAN	39440	0.0	0.0		
3/23/2010	8	UAN	41024	44853.8	17.9	11.1	0.029

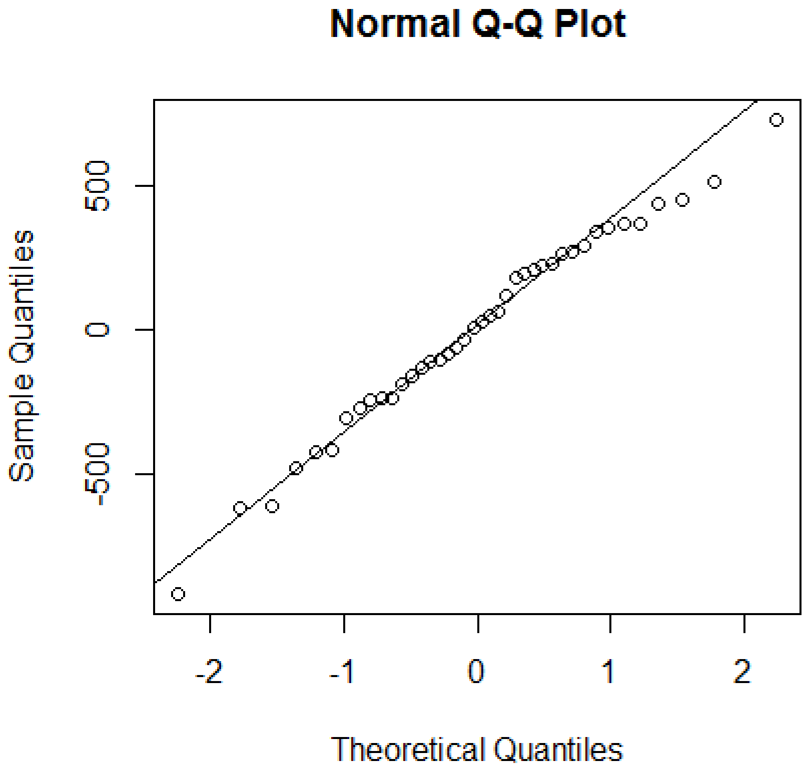
3/24/2010	8	UAN	41088	1812.3	0.7		
3/29/2010	8	UAN	41869	22126.7	8.9	11.2	0.031
4/5/2010	8	UAN	42319.6	12748.2	5.1		
4/13/2010	8	UAN	42939.7	17559.2	7.0	11.1	0.031
4/22/2010	8	UAN	43343	11420.2	4.6		
5/13/2010	8	UAN	46283	83251.4	33.3	11.2	0.032
5/18/2010	8	UAN	47875	45080.3	18.0	11.7	0.033
5/25/2010	8	UAN	48710	23644.5	9.5	11.5	0.033
6/1/2010	8	UAN	49026	8948.1	3.6		
6/4/2010	8	UAN	49083	1614.1	0.6		
6/9/2010	8	UAN	49272	5351.9	2.1		
6/11/2010	8	UAN	49488	6116.4	2.4	12.1	0.037
6/15/2010	8	UAN	52201	76823.5	30.7	16.6	0.043
6/22/2010	8	UAN	53784	44825.5	17.9	16.6	0.036
6/29/2010	8	UAN	57807	113918.5	45.6	21.4	0.002
7/6/2010	8	UAN	59556	49526.1	19.8	21.6	0.002
7/13/2010	8	UAN	60354	22596.8	9.0	22.6	0.013
7/29/2010	8	UAN	60656	8551.7	3.4	19.9	0.002
8/5/2010	8	UAN	61649	28118.6	11.2	18.8	0.002
8/13/2010	8	UAN	68024	180519.6	72.2	14.5	0.002
8/18/2010	8	UAN	68935	25796.6	10.3	16.0	0.002
8/30/2010	8	UAN	69069	3794.5	1.5	15.7	0.018
9/1/2010	8	UAN	69241	4870.5	1.9	13.4	0.002
9/8/2010	8	UAN	69711	13308.9	5.3	14.7	0.002
10/16/2010	8	UAN	70885	33243.9	13.3	3.8	0.002
3/15/2010	10	PM	24978		0.0		
3/18/2010	10	PM	24978	0.0	0.0		
3/23/2010	10	PM	25627	18377.6	8.8	8.3	0.030
3/24/2010	10	PM	25861	6626.1	3.2		
3/29/2010	10	PM	26063	5720.0	2.7	8.3	0.036
4/5/2010	10	PM	26082	538.0	0.3		
4/13/2010	10	PM	26283	5691.7	2.7	8.1	0.034
4/22/2010	10	PM	26283	0.0	0.0		
5/13/2010	10	PM	27939.2	46898.3	22.3	8.5	0.034
5/18/2010	10	PM	28928	27999.7	13.3	9.3	0.034
5/25/2010	10	PM	29179	7107.5	3.4	9.7	0.034
6/1/2010	10	PM	29179	0.0	0.0		
6/4/2010	10	PM	29179	0.0	0.0		
6/9/2010	10	PM	29179	0.0	0.0		
6/11/2010	10	PM	29292	3199.8	1.5	10.5	0.038
6/15/2010	10	PM	31400	59691.8	28.4	12.0	0.055

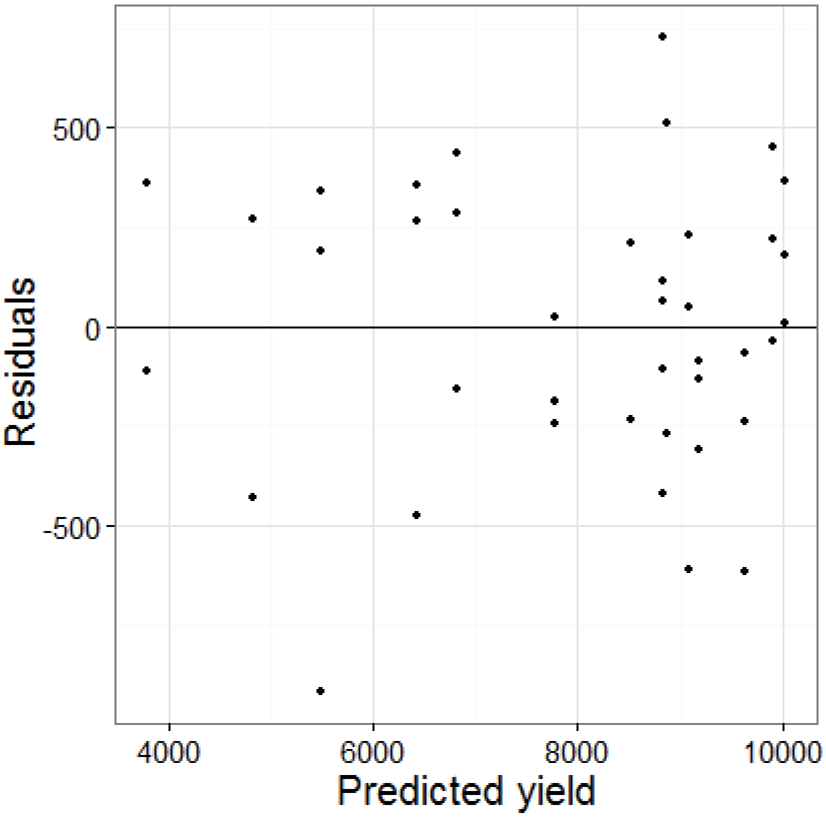
6/22/2010	10	PM	32175	21945.5	10.5	11.0	0.037
6/29/2010	10	PM	35059	81665.7	38.9	13.9	0.023
7/6/2010	10	PM	35975	25938.2	12.4	15.3	0.002
7/13/2010	10	PM	36162	5295.2	2.5	16.6	0.013
7/29/2010	10	PM	36319	4445.7	2.1	11.7	0.037
8/5/2010	10	PM	37299	27750.5	13.2	9.8	0.011
8/13/2010	10	PM	42106	136118.9	64.8	6.6	0.011
8/18/2010	10	PM	42502	11213.5	5.3	7.9	0.002
8/30/2010	10	PM	42502	0.0	0.0		
9/1/2010	10	PM	42797	8353.5	4.0	6.1	0.002
9/8/2010	10	PM	43073	7815.4	3.7	7.2	0.002
10/16/2010	10	PM	43735	18745.7	8.9	1.6	0.002
3/15/2010	check	None	160616		0.0		
3/18/2010	check	None	167587	197396.4	42.0		
3/23/2010	check	None	175210	215859.0	45.9	5.0	0.033
3/24/2010	check	None	176204	28146.9	6.0		
3/29/2010	check	None	180427	119581.8	25.4	5.1	0.033
4/5/2010	check	None	182772	66397.2	14.1		
4/13/2010	check	None	186071	93422.8	19.9	5.4	0.035
4/22/2010	check	None	187457	39247.1	8.4		
5/13/2010	check	None	198003	298629.0	63.5	7.0	0.037
5/18/2010	check	None	204388	180802.8	38.5	7.0	0.037
5/25/2010	check	None	207339	83562.9	17.8	7.4	0.038
6/1/2010	check	None	208647	37038.4	7.9		
6/4/2010	check	None	209035	10986.9	2.3		
6/9/2010	check	None	209657	17613.0	3.7		
6/11/2010	check	None	210310	18490.9	3.9	8.7	0.040
6/15/2010	check	None	218955	244798.7	52.1	9.6	0.046
6/22/2010	check	None	225134	174969.5	37.2	9.7	0.039
6/29/2010	check	None	226140	28486.7	6.1	9.5	0.010
7/6/2010	check	None	226140	0.0	0.0	10.2	0.002
7/13/2010	check	None	228153	57001.7	12.1	11.2	0.011
7/29/2010	check	None	232840	132720.8	28.2	7.1	0.002
8/5/2010	check	None	239370	184908.7	39.3	7.4	0.002
8/13/2010	check	None	254505	428574.8	91.2	6.3	0.002
8/18/2010	check	None	260870	180236.4	38.3	6.2	0.002
8/30/2010	check	None	263087	62778.3	13.4	4.6	0.002
9/1/2010	check	None	264719	46213.0	9.8	5.1	0.002
9/8/2010	check	None	269410	132834.1	28.3	5.3	0.002
10/16/2010	check	None	279628	289341.1	61.6	0.6	0.017

APPENDIX D. STATISTICS

APPENDIX D1. Yield Modeling

MLR





ANOVA

```
Response: yield
                  Sum Sq Df   F value    Pr(>F)    
(Intercept)    242075252  1 1665.9042 < 2.2e-16 ***
year            33090633  4   56.9305 3.387e-12 ***
treatment        3113575  2   10.7134 0.0004361 ***
year:treatment   6360869  8    5.4717 0.0004760 ***
Residuals        3632791 25                        
```

Tukey

```
$treatment
              diff        lwr        upr    p adj
PM2-PM    876.8670   530.1591  1223.5748 4.00e-06
UAN-PM   -912.4684 -1300.0996  -524.8373 1.19e-05
UAN-PM2 -1789.3354 -2176.9666 -1401.7043 0.00e+00

$year
                  diff        lwr        upr     p adj
2011-2010    -3.305372  -563.0695   556.4588 1.0000000
2012-2010  -192.779424  -752.5436   366.9847 0.8476832
2013-2010 -3929.647066 -4489.4112 -3369.8829 0.0000000
2014-2010 -2665.748903 -3225.5131 -2105.9847 0.0000000
2012-2011  -189.474052  -749.2382   370.2901 0.8554852
2013-2011 -3926.341694 -4486.1059 -3366.5775 0.0000000
2014-2011 -2662.443531 -3222.2077 -2102.6794 0.0000000
2013-2012 -3736.867642 -4296.6318 -3177.1035 0.0000000
2014-2012 -2472.969479 -3032.7336 -1913.2053 0.0000000
2014-2013  1263.898163   704.1340  1823.6623 0.0000056
```

R code

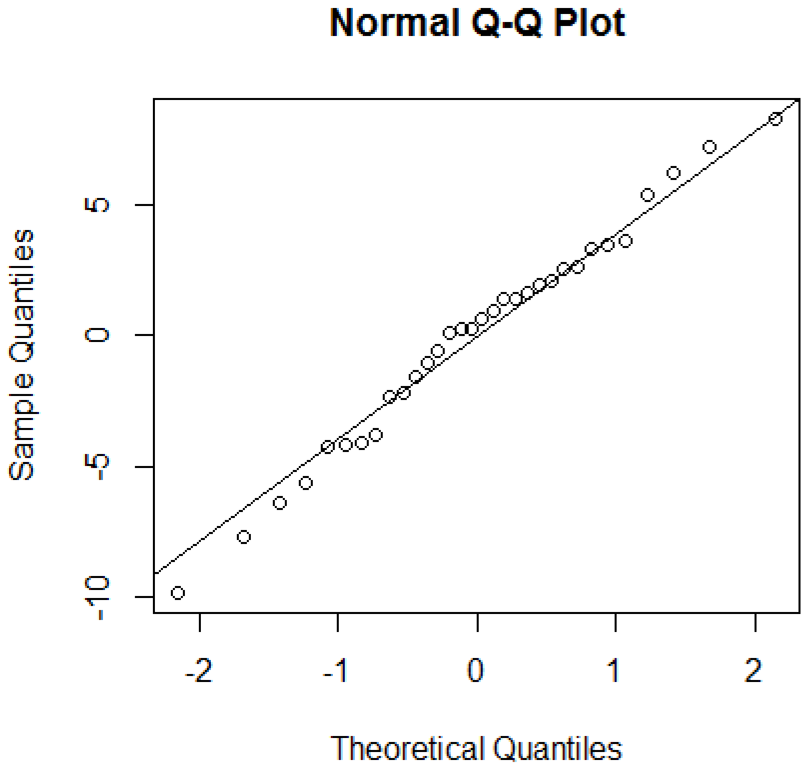
```
############################################################################################
############################  prerequired functions ##########################################
############################################################################################
print.regsub <- function(l, sort='BIC', best=NULL) {
 # function written by PMD, 12 April 2015
 # print a table with model selection stats
 #   based on information produced by summary.regsubsets()
 # l is an object returned by summary() of a regsubsets() result
 # sort is a character string with the variable to sort by
 #   must be one of the names in the print.regsub() output
 # best is the number of results to print, NULL prints all

 var <- apply(l$which, 1, function(x){
   paste(l$obj$xnames[x][-1],collapse=' ' )})
 nvar <- apply(l$which[,-1], 1, sum)
  aic <- l$bic - log(l$obj$nn)*nvar + 2*nvar
```

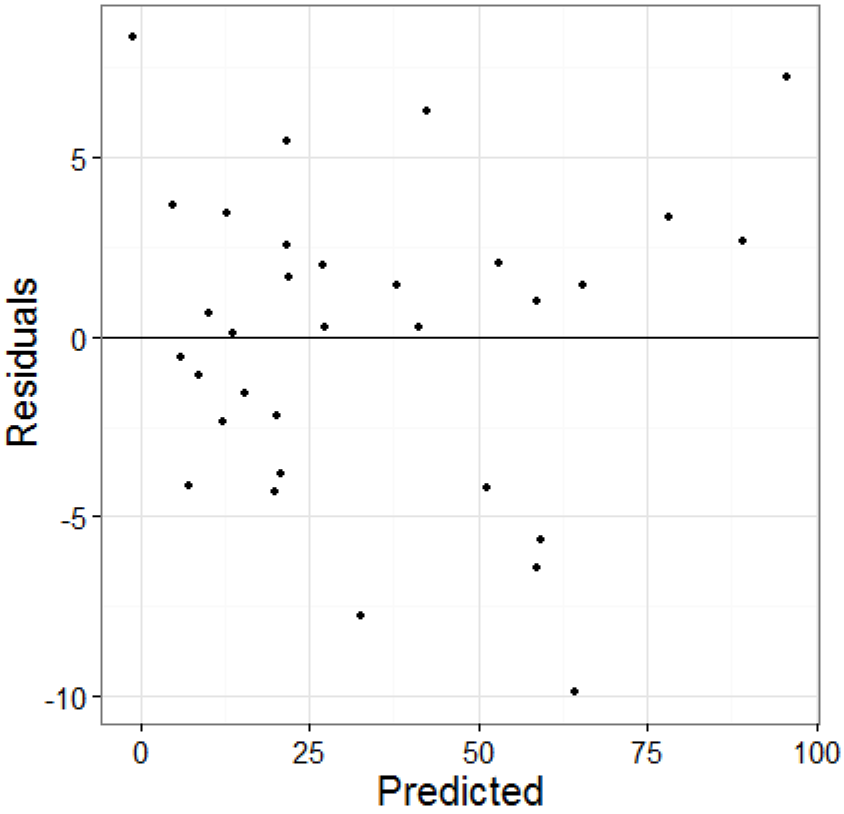
```
  temp <- data.frame(model=var, nvar=nvar, Rsq=l$rsq, AdjRsq=l$adjr2,
                 Cp=l$cp, AIC = aic, BIC=l$bic)
 o <- order(temp[,sort])
 if (!is.null(best)) {
   o <- o[1:best]
 }
 temp[o,]
}
#Cite from STAT501, Dr. Dixon iastateregmdyield <- regsubsets(yield ~
                 #temperature+
                   gddcul+radncul+raincul+treatment+
                   gddcul:treatment+radncul:treatment+raincul:treatment+
                   radncul:raincul
                 ##treatment:temperature+treatment:gddcul+treatment:radncul+treatment:raincul+
                 #N_rate+N_rate:temperature+N_rate:gddcul+N_rate:radncul+N_rate:raincul+
                 #P_rate+N_rate:temperature+N_rate:gddcul+N_rate:radncul+N_rate:raincul+
                 #K_rate+N_rate:temperature+N_rate:gddcul+N_rate:radncul+N_rate:raincul+
                 #N_rate:P_rate+N_rate:K_rate+P_rate:K_rate+N_rate:P_rate:K_rate
               ,
               data=mdyieldandload2, method='exhaustive' ,
               nbest=100, really.big=T)
summaryregmdyield<-summary(regmdyield)
# use a function from Dr. Dixon Iastate (remember to run first)
print.regsub(summaryregmdyield,sort='BIC', best=20)

#this shows that temperature, gddcul, radncul, raincul, treatment, N_rate, and radncul*treatment are the chosen variables for mdyield

mdyield<-lm(yield ~
           #radncul+treatment+temperature:treatment+temperature:N_rate+
           #gddcul:N_rate+radncul:N_rate+raincul:N_rate+N_rate:P_rate:K_rate
           gddcul+radncul+raincul+treatment+radncul:treatment+radncul:raincul
          ,
          data=mdyieldandload2)
```

```
summary(mdyield)


mdyieldaov<-aov(yield ~
            #radncul+treatment+temperature:treatment+temperature:N_rate+
            #gddcul:N_rate+radncul:N_rate+raincul:N_rate+N_rate:P_rate:K_rate
            gddcul+radncul+raincul+treatment+radncul:treatment+radncul:raincul
           ,
  data=mdyieldandload2)
Anova(mdyieldaov,type=3)


#tukey


mdyieldaov2<-aov(yield~year+treatment+year:treatment,data=mdyieldandload2)
Anova(mdyieldaov2,type=3)
TukeyHSD(x=mdyieldaov2, c('treatment','year'), ordered = FALSE, conf.level = 0.95)
TukeyHSD(x=mdyieldaov, 'treatment', ordered = FALSE, conf.level = 0.95)
```

APPENDIX D2. NO$_3$-N Load Modeling

MLR





ANOVA

```
Response: N_yield
                Sum Sq Df F value    Pr(>F)   
(Intercept)      827.1  1  5.2506 0.032927 * 
year              42.0  3  0.0889 0.965329   
treatment       1451.9  2  4.6085 0.022591 * 
year:treatment  3963.7  6  4.1938 0.006858 **
Residuals       3150.4 20
```

Tukey

```
             diff        lwr       upr     p adj
PM2-PM  29.712638 16.749433 42.67584 0.0000324
UAN-PM  38.243143 23.749840 52.73645 0.0000049
UAN-PM2  8.530505 -5.962799 23.02381 0.3171039
```

```
                diff         lwr       upr     p adj
2012-2010 -14.303644 -31.8680556  3.260768 0.1366087
2013-2010   2.701147 -14.8632647 20.265559 0.9725508
2014-2010  23.564952   6.0005404 41.129364 0.0062919
```

```
2013-2012  17.004791  -0.5596209 34.569203 0.0599061
2014-2012  37.868596  20.3041842 55.433008 0.0000372
2014-2013  20.863805   3.2993933 38.428217 0.0163822
```

R code

```
###############################################################################################3

################ ------N_load model focus on treatment and climate influence-------#################

###############################################################################################3

mdyieldandload2<-read.csv("mdyieldandload2.csv")[,-1]

names(mdyieldandload2)

mdyieldandload2$year<-as.factor(mdyieldandload2$year)

mdyieldandload2[,c("year","treatment","plot","N_rate","yield","rainfall","raincul","flow","drain","N_conc","N_load")]



scatterplot.matrix(~year+treatment+year:treatment

          +rainfall+flow+N_conc+drain+N_load

          ,

          data=mdyieldandload2)

###########################################################3

# outlier exclude

residuals(mdN_load)


min(residuals(mdN_load))


mdyieldandload2[,c("year","treatment","plot","flow","drain","N_conc","N_load")]

str(mdyieldandload)


#mdyieldandloadsubn<-subset(mdyieldandload2,mdyieldandload2$N_load>=1.85579|mdyieldandload2$N_load<=1.85578)

#mdyieldandloadsubn[,c("year","treatment","plot","N_load")]



################################################regmdN_load <- regsubsets(N_yield ~

               treatment

              +yield
```

```
              +N_conc
              +drain
              +rainfall
              +temperature
              +radn

              +treatment:N_conc
              +treatment:drain
              +treatment:rainfall
              +treatment:yield
              +treatment:temperature
              +treatment:radn

              +yield:rainfall
              +yield:N_conc
              +yield:drain
              +yield:temperature
              +yield:radn
              ,
              data=mdyieldandload2, method='exhaustive' ,
              nbest=100, really.big=T)
summaryregmdN_load<-summary(regmdN_load)
# use a function from Dr. Dixon Iastate (remember to run first)
print.regsub(summaryregmdN_load,sort='BIC', best=20)

mdN_load<-lm(data=mdyieldandload2,N_yield~
        #year+treatment+year:treatment
        #year+treatment+drain+year:treatment+year:N_conc
        #drain+N_rate+year:treatment+year:N_conc+treatment:N_conc+year:N_rate+treatment:N_rate+year:drain
        #treatment+N_conc++drain+treatment:drain
        yield+N_conc+drain+treatment:drain+treatment:yield+treatment:temperature+yield:drain
      )
summary(mdN_load)
```

```
mdN_loadaov<-aov(data=mdyieldandload2,N_yield~
         #year+treatment+year:treatment
         #year+treatment+N_conc+drain+year:treatment+year:N_conc+year:drain
         yield+treatment+N_conc+drain+treatment:drain+treatment:yield+treatment:temperature+yield:drain
)
Anova(mdN_loadaov,type=3)
#tukey
mdN_loadaov2<-aov(data=mdyieldandload2,N_yield~
        year+treatment+year:treatment
)
Anova(mdN_loadaov2,type=3)

TukeyHSD(x=mdN_loadaov2, c('treatment','year'), ordered = FALSE, conf.level = 0.95)
#check assumptions
histogram(residuals(mdN_loadaov2))
qqnorm(residuals(mdN_loadaov2))
qqline(residuals(mdN_load))



qqnorm(residuals(mdN_load))
qqline(residuals(mdN_load))
plot(mdN_loadaov2$fitted.values,rstudent(mdN_loadaov2))
abline(h=0)
qplot(predict(mdN_load), residuals(mdN_load),
   ylab="Residuals", xlab="Predicted"
) +
 theme_bw()+
 theme(axis.text=element_text(size=15,colour="black"),
    axis.title=element_text(size=20)
 )+
 geom_hline(yintercept=0)
```

```
qplot(predict(mdN_loadaov2), residuals(mdN_loadaov2),alpha = .001,
      ylab="Residuals", xlab="N_load"
) +abline(0,0)
```

APPENDIX D3. NO_3-N Concentration ANOVA and Tukey

ANOVA

```
Response: N_conc
                Sum Sq  Df F value    Pr(>F)    
(Intercept)     4640.4   1 87.2659 < 2.2e-16 ***
year            1282.8   3  8.0411 3.395e-05 ***
treatment       1319.7   2 12.4093 6.212e-06 ***
year:treatment 19715.6   6 61.7938 < 2.2e-16 ***
Residuals      18611.5 350                      
```

Tukey

```
$treatment
             diff        lwr      upr     p adj
PM2-PM  21.198898 19.0736863 23.32411 0.0000000
UAN-PM  24.379907 22.1145631 26.64525 0.0000000
UAN-PM2  3.181009  0.8966479  5.46537 0.0032953
```

```
$year
               diff       lwr      upr p adj
2012-2010 15.843421 13.231224 18.45562     0
2013-2010 24.782630 22.283463 27.28180     0
2014-2010 33.456629 30.165569 36.74769     0
2013-2012  8.939208  6.061547 11.81687     0
2014-2012 17.613207 14.026262 21.20015     0
2014-2013  8.673999  5.168513 12.17948     0
```

R code

```
##########################################################################################
##########################--------------------------------------##########################
#############------------------------N_conc modeling ------------------------#############
##########################--------------------------------------##########################
##########################################################################################
wq<-read.csv("waterquality.csv")[,-1]
names(wq)
wq$year<-as.factor(wq$year)
wq$month<-as.factor(wq$month)
wq$day<-as.factor(wq$day)
wq$plot<-as.factor(wq$plot)
wq$BA<-as.factor(wq$BA)
wq$date<-as.Date(wq$date,formate="%Y/%m/%d")
wq$date2<-as.Date(format(wq$date, "%m-%d"),"%m-%d") # add a month-day column
wq<-na.omit(wq)
wq2<-summarise(group_by(wq,month,day,date,date2,BA,treatment,plot)
                              ,area=mean(area)
                              ,rainfall=mean(rainfall),DD=mean(DD)
                              ,flow=mean(flow),drain=mean(drain)
                              ,N_conc=mean(N_conc),P_conc=mean(P_conc)
                              ,N_yd=mean(N_yd),P_yd=mean(P_yd)
)
```

```
wq2$year<-"Overall"
names(wq)
names(wq2)
wq2<-rbind(wq,wq2)
names(wq2)


qplot(data=wq,x=DD,y=N_conc)
qplot(data=wq,x=DD,y=N_conc,facets=year~treatment)
qplot(data=wq,x=BA,y=N_conc,geom="boxplot",facets=treatment~year)
qplot(data=wq,x=DD,y=N_conc,facets=treatment~year,colour=plot,shape=BA,size=I(3))
qplot(data=wq,x=DD,y=N_conc,colour=BA)
qplot(data=wq,y=N_conc,x=year,geom="boxplot")
qplot(data=wq,y=N_conc,x=treatment,geom="boxplot")

scatterplot.matrix(~
                     year#+month
                   +treatment
                   #+year*month
                   +year*treatment
                   #+month*treatment
                   +flow+flow*year+flow*treatment
                   #+flow*month
                   +rainfall+rainfall*year+rainfall*treatment
                   #+rainfall*month
                   +DD+BA+DD*BA
                   +N_conc
                   #+DD*year+DD*treatment+DD*flow
                   #+BA*year+BA*treatment+BA*flow

                   ,
                   data=wq
                   )

###################################################3
# outlier exclude
residuals(mdN_conc)
residuals(mdN_conc)[185]
order(residuals(mdN_conc))[1:4]
rstudent(mdN_conc)
max(rstudent(mdN_conc))
min(rstudent(mdN_conc))
wq[c(202),c("year","treatment","plot","N_conc")]
wq[c(202,276,259,221),c("year","treatment","plot","N_conc")]
str(wq)

wqsubn<-subset(wq,wq$N_conc>=0.08522|wq$N_conc<=0.08521)
wqsubn<-subset(wqsubn,wqsubn$N_conc>=0.51624|wqsubn$N_conc<=0.51623)
wqsubn<-subset(wqsubn,wqsubn$N_conc>=0.35407|wqsubn$N_conc<=0.35406)
wqsubn<-subset(wqsubn,wqsubn$N_conc>=0.82432|wqsubn$N_conc<=0.82431)

wqsubn[c(202,276,259,221),c("year","treatment","plot","N_conc")]


#############

regmdN_conc <- regsubsets(N_conc~
                            treatment
                          +rainfall
                          +drain
                          +year:drain
                          +year:rainfall
                          +treatment:drain
                          +treatment:rainfall


                          ,
                          data=wq, method='exhaustive' ,
                          nbest=30, really.big=T)
summaryregmdN_conc<-summary(regmdN_conc)
# use a function from Dr. Dixon Iastate (remember to run first)
print.regsub(summaryregmdN_conc,sort='BIC', best=20)
```

```
mdN_conc<-lm(data=wq,N_conc~
               treatment
             +drain
             +year:drain
             +year:rainfall
             +treatment:rainfall

)
summary(mdN_conc)



mdN_conc2<-aov(data=wq,N_conc~
                 treatment
               +drain
               +year:drain
               +year:rainfall
               +treatment:rainfall
               )
Anova(mdN_conc2,type=3)




mdN_concaov<-aov(data=wq,N_conc~
                 year+treatment+year:treatment

)
Anova(mdN_concaov,type=3)
###########################check assumption
#histogram(residuals(mdN_conc))
#shapiro.test(residuals(mdN_conc))
qqnorm(residuals(mdN_concaov))
qqline(residuals(mdN_concaov))
qplot(predict(mdN_concaov), residuals(mdN_concaov), 
      ylab="Residuals", xlab="N_conc"
) +abline(0,0)
#plot(mdN_conc$fitted.values,rstudent(mdN_conc))
#abline(h=0)
#shapiro.test((mdN_conc))

# tukey test

TukeyHSD(x=mdN_concaov, c('treatment','year'), ordered = FALSE, conf.level = 0.95)
```

APPENDIX D4. PO$_4$-P Wilcoxon Rank Sum Test

PO$_4$-P load Wilcoxon test

	p-value
PM-PM2	0.729
PM-UAN	0.4727
UAN-PM2	0.1569

	p-value
2010-2012	0.01352
2010-2013	0.000155
2010-2014	0.1049
2012-2013	0.3717
2012-2014	0.0829
2013-2014	0.04988

R code

```
#######################################################################################3
############### ------P_load model focus on treatment and climate influence-------##########
#####
#######################################################################################3
mdyieldandload2<-read.csv("mdyieldandload2.csv")[,-1]
mdyieldandload2$P_load
names(mdyieldandload2)
mdyieldandload2$year<-as.factor(mdyieldandload2$year)
scatterplot.matrix(~raincul+treatment+
                     treatment:raincul+
                     P_rate+P_rate:raincul+P_rate:treatment+
                     #P_rate+P_rate:raincul+
                     #K_rate+K_rate:raincul+
                     #N_rate:P_rate+N_rate:K_rate+P_rate:K_rate+
                     yield+yield*raincul+yield*treatment+
                     yield*P_rate#+yield*P_rate+yield*K_rateN_load
                   ,
                   data=mdyieldandload2)

###################################################3
# outlier exclude
residuals(mdP_load)

max(residuals(mdP_load))
rstudent(mdP_load)
max(rstudent(mdP_load))
min(rstudent(mdP_load))
mdyieldandload2[,c("year","treatment","plot","P_load")]
str(mdyieldandload)

mdyieldandloadsubp<-subset(mdyieldandload2,mdyieldandload2$P_load>=0.03166|mdyieldandload2$P_
load<=0.03165)
mdyieldandloadsubp<-subset(mdyieldandloadsubp,mdyieldandloadsubp$P_load>=0.006026|mdyieldandl
oadsubp$P_load<=0.006025)
mdyieldandloadsubp<-subset(mdyieldandloadsubp,mdyieldandloadsubp$P_load>=0.019634|mdyieldandl
oadsubp$P_load<=0.019633)
```

```
mdyieldandloadsubp[,c("year","treatment","plot","P_load")]

######################3
regmdP_load<- regsubsets(P_yield ~
                           treatment
                         +yield
                         +P_conc
                         +drain
                         +rainfall
                         +treatment:P_conc
                         +treatment:drain
                         +treatment:rainfall
                          ,
                          data=mdyieldandload2, method='exhaustive' ,
                          nbest=100, really.big=T)
summaryregmdP_load<-summary(regmdP_load)
# use a function from Dr. Dixon Iastate (remember to run first)
print.regsub(summaryregmdP_load,sort='BIC', best=20)





mdP_load<-lm(data=mdyieldandload2,P_yield~
               yield+P_conc+drain
)
summary(mdP_load)
mdP_loadaov<-aov(data=mdyieldandload2,P_yield~
                   yield+P_conc+drain
                 )
Anova(mdP_loadaov
      ,type=3
      )
#
mdP_loadaov<-aov(data=mdyieldandload2,P_yield~
                  year+treatment#+year:treatment
)
Anova(mdP_loadaov
      ,type=3
)

qplot(data=subset(mdyieldandload2,mdyieldandload2$year!="2011"),x=treatment,y=P_load,facets=~
year)
qplot(data=subset(mdyieldandload2,mdyieldandload2$year!="2011"),x=year,y=P_load,facets=~treat
ment)
qplot(data=subset(mdyieldandload2,mdyieldandload2$year!="2011"),x=treatment,y=P_load,geom="bo
xplot")
qplot(data=subset(mdyieldandload2,mdyieldandload2$year!="2011"),x=year,y=P_load,geom="boxplot
")



#check assumptions
qqnorm(residuals(mdP_load))
qqline(residuals(mdP_load))
plot(mdP_load$fitted.values,rstudent(mdP_load))
abline(h=0)
qplot(predict(mdP_load), residuals(mdP_load),alpha = .001,
      ylab="Residuals", xlab="P_load"
) +abline(0,0)

# notice
# although log transform is used its still unable to make a model for P_load that does not
# violate the assumption of multiple linear regression
# and the results shows no significant relationship between the variables and P_load despite
of the violation of assumptions
```

```
# As none of the linear model is acceptable for P load , wilcox.test will be used to only che
ck the affect of different treatment
#
names(mdyieldandload2)
wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="PM")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="PM2")$P_yield),
  paired=F
  )

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="PM")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="UAN")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="UAN")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$treatment=="PM2")$P_yield),
  paired=F
)
# check wilcox assumption
qplot(data=mdyieldandload2,x=P_load,facets=~treatment,geom="histogram")



wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2010")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2012")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2010")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2013")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2010")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2014")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2012")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2013")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2012")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2014")$P_yield),
  paired=F
)

wilcox.test(
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2013")$P_yield),
  na.omit(subset(mdyieldandload2,mdyieldandload2$year=="2014")$P_yield),
  paired=F
)
```

PO$_4$-P concentration Wilcoxon test

	p-value
PM-PM2	0.189
PM-UAN	0.07011
UAN-PM2	0.002086

	p-value
2010-2012	< 2.2e-16
2010-2013	< 2.2e-16
2010-2014	0.000729
2012-2013	2.87E-05
2012-2014	2.08E-07
2013-2014	0.007566

R code

```
###########################################################################################
##########################--------------------------------------##########################
#############------------------------P_conc modeling ------------------------#############
##########################--------------------------------------##########################
###########################################################################################
wq<-read.csv("waterquality.csv")[,-1]
names(wq)
wq$year<-as.factor(wq$year)
wq$month<-as.factor(wq$month)
wq$plot<-as.factor(wq$plot)
wq$BA<-as.factor(wq$BA)
wq$date<-as.Date(wq$date,formate="%Y/%m/%d")
wq$date2<-as.Date(format(wq$date, "%m-%d"),"%m-%d") # add a month-day column
wq<-na.omit(wq)



scatterplot.matrix(~
```

```
          year#+month
         +treatment
         #+year*month
         +year*treatment
         #+month*treatment
         +flow+flow*year+flow*treatment
         #+flow*month
         +rainfall+rainfall*year+rainfall*treatment
         #+rainfall*month
         +DD+BA+DD*BA
         +P_conc
         #+DD*year+DD*treatment+DD*flow
         #+BA*year+BA*treatment+BA*flow

         ,
         data=wq
)

#####################################################3
# outlier exclude
residuals(mdP_conc)
max(residuals(mdP_conc))
subset(residuals(mdP_conc),residuals(mdP_conc)>=0.1)
order(residuals(mdP_conc))[1:5]

rstudent(mdP_conc)
max(rstudent(mdP_conc))
min(rstudent(mdP_conc))
wq[c(10),c("year","treatment","plot","P_conc")]
wq[c(169,170,151,100,250),c("year","treatment","plot","P_conc")]
str(wq)

wqsubp<-subset(wq,wq$P_conc<=0.1)
```

```
wqsubp[,c("year","treatment","plot","P_conc")]
#wqsubp[which(wqsubp$P_conc==0),c("P_conc")]<-0.000002
#wqsubp<-subset(wq,wq$treatment!="UAN")

#############

regmdP_conc <- regsubsets(P_conc~
                    year+treatment+year:treatment
                   +flow
                   +rainfall
                   +drain
                   +BA
                   +year:flow
                   +year:drain
                   +year:rainfall
                   +year:BA
                   +treatment:flow
                   +treatment:drain
                   +treatment:rainfall
                   +treatment:BA



                   ,
                   data=wq, method='exhaustive' ,
                   nbest=30, really.big=T)
summaryregmdP_conc<-summary(regmdP_conc)
# use a function from Dr. Dixon Iastate (remember to run first)
print.regsub(summaryregmdP_conc,sort='BIC', best=20)




mdP_conc<-lm(data=wq,P_conc~
```

```
              year
            +treatment
            +year:treatment
            +year:BA
            +year:drain
            +year:flow
            +treatment:rainfall

)
summary(mdP_conc)



mdP_conc2<-aov(data=wq,P_conc~
                year
              +treatment
              +year:treatment
              +year:BA
              +year:drain
              +year:flow
              +treatment:rainfall

)
Anova(mdP_conc2
     ,type=3
     )
###########################check assumption
#histogram(residuals(mdN_conc))
#shapiro.test(residuals(mdN_conc))
qqnorm(residuals(mdP_conc))
qqline(residuals(mdP_conc))
qplot(predict(mdP_conc), residuals(mdP_conc),
     ylab="Residuals", xlab="P_conc"
```

```
) +abline(0,0)
#plot(mdN_conc$fitted.values,rstudent(mdN_conc))
#abline(h=0)
#shapiro.test((mdN_conc))

#### wilcox test
#

names(wq)
wilcox.test(
  na.omit(subset(wq,wq$treatment=="PM")$P_conc),
  na.omit(subset(wq,wq$treatment=="PM2")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$treatment=="PM")$P_conc),
  na.omit(subset(wq,wq$treatment=="UAN")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$treatment=="UAN")$P_conc),
  na.omit(subset(wq,wq$treatment=="PM2")$P_conc),
  paired=F
)

#year


wilcox.test(
  na.omit(subset(wq,wq$year=="2010")$P_conc),
  na.omit(subset(wq,wq$year=="2012")$P_conc),
```

```
  paired=F
)


wilcox.test(
  na.omit(subset(wq,wq$year=="2010")$P_conc),
  na.omit(subset(wq,wq$year=="2013")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$year=="2010")$P_conc),
  na.omit(subset(wq,wq$year=="2014")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$year=="2012")$P_conc),
  na.omit(subset(wq,wq$year=="2013")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$year=="2012")$P_conc),
  na.omit(subset(wq,wq$year=="2014")$P_conc),
  paired=F
)

wilcox.test(
  na.omit(subset(wq,wq$year=="2013")$P_conc),
  na.omit(subset(wq,wq$year=="2014")$P_conc),
  paired=F
)
```

```
# check wilcox assumption

qplot(data=wq,x=P_conc,facets=~treatment,geom="histogram")
```