12-2006

A Statistical Analysis of the Distribution of Roads Salt in Blueberry Farm Soils of Van Buren County, Michigan

Melissa M. Kovach

A STATISTICAL ANALYSIS OF THE DISTRIBUTION OF ROAD SALT IN BLUEBERRY FARM SOILS OF VAN BUREN COUNTY, MICHIGAN

by

Melissa M. Kovach

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Geography

Western Michigan University
Kalamazoo, Michigan
December 2006

ACKNOWLEDGMENTS

This research project would not have been thought of if it were not for a friend, Vicki Katko. She is an environmental quality analyst for the Jackson District of the Michigan Department of Environmental. She brainstormed with me and together we came up with this thesis idea. I thank her. My cousin Diane also needs to be thanked. She helped me realize how much work and effort I was going to have to put into this, and I needed that. Thank you Diane. This research project also could not have been done without the support and discipline from Dr. Lisa DeChano, my graduate advisor. She helped me stay focused and was always there for me when I needed assistance and guidance. I look up to her and thank her completely. My other committee members Dr. Kathleen Baker and Dr. Gregory Veeck also need to be recognized. They have been enthused throughout my research and supported me the whole way. I also thank Dr. Dave Lemberg for purchasing the Aquarterr instrument so that I could detect salinity in the soil in a non-expensive way. I would not have been able to complete this project if it was not for him and the instrument. Another person that needs to be brought to attention is my older brother, Matthew. He helped me collect data and never complained. He has always been supportive of me and if it were not for him, I could not have gotten through this. Other people who helped me collect data were Rose Ann Switt, a person in which became an enduring friend, and my older sister, Monica. I would also like to thank Paw Paw LeDuc's blueberry farms and Kovach's blueberry farms for letting me use their farms in my study. Also, my parents need to be recognized. The trust and independence they give me is very much appreciated.

I would also like to thank Mark Longstroth, Barry Anttila and Dr. Randy Schaetzl. Mr. Longstroth works for the Michigan State University Extension office in Paw Paw, Michigan and is Van Buren County's fruit agent. He gave me some insight into the type of issues local farmers have and was definitely supportive of my research. Mr. Anttila is the Van Buren County Highway Engineer and helped me with the county's road salt statistics. Dr. Schaetzl is a professor at Michigan State University and has helped and supported me through this whole journey. I thank all of them very much. Without their help, my research would not have been complete.

Melissa M. Kovach

A STATISTICAL ANALYSIS OF THE DISTRIBUTION OF ROAD SALT IN BLUEBERRY FARM SOILS OF VAN BUREN COUNTY, MICHIGAN

Melissa M. Kovach, M.A.

Western Michigan University, 2006

The purpose of this research is to compare and analyze the leaching of road salt (sodium chloride) in soils of blueberry farms. Due to recent events in Ottawa County, Michigan, road salt is increasingly being blamed for blueberry production loss. Sodium chloride is harmful because once a significant amount of salt enters the soil profile the salt is unable to be flushed out, and reduces the chance for nutrients to reach the plant for effective growth. This study tested the farms' soils for salinity before winter (October 2005), during winter (March 2006) and after winter (May 2006) to determine if there was an increase during the winter due to applications of the road deicer. Data were collected from four blueberry farms in Van Buren County, Michigan. The four farms were different distances from major roadways to test the effects of distance-to-road on the dispersal of the salts. Soil salinity readings were taken in a systematic pattern with more than one hundred sample points from each farm for each round. Statistical analysis techniques were used to examine the spatial distribution of salt in the soils. Results indicated, as expected, an increase in sodium chloride in blueberry soils occurred during the winter season due to the amount of salt applied to the roads. This research provides important information to county officials for implementing alternative road deicers for environmentally sensitive areas.

TABLE OF CONTENTS

ACKNOWLEDGMENTS ii

LIST OF TABLES vi

LIST OF FIGURES vii

CHAPTER

1.0 INTRODUCTION 1

1.1 Background 1

1.2 Structure of Thesis 2

2.0 LITERATURE REVIEW 4

2.1 Blueberry Production 4

2.2 Road Salt and its Impacts 6

3.0 METHODOLOGY 14

3.1 Study Site 14

3.2 Data Collection 18

3.3 Data Analysis 19

4.0 RESULTS AND DISCUSSION 21

4.1 Farm W 21

4.2 Farm X 30

4.3 Farm Z 35

4.4 Farm Y 40

4.5 Comparison of all Farms 46

4.5.1 Round 1 46

Table of Contents—continued

CHAPTER

4.5.2 Round 2 46

4.5.3 Round 3 48

5.0 CONCLUSIONS 50

5.1 Summary 50

5.2 Future Research Opportunities 50

BIBLIOGRAPHY 54

LIST OF TABLES

3.1 Total number of sampling points for all farms and all rounds.................... 19

4.1a Mean and standard deviation of salinity for Farm W, all rounds................ 25

4.1b ANOVA output for Farm W all rounds.. 27

4.1c Post-hoc LSD results for Farm W.. 27

4.1d Farm W LSD analysis of sampling points, all rounds 29

4.2a T-test descriptives for Farm X 33

4.2b T-test significance for Farm X.. 33

4.2c T-test output significance between sampling points for Farm X 34

4.3a T-test descriptives for Farm Z.. 38

4.3b T-test output significance for Farm Z 39

4.3c T-test output significance between sampling points for Farm Z................. 39

4.4a T-test descriptives for Farm Y 44

4.4b T-test output significance for Farm Y... 44

4.4c T-test output significance between sampling points for Farm Y 45

4.5a Mean salinity for each farm for rounds 2 and 3 47

4.5b ANOVA output significance for round 2 47

4.5c Significant differences between the farms for round 2 48

4.5d ANOVA output significance for round 3 49

4.5e Significant differences between the farms for round 3 49

LIST OF FIGURES

2.1 United States Blueberry Production, 2004 5

2.2 Michigan Counties 12

3.1 Blueberry Acreage by Michigan County 1997 15

3.2 Van Buren County Townships 17

4.1a Farm W Round 1 Salinity 23

4.1b Farm W Round 2 Salinity 24

4.1c Farm W Round 3 Salinity 26

4.1d Farm W Average Salinity per Sampling Point 28

4.2a Farm X Round 2 Salinity 31

4.2b Farm X Round 3 Salinity 32

4.2c Farm X Average Salinity per Sampling Point 35

4.3a Farm Z Round 2 Salinity 36

4.3b Farm Z Round 3 Salinity 37

4.3c Farm Z Average Salinity per Sampling Point 40

4.4a Farm Y Round 2 Salinity 42

4.4b Farm Y Round 3 Salinity 43

4.4c Farm Y Average Salinity per Sampling Point 46

1.0 INTRODUCTION

1.1 Background

In December of 2004, several Ottawa County, Michigan, blueberry farmers filed a civil suit against the Michigan Road Commission. The suit alleged that in recent years, the road commission had been increasing its volume of deicing salt on county roads during the winter months (Moroney, 2005a), which had contributed to the production loss of blueberries near roads. These farmers asked the courts to compensate them for their damages and, further, petitioned the court to require that the Road Commission decrease the amount of salt used on icy roads, especially near farms within 20 to 50 feet from the road. A Road Salt Committee was formed under the guidance of the Ottawa County Planning Commission and the Ottawa County Road Commission in 2004. After much deliberation, the Road Commission made changes to its program including a decrease in salt quantities and an increase in sand quantities distributed on roads during the winter months of November to late February (Moroney, 2005b).

The Ottawa County Planning Commission appointed the Road Salt Committee to implement new strategies to avoid any further environmental impacts related to road salt application (Ottawa County, 2004). The Road Salt Committee's plan was to reduce road salt applications by 25 percent by 2009 and by 75 percent in the environmentally sensitive areas by 2007. Among several salt reduction goals, one was to train all Road Commission salt truck operators to properly recognize the problem and learn how to prevent further damage. Through these collective efforts and a better understanding of the problem, the Ottawa County Road Commission decreased their salt applications in 2005 and will continue to do so.

The problems that arose in Ottawa County are making farmers in other counties reflect on their potential blueberry production losses due to this problem. Road salt application is a main concern with production loss because most farms are within close proximity to the road, whether it be a high traffic or low traffic roadway. This is particularly the case for operations with significant retail (U-PICK) activities where easy access is an important consideration.

The purpose of this research was to analyze the amount of leached road salt in the soil and determine its distribution in farm soils with relation to the road. The objectives were (1) to collect structured soil salinity measurements in four different blueberry farms in Van Buren County, Michigan, before (October 2005), during (March 2006) and after winter (May 2006) to determine if the amount of salinity in the soil changed during these times, (2) to determine if the salinity concentrations found in the soil sampled were highest during the winter when salt applications were greatest, and (3) to determine if the salinity concentrations were higher near the roadways.

This research is unique in the fact that there is a lot of literature on the negative impacts that salt has on the environment, but little research analyzes the distribution of salt, how far the salt can leach from its application source in the soil and how it may specifically affect blueberry production. This research will indicate whether or not blueberry farmers should be concerned with the salinity in the soil and if further precautionary measures are required state-wide.

1.2 Structure of Thesis

The remainder of the thesis is structured as follows. Chapter 2 consists of a review of pertinent literature that guided this research. Chapter 3 describes each farm and describes the way in which data were collected and analyzed. Chapter 4 discusses the results of the analysis performed. Chapter 5 summarizes the entire study and suggests topics for future research that stem from this research.

2.0 LITERATURE REVIEW

2.1 Blueberry Production

Blueberries are high in antioxidants which help prevent cellular damage that causes cancer. Blueberries are also low in fat, sodium free, high in fiber and a good source of Vitamins A and C. The pigment that makes the blueberries blue is called Anthocyanin, which is said to be responsible for these major health benefits. The per capita consumption of blueberries is at a meek 16 ounces per person per year, but with these major health benefits, blueberry consumption is expected to increase (Gentry, 2001).

North America produces 90% of blueberries consumed worldwide. The blueberry is grown in more than 38 states and provinces of Canada. The United States and Canada produced 366 and 415 million pounds of blueberries in 1999 and 2000 respectively (Gentry, 2001). Michigan and New Jersey are the top blueberry producers in the U.S., with Oregon, North Carolina, Georgia and Washington next (Figure 2.1). Blueberry industries have also developed in South America, Australia, New Zealand and Europe with more than 42,000 million pounds harvested each year. Although the United States and Canada are the largest producers and consumers of blueberries, the market around the world is also on the rise (U.S. Highbush Blueberry Council).

Blueberries are very specific in their growing needs. They need an average growing season of 160 days and moderate winter and spring temperatures. Late spring and early fall frosts can damage plants. Well drained, sandy, and acidic soils are ideal for blueberries. The plant requires a soil pH between 4.5 and 5.5, and readily available water throughout the growing season. High water tables supply the plant's everyday need for

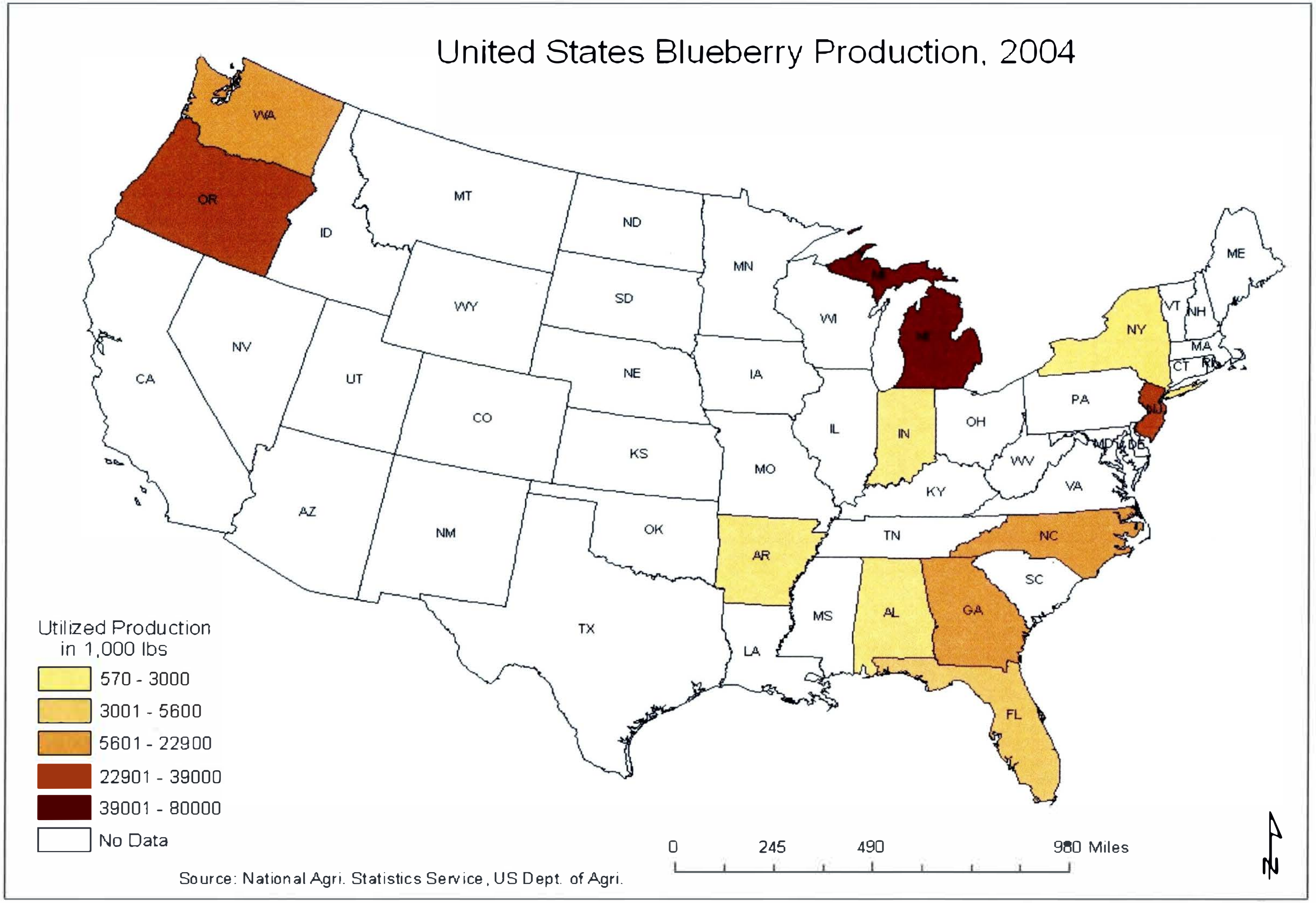


Figure 2.1 United States Blueberry Production, 2004.

moisture, which is an important secondary requirement. The soil series of major blueberry growth in Michigan include Au-Gres, Au-Gres-Saugatuck, Covert, Houghton, Morocco, Napoleon, Newton, Pipestone-Kingsville and Thetford because these soils tend to be acidic and sandy with a varying organic content (Hanson & Hancock, 1998). Ideally, organic matter needs to be high in blueberry soils because it increases water holding capacity and aeration of soils. Blueberries have shallow roots that are sensitive to soil compaction and poor drainage.

Michigan is the leading state in blueberry production with over 17,000 acres and close to 600 farms. Michigan produced 66 million pounds in 2005 (NASS,2005). Southwest Michigan is the best area for blueberry production because the temperature is moderated by Lake Michigan and the soil is sandy acidic. This subject is discussed more thoroughly in Chapter 3.

2.2 Road Salt and its Impacts

Sodium chloride (NaCl) mixed with sand is the main deicing material used on roads in winter in the state of Michigan. It is the most cost efficient and easily accessible product to melt snow and ice from the road to improve traffic safety throughout the winter season. Nearly 10 million metric tons of road salt is applied to U.S. roadways each year and over 400,000 metric tons are applied to Michigan roadways alone (D'Itri, 1992). An average of 2,500 tons of this mixture is applied to major roadways in Van Buren County (VBC) with a small drop in temperature in the winter season and with any slight forecast of snowfall. The ratio of sand to salt in VBC is 5:1 but no salt is applied to the roads if the temperature is below 26 degrees F because at this temperature snow melted by road salt becomes ice and does not improve traffic safety. In the 2005-2006 winter season it snowed for a few weeks in December, before Christmas, and then snowed sporadically until late March. The VBC Road Commission applied over 3,300 tons of road salt throughout this particular winter season (Anttila, 2006).

While sodium chloride is beneficial for winter snow and ice melt, it has been increasingly proven to be harmful in many other ways. Motor vehicle bodies start to corrode due to the large amount of salt applied to the roads, which then sticks to the vehicle. It is a matter of how much road salt is on the vehicle and how long it stays there that determines how much vehicle corrosion occurs. When road salt comes in contact with water, it increases the rusting rate because chloride ions increase the conductivity of water, which deteriorates motor vehicles (Wegner & Yaggi, 2001).

Roads themselves are also impacted by the amount of salt applied during the winter months. Chemically, salt damages the road by weakening the pavement and making it easier for pieces of the road to break off. Physically, when enough snow accumulates, plow trucks start moving the snow around creating disturbance of the roads, which causes the roads to split and break off; hence creating an abundance of pot holes on roads and in parking lots during winter (Shi, 2005).

Along with the negative impacts this chemical has on cars and roads, it is also highly harmful to the environment. One harm salt has on the environment is its impact on groundwater. Road salt has the ability to infiltrate the ground and reach the water table, which then affects the groundwater/drinking water. With an excessive amount of snow and ice melt, and rain salt has a higher chance of leaching into the ground. It is highly crucial that road salt storage occurs indoors since storing it outdoors increases the risk of it leaching into the ground and reaching the water table. The amount of sodium chloride in the groundwater and/or drinking water is directly correlated to the amount of road salt application during the winter (Wegner & Yaggi, 2001).

Another harmful effect that road salt has on the environment is its impacts on the soil. Salt is a vital and common component of soil due to mineral weathering, inorganic fertilizers, manures and irrigation waters. But, exceedingly high sodium chloride levels in soils create imbalances in plants, which restrain water absorption and reduce root growth. An excess of salt in the soil creates obstacles for the nutrients to move up the plant and thus, disrupts the uptake of plant nutrients inhibiting long term growth (Chiras, 2001).

Multiple cases of this problem have been reported by researchers around the world. In Ontario, Canada, an experiment was conducted to determine the levels of NaCl in their soils along the roadside. This study found that salt concentrations in soils changed with distance from the highway, soil depth and time of year. In April 1974, the NaCl concentrations were generally higher in the upper 5cm of the soil than the greater depths because of the end of winter deicing salt applications. In August and September of the same year, the levels of salt at greater soil depths were increased due to leaching. November salt levels in the shorter and greater depths of the soil were consistently higher than those in August because of the winter season deicing practices (Hofstra & Smith, 1984).

In the Indus Basin of Pakistan, soil salinity is a major environmental and community problem (Gulzar et al., 2003). The long term use of canal-based irrigation leads to high salt content in the soil. Because of this problem, Gulzar and others at the University of Karachi, Pakistan, tested the seeds of *A. lagopoides* for tolerance of saline soils in a controlled experiment. Seeds were placed in pots of soil and the amount of a NaCl solution added was increased gradually on a day-to-day basis to certain pots. The results indicated that the weight of the shoots formed from the seeds decreased with an increase of salt in the soil (Gulzar et al., 2003).

Within the United States, a number of studies examining salt effects on the environment have also been conducted. In Massachusetts, soil samples were taken from major US routes and interstates and also at various sites on the University of Massachusetts' (UMA) campus to test the amount of salt in roadside soils. This research was conducted through the Plant and Soil Sciences Department at UMA. This study examined the injury to plants along roadsides and assessed relationships between damage and the amount of sodium in the plants and soils. Soil samples were taken 12 inches down, at 5 or 10-foot increments, perpendicular to the road. The soil was dried and tested for pH, electrical conductivity (EC), and sodium (Na) concentrations. The results showed that Na in the soil decreased as the distance from the road increased ranging from 101mg at 5 feet from the road to 16mg at 30 feet from the road. Also, there was a considerable drop in Na in the soil after 15 feet (5meters). Bryson and Barker (2002) suggest the Na in the soil is from road salt application and spray; therefore, the higher concentrations are near the road. This study also concluded that the soil pH levels were higher than 7 (average acidity) at distances closer to the road and the EC readings were highest at sites close to the road (Bryson & Barker, 2002).

More locally, Talicska (1999) also studied the salt concentrations in soil using the Sodium Absorption Ratio (SAR). SAR is the ratio between soluble sodium and soluble divalent cations. It can be used to predict the exchangeable sodium percentage of soil equilibrated with a given solution (Talicska, 1999). The study was conduced at four different locations with the same soil texture in Grand Traverse County, Michigan, for the winter season of 1996-1997. Soil samples were taken five times along three 10 meter long transects that were 6 meters apart (perpendicular to the roadway). At each sampling point, soil was extracted at 8 centimeters, 60 centimeters and 100 centimeters to observe any sodium accumulation in the soil. The results show that the highest SAR levels correspond with the sites that received the most road salt, indicating that the salt applied to the road during the winter season leaches into the farm soils at a considerable rate that negatively impacts the soil and, of course, subsequent plant growth.

The immediate and most visible harmful effect salt has on the environment is to the roadside vegetation. Along roads and sidewalks physical evidence shows that road salt damages vegetation because it turns brown and dies in comparison to vegetation farther away from the salt application. This is the initial observable damage of what salt does to the plant. Taking a closer look, salt spray from traffic and plow trucks can occur up to, but not limited to, 300 feet from the road (Ottawa County, 2004). When plants absorb road salt, their ability to obtain water is hindered thus plants become dehydrated, turn brown and effectively decrease growth. The effects have been documented in global, national, and regional studies.

Globally, the Swedish National Road Administration has implemented a rule that everyone with the intention of using salt for deicing purposes must acquire the necessary knowledge of how sodium chloride harms the roadside environment. This rule was added to their environmental policy to help promote environmental and ecological sustainability. A field experiment was performed in order to test the salt spray and how it affected the vegetation along a study site of an 800-meter section of a main highway in Sweden, just north of Stockholm (Lundmark, 2005). The highway had a high density of traffic (about 90,000 vehicles). This study was performed from December 2003 to April 2004 at different distances from the road. The results showed, yet again, that decreasing sodium levels were measured and well detected as the distance from the road increased. (Lundmark, 2005).

Nationally, the University of Massachusetts has researched salt accumulation along the roadside and has documented this vegetation destruction. Their focus plant was the pine tree and found that pine needles facing the road turned brown due to an increase of salt and a decrease of moisture. The number of pine trees with brown or dead pine needles decreased as the distance from the road increased (Bryson & Barker, 2002).

Massachusetts is not the only state that has been plagued by road salt harming roadside vegetation. Regionally, Michigan also has documented cases of this. One case in particular is that of blueberry bushes in Ottawa County (OC). In this county, north of Van Buren County (Figure 2.2), blueberry plants were highly impacted by the road salt. In 1999, OC blueberry growers were concerned about their low yields and were suggesting the deicing methods had something to do with it (Berkheimer, 2004). Then five years later, these blueberry farmers of OC filed civil suits against the Ottawa County Road Commission. They implied that due to the amount of salt applied to the roads and salt spray from passing traffic, their blueberry bushes along the road front dried out. This in turn disabled the plant to grow efficiently and produce blueberries to the fullest potential.

Figure 2.2 Michigan Counties

Every year production decrease led these farmers to believe road salt was the culprit and wanted changes to occur. The OC Road Commission formed a committee and researched this case more. The outcome of this study was a change from 50/50 sand/salt mixture to a 70/30 mixture. This new mixture melts ice and snow on roads but is presumably far less detrimental to blueberry bushes. Because this change is so new, no comprehensive follow-up studies have been reported to date. The OC Road Commission will continue to work with the blueberry farmers to help ensure productive growing seasons in the future.

Berkheimer (2004) studied 12 blueberry farms in Ottawa and Muskegon Counties, Michigan (Figure 2.2). These farms were surveyed for flower bud damage in May of 2002, 2003, and 2004. The farms in this study were in close proximity to high traffic roads. Five to ten twigs from each of two roadside bushes were examined and the numbers of dead and live flower buds were counted. The results showed that overall flower bud damage varied by year but generally, the greater bud damage occurred in bushes closest to the road. Berkheimer (2004) concluded that much of the flower bud damage and mortality is due to the use of deicing road salt spray that was carried downwind from the roads to the fields.

In conclusion, much of the literature on how the road salt impacts the environment reflects negative effects. Too much salt in or around any plant will reduce its growing process because salt alters the plant's ability to soak up nutrients needed to grow effectively. While many of the studies cited previously indicate these harmful effects, there remains a lot more research at the micro-scale that informs interested parties of how great an impact road salt has on farm fields and how far from the roadside this chemical may migrate. This research is intended to address these issues.

3.0 METHODOLOGY

3.1 Study Site

In the United States, Michigan is the number one state in blueberry production. Michigan's fruit belt borders the eastern coast of Lake Michigan with the main fruit producing counties in southwest Michigan. Lake Michigan creates ideal environmental conditions for fruit production because of the uniform rainfall during the summer and modification of climate extremes throughout the region (Armstrong, 2006). Michigan has microthermal climates with warm/hot summers that create warm temperatures for the growing season. Lake effect region insulates the soil to keep it from freezing which helps avoid root damage. The lake effect snow provides an effective recharge of soil moisture in the late winter and early spring (Armstrong, 2006). Sandy glacial soils and high water tables are found in this region, which result in excellent soils for the growth of blueberries having a pH in the 4.5 to 5.5 range. The rolling landscape left long ago from glaciers provide efficient topography for fruit production. On flat land, the wind and temperatures create extremes. But the rolling topography found in southwest Michigan creates a buffer for strong winds and higher elevation points may be 2 to 5 degrees warmer during the day which is a variation that can make a large difference in blueberry production (Armstrong, 2006).

In 1997, Michigan produced 76 million pounds of blueberries. Van Buren County (VBC) is the leading county in Michigan for blueberry production (Figure 3.1). VBC has over 7,000 acres of blueberry farms on 191 farms (Michigan State University Extension, 2000). Although other fruit farm acreage in VBC has been decreasing since 1994,

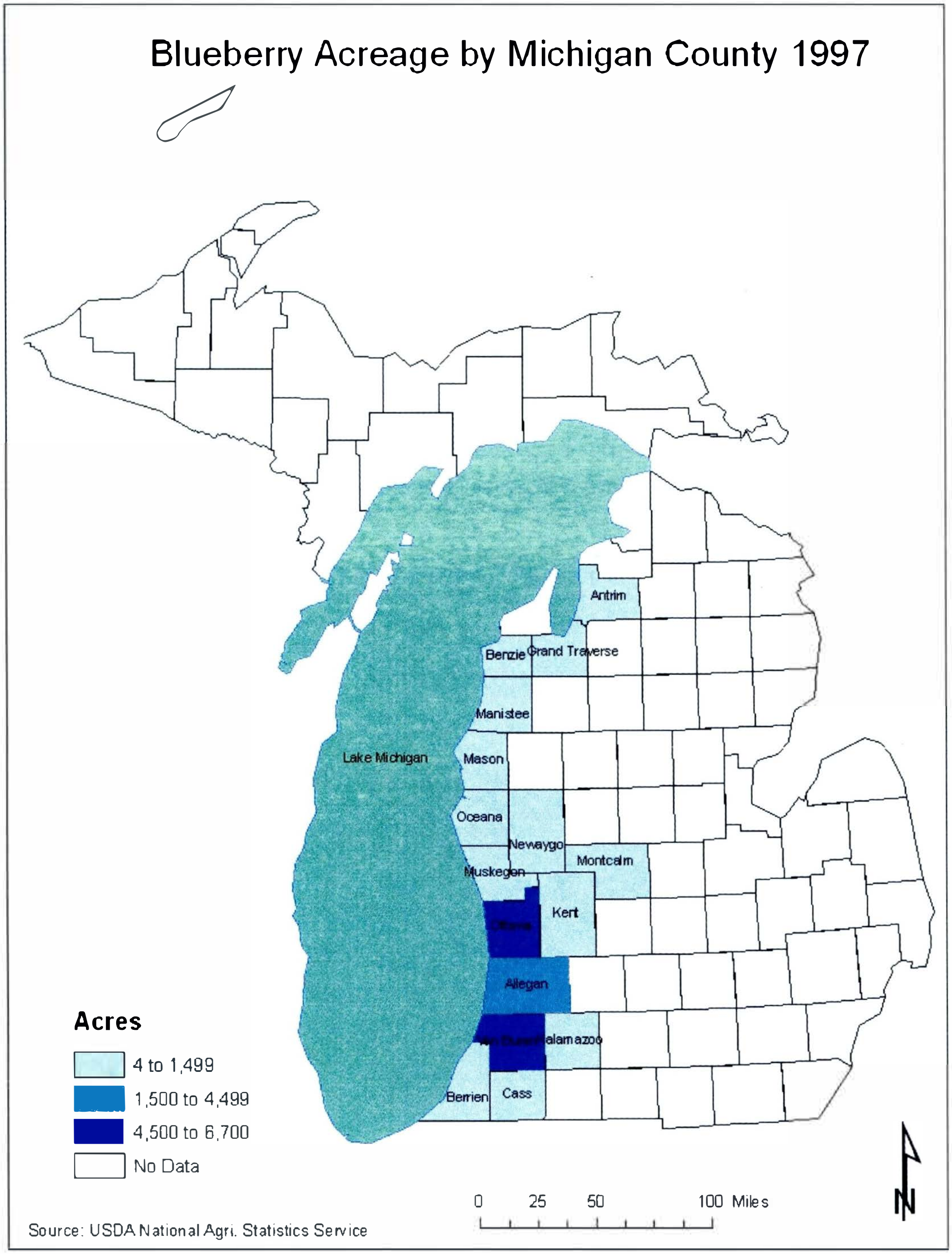


Figure 3.1 Blueberry Acreage by Michigan County 1997

acreage for blueberry and grape production has been increasing (Michigan State University Extension, 2000). Blueberries have such great success in VBC because the environmental conditions required to produce blueberries are close to optimal.

Four farms from which data (soil moisture, soil temperature and soil salinity) were collected are located in Van Buren County, Michigan. These farms were chosen because they are located on high traffic roadways. Three of the farms are located along M43 between 25th and 29th Streets in Almena Township (Figure 3.2). The fourth farm is located on M40 between 40th and 46th Avenues on the border of Almena and Waverly Township. The Joe Kovach blueberry farm (Farm X) is approximately 80 acres. There is a barn used for U-pick, a small parking area and an irrigation pond. Blueberry bushes run parallel to M43 for 131 meters beginning at 55.1 meters from the road's edge. The surface slopes downward into a ditch at the 9- meter mark.

LeDuc farms of Paw Paw, Michigan, own the other 3 farms used in this study. The large farm (Farm Y) is also along M43, just past County Road 653. This farm also encompasses approximately 80 acres. For the first and second rounds of sampling, there was an irrigation pond, a barn and a selling stand between M43 and the blueberry bushes. As of late March 2006, the irrigation pond was drained and the buildings were removed. These blueberry bushes run parallel to M43 for 149 meters and are 94 meters from the road. This surface also slopes downward into a ditch at the 10-meter mark. The ditch is about 7 meters wide.

Across the street is a smaller field also owned by LeDuc farms (Farm Z). This farm has 79 meters of road frontage and the bushes start 45 meters from the road. There is also a prominent ditch 14 meters from the road and is approximately 4 meters wide.

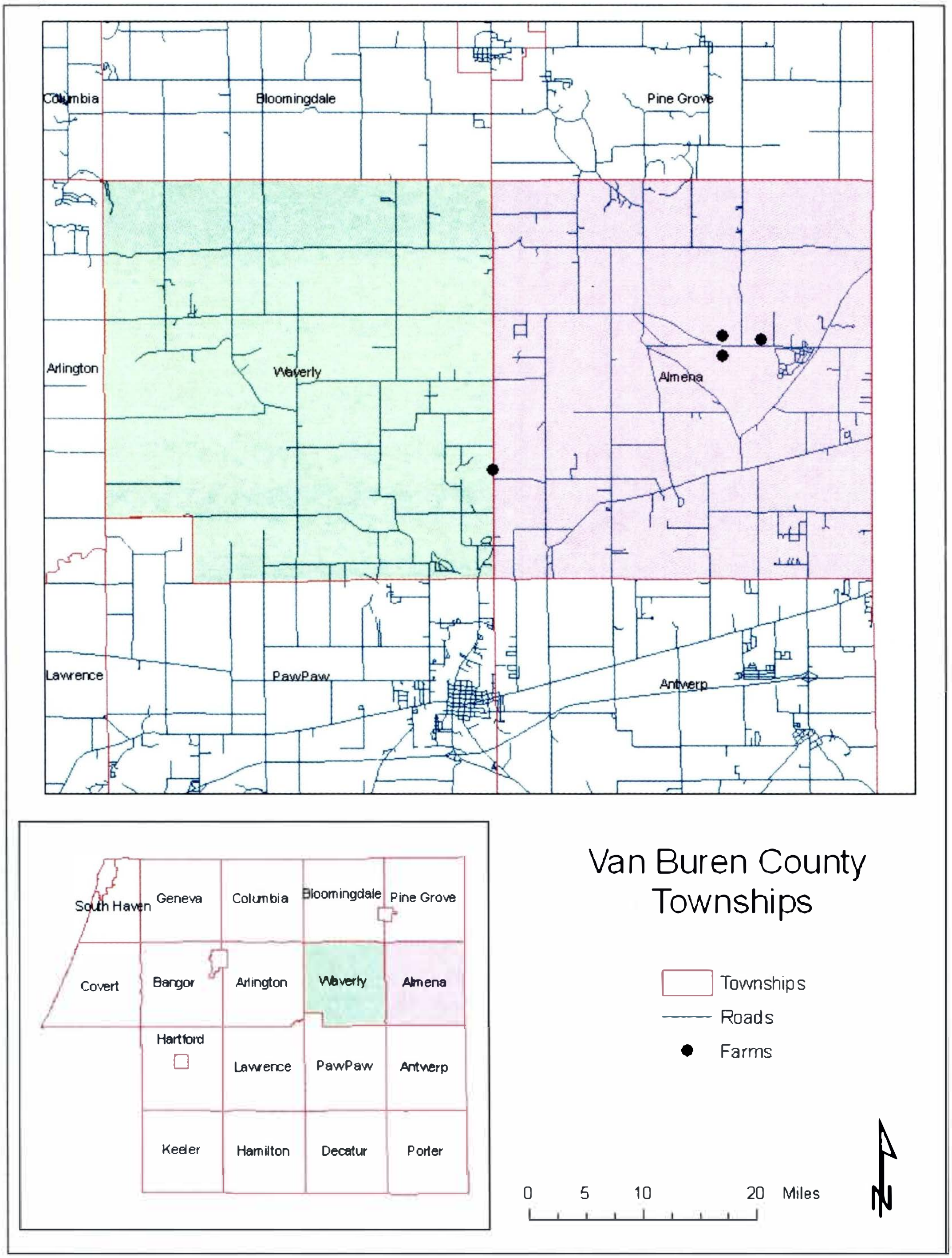


Figure 3.2 Van Buren County Townships

The final farm is on M40 (Farm W). This farm has 100 meters of road frontage and the bushes start approximately 17 meters from the road. From the road, there is a slope that leads into a small ditch, which is approximately 10 meters from the road and runs the entire length of the road frontage.

These blueberry fields grow on the soil known as Coloma-Spinks-Oshtemo. It is Ottokee loamy fine sand. The topography is nearly level to hilly, varying from somewhat excessively drained to well drained, which is best for blueberry plants, with sandy and loamy soils on the outwash plains and moraines (U.S. Department of Agriculture, 1983).

3.2 Data Collection

Data were collected three times on each farm. Samples for round 1 data were collected in October- November 2005, round 2 data were collected in March 2006, and round 3 data were collected in May 2006. The moisture, temperature and salinity measurements were taken with an Aquaterr instrument (Aquaterr Instruments, Inc., Costa Mesa, CA). The Aquaterr probe is a digital soil moisture, temperature and salinity meter. The moisture function reads the soil moisture on a scale from 0% to 100% where 0% means the soil has no moisture and 100% means the soil is completely saturated. The soil temperature is read in degrees Fahrenheit and salinity in microSiemens (μS). The range of salinity measured on the Aquaterr probe is from 0 to 1500 μS.

On each farm, the same data collection method was used. A transect was placed perpendicular to the road, parallel to the edge of the farm field. Subsequent transects were laid 10 meters apart for the length of each farm's road frontage. Soil moisture, temperature and salinity were measured every meter for the first 10 meters and then every 15 meters afterwards for up to 100 meters. Samples were taken across the transects instead of down the transects because it was easier for the operator to measure parallel to the road than perpendicular from the road. Table 3.1 shows the number of sampling points per transect as well as the total number of transects for each farm.

Table 3.1 Total number of sampling points for all farms and all rounds.

	Number of Sampling Points per Transect	Total Number of Transects	Total Number of Samples
Farm X	16	13	208
Farm Y	16	14	224
Farm Z	16	8	128
Farm W	15	10	150

3.3 Data Analysis

Data were visually examined spatially in ESRI ArcMap ® (ESRI, 2006). In order to do this, latitude and longitude coordinates were created and then were added as a layer to ArcMap. A shapefile was created and then the specific farm data from all three rounds were added to the shapefile to create maps that show the distribution of soil salinity for each farm for every transect and for every sampling point.

Standard deviations and variances for each variable were calculated to determine the variability and/or similarity between farms, sampling points and transects. Standard deviations were calculated to determine the average distance the values are from their mean. Variances were calculated to show the square of the standard deviation. This is a measure of its statistical dispersion, indicating how far from the expected value each value lies. The variance is the average of the square of the distance of each data point from the mean (Berkheimer, 2004).

Analysis of variance (ANOVA) was performed for Farm W only because all three rounds were sampled accurately. ANOVA procedures compare means by splitting the overall observed variance into different parts. This allows comparing of several groups of observations. ANOVA indicates significant differences between rounds and between sampling points. Individual T-tests were performed for Farms, X, Y and Z to determine if there were significant differences between rounds 2 and 3.

4.0 RESULTS AND DISCUSSION

This chapter evaluates data collected from the four study farms in Van Buren County, Michigan, during the 2005-2006 study period. Maps in the chapter show the distribution of soil salinity values that were collected at the four farms. Three rounds of data were collected for Farm W so there are three maps for this farm. Farms X, Y and Z have two maps each showing the distribution of soil salinity throughout the sampled farm fields for rounds 2 and 3. Analysis of Variance (ANOVA) and Fisher's Least Significant Difference (LSD) Post-Hoc tests were performed on Farm W comparing and discussing the mean salinity for all three rounds. Data were also analyzed across sampling points that were parallel to the road to see if salinity concentrations were higher for sampling points near the road. Independent T-tests were performed for Farms X, Y and Z to determine if there was a significant difference in salinity between rounds 2 and 3 within all sampling points at these farms. T-tests were also performed for these three farms to see if salinity was higher closer to the road. Results for Farm W will be presented first given that ANOVA was used to analyze these data for three rounds, as opposed to the analysis of two rounds for the fields located at the other three farms.

4.1 Farm W

This blueberry farm was the first farm sampled. Round 1 consisted of 35 transects 3 meters apart for the 100 meters of road frontage. There was not much variation in the salinity found within these close (3 meter) transects so, the transects were changed to 10 meters apart for the other two sampling periods as well as for the fields located at the other three farms.

The Aquiterr instrument that was used to collect data on soil moisture, temperature and salinity malfunctioned when Farm W was 85% sampled. The sensor part of the instrument cracked, therefore inaccurate readings were assumed. This farm's round 1 data were used in analysis but data for the other farms (X, Y, and Z) could not be collected for round 1 data while the instrument was being repaired.

Farm W is only 79 meters in length, therefore, sampling point 14 and 15 are only 9 meters apart, instead of 15 meters apart. Figure 4.1a shows the distribution of the salinity throughout the farm for round 1. The salinity is higher within the first 12 sampling points. Salinity values increase towards the ditch and then decrease towards the back of the field. This indicates that road edge soil has high salinity variability. Sampling point 13 exhibits higher salinity concentrations in transects D through K. This is due to a moist area in the field that locked in the salinity and held it there. However, this sampling point did not exhibit higher salinity contents for the other two rounds. Sampling points 14 and 15 are not considered since the instrument cracked at the beginning of sampling point 14. These readings are assumed inaccurate and therefore, are not included in the analysis.

Figure 4.1b shows the salinity distribution for round 2 (March 2006) on Farm W. Values reported in the figure definitely indicate that there is more salinity near the road, and then these values diminish moving toward the back of the field, implying much variability in the first ten meters from the road. It can be assumed that this is from the road salt that is applied during the winter months and affects the roadside soil salinity content only to the ditch, but statistical tests that allow a comparison of salinity values are needed to determine if there is indeed a statistically significant difference. Salt is applied

Figure 4.1a Farm W Round 1 Salinity

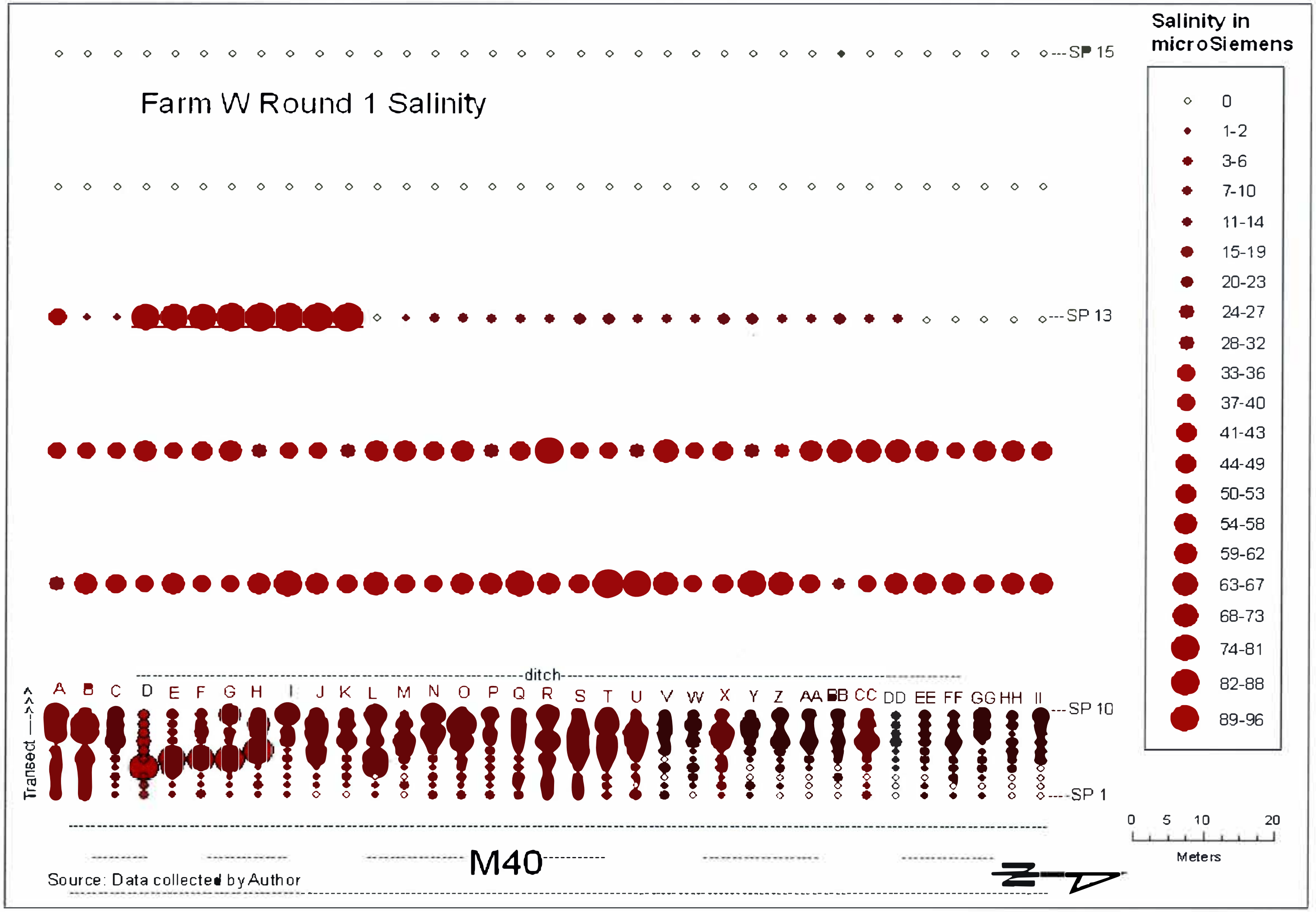
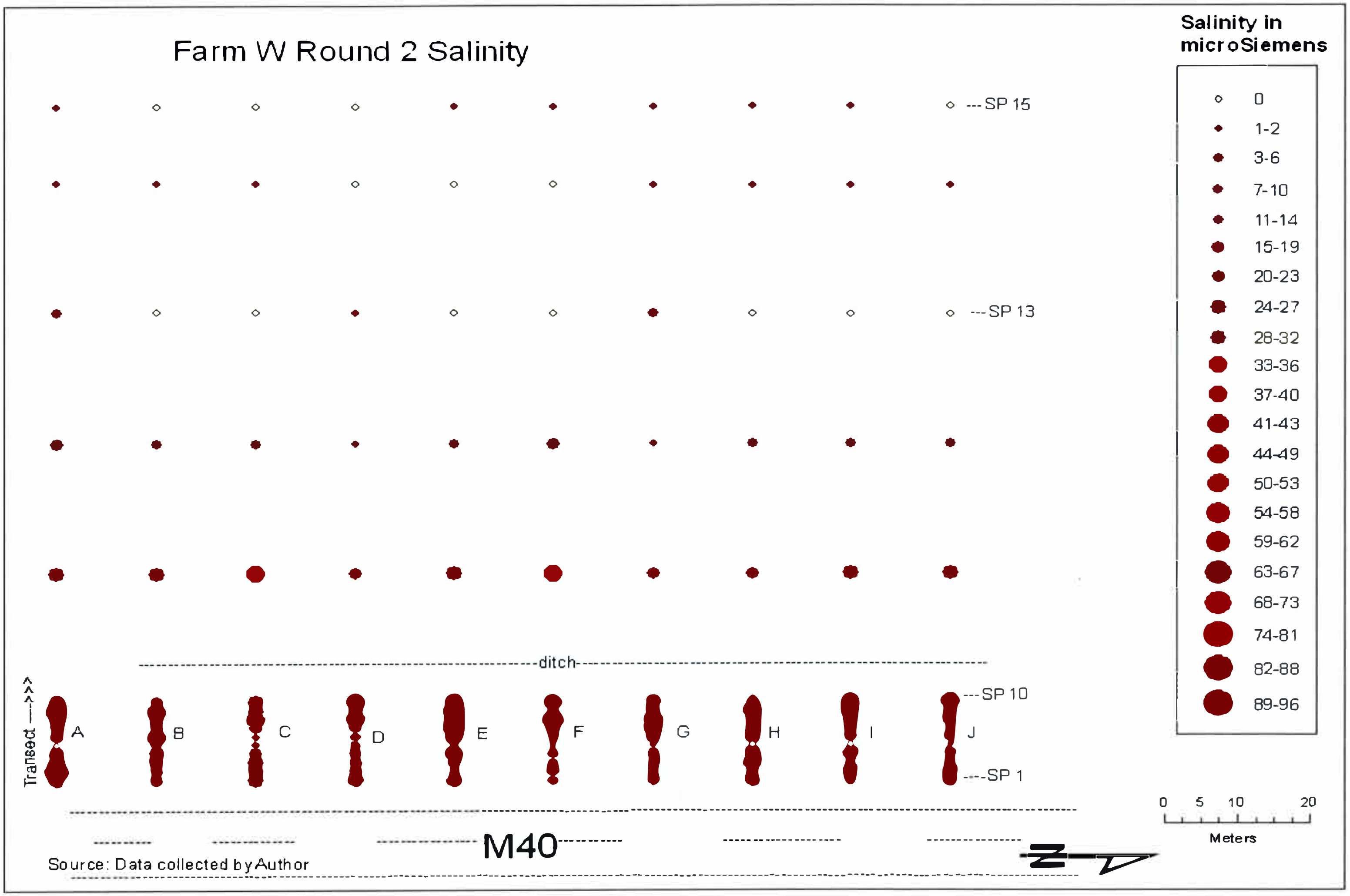


Figure 4.1b Farm W Round 2 Salinity



generously on the roads during this season, making it very likely that the salt may leach into the soil, which then increases the salinity content in any roadside surface.

Figure 4.1c shows the salinity values for Farm W for the third sampling period, which was May 2006. It is obvious that the samples with higher salinity concentrations are located near the road and ditch. This finding exhibits the same general pattern as the salinity distributions of rounds 1 and 2. Again, sampling point 13 had higher salinity content which is a result of very moist soil.

Table 4.1a displays the average salinity sum values and standard deviation for each transect for each round. Results of the ANOVA analysis for Farm W indicated a significant difference across the three rounds of 0.000 on the 95% confidence interval (Table 4.1b). The significance of 0.000 indicates that a random result will occur once in 10,000 times. The mean salinity for round 1 was 283.77 µS. The mean salinity for round 2 was 230.10 µS and round 3 was 159.10 µS. The salinity was highest in round 1 but the fact that round 1 had more transects may have influenced these results. Salinity sums for each transect was the dependent variable and the time period (of three rounds) was the factor. A post-hoc Fisher's LSD calculation (shown in Table 4.1c) proved there were significant differences between all sampling rounds. These significant differences suggest that road salt applications do impact the amount of salt in the soil, which supports one of the hypotheses of this research.

Table 4.1a Mean and standard deviation of salinity for Farm W, all rounds.

Round	Number of Transects	Mean	Std. Deviation
1	35	283.77	89.417
2	10	230.10	29.069
3	10	159.10	11.110
Total	55	251.35	86.813

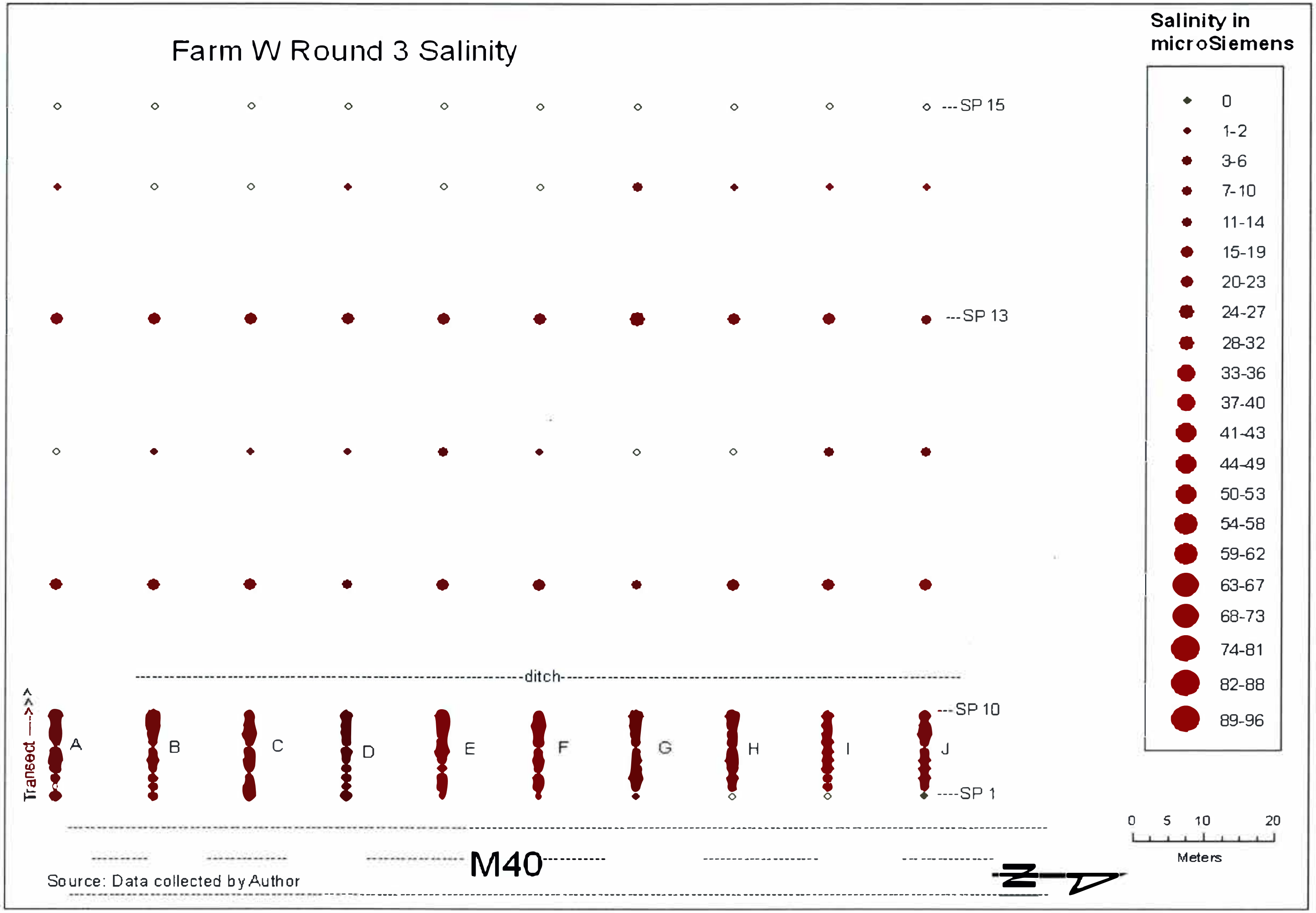


Figure 4.1c Farm W Round 3 Salinity

Table 4.1b ANOVA output for Farm W for all rounds.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	126406.465	2	63203.232	11.714	.000
Within Groups	280559.971	52	5395.384		
Total	406966.436	54			

Table 4.1c Post-hoc LSD results for Farm W.

(I) Round	(J) Round	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	53.671(*)	26.338	.047	.82	106.52
	3	124.671(*)	26.338	.000	71.82	177.52
2	1	-53.671(*)	26.338	.047	-106.52	-.82
	3	71.000(*)	32.849	.035	5.08	136.92
3	1	-124.671(*)	26.338	.000	-177.52	-71.82
	2	-71.000(*)	32.849	.035	-136.92	-5.08

* The mean difference is significant at the .05 level.

Table 4.1d shows the results of the post-hoc Fisher's LSD test indicating sampling points 1-3, 7, and 11-12 had significant differences across the three sampling rounds. The first three sample points probably had the largest differences between the three rounds because they are closest to the road and therefore, will exhibit higher ranges of salinity content through the seasons. Sampling Point 7 is located on the slope of the hill that leads to the ditch so this sample point may show higher salinity because it is at a point of leaching transition. Sample points 11 and 12 are points beyond the ditch, moving towards the actual blueberry bushes but where road salt remains or migrates back down into the ditch; therefore at these points there is an accumulation of salt that probably results in a significant difference.

Figure 4.1d is a graph showing the average salinity per sampling point compared to the distance from the road. The graph indicates that round 1 had the highest salinity

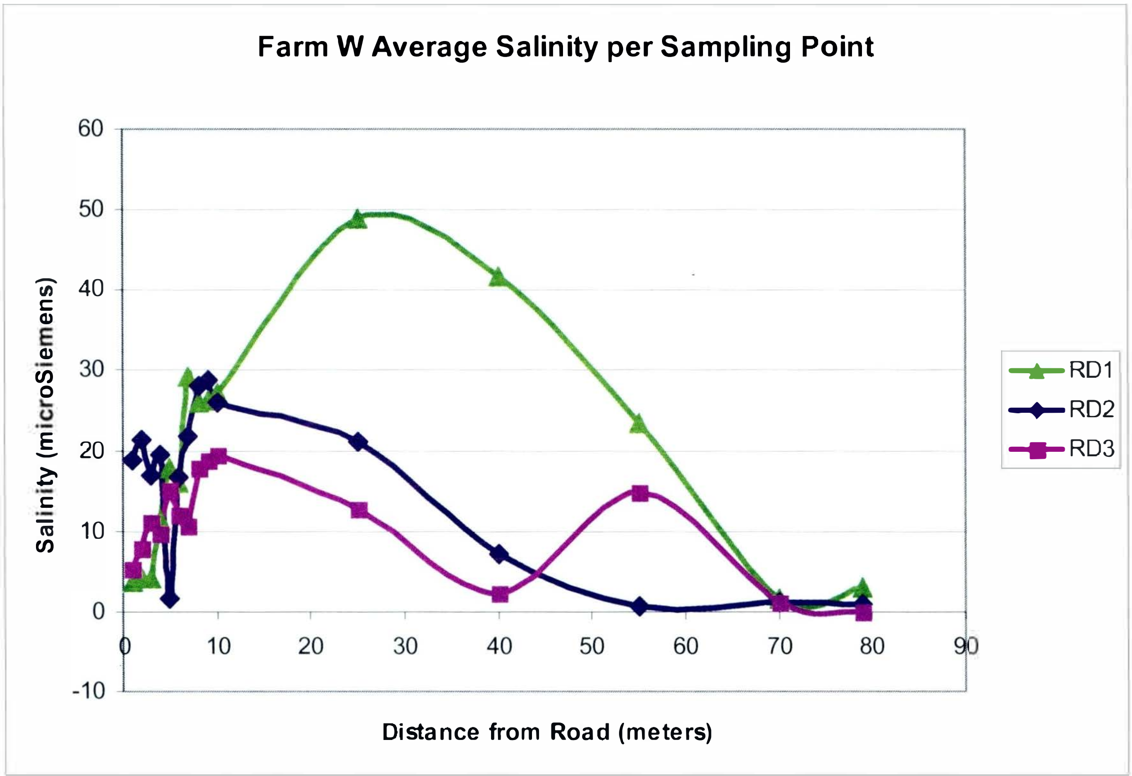


Figure 4.1d Farm W Average Salinity per Sampling Point

content but that was a result of the 35 transects instead of 10. The graph also indicates that, generally, the higher salinity concentrations are within the first 10 meters from the road. This is due to the precipitation and snow melting on the road that washes salt more quickly from the road to the upper layer of soil that is immediately adjacent to the road. Round 2 and 3 follow the same general trends, with round 2 salinity being higher, except for the anomaly at 55 meters (sampling point 13). Sampling point 13 had a higher moisture content during round 3 than in round 2 because water did not drain as quickly from the soil in that area on the farm during round 3.

Table 4.1d Farm W LSD analysis of sampling points, all rounds.

	F	Sig.
Sampling Point 1	29.331	0.000
Sampling Point 2	18.866	0.000
Sampling Point 3	20.300	0.000
Sampling Point 4	1.136	0.329
Sampling Point 5	2.622	0.082
Sampling Point 6	0.263	0.770
Sampling Point 7	5.857	0.005
Sampling Point 8	1.338	0.271
Sampling Point 9	1.089	0.344
Sampling Point 10	1.363	0.265
Sampling Point 11	36.061	0.000
Sampling Point 12	63.518	0.000
Sampling Point 13	2.945	0.061
Sampling Point 14	0.039	0.961
Sampling Point 15	0.620	0.526

4.2 Farm X

Round 1 data were not analyzed due to instrument malfunction. Figure 4.2a shows the distribution of the salinity for round 2 for this farm. It is clear that the majority of the salinity is near the road presumably from the salt application spray from traffic, surface water runoff and salt-treated snow melt. Farm X experiences higher traffic than Farm W, therefore Farm X has more salinity within the first 10 meters from the road. Figure 4.2b shows the salinity distribution for round 3 and again higher salinity values are clearly closest to the road.

Table 4.2a displays basic information for rounds 2 and 3. Table 4.2b shows the Independent T-test results indicating significant differences between Farm X's 2nd and 3rd round of sampling. Table 4.2b reports a statistical difference between the two rounds of 0.000 on the 95% confidence interval (Sig. 2-tailed in table). Since the statistical significance is lower than 0.05, this test proves the salinity in the soil was higher during the winter than after the winter. As before, it is assumed that these findings are because of the road salt applications. Therefore, my hypothesis that salt levels in the blueberry fields are higher in winter when road salt is applied was accepted.

Table 4.2c provides further test results including sampling point (SP) descriptive statistics for the mean transect salinity sums, the F-statistic and most importantly, the level of significance for the test. Every sampling point included in the analysis was significantly different except for points 4 and 9. Sample points 4 and 9 are located within 10 meters from the road and did not show any variation between the 2nd and 3rd rounds. The sampling points, which are parallel to the road, have significant differences in salinity. This finding means that my hypothesis that points closest to the road will have

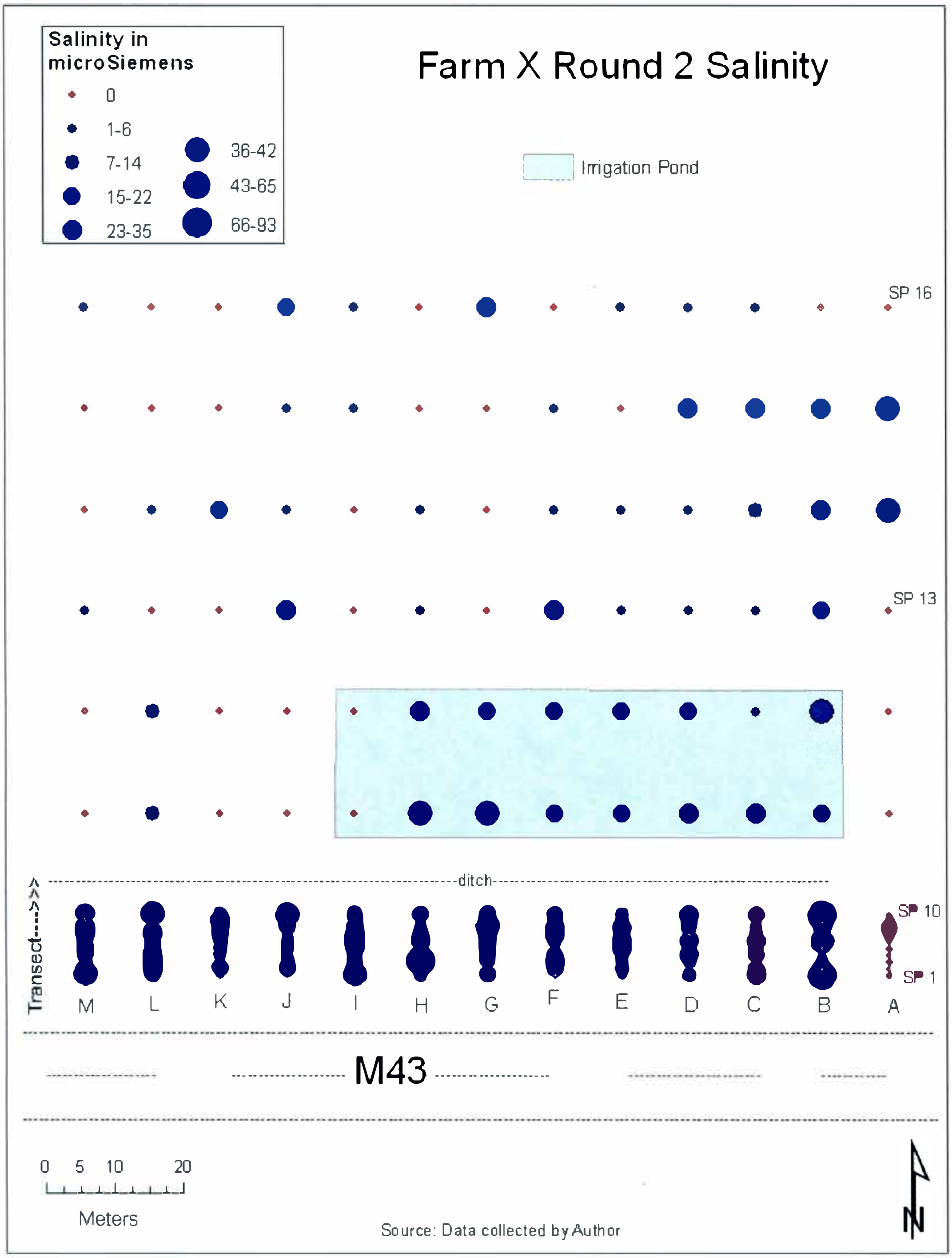


Figure 4.2a Farm X Round 2 Salinity

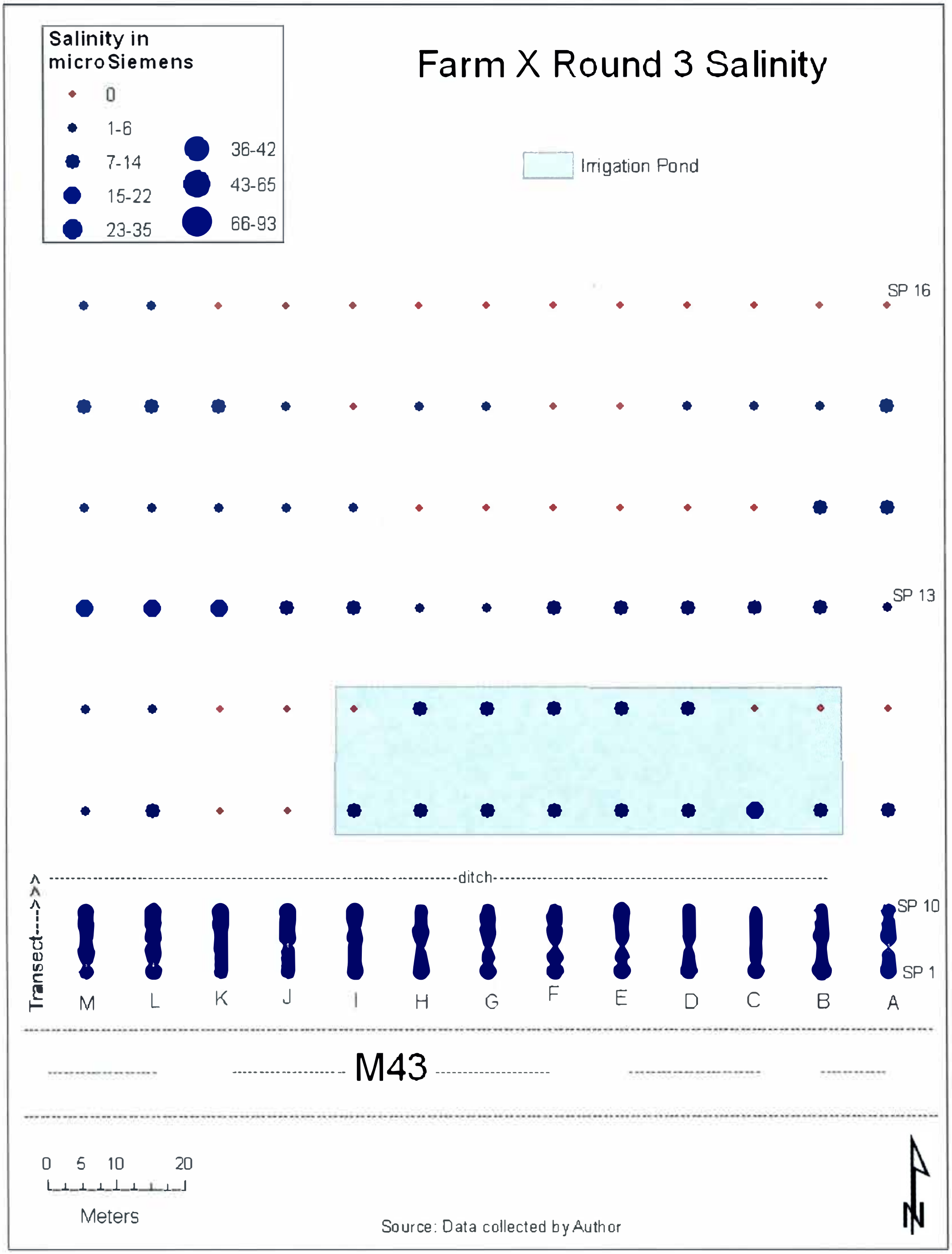


Figure 4.2b Farm X Round 3 Salinity

Table 4.2a T-test descriptives for Farm X.

	Round	N	Mean	Std. Deviation	Std. Error Mean
SUMSAL	2	13	231.62	77.302	21.440
	3	13	144.15	13.082	3.628

Table 4.2b T-test output significance for Farm X.

	Levenes's Test for Equality of Variances		
	F	Sig.	Sig. (2-tailed)
Equal variances assumed	6.160	0.020	0.000
Equal variances no assumed			0.002

more salinity in the soil is also accepted. Also see Figure 4.2c which is a graph comparing the average salinity per sampling point to the distance from the road. The graph shows that the higher salinity concentrations are within the first eleven sampling points, which is within 25 meters from the road. The salinity per sampling point in round 2 stayed consistently higher than in round 3. However, there was more salinity at sampling point 13 during round 3 than in round 2. Sampling Point 13 is located behind the pond and there was more moisture at that point during round 3 than in round 2, which is the result in a higher salinity value.

Table 4.2c T-test output significance between sampling points for Farm X.

	Round	Number of transects	Mean	F	Sig.	t	Sig. (2-tailed)
SP 1	2 3	13	20.62 17.31	10.110	0.004	0.470	0.643 0.647
SP 2	2 3	13	11.92 6.46	8.237	0.008	1.661	0.110 0.114
SP 3	2 3	13	19.31 11.46	8.542	0.007	1.288	0.210 0.222
SP 4	2 3	13	12.31 7.69	2.648	0.117	1.338	0.193 0.197
SP 5	2 3	13	14.31 3.85	6.896	0.015	2.900	0.008 0.011
SP 6	2 3	13	22.08 13.31	27.335	0.000	2.808	0.010 0.014
SP 7	2 3	13	18.62 12.46	15.808	0.001	1.735	0.096 0.105
SP 8	2 3	13	22.08 12.85	22.278	0.000	3.361	0.003 0.005
SP 9	2 3	13	3.08 11.54	0.280	0.602	-3.400	0.002 0.003
SP 10	2 3	13	27.00 14.54	4.747	0.039	1.928	0.066 0.075
SP 11	2 3	13	16.54 9.92	13.424	0.001	1.378	0.181 0.188
SP 12	2 3	13	12.08 5.00	14.691	0.001	1.876	0.073 0.079
SP 13	2 3	13	7.23 10.38	7.314	0.012	-0.848	0.405 0.409
SP 14	2 3	13	8.38 2.46	11.500	0.002	1.592	0.124 0.134
SP 15	2 3	13	11.23 4.62	28.301	0.000	1.435	0.164 0.173
SP 16	2 3	13	4.85 0.31	9.675	0.005	1.684	0.105 0.118

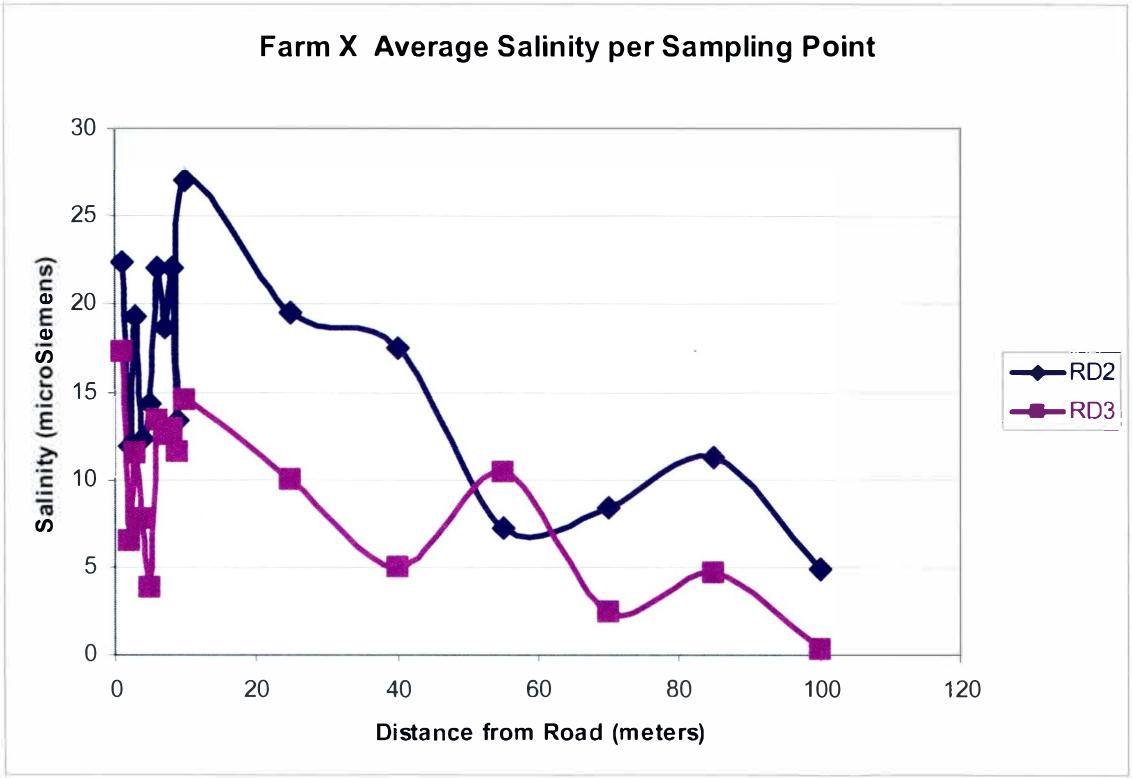


Figure 4.2c Farm X Average Salinity per Sampling Point

4.3 Farm Z

The salinity in round 2, shown in Figure 4.3a, is very exclusive to the sampling points closest to the road. There is practically no salinity detected beyond 10 meters. This same pattern was found for round 3 as well, shown in Figure 4.3b. The only difference between the two maps is that in round 2 (winter) the salinity concentrations are higher for many of the points.

The tables that follow are the results from the Independent T-tests that test for the presence of statistically significant differences between the salinity concentrations across the transects between the 2nd and 3rd rounds. Table 4.3a indicates the mean salinity transect sum was higher in round 2 (winter, March 2006) than it was in round 3 (after winter, May 2006) which indicates that road salt did increase the salinity content in the

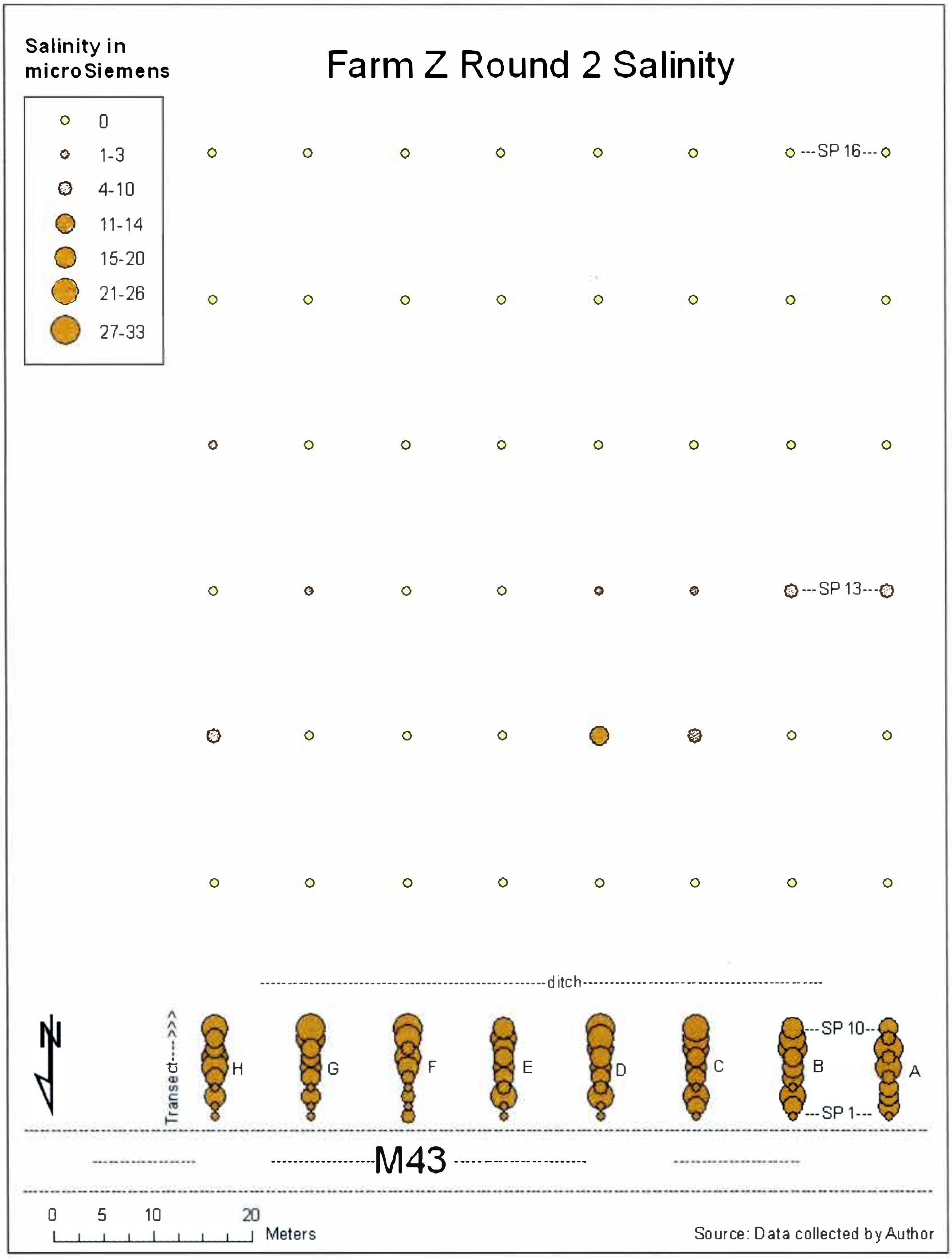


Figure 4.3a Farm Z Round 2 Salinity

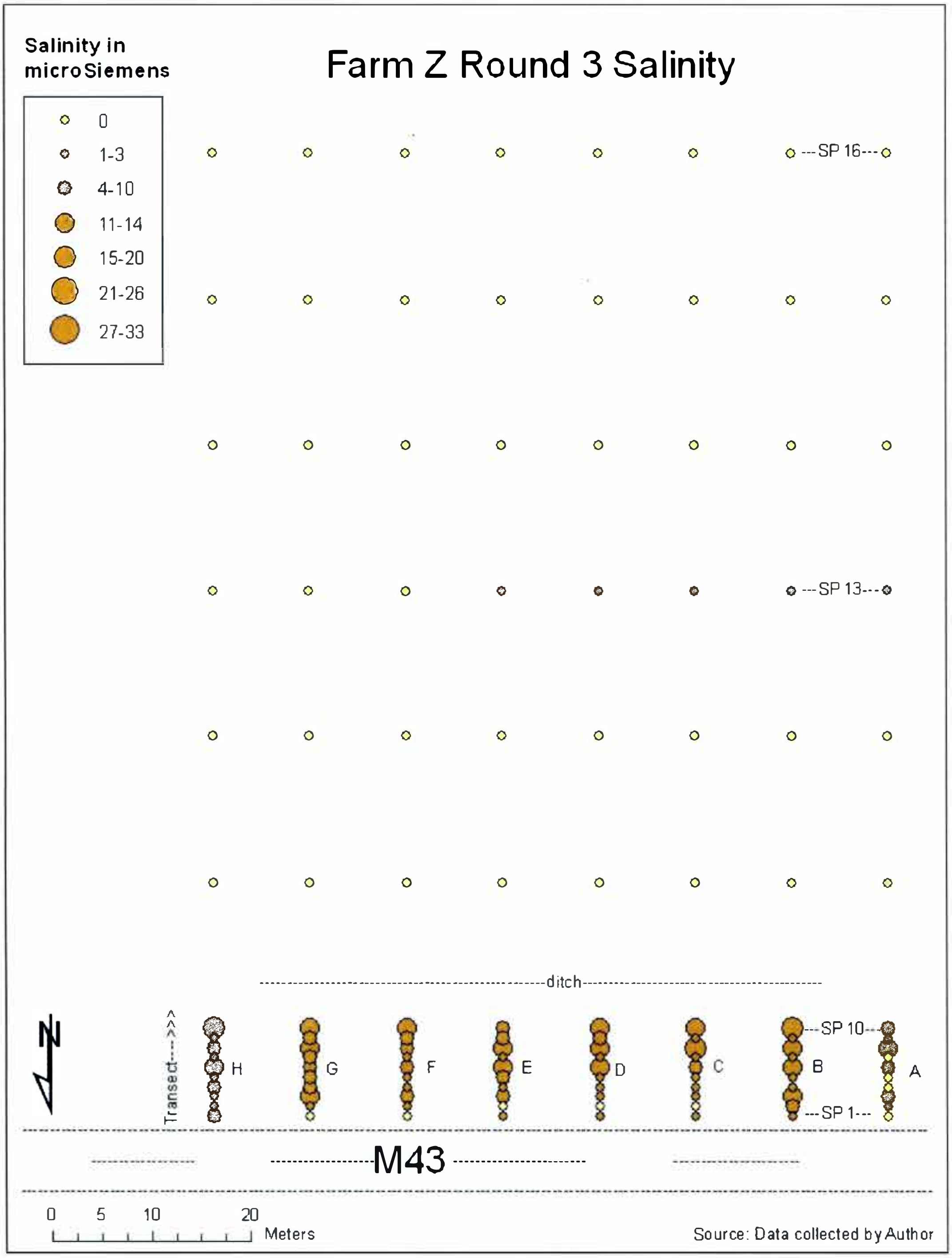


Figure 4.3b Farm Z Round 3 Salinity

soil during the winter season. Again this supports the hypothesis. Table 4.3b shows the results of the t-test, indicating a significant difference of 0.000 (Sig. 2-tailed in table) on the 95% confidence interval.

Table 4.3c displays the locations of the most significant differences between sampling points for the 2nd and 3rd rounds. Sample points 2, 7, 8, and 12 are the only points with significant differences. This means that the salinity concentrations changed throughout the rounds for only those four sampling points. This result may well be due to the topography near these particular sampling points, which are on a downslope nearing a ditch. Sample points 2, 7, and 8 are within the first 10 meters of the road frontage and should be expected to exhibit the greatest differences between the two sampling rounds. Sample point 12 had a lot of gravel indicating good drainage properties and the inability to hold salt content; therefore it makes sense that sample point 12 recorded significant differences in salinity between the two rounds.

Figure 4.3c is a graph comparing the average salinity content to the distance from the road. The graph shows that higher salinity concentrations are within the sampling points that are 25 meters from the road or closer.

Table 4.3a T-test descriptives for Farm Z.

	Round	N	Mean	Std. Deviation	Std. Error Mean
SUMSAL	2	8	194.988	15.9859	5.6519
	3	8	60.125	8.6592	3.0615

Table 4.3b T-test output significance for Farm Z.

	Levenes's Test for Equality of Variances		
	F	Sig.	Sig. (2-tailed)
Equal variances assumed	9.425	0.008	0.000
Equal variances no assumed			0.000

Table 4.3c T-test output significance between sampling points for Farm Z.

	Round	**Number of transects**	**Mean**	**F**	**Sig.**	**t**	**Sig. (2-tailed)**
SP 1	2	8	2.63	1.064	0.320	1.155	0.267
	3		1.25				0.276
SP 2	2	8	5.75	26.926	0.000	1.882	0.081
	3		1.50				0.097
SP 3	2	8	18.38	3.472	0.084	3.744	0.002
	3		7.63				0.003
SP 4	2	8	51.613	3.8831	0.071	41.263	0.000
	3		2.875				0.000
SP 5	2	8	11.88	.000	1.000	9.836	0.000
	3		2.50				0.000
SP 6	2	8	17.75	1.316	0.271	7.555	0.000
	3		10.88				0.000
SP 7	2	8	15.25	9.432	0.008	7.354	0.000
	3		2.25				0.000
SP 8	2	8	20.63	13.281	0.003	2.946	0.011
	3		12.00				0.019
SP 9	2	8	21.50	2.366	0.146	5.356	0.000
	3		5.25				0.000
SP 10	2	8	23.25	4.445	0.054	4.510	0.000
	3		12.88				0.002
SP 11	2	8	.00				
	3		.00				
SP 12	2	8	3.50	23.886	0.000	1.861	0.084
	3		.00				0.105
SP 13	2	8	2.88	3.200	0.095	1.820	0.090
	3		1.13				0.102
SP 14	2	8	.00				
	3		.00				
SP 15	2	8	.00				
	3		.00				
SP 16	2	8	.00				
	3		.00				

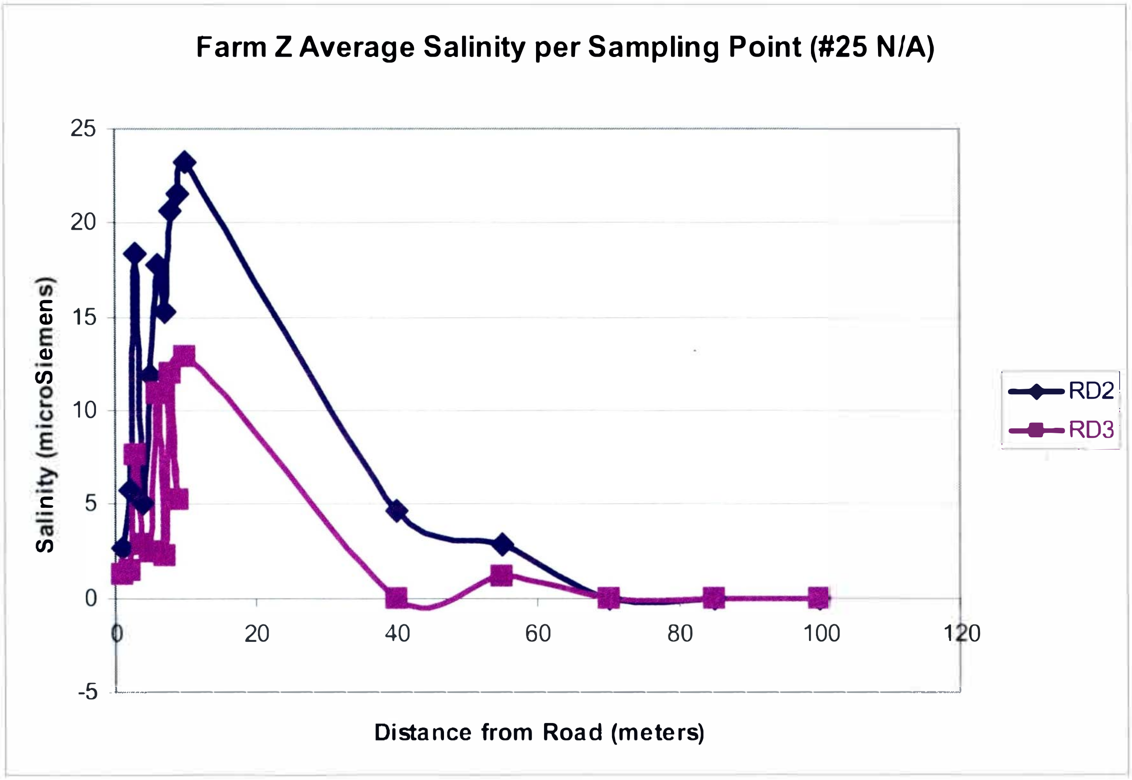


Figure 4.3c Farm Z Average Salinity per Sampling Point (#25N/A)

4.4 Farm Y

Transect N was pure gravel past the first 10 sampling points because a barn lies east of transect N. Figure 4.4a shows the salinity distribution across sampling points for round 2. It is evident that the majority of higher salinity points are near the road and around the irrigation pond. Again, this may well be due to the road salt applications during the winter season that helps lower the melting point of water to reduce the chance for ice formation on the road. Nonetheless, results of the sampling indicate the salinity is clearly higher near the road, regardless of the reason. It is also higher around the pond because the salt is able to dissolve better in the wetter soils and as a consequence the instrument can detect it more accurately.

Prior to the samples taken during round 3 (after winter, May 2006), the irrigation pond was drained and filled in with soil. Figure 4.4b shows the salinity distribution for this farm and once again, values are clearly higher near the road. The topography of hard sand on the west side of the field and very dark, moist sand near the area where the pond was located suggests poor drainage properties. The hard ground was consistent between the rounds and the soggy areas appeared to have been that way for some time.

Table 4.4a indicates the mean transect salinity sum for round 2 was higher than for round 3. Table 4.4b reports the 2-tailed significance of the independent t-tests, which shows a 0.003 on the 95% confidence interval. The hypothesis was accepted for this farm. The probable cause for the significant differences in the salinity between the two rounds is the alteration of the study site due to changes made by the new owners. The soil between the road and the blueberry plants was moved around after winter which may have disrupted the actual distribution of salt throughout the field.

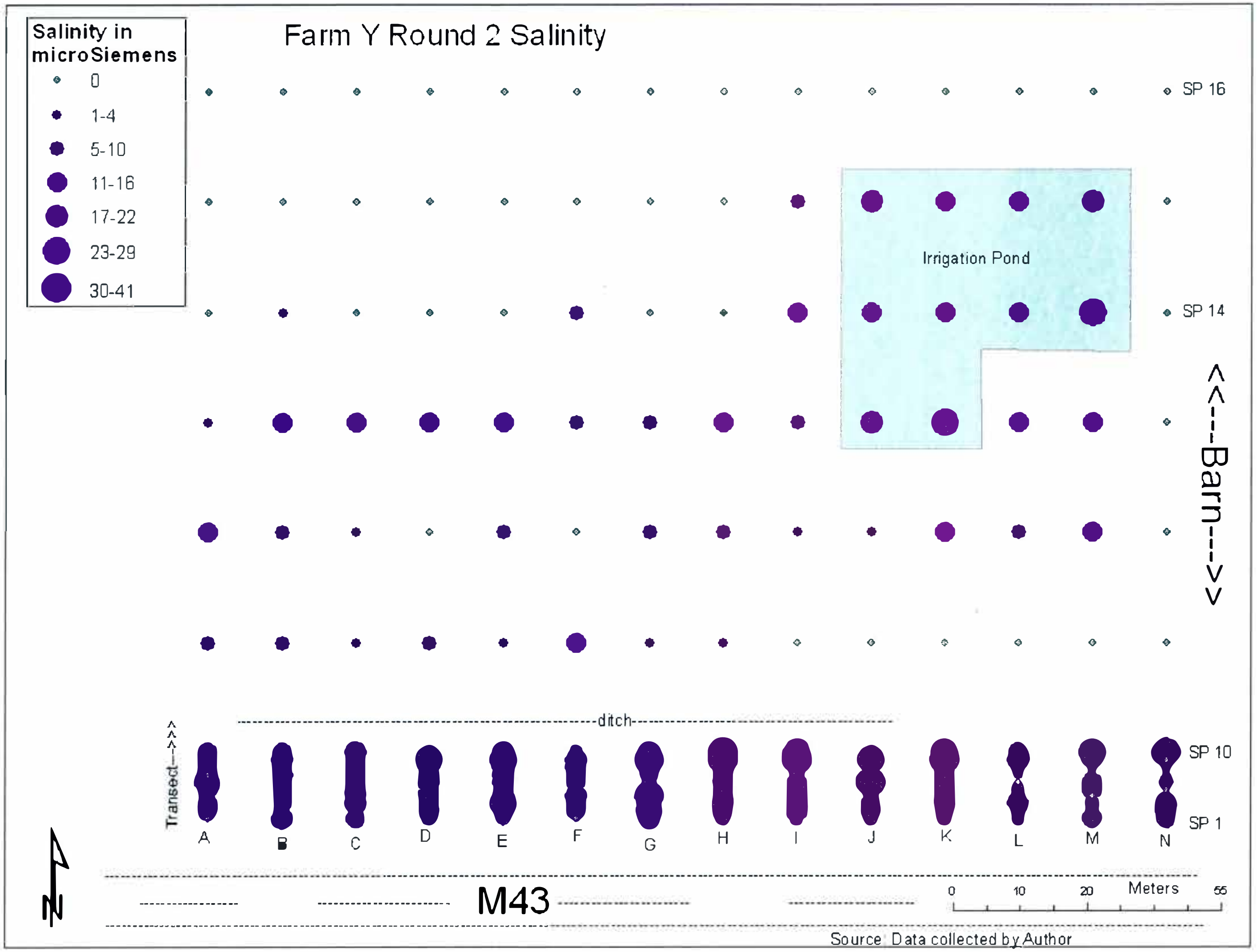


Figure 4.4a Farm Y Round 2 Salinity

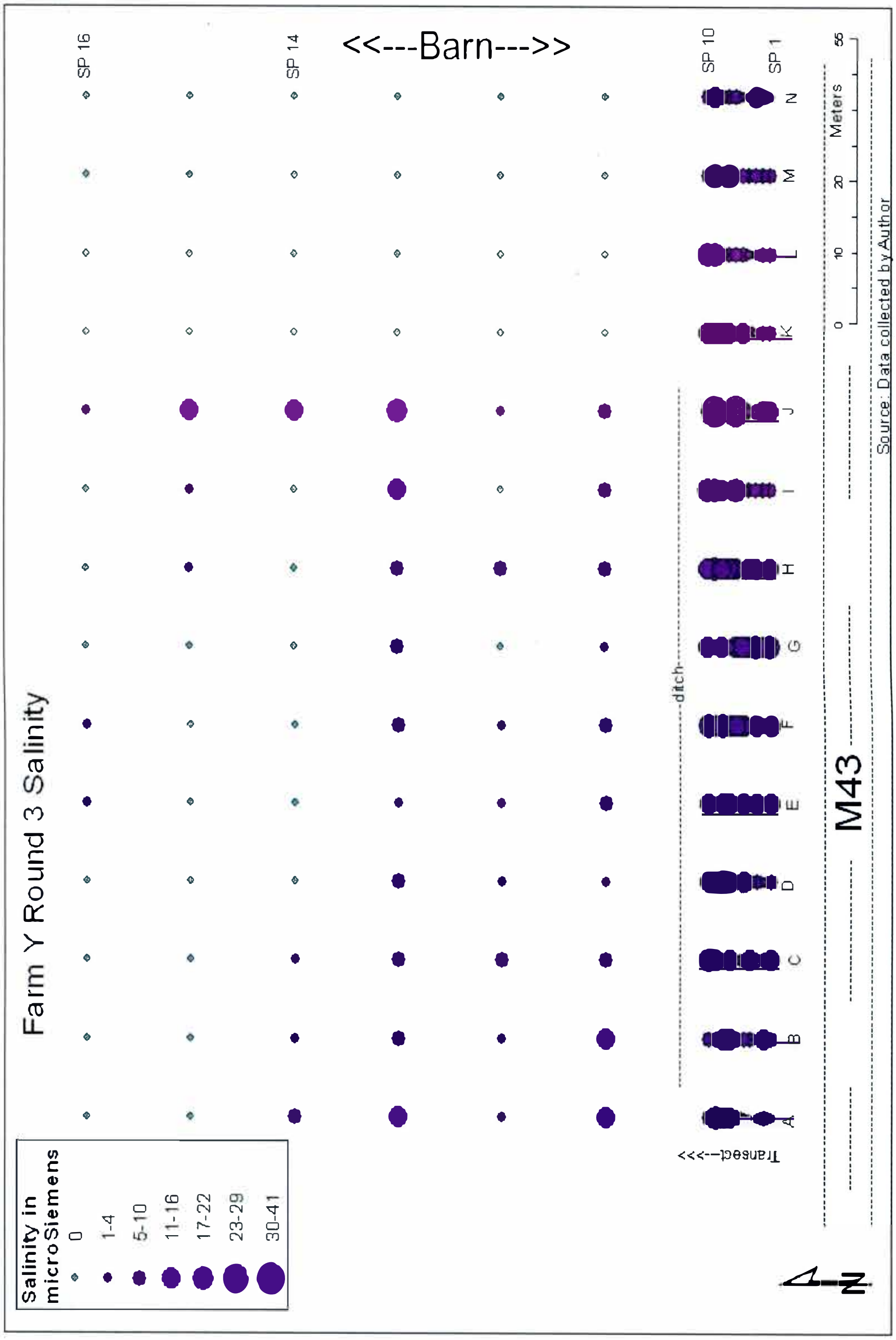


Figure 4.4b Farm Y Round 3 Salinity

Table 4.4a T-test descriptives for Farm Y.

	Round	N	Mean	Std. Deviation	Std. Error Mean
SUMSAL	2	14	174.21	35.107	9.383
	3	14	129.57	36.259	9.691

Table 4.4b T-test output significance for Farm Y.

	Levenes's Test for Equality of Variances		
	F	Sig.	Sig. (2-tailed)
Equal variances assumed	0.146	0.706	0.003
Equal variances no assumed			0.003

Table 4.4c displays the significance between the sampling points. Sample points 2, 4, 7, 10 and 14-16 had significant differences between the two rounds. This is due to the changing of the salinity concentrations during and after winter. Sample points 14-16 had very low salinity concentrations for both rounds which is expected since these points are sited at a distance of 70 meters or more from the road, and do not appear to be affected by the salt applications during the winter. Figure 4.4c is a graph comparing the salinity concentrations to the distance from the road for Farm Y. Again, it shows that the higher salinity concentrations are within 25 meters from the road. The graph also shows that round 2 salinity was higher than round 3 and had the same general trend, except for the anomaly of sample point #11, which was 25 meters from the road. At this point, round 3 salinity was higher than round 2 for reasons unknown.

Table 4.4c T-test output significance between sampling points for Farm Y.

	Round	Number of transects	Mean	F	Sig.	t	Sig. (2-tailed)
SP 1	2 3	14	9.71 9.64	0.604	0.444	.036	0.972 0.972
SP 2	2 3	14	14.21 9.14	5.259	0.030	3.169	0.004 0.004
SP 3	2 3	14	15.93 8.07	0.151	0.701	4.184	0.000 0.000
SP 4	2 3	14	13.50 7.71	6.010	0.021	2.109	0.045 0.049
SP 5	2 3	14	10.71 8.79	1.592	0.218	1.125	0.271 0.273
SP 6	2 3	14	14.71 11.79	0.182	0.673	1.029	0.313 0.313
SP 7	2 3	14	10.43 12.21	9.832	0.004	-.934	0.359 0.364
SP 8	2 3	14	10.64 12.64	1.041	0.317	-.996	0.329 0.329
SP 9	2 3	14	23.29 16.43	1.867	0.184	2.008	0.055 0.057
SP 10	2 3	14	19.57 14.00	4.490	0.044	2.227	0.035 0.037
SP 11	2 3	14	2.86 5.93	1.753	0.197	-1.785	0.086 0.086
SP 12	2 3	14	5.43 2.43	2.395	0.134	1.941	0.063 0.064
SP 13	2 3	14	11.36 7.43	.233	0.633	1.532	0.138 0.138
SP 14	2 3	14	6.43 1.86	13.679	0.001	1.899	0.069 0.073
SP 15	2 3	14	5.43 1.21	18.371	0.000	1.809	0.082 0.088
SP 16	2 3	14	.00 .29	18.029	0.000	-1.749	0.092 0.104

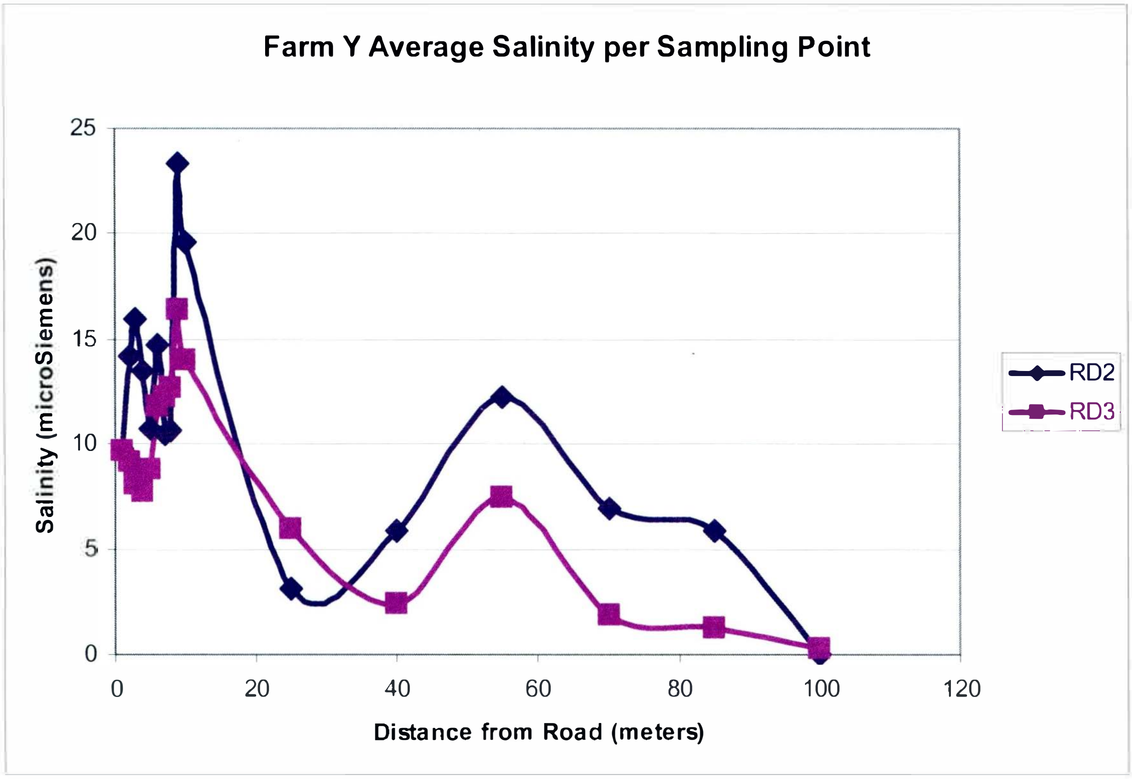


Figure 4.4c Farm Y Average Salinity per Sampling Point

4.5 Comparison of all Farms

4.5.1 Round 1

Again, after the first farm was almost completely sampled, the sampling instrument broke. Farm W was the only farm in which round 1 data were collected and thus a farm by farm comparison cannot be completed for the before winter season.

4.5.2 Round 2

In round 2 (winter), samples collected at Farm X and Farm W had the highest salinity concentrations of 231.62 µS and 230.10 µS. Farm Y recorded the least amount of salt at 174.21 µS. All in all, samples taken during round 2 recorded the most salinity on all 4 farms compared to all 3 rounds (Table 4.5a). Results of ANOVA analysis showed statistically significant differences of 0.012 at the 95% confidence interval.

Table 4.5a Mean salinity for each farm for rounds 2 and 3.

Farms	Number of Transects	Mean Salinity for Round 2 (µS)	Mean Salinity for Round 3 (µS)
Y	14	174.21	129.57
X	13	231.62	144.15
Z	8	194.99	60.13
W	10	230.10	159.10

Table 4.5b ANOVA output significance for round 2.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29415.694	3	9805.231	4.139	.012
Within Groups	97123.183	41	2368.858		
Total	126538.876	44			

These results are reported in Table 4.5b. The post-hoc Fisher's LSD test indicated that the only statistically significant differences were between Farm Y and Farm X, and between Farm Y and Farm W (Table 4.5c). The differences between the samples taken a Farm Y and Farm X may be a result from the topography of the fields. Farm X is a lot flatter and no renovation has occurred on this field. The differences between Farm Y and Farm W come from their different locations, and again, possibly some of these differences may also be due to renovations on Farm Y.

Table 4.5c Significant differences between the farms for round 2.

(I) FARM	(J) FARM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Farm Y	Farm X	-57.40(*)	18.746	.004	-95.26	-19.54
	Farm Z	-20.77	21.571	.341	-64.34	22.79
	Farm W	-55.89(*)	20.152	.008	-96.58	-15.19
Farm X	Farm Y	57.40(*)	18.746	.004	19.54	95.26
	Farm Z	36.63	21.871	.102	-7.54	80.80
	Farm W	1.52	20.472	.941	-39.83	42.86
Farm Z	Farm Y	20.77	21.571	.341	-22.79	64.34
	Farm X	-36.63	21.871	.102	-80.80	7.54
	Farm W	-35.11	23.087	.136	-81.74	11.51
Farm W	Farm Y	55.89(*)	20.152	.008	15.19	96.58
	Farm X	-1.52	20.472	.941	-42.86	39.83
	Farm Z	35.11	23.087	.136	-11.51	81.74

* The mean difference is significant at the 0.05 level.

4.5.3 Round 3

Table 4.5a shows that the samples taken at Farm W had the highest mean salinity of 159.10 µS for round 3 (after winter, May 2006). Samples taken on Farm X had a salinity transect sum of 144.15 µS, while Farm Y had a salinity transect sum of 129.57 µS and Farm Z had a salinity transect sum of 60.13 µS. ANOVA results indicate a 0.000 significant difference on all four farms for round 3 at the 95% confidence interval (Table 4.5d). Post-hoc Fisher's LSD tests indicated that Farm Z recorded significant differences with all the other farms due to it being the lowest salinity for round 3 (Table 4.5e). This is due to the landscape underneath the blueberry bushes. The soil profile of this farm includes much gravel which allows better drainage than that found on the other farms.

Table 4.5d ANOVA output significance for round 3.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	49955.104	3	16651.701	32.853	.000
Within Groups	20780.896	41	506.851		
Total	70736.000	44			

Table 4.5e Significant differences between the farms for round 3.

(I) FARM	(J) FARM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Farm Y	Farm X	-14.58	8.671	.100	-32.09	2.93
	Farm Z	69.45(*)	9.978	.000	49.30	89.60
	Farm W	-29.53(*)	9.321	.003	-48.35	-10.70
Farm X	Farm Y	14.58	8.671	.100	-2.93	32.09
	Farm Z	84.03(*)	10.117	.000	63.60	104.46
	Farm W	-14.95	9.470	.122	-34.07	4.18
Farm Z	Farm Y	-69.45(*)	9.978	.000	-89.60	-49.30
	Farm X	-84.03(*)	10.117	.000	-104.46	-63.60
	Farm W	-98.98(*)	10.679	.000	-120.54	-77.41
Farm W	Farm Y	29.53(*)	9.321	.003	10.70	48.35
	Farm X	14.95	9.470	.122	-4.18	34.07
	Farm Z	98.98(*)	10.679	.000	77.41	120.54

* The mean difference is significant at the 0.05 level.

The four study farms located in Van Buren County that were used in this research measured different salinity concentrations through the seasons. That alone suggests that there is a contributing factor that allows salt content to fluctuate over time. Road salt application during the winter season is the main contributing factor. The hypothesis that salinity concentrations in the soil would be higher during the winter season was accepted for all four farms. On these farms, the salinity concentrations changed significantly with samples taken during the winter having the highest concentrations. This research provides important information to county officials and road commissions for implementing alternative road deicers for environmentally sensitive areas. More implications of the research will be discussed in the next chapter.

5.0 CONCLUSIONS

5.1 Summary

This study compares salinity concentrations in soils on four blueberry farm before, during and after the winter season of 2005-2006 in Van Buren County, Michigan. Specifically, the hypothesis of this study was that the salinity concentrations found in soils on blueberry farms would increase during the winter season within the farm fields due to the use of salt for snow management on the roads. I also hypothesized that the greatest concentrations of salt in the fields would be closer to the road. This hypothesis was found to be valid (accepted) for all four farms because higher salinity concentrations were found within close distances from the road, but not necessarily on the road edge. All four of the study farms had statistically significant differences between the rounds and showed higher salinity concentrations for round 2.

Analysis of Variance (ANOVA) and Independent t-tests were the most appropriate and useful statistical tests for comparing the salinity concentrations on all farms for all rounds. Results from these tests indicate that the salinity concentrations were different within the farm between the sampling rounds and indicated which rounds specifically had significant differences. The distribution maps made in ESRI ArcMap® (9.0) (ESRI, 2006) showed the salinity concentrations were highest for those samples taken closer to the road. Therefore it can reasonably be assumed that the salinity in the soil is due to the use of road salt during the winter months in the county.

5.2 Future Research Opportunities

This research demonstrated that salt concentrations in the soil of fields of the blueberry farms used in this study did in fact significantly increase in all four locations during the winter season. Previous research cited in this study has indicated that higher salt concentrations undoubtedly will lower yields because the salt is harmful to the effective growth of blueberry bushes. Future research should focus on the identification of the actual thresholds of salt concentration that will have a direct impact on yields. That is, how much salt in the soil will actually affect the plant growth? Additional studies are needed to determine how counties can avoid excessive road salt applications and/or mitigate the way salt is applied in areas of concern so as to minimize the impacts of salt on farmer's yields and incomes. Alternatively, if no changes are made by the County Road Commission, then it seems that a compensation program of some form is in order.

If this study was to be conducted at a later date, a few aspects of the project design should be changed. First, it would be helpful to extract soil samples from the ground and get them professionally analyzed in a laboratory for sodium and chloride concentrations. This would provide a more accurate way of detecting higher concentrations (if any) of road salt in soils on blueberry farms. While laboratory analysis is expensive, it would greatly enhance the interpretation of the results of the study. Second, it would be beneficial to analyze the salinity at different soil depths and determine at what depth the most salinity accumulates. Thirdly, sampling farms with blueberry bushes even closer to the road than those participating in this study may provide a good contrast to this study. Results indicate that salinity in the soil is indeed higher near the road but for the fields sampled in this study, the closest blueberry bushes on these farms were located a minimum of 18 meters (Farm W) from the road. This distance includes a ditch located 10 meters from the road. Because of the ditch, the salinity runoff is more likely to be concentrated there and not reach the actual plants to interrupt growth. The ditch and the greater distance both act as significant barriers to the salt leaching into the soil directly below the blueberry plants and therefore may not hinder plant growth and production at all. Therefore, a ditch along the road frontage of blueberry farms is recommended to help alleviate salt leaching into the soil near the bushes. Of course, many blueberry farms in western Michigan do not have ditches, and these farms logically will be even more at risk than those included in the study.

This study answered the questions related to increases in salinity in blueberry fields due to the use of road salt by the County Road Commission during the winter months. However, it also raises additional questions and provides future research possibilities. Analyzing sodium chloride in blueberry farm soil improves the efficiency of the growth management cycle because it identifies a condition that might impair the plants' growth and potentially decrease production and returns to investment. This research also indicates that county officials who should be concerned with the sand/salt ratio applied to roads during the winter season because road salt does have an impact on roadside vegetation and soils. Based on the literature reviewed during the course of the project, it was found that enough salt spray can leach into the soil which can inhibit the nutrients uptake, limiting effective growth. Severe cases of salt exposure can dehydrate the bush, preventing buds to bloom thus significantly reducing yields. It was also found that toxic levels of salt spray, along with other factors, can lead to decreased blueberry yields, as in the Ottawa County case. Decreased yields due to factors beyond their control, is a condition farmers should indeed resent.

Blueberries are gaining popularity with the benefits they provide to human health. Therefore, blueberry farmers will try to grow and sell as many blueberries as they can. Road salt can interrupt effective growth for these blueberries so it is vital that certain steps be taken to mitigate the influence of road salt on the crop. Possible solutions include, decreasing the amount of salt applied to the roads during the winter, and/or changing snow management tactics where sensitive plants, i.e. blueberry, are located.

BIBLIOGRAPHY

Anttila, B. Van Buren County Highway Engineer Personal Contact 2006, March 21 and 22.

Armstrong, K.J. "The Secret Ingredient: How Soil, Climate and Hard Work helped to produce the World's Finest Fruit." *Michigan History Magazine,* 90, no.3 (2006):6-12.

Berkheimer, S.F. "Deicing Salt Injury to Highbush Blueberry (*Vaccinium corymbosum L.)* in West Michigan." Master Thesis, Michigan State University 2004.

Bryson, G.M. & Barker, A.V. " Sodium Accumulation in Soils and Plants along Massachusetts Roadside." *Communications in Soil Science and Plant Analysis* 33, nos.1&2, (2002): 67-78.

Chiras, D.D. *Environmental Science: Creating a Sustainable Future 6th ed.* Jones and Bartlett Publishers, Inc. Massachusetts, 2001.

D'Itri, F.M. *Chemical Deicers and the Environment.* Lewis Publishers, Inc. Michigan, 1992.

Environmental Systems Research Institute [ESRI] ArcMap Version 9.0 Redlands, CA 2006.

Gentry, K. Blueberry Production and Consumption Continue to Increase. (2001, May) *The Fruit Growers News.*

Gulzar, S., Khan, M.A. & Ungar, I.A. "Effects of Salinity on Growth, Ionic Content, and Plant-Water Status of *Aeluropus Iagopoides.*" *Communications in Soil Science and Plant Analysis* 34, nos.11&12, (2003): 1657-1668.

Hanson, E.J. & Hancock, J.F. "Hints on Growing Blueberries." Michigan State University Extension, 1998.

Lundmark, A. " Modeling the Impacts of Deicing Salt on Soil Water in a Roadside Environment." Swedish Road Administration through the Centre for Research and Education in Operation and Maintenance of Infrastructure, 2005.

Michigan State University Extension, Blueberry Production in Michigan 2000. Van Buren County Horticulture [Online] Available: http://www.canr.msu.edu/vanburen.fbbprod.htm [2006, July 9].

Moroney, K. Farmers suing over berry damage. *The Holland Sentinel* [Online] Available: http://www.hollandsentinel.com/cgi-bin/printme.pl [2005a, January 21].

Moroney, K. Farmers sue county over road salt use. *The Grand Haven Tribune* [Online] Available: http://www.grandhaventribune.com.paid/287324384558585.bsp [2005b, January 21].

National Agriculture Statistic Service [NASS] Michigan Fruit Inventory 2000-2001 [Online]
Available: http://www.nass.usda.gov/mi/mi_fruit01/blueberries.pdf [2006, July3].

Ottawa County "Recommendations for Salt Management" Ottawa County Planning Report August 2004.

Shi, X. "The Use of Road Salts for Highway Winter Maintenance: An Asset Management Perspective." ITE District 6 Annual Meeting, Kalispell, MT, 2005.

Talicska, M.L. "Effects of roadside salt on nearby soils in NW Lower Michigan." Master Thesis, Michigan State University,1999.

U.S. Department of Agriculture. Soil Survey of Van Buren County, Michigan. Soil Conservation Service 1983.

U.S. Highbush Blueberry Council [Online] Available: http://www.blueberry.org/ [2006].

Wegner, W. & Yaggi, M. "Environmental Impacts of Road Salt and Alternatives in the New York City Watershed." *The Journal for Surface Water Quality Professionals: Stormwater* 2001 [Online] Available: http://www.forester.net/sw_0107_environmental.html [2005, March 14].