Recognizing Patterns Within Cropland Vegetation: A Crop Anomaly Classification System

Paul G. Carter¹, Christian J. Johannsen² & Bernard A. Engel³

¹Assistant Professor, Washington State University Extension, Columbia County; ²Department of Agronomy, Purdue University; ³Agricultural and Biological Engineering, Purdue University

ABSTRACT

The framework for a national classification system for agricultural cropland anomalies utilizing remote sensing information is presented. Cropland anomalies in Midwest USA have been identified in field crops of corn (Zea mays), soybeans (Glycine max), wheat (Triticum), and miscellaneous hay crops such as alfalfa (Medicago sativa). By identifying cropland anomalies through ground observations and describing the characteristics associated with them, it is possible to group them according to common casual properties such as water, nutrition, weeds, insects, disease, and management, leading to the development of a Cropland Anomaly Classification System. This system advances understanding of specific anomalies and provides an environment for standardization of anomaly characteristics while allowing the possibility for producers and managers to make sound economic decisions. The introductions of new technologies in remote sensing such as increased spatial, spectral, and temporal resolution will cause continual development and improvement of the proposed Anomaly Classification System.

Keywords: classification systems, crops, anomalies
INTRODUCTION

“Man has a passion for classifying everything. There is reason for this; the world is so complex that we could not understand it all unless we classified like things together.”
Soils and Men, Yearbook of Agriculture, 1938.

Agriculture in the past decade has felt the urgency to make major adjustments for new technology, scientific advancements, and economies of scale, feeling that no previous generation has been dealt this opportunity or scourge. As information is available at our fingertips, we are overcome with news from around the world, happening before our eyes as we go about daily tasks.

Upon studying some of the thoughts of a century before us, we discover that today’s farmer feels the same pressure to adjust as their ancestors before them. More than a century ago, F.H. King (1895) penned these thoughts, “The business of farming has now become so complex, the sciences to which it must look for direction are so numerous, and the needs of the world for great quantities of materials for cheap and wholesome food and clothing are growing so rapidly more urgent, that the farmer of Nineteen Hundred must rise upon a plane of better directed efforts and more economic methods. He can no longer do as most of us say the squirrel did, plant without thought of adaptation or fitness, but simply as and because his father, grandfather, and great-grandfather did.” Having recently entered the 21st Century, we hear farmers say the same words and feel the same urgency that those pioneers of that time surely must also have felt. Obviously we are not the first to walk this way for every generation before us has experienced the same excitement and pain. We must learn from this and not pass along only mere facts. As information is transferred, we must teach farmers to observe, interpret, and correlate the accumulation of data, which each year come from their experiences of planting, nurturing, and harvesting.

In many ways the challenges we face are similar to those of previous generations and centuries. However, we face the new century with new tools and more information about our resources not available to any previous generation. Producers of raw agricultural commodities are collecting vast amounts of high-resolution spatial, spectral, and temporal information with the intent to more efficiently manage production resources. The incomprehensible magnitude of the continuous accumulation of this data about the earth’s system, of which plants and soils are vital components, demands more innovative and usable classification systems of these resources. Many of these resources are in limited or dwindling supply, therefore, requiring more production from the same unit.

OBJECTIVES

The general objective of this study was to develop a classification system for cropland vegetation anomalies that will assist remote sensing investigators and their clients by providing a set of standardized descriptions for characterizing crop anomalies presented in an orderly framework that will enhance causal understanding. To accomplish this objective more specific objectives are defined:

1. Develop a framework for a crop anomaly classification system that will allow for the orderly listing of crop and soil anomalies that will serve as a basic framework to be adapted to any geographic area where crops are grown.

2. Develop and describe a more extensive list of cropland anomalies that are found within agricultural field vegetation for the U.S. Corn Belt focusing on corn, soybeans, wheat, and hay crops to demonstrate the utility of a crop anomaly classification system.

3. Categorize each crop anomaly into the designed classification framework to verify that the anomaly classification system is adequate for grouping anomalies.

4. Provide detailed descriptions and characteristics of each crop anomaly listed under objective two.

WHY DO WE DEVELOP CLASSIFICATION SYSTEMS

Cline (1949) stated, “The purpose of any classification is so to organize our knowledge that the properties of objects may be remembered and their relationships may be understood most easily for a specific objective. The process involves formation of classes by grouping the objects on the basis of their common properties. In any system of classification, groups about which the greatest number, most precise, and most important statements can be made for the objectives serve the purpose best. As the things important for one objective are seldom important
for another, a single system will rarely serve two objectives equally well.”

From this statement three conclusions can be drawn. One, classifications are for the organization of knowledge at a given moment in time. We can be certain in today’s multiplication of knowledge that change to the classification system will be required as new knowledge is gained. Two, a classification system is developed to accomplish an objective or goal, which affects how the classification is designed. Three, a classification system requires the grouping of objects according to common properties determined to be important. “Classifications are orderly abstracts of knowledge and of concepts derived from knowledge both of which are legacies from experience of the past” (Cline 1963). “Classification is the mirror, in which the present condition of science is reflected; a series of classifications reflects the phases of its development” (Soil Survey Staff, 1975).

**IMPORTANT CLASSIFICATION SYSTEMS IN USE**

It is necessary that one understand the importance of previous classification systems and how they affect everyday decisions. Many classification systems have been incorporated into agriculture, and they assist with understanding the environment and resources around us as more knowledge is acquired from new and continuous studies. An important classification system used for the design of the proposed anomaly classification system is “The Land Use and Land Cover Classification System for Use with Remote Sensor Data” developed by Anderson et al. (1976). This was the first classification system designed specifically for use with remote sensing data.

**LAND USE AND LAND COVER CLASSIFICATION SYSTEM**

For many years, agencies at the various governmental levels have been collecting data about land, but for the most part they have worked independently and without coordination. Too often this has meant duplication of effort, or it has been found that data collected for a specific purpose were of little or no value for a similar purpose only a short time later (Anderson et al., 1976). The demand for standardized land use and land cover data can only increase as we seek to assess and manage areas of critical concerns for environmental control such as flood plains and wetlands, energy resource development and production areas, wildlife habitat, recreational lands, and areas such as major residential and industrial development sites.

The land use and land cover system for use with remote sensor data evolved from federal, state, and local governments need to standardize data analyses and information systems and discussions. The objective was to develop a national classification system that could use inputs from both conventional and remote sensor data sources. Remote sensor data may provide a current data set covering large areas at a given instant. In the processing of data, the interpreter’s knowledge is critical as various patterns, textures, shapes, and site associations are used to classify the scene. There must be some understanding of the environment being studied.

The Anderson system used a structure of Levels I and II with the flexibility to develop future Levels III, IV and V as the end users had need (Table 1). Attention was given mainly to the more generalized first and second levels of categorization. Each level was developed with the use of certain spatial resolution data in mind, realizing that Level I could use the lower resolution data (less expensive) and the subsequent levels would require higher resolution data (more detailed but more expensive).

There is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. In almost any classification process, it is rare to find the clearly defined classes that one would like.

The classification system satisfies three major attributes of the classification process: 1) it gives names to categories by simply using accepted terminology; 2) it enables information to be transmitted; and 3) it allows inductive generalizations to be made. The classification
system is capable of further refinement and the basis of more extended and varied use. As further advances in technology are made, it may be necessary to modify the classification system for use with automatic data analysis.

WHAT IS AN ANOMALY?

An anomaly is: 1) something observed that deviates in excess of normal variation, or 2) something inconsistent with what would naturally be expected (Webster’s New Collegiate Dictionary, 1977). An agricultural anomaly is an agronomic (vegetation or soil) deviation or inconsistency in excess of “normal” variation from what one would expect to observe. Agricultural cropland anomalies are observed areas within fields that show abnormal characteristics, good or bad. Anomalies can occur anywhere in the field and be caused by the direct or indirect influence of natural factors or human involvement. They are recorded with a type of remote sensing device, such as a camera or a special type of sensor, and usually with a geographic location that can be referenced with a global positioning system (GPS) for purposes of analyzing, evaluating, and future return to the same location or plant.

When considering agricultural crops in conjunction with remote sensing information, many deviations or inconsistencies would qualify as an anomaly, but some variations are not clear as to whether they are anomalies based on the definition as stated earlier. Some of the more clearly qualifying conditions might include water damage where the crop is only slightly damaged or completely destroyed or weed patches that were not controlled by a chemical application. There are other variations not as easily understood but which could fulfill the definition. Some patterns thought to be abnormal may be quite normal for a regional area and management system. One might consider two varieties of corn or soybeans planted in a field in alternating strips having distinct visible variation between the varieties. These strips may be considered a deviation from normal by crop scouts or a computer analyst, but the farmer who planted the crop will be fully expecting that variation, and therefore it would not be an anomaly to him. This determination cannot be made without first verifying the cause of the pattern, requiring a trip to the field in many cases. Intent and knowledge of farm management are critical factors needed for good analysis of the data.

Many anomalies are inter-related and exhibit the same similar shape, size, color and pattern, making it very difficult to confirm causation without further analysis. It may be possible by studying many observations and the underlying causes that one can begin to develop a knowledge base to increase the probability of accurately diagnosing the cause of the anomaly before site visitation, but this approach is not addressed in this study. A thorough knowledge of agriculture and the management practices of producers will be necessary when considering abnormalities.

WHY AN ANOMALY CLASSIFICATION SYSTEM?

An anomaly classification system will have the same effect on identifying and researching anomalies as the soil classification system did with soils. The purpose of this study is to develop a national anomaly classification system for agricultural cropland to identify field crop anomalies as observed with remote sensing images and images formed by yield monitor data information. By classifying these anomalies, one can: 1) develop a common system to discuss anomalies (common language), 2) establish possible anomaly patterns, 3) suggest procedures for automatic detection, and 4) suggest methods to eliminate or reduce causes of anomalies. To distinguish discrete anomalous areas in remote sensing images, higher spatial, spectral and temporal resolution data may be required. However, some anomalies can be distinguished at all spatial resolutions. Lower resolution data require large anomalous areas for visibility, whereas higher resolution data can identify smaller, more discreet areas. There are many other anomalies that one can think of in other agricultural production specialty crops, but this study focuses on the Midwest corn (Zea mays), soybeans (Glycine max), wheat (Triticum), and miscellaneous hay crops as alfalfa (Medicago sativa), clover (Trifolium), fescue (Festuca), and orchardgrass (Dactylis glomerata). This proposed classification system could be expanded to meet the needs of producers of specialty crops, as well as, the common crops of the Midwest covered in this analysis. To assist in the use of this classification system,
Table 1. Land use and land cover classification system for use with remote sensor data.

<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urban or Built-up Land</td>
<td>11. Residential</td>
</tr>
<tr>
<td></td>
<td>12. Commercial and Services</td>
</tr>
<tr>
<td></td>
<td>13. Industrial</td>
</tr>
<tr>
<td></td>
<td>14. Transportation, Communications, and Utilities</td>
</tr>
<tr>
<td></td>
<td>15. Industrial and Commercial Complexes</td>
</tr>
<tr>
<td></td>
<td>16. Mixed Urban or Built-up Land</td>
</tr>
<tr>
<td></td>
<td>17. Other Urban or Built-up Land</td>
</tr>
<tr>
<td></td>
<td>22. Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas</td>
</tr>
<tr>
<td></td>
<td>23. Confined Feeding Operations</td>
</tr>
<tr>
<td></td>
<td>24. Other Agricultural Land</td>
</tr>
<tr>
<td>3. Rangeland</td>
<td>31. Herbaceous Rangeland</td>
</tr>
<tr>
<td></td>
<td>32. Shrubs and Brush Rangeland</td>
</tr>
<tr>
<td></td>
<td>33. Mixed Rangeland</td>
</tr>
<tr>
<td>4. Forest Land</td>
<td>41. Deciduous Forest Land</td>
</tr>
<tr>
<td></td>
<td>42. Evergreen Forest Land</td>
</tr>
<tr>
<td></td>
<td>43. Mixed Forest Land</td>
</tr>
<tr>
<td>5. Water</td>
<td>51. Streams and Canals</td>
</tr>
<tr>
<td></td>
<td>52. Lakes</td>
</tr>
<tr>
<td></td>
<td>53. Reservoirs</td>
</tr>
<tr>
<td></td>
<td>54. Bays and Estuaries</td>
</tr>
<tr>
<td>6. Wetland</td>
<td>61. Forested Wetland</td>
</tr>
<tr>
<td></td>
<td>62. Non-forested Wetland</td>
</tr>
<tr>
<td>7. Barren Land</td>
<td>71. Dry Salt Flats</td>
</tr>
<tr>
<td></td>
<td>72. Beaches</td>
</tr>
<tr>
<td></td>
<td>73. Sandy Areas and other than Beaches</td>
</tr>
<tr>
<td></td>
<td>74. Bare Exposed Rock</td>
</tr>
<tr>
<td></td>
<td>75. Strip Mines, Quarries, and Gravel Pits</td>
</tr>
<tr>
<td></td>
<td>76. Transitional Areas</td>
</tr>
<tr>
<td></td>
<td>77. Mixed Barren Land</td>
</tr>
<tr>
<td>8. Tundra</td>
<td>81. Shrub and Brush Tundra</td>
</tr>
<tr>
<td></td>
<td>82. Herbaceous Tundra</td>
</tr>
<tr>
<td></td>
<td>83. Bare Ground Tundra</td>
</tr>
<tr>
<td></td>
<td>84. Wet Tundra</td>
</tr>
<tr>
<td></td>
<td>85. Mixed Tundra</td>
</tr>
<tr>
<td>9. Perennial Snow or Ice</td>
<td>91. Perennial Snowfields</td>
</tr>
<tr>
<td></td>
<td>92. Glaciers</td>
</tr>
</tbody>
</table>
new and better electronic hardware equipment and analysis software are being continually developed. Many of these new advancements will be incorporated by farm managers of production agriculture as they become larger and seek to become more efficient. Farmers integrating new equipment and services will force suppliers and grain purchasers to develop new services to maintain business operations. The interpretation of remote sensing data, as well as, other data requires the services of trained individuals in agronomy and geographic information systems (GIS) to understand causality and relationships.

WHY USE REMOTE SENSING?
Remote sensing sensors are being widely used to gather information about features on the earth’s surface. During the past decade an increasing number of agricultural industries and service providers have used this information, and they are finding these methods of gathering information are an attractive alternative to typical crop scouting. These sensors have the capacity to cover large areas, quickly collecting observations of areas that are difficult to access and easily repeating coverage while providing a permanent record. With a minimum amount of ground sampling, remote sensing data can assist in identification while making area measurements and mapping of major soil boundaries (Bauer, 1975). Early detection can help prevent losses later in the season, if correction measures are applied before permanent plant damage results (Space Imaging, 1999). Crop stress can be caused by factors including nutrition, water, or chemicals. Other spatial patterns may be caused by invasion of various weed species.

DEFINITIONS
Level I and II are factors that affect crops and it is recognized that more than one factor may be involved at one specific time. Included here is additional information to provide a general understanding of what is included at the Level I category.

100 WEATHER ANOMALIES
Weather has a great influence on farmland field operations and crop development. Of all weather elements (water, wind, hail, frost, and lightning), water typically leads to the most detrimental effect (Figure 1). Methods have been developed to compensate for the effects of water supplies on crops by the implementation of irrigation for supplemental water and drainage (tile and surface drainage) systems to remove excess water. The lack of water for crop production affects nearly all commodity production and as one moves west and north in the US Corn Belt, the effects of diminishing moisture worsens. National weather records verify that annual rainfall in general diminishes gradually in both directions.

This section is a discussion of some of the major weather anomalies. They may vary in size from a few square meters to many hundred square meters. The smaller anomalies of a few meters, e.g. lightning damage as shown in Figure 2, will only be observable with high-resolution (less than 2 m) data, whereas the larger areas will be visible with lower resolution data.

200 NUTRIENT ANOMALIES
The anomalies developed due to varying levels of nutrition, as affecting vegetative plant growth, will have varying reflectance as observed with remote sensing equipment (Figure 3). These observations will be helpful in the ability to accomplish variable rate applications of
<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
</tr>
</thead>
<tbody>
<tr>
<td>100. Weather</td>
<td>110. Water</td>
</tr>
<tr>
<td>120. Wind</td>
<td>130. Hail</td>
</tr>
<tr>
<td>140. Frost/Freeze</td>
<td>150. Lightning</td>
</tr>
<tr>
<td>220. Deficient</td>
<td>230. Imbalance</td>
</tr>
<tr>
<td>300. Drainage</td>
<td>310. Natural</td>
</tr>
<tr>
<td>320. Man Managed</td>
<td>400. Weeds</td>
</tr>
<tr>
<td>410. Species</td>
<td>420. Soil Characteristics</td>
</tr>
<tr>
<td>430. Chemical application</td>
<td>440. Harvesting</td>
</tr>
<tr>
<td>450. Management</td>
<td>500. Insects</td>
</tr>
<tr>
<td>510. Wind carried</td>
<td>520. Soil and residue borne</td>
</tr>
<tr>
<td>530. Wind carried and soil/residue borne</td>
<td>600. Disease</td>
</tr>
<tr>
<td>610. Wind carried</td>
<td>620. Soil and residue borne</td>
</tr>
<tr>
<td>630. Insect carried</td>
<td>700. Crop residue</td>
</tr>
<tr>
<td>710. Tillage</td>
<td>720. Harvest</td>
</tr>
<tr>
<td>730. Weather</td>
<td>800. Chemical</td>
</tr>
<tr>
<td>810. Equipment</td>
<td>820. Operator</td>
</tr>
<tr>
<td>830. Soil</td>
<td>900. Mechanical</td>
</tr>
<tr>
<td>910. Tillage</td>
<td>920. Planter</td>
</tr>
<tr>
<td>930. Sprayer</td>
<td>940. Cultivation</td>
</tr>
<tr>
<td>950. Harvest</td>
<td>1000. Animal</td>
</tr>
<tr>
<td>1010. Residue</td>
<td>1020. Environment</td>
</tr>
<tr>
<td>1030. Tillage/planting system</td>
<td>1100. Management</td>
</tr>
<tr>
<td>1110. Tillage practices</td>
<td>1120. Alternate variety strips</td>
</tr>
<tr>
<td>1130. Replanting of crops in the same field</td>
<td>1140. Field history</td>
</tr>
<tr>
<td>1150. Animal waste application</td>
<td></td>
</tr>
</tbody>
</table>

*Table 2. A proposed Crop Anomaly Classification System for use with remote sensing data.*
Recognizing Patterns Within Cropland Vegetation

300 DRAINAGE ANOMALIES

Soil drainage is an important element of crop production for many soils in the Midwest. Soils are considered well drained to poorly drained in their unaltered landscape. Natural drainage will eventually develop over long periods of time (considered as erosion). When the fertile flat prairies were plowed for crop production, farmers found that drainage was needed for areas that were too wet for good production. This led to the development of surface ditches to carry excess water, allowing for farming productive, as well as, marginal land. As newer technologies developed, more drainage in the form of tile or subsurface drains was used to manage the marginal land. There are many anomalies that occur due to drainage methods and techniques (Figure 4). These areas are grouped into Natural and Managed drainage within the Crop Anomaly Classification System.

400 WEED ANOMALIES

Weed and grass anomalies in field crops are very detrimental to good production levels. They rob crops of needed nutrients and moisture while competing for space and sunlight. Control of some of these bandits can be very difficult, but by identifying their location with remote sensing images and GPS, specific and isolated treatments can be applied to assist in their elimination (Figure 5).

Patterns of weed and grass anomalies are randomly located throughout the field. Many factors affect where these anomalies are found and their patterns of patches and streaks provide valuable clues as to the type of plants to be treated and the possible causation.

500 INSECT ANOMALIES

Patterns of the observed anomalies will be randomly dispersed (Walker and Taylor, 1998) or complete coverage making it more uniformly solid. The anomaly then is the infected field compared to other fields in the area. Most insects invade from two primary sources, origination in the soil or residue and traveling wind currents.

The randomness of insect anomalies is due to the nature of the insect’s colonization and travel, and few things can be economically done to alter insect invasion. There are some controls that may be introduced, such as resistant plant varieties, to particular insects and the use of selective insecticides.

Insects carried by wind naturally follow the prevailing winds at that time and which can vary between years. Some insects falling into this category are potato leafhopper, corn rootworm, European corn borer, and armyworm. The corn rootworm, European corn borer, and nematodes are also present and over winter in the plant residue or soil profile each year.

600 DISEASE ANOMALIES

Anomalies due to plant disease are often the result of some other stress on the plants, related to weather, mechanical, or insect stresses. These stresses weaken the plant and allow diseases to invade through the weakened plant cell structures. Anomalies will often appear as irregular shaped patches randomly dispersed within the field and may follow soil type delineation or other soil characteristics, as well as, previous crop residues. Crop rotations will break some of the disease cycles while others will actually cause selective breeding of the disease and strengthen its ability to infect the crop.

Windy conditions and insects, transport disease infections, as well as, being sustained in the soil or the previous plant residue. Many diseases infect crops early in plant development, but due to good growing conditions and plant health, the crop may never exhibit visual signs of the problem.

700 CROP RESIDUE ANOMALIES

These anomalies can be observed as streaks, bunches, and piles where plant residue is normally uniformly distributed on the soil surface. The anomalies may have been caused by a mechanical influence or by weather events, such as flooding of fields (Figure 6). Pictures and images showing residue anomalies will be visible throughout the year, even when crops are growing through them. Heavy residue of many crops will have an allelopathic effect on growing plants. Also, the residue will have a background reflectance value different from the bare soil, and there-
Figure 1. Circles (a) show three areas of ponding damage within this section of a soybean field. Arrow (b) points to weed growth in the area where water once stood and destroyed the soybean crop.

Figure 2. Lightning damage in a field of soybeans. The center of the area has a lighter yellow, and nearly white with some of the vegetation having burned edges.

Figure 3. Nitrogen deficiency anomaly within an irrigated corn field. The lighter areas show plants that are yellowing due to less nitrogen in sandy soils. Source: Pioneer Hi-bred International, Inc.

Figure 4. Wet area of a field where tile (a) was installed many years earlier. The yellow areas (b) on each side show excess water damage. Source: David Kusel, Manning, Iowa.

Figure 5. Giant ragweed anomaly that has grown above the top of the corn canopy, photo collected in August 1997, Agronomy Center for Research & Education, Purdue University.

Figure 6. Water has left streaks of soybean residue where runoff moved across the present and previous rows of crop. Bare soil can be seen between the drifted material. Source: David Kusel, Manning, Iowa.
fore result in remote sensed images that are difficult to interpret with computer software classifiers.

800 CHEMICAL ANOMALIES

Chemicals are applied for the control of weeds, insects, and diseases that damage many agricultural crops each year. Anomalies due to the applications of these chemicals occur in most crop production fields of the Midwest each year, as well as the irregular patterns caused by pests (Figure 7). With new technologies to assist application operators in driving more consistently and mixing the chemicals more accurately and therefore more uniform application patterns, a decrease in these anomaly occurrences would be expected. The use of GPS equipment by precision farming assists operators in maintaining the proper width for driving, and thereby reduces swath width overlapping and skips. Controls of various types are more reliable, producing more consistent results than one might see in remotely sensed images prior to 1998. Chemicals are packaged so that it is easier to make the proper solution rates, and they may be applied as dry or wet materials and with hand operated equipment for small areas, surface vehicle equipment, or aerial equipment.

900 MECHANICAL ANOMALIES

Mechanical anomalies of the growing crop may be observed as direct or indirect plant variation. Some of these factors may not be readily seen as the cause of variation because of delayed effects from previous field activities. Fall tillage can generate soil surface spectral anomalies and lead to vegetative spectral anomalies the following cropping season. This might be due to an area that was not tilled in the fall because of operator error or bunching of some of the residue due to a malfunction of the implement. One may not recognize these anomalies as being caused by a mechanical tool, since it shows up as an observation of plant growth such as a planter malfunction shown in Figure 8. For example, compaction of the soil due to earlier field operations in the winter or spring when the soil is too wet may have an effect on the growing crop that is visible well into the season.

Harvesting and tillage patterns will not directly impact the growing crop (excluding cultivation), but instead will exhibit indirect effects such as plant stand density, above/below average plant health or growth, color intensity, and various spectral reflectance values. All of these are secondary responses to conditions resulting from earlier activities. Initial observations are anomalies that show as soil reflectance when the ground is bare or sparsely covered. These patterns are plainly visible in reflectance as the field operation takes place and when an area is missed. Cultivation of the growing crop on the other hand will directly affect the plant, possibly causing limited plant damage.

1000 ANIMAL ANOMALIES

Damage of crops due to animals has always been a problem, but has become more frequent since farming has changed from clean tillage to conservation tillage and no-till. Through conservation program funding for the restoration of wetlands and land purchases by wildlife oriented groups for animal sanctuaries, more lands are available for animal shelter. The damage from wild animals often is considered as large a problem as issues such as seed germination or insect damage. Studies by Pickle (1999) in cooperation with the University of Illinois, have verified that ground squirrels and meadow voles reduce corn stand populations and therefore crop yields while generating anomalies of specific characteristics.

1100 MANAGEMENT ANOMALIES

Management decisions and practices can generate field crop vegetation anomalies. Decisions like working in the field when it is too wet and causing soil compaction, planting different crops within the same field (Figure 9), and replanting crop areas after being drowned out due to wet weather (Figure 10) make crop fields look different from normal expectations.

PATTERNS OF MIDWEST CROPLAND ANOMALIES

Many observed anomalies are interrelated and vegetation may exhibit similar shape, size, color, and pattern, making it very difficult to confirm causation. It may be possible by studying many of these observations and the underlying causes that one can begin to develop a knowledge basis adequate for increasing the prediction probability of the anomaly cause without field visitation.
Figure 7. A fall seeded wheat field following a corn crop that had been treated with atrazine for weed control. Anomalies of chemical carry-over due to excessive rates are visible due to stunted vegetation.

Figure 8. Corn rows missing due to a planter malfunction.

Figure 9. Standard color photograph of different corn varieties side by side in the same field taken in late July, South Western Minnesota.

Figure 10. Color infrared image of a soybean field. Image was collected in early September when the original soybean planting (a) started to mature (drop leaves) and the replanted soybeans (b) are still growing.
LIST OF REFERENCES