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PROLOGUE

In the fall of 1988 a group of faculty from the College of Agricultural and Life Sciences at the University of Wisconsin-Madison met to design a cropping systems trial. At that time there was growing dissension within the agricultural community; the popular debate was pitting organic farmers against a cartel of agribuisness interests and the University. One extreme saw the other as the agents of destruction of the rural environment, while the other viewed its critics as modern-day Luddites attempting to sabotage the most successful food production system ever developed. While on one side, testimonials appearing in popular farm magazines were considered "proof" that low input systems were better; for the other side, thirty-five years of research data showed conclusively that high input systems were both profitable and sustainable.

The group decided there was an urgent need to address the sustainability issue in Wisconsin agriculture and to do it as "honest brokers", investigating both the benefits and limitations of alternative production strategies. It was felt that this type of work required both scientific and educational objectives. While value judgments about production strategies abounded, there was relatively little good science that served to quantify the production, profit, and environmental impacts of different farming strategies. It was decided therefore, to develop a replicated trial and invite as many disciplines as necessary to accurately characterize different systems. In addition to comparing production strategies, it was envisioned that different technologies would be tested in either adjacent **SATELLITE TRIALS** or by **SUPERIMPOSING TREATMENTS** on the cropping systems plots themselves.

A second issue of concern was how to use the study as a focal point for discussion within the agricultural community. It was felt that the development of sustainable agricultural land-use systems was not only a research question, but also a political issue that focused on community objectives. It was decided that the project should serve both as a facilitator for discussing the future of farming in Wisconsin and an agent to draw the community together in a common quest for a prosperous and environmentally sound agricultural sector. These reflections greatly widened the scope of the trial and during the winter of 1989, led the team to invite close collaboration with county extension personnel, a non-profit organic farming research organization (Michael Fields Agricultural Institute), and farmers themselves. Thus was born the Wisconsin Integrated Cropping Systems Trial (WICST).

The Steering Committee of the group investigated four locations for the cropping systems trial and selected two: the county farm in Walworth County (the Lakeland Agricultural Complex) and the Arlington Research Station in Columbia County. Both sites were operating farms and most importantly, both had a strong commitment to increase their involvement with the local community. In the summer of 1989, a uniformity trial was conducted at both sites in order to better characterize the inherent heterogeneity of the fields selected for the trial. The crop rotation trial proper has been conducted for two years (1990 and 1991). Operating funds for the project the past three years have come primarily from the a grant from the Center For Integrated Agricultural Systems (CIAS) and Pioneer Hi-Bred International and the donation of supplies and time from the personnel on the team. In mid-summer of 1991 the WICST Project received a substantial four-year grant from the Kellogg Foundation. What follows is a report covering the first three years of activities of the Wisconsin Integrated Cropping Systems Trial Project.

Spring, 1992

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I. OBJECTIVES AND TREATMENT DESIGN OF THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIAL

A. PROJECT OBJECTIVES

The overall objectives of the Wisconsin Integrated Cropping Systems Trial are two-fold:

1. To compare alternative agricultural land management strategies using the performance criteria of productivity, profitability, and environmental impact. A short-term objective (4 to 6 years) is to be able to quantify the "costs" of adopting lower input production strategies. A longer term objective (12 to 15 years) is to quantify the effects of the alternative land management systems on the environment.

2. To involve the agricultural community in the experiment. It was anticipated that because the results of comparing production strategies would highlight "trade-offs" rather than identify a "winner", the debate engendered by this research would be as import as the results themselves. To promote this debate however, it is important that the community share ownership in the trial. A survey of different members of the community indicated the following information requirements.

a. **Producers:** primarily interested in yields, variable costs, labor and machinery requirements, and risks engendered by the alternative systems. They expressed interest in "systems" analysis and would be more confident if the results came from "large plots".

b. **Agribuisness:** primarily interested in the economics of input and machinery use and their effects on the environment. They would want only Best Management Practices (BMP) applied.

c. **Extension:** primarily interested in good economic and environmental data that could be used in extension meetings as well as the possibility of developing educational materials for producers and youth (FFA, school children).

d. **Policy Makers:** interested in the interface between rural agriculture and the urban voter (e.g., food quality, agriculture and water quality), as well as the profitability of the agricultural sector in general.

e. **Researchers:** concerned with both the validity of the measurements (sampling procedures) and their interpretation. The concerns of this group played a major role in the decisions to: 1) have a uniformity year; 2) establish four repetitions at each site; 3) employ a "staggered start" for the initiation of treatments; and 4) select a full spectrum of rotations (e.g., continuous corn at one extreme, rotational grazing at the other).

B. TREATMENT DESIGN

Two themes dominated the discussion on defining the rotations for the trial. One impulse was agro-ecological and promoted focusing on underlying biological processes in agriculture, while the other, was production-oriented and wanted to compare a range of systems that would be feasible in today's "market".

It was decided to construct the treatments to test the agro-ecological hypothesis that increasing rotation complexity would permit less reliance on external inputs. It was agreed to compare high external input systems (low plant diversity) with medium and low input (high plant diversity) systems. The treatments would represent entire rotation strategies. The alternative approach of looking at specific agronomic components (e.g., tillage options, weed control methods, sources of nutrients) within a limited number of rotations was rejected. It was felt that these questions were already being addressed by the satellite trials and research already underway.

From the production viewpoint came the decision to identify two different producer clients: cash grain and dairy farmers. This decision was based on the belief that over the next 20 years there will be more and more agricultural specialization. Cash grain production without access to manure or leguminous sod plow-down is expected to increase. By the same token, more and more dairy farms are expected to increase in size and animal numbers and therefore their need for quality forage and sound manure management plans. Within each rotation, only high levels of management would be used, again based on the assumption that poor managers will be forced to abandon farming in the near future.

The resulting treatment design is a factorial with three levels of biodiversity (or levels of external inputs), and two types of enterprises (cash grain and dairy), for a total of six rotations. These rotations consist of 14 phases in all.

Cash Grain Rotations: These rotations are required to produce a cash crop each year and have no access to manure. Farm size was estimated at 500 acres and the equipment was dimensioned accordingly (e.g., 6-row equipment).

R1 Continuous corn for grain. Cereal monocropping will require the addition of substantial amounts of inputs to maintain soil fertility and control weeds. Best Management Practices (BMP's) are being employed.

R2 Drilled soybean-corn. More complex a rotation than the first, this rotation will benefit from reduced nitrogen inputs and soil insecticides. Weeds will be controlled chemically. Best Management Practices (BMP's) are being employed in this two-year rotation.

R3 Row soybeans/winter wheat-wheat/red clover-corn. In this rotation, corn is planted only one year in three. The use of a green manure crop, in addition to soybeans, will limit the need for additional nitrogen. Phosphorous and potassium will be mined from the soil since no fertilizer will be applied. All weed control will be done mechanically, but it is expected that the vegetative cover supplied by the winter small grain and red clover for 18 months of this 36-month rotation will help keep weed pressures low.

This will be the riskiest rotation of the three. The window for the establishment of the wheat in the fall after soybeans is narrow. There is then a moderate probability of an open, cold winter that can cause significant winter-kill of the wheat in southern Wisconsin. Finally, the success of the frost-seeding of the red clover into the wheat is uncertain. Satellite trials comparing aerial seeding at leaf yellowing of soybeans, and no-till drilling after bean harvest were designed, as well as comparing frost seeding of red clover in wheat with sequential seeding after wheat. It was decided if the winter wheat failed, either the empty spots would be filled in with spring wheat, or the entire plot reseeded to oats plus red clover.

Dairy Rotations: These rotations were required to produce quality forage, and receive the equivalent of 10t/A/yr. of manure. This rate is based on a stocking density of one cow plus replacement per three tillable acres. In the two haying systems, the manure is applied in the fall of the final sod year and the fall of the corn year. In the grazing system, the manure will be deposited directly on the plots. In the haying rotations, the first and fourth cuts will be taken as haylage, and the second and third as baled hay. Farm size was estimated at 250 acres and the equipment dimensioned accordingly (e.g., 4-row equipment).

R4 "Green gold" alfalfa rotation (a-a-a*-c*). This rotation does not use a companion crop to establish the alfalfa but rather a herbicide. An intensive cutting schedule (4x-5x/yr.) and top dressing with potassium fertilizer should result in excellent yields of high quality hay. In the forth year, the stand is plowed under and corn is grown using BMP's. Twenty tons of dairy manure is to be added to the system at the two points indicated by the asteriks This system has a sole-seeded legume for three years, a one-year break with a cereal, and then back to alfalfa.

R5 "Rapid turnaround" alfalfa rotation (o/a-a*-c*). In this system the interaction between legumes and grasses is increased. The alfalfa is companion planted with oats which removes the need for a seeding year herbicide. Also, there is only one hay year, reducing the probability of quackgrass infestation. The corn year is conducted without herbicide or fertilizer. Fifteen tons of dairy manure is added to the system at the two points indicated by the asteriks.

R6 "Intensive grazing" (brome/timothy/red clover). This treatment will have two 400 pound heifers on each plot for approximately 150 days/yr. Paddock production, complemented with hay and concentrate will focus on maintaining an average 1.8 lb./day weight gain. The simultaneous occurrence of grasses, legumes, and animals on the plots makes this the most diverse rotation of the six. It is anticipated that the pasture will be renovated with red clover every three years. As with the low input cash grain rotation however, this is the riskiest of the three forage rotations. Dry weather will result in increased feed purchases and wet weather will increase trampling and affect stand longevity.

Extreme cold in the early fall, open winters, and fluctuating early spring temperatures all increase the probability of winter-kill in legume sod rotations. If the alfalfa was killed during the rotation, it was decided to follow one of two strategies: 1) if it was the last year of the stand, red clover and annual ryegrass would be no-till planted into the sod; 2) if it was the first hay year (R4) then annual ryegrass would be no-tilled in to the remaining stand and the alfalfa replanted with herbicide in late summer.

In addition to defining the sequence of crops and general rules that would be followed in each rotation, the committee established a detailed set of agronomic practices that would prevail.

1. Variety Selection (Appendix I): Due to the rapid change in cultivars, particularly in the cash grain crops, it was decided to re-evaluate the selections every four years. In a careful review of the rotations, it was also decided that, based on current knowledge, only one cultivar of each crop was necessary (ie. low input systems didn't require a different corn cultivar than higher input systems). With respect to date of planting, it was thought that there might be an advantage to delayed planting in the mechanical weed control plots. It was decided to start the trial with common dates, but to set up a satellite trial to investigate this question.

2. Nutrient Management: The cash grain rotations only have access to fertilizer and short season green manure crops (R_3). Fertilizer additions follow University recommendations, which are based on soil testing (potassium and phosphorous) and early spring nitrate tests. The high input dairy rotation (R_4) will also use fertilizer (potassium topdressing). All three dairy rotations will have access to manure. Annual nutrient inputs to each rotation are summarized in Appendix IIA. Also in that Appendix (IIC) is an estimated nutrient budget for each rotation. It is expected, as this mass balance approach highlights, the low input systems will be drawing down soil reserves, particularly of phosphorous and potassium.

3. Tillage Systems: It was decided, based on tillage survey data, that ridge-till and no-till were still very rare in Wisconsin (see Appendix IIIA). All the rotations were designed therefore as conservation tillage systems relying on fall chisel plowing and spring disking to provide adequate seed bed preparation with 30% residue cover (See Appendix IIIB). The soil erosion objective was to meet the requirements of the Soil Conservation Service (SCS). Soil loss (t/A) was estimated under a range of physical conditions with this tillage program using the Universal Soil Loss Equation (See Appendix IIIC).

4. Weed Control (Appendix IV): The use of recommended herbicide rates and a single cultivation in the row crops is the strategy in the higher input rotations (R_1, R_2, R_4). In the lower input systems, weeds will be managed by the competitiveness of the rotation, and mechanically with rotary hoeing and cultivation. Due to the heterogeneity of weed populations, controlling weeds is being done on a plot by plot basis, rather than strictly adhering to one weed control protocol. This means that heavily infested plots will receive added attention if the initial herbicide or mechanical cultivations are ineffective.

C. THEORETICAL COMPARISON OF THE ROTATIONS

Table 1 presents a summary of the theoretical calculations comparing the six rotations. Column one lists estimated yields per acre during each phase of the rotation. These numbers have been converted to Above Ground Net Productivity (ANP) in Column 2. As expected, continuous corn (15,780 lb/a/yr) compares very favorably with both the other production systems, as well as, productive stands of red oak (Quercus rubra; 8,930 lb/a/yr) or, tall grass prairie (10,710 lb/a/yr)*. However, these levels of production by the agricultural systems are achieved with heavy energy subsidies (Col. 3). In the case of continuous corn, over half of this energy is in the form of nitrogen fertilizer. The estimated variable costs and labor input per acre are listed in columns four and five. The source of nitrogen for the corn phase, a crop common to five of the rotations is outlined in column six. The list of pesticides anticipated to be used in the trial are listed in columns seven and eight. The final column shows the estimated annual soil loss from each rotation on a 4% slope.

These factors clearly indicate that the six rotations represent a wide spectrum of input levels and productivity. Continuous corn will be the most aggressive land management system, producing the most biomass, requiring the highest energy subsidy, using the most chemicals, and provoking the greatest erosion. The three-phase cash grain system (R3) is expected to

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* Personal communication, T. Gower, Forestry Dept. UW-Madison

Table 1. Productivity, Economic, and Environmental Comparisons Between Rotations. Wisconsin Integrated Cropping Systems Trial, 1989.

Rotation1	Predicted Yield/acre	Mean above ground productivity[1] lb/a/yr	Mean energy input[2] Kcal/a/yr	Labor hr/a/yr	Variable[3] Costs $/a/yr	Chemical inputs: Fert N on corn lb/a	Chemical inputs: Herbicide AI/a	Chemical inputs: Insecticide AI/a	Erosion[4] t/a/yr
R_1 Cont. Corn	150 bu	15,780	1,888,000	1.65	140	150	Atrazine 2 lb Alachlor 2 lb	Counter 1.4 lb	4.1
R_2 drilled soybean corn	55 bu 160 bu	12,510	1,216,000	1.40	104	110	Bladex 2.5 lb Alachlor 2.5 lb Sencor .5 lb Treflan 1.5 lb	0	4.0
R_3 row soybean wheat corn	40 bu 60 bu/2t straw 120 bu	10,010	538,000	1.78	50	0	0	0	2.9
R_4 seeding alfalfa hay I hay II corn	3t dm 5t dm 5t dm 160 bu	10,710	1,421,000	1.85	110	10	Eptam 2.9 lb Bladex 2.0 lb Alachlor 2.5 lb	Lorsban 1 lb	1.9
R_5 oats/alfalfa hay I corn	60 bu/2t dm 4t dm 120 bu	9,440	974,000	1.59	45	10	0	0	1.6
R_6 rotational grazing	4t dm	8,000	129,000	2.0	16	na	0	0	0.5

1. Mean above ground productivity: dry matter biomass production per acre per year. Calculated based on the following harvest indices: Corn = .45; soybean = .35; wheat = .42; oat = .45
2. Mean energy input includes only seed, fertilizer, lime, manure, pesticides, and fuel. Based on Pimentel, D. 1980 Handbook of Energy Utilization in Agriculture, CRS Press Inc.
3. Variable costs include seeds, fertilizer, pesticides, drying, fuel, and labor. Costs are based on 1988 Wisconsin Crop Budgets. R. Klemme and L. Gillespie.
4. Erosion estimates were made using the USLE for a 4% slope, 200 feet long with a silt loam soil and contour planting.

produce only 65% of the biomass, but with one-third of the energy subsidy, no added chemicals, and reduced erosion. In the same manner, the "green gold" option (R4) may be the most productive forage system, producing nearly 25% more biomass than the rotational grazing, but with ten times the energy and variable cost inputs. In general, the cash grain rotations appear to be more aggressive than the forage systems.

II. SITE SELECTION

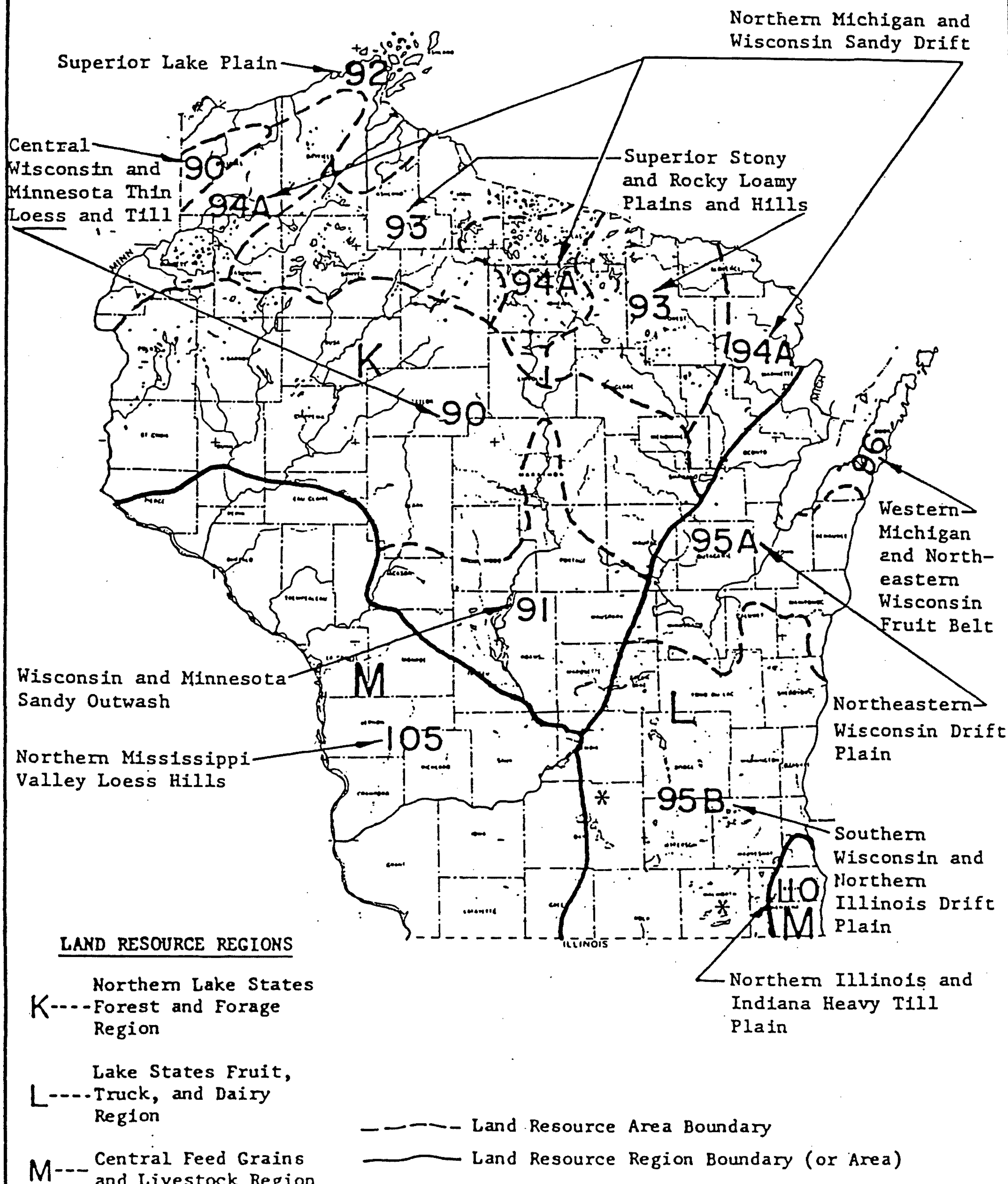
After an initial review of four sites, and an appreciation of the time commitment necessary to make this project succeed, it was decided to focus attention in the southern part of the State. Major Land Resource Area (MLRA) 95B was selected (See Map 1).

A. SOIL CHARACTERISTICS

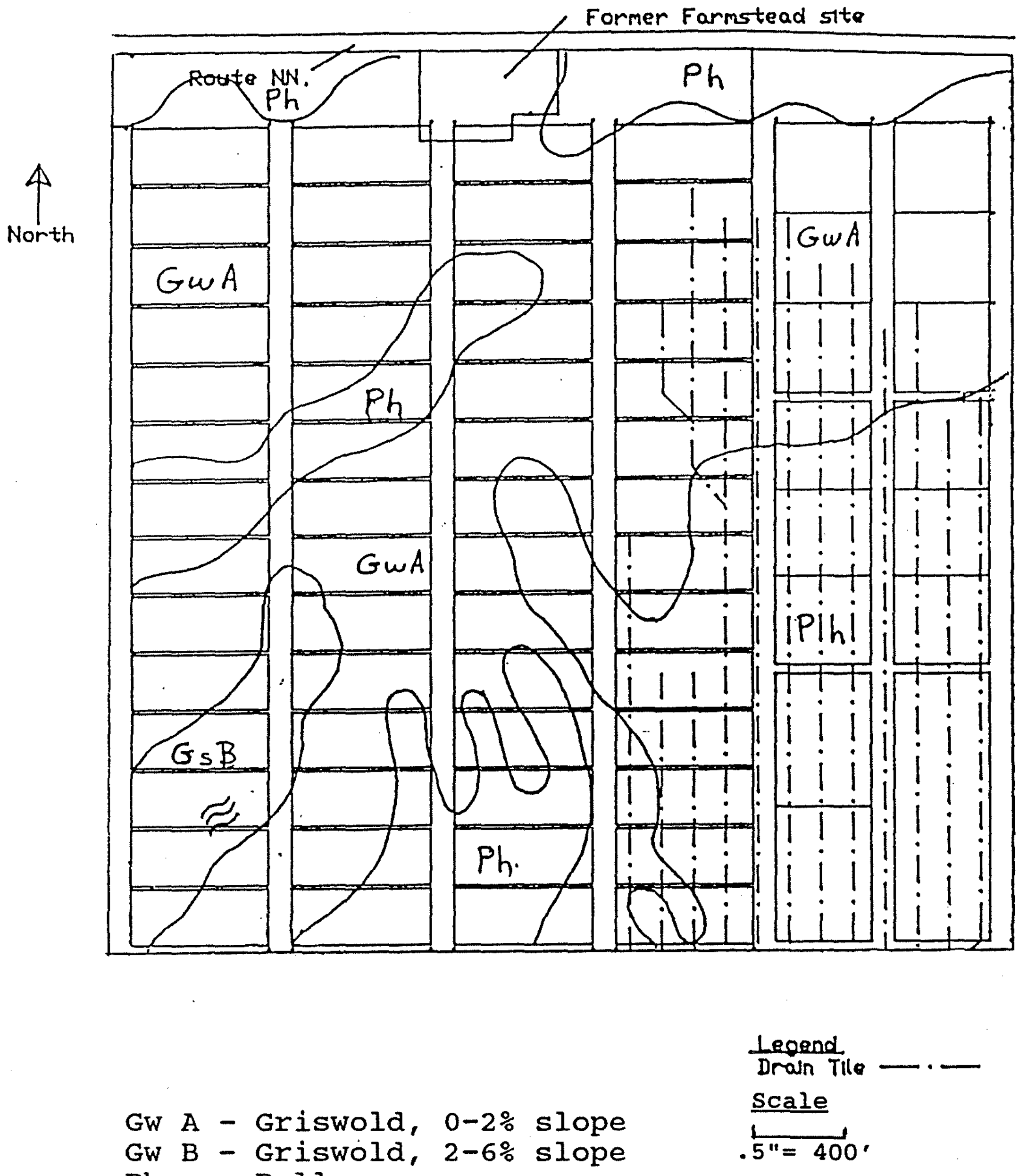
More than 90 percent of this MLRA is in farms, 65 percent of which is cropland. Feed grains and forage for livestock are the chief crops. Most of the soils are Udolls and Udalfs, the former being formed under prairie vegetation, and the latter under forest (USDA Handbook 296, 1981). Two major soil gradients within the area are the depth of the silty cap over glacial till, and internal drainage. Among the Mollisols, moderately deep, medium textured Typic Argiudolls are found on the uplands, and shallower, wetter Aquic Argiudolls are found lower on the toposequence. In the Wisconsin part of MLRA 95B, the well-drained, deep soils represented by the Plano series encompass 460,609 acres. The somewhat poorly drained soils represented by the Griswold mottled subsoil variant cover 137,625 acres, and the poorly drained Pella series and similar soils represent 138,965 acres.

The site selected on the Walworth County Farm (Lakeland Agricultural Complex) was mapped by David Roberts of the Soil Conservation Service. The major mapping units are a Griswold, mottled subsoil variant (63%) and a poorly drained Pella (32%). The remaining unit is a Griswold (5%) which is found on a ridge in the southwest part of the field (see Map 2). A summary of the soil characteristics are listed in Table 2. Generally there is a silt-loam surface horizon (0-15") rich in organic matter (3%) followed by a clay-loam or sandy clay-loam B-horizon (15-26"). Average depth to compacted glacial till on the Griswold mottled subsoil variant is 35 inches and 54 inches in the Pella mapping unit. The till was deposited by the last advance of the Lake Michigan Glacier and ranges in texture from a gravelly sandy-loam to a sandy-loam. During wet periods, this area may have the water table within 1 to 3 feet of the surface. The eastern third of the field, which includes repetition four and the satellite blocks, is tiled.

Map 1 MAJOR LAND RESOURCE AREAS FOR WISCONSIN



Map 2 Soils Map of the Wisconsin Integrated Cropping Systems Trial - Lakeland Agricultural Complex



Gw A - Griswold, 0-2% slope
Gw B - Griswold, 2-6% slope
Ph - Pella

* Drawn by D. Roberts, SCS, Beaver Dam, WI

Table 2. Soil Characteristics at the Trial Site.

Mapping Unit	Mapping symbol	Drainage class	Area of similar soils MLRA 95 B[1]	Percent experimental Area	Mean depth to till (in)	Mean depth to mottles (in)	Yield potential[2]			
							Corn bu/a	Soybean bu/a	Wheat bu/a	Alfalfa t dm/a
A. Lakeland Agricultural Complex										
Griswold Mottled Subsoil	Gw A	somewhat poorly drained	137,625	63	35	20	150	50	45	5.1
Pella	Ph	poorly drained	138,965	32	54	12	150	50	–	4.0
Griswold	Gw B	well drained	460,609 (Griswold Gw B and Plano Pn A combined)	5	10	36	115	38	42	4.4
B. Arlington Research Station										
Plano	Pn A	well drained		100	55	34	160	53	56	5.8

[1] Calculated by D. Roberts, SCS, Beaver Dam.
[2] Soil Conservation Service, 1990 "Productivity of Wisconsin Soils" mimeo.

On the Arlington Research Station in Columbia County, the entire site selected for the trial is mapped as a Plano silt-loam. Working on a 90-foot grid pattern, Dr. Kevin McSweeney of the UW-Madison Soil Science Department mapped depth of loess and depth to mottles. Soil characteristics are summarized on Table 2. The silt-loam A horizon is 8 inches (20 cm) deep with an organic matter level of 4.4%, and the loess mantel is generally deeper than 5 feet (>125 cm). The glacial till is from the Green Bay Lobe and is similar to the Walworth site in texture. Groundwater is greater than 80 feet deep and the area is well drained.

B. CLIMATE

Rainfall decreases from south to north in the study area. Average rainfall is 37 inches at the Lakeland Agricultural Complex but only 31 inches at the Arlington site. Throughout the area, approximately two thirds of the rainfall occurs during the growing season (April-October). Both sites have 160-165 frost-free days.

C. AGRICULTURAL ENTERPRISES

According to the 1987 Census of Agriculture, Major Land Resource Area 95B contains 19,663 farms or 26% of the farms in the State (See Table 3). Approximately 40% of these farms are greater than 180 acres in size. While in the State as a whole, dairy cows are found on 50% of the farms, in MLRA 95B this is only the case on 40% of the farms. The two sites for the trial are in counties where cash grain farming is predominant and only 30% of the farms also have cows. The major crops in the area are; corn for grain, alfalfa hay, corn for silage, soybeans, processing crops, and winter wheat. Of the two trial sites, Walworth County has the greatest soybean acreage, and Columbia County the greatest acreage of processing crops. The value of agricultural production per farm in 1987 was above the State average in MLRA 95B.

Table 3. Farm Enterprise Statistics, 1987.

	State	MLRA 95 B[3]	Columbia County	Walworth County
No. of Farms[1]	75,131	19,663	1,513	980
Farms > 180acres[1]	46%	38%	41%	40%
% of all farms[1] with milk cows	50%	40%	32%	30%
Ave No. cows/farm[1]	47	53	61	50
Acres Corn-grain[2]	2,800,000	1,046,000	109,900	82,200
Acres Corn-silage[2]	730,000	203,300	13,700	9,100
Acres alfalfa hay[2]	2,800,000	599,500	38,500	20,100
Acres Soybean[2]	330,000	197,050	11,200	25,000
Acres Processing Crops[2]	326,800	175,800	15,400	10,800
Acres winter wheat[2]	85,000	64,300	3,200	4,200
Market value of all Ag[1] Products per farm	$65,351	$72,030	$64,162	$82,263

[1] 1987 Census of Agriculture Vol 1 part 49, Wisconsin: State and County Data. US Dept. of Commerce, Bureau of Census. US Govt. Printing Office, Washington, DC. Issued, March 1989.

[2] Agricultural Statistics - Wisconsin 1988. National Agricultural Statistics Service, USDA. Processing crops include green peas, sweet corn and snapbeans.

[3] Includes Calumet, Columbia, Dane, Dodge, Fond du Lac, Green Lake, Jefferson, Kenosha, Milwaukee, Ozaukee, Racine, Rock, Sheboygan, Walworth, Washington, Waukesha, and Winnebago counties.

III. THE UNIFORMITY YEAR--1989

A. INTRODUCTION

Based on a review of the objectives of the trial and the selection of six rotations, it was obvious that a large area of land would be necessary at each site. The fields selected for the trial had previously been planted in a range of crops so it was decided to conduct a uniformity year prior to establishing the trial. The uniformity year had two objectives:

1. to assure that all the plots would have the same immediate cropping history (e.g., same previous crop)
2. to identify the variability in the field so as to facilitate blocking the experiment (aspects of soil variability at the Lakeland Agricultural Complex are shown in Map 2).

Once the Arlington site was planted to corn, a 90-foot x 90-foot grid was established and small plot markers placed in the field. This grid was then used by the team members to plot the field topography, soil physical characteristics, soil chemical fertility, and weed seed numbers. At the Lakeland Agricultural Complex, intensive sampling did not begin until 1990.

B. RECENT FIELD HISTORY AND 1989 AGRONOMIC CALENDAR

Arlington Research Station

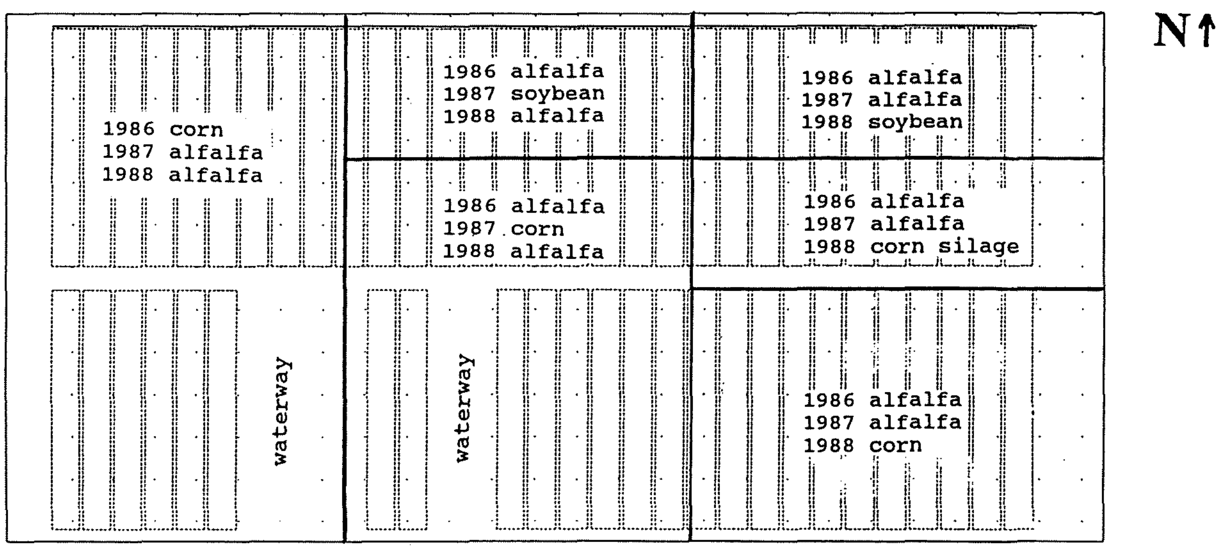
Fields 440 (24.8a), 441 (23.8a), and 442 (23a) had been in an alfalfa-alfalfa-corn rotation for the previous 10 years. In both 1987 and 1988 the field in the corn phase (441 and 442 respectively) had the northern quarter planted to a soybean screening trial (see map 3a). Due to the proximity to the Emmons Blaine Dairy, the fields had been historically heavily manured, both prior to and just after the corn phase of the rotation.

Lakeland Agricultural Complex

The large field chosen for the Wisconsin Integrated Cropping Systems trial had been managed as several fields in the recent past. The eastern two thirds had been in corn in 1988 and the western third in alfalfa and grass. Map 3b summarizes the recent cropping history of the field.

The agronomic activities during the uniformity year at both locations are summarized in table four.

Map 3a Recent Cropping History - Arlington Research Station



Map 3b Recent Cropping History - Lakeland Agricultural Complex

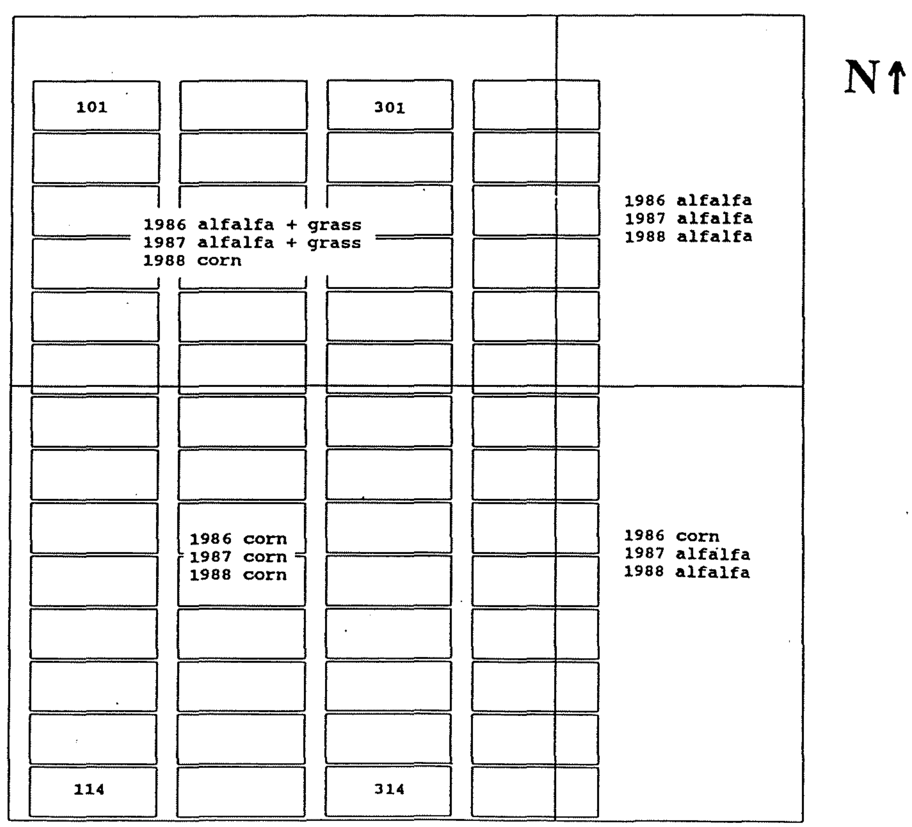


Table 4. Agronomic Calender for the Uniformity Year

	Arlington Research Station	Lakeland Agricultural Complex
Tillage	440-Fall 1988-Ranger application and chisel plowed	Corn ground-Fall 1988-chisel plowed
	441-April 20, 1989-Banvel +2,4-D applied and chisel plowed	hayground-April 26, 1989 moldboard plowed
	442 Fall 1988-chisel plowed	
	May 2, 1989-entire field cultivated with Till-all	May 1, 1989-entire field cultivated
Fertilizer	None	Dec. 2, 1988 Bulk application corn since 1986 130 lb/a 0-0-60 First year corn 220 lb/a 0-0-60 75 lb/a 0-44-0 Old hayground 315 lb/a 0-0-60 80 lb/a 0-44-0
Plant	May 3 Dekalb 547 30,700 seeds/a	May 4 Pioneer 3737 29,900 seed/a 10 gal/a 10:34:0
Weed control	rotary hoe May 10, 18, 25 Cultivate June 8, 28 Directed spray 2, 4-D-July 5	Lasso (3 qt/a), atrex (.5 lb/a) Bladex (2.5 lb/a) Cultivate Corn ground May 25, June 14, 22 hayground June 14
Harvest	October 26, 1989	Oct 13, 1989

C. RESULTS OF THE UNIFORMITY YEAR

1. CORN YIELDS AND BLOCKING THE TRIAL

J. L. Posner and M. C. Casler*

In October, 1989, the corn was harvested with a 6-row (30-inch row spacing) combine. At both sites however, shortly after planting in the spring, a 5-foot swath was cut running perpendicular to the rows at intervals of 90 feet. This was done to outline the limits of the harvest plots. Yields were then measured in each 85-foot plot in one pass out of three (see figure 1). Yields from the 15 x 85 ft harvest strip were considered representative of the entire 45 x 90 ft unit plot size. At the Arlington site, half of the harvest strips had the initial grid sample points (90 x 90 ft) at their center. At both sites (see Maps 4 and 5) the yield data was entered into a Geographic Information System (GIS). At the Arlington Research Station 625 plots were harversted; at the Lakeland Agricultural Complex, 665 plots. Mean corn yields were 130 bu/A at the former and 155 bu/A at the latter.

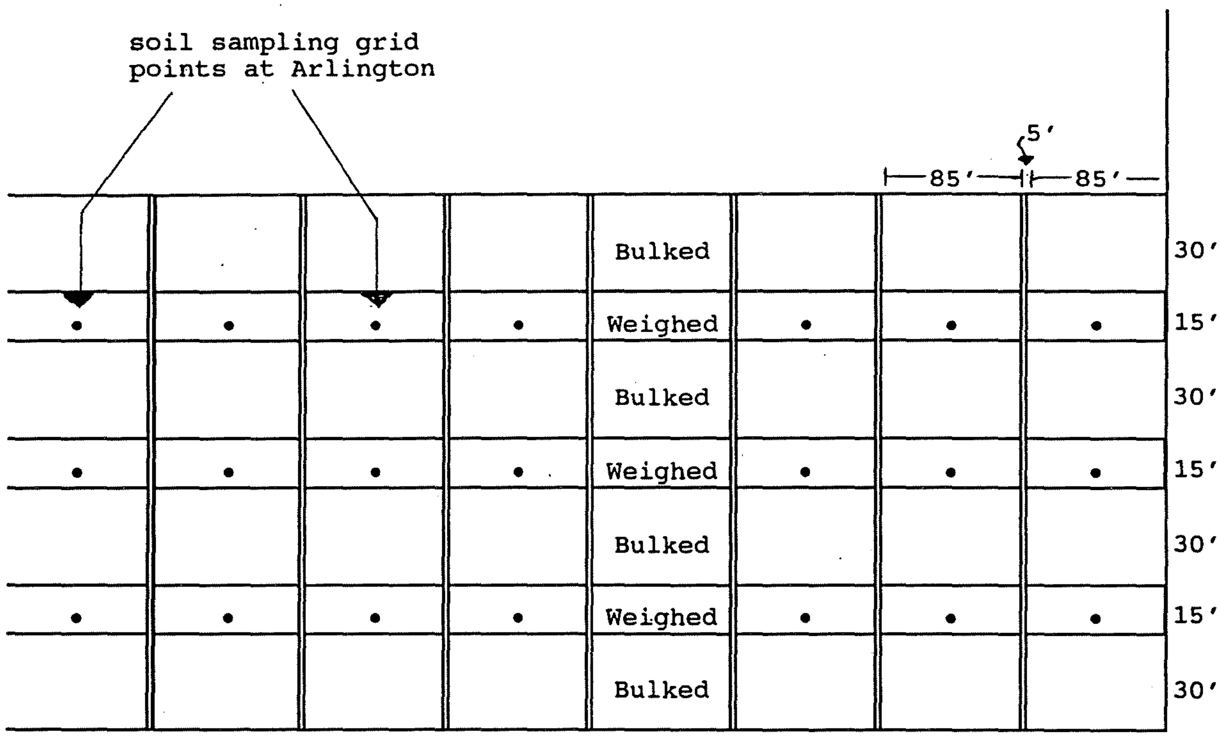
A computer program was written by M. Casler that permitted aggregating the unit yield plots (45 x 90 ft) into field plots of various sizes (plot area) and shapes, as well as then aggregating field plots into different block shapes. The output of each analysis was the Least Signifigant Difference (P=0.05) resulting from that plot size and shape as well as configuration of plots into blocks. All plot sizes that permitted all the treatments to be replicated at least twice were run through the program. The analysis was simplified by assuming that the trial had 12 treatments and only using a subset of the data. At Arlington, only 24 rows and 24 columns of plot data was used, while at the Lakeland site it was 12 rows by 24 columns.

Table 5 a and b summarize the data of the effect of plot size and replication number on the LSD (P=0.05) of corn yields. These numbers are the means of all the different configurations within a given plot size as well as configurations of block shapes containing all 12 treatments. As expected, increasing plot size reduces the LSD but increasing the repetitions does so even more rapidly. Since we wanted large plots to permit the use of farm machinery and the possibility of superimposed trials, it was felt that at least 0.5 acre per plot would be necessary. At both sites it appeared that 4 repetitions and plots of 0.744 acre would result in excellent LSD (P=0.05) values of approximately 8 bu/A. At the Arlington Research Station, it was found that there was little advantage of one block configuration over another, while at Lakeland Agricultural Complex, long repetitions running north-south were best. Based on these analyses plot layout took place in early spring 1990.

* Assistant Professor and Professor, respectively, Dept. of Agronomy, Univ. Wisconsin, Madison

Figure 1. Schematic Drawing of Homogneity Year Corn Harvest, 1989

A. Harvest Grid



B. "Unit" Plot

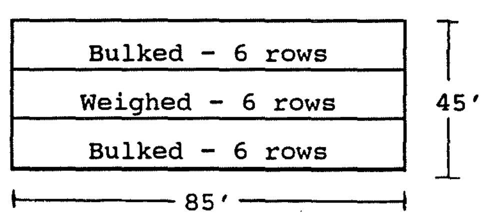


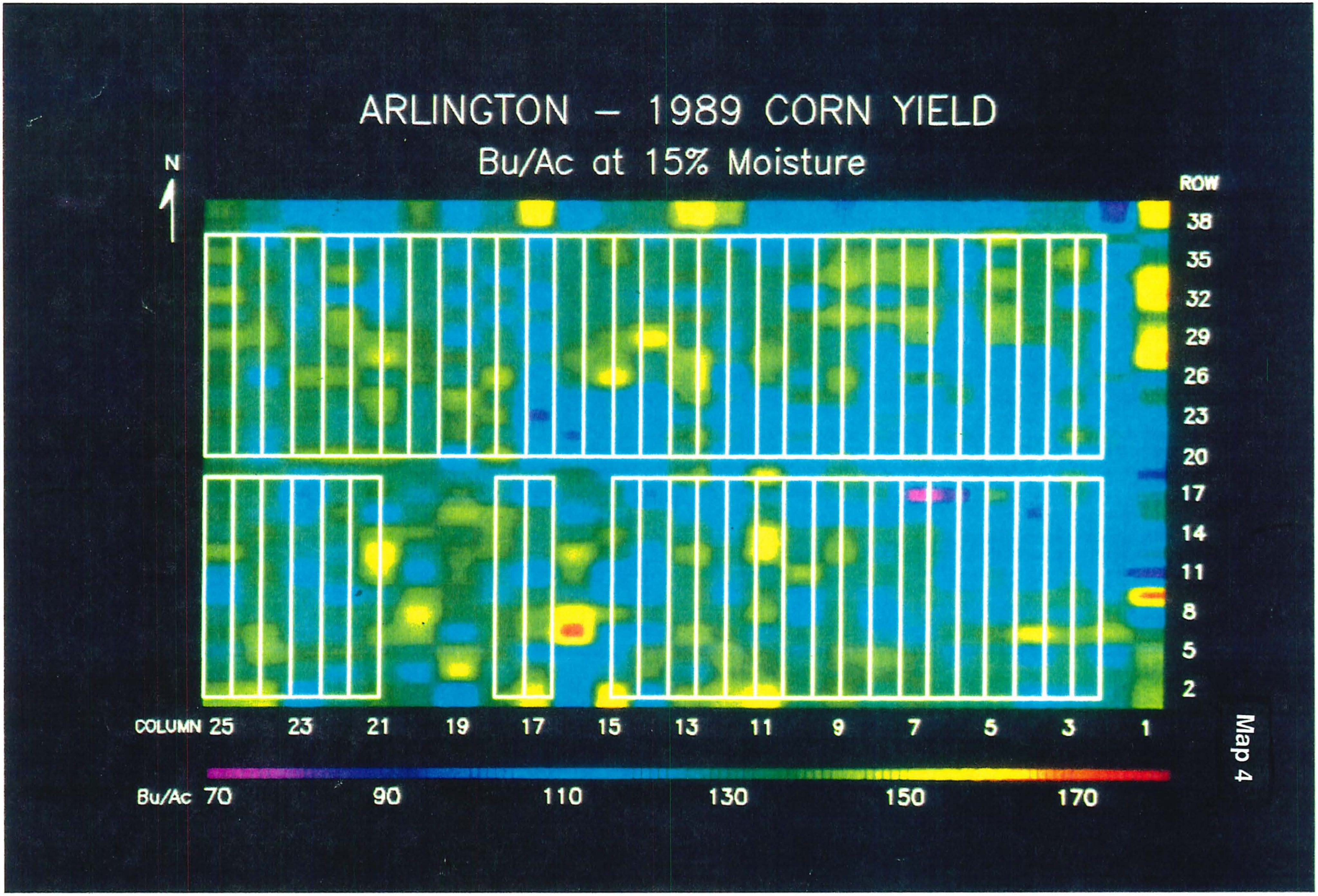
Table 5. The Effect of Plot Area and Number of Repetitions on LSD (P=0.05) During the Uniformity Year, 1989.

a. Lakeland Agricultural Complex

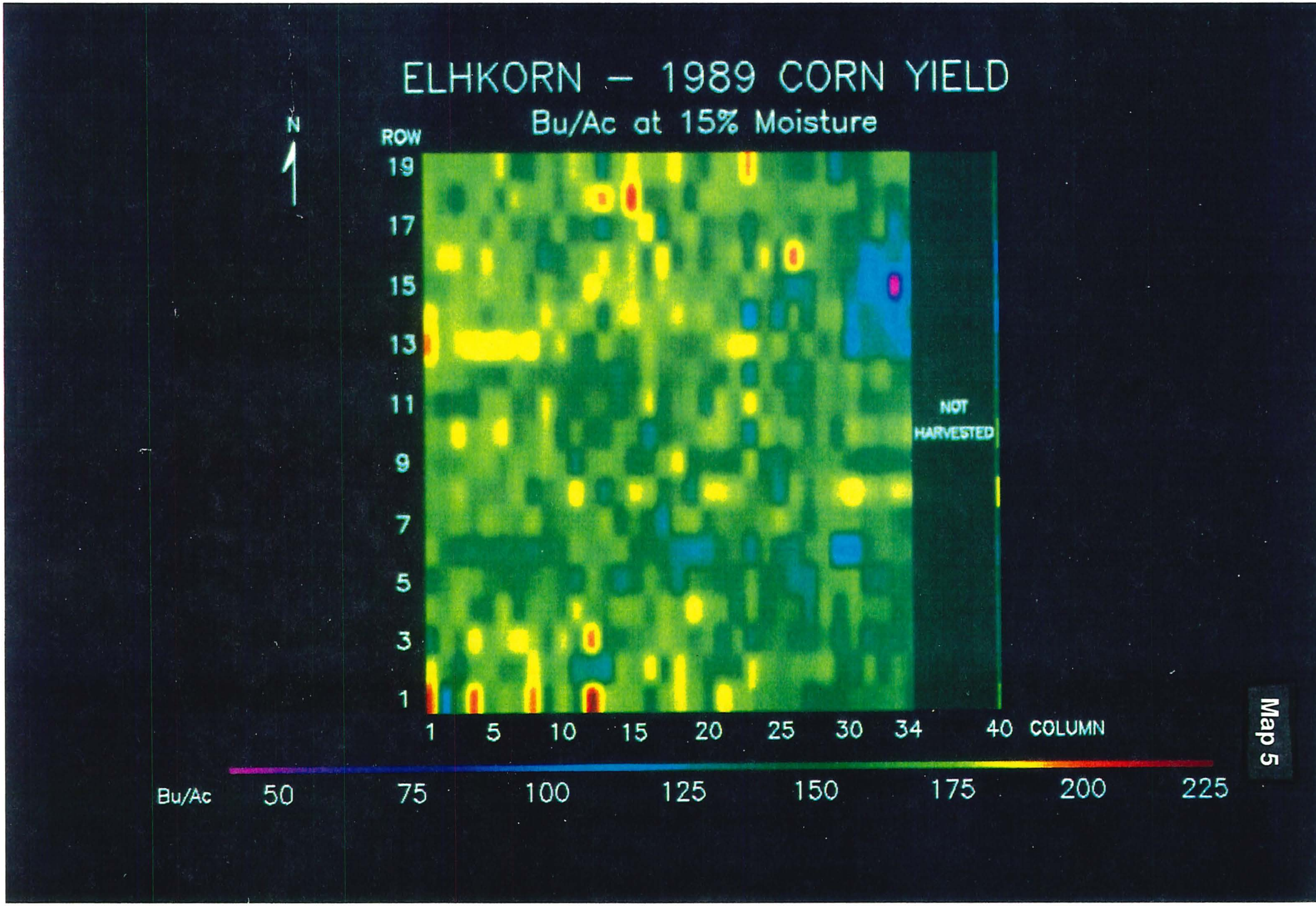
Plot Size (acres)	LSD (P=0.05) bushels			
	r=3	r=4	r=5	r=6
0.093	22.1	19.2	17.1	15.6
0.186	15.1	13.0	11.7	10.7
0.279	13.3	11.5	10.3	9.4
0.372	----	----	----	----
0.558	10.7	9.2	8.3	7.5
0.744	----	----	----	----

b. Arlington Research Station

Plot Size (acres)	LSD (P=0.05) bushels			
	r=3	r=4	r=5	r=6
0.093	17.6	15.2	13.6	12.4
0.186	13.6	11.8	10.5	9.6
0.279	12.3	10.6	9.5	8.7
0.372	11.0	9.6	8.6	7.8
0.558	10.5	9.1	8.1	7.4
0.744	9.5	8.3	7.4	6.7



ARLINGTON – 1989 CORN YIELD
Bu/Ac at 15% Moisture
N
ROW
38
35
32
29
26
23
20
17
14
11
8
5
2
COLUMN 25 23 21 19 17 15 13 11 9 7 5 3 1
Bu/Ac 70 90 110 130 150 170
Map 4


ELHKORN – 1989 CORN YIELD
Bu/Ac at 15% Moisture
N
ROW
19
17
15
13
11
9
7
5
3
1
1
5
10
15
20
25
30
34
40
COLUMN
NOT HARVESTED
Bu/Ac
50
75
100
125
150
175
200
225
Map 5

2. WEED SEED MONITORING DURING THE UNIFORMITY YEAR

J. Doll, T. Mulder, and J. Posner*

One of the key concerns farmers have about cropping systems using reduced tillage and less herbicides is whether or not they will be able to achieve acceptable weed control. Many studies have been done to show that weeds can be managed in reduced tillage systems when herbicides are still used but we have little data on the effects of tillage and mechanical weeding systems on the long-term aspects of weed management. The Cropping Systems trials in Columbia and Walworth counties give us the opportunity to make many valuable observations on the long-term consequences on weed ecology of different production strategies in cash grain and forage enterprises.

Objectives. In the uniformity year, soil samples were taken throughout the Arlington Research Station (ARS) site in Colombia County to (1) obtain data on the density and diversity of weeds in the field and (2) determine if there were any obvious weed distribution patterns that should be considered for determining the layout of the trial. Limited soil sampling for weeds was done at the Lakeland Agricultural Complex (LAC) site (Walworth County) in 1989.

Methodology. At ARS, 162 soil samples were taken in early May on a 90 x 180 ft grid pattern. Only 12 soil samples were collected at the LAC. Sample collection was similar to that used at ARS and a rough grid pattern was used to get a cross-section view of the weediness of the field.

At both sites, samples consisted of 10 cores 0.75 inch in diameter and 6 inches deep, giving approximately 1.5 lb of soil per sample. The soil was stored at 38°F until mid-May. Each sample was mixed with an equal weight of silica sand and placed in a plastic tray with small holes in the bottom. The soil was approximately 1 inch deep in the trays. The trays were placed on a capillary mat in a greenhouse.

As the seeds germinated, the weed seedings were identified and removed. After several weeks, germination ceased. The soil/sand mixture was dried, remixed, returned to the flat and watered for another germination cycle. This process was repeated three times and all germination observations were completed by early October.

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* Graduate Assistant, Weed Scientist, and Cropping Systems Agronomist, respectively, Dept. of Agronomy, Univ. Wisconsin, Madison.

Results

Arlington Research Station. The seedling counts for the three observations were totaled for each species. Maps 6a and 6b show the relative distribution of the both grass and broadleaf weeds. Weed density varies throughout the field but the patterns are such that it was not realistic to use this factor as a consideration in arranging the blocking pattern in the field. More importantly, these data will serve as the point of comparison for changes that occur in the future.

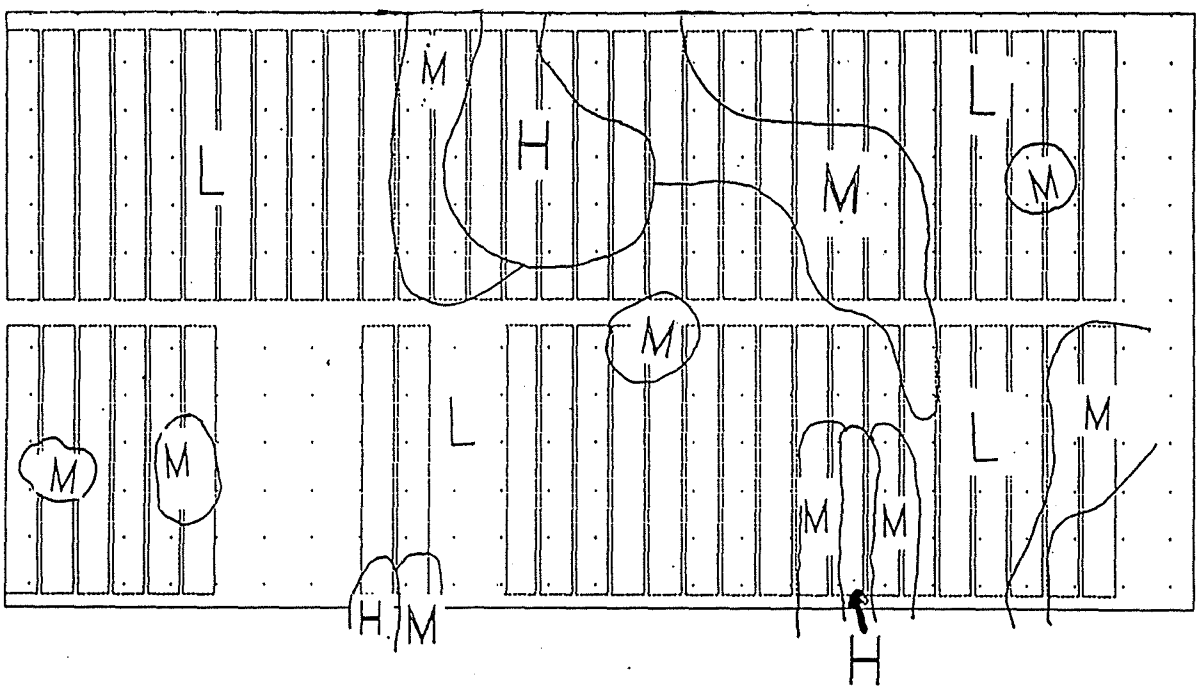
The species found at ARS and their densities are given in Table 6a. An average of 141 grasses and 582 broadleaf weeds/sq ft. were found in the top 6 inches of the soil profile. Of the total weeds, 80% were broadleaves and 20% were grasses and five species accounted for 86% of all the weeds. There was little correlation between the patchy distribution of the weeds and previous cropping history (compare maps 3a and 3b to 6a and 6b). The expected correlation of higher densities of broadleaves coinciding with the higher levels of grasses was observed. Thus whatever accounts for the areas of higher populations affected broadleaves and grasses similarly.

Lakeland Agricultural Complex. There was an average of 84 grasses and 65 broadleaf weeds/sq ft at this site. Of these, 56% were grasses and 44% were broadleaves and five species accounted for 78% of all weeds. Thus the weed density appears to be much lower here than at the ARS. Densities of individual species are reported in Table 6b.

Both sites. Fall panicum is abundant at both locations. Giant and green foxtail and velvetleaf comprise more of the weed spectrum at LAC than ARS while redroot pigweed, common lambsquarters and large crabgrass are more common at ARS. Few perennial weeds common in established forages were found (yellow rocket, white cockle, etc.). Shepherd's purse is a common weed in new alfalfa seedings and in the final years of a forage rotation and both locations have an abundance of this weed.

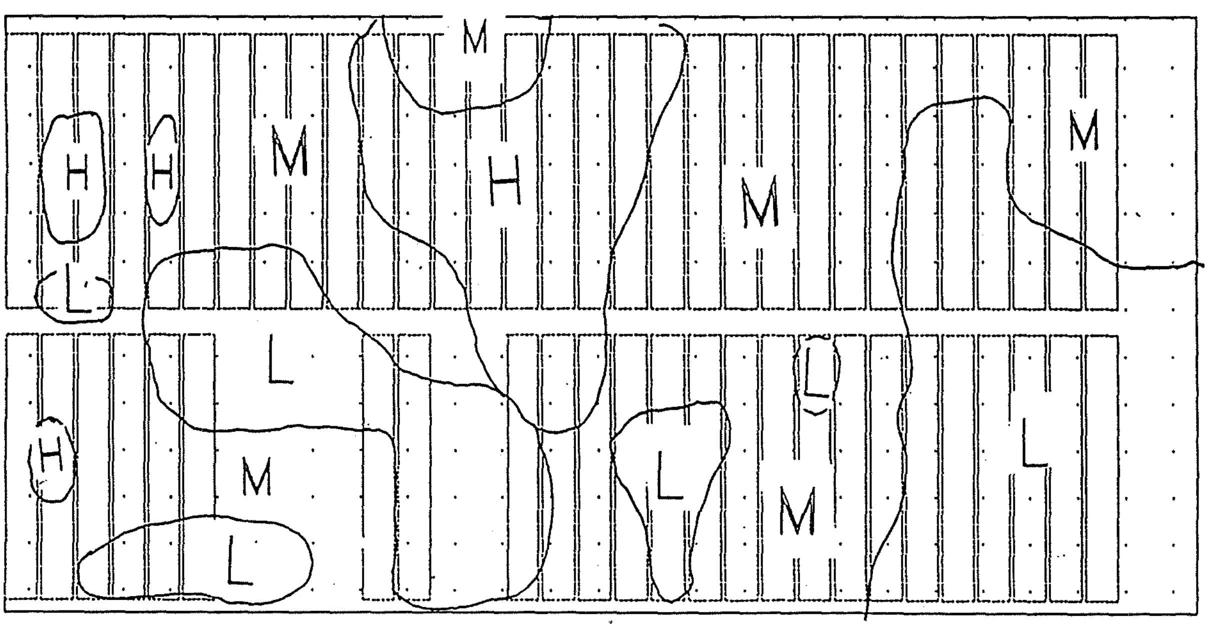
Maps 6a and 6b. Weed Density in the ARS Site as Determined by Soil Sampling in 1989.

a. Grass Weeds



Grass densities: L = low density (< 160 seedlings/sq ft.); M = medium density (160-390); H = high density (> 390)

b.Broadleaf Weeds



Broadleaf densities: L = low density (< 325 seedlings/sq ft.); M = medium density (325-975); H = high density (> 975)

Table 6a. The Weed Species and Their Relative Proportions Found in the Cropping Systems Trial at Arlington Research Station in 1989 (n = 162).

GRASSES (141/sq ft)	(%)	BROADLEAVES (582/sq ft)	(%)
Fall panicum	59.9	Redroot pigweed	43.6
L. crabgrass	22.5	Com. lambsquarters	34.0
Barnyardgrass	6.8	Shepherdspurse	10.2
Green foxtail	5.4	Yellow woodsorrel	4.1
Yellow foxtail	3.8	Speedwell purslane	3.1
Giant foxtail	1.6	E. Black nightshade	1.6
		Knotweed	1.1
		Penn. smartweed	0.9
		Velvetleaf	0.7
		Sow thistle	0.4
		Wild buckwheat	0.1
		Kochia	0.1

Table 6b. The Weed Species and Their Relative Proportions Found in the Cropping Systems Trial at the Lakeland Agricultural Complex in 1989 (n = 12).

GRASSES (84/sq ft)	(%)	BROADLEAVES (65/sq ft)	(%)
Fall panicum	46.4	Shepherdspurse	30.4
Giant foxtail	39.3	Velvetleaf	21.7
Green foxtail	10.7	Penn. smartweed	17.4
Barnyardgrass	3.6	Com. lambsquarters	13.0
		Redroot pigweed	8.7
		Sow thistle	4.3
		Galinsoga	4.3

3. Baseline Soil Fertility Sampling - Arlington, 1989

E. Schulte*

The field at Arlington was sampled using the same 90 x 90 ft grid pattern used for soil characterization and yield measurements. Every other grid point was sampled in each row, staggering the points in each row. That is, even-numbered columns were sampled in one row, odd-numbered columns in the next row. Samples were taken at depths of 0 to 15, 15 to 30, 30 to 60 and 60 to 90 cm. The first two increments were taken with 3.2-cm Oakfield probe, the second two with a 1.9-cm diameter probe. Four cores were composited at each sampling site.

The 0- to 15-cm samples were analyzed for pH, SMP buffer pH, organic matter, Bray-1 P and K, exchangeable Ca and Mg and sulfate-S by the UWEX Soil & Plant Analysis Lab. The remaining samples were dried, ground, and saved for future analysis.

Analytical Results. The spacial distribution of available potassium and phosphorous (0-15 cm), were entered in GIS format (not shown). The range, mean and standard deviation for each test are shown below (Table 7).

Table 7. Soil Test Data for Arlington Surface Samples (0 to 15 cm; n=162).

Soil test	Range	Mean	SD	Plano mean from soil test summary[1]
pH	5.7 to 6.9	6.5	0.22	6.4
O.M.,%	2.5 to 6.2	4.4	0.64	
P, lbs/A	72 to 400	203	71	125
K, lbs/A	210 to 999	519	181	342
Ca, lbs/A	3100 to 4600	3470	255	3370
Mg, lbs/A	1100 to 1720	1260	98	1060
S, lbs/A	5 to 40	19	5	18

[1] Mean of 5,540 Plano silt loam samples in Wisconsin labs from 1/1/82 to 12/31/85.

Soil pH, organic matter, Ca, Mg, and S are all within the normal range for this soil. Available P and K levels are high, but 13% of 5,540 Plano silt loam soils analyzed in Wisconsin labs from 1982 through 1985 had more than 125 lbs P/A and 25% had over 400 lbs K/A. With an estimated P buffering capacity of 2 lbs. P removal per 1 lb decrease in soil P and 23 lbs P per 160 bu of corn grain, it will take 15 years with continuous corn to drop soil P to a level where response to P is likely. Use of starter fertilizer containing P even at minimal levels will lengthen this period, as will P extracted from the subsoil. Thus, this field can sustain high yields of corn for probably 25 years or more with only a minimum of starter fertilizer (5 lbs P, 5 lbs K/A). Nevertheless, this is the situation on many farms and decreased soil test levels of P and K can be monitored regardless of the starting point. Deficiency levels obviously will occur sooner when initial soil P and K are lower.

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4. SOIL STRENGTH MAPPING - CONE INDEX SUMMARY

R. T. Schuler*

As a plant grows, its roots must penetrate the soil to obtain water and nutrients. Soils with high strength create large resistance for the developing roots, which may limit plant growth and the resulting crop yield. Pushing a steel cone vertically into the soil and measuring the resistant force is one method of determining soil strength. The measured force divided by the base area of the cone provides a value referred to as the cone index, which is an indication of soil strength.

Although soil strength is a major factor influencing cone index, there are many other important factors that affect soil strength. Soil type, moisture, and bulk density are some of these factors.

The standardized procedure for obtaining cone index consists of pushing a steel cone (30 degrees and 1.28 centimeter base diameter) into the soil at a constant speed of 46 centimeters per minute. As the cone is pushed through the soil, the required force is recorded every 0.4 seconds. At the same time, the position of the cone is recorded. Using the base area of the cone and the force, the cone index, a pressure in kiloPascals(kPa), is determined for every 0.4 seconds of vertical cone movement into the soil. Values are determined from the soil surface to a depth of 56 centimeters. For discussion purposes, the cone index values are averaged for each two centimeters of soil depth to 56 centimeters.

Arlington Research Station (Columbia County)

Cone index measurements were taken to evaluate the soil strength throughout the field area where plots were being established. The cone penetrometer measurements were taken on June 8 and 9, 1989. The data were evaluated with respect to differences in soil strength in the field due to previous cropping practices and the presence of compaction due to tillage practices such as moldboard plowing. The primary purpose of these measurements was to obtain baseline data on the soil strength at the initiation of this long-term study.

A total of 139 penetrations were made at the Arlington Research Station. The data summarization is organized on the basis of the crop grown during the 1988 growing season (see map 3a). The areas which had alfalfa in 1988 were also divided into north and south halves. Table 8 lists seven field areas evaluated and the number of penetrations in each.

* Professor, Agricultural Engineering Department, University of Wisconsin-Madison.

Table 8. Field Areas and Number of Penetration Measurements.

Crop	Number of measurements
Alfalfa, 2nd year, North half	20
Alfalfa, 2nd year, South half	24
Alfalfa, 1st year, North half	24
Alfalfa, 1st year, South half	27
Soybeans	8
Corn for silage	11
Corn for grain	24

The cone index was plotted against depth to evaluate where differences occur between field areas and at various depths, shown in Figures 2 and 3. The alfalfa fields were divided into north and south halves due to their size and some visual differences in the soil. The recorded values for cone index are typical for silt loam soils at 20 to 25 percent gravimetric moisture basis, which was present at the time of the cone index measurements. In the alfalfa areas, a high soil strength layer was present at a depth of 20 to 30 cm, shown in Figure 2. For the first-year alfalfa, north half, the cone index increases from 24 kPa near the soil surface to 1791 kPa at a soil depth of 28 cm. At this point, the cone index decreases with increased depth until 40 cm where the index is 1355 kPa. A probable cause for this layer may be moldboard plowing, which occurred earlier in the season. This layer was less noticeable in the second-year alfalfa areas, which can be attributed to an extra season of freezing-thawing and wetting-drying cycles. In the 8- to 16-cm depth, the southern halves of both the first- and second-year alfalfa areas have a higher cone index. This may be caused by a shallower depth of loess (see map 3). From 40 to 56 cm, cone index differences among alfalfa areas are very small.

For the areas where corn and soybeans were grown in 1988, a layer of high soil strength did not appear to exist (Figure 3). To provide a reference, cone indices for the southern half of the first-year alfalfa area were also plotted in Figure 3. The cone index is much lower for the soybean and corn silage areas from 14 to 28 cm below the soil surface, which coincides with a lower bulk density found in the soil evaluation portion of this study. For 32 to 56 cm below the soil surface, very little differences in cone index existed among soybeans, corn silage, corn grain, and the southern half of first-year alfalfa.

Lakeland Agricultural Complex (Walworth County)

In 1990, a set of baseline penetrometer measurements was collected in 24 plots with three replicate measurements in each plot. A total of 72 sets of data was collected. The six plots in each of the four blocks were chosen based on the cropping treatments that had been initiated in May of 1990.

A complete randomized block design was used to evaluate the impact of treatments and blocks. Blocks 1 and 2 were quite similar and blocks 3 and 4 were quite similar. But a difference did exist

Figure 2. Cone Index Versus Depth for Alfalfa Fields used for the Wisconsin Integrated Cropping System Study, Arlington Research Station

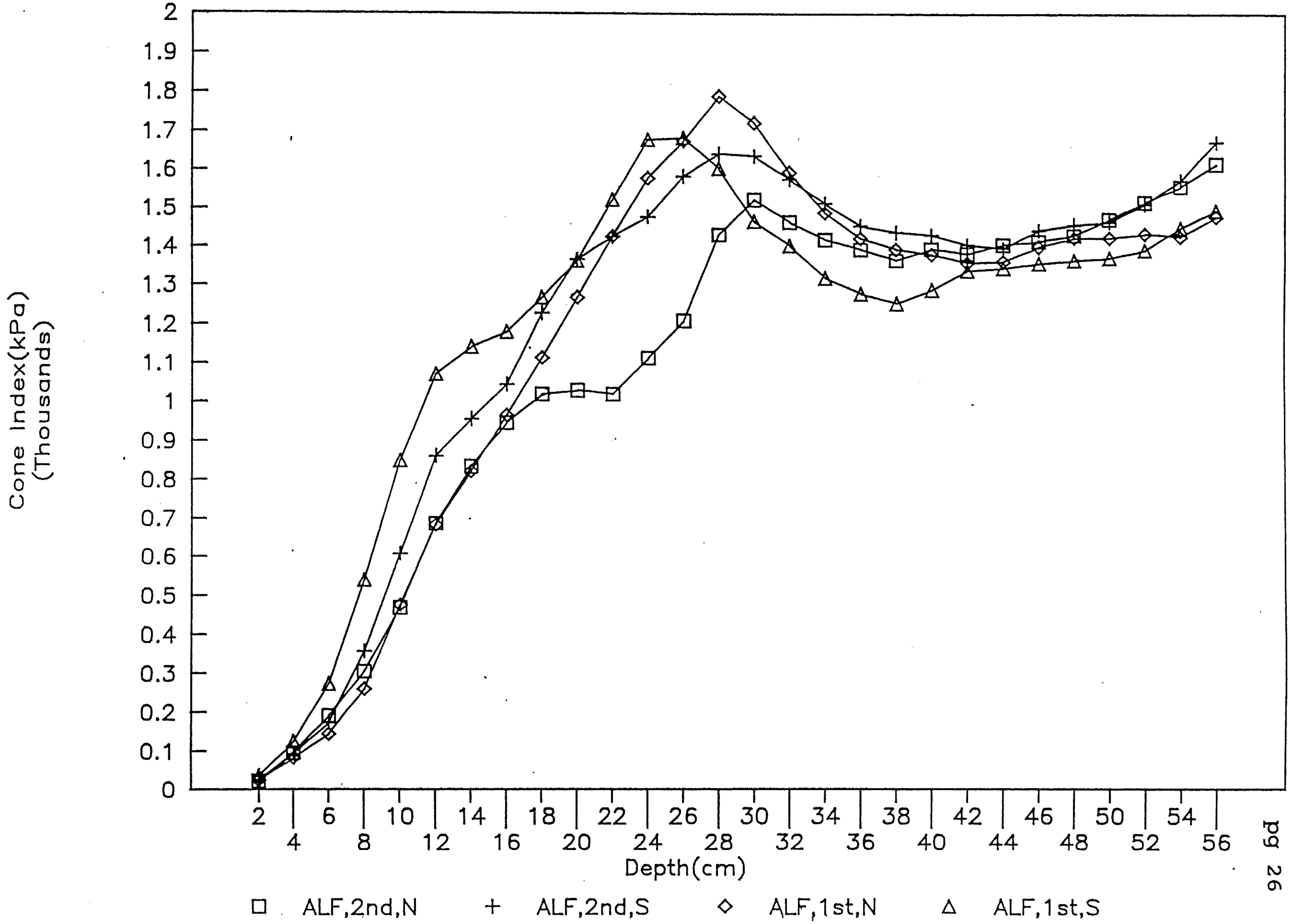
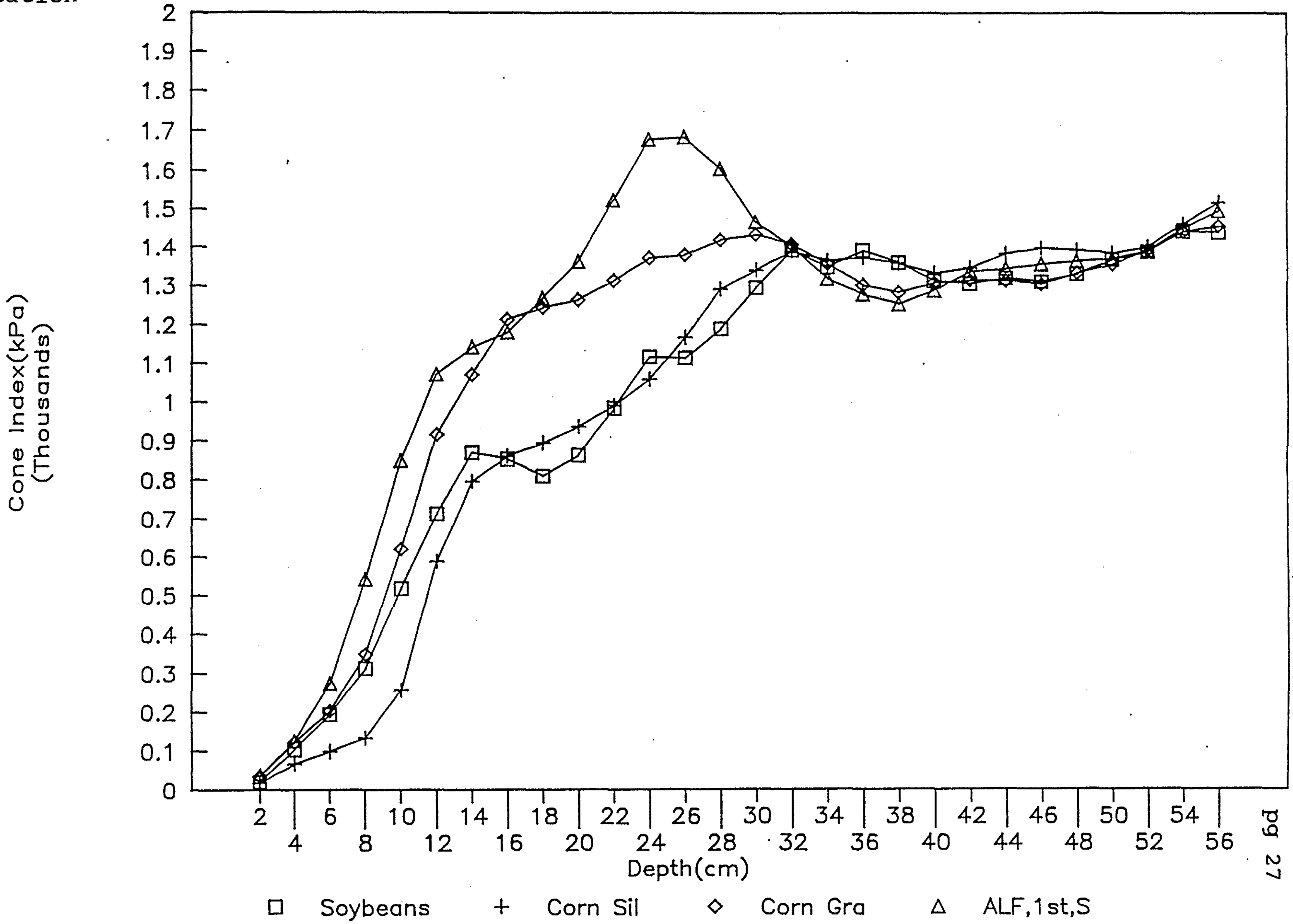


Figure 3. Cone Index Versus Depth for Soybean, Corn Silage, Corn Grain, and South Half (first) Alfalfa Field used for Wisconsin Integrated Cropping System Study, Arlington Research Station



between the two pairs of blocks. This was attributed to soil moisture differences. The penetrometer measurements on blocks 1 and 2 were completed on August 16 when the gravimetric soil moisture was 15 percent and blocks 3 and 4 were completed on August 23, when the soil moisture was 30 percent. Soil moisture has a very significant effect on cone index.

For the six cropping systems in the first year, the cone index for the oats plots was higher than corn, narrow row beans, and wide row beans for the soil from the surface to 10 centimeters below the surface. Only the oats plots exhibited a layer of high soil strength, which may be attributed to spring manure application. The plot designated as pasture had greater resistance than the corn and wide row beans. For the subsoil, the resistance for corn plots was greatest compared to the other treatments.

In general, the cone index measurements for these plots were within the range of published data when considering the soil moisture. In blocks 1 and 2, cone indices reached 4000 kPa which is in the range normally found is a silt loam soil at 15 percent moisture. For blocks 3 and 4, the cone indices reached 2000 kPa which is normal for a silt loam soil at 30 percent soil moisture.

In summary, the baseline data obtained were representative for this soil. It is anticipated that future cone index or soil strength measurements will be influenced by the cropping systems used in the Wisconsin Integrated Cropping System Study.

IV. RESULTS FROM THE FIRST TWO YEARS

A. Yields, Weather, and Agronomic Calendar in 1990 and 1991

A. Wood, J. Hall*, D. Mueller, and J. Posner**

1990 Total growing season rainfall during the 1990 season was close to the 30-year average (see Table 9). The combination of a wet May (5.53 in) and the more poorly drained soils at the Lakeland Agricultural Complex (LAC) however, resulted in delayed planting. New seedings went in May 30th, about 6 weeks later than recommended, and corn was planted a month late. The 104-day Pioneer 3578 hybrid was replaced by a 90-day hybrid (Pioneer 3790). Heavy spring rains fell in June (6.32 in) at the Arlington Research Station (ARS) after timely planting took place. Corn (165 bu/A) and soybean yields (55 bu/A) were above target yields at both sites (see Table 10). Seeding year hay yields were poor at LAC due to the late planting and were not harvested but clipped twice to reduce weed infestations. At ARS hay yields (4 t dm/A) were excellent. During this first year, the oats in rotation five were harvested as oatlage. It was subsequently decided that in future years the oats will be taken for grain and straw. The agronomic diary of 1990 activities for both sites can be found in Appendix V A (LAC) and Appendix VI A (ARS).

1991 Timely planting at both sites was possible in 1991. Atypically warm May temperatures adversely affected the winter wheat crop and yields were only mediocre (64 bu/A). The ensuing summer was dry and only 50% of the normal May thru August precipitation fell at the Lakeland Agricultural Complex (8.2 in.); 10 inches (54% of normal) fell at the Arlington Research Station. Continuous corn yields plummeted to 121 bu/A at LAC, while corn following soybeans produced well considering the poor rainfall (145 bu/A). At ARS continuous corn yields were 160 bu/A while the rotated corn yielded 185 bu/A. As a result, one can calculate that the "rotation effect" increased corn yields by 20% at LAC and 15% at ARS. Soybean yields were good at both sites and drilled beans (R_2) outyielded row beans (R_3) by 19% at ARS and 12% at LAC.

Hay yields were outstanding at ARS with established plots producing over 5.5 t dm/A and the new seedings also producing well (Table 10). At LAC the dry summer adversely affected the established plots (3.5-4 t dm/A) as well as the new seedings. In rotation three, the wheat was frost seeded with red clover and by Novemeber the red clover roots and tops biomass contained 125 lb N/a at ARS and 45 lb N/a at LAC. The agronomic diary of 1991 activities for both sites can be found in Appendix V B (LAC) and Appendix VI B (ARS).

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* Superintendent and Research Supervisor, respectively at Lakeland Agricultural Complex

** Superintendent and Research Supervisor, respectively at Arlington Research Station

Table 9. Arlington Research Station: Inches of Rainfall and Deviation from 30-year Mean[1]

Month	1991	1990	1989	30-yr avg 1959-1988
April	4.52(+1.53)	2.49(-0.50)	1.36(-1.63)	2.99
May	1.91(-1.28)	4.25(+1.06)	1.76(-1.43)	3.19
June	2.63(-1.17)	6.32(+2.52)	2.01(-1.79)	3.80
July	3.75(+0.29)	1.57(-1.89)	3.78(+0.32)	3.46
August	1.78(-2.11)	5.36(+1.02)	4.34(+0.45)	3.89
September	4.70(+0.87)	1.22(-3.01)	3.83(-0.40)	4.23
Growing Season Total	19.29	21.21	17.08	21.56
Yearly Total	35.33	34.15	24.30	31.14

Lakeland Agricultural Complex: Inches of Rainfall and Deviation from 30-year Mean Cropping Systems trial

Month	1991[2]	1990[2]	1989[3]	30-yr avg 1959-1988[3]
April	4.15(+0.35)	2.47(-1.33)	1.53(-2.27)	3.80
May	2.32(-0.94)	5.53(+2.27)	2.00(-1.26)	3.26
June	1.56(-2.37)	5.26(+1.33)	1.23(-2.70)	3.93
July	2.45(-1.90)	2.51(-1.84)	6.42(+2.07)	4.35
August	2.04(-1.97)	3.93(-0.08)	3.45(-0.56)	4.01
September	4.94(+0.88)	0.96(-3.10)	4.78(+0.72)	4.06
Growing Season Total	17.46	20.66	19.41	23.41
Yearly Total[3]	38.66	40.86	27.35	37.53

[1]Data from Arlington National Weather Service Cooperative station.

[2]Data from Lakeland Ag. Complex Automated Weather Station.

[3]Data from Lake Geneva National Weather Service Cooperative station (7 miles southeast of the Lakeland Ag. Complex).

Table 10. Yields During the 1990 and 1991 Growing Seasons at the Wisconsin Integrated Cropping Systems Trial.

Rotation	Crop	Target	Yields per acre			
			Arlington Research Station		Lakeland Agricultural Complex	
			1990	1991	1990	1991
R_1	Corn	150 bu	166	160	164	121
R_2	Soybeans	55 bu	57	60	53	59
	Corn	160 bu	---	185	---	145
R_3	Soybeans	40 bu	52	51	54	51
	Wheat	60 bu	---	64	---	64
	Corn	120 bu	---	---	---	---
R_4	D.S. Alfalfa	3 t	4.3	5.8	0	3.9
	Est. Alfalfa	5 t	---	5.1	---	.5
	Est. Alfalfa	5 t	---	---	---	---
	Corn	160 bu	---	---	---	---
R_5	Oats/Alf	60bu/2t	2.1t[1]/2.1t	55bu/1.4t	.9t[1]/0t	54bu/.5t
	Est. Alfalfa	4 t	---	5.8	---	3.5 t
	Corn	120 bu	---	---	---	---
R_6	Grazing[2]	4 t	4 t	4.7	0	3.4 t

[1] During 1990 the oats were harvested as oatlage at both sites.

[2] During 1990 and 1991, rotation 6 was cut as a hay field, not grazed.

B. Earthworm Ecology in Agriculture: 1990 and 1991 Data from the Wisconsin Integrated Cropping Systems Trial

G. G. Brown and J. L. Posner*

INTRODUCTION

Earthworms are considered biological indicators of soil health (Curry and Good, 1992; Daugbjerg et al., 1988; Lavelle et al., 1989). They have significant effects on soil chemical, physical, and biological properties and processes. Conversely, soil properties, climate, and agricultural practices affect earthworms (Figure 4). Soil physical and chemical limiting factors include organic matter content and quality (C:N ratio), temperature, moisture, pH, and texture. Biological constraints include the abundance of microflora and fauna and interspecies interactions, including predation and exclusion by competition. This report will discuss briefly the positive physical and chemical effects of earthworms on soil properties and processes, the effect of agricultural practices on earthworm populations, and finally, it will review the potential effects of the Wisconsin Integrated Cropping Systems Trial (WICST) on earthworm populations at the Arlington Agricultural Research Station (Columbia Co.), and at the Lakeland Agricultural Complex (Walworth Co.).

EARTHWORMS AND SOIL PROPERTIES

Changes in the soil physical, chemical, and biological properties and processes induced by earthworms are achieved by their burrowing within the soil and casting above and below the soil surface. The extent of the changes induced by their activity will depend on the species of earthworm and its ecological category, i.e., surface dwellers and feeders (epigeics), subsurface dwellers and surface feeders (anecics) and subsurface dwellers and feeders (endogeics) (Lavelle et al., 1989). The soil and the microflora and fauna living in the soil influenced by earthworm activity have been called the "drilosphere" (Lavelle 1988). Chemical and biological transformations in the drilosphere include higher concentrations of nutrients and plant growth regulators than uningested soil, increased humification and stabilization of organic matter, higher enzymatic activities, higher numbers of beneficial microflora, and lower numbers of plant pathogenic fungi, bacteria and nematodes (Bhatnagar, 1975; Businelli et al., 1984; Dash et al., 1979, 1980; Day, 1950; Krishnamoorthy and Najranabhaiah, 1986; Lee, 1985; Loquet et al., 1977; Roessner, 1986; Simek and Pizl, 1989; Striganova et al., 1989; Syers and Springett, 1984; Tomati et al., 1987, 1988; Yeates, 1981). Physical transformations include increased water

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stability of dried casts, higher infiltration rates in the burrows, greater incorporation of surface organic materials and fertilizers, and increased pore space (aeration) (Lee, 1985; Mackay and Kladivko, 1985; Shipitalo and Protz, 1988; Springett, 1985; Zachmann and Linden, 1989). Graff (1971) estimated that lumbricid earthworms turned over as much as 25% (by weight) of the A_h horizon (0-10 cm) each year in a German pasture. These chemical, physical, and biological changes to the soil environment promoted by earthworms have resulted in increases in crop yields (Figure 5) of up to 200-300% in some cases (Hopp and Slater, 1949; Rhee, 1965).

However, not all the transformations to the soil caused by earthworms to the soil are good. For instance Edwards et al. (1990, 1992) reported that earthworm burrows open to the soil surface could be important channels in the downward movement of nitrate and other water-soluble chemicals. Svensson et al. (1986) and Elliot et al. (1991) reported increased denitrification in earthworm casts, and Hutchinson and Kamel (1956) and Hampson and Coombs (1989) reported the spread of certain plant pathogenic fungi by earthworms.

AGRICULTURAL PRACTICES AND EARTHWORM POPULATIONS

Agricultural practices affect earthworm populations primarily by changing the soil environment as a habitat for earthworm growth and activity. Different practices can have varying effects, either positive or negative, on earthworm populations. Practices that negatively affect earthworms include: plowing and cultivating, applying pesticides or wastes toxic to earthworms (e.g., industrial or sewage sludge), extensive fertilization without liming (leads to soil acidification), application of anhydrous ammonia, compaction, and row crop monocultures (Aritajat et al., 1977; Bostrom, 1986, 1988; De St. Remy and Daynard, 1982; Edwards, 1980; Edwards and Lofty, 1975, 1982a; Hopp, 1947; Lofs-Holmin, 1983; Ma et al., 1990). Factors which benefit earthworms are: limited or no-tillage, mulching, moderate fertilization, application of manure and organic fertilizers, liming of acid soils, protective soil surface cover overwinter, irrigation of drier soils, crop rotations with legumes, and surface and subsurface drainage (Edwards and Lofty, 1982b; Gerard and Hay, 1979; Hopp and Hopkins, 1946; House and Parmelee, 1985; Madge, 1981; Scullion and Ramshaw, 1987; Slater and Hopp, 1947; Teotia et al., 1950; Tisdall, 1985; Westernacher and Graff, 1987).

EARTHWORMS IN THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIAL

To study earthworm populations in the WICST first of all a literature search was made to find out more about their basic ecology, what effect agricultural practices have on earthworms and which are the best sampling methods. Several hypotheses formulated at the outset of the experiment were:

1 - Earthworm populations are lower in cash grain systems than in forage systems due to poorer ground cover (R1+R2+R3<R4+R5+R6).

2 - Earthworm populations decrease with increasing soil disturbance (tillage and cultivation) (R6>R4>R5>R3>R2>R1).

3 - Earthworm populations increase with an increasing legume component (in number of years) in the cultivated systems due to the higher quality of legumes as food for earthworms (R6>R4>R5>R3>R2).

4 - Systems with more winter ground cover will have more earthworms than those with less winter cover (R3>R2).

The resulting sequence of earthworm abundance (in decreasing order) was identified from the hypotheses: R6>R4>R5>R3>R2>R1, where R1 = continuous corn, R2 = narrow row soybeans/corn, R3 = wide row soybeans/ wheat-red clover/corn, R4 = alfalfa/alfalfa/alfalfa/corn, R5 = oats-alfalfa/alfalfa/corn, and R6 = red clover-timothy-brome pasture. These hypotheses were primarily derived from previous work done by Henry Hopp and co-workers in Pennsylvania in the 1940's (Hopp, 1947; Hopp and Hopkins, 1946; Hopp and Linder, 1947; Slater and Hopp, 1947). Very little work has been done since then on this subject in the United States and no formal survey of the earthworm fauna and its distribution has been done in Wisconsin. The results of the WICST therefore represent a pioneering attempt at quantifying the earthworm distribution in different cropping systems in Wisconsin.

Sampling Methodology

To sample earthworm populations, the handsorting method was chosen since, with careful sorting and the help of sieves, this method can be very efficient at estimating population density (Axelson et al., 1971; Lee, 1985). Unfortunately this method often causes an underestimation of earthworm abundance because small young individuals are difficult to see and often missed in the sorting process.

Samples were taken with a cylindrical metal core 5" in diameter and 10" deep (12.5 x 25 cm) and hand-sorted through a 1/8" sieve. Cocoons, young, and mature individuals were separated. Most endogeic earthworms live in the top 25 cm and would thus be included in the cores; however, some deep burrowing species, e.g., *Lumbricus terrestris* (the nightcrawler), are often found deeper within the soil and might therefore be excluded from these samples. Two samples were taken per plot (equivalent to 1 sample every 0.4 acres) totaling 48 samples for each location (eight for each treatment). This relatively low sampling density was chosen due to time constraints. Only the 24 original plots (four per treatment) were sampled at subsequent sampling dates because of the staggered start of the trial. The first sampling date (Spring 1990) was when the first treatments were installed after a year of homogenization (field corn). Samples were taken in mid-spring (4/27/90 and 5/2/91 at Arlington; 5/9/90 and 5/2/91 at LAC) and fall (9/23/90 and 10/15/91 at Arlington; 10/5/90 and 10/26/91 at LAC) since these are the periods of maximum activity.

Results

The earthworm fauna of the two locations of the trial consisted primarily of three lumbricid species commonly found in Midwestern US agricultural fields: *Aporrectodea tuberculata*, *Aporrectodea turgida* (both endogeic) and *Lumbricus terrestris* (anecic). The latter species appeared only rarely in the samples, due to the shallow sampling depth. Earthworm populations at both sites were fairly similar. The soils at the sites are both prairie- derived Mollisols of similar texture (silt loams) and rich in organic matter, the only difference between the two being the presence of a high water table at LAC. Results of the four sampling times are shown in Figure 6 and Figure 7. The initial earthworm population at the beginning of the trial (Spring 1990) was 279 $\pm$ 101.14 per m^2 at Arlington and 197 $\pm$ 87.37 per m^2 at LAC. There was considerable variability between plots, probably due to residual effects of previous crops (See Maps 5a and 5b) and the relatively low sampling rates. Despite this initial variability, the trend for increased abundance in forage systems was clearly noticeable in subsequent samples. In contrast, cash grain systems showed either stationary or decreased earthworm abundance. These results confirm hypothesis #1 and are in agreement with the findings of Hopp and co-workers. A brief look at the cultural practices involved in each system sheds some light as to the reasons for these trends:

1- Continuous corn requires the use of corn root worm insecticides, known to be toxic to earthworms (Haque and Ebing 1983). Other factors detrimental to earthworms are: lack of legumes and cover crop winter-kill; and, the presence of tillage and cultivation. Therefore, this treatment should support the lowest earthworm population and, in fact, the data confirm this;

2- Narrow row soybeans/corn represents a lesser extreme than continuous corn, including a 50% legume component. However, this treatment still receives herbicides, some of which may be mildly toxic to earthworms, and it is spring disked (for soybeans) and chisel plowed (after corn), disturbing the soil and leaving little residue for winter protection. These are practices that can potentially lower earthworm populations;

3- Wide row soybeans/wheat-red clover/corn displays a greater abundance of earthworms than R1 and R2. This rotation includes a overwintering small grain followed by a legume green manure crop. These practices benefit earthworm populations by providing winter protection (wheat) and a rich food source (clover). However, at the same time, this rotation also includes a high degree of surface soil disturbance in the corn and soybean years (rotary hoeing, cultivation). Perhaps these are balanced out by increased winter protection and a greater legume component. Evidence for this can be seen in the figures, which show an increase in earthworm numbers in the fall 1991 sampling;

4- Three years of alfalfa/one year of corn promises to be one of the most beneficial treatment for earthworm populations. Frequent tillage in the cash grain systems stifles earthworm activity and kills many of the surface dwelling earthworms as well as destroying anecic and endogeic burrows. A reduction in tillage, abundance of rich food (alfalfa) for a longer period of time, winter surface protection, and additions of manure in this rotation promise to result in very high earthworm populations. These in turn, are likely to promote significant changes to the soil, improving its physical and chemical conditions for plant root growth and consequently, crop yield (Figure 5). In fact, the data show this rotation as having the highest abundance of all rotations in the fall of both years;

5- Companion oats-alfalfa/alfalfa/corn also shows such promising features as a reduction in tillage, abundance of rich food (alfalfa), winter surface protection, and additions of manure. However, the shorter alfalfa phase in this system might lead to a slight disadvantage over the previous rotation. Figure 6 and 7 show a clear upward trend from the original numbers, though these seem to be somewhat lower than those of R4 overall. This difference will probably be attenuated when the corn year disrupts the cycle one year more often than in R4;

6- Pasture has a stabilizing effect on earthworm populations. The constant inputs of organic matter by the roots and manure provide abundant food, the lack of tillage and presence of soil surface protection overwinter have an ameliorating effect on the soil environment. At the fall 1991 sampling, earthworm populations were still on the rise. However, it can be expected that they will reach a plateau at some high level. In this rotation, as in R4, earthworms are expected to have a highly significant beneficial effect on soil processes.

In situ observations of earthworm populations in agricultural systems, including seasonal abundance studies such as this one, will give ideas as to how the soil functions in relation to its habitat for earthworms, and continued empirical work on earthworm biology and ecology will provide the basis for estimating the contribution of earthworms to the functioning of the soil as a habitat for plant roots. Much about the interactions between earthworms and agricultural practices and the effects of earthworms on the soil of different cropping systems remains to be researched. In the two years of monitoring earthworm populations in the WICST, several trends have already established themselves and continued sampling will provide the basis for comparisons between treatments (testing the hypotheses).

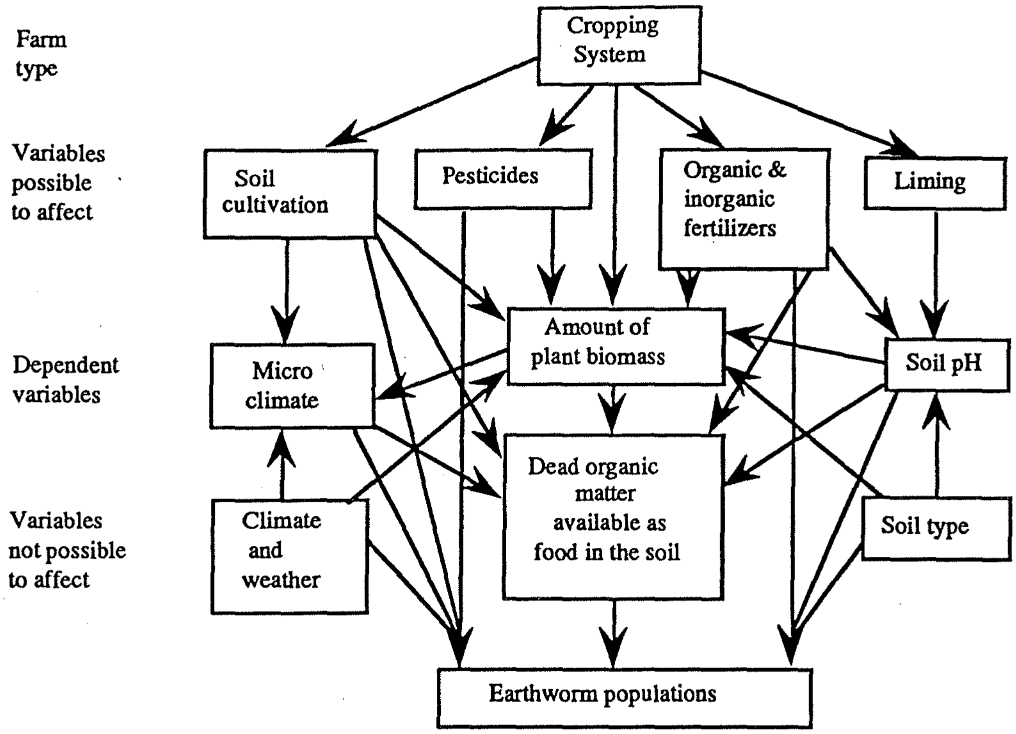


Figure 4- A diagram of the variables influencing the earthworm populations in arable soils (adapted from Lofs Holmin 1983).

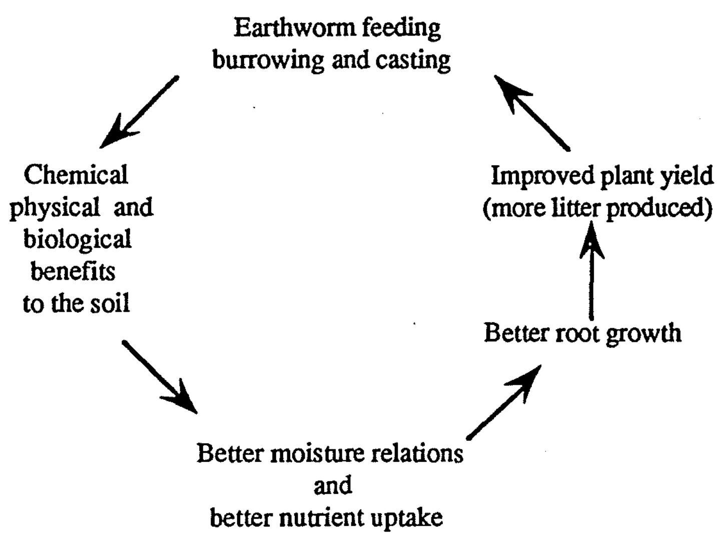


Figure 5- Interrelationships between earthworm activities, soil properties and plant growth (modified from Syers and Springett 1983).

Figure 6 - Earthworm abundance (No. m-2) in the WICST at Arlington in the Spring and Fall of 1990 and 1991 (mean + se).

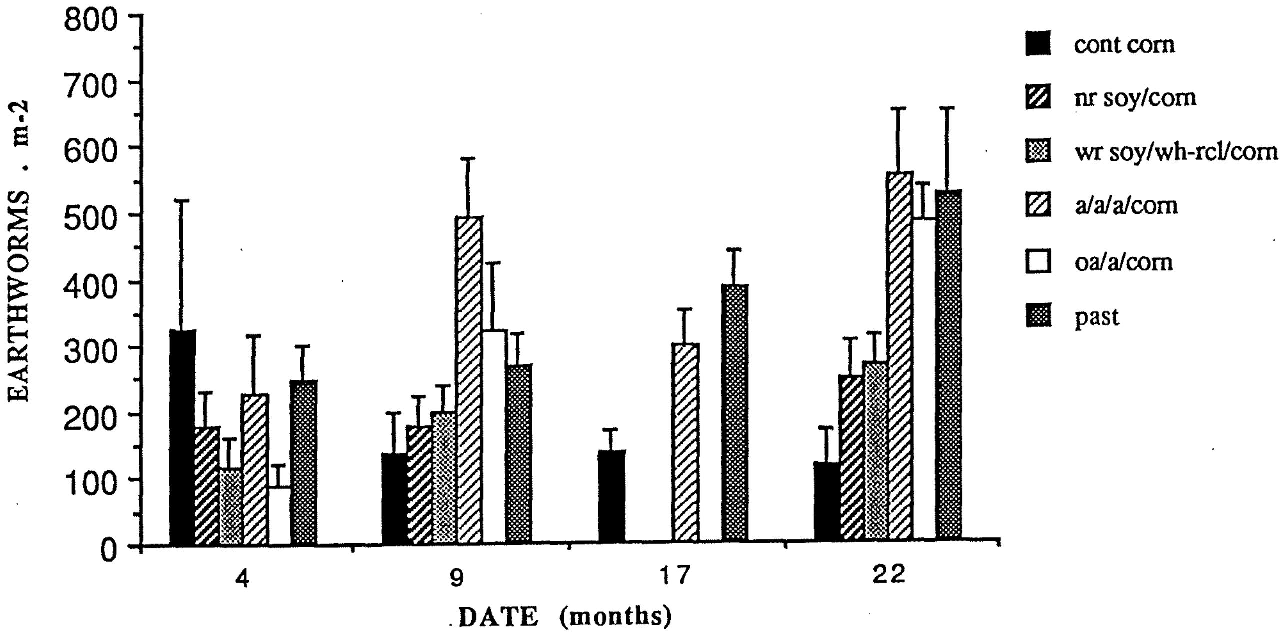
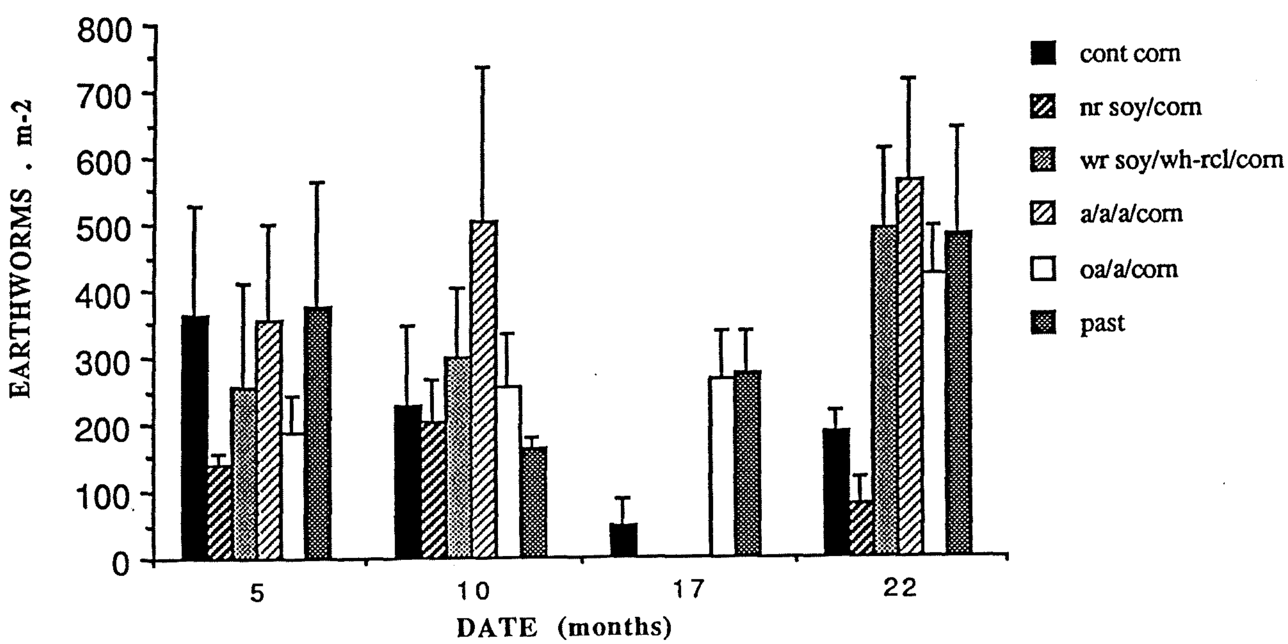


Figure 7 - Earthworm abundance (No. m-2) in the WICST at the Lakeland Agricultural Complex in the Spring and Fall of 1990 and 1991 (mean + se).



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C. Weed Seed Monitoring: Results from 1990 and 1991

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Objectives. We will obtain baseline data on the density and diversity of weed species in each replication of each rotation as it enters the rotation scheme in 1990 and then compare the effects of level of input for the cash grain and forage systems in terms of changes in weeds abundance and species shifts at later times. Specifically, we hope to test the following hypotheses.

Hypotheses Regarding Weed Seeds/Seedlings

A. Cash Grain Systems
1. With herbicides as part of the control program (R1 and R2), there will be fewer weed escapes and weed seed populations will decline more rapidly than in the rotation with only mechanical weed control practices (R3).
2. Weed species shifts (especially to annual grasses like fall panicum) will occur more rapidly when continuous corn is produced (R1) than when more diverse rotations are used (R2 and R3).

B. Forage Systems
1. Weed seed populations will decline more rapidly in the longer term forage rotation with herbicides (R4) than in the shorter one (R5) because more weed seeds will be produced in the shorter rotation without herbicides.
2. Rotational grazing (R6) will eventually have fewer weed seeds than alfalfa based forage systems (R4 and R5).

C. Cash Grain vs. Forage Systems
1. Weed seed populations will decline more slowly in a long term forage rotation (R4) than in rotations with annual tillage (R1, R2 and R3).
2. The permanent pasture system (R6) will eventually have the least weed seed of all rotations.

Methods. To determine weed density and species diversity, the plots were divided into approximate thirds and one subsample was collected in each third of every plot entering the rotation in 1990. Due to the staggered entry of the rotations, only six treatments (of the total of 14) were initiated and sampled in 1990. A total of 72 subsamples were collected (six rotations x 4 replications x 3 subsamples per plot) at both the ARS and LAC sites, representing a total of 30 cores per plot (3 subsamples x

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10 cores each) and 120 soil cores per treatment (4 replications x 3 subsamples per plot x 10 cores per subsample).

Cores were 0.75 inch in diameter and were taken to a 6 inch depth, giving approximately 1.5 lb of soil per sample. The soil was stored at 38°F until mid May. Each subsample was mixed with an equal weight of silica sand and placed in a plastic tray with small holes in the bottom. The soil was approximately 1 inch deep in the trays. The trays were placed on a capillary mat in a greenhouse.

As the seeds germinated, the weed seedings were identified and removed. After several weeks, germination ceased. The soil/sand mixture was dried, remixed, returned to the flat and watered for another germination cycle. This process was repeated three times and all germination observations were completed by early October. The number of seedlings for the three subsamples was totaled and an average number per plot was calculated and this value was transformed into the number of seedlings per square foot.

Results

The number of weed seedlings measured was relatively constant for all rotations in the baseline year (Table 11). The weed populations are higher in replication III at the Arlington Research Station (ARS) and in replication IV at the Lakeland Agricultural Complex (LAC) site (data not shown). Since 1989, there has been a general decline in weed populations for the newly initiated plots due to good weed management the years these plots were in filler corn.

Weed seed populations declined at both sites in the continuous corn system and remained constant in the corn-soybean rotation. Both of these systems include herbicide use and this is working to prevent weed seed increases. In contrast, the systems based only on cultural and mechanical controls (R3 and R5) allowed weed seeds to increase substantially (Table 11). In R3, we did not achieve the level of control desired in the soybeans and in R5, annual grasses appeared and set seed following the oat harvest. At the ARS site, the use of herbicides in R4 successfully suppressed weeds but not at the LAC site. Weed seed populations increased greatly in all forage systems at LAC but only in R5 at ARS. This was due to the poor forage growth in 1990 at the later site that resulted in little crop competition with weeds.

The weed composition at ARS was predominantly broadleaves and the ratio of these to grasses was similar for R1 and R2, but shifted to more broadleaves in R3 from 1990 to 1991 due to the difficulty of controlling common lambsquarters and pigweed with rotary hoeing and cultivation in soybeans (Table 12). The proportion of broadleaf weeds in R1 was similar at both sites, but annual grasses were much more abundant in R2 and R3 at LAC. This was due to giant foxtail that escaped control in the

Table 11. Baseline and Second Year Weed Population Data at ARS and LAC for 1990 and 1991.

Cropping system	ARS 1990	ARS 1991	LAC 1990	LAC 1991
Cash grain based systems				
90-91 crops	(-----------number/sq ft			-----------)
1. c-c	491	223	231	103
2a. sb-c	475	559	231	193
2b. c-sb	-	206	-	87
3a. sb/w-w/rc	223	511	215	366
3b. c-sb/w	-	734	-	89
Forage based systems				
4a. alf-alf	551	351	318	1144
4b. c-alf	-	348	-	120
5a. o/alf-alf	489	850	337	693
5b. c-o/alf	-	598	-	122
6. pasture	427	467	160	1002

Table 12. Baseline and Second Year Weed Composition Data at ARS and LAC for 1990 and 1991.

Cropping system	ARS				LAC			
	bdlv		grass		bdlv		grass	
	90	91	90	91	90	91	90	91
Cash grain based systems	(---------------Percent							---------------)
90-91 crops								
1. c-c	87	87	13	13	88	82	12	18
2a. sb-c	78	77	22	23	40	30	60	70
2b. c-sb	-	79	-	21	-	87	-	13
3a. sb/w-w/rc	71	82	29	18	47	17	53	83
3b. c-sb/w	-	88	-	12	-	52	-	48
Forage based systems								
4a. alf-alf	85	86	15	14	61	28	39	72
4b. c-alf	-	64	-	36	-	82	-	18
5a. o/alf-alf	84	68	16	32	35	17	65	83
5b. c-o/alf	-	80	-	20	-	60	-	40
6. pasture	84	78	16	22	58	10	42	90

* Filler corn, weed seeds not measured

soybeans. In the forage systems, grasses increased in all cases except for R4 at ARS. The increase was most dramatic in R6 at LAC and was due to many foxtail weeds going to seed as the pasture was established late, on May 30, 1990.

In 1991, the cash grain systems at the ARS site averaged 20 million weed seedlings per acre and the forage systems, 23 million. These are not the populations of weeds that would appear in a field in one season. We sample to a 6-inch depth and place all seeds in only a 1-inch layer of soil/sand and keep the soil moist and warm for three germination cycles. However, these populations do represent the weed seed bank that a producer must be conscious of in designing appropriate weed management strategies.

At the LAC site, there was great variation in weed types across rotations following the uniformity year (35% broadleaf weeds in R5 and 88% in R1). Weed composition has been relatively constant in continuous corn (R1) and the corn-soybean rotation (R2), but grass percentages have increased considerably in all other rotations. The density of weeds in the continuous corn and corn-soybean rotation has declined, but has increased for all other rotations, especially in the direct seeded alfalfa and pasture systems. This is a reflection of the dry weather and leafhopper infestation in 1990 that greatly reduced the forage's ability to compete with weeds, especially the foxtail species. For 1991, the cash grain based systems averaged 8 million weed seedlings per acre and the forage based systems averaged 26 million.

When averaged over all rotations, the percentages of broadleaf and grass weeds has remained relatively constant for 1990 and 1991 at ARS , but has shifted to less broadleaves at LAC (Table 13). From 1990 to 1991, the total number of weed seedlings increased slightly from 442 to 484/ft sq at ARS but increased substantially from 249 to 399/ft sq at LAC. Among the broadleaf species, redroot pigweed and common lambsquarters predominate at ARS while at LAC the species were more varied with redroot pigweed, velvetleaf, and shepherdspurse the principal species (Table 14). There was a noticeable decline and increase in the proportions of shepherdspurse and corn spurry, respectively, that were present in 1990 to 1991 at LAC and we have no explanation for this.

Table 13. Comparison of Weed Composition and Density for 1990 and 1991 in the WICST at ARS and LAC.

	ARS				LAC			
	% weed type		no./sq ft		% weed type		no./sq ft	
	90	91	90	91	90	91	90	91
Grasses	17	22	77	104	46	74	115	296
Bdleaves	83	78	365	380	54	26	133	103
Total	100	100	442	484	100	100	248	399

Table 14. The Common Broadleaf Weed Species Observed at the ARS and LAC Sites in 1990 and 1991.

	ARS		LAC	
	1990	1991	1990	1991
	(--------- % of each species ---------)			
Redroot pigweed	35.7	24.1	12.9	12.4
Com. lambsquarters	37.5	47.5	6.8	7.1
Velvetleaf	2.9	0.8	17.0	14.5
Penn. smartweed	0.4	1.2	5.1	6.6
Shepherdspurse	8.3	6.6	21.4	8.4
Yellow woodsorrel	2.9	3.9	5.4	4.2
Speedwell purslane	8.7	9.6	1.7	5.5
E. black nightshade	1.2	3.2	2.0	0.3
Knotweed	0.4	1.0	0.0	0.5
Sowthistle	0.1	0.0	2.0	0.5
Wild buckwheat	0.0	0.0	0.0	0.0
Kochia	0.1	0.0	0.0	0.0
Dandelion	1.4	0.8	3.7	1.6
Buckhorn plantain	0.2	0.2	0.7	1.0
Com. ragweed	0.1	0.0	0.7	0.0
White cockle	0.1	0.1	1.4	1.8
Corn spurry	0.0	0.0	0.0	17.9
Common purslane	0.0	0.0	0.0	7.4

Fall panicum is the dominant annual grass at ARS and at LAC giant foxtail predominates (Table 15). Few changes in the proportion of grasses occurred at ARS between 1990 and 1991 but at LAC, total grasses increased, mainly as a result of increases in the relative abundance of fall panicum and barnyardgrass. This is a result of the grasses going to seed in several of the forage based rotations at this site.

Table 15. The Common Grass Weed Species Observed at the ARS and LAC Sites in 1990 and 1991.

	ARS		LAC	
	1990	1991	1990	1991
	(--------- % of each species ---------)			
Fall panicum	43.9	41.4	7.5	31.9
Giant foxtail	21.9	11.7	71.4	40.7
L. crabgrass	17.0	23.2	0.4	0.0
Green foxtail	17.0	6.8	17.6	6.3
Barnyardgrass	1.8	7.3	2.4	19.6
Yellow foxtail	7.6	6.3	0.4	0.8
Quackgrass	0.0	0.0	0.4	0.2

Future monitoring.

Now that nearly all rotations are in place, we have developed a scheme to systematically sample each rotation on a planned schedule. The rationale behind the sampling schedule is as follows:

- Sample plots every other year in continuous corn (R1) and in the spring of the year after corn has been grown in rotation with other crops (R2, R3, R4 and R5).
- Sample plots in the low input cash grain system (R3) in the year after wheat/red clover are plowed down to see if seed populations are higher after this phase of the rotation than following corn.
- Sample the forage based alfalfa systems (R4 and R5) after the last harvest year of alfalfa.
- Sample the pasture system (R6) every fourth year.

D. Comparison of Potato Leafhopper Dynamics in Direct and Companion Seeded Alfalfa

D. B. Hogg, E. E. Espe & J. L. Wedberg*

BACKGROUND

The potato leafhopper (PLH), *Empoasca fabae*, is the most destructive insect pest of alfalfa in Wisconsin. PLH problems can be particularly severe in new alfalfa seedings, due to the vulnerability of the seedlings and the prolonged period prior to the first cutting, which permits leafhopper population buildup in the crop. The PLH feeds on literally hundreds of different plant species from a range of families. However, this insect has a distinct nonpreference for grasses. Thus, one might expect that alfalfa established with an oat companion crop would tend to support fewer PLH than would direct seeded alfalfa. The intent of this project was to investigate this hypothesis, utilizing the direct seeded alfalfa (R4) and oats/alfalfa plots (R5) at the Arlington Research Station (ARS) and Lakeland Agricultural Complex (LAC) sites of the Wisconsin Integrated Cropping Systems Trial.

METHODS

1990 - We attempted to sample the plots at both locations on a weekly basis, from the time PLH arrived until plots were harvested. At ARS, plots were seeded on 23 April and were cut on 25 June (R5) and 3 July (R4). At LAC, plots were not seeded until 30 May and were cut on 19 July. At both sites the oats/alfalfa plots were harvested for oatlage. Sampling methods for PLH included sweeping and the use of a vacuum sampler (D-Vac). The sweep net provides a relative estimate of PLH density; the D-Vac provides an estimate of "absolute" density for PLH adults, but it is not as reliable a sampling method for PLH nymphs. In addition to insect counts, on each sampling occasion we estimated crop height (alfalfa and oats), and we estimated stand densities on one occasion for each site. Data were analyzed by ANOVA.

1991 - Only the ARS site was utilized. Plots were seeded on 8 April; the direct seeded plots were cut on 19 June, and the oats/alfalfa plots were harvested for grain and were cut on 16 July. We continued to sample the oats/alfalfa plots after the direct seeded plots had been cut. Plots were sampled as in 1990, except only the D-Vac sampler was used for PLH. Data were analyzed by ANOVA when comparisons between establishment methods could be made.

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RESULTS

1990 - At the ARS site, alfalfa establishment method had essentially no effect on absolute PLH densities (Table 16). Leafhopper numbers built up rapidly in the plots, but no nymphs were found by 21 June, indicating little or no PLH reproduction. The plots were cut starting on 25 June. As expected, sweep net counts tended to be higher in the direct seeded as opposed to the companion seeding ($\underline{P} < .01$), because the oats restricted the movement of the sweep net through the crop. Also, windy conditions on 21 June probably depressed the PLH sweep counts in all plots. In terms of crop parameters (Table 17), the presence of oats had an effect on either the height of the alfalfa crop or plant density.

Table 16. Insect Count Data from Potato Leafhopper Study, ARS Cropping Systems Trial, 1990.

Date	Direct Seeded Alfalfa	Companion Cropped Alfalfa
	PLH adults per 20 sweeps	
7 June	0.8	1.3
14 June	10.8	4.4
21 June	11.8	2.6
	PLH adults per 0.9 m^2 (D-Vac)	
7 June	2.3	3.1
14 June	49.4	47.1
21 June	72.6	59.0

Table 17. Crop Information from Potato Leafhopper Study, ARS Cropping Systems Trial, 1990.

Date	Direct Seeded Alfalfa	Companion Cropped Alfalfa	Companion Cropped Oats
	CROP HEIGHT (cm)		
7 June	13.5	14.8	33.3
14 June	26.5	29.8	52.8
21 June	32.5	32.5	55.0
	STAND DENSITY (0.1 m^2)		
14 June	25.0	21.5	5.3

At the LAC site, alfalfa establishment method had a significant effect on the absolute densities of PLH adults ($P < .05$) (Table 18). Small numbers of PLH nymphs were found on 9 July, indicating that PLH reproduction had begun by about 30 June (PLH egg development requires about nine days). Sweep net samples were not taken at the LAC site. In terms of crop parameters (Table 19), the presence of oats had no measurable effect on alfalfa height, but there was a significant effect ($P < .05$) on alfalfa plant density.

Table 18. Insect Count Data from Potato Leafhopper Study, LAC Cropping Systems Trial, 1990.

Date	Direct Seeded Alfalfa	Companion Cropped Alfalfa
	PLH adults per 20 sweeps	
28 June	0	0
9 July	1.9	2.3
	PLH adults per 0.9 m^2 (D-Vac)	
28 June	3.1	5.0
9 July	41.6	8.8

Table 19 Crop Information from Potato Leafhopper Study, LAC Cropping Systems Trial, 1990.

Date	Direct Seeded Alfalfa	Companion Cropped Alfalfa	Companion Cropped Oats
	CROP HEIGHT (cm)		
28 June	5.2	6.6	26.3
9 July	15.0	11.6	8.2
	STAND DENSITY (0.0625 m^2)		
23 July	13.1	6.0	8.8

1991 - In contrast to the 1990 ARS data, alfalfa establishment method had a large and significant ($P < .05$) effect on absolute PLH densities (Table 20). Leafhopper nymphs were found in both treatments on 13 June, suggesting that egg laying had begun in early June. PLH numbers built up rapidly in the oats/alfalfa plots following the 13 June sample and reached extremely high levels on 2 July. In terms of crop parameters (Table 21), the presence of oats had a significant ($P < .05$) effect on the height of the alfalfa crop on 13 June. The effect of establishment method on alfalfa stand density was large and highly significant ($P < .01$).

Table 20. Insect Count Data from Potato Leafhopper Study, D-Vac Sampling (numbers per 0.09 m^2), ARS Cropping Systems Trial, 1991.

Date	Direct Seeded Alfalfa		Companion Cropped Alfalfa	
	Adults	Nymphs	Adults	Nymphs
5 June	19.1	0	7.8	0
13 June	29.8	0.3	13.5	0.6
20 June	--	--	17.8	7.0
27 June	--	--	45.9	57.4
2 July	--	--	115.4	82.7
11 July	--	--	168.4	64.9

Table 21. Crop Information from Potato Leafhopper Study, ARS Cropping Systems Trial, 1991.

Date	Direct Seeded Alfalfa	Companion Cropped Alfalfa	Companion Cropped Oats
	CROP HEIGHT (cm)		
5 June	39.4	36.9	56.3
13 June	45.5	39.3	79.3
20 June	--	43.7	96.3
27 June	--	48.3	97.9
2 July	--	42.4	--
11 July	--	39.4	--
	STAND DENSITY (0.0625 m^2)		
13 June	28.8	16.1	18.0

DISCUSSION

The data on the effect of alfalfa establishment on PLH density, collected for three "site-years" (two at ARS, one at LAC) seem at first contradictory. At ARS in 1990, PLH numbers were unaffected by the presence of oats, whereas the opposite occurred at LAC in 1990 and ARS in 1991. However, the results may be related to relative differences in alfalfa density. At ARS in 1990, alfalfa stand densities were similar in the direct seeded and oats/alfalfa plots; whereas at LAC in 1990 and ARS in 1991, the presence of oats resulted in reduced alfalfa densities relative to the direct seeded plots. Thus, PLH densities may have simply been determined by the amount of alfalfa available in the plots rather than the presence of oats. Although the oats/alfalfa plots initially supported relatively fewer PLH at ARS in 1991, PLH populations built up to extremely high numbers because the plots were not harvested until the oat grain had matured. By the time of harvest the alfalfa was badly yellowed (hopperburned) from PLH feeding injury. In fact, the PLH nymph population appeared to decline between 2 and 11 July, suggesting a reduction in leafhopper egg laying activity in response to declining plant quality. The implications of feeding injury such as this on the subsequent yield, quality, and persistence of an alfalfa stand have not been explored.

E. Economic Analysis of the Wisconsin Integrated Cropping Systems Trial - 1990 and 1991

R. M. Klemme, W. E. Saupe*, and J. L. Posner**

Introduction

The strength of the Wisconsin Integrated Cropping Systems Trials (WICST) in terms of reliability of the analyses and its relevance for educational programs has been enhanced because of the following three characteristics:

a) The input, production, and economic analyses are based on data from systems of agricultural production, not on comparisons among individual crops.

b) The systems to be studied and methods of economic analysis were selected by consultation and agreement among farm operators, county Extension faculty, and university research scientists.

c) The plots are large enough to be treated using conventional farm equipment for the region, yet meet the highest standards for experimental design. In addition, the demonstrations are conducted at two locations, both in important farming areas of the state.

The economic analysis addresses the profitability of a system of production, that is, the combined profitability of all crops in a rotation. It focuses decisions on the entire rotation rather than spurious comparisons between the most profitable crop in one system versus the most profitable crop in another. The analysis is made from data on inputs and production for each crop and animal enterprise each year, with the information presented in a crop budget format.

During the 12 or more years of the trials, additional information about the crops and use of these crops in each system will be acquired. While a short-term trial can produce an estimate of the average profitability of each system, the additional years in the WICST will generate information on the year to year variability in profitability. The trials are also unique in permitting evaluation of the costs and returns during the transition years from conventional to organic cropping systems. The long-term nature of the trials permits measuring and evaluating environmental costs and effects associated with the various systems.

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Finally, the large size of each plot permits use of the same full-size farm machinery used on farms in the neighborhood, increasing the credibility of the farm applicability of the practices. The researchers also have the flexibility to treat each plot as a separate field.

The economic analysis presented below illustrates the basic methodology to be used in analyzing the six cropping systems from the WICST. The analysis is divided into three parts. The first two parts contain a general description of the methodology used to generate the enterprise and systems budgets included in the analysis. The third part describes the "focus group" approach to determine what various user groups would like to see in future economic analyses. A sample of responses from farmer-advisors from one study area is reported, reflecting farmers' perspectives on the economic analysis.

Budget Reporting Description

The budgets presented below (and the examples shown in Appendix VII) are based on traditional enterprise budgeting techniques. They contain enterprise-based information on enterprise sales (gross returns), input costs (variable and fixed), and a summary of returns to various farm resources. The examples presented in the appendices are based on the 1990 and 1991 continuous corn Rotation 1 (R1), see Appendices VII A to VII D from the Arlington Research Station and Lakeland Agricultural Complex sites, respectively; the 1990 soybean crop from Rotation 2 (R2) shown in Appendices VII E and VII F, respectively; and the 1991 corn and soybean crops from Rotation 2 (R2) shown in Appendices VII G to VII J, respectively.

As we will discuss in more detail below, one of the measures that seems most important to farmers is the return to the farm's fixed resources (gross returns minus variable costs) for the entire crop rotation. In the case of continuous corn rotation R1, the system consists of a single enterprise -- corn. Thus the enterprise and system budgets are identical.

However, cropping systems' budgets for multi-year rotations can only be calculated when all crops (phases) in the rotation are produced in the same year. Given that data exist only for two years, 1990 and 1991, the only systems that can be evaluated so far are R1 and R2.[1]

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[1] Several cropping systems (rotations) in the WICST are three or four years long so the first analyses across all systems can not be made until after the 1993 cropping year is completed. After that, each additional year will provide more information about the average profitability of each system and the variability in the profitability.

Enterprise and System Returns

The budget methodology that we are currently using can be illustrated by going through the 1990 continuous corn budget (Appendix VII A). The average yield on the four plots (replicates) equaled 165.78 bushels per acre. Given a harvest time price of $2.28 per bushel, this enterprise had a total value of $377.97 per acre.

The direct (variable) costs of $119.48 per acre equal the actual costs of purchased seed, fertilizer, and pesticides; custom operations hired; leased equipment; and grain drying plus the estimated fuel and repair costs of field machine operations from tillage following the harvest of the previous crop through the harvest of the current crop.[2]

What remains after the variable costs are paid is called the gross margin and represents the returns to labor, capital, and land. The gross margin was a little over $258 per acre for continuous corn in 1990.

Assuming that a farmer grew 500 acres of continuous corn, then the whole-farm return to the fixed resources would equal almost $130,000 per year (500 acres times $258 gross margin per acre). If the family drew $25,000 from the farm for living expenses and personal income taxes, then $105,000 would be left for machinery replacement, land rent, property and business income taxes, and debt service. If the farmer rented (say) 300 acres at $100 per acre and paid $40 per acre property taxes on (say) 200 acres that was owned, then $67,000 would be left for machine replacement and debt service. As you can see, the overall farm profitability and net cash flow are going to depend on a number of factors including, but not limited to, the gross margin of the corn enterprise.

In order to compare the two rotations, the gross margins from corn and soybeans grown in rotation R2 must be averaged to determine a figure comparable to the gross margin for continuous corn. The system gross margin for rotation R2 at the Arlington Research Station (Columbia County) site (Table 22) equals about $275 per acre (about $279 in corn and $271 for soybeans). This compares to the 1991 gross margin for continuous corn of $233 per acre. Similarly, the 1991 gross margin for the corn-soybean rotation (R2) at the Lakeland Agricultural Complex (Walworth County) of $248 per acre exceeded the continuous corn gross margin of $187 per acre.

The data are for the first two years of the trials and tell only a portion of the story about how these systems will compare

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[2] These estimated costs are based on the actual field operations used, in this case, on the Arlington Research Station site in Columbia county. The costs for fuel and repairs are for the operations in the Minnesota Farm Machinery Economic Cost Estimates for 1991 that most closely resemble the actual operations.

over time. These systems will be compared over a number of years in order to examine the impacts of weather, cultural factors, and prices on system profitability. But the above discussion does illustrate the concepts of gross margins and systems analysis. We would note, however, that any measurable contribution of the cropping systems to environmental contamination and environmental costs is important and will need to be factored into the economic analysis.

Table 22. Yields (bu per acre) and Gross Margins ($ per acre) for R1 (continuous corn) and R2 (corn soybeans) Cropping Systems at the Lakeland Agricultural Complex and the Arlington Research Station sites, 1990 and 1991.

Arlington Research Station:			
Continuous Corn	1990	1991	Avg. (90-91)
Corn Yield	165.8	160.0	162.9
Gross Margin	$ 258	$ 233	$ 246
Corn-Soybean		1991	
Corn Yield		184.7	
Soybean Yield	56.7	60.4	
Gross Margin		$ 275	
Lakeland Agricultural Complex:			
Continuous Corn	1990	1991	Avg. (90-91)
Corn Yield	163.6	121.1	142.4
Gross Margin	$ 244	$ 187	$ 216
Corn-Soybean		1991	
Corn Yield		144.7	
Soybean Yield	52.8	58.7	
Gross Margin		$ 223	

Source: Economic analysis of WICST data (details found in Appendices VII A through VII J).

Future Directions

A more thorough economic analysis and the inclusion of environmental costs into this analysis are near-term objectives of this project. As the study progresses to a point where all crops/phases are being completed in the same year, we will be able to include these systems in the comparative analysis as we have done with Rotations one and two (Table 22). With that data, we will be better able to address questions involving the transition from continuous corn to various alternative crop rotations. In addition, we will begin to incorporate variability of returns into the comparative analysis that in the short term is limited to a comparison of averages. We will also be making use of the data concerning different environmental impacts across systems in terms of soil erosion and movement of fertilizers and pesticides through the soil.

Another important objective of the Wisconsin Integrated Cropping Systems Trials is the dissemination of project results to a range of audiences -- farmers, environmentalists, policy-makers, urban consumers, students, etc. An important aspect of teaching is how the information is packaged and presented. In other words, we must deliver the information in a form that is readily understandable and usable. Therefore, we are currently in the process of conducting focus-group sessions to address a variety of such questions and issues that the WICST's Advisory Board raised during the annual winter meeting in January 1992. Those questions, along with suggestions from the Columbia and Walworth county farmers on the Advisory Boards are reported in Appendix VIII.

Some of the suggestions concerning the analysis from the first two focus group meetings with farmers have already been adopted. For example, using harvest prices to calculate total value, using gross margins as a key profit indicator, and examining the rotations from a system's perspective were strong suggestions from those two groups. Other issues, including pricing the crops in the livestock rotations, valuing cow manure that is applied on Rotations 4-6, determining the process for assigning environmental costs, and valuing and assigning labor costs remain elusive and will continue to be addressed as we conduct these sessions with farm, academic, and environmental groups.

F. Phosphorous and Potassium Nutrient Cycling: Results from 1990 and 1991

T. K. Iragavarapu, J. L. Posner, and E. E. Schulte*

Of crucial concern in evaluating any long-term cropping system for profitability, productivity, and environmental impact is the cycling and efficiency of nutrient use. This study is aimed at the construction of phosphorus and potassium nutrient budgets in the field for each of the six rotations in the cropping systems trial (see Appendix II C for the theoretical budget). One objective is to see if the soils at the two sites (ARS, and LAC) will be able to sustain optimum yields without any fertilizer additions of P and K in the low input rotations (R_3, and R_6).

Our hypotheses are:

1 - Potassium removal will be greater in the forage systems compared to cash grain systems ($R_4+R_5+R_6 > R_1+R_2+R_3$).

2 - Phosphorus removal will be greater in cash grain systems compared to forage rotations ($R_1+R_2+R_3>R_4+R_5+R_6$).

3 - P and K removal will be greater due to higher yields in the high-input systems than the low-input systems ($R_1+R_4 > R_2+R_5 > R_3+R_6$).

4 - Draw-down of surface horizon P and K will be faster in the low-input systems (R_3, and R_6) compared to high-input systems (R_1, and R_4).

Materials and Methods

The nutrient budgets for P and K are being constructed using a mass balance theory, which states that inputs into a system minus outputs equals change in soil storage:

Change in soil storage = Inputs - Outputs......[1]

Phosphorus: $\Delta Ps = (Pf + Pm) - (Pc + Pe + Pl)$ ....[2]

Potassium: $\Delta Ks = (Kf + Km) - (Kc + Ke + Kl)$ ....[3]

where: ΔXs = change in soil storage
Xf = fertilizer additions
Xm = manure additions
Xc = crop removal
Xe = erosion losses
Xl = leaching losses

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1. Inputs: Fertilizer tags are used for N, P, and K additions. Actual rate of manure application in the forage plots is determined by weighing the spreader prior to and after spreading. Manure samples are collected from each load to analyze for nutrient composition of the manure.

2. Outputs: Crop removals of P and K are measured from the harvested yield. Two grab samples are collected from each plot for tissue analysis to determine P and K content. Forage and grain samples are analyzed with NIR (Near Infra Red) reflectance spectroscopy for crude protein and quality, and wet chemistry analysis for P and K content at the UW-Soil and Plant Analysis Laboratory.

3. Change in soil storage: We are measuring available P and exchangeable K as indicators of soil P and K, since only a small portion of total P and K are available at any one time to the plants.

a. Soil sampling density: DeGaubeka (1969), working with P and K at Arlington, found that compositing seven cores per acre is the most efficient sampling density to account for most of the soil variability. Since the plots at ARS and LAC are 0.7-0.8 acres in size, five cores were bulked per plot. A 1½" diameter probe was used to collect the soil samples.

b. Depth of sampling: Numerous authors have measured the importance of deeper roots (> 6") in the nutrition of annual (Jankus, 1959; Taylor and Klepper, 1973), and perennial crops (Ogus and Fox, 1970; Peterson et al., 1983). As a result, it was decided to sample at several depths, i.e., 0-6",6-12",12-24",24-36" for available P and exchangeable K. Although not affecting the budget per se, the cycling of nutrients from deeper depths to the soil surface in plant residue (phyto cycling) is another reason to sample more than just the plow layer.

c. Frequency: Sampling for soil available P and exchangeable K took place as each plot entered the rotation, and will again take place at the end of the cycle of each of the six rotations. For example, by spring 1992 , one cycle was completed in the Sb-C rotation (R_2).

d. Chemical analysis: Soil available P and exchangeable K are analyzed after extraction with 0.03 N NH_4F in 0.025 N KCl (Bray-1 extract) according to the methods of Schulte et al. (1987).

Results

Since both of the sites are on an A slope (0-2%), and conservation tillage practices are being followed, erosion losses of P and K are expected to be negligible. Also movement of manure and fertilizer additions should be minimized due to their immediate incorporation. We do not expect any leaching losses of phosphorus since most of the phosphorus is insoluble in water. Potassium is also not subject to leaching losses since it is fixed to the negatively charged clay particles. Therefore, the above equations 2 & 3 are simplified as follows:

$$\Delta Ps = (Pf + Pm) - (Pc) \quad [4]$$

$$\Delta Ks = (Kf + Km) - (Kc) \quad [5]$$

Initial fertility: The initial fertility status of the two sites in 1990 was high (Table 23). This is attributed to the rich silt loam loess that was deposited after glaciation, the high organic matter content of these prairie soils, and past fertilizer and manure applications. The initial soil available P and exchangeable K values are above the optimum soil test levels for Wisconsin (Schulte et al., 1982). Therefore, no fertilizer additions of P and K were warranted at either of the sites. However, the forage rotations (R_4, R_5, and R_6) are manured at an average rate of 10 ton/acre/yr. The manure rates were based on the fact that typically, dairy farms have approximately 10 t/yr to spread on each tillable acre (50-cow herd with replacements on 200 tillable acres produces on an average 8.1 t of manure/A/yr).

Table 23. Initial Soil Fertility (0-6") at Arlington Research Station (ARS) and Lakeland Agricultural Complex (LAC), 1990

Site	Soil type	Sub-soil group[1]	pH	Organic matter	Phosphorus	Potassium
				%	ppm	ppm
ARS	Plano sil	B	6.5	4.7	108	255
LAC	Plano sil	B	6.3	5.2	58	188
Critical Level[2]					15	88

[1] Sub-soil group B has medium P and K nutrient supplying power, and a buffering capacity of 4.5 and 2.5 for P_2O_5 and K_2O, respectively.

[2] Soils lower than this threshold soil test level will respond profitably to the added nutrients in 60% or more of the cases - Schulte, E. 1982. Optimum soil test levels for Wisconsin - UW-Ext. Bull # A 3030.

Manure analysis: Nutrient content of the manure applied at both the sites in 1990 and 1991 are given in Table 24. The nitrogen content of the manure was similar at both the sites, whereas the phosphorus and potassium content of the manure at Lakeland Agricultural Complex is higher than that from the Arlington Research Station site. The high potassium content at LAC could be due to the bedding material (straw) used at that site.

Table 24. Nutrient Composition of Stacked Manure Applied at Both the Sites in 1990 and 1991.

Rotation	ARS			LAC		
	N	P	K	N	P	K
1990	lb/ton of manure					
R_4. A-A-A-C	11.7	2.8	7.9	12.4	5.0	14.0
R_5. O/A-A-C	12.1	3.7	9.2	13.3	4.6	15.1
R_6. P-P-P	12.1	3.7	9.2	11.7	4.1	13.3
1991						
R_4. A-A-A-C	13.1	3.4	10.9	12.9	6.2	14.1
R_5. O/A-A-C	13.1	3.1	11.1	13.1	4.5	13.1
R_6. P-P-P	13.1	3.2	10.0	12.2	3.6	10.2

ARS = Arlington Research Station
LAC = Lakeland Agricultural Complex

<u>Phosphorus and potassium budgets (1990)</u>: Phosphorus off-take was similar between corn and soybean plots (Table 25). Phosphorus removal in cash grain and forage systems is modest and rarely exceeds 30 lb/acre. Due to manure applications, however, the forage plots show a net P accumulation. At both ARS and LAC, soybeans removed twice as much K as corn. At Arlington, the forage plots removed on an average more than four times as much K as did soybeans. It seems from the nutrient balance for K that the manure applications did not cover off-take and soil reserves will be lowered. At LAC, the forage plots show a net accumulation of potassium since no forage cuts were taken in 1990 due to late planting.

Table 25. Phosphorus and Potassium Nutrient Balance (lbs/ac) in the Wisconsin Integrated Cropping System Trials, 1990

Rotation	Yield /acre[a]	Phosphorus (P) Input	Phosphorus (P) Crop removal	Phosphorus (P) **Balance**	Potassium (K) Input	Potassium (K) Crop removal	Potassium (K) **Balance**
				<u>Arlington Research Station (ARS)</u>			
1. <u>C</u>-C-C	166	11	31	**-20**	20	34	**-14**
2. <u>Sb</u>-C-Sb	57	0	21	**-21**	0	63	**-63**
3. <u>Sb</u>-W/rc-C	52	0	20	**-20**	0	56	**-56**
4. <u>A</u>-A-A-C[b]	4.2	56	22	**+34**	158	254	**-96**
5. <u>O/A</u>-A-C[c]	2.1/2.1	56	23	**+33**	138	244	**-106**
6. <u>P</u>-P-P[d]	4.0	37	25	**+12**	92	308	**-216**
				<u>Lakeland Agricultural Complex (LAC)</u>			
1. <u>C</u>-C-C	164	4	24	**-20**	8	28	**-20**
2. <u>Sb</u>-C-Sb	53	0	18	**-18**	0	57	**-57**
3. <u>Sb</u>-W/rc-C	55	0	18	**-18**	0	58	**-58**
4. <u>A</u>-A-A-C[b]	0[e]	100	0	**+100**	280	0	**+280**
5. <u>O/A</u>-A-C[c]	0.88	69	5	**+64**	227	56	**+171**
6. <u>P</u>-P-P[d]	0[e]	41	0	**+41**	133	0	**+133**

[a] The yields of corn and soybeans are in bushels/acre. Forage yields are in tons of dry matter/acre.
[b] 20 T/acre of dairy manure applied.
[c] 15 T/acre of dairy manure applied.
[d] 10 T/acre of dairy manure applied.
[e] Forage was not harvested due to late planting

Note: For manure analysis, refer to Table 24.

Phosphorus and potassium budgets (1991): P off-take was similar between corn and soybeans (Tables 26 a&b). Soybeans removed twice as much K as corn similar to 1990. The seeding year sole seeded and companion seeded alfalfa show a net P accumulation due to manure applications. Due to the lower forage yields, there is a less K removal at LAC compared to ARS.

Table 26a. Phosphorus and Potassium Nutrient Balance (lb/ac) at Arlington Research Station (ARS), 1991

		Phosphorus (P)			Potassium (K)		
Rotation	Yield /acre[a]	Input	Crop removal	**Balance**	Input	Crop removal	**Balance**
1. C-C-C	160	11	27	**-16**	20	30	**-10**
2. Sb-C-Sb	185	11	30	**-19**	20	34	**-14**
Sb-C-Sb	61	0	24	**-24**	0	72	**-72**
3. Sb-W/rc-C	51	0	18	**-18**	0	59	**-59**
Sb-W/rc-C Straw	64 0.9	0	17	**-17**	0	33	**-33**
4. A-A-A-C[b]	5.1	68	28	**+40**	218	344	**-126**
A-A-A-C	5.8	0	31	**-31**	0	296	**-296**
5. O/A-A-C	5.8	0	33	**-33**	0	316	**-316**
O/A-A-C[c] Oats Straw	1.4 55 0.9	47	20	**+27**	167	164	**+3**
6. P-P-P[d]	4.7	32	27	**+5**	100	283	**-183**

[a] Yields of corn, soybean, and oats are in bushels/acre. Forage yields are in tons of dry matter/acre.
[b] 20 T/acre of dairy manure applied.
[c] 15 T/acre of dairy manure applied.
[d] 10 T/acre of dairy manure applied annually.

Note: For manure analysis, refer to Table 24.

Table 26b. Phosphorus and Potassium Nutrient Balance (lbs/ac) Lakeland Agricultural Complex (LAC), 1991

Rotation	Yield /acre[a]	Phosphorus (P) Input	Phosphorus (P) Crop removal	Phosphorus (P) **Balance**	Potassium (K) Input	Potassium (K) Crop removal	Potassium (K) **Balance**
1. C-C-C	121	4	21	**-17**	8	23	**-15**
2. Sb-C-Sb	145	10	21	**-11**	25	25	**0**
Sb-C-Sb	59	0	21	**-21**	0	66	**-66**
3. Sb-W/rc-C	52	0	18	**-18**	0	57	**-57**
Sb-W/rc-C	32						
Straw	0.4	0	8	**-8**	0	16	**-16**
4. A-A-A-C[b]	0.5	124	3	**+121**	282	26	**+256**
A-A-A-C	3.9	0	21	**-21**	0	215	**-215**
5. O/A-A-C	3.5	0	20	**-20**	0	172	**-172**
O/A-A-C[c]	0.5						
Oats	54	68	14	**+54**	197	115	**+82**
Straw	1.1						
6. P-P-P[d]	3.4	36	20	**+16**	102	200	**-98**

[a] Yields of corn, soybean, and oats are in bushels/acre. Forage yields are in tons of dry matter/acre.
[b] 20 T/acre of dairy manure applied.
[c] 15 T/acre of dairy manure applied.
[d] 10 T/acre of dairy manure applied annually.

Note: For manure analysis, refer to Table 24.

Two-year nutrient balance: At the end of two cropping seasons, the nutrient budgets for P and K seem to agree with our hypotheses. The cash grain rotations are slowly depleting the soil reserves of phosphorus (Table 27). As anticipated, there is a large deficit of potassium in the forage rotations compared to cash grain rotations. Potassium needs of forage treatments, where production is good (ARS), is not met by manure and we expect it to show up in a change in soil test levels (storage) of potassium. The net accumulation of potassium in the forage rotations at LAC is due to the fact that no forage cuts were taken in the summer of 1990.

Table 27. Two-year Phosphorus and Potassium Balance in the Wisconsin Integrated Cropping Systems Trial (1990-91)

	Input		Output		Balance	
Rotations	ARS.	LAC.	ARS.	LAC.	ARS.	LAC.
	---------- lb/acre phosphorous ----------					
1. C-C-C	22	8	58	45	-36	-37
2. Sb-C-Sb	11	10	51	39	-40	-29
3. Sb/w-w/rc-C	0	0	37	26	-37	-26
4. A-A-A-C	56	100	53	21	+3	+79
5. O/A-A-C	56	69	56	25	0	+44
6. P-P-P	69	77	52	20	+17	+57
	---------- lb/acre potassium ----------					
1. C-C-C	40	16	64	51	-24	-35
2. Sb-C-Sb	20	25	97	82	-77	-57
3. Sb/w-w/rc-C	0	0	89	74	-89	-74
4. A-A-A-C	158	280	550	215	-392	+65
5. O/A-A-C	138	227	560	228	-422	-1
6. P-P-P	192	235	591	200	-409	+35

ARS = Arlington Research Station
LAC = Lakeland Agricultural Complex

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G. Water Percolation and Breakthrough Time Study on the Cropping Systems Trial

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Leaching is a function not only of the amount of material in the root zone, but also the amount of water percolating through it (Bolton et al., 1970). The objective of this study was to use existing models to simulate a water balance for each of the six rotations of the WICST, and monitor water percolation and leaching. Crops with high evapotranspiration (ET) requirements will have less water available for percolation compared to crops with low ET values. For example, corn with a short period of active growth, and planted in rows (30"), should have more percolation losses compared to a drilled perennial like alfalfa. The following evapotranspiration (ET) values were reported for different crops:

Crop	Yield	ET	Source
Alfalfa	4.0 T	610 mm	Peterson (1972)
Corn	127 bu	561 mm	Hattendorf et al. (1988)
Soybean	40 bu	490 mm	Hattendorf et al. (1988)
Winter wheat	41 bu	262 mm	Entz and Fowler (1989)

In order to estimate the partitioning of rainfall between evapotranspiration, runoff, and percolation for each of the six crop rotations in the WICST, the GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model developed by Leonard et al. (1987) was used. The hydrology component of this model uses daily climatic data to calculate the water balance in the root zone. The GLEAMS model uses a modified Penman equation (Ritchie, 1972) to calculate ET, and the Soil Conservation Service (SCS) curve number (USDA, 1972) to calculate runoff. The percolation model is based on the assumption of a piston-type movement of water downward in the soil. A storage routing technique is used to simulate redistribution of infiltrated water within the root zone, and percolation out of the bottom of the root zone is estimated.

Simulating the partitioning of rainfall at the two sites (Table 28) resulted in several interesting observations:

1. Evapotranspiration in the close-canopy forage rotations (R_4, R_5, and R_6) was approximately 6-7% higher than in the row crop, cash grain rotations (R_1 & R_2)

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2. Due to better ground cover, runoff was 20-25% lower under the forage rotations (R_4, R_5, and R_6) compared to row crops (R_1 & R_2). Irrespective of the type of the crop, maximum runoff was noticed during the snow-melt months of March and April (not shown on Table 28).

3. Estimated annual percolation losses under the rotations was generally low. Percolation losses represented 2-6% of incoming rainfall at Arlington Research Station, and 6-14% at the higher rainfall Lakeland Agricultural Complex. Maximum percolation losses were observed during soil thawing periods (March and April) in all the rotations. The low percolation losses simulated by GLEAMS could be due in part to the piston-type percolation model used in the hydrology component.

Leaching Frame Study - 1990

In an effort to monitor water movement and leaching under the rotations in the WICST, bromide tracer methodology was employed. A preliminary monitoring study was conducted during the summer in 1990 at the Lakeland Agricultural Complex (Walworth County) site.

Several workers have used halide anions (Br^- or Cl^-) as tracers of water movement (Carlan et al., 1985; Rice et al., 1986; and others), mainly because they are not adsorbed to the negatively charged clay particles in the soil. These selected anions have been found to faithfully mimic water movement in soil once a correction is made for the volume of exclusion. This anion exclusion is the volume of soil pore space unavailable to negatively charged ions as they are repelled by clay particles (Smith, 1972). As a result of this repulsion, these anions tend to move slightly faster than water (Smith and Davis, 1974). Bromide has been found to have desirable characteristics as a tracer under field conditions as it is easily detected and unlikely to contaminate the environment (Onken et al., 1977). Although bromide can be toxic to animals at higher levels, it is not regarded as particularly toxic to plants (Martin, 1966).

Currently two approaches are used to describe the actual movement of water through the soil: a) piston-like (percolating water displaces resident water as it moves down); and, b) macropore flow (water bypasses the bulk of the soil and moves through macropores (Thomas and Phillips, 1979). The objective of this preliminary study was to monitor water movement through the soil with a bromide tracer. Three treatments were selected: 1) natural rainfall, 2) 12.7 mm (0.5") of simulated rainfall applied twice a week, and 3) 50.8 mm (2.0") of simulated rainfall every 14 days. Our hypothesis was that if piston flow dominated, depth to the peak of bromide concentration band would be predominately determined by the amount of water added (leaching volume). On the other hand, if macropore flow dominated, the partitioning of

Table 28. Water Balance Calculations by GLEAMS 12-year Averages (1975-1986)

Rotation	Precipitation (mm)	ET (mm)	Runoff (mm)	Percolation (mm)
		Arlington Research Station (ARS)		
1.C-C-C	795	653 (82)	91 (12)	51 (6)
2.Sb-C-Sb	795	658 (83)	94 (12)	43 (5)
3.Sb-W/rc-C	795	704 (88)	71 (9)	20 (3)
4.A-A-A-C	795	693 (87)	74 (9)	26 (3)
5.O/A-A-C	795	682 (86)	76 (10)	37 (4)
6.P-P-P	795	707 (89)	72 (9)	16 (2)
		Lakeland Agricultural Complex (LAC)		
1.C-C-C	996	727 (73)	132 (13)	137 (14)
2.Sb-C-Sb	996	742 (74)	135 (14)	119 (12)
3.Sb-W/rc-C	996	803 (81)	107 (11)	86 (9)
4.A-A-A-C	996	777 (78)	109 (11)	110 (11)
5.O/A-A-C	996	760 (76)	116 (12)	120 (12)
6.P-P-P	996	822 (83)	112 (11)	62 (6)

Numbers in parentheses are percentage of total precipitation.
C=corn;Sb=soybean; W=winter wheat; rc=red clover; O/A=oats and alfalfa companion seeded; A=sole seeded alfalfa; P=pasture (50% red clover + 25% brome grass + 25% timothy). Simulations were run on a 2% slope on a plano silt loam soil. Rooting depths of 34" for corn and soybeans; 60" for alfalfa were used. SCS runoff curve numbers of 74, 75, and 61 were used for corn, soybeans, and alfalfa, respectively.

the rainfall would be more important than the total amount, i.e., a greater percent of total rainfall would move by macropore flow during infrequent intense showers (treatment 3) than frequent small events (treatment 2). If the former model of water transport was correct, the depth of bromide concentration band would indicate leaching volume. If however, the latter model was correct, the bromide tracer could no longer be used to estimate leaching volumes, but only to identify breakthrough times to groundwater.

Materials and Methods

The treatments were replicated three times in a completely randomized design (CRD).

Leaching frame installation: Nine 1 m x 1 m metal leaching frames were used as experimental units. The frames were installed 15.2 cm deep into the soil to prevent surface runoff losses of water. Leaching frames under treatments 2 and 3 were kept covered at all times to prevent natural rainfall from entering.

Rainfall simulator: A drop-forming rainfall simulator, made of plexiglass, having holes 2.54 cm apart, was used to simulate artificial rainfall in treatments 2 and 3. The rainfall simulator was placed on the leaching frames while applying the water.

Bromide salt application: Potassium bromide (KBr^-) was applied at the rate of 300 kg ha^{-1} (198 kg ha^{-1} of Br^-) to each of the nine leaching frames in 12.7 mm water on June 25, 1992.

Soil sampling: Sampling took place in June, August, and November during 1990. All the frames were sampled two days after the bromide was applied to determine the uniformity of application. Subsequent sampling (August) took place after the frames had received 188 mm, and 152 mm cumulative rain under natural rainfall and artificial rainfall treatments, respectively. Final sampling (November) took place after natural and artificial rainfall treatments had received 328 mm, and 457 mm, respectively.

Each leaching frame was subdivided into four quadrants and a sample was drawn from each quadrant. Soil cores were drawn with a 19.05-mm diameter probe to a depth of one meter in 20-cm sections. The top 20-cm soil column was subdivided into four 5-cm sections. The holes were then filled with a bentonite + soil mixture to prevent preferential flow of water through these holes. After taking gravimetric soil moisture measurements, the eight sections in each core were analyzed separately for bromide.

Percent bromide recovery was calculated by dividing the amount of bromide recovered in the top 100 cm by the amount applied. The application rate was 1.98×10^{-3} g Br^- cm^{-2}. Measured concentrations by depth were corrected for bulk density and sample volume and summed to give total bromide recovery: $\Sigma\ [Br^-]_{ppm} \times B.D_{g/cc} \times volume_{cc}$.

<u>Bromide analysis:</u> Five-gram sub-samples of soil were extracted with 50 ml of 0.001 M ($SrCl_2$). Bromide was determined using an Orion Model 94-35 bromide electrode (Onken et al., 1977), and a Model 90-01 single junction reference electrode. To reduce potential interference, an ionic strength adjuster of 5 M $NaNO_3$ was added at the rate of 2% by volume. The tip of the electrode was cleaned frequently with polishing strips. New working standard solution of 0.001 M $SrCl_2$ was prepared every week. Known standard was run between every ten samples.

Results

<u>Bromide recovery:</u> Percent Br^- recovery is the amount of bromide detected in the soil profile with our sampling procedure to one meter depth. We focused on percent Br^- recovery at each sampling time to determine how much of the added tracer is lost from the system. Since runoff was controlled, and no crops were growing in the frames, the loss of bromide could only be due to leaching. Table 29 summarizes the percent recovery data. All the bromide was recovered two days after application. Half of the applied bromide was lost from the system with only 140 mm rain received between August and November in treatment 1. Whereas only 26% of bromide was lost in the same period of time even with an accumulation of 305 mm rain in treatments 2 and 3. While the drop-forming simulator facilitated uniform water distribution, the application of water, whether 12.7-mm or 50.8-mm increments (treatments 2 and 3), was rapid, resulting in ponding, promoting macropore flow. A larger percent Br^- recovery in these treatments compared to natural rainfall suggests that macropore flow dominated under the artificial rainfall treatments. Bromide remained in the soil matrix and the water that was subsequently applied, bypassed the matrix, and moved through the macropores. In natural rainfall treatment, however, the bromide got redistributed into the soil matrix, and then moved downwards more steadily with the more slowly percolating water. Nevertheless, only 50% recovery in November in treatment 1 indicates that macropore flow is still important even under natural conditions.

Table 29. Percent Bromide Recovery (0-100 cm) at Different Sampling Dates During 1990.

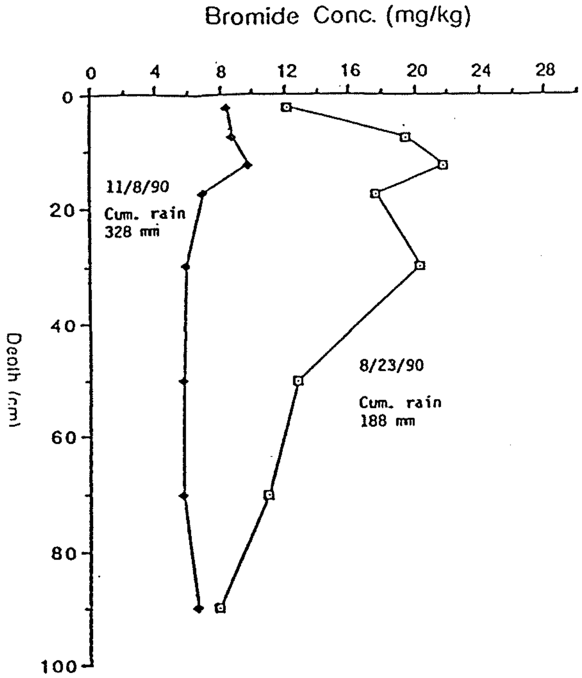
Sampling date	Treatment # 1 (Natural rainfall)	Treatment # 2 (12.7 mm twice a week)	Treatment # 3 (50.8 mm every two weeks)
	---------------% Recovery---------------		
6/27/1990	100.0	100.0	100.0
8/9/1990†	103.0	85.1	91.5
11/8/1990	49.2	58.2	64.9

* Treatment #1 sampled on 8/23/1990

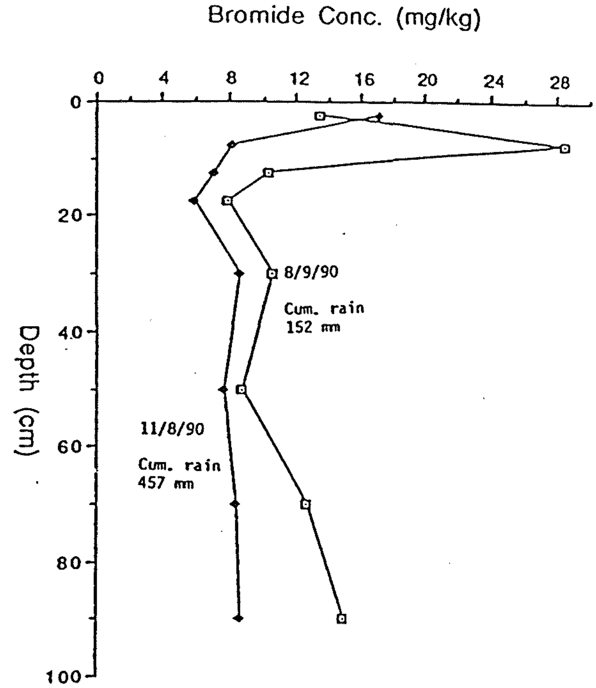
<u>Bromide distribution in the soil:</u> By six weeks after the initiation of the experiment (August), bromide had leached to one meter depth under all three rainfall regimes (Fig. 8). Whereas the highest concentration of bromide was still in the top 20 cm, no clear pattern of slug movement appeared. By November, bromide was nearly equally distributed throughout the profile in all three treatments. The lack of a high bromide concentration band, descending with time, indicates that water did not move by downward displacement. Macropore flow appears to dominate in this silt loam soil. The initial hypothesis that depth to the bromide concentration band would permit estimating leaching volume proved unworkable.

<u>Conclusions:</u> It can be concluded from this preliminary study that macropore flow of water dominated compared to piston-like flow under these conditions, and bromide moved beyond one meter depth in the soil in only one growing season.

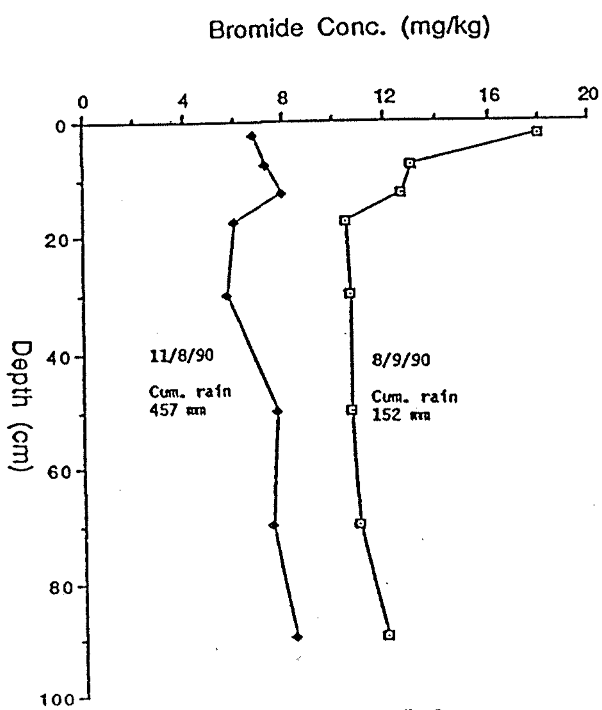
Figure 8 Br^- Distribution in the Soil Profile (100 cm) in August and November Under Different Treatments During 1990.



Treatment # 1



Treatment # 2



Treatment # 3

Crop Rotation Study - 1991

The leaching frame study indicated that macropore flow is the dominant mechanism of water movement at the Lakeland Agricultural Complex site. It was decided in the spring of 1991 to estimate solute transit times using bromide tracer under the different crop rotations in the Wisconsin Integrated Cropping Systems Trial (WICST). We hypothesized that different rates of bromide movement would be a function of water use pattern of crops and rainfall distribution. It was expected that bromide would move more slowly under crops like alfalfa with high water demand compared to row crops like corn. The objective of this study was to rank the rotations in terms of their effect on groundwater quality as a function of solute transit times.

Materials and Methods

1. Treatments: The five rotations that are being compared are: 1) R_1-Continuous corn; 2) R_2-Soybean-corn; 3) R_3-Soybean-wheat/red clover-corn; 4) R_4-Alfalfa-alfalfa-alfalfa-corn; and 5) R_5-Oats/alfalfa-alfalfa-corn. Bromide was applied to the first phase of each of these five rotations, e.g., soybean plots in R_2 (sb-c-sb), and companion seeded alfalfa plots in R_5 (o/a-a-c). Pasture plots in R_6 were not included in this study since bromide could affect the grazing animals health.

2. Well installation: In early spring 1991, one monitoring well was installed in the center of the sub-plot to be treated with bromide in each of the continuous corn (R_1,T_1), narrow-row soybean (R_2,T_3), wide-row soybean (R_3,T_6), sole seeded alfalfa (R_4,T_7), and companion seeded alfalfa (R_5,T_{12}). Although not part of the bromide study, wells were installed in the pasture plots (R_6,T_{14}). Two check wells (13 and 28 feet deep) were also installed to monitor depth to water table during the growing season. One check well was installed deeper than the other to determine the groundwater pressure distribution. Wells are 13′ deep in the northern end, and 10′ deep in the lower southern end of the field. Wells were constructed using 38.1 mm (i.d) PVC pipes. These pipes have a 5′ screen at the bottom in the water. The top of the wells are capped and sit 18" below the soil surface and are covered with aluminum cans to protect the wells from being damaged. The aluminum cans are placed on a metal plate surrounding the tube. Wells were placed below the soil surface to facilitate field work.

3. Bromide application: On May 22nd a one-time application of potassium bromide salt was uniformly applied to a 5m x 5m sub-plot surrounding the monitoring well at the rate of 300 kg ha^{-1} (198 kg ha^{-1} of Br^-). Seven hundred and fifty grams of KBr^- was dissolved in five liters of water per plot, and was applied using

a sprayer with four spray nozzles attached to the boom. The boom had a swath width of five feet (1.52 m).

4. Post-application cultivations: The mechanical mixing of bromide with the soil was not uniform across the treatments. Due to the inclusion of row crops and perennial legumes in the rotations, cultivation practices differ for the five rotations under the study. For example, the wide-row soybean plots in R_3 were rotary hoed and cultivated twice during the 1991 growing season after bromide application, while the continous corn was cultivated only once. Obviously the sod crops and drilled beans had no further soil disturbance after planting.

5. Soil sampling: Soil sampling took place initially to determine background bromide content in the soil and for initial moisture measurement. Subsequent sampling took place in the second week of August, and again in November after the crops were harvested to determine bromide distribution in the soil. Eight samples were taken from each plot. Four samples were drawn to a depth of one meter in six increments (0-10, 10-20, 20-40, 40-60, 60-80, and 80-100 cm), and the other four to a depth of 20 cm in two increments (0-10 and 10-20 cm). Each sample was analyzed separately.

6. Groundwater sampling: Wells were drained three times before taking a sample for analysis. Initial water samples were collected to determine baseline atrazine, nitrate, and bromide concentrations. Water samples were drawn using a bail (0.64 cm i.d x 61 cm h). Samples are being collected twice a year (spring and fall) to monitor groundwater quality changes in terms of atrazine, nitrate, and bromide. Samples for atrazine and nitrates were analyzed at the State Laboratory of Hygiene, and bromide analysis was done at the UW-Plant and Soil Analysis Laboratory.

7. Tissue sampling: Tissue samples were collected from the bromide-treated area to determine the crop uptake of bromide. Corn and soybean grain samples were collected at physiological maturity, and in case of forage legumes, a grab sample was collected from bromide-treated area each time a cut was taken.

Results

During the 1991 growing season, considerable fluctuation in the height of the water table was noticed. The water table was at less than 2 feet below the soil surface in May 1991 (Table 30). By August, the water table had dropped to 8 feet depth due to the dry weather that prevailed between May and August. By December, the water table had risen to 3.3 feet due to heavy post-season rainfall received during the month of October.

The atrazine levels in the water samples are within the safe limits (Table 30). However, the baseline nitrite+nitrate-N concentrations were above the safe limit (10_{ppm}) in all the wells.

Background Br^- concentration was zero in all but one well (Table 30). Bromide was detected in the groundwater by December. However, the bromide concentrations among the treatments differed significantly at .05 P level. Highest concentrations of bromide (29.9_{ppm}) were detected under poorly grown (only a single cut was taken) new seeding alfalfa plots . Bromide concentrations were less (5.5_{ppm}) under companion seeded alfalfa plots, probably due to the good yield of oats in 1991. Also, bromide concentrations were greater (11.4_{ppm}) under narrow-row soybeans compared to wide-row soybeans (4.6_{ppm}), which had winter wheat sown just before harvest. Even though the treatments differed significantly in bromide concentration, bromide was detected in all the wells within one growing season. This suggests that macropore flow is the dominant mechanism explaining water percolation under natural field conditions. A dry period during the months of May, June, July, and August resulted in the development of cracks in the soil at this site. Excess rainfall received during the months of September and October could have leached the bromide through these cracks deeper into the soil.

This rapid movement of bromide to the groundwater suggests that preferential flow is the dominant mechanism, and surface-applied chemicals could reach groundwater within one growing season under these field conditions.

Table 30. Atrazine, Nitrate, and Bromide Concentrations in the Monitoring Wells at Lakeland Agricultural Complex.

Field ID#	Treat-ment#	Well #	Depth to Water Table (ft.) 5/20/91	Depth to Water Table (ft.) 12/10/91	Atrazine Conc.(ppb) 5/20/91	Atrazine Conc.(ppb) 12/10/91	Nitrate + Nitrate-N Conc.(ppm) 5/20/91	Nitrate + Nitrate-N Conc.(ppm) 12/10/91	Bromide Conc.(ppm) 5/20/91	Bromide Conc.(ppm) 12/10/91†
101	1	EC361	--	4.5	0.4	1.3	80.8	41.5	6.3	18.7
210	1	EC371	1.4	2.7	0.1	0.4	52.8	48.5	0.0	9.0
303	1	EC373	2.0	3.3	0.1	1.9	34.9	21.3	0.0	14.7
Mean							56.2	37.1	2.1	14.1
108	2	EC365	1.4	3.4	0.2	0.5	70.8	60.5	0.0	1.8
203	2	EC367	1.0	2.9	0.3	0.4	11.4	14.0	0.0	14.5
304	2	EC374	1.6	3.4	0.1	0.4	12.8	20.1	0.0	17.9
Mean							31.7	31.5	0.0	11.4
111	6	EC366	2.8	4.5	0.3	0.3	60.8	43.8	0.0	6.6
208	6	EC369	0.9	3.0	0.2	0.5	37.3	28.6	0.0	2.9
306	6	EC376	1.6	3.1	0.1	0.3	28.8	42.3	0.0	4.4
Mean							42.3	38.2	0.0	4.6
102	8	EC362	2.0	5.0	0.2	0.3	38.7	15.1	0.0	24.5
209	8	EC370	1.3	3.2	0.4	0.5	48.8	6.8	0.0	28.0
305	8	EC375	2.0	3.5	0.1	0.2	34.8	10.3	0.0	37.1
Mean							40.8	10.7	0.0	29.9
105	12	EC364	1.3	3.1	0.1	0.2	16.5	15.4	0.0	1.2
207	12	EC368	1.5	3.7	0.2	0.3	69.6	49.7	0.0	3.0
309	12	EC377	1.3	2.8	0.1	0.2	11.9	7.3	0.0	12.4
Mean							32.7	24.1	0.0	5.5
104	14	EC363	1.7	3.6	0.1	0.3	24.7	21.3	--	6.6
213	14	EC372	--	2.0	--	0.2	--	2.2	--	0.0
314	14	EC378	--	2.9	--	0.2	--	63.2	--	0.0
1S[1]	-	EC379	1.8	4.0	--	0.1	--	31.1	--	--
1D[2]	-	EC380	1.9	3.8	--	0.2	--	6.9	--	--

[1] Check well #1 - 13 feet deep - Located in the northern end of the field
[2] Check well #2 - 28 feet deep - Located in the northern end of the field
† Treatments differed significantly at .05 P level

Treatment codes in 1991:
1 = continuous corn (C-C-C)
2 = narrow-row soybean phase of soybean-corn-soybean (Sb-C) rotation
6 = Wide-row soybean phase of soybean-wheat/red clover-corn (Sb-W/rc-C) rotation
8 = Seeding year alfalfa phase in alfalfa-alfalfa-alfalfa-corn (A-A-A-C) rotation
12 = Companion seeded alfalfa phase in oats/alfalfa-alfalfa-corn (O/A-A-C) rotation
14 = Continuous pasture. Bromide was not applied as it could affect grazing animals' health.

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H. Nitrate Monitoring in the Cropping Systems Trial: 1990 and 1991 Results

T. K. Iragavarapu, J. L. Posner, and L. G. Bundy*

Groundwater pollution by agri-chemicals has been a major concern in the upper Midwest. Of all the potential groundwater pollutants, nitrates have been found to be the most common in Wisconsin (WDNR, 1988). The amount of inorganic nitrogen remaining in the soil profile following crop harvest is an important factor that reflects the "nitrate leaching" potential of a particular field situation (Chichester, 1977). Besides precipitation pattern and nitrogen fertilizer management, the amount of nitrogen remaining in the soil profile is also a function of the types of crops grown (Bolton et al., 1970; Olsen et al., 1970). Most of the past research, however, has only focused on continuous corn fertilized at various N rates and times (Roth and Fox, 1990; Jokela and Randall, 1989). This newly initiated long-term study will compare fall nitrate levels under four different crop rotations. The four rotations under study are: a) R_1 -continuous corn, b)R_2 - corn-drilled soybeans, c)R_3 - row (30") soybeans-wheat/red clover-corn, and d)R_4 - alfalfa-alfalfa-alfalfa-corn. The crops in R_1,R_2, and R_4 are being fertilized according to the Best Management Practices. Nitrate monitoring is being conducted at both Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC).

Field studies conducted in Wisconsin (Olsen et al., 1970; Bundy and Malone, 1988) and Minnesota (Jokela and Randall, 1989) on silt loam soils have shown that nitrates can leach over winter. Lysimeter results show that the majority of water percolation and nitrate leaching takes place from late fall to early spring in North Central States (Chichester, 1977). However, that substantial amounts of nitrate carry over to the next spring, was also observed in both Minnesota (Malzer et al. 1980) and Pennsylvania (Roth and Fox, 1990). Keeping this in view, it was decided to collect not only fall samples to estimate leaching potential, but also spring nitrate samples. These latter samples are being collected for two reasons: a) to correct nitrogen fertilizer application on continuous corn plots, and b) to measure changes in soil NO_3-N over the winter.

Our system-wide hypotheses, which can only be tested once the rotations have completed several cycles, include:

1 - Fall nitrate levels will be higher in cash grain systems than forage systems $R_1 + R_2 + R_3 /3 > R_4$.

2 - Fall nitrate levels will be higher in systems with greater N additions than those with lower N additions $R_1 > R_2 > R_4 > R_3$.

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Our annual hypotheses include:

3 - Fall nitrate levels will be lower after a legume than after a cereal.
4 - Fall nitrate levels will be lower after a phase with a longer vigorous growth cycle than one with a shorter cycle i.e., Sb/w < Sb.
5 - Fall nitrates will be higher under corn fertilized with inorganic nitrogen at higher N rates i.e., C-<u>C</u> vs.Sb-<u>C</u>.
6 - Fall nitrates will be higher after corn fertilized with inorganic N than when fertilized with organic N i.e., C-<u>C</u> and Sb-<u>C</u> > W/rcl-<u>C</u> and A-<u>C</u>.

<u>Materials and Methods:</u>

Nitrate samples were taken in 1-ft increments to a depth of 3 ft. Sampling took place in fall (once the soil cools down to 50°F) after the crop harvest, and in the next spring prior to planting (before the soil warms up above 50°F). Five samples were taken per plot and bulked. Soil samples were also taken along the hedge rows as a non-agricultural or "background" nitrate level check. NO_3-N analysis is done using the steam distillation method of Bremner (1965).

<u>Results:</u>

<u>Fall NO_3-N:</u> After two cropping seasons (1990 and 1991), fall nitrate data (Table 31) trend seems to support our initial hypotheses. Data averaged over the two years at both the locations indicates the fiollowing:

- Fall NO_3-N levels under corn plots is greater than that of legume plots (H_3).
- Fall nitrate levels were also lower under longer growing season phases compared to shorter growing season phases (H_4).
- Fall nitrate levels were higher where corn was fertilized with higher rates of inorganic N (H_5).

In general, the fall nitrate levels are higher at LAC than ARS. Negligible amounts of fall nitrates at ARS in 1991 could be due to the high post-season rainfall (4.7" and 6.8" received during September and October respectively). Surprisingly, this excess precipitation did not affect profile nitrate content at LAC. This difference between the two sites in fall nitrate accumulation suggests that the soils at ARS are well-drained compared to LAC. Also, lower crop yields at LAC compared to ARS could have resulted in more fall NO_3-N accumulating at LAC in 1991 in spite of any leaching losses.

Table 31. Fall Nitrates in Top Three Feet of the Soil Profile in 1990 and 1991 in the WICST.

Crop	Fall 1990		Fall 1991		Average	
	LAC.[1]	ARS.[2]	LAC.[3]	ARS.[4]	LAC.	ARS.
R_1. Corn	198	87	133	48	**166**	**68**
R_2. Corn after soybeans	-	-	125	41	**125**	**41**
R_2. Narrow-row soybeans	55	79	76	42	**66**	**61**
R_3. Wide-row soybeans[5]	49	75	34	25	**42**	**50**
R_3. Wheat/red clover	-	-	50	26	**50**	**26**
R_4. New seeding alfalfa[6]	34	46	67	32	**51**	**39**
R_4. alfalfa[7] Hay I	-	-	72	27	**72**	**27**
Check[8]	-	-	33	26	-	-
LSD (0.05)	29	NS	39	5	-	-

units?

LAC = Lakeland Agricultural Complex - Walworth County
ARS = Arlington Research Station - Columbia County

[1] Sampled on 11/02/1990
[2] Sampled on 11/06/1990
[3] Sampled on 11/16/1991
[4] Sampled on 11/20/1991
[5] Winter wheat flown over just prior to soybean harvest
[6] nitrates under seeding year alfalfa plots in 1990 and 1991. Received 20 T/acre of dairy manure.
[7] Alfalfa planted in 1990 received 20 T/acre of dairy manure in spring of 1990.
[8] nitrate samples taken along the hedge rows as a non-agricultural check.

Over-winter NO_3-N change: Except under continuous corn plots at LAC, the nitrate levels were close to background NO_3-N levels in fall 1990 (Table 32). Under continuous corn plots at LAC, a significant decrease of 68 lb/A of NO_3-N was noticed in spring 1991 from previous fall, suggesting leaching might have taken place. Bundy and Malone (1988) also observed greater overwinter changes in soil NO_3-N where fall soil NO_3-N accumulations were high.

Spring nitrates in 1991 increased from previous fall in all the legume plots except in wide-row soybean plots at ARS. This suggests either mineralization or nitrification prior to sampling under these plots. The difference between the two sites was probably due to the time of spring nitrate sampling. In spring 1992, a significant increase in profile nitrate content was again noticed from the previous fall in all the treatments at ARS and most of the treatments at LAC. This overwinter increase suggests that mineralization might have taken place due to the unusually warm winter and spring of 1991-92 in southern Wisconsin.

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Table 32. Comparison of Fall and Spring Nitrates to Three Feet Depth at Arlington Research Station and Lakeland Agricultural Complex

Rotation	Fall 1990[1]	Spring 1991[2]	Difference	T test	Fall 1991[3]	Spring 1992[4]	Difference	T test
				Arlington Research Station (ARS)				
1.C-C	87	81	-6	NS	48	76	+28	*
2.Sb-C	78	92	+14	NS	41	57	+16	*
Sb	-	-			42	69	+27	*
3.Sb/w-w/rc	75	55	-20	NS	26	59	+33	*
Sb/w	-	-			25	57	+32	*
4.A-A	46	64	+18	*	27	60	+33	*
A	-	-			32	58	+26	*
5.Check	-	-			26	41	+15	NS
				Lakeland Agricultural Complex (LAC)				
1.C-C	198	129	-69	*	133	62	-71	*
2.Sb-C	55	79	+24	*	125	74	-51	NS
Sb	-	-			76	71	-5	NS
3.Sb/w-w/rc	49	97	+48	*	49	63	+14	NS
Sb/w	-	-			34	55	+21	*
4.A-A	34	126	+92	*	71	77	+6	NS
A	-	-			67	77	+10	NS
5.Check	-	-	-		33	72	+39	*

[1] Sampled on 11/6/90 and 11/2/90 at ARS and LAC, respectively
[2] Sampled on 4/5/91 and 4/23/91 at ARS and LAC, respectively
[3] Sampled on 11/20/91 and 11/16/91 at ARS and LAC, respectively
[4] Sampled on 4/1/92 and 4/8/92 at ARS and LAC, respectively

* = significant difference at .05 probability level
NS = not significant

V. OUTREACH ACTIVITIES

A. Columbia County Committee: Educational Activity Report 1990-1991

Raymond Saxby* and Dwight Mueller**

Over the past two years, several educational activities have been held. In this report an attempt will be made to describe the educational activities of 1991, educational objectives, teaching methods, and some observed results or impressions. A wide variety of groups (Table 33) visited the WISCT research trial in 1991. As we toured the site, a description of the objectives, cropping systems, and problems encountered were presented and this generated some very good discussion. This varied from the more technical "how to" questions to more philosophical questions on how and why we chose the particular cropping systems, or what does sustainability mean. Many of the visitors seem to be taking a wait-and-see attitude and were definitely interested in hearing about future results.

In September of 1991, a tour of the plots and some satellite plots was held. The primary audience was the Columbia County Corn Growers Association membership. Researchers described the past summer's activities in front of their plots. Strategies for reducing chemicals and commercial fertilizers while maintaining yields was emphasized. Fifteen cash grain farmers observed the plots and asked questions of the researchers.

One of the highlights in 1991 took place on August 29, when a twilight meeting titled "Farming the Prairie for Ducks and Butter" was held. Ninety-seven people registered for the program. The primary audience consisted of city of Madison residents who are Audubon Society members. The program's purpose was to inform them of experimental work that is being done to help farmers be better environmentalists. Several presentations were made at the home of the manager of Goose Pond. The audience then went to the site on the Arlington Research Station where the Integrated Cropping Systems Trial Plots are located.

The naturalist that manages the Madison Audubon Goose Pond Sanctuary provided a field tour of prairie plantings near Goose Pond on Conservation Reserve Program acres. The Columbia County Extension Agent and the Manager of the Arlington Research Station presented a poster talk on agriculture production practices they are promoting with farmers to protect water quality in rural areas. A Wildlife Manager from the Wisconsin Department of Natural Resources discussed ways to create wildlife habitat on farms in the area. University of Wisconsin Agronomists discussed the benefits and difficulties encountered in the crop rotation systems being studied.

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Comments from several in the audience indicated that they had a much better appreciation for what the farming community was doing to solve environmental problems. We hope to continue this and similar programs in the future aimed at groups that have not been our traditional audiences.

The Columbia County Advisory Committee met with the Walworth County Advisory Commttee at the Elkhorn site. This meeting allowed the two committees to compare the work being done at each site. A report was presented by each committee and plans for the next year were dicussed. Next year the plans are to meet at the Columbia County site.

The largest group to visit our main research and satellite trials were those attending the Sustainable Agriculture Field Day. Many in attendance already embrace the philosophies of reducing or eliminating purchased chemical and fertilizer inputs and have already tried or are ready to implement practices which would help them attain these goals. Questions tended to be more technical and advanced. Questioners were searching for answers to problems they were encountering. We sensed some skepticism as to whether University researchers would be committed to conduct this type of research. However, others commented that it was encouraging to see the University conducting research in this area.

In another event, approximately 60 State Vo/Ag instructors were hosted at the research station as part of their summer conference. While they supported the idea of reduced chemical and fertilizer usage, they were skeptical that a producer could completely eliminate the use of these purchased inputs. It would be interesting to have this group back in a few years after more data is gathered.

Two groups who expressed deep concern with what was happening in rural America were the State National Farm Organization Board and the Southern Wisconsin Lutheran Ministers Rural Concerns Task Force. Some of the issues they brought up included, the continued farm exodus, increasing farm size, farm family stress, and breakdown and high unemployment in rural communities. They also expressed concern about environmental problems, particularly what was happening to groundwater in their areas.

Another interesting tour was a group of Lithuanian agricultural researchers. They spent the afternoon at the research station and a good share of that time at our research site. Many questions were asked about how we were conducting this research and why we chose the type of cropping systems. These researchers were very interested in our study since this was considered high priority for future research in their country.

Other important groups to tour the site were US Congressman Scott Klug, participants in the Wisconsin Rural Leadership Training Program, and several school classes. A seventh grade group from Elm Grove Lutheran showed particular interest in some of the basic agronomic practices that can be used to control weeds, insects, and diseases while providing nutrients to subsequent crops.

In addition to the groups that have been identified in this report, many individual contacts were made with news media, radio stations, crop consultants, agribusiness representatives, and Nutrient Pest Management personnel. They have had many questions and are eager to start getting results of the crop rotation trials.

We also initiated our on-farm program during an evening meeting that was held at the Rio High School to discuss WICST. Several area farmers attended this meeting because of their desire to modify their farming practices to be more environmentally sound without going broke. This meeting provided contacts that will be used in the summer of 1992 for on-farm demonstrations with leguminous cover crops.

Table 33. Educational Activity Report for Columbia County

	No. of Participants
- Farming the Prairie for Ducks and Butter	100
- Sustainable Agriculture Field Day	200
- Columbia County Corn Growers Tour	10
- County Committee Tour to Walworth County	20
- Rio High School Farmer Information Meeting	10
- VO-AG Teachers Summer Confernce	60
-Lutheran Ministers Rural Concerns Task Force	30
- Lithuanian Agriculture Researchers	10
- NFO State Board	15
- Elm Grove Lutheran Seventh Graders	40
- U.S. Congressman Scott Klug and Party	5
- Individual Contacts Off Site	10
- Crop Consultants	
- Agri-Business Reps	
- Co-Op Agronomists	
- NPM Personnel	
Total Contacts	510

B. Walworth County Committee: Educational Activity Report 1990 and 1991

L. Cunningham*, J. Hall**, A. Wood*

The Walworth County WICST Project target audience continues to increase in size and diversity (Table 33a and b). During these initial project years, public awareness and educational activities have reached an audience ranging from local farmers to inner city youth to Japanese government officials. This report will provide an overview of the activities used to promote public awareness and understanding of the WICST Project.

Excellent media coverage of presentations and activities introducing and explaining the project resulted in numerous feature articles in local, regional and state publications. Feature aricles have appeared in Country Today, Farming Magazine and the Wisconsin Agriculturist. The use of the project as a Sustainable Agriculture Outside Classroom was featured in several news articles. Team member, Lee Cunningham, UW-Extension Agent, partiticpated in a "Food Safety/Sustainable Agriculture educational video which was presented by satelite in 15 states.

Involvement of local policy makers and agriculture agency personnel displays the multiplier effect as more groups become involved in the success of the project. Letters of support were received from the following committees; Walworth County Land Conservation, Soil Conservation Service, Agriculture Stabilization Conservation Service.
Presentations to these groups by key team members; Josh Posner, UW-Madison; John Hall, Michael Fields Agricultural Institute; Alan Wood, County Farm Manager; and UW-Extension Agent, Lee Cunningham, greatly strengthened the cooperative bond between the general public, private research groups, farming commmunity and the University.

Committment by local agriculture instructors to project involvement, FFA students participation in WISCT Field Day, and use of the project as a Sustainable Agriculture Outside Classroom for numerous elementary and secondary school groups illustrates the success of public school educational activities. Students gain a better understanding of farming practices, the need to protect groundwater quality, and crop identification, including the use of each specific crop in the food chain. Team members promote the project whenever possible as illustrated by Farm Manager, Alan Wood's presentation to an adult continuing education Sustainable Agriculture class at Blackhawk Technical College.

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* Walworth County Extension Agent and County Farm Supervisor, respectively
** Michael Fields Agricultural Institute Agronomist

Enhancement of public awareness continues as increasing numbers of groups become familiar with project objectives and activities. Both urban and rural business leaders are becoming better informed about the goals of Sustainable Agriculture. Agribusiness people involved in pesticide, fertilizer and seed sales have been been introduced to the project through Extension Update Programs. Local business representatives such as the Eklhorn Kiwanis and the Burlington Rotarians have been introduced to the educational mission of the project.

A special field tour of the Walworth site was held for members of the Sustainable Agriculture Working Group and Coalition in conjunction with their summer meetings held at Michal Fields Institute. This group is made up of 27 non-profit organizations forming a network of farm, food, conservation, environmental, religious, and rural groups concerned with agricultural policy issues.

The Sustainable Farmers Education Network, the Rodale Institute, and the Micheal Fields Agricultural Institute jointly sponsored a "Take Charge Workshop" directed toward helping farmers maintain a profitable cash flow and protect the environment. Lee Cunningham introduced the WISCT Project at the workshop. Local farmers have shown great interest in project activities and results. Farmer participation on the advisory board has added an element of credibility to the project for the family farm audience.

Public events sponsored by the WDATCP Sustainable Agriculture Program at which the project has been presented include a Poster Session at Arlington and the Sustainable Agriculture Conference at Wisconsin Dells. Locally sponsored events such as the Walworth County Dairy Breakfast have included tours of the project site. Participatory field days have proved to be very successful.

International interest in the project continues to develop as tours are requested by visiting groups involved in agriculture in countries such as Uganda, Pakistan, Bangladesh, Japan, Canada, Mexico, Russia, and Poland. The international visitors gained valuable knowledge about our sustainble agriculture objectives and activities. The experience could prove to create valuable ties between our nations.

Table 34 WICST User Group Contacts - Walworth County

A. 1990

Site Visits

	No. of Participants
- Committee Members of Land Conservation, ASCS, and Soil Conservation	14
- County Seed Dealers	31
- County Board Members (Includes Bd. members from other counties)	40
- Interested Citizens attending County Board Meeting	15
- Arlington Sustainable Ag Field Day Participants	167
- High School Ag Teachers	6
- First Annual WICST Field Day Participants	151
- High School FFA Students	68
- State Representatives	6
- Inner City 6th Graders	56
- International Ag Professionals	15
- Pesticide Dealers	47
- Fertilizer Dealers	76
- Farmers attending Private Applicator Certification Classes	106
Total Site Contacts	798
Media Contact	
- TV News Coverage from Channel 4, Milwaukee	500,000
- Radio Audience - Harvard	2,500
- Farmers through Farming Magazine Article	1,000
Total Media Contacts	503,500

B. 1991

Site Visits

- Seed Dealers	28
- Farmers through Pesticide Certification Classes	103
- Whitewater Business Leaders "Kiwanis"	12
- U.W. Staff and related Ag Proffesionals including Dean Jorgenson, Dean Fields, Gayle Worf (Director of IPM Program)	41
- Producers at "Farming for Profit Seminar"	195
- County Ag Profesionals through Ag Workers Group	18
- General Public at Dairy Breakfast WIUCST Tours	720
- Local High School Ag Teachers	6
- Tri-County Marketing Gropup Members	16
- County Board Members	35
- Japenese Government Officials	15
- Kiwanis Members - Elkorn	38
- School Administrators	3
- Japenese Students	35
- Canadian Ag Producers	47
- Japenese Government Officials including Japan's equivalent to the Director of the E.P.A.	8
- Ag Professionals from the Sustainable Ag Coalition (Lobbyist Group)	37
- Fall WICST Field Day	39
- Children - 6th Grade Level	56
- Foreign County Representatives - Ag Related Government Officials	15
Total Site Contacts	1467
Group Contacts	
- Individuals at Wisconsin Dells Sustainable Ag Conference	247
- Individuals at Rodale Institute	56
Total Group Contacts	303

Appendix I. Seed Varieties, Planting Dates and Planting Rates to be used on the Wisconsin Integrated Cropping Systems Trial, 1989.

Rotation	Variety
R1	
Continuous Corn	DeKalb 547 (104 day)*, plant May 1, 30 inch row spacing, 32,000 seeds/A
R2	
Narrow Row Soybean	Pioneer 9272 (Group II), plant May 15, 6 inch row spacing, 1.5 bu/A
Corn	DeKalb 547 (104 day)*, plant May 1, 30 inch row spacing, 32,000 seeds/A
R3	
Wide Row Soybean	Pioneer 9272 (Group II), plant May 15, 30 inch row spacing, 1 bu/A
Wheat/Red Clover	Caldwell wheat, 3 bu/A, aerial seed Sept 10 Arlington medium red clover, 12 lb/A frost seed Mar 10
Corn	DeKalb 547 (104 day)*, plant May 1, 30 inch row spacing, 32,000 seeds/A
R4	
Alfalfa	Magnum III, plant Apr 15, 15 lb/A
Corn	DeKalb 547 (104 day)*, plant May 1, 30 inch row spacing, 32,000 seeds/A
R5	
Oats/Alfalfa	Horicon oats, 2 bu/A, plant Apr 15 Magnum III alfalfa, 15 lb/A, plant Apr 15
Corn	DeKalb 547 (104 day)*, plant May 1, 30 inch row spacing, 32,000 seeds/A
R6	
Pasture	Timothy - Toro 4 lb/A Bromegrass - Badger 8 lb/A Red Clover - Marathon 7 lb/A plant Apr 15, renovate clover every third year

* Pioneer 3578 (104 day) was the corn variety chosen for the Lakeland Agricultural Complex.

Appendix II.A. Anticipated Nutrient Inputs into the Wisconsin Integrated Cropping Systems Trial (WICST), 1989

Rotation		Fertilizer			Manure		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
R_1.	C-C-C[1]	160	60	60	-	-	-
R_2.	Sb[2]	0	45	50	-	-	-
	C	120	60	60	-	-	-
R_3.	Sb[3]	-	-	-	-	-	-
	W	-	-	-	-	-	-
	C	-	-	-	-	-	-
R_4.	A[4]	0	0	0	120	80	190
	A	0	65	250	-	-	-
	A	0	65	250	-	-	-
	C	6	24	24	120	80	190
R_5.	O/A[5]	-	-	-	90	60	143
	A	-	-	-	-	-	-
	C	-	-	-	90	60	143
R_6.	P-P-P[6]	-	-	-	63	27	54

[1] 250 lb/ac of starter (6-24-24). Fertilizer additions are based on optimum soil test values for P and K and yield goal -"New Soil Test Recommendations" - UWEX publication # A 2809 by Kelling et al. (1989).

[2] Soybean P and K additions are based on UWEX publication # A 2809 by Kelling et al. (1989). Corn nitrogen needs reduced by 40 lb/ac due to soybean credits.

[3] No fertilizer additions in R_3

[4] Seeding year alfalfa and corn phase get 20 T/ac of dairy manure. Actual nutrient content in the manure after losses due to storage (manure pack), and application (soil incorporated) is approximately 6:4:9.5 lb of N, P_2O_5, and K_2O per ton of manure - Table 4 in "Applying Manure to Wisconsin's Cropland- Benefits and Problems". UW Ext. Bull by J.B. Petersen et al. (1984). Seeding year alfalfa N, P, and K requirements will be met by manure. In years 2 and 3, P and K top dressings for alfalfa are based on optimum soil test values for P and K and yield goal of 5 tons DM/acre - "New Soil Test Recommendations" - UWEX publication # A 2809 by Kelling et al. (1989). In the corn phase, the nitrogen fertilizer requirement after alfalfa plowdown and manure will be zero. However, 100 lb of starter (6-24-24) will be applied.

[5] 15 T/ac of dairy manure applied to companion seeded alfalfa and corn phase.

[6] Nutrient content of 6.6 tons of manure produced by two heifers over a period of 150 days. Initial weight of each heifer is 400 lb. Each heifer gains 1.8 lb weight per day, an average weight of 535 lb per heifer is used to calculate manure produced per day. Each heifer produces 44 lb manure/day.

Appendix II.B. Estimated "Available" Nitrogen for Corn in the Wisconsin Integrated Cropping Systems Trial (WICST), 1989

	Rotation	Nitrogen Fertilizer-N (lbs/ac)	"Credits" Crop-N[1] (lbs/ac)	Manure-N[2] (lbs/ac)	Total (lbs/ac)
R_1.	C-C-C	160	0	0	160
R_2.	Sb-C-Sb-C	120	40	0	160
R_3.	Sb-W/rc-C	-	65	0	65
R_4.	A-A-A-C	6	90	80	176
R_5.	O/A-A-C	0	90	60	150

[1] Crop-N: nitrogen credits based on 1 lb N per bushel of soybeans up to 40 lb. For alfalfa, 40 lb N + 1 lb N for each per cent stand of alfalfa (Bundy, L. G. UW-Ext. Bull # A 3340). Red clover estimate is based on L. G. Bundy 1985. UW-Ext. Bull # A 2519.

[2] Manure-N: nitrogen credit is based on 4 lb available N/ton of stacked manure (Bundy, L.G. 1985. UW-Ext. Bull # A 3340).

Appendix II.C. Summary of Estimated Nutrient Budgets for the Wisconsin Integrated Cropping Systems Trial[1], 1989

Rotation	N	P_2O_5 lbs/ac/yr	K_2O
Cash Grain			
R_1 Continuous corn	+25	+5	+22
R_2 Soybean-corn	-64	-1	-2
R_3 Soybean-wheat/clover-corn	-84	-43	-51
Forage			
R_4 Alfalfa hay-hay-hay-corn	-47	+31	+70
R_5 Oats-alfalfa-corn	-52	-10	-37
R_6 grass/legume pasture	-60	-24	-138

[1] This NPK budget includes only measurable inputs and outputs. Inputs include fertilizer, manure, and symbiotic-N fixation by legumes (estimated). Outputs will be crop removals. Nitrogen losses from the system however, also include gaseous losses, run-off and leaching. This later component will be estimated by deep nitrate sampling in fall of each year. Transformations within the system include immobilization, mineralization (N and P) as well as fixation and release (P and K). The available form of these nutrients will be measured by regular soil test procedures.

Appendix III.A. Conservation Tillage Trends in Corn and Soybeans - Percent of Total Corn and Soybean Acres in Which No-till, Ridge-till and Mulch-till Has Been Used.[1]

CORN

	MLRA 95B[2]			Walworth County			Columbia County		
Year	NT[3]	RT[4]	MT[5]	NT	RT	MT	NT	RT	MT
					%				
1987	3.2	1.4	36.4	2.8	0.5	28.0	7.0	0.4	71.4
1988	3.1	1.3	33.0	2.3	0.4	25.0	7.7	0.4	76.9
1989	3.0	1.1	30.7	2.2	0.3	20.1	7.5	0.4	74.6
1990	3.5	1.1	33.0	2.3	0.4	24.9	9.7	0.4	81.0
1991	4.0	1.1	37.2	2.4	0.5	27.3	10.1	0.4	82.6

SOYBEAN

	MLRA 95B			Walworth County			Columbia County		
Year	NT	RT	MT	NT	RT	MT	NT	RT	MT
					%				
1987	3.9	0.1	24.1	0.7	0.0	26.8	30.0	0.0	50.0
1988	2.8	1.4	15.7	0.4	0.2	20.0	20.0	0.0	70.0
1989	0.2	0.0	2.8	0.4	0.2	12.5	20.0	0.0	50.0
1990	2.2	1.1	12.4	0.4	0.2	15.5	15.8	0.0	63.2
1991	5.9	1.2	14.7	0.4	0.2	20.2	13.3	0.0	60.0

[1]Conservation Technology Information Center, West Lafayette, Indiana 1987-1991.

[2]Major Land Resource Area including southeastern Wisconsin and northern Illinois in which both locations of the WISCT are located.

[3]No-Till. Soil left undisturbed prior to planting.

[4]Ridge-Till. Surface residue moved aside when planting into permanently maintained ridges.

[5]Mulch-Till. Entire soil surface is disturbed prior to planting. However, 30% residue cover remains after planting.

Appendix III.B. Projected Tillage Practices by Rotation for the Six Rotations of the Wisconsin Integrated Cropping System Trial, 1989.

Rotation	Tillage and Cultivation Practices
R1	
Continuous Corn	Spring - single pass seedbed preparation*, conventional plant, cultivate (1X) Fall - chisel plow (straight shank)
R2	
Narrow Row Soybean	Spring - single pass seedbed preparation*, conventional drill
Corn	Spring - no-till plant*, cultivate (1X) Fall - chisel plow (straight shank)
R3	
Wide Row Soybean	Spring - single pass seedbed preparation*, rotary hoe (2X), cultivate (2X) Fall - aerial seed wheat
Wheat/Red Clover	Spring - frost seed clover
Corn	Spring - chisel plow (sweeps), conventional plant, rotary hoe (2X), cultivate (2X) Fall - chisel plow (straight shank)
R4	
Direct Seeded Alfalfa	Spring - single pass seedbed preparation*, conventional drill
Established Alfalfa I	
Established Alfalfa II	Fall - apply manure, chisel plow (sweep)
Corn	Spring - single pass seedbed preparation, conventional plant, cultivate (1X) Fall - apply manure, chisel plow (straight shank)
R5	
Oats/Alfalfa	Spring - single pass seedbed preparation*, conventional drill
Established Alfalfa I	Fall - apply manure, chisel plow (sweep)
Corn	Spring - single pass seedbed preparation, conventional plant, rotary hoe (2X), cultivate (2X) Fall - apply manure, chisel plow (straight shank)
R6	
Pasture	Establishment - single pass seedbed preparation, conventional drill Red Clover renovation** - no-till drill

* 30% corn residue and 40 % soybean residue expected

** once every three years expected

Appendix III.C. Predicted Soil Loss Due to Erosion by Rotation of the Six Rotations of the Wisconsin Integrated Cropping Systems Trial using the Universal Soil Loss Equation[1].

Land slope[2]	slight				moderate			
Conserv. practice	contouring		none		contouring		none	
Soil erosivity[3]	low	high	low	high	low	high	low	high
Rotation	Tons/Acre							
C-C-C	1	1	1	2	7	9	12	16
C-Sb	1	1	1	2	7	9	11	15
C-Sb/Wh-Wh/Rc	1	1	1	1	5	7	8	11
A-A-A-C	<1	1	1	1	3	4	5	7
O/A-A-C	<1	<1	1	1	3	4	5	6
Pasture	<1	<1	<1	<1	2	2	2	2

[1]Data for computations from - Wischmeier, W.H. and Smith D.D. 1978. Predicting rainfall erosion losses-a guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook No. 537. 57pp.
R (rainfall and runoff factor) = 140 for southeastern Wisconsin.
C (cover and management factor) = .15, .145, .106, .068, .06, .02 for the six rotations, respectively.

[2]Computed using slope steepness - slope lengths of 2% - 200 ft and 8% - 400 ft for slight and moderate slopes, respectively.

[3]Computed using erodibility ratings of .28 (low) for Lapeer FSL and .37 (high) for Dodge SiL soils. (Erosivity ratings would be higher on soils where past erosion has decreased top soil depth and present mixed plow layer includes higher percentage of subsoil than when soils were classified.)

*Adding strip cropping would further reduce erosion by 50% on rotations that include row crops and solid seeded crops.

Appendix IV. Projected Pest Control Practices by Rotation for the Six Rotations of the Wisconsin Integrated Cropping System Trial, 1989.

Rotation	Pest Control Practices
R1	
Continuous Corn	Lasso 2.5 qt/A + Atrazine 2 qt/A (preemerge), cultivate (1X) Counter 15G 9 lb/A (planter applied)
R2	
Narrow Row Soybean	Treflan 1.5 pt/A + Lexone DF .75 lb/A (preplant-incorporated)
Corn	Lasso 2 qt/A + Bladex 2.5 qt/A (preemerge), cultivate (1X)
R3	
Wide Row Soybean	Rotary hoe (2X), Cultivate (2X)
Wheat/Red Clover	None
Corn	Rotary hoe (2X), Cultivate (2X)
R4	
Direct Seeded Alfalfa	Eptam 2 qt/A (preplant-incorporated)
Established Alfalfa I	Malathion 1 qt/A (if needed)
Established Alfalfa II	Malathion 1 qt/A (if needed)
Corn	Lasso 2 qt/A + Bladex 2.5 qt/A (preemerge), cultivate (1X)
R5	
Oats/Alfalfa	None
Established Alfalfa I	None
Corn	Rotary hoe (2X), Cultivate (2X)
R6	
Pasture	None

Appendix V. A1. LAKELAND AGRICULTURAL COMPLEX WICST - INPUT/OUTPUT DATA - Cash Grain Rotations - 1990

Crop	Continuous Corn	Filler Corn	Narrow Row Beans	Filler Corn	Wide Row Beans	Filler Corn
Rotation	R1	R2	R2	R3	R3	R3
Treatment	1	2	3	4	5	6
Plot #'s	101,210,303,401	108,203,304,409	113,206,311,410	109,204,308,404	107,205,307,406	111,208,306,407
Primary Tillage	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89
Secondary Tillage	Disk Tilloll	Disk Tilloll	Disk Tilloll	Disk Tilloll	Disk Tilloll	Disk Tilloll
Planting Date	5/31/90	5/31/90	5/31/90	5/31/90	6/1/90 soybean 9/19/90 wheat	5/31/90
Variety	Pioneer 3790	Pioneer 3790	Pioneer 9272	Pioneer 3790	Pioneer 9272 Caldwell-wheat	Pioneer 3790
Population	32,000	32,000	205,500	32,000	149,430 soybean 180 lb/A wheat	32,000
Fertilizer	100 lb 4-10-10 150 lb 82-0-0	100 lb 4-10-10 150 lb 82-0-0	None	100 lb 4-10-10 150 lb 82-0-0	None	100 lb 4-10-10 150 lb 82-0-0
Pesticides	Atrazine 2 lb/A Lasso 2 qt/A preemerge Counter 15G 9 lb/A planter applied	Lasso 1.9 qt/A preemerge 2,4-D .5 pt/A post Counter 15G 9 lb/A planter applied	Treflan 1.5 pt/A Lexone DF .67 lb/A ppi	Lasso 1.9 qt/A preemerge 2,4-D .5 pt/A post Counter 15G 9 lb/A planter applied	None	Lasso 1.9 qt/A preemerge 2,4-D .5 pt/A post Counter 15G 9 lb/A planter applied
Mechanical Weeding	S-tine cult. 7/27/90	S-tine cult 7/2/90 No-till cult. 7/7/90	None	S-tine cult. 7/2/90 No-till cult. 7/7/90	Rotary hoe 6/18/90 S-tine cult. 6/19, 6/25/90 No-till cult. 7/6/90	S-tine cult. 7/2/90 No-till cult. 7/7/90
Harvest	11/16/90	11/16/90	10/23\90	11/16/90	10/23/90	11/16/90
Yield	164 bu/A	153 bu/A	53 bu/A	150 bu/A	54 bu/A	149 bu/A
1991 Crops	Corn	Narrow Row Beans	Corn	Filler Corn	Wheat/ Red Clover	Wide Row Beans

Appendix V. A2. LAKELAND AGRICULTURAL COMPLEX WICST - INPUT/OUTPUT DATA - Forage Rotations - 1990

Crop	D. S. Alfalfa	Filler Corn	Filler Corn	Filler Corn	Oats/Alfalfa	Filler Corn	Filler Corn	Pasture
Rotation	R4	R4	R4	R4	R5	R5	R5	R6
Treatment	7	8	9	10	11	12	13	14
Plot #'s	103,202,310,411	102,209,305,402	110,212,302,414	112,214,301,403	106,211,312,413	105,207,309,412	114,201,313,405	104,213,314,408
Primary Tillage (Fall)	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89
Secondary Tillage (Spring)	Disk Tilled 5/15/90	Disk Tilled →	Disk Tilled	Disk Tilled	Disk Tilled	Disk Tilled	Disk Tilled	Disk Tilled
Planting Date	5/30/90	5/31/90	5/31/90	5/31/90	5/30/90	5/31/90	5/31/90	5/30/90
Variety	Magnum III	Pioneer 3790	Pioneer 3790	Pioneer 3790	Horicon-oats Magnum III-alf.	Pioneer 3790	Pioneer 3790	Marathon-rd clov. Toro-timothy Badger-brome
Population	16.5 lb/A	32,000	32,000	32,000	50 lb/A oats 16.1 lb/A alf.	32,000	32,000	6.1 lb/A rd clov. 3.5 lb/A timothy 3.1 lb/A brome
Fertilizer	2.5 T/A lime 5/3/90 20 T/A manure 5/29/90	2.5 T/A lime 5/3/90 20 T/A manure 11/26/90	2.5 T/A lime 5/3/90	2.5 T/A lime 5/3/90	2.5 T/A lime 5/3/90 15 T/A manure 5/29/90	2.5 T/A lime 5/3/90 15 T/A manure 11/26/90	2.5 T/A lime	2 T/A lime 5/3/90 10 T/A manure 5/29/90
Pesticides	Eptam 2 qt/A ppi	Lasso 1.9 qt/A preemerge 2,4-D .5 pt/A post	Lasso 1.9 pt/A preemerge 2,4-D .5 pt/A post	Lasso 1.9 pt/A preemerge 2,4-D .5 pt/A post	None	Lasso 1.9 pt/A preemerge 2,4-D .5 pt/A post	Lasso 1.9 pt/A preemerge 2,4-D ,5 pt/A post	None
Mechanical Weeding		S-tine cult. 7/2/90 No-till cult. 7/7/90	S-tine cult. 7/2/90 No-till cult. 7/7/90	S-tine cult. 7/2/90 No-till cult. 7/7/90		S-tine cult. 7/2/90 No-till cult. 7/7/90	S-tine cult. 7/2/90 No-till cult. 7/7/90	
Harvest	7/19/90* 8/13/90*	11/16/90	11/16/90	11/16/90	7/18/90 oatlage 8/24/90 alfalfa*	11/16/90	11/16/90	7/19/90* 8/24/90*
Yield	None	158 bu/A	151 bu/A	152 bu/A	.9 T DM/A oat.	152 bu/A	154 bu/A	None
1991 Crops	Alfalfa Hay	D.S. Alfalfa	Filler Corn	Filler Corn	Alfalfa Hay	Oats/Alfalfa	Filler Corn	Pasture

* mostly weeds - chopped and blown back onto field

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Appendix V. B1. LAKELAND AGRICULTURAL COMPLEX WICST - INPUT/OUTPUT DATA - Cash Grain Rotations - 1991

Crop	Continuous Corn	Narrow Row Beans	Corn	Filler Corn	Wheat/Red Clover	Wide Row Beans
Rotation	R1	R2	R2	R3	R3	R3
Treatment	1	2	3	4	5	6
Plot #'s	101,210,303,401	108,203,304,409	113,206,311,410	109,204,308,404	107,205,307,406	111,208,306,407
Primary Tillage	Chisel Plow 11/26/90	Chisel Plow 11/26/90	No-Till	Chisel Plow 11/26/90	None	Chisel Plow 11/26/90
Secondary Till.	Tilloll	Tilloll	None	Tilloll	None	Tilloll
Planting Date	5/11/91	5/14/91	5/16/91	5/11/91	9/19/90 wheat 4/1/91 clover	5/13/91 soybean 8/29/91 wheat
Variety	Pioneer 3578	Pioneer 9272	Pioneer 3578	Pioneer 3578	Caldwell - wheat Arling. - rd clov.	Pioneer 9272 Caldwell - wheat
Population	32,000	213,435	32,000	32,000	180 lb/A wheat 15.5 lb/A clover	136,425 soybean 180 lb/A wheat
Fertilizer	100 lb/A 4-10-10 122 lb/A 82-0-0	None	100 lb/A 4-10-10 122 lb/A 82-0-0	122 lb 82-0-0	None	None
Pesticides	Confidence* 2 qt/A Atrazine 1.5 lb/A post Counter 15G 5 lb/A planter applied	Pinnacle .25 oz/A Classic .25 oz/A COC 1 qt/A 28%N 1 gal/A Assure 14 oz/A COC 1 qt/A post	Ranger 1.5 qt/A preemerge Confidence 2 qt/A Bladex 90DF 2 lb/A post	Counter 15G 5 lb/A planter applied	None	None
Mechanical Weeding	None	None	No-till cult. 6/19/91	Rotary hoe 5/20/91 No-till cult. 6/18/91	None	Rotary hoe 5/17/91 306,407 5/23/91 111,208 5/31/91 - all No-till cult. 6/15/91 S-tine cult. 6/23/91
Yield	121 bu/A	59 bu/A	145 bu/A	116 bu/A	64 bu/A	51 bu/A
1992 Crops	Corn	Corn	Narrow Row Beans	Wide Row Beans	Corn	Wheat/ Red Clover

* 4 lb/gal alachlor (identical to Lasso)

Appendix V. B2. LAKELAND AGRICULTURAL COMPLEX WICST - INPUT/OUTPUT DATA - Forage Rotations - 1991

Crop	Est. Alfalfa	D. S. Alfalfa	Filler Corn	Filler Corn	Est. Alfalfa	Oats/Alfalfa	Filler Corn	Pasture
Rotation	R4	R4	R4	R4	R5	R5	R5	R6
Treatment	7	8	9	10	11	12	13	14
Plot #'s	103,202,310,411	102,209,305,402	110,212,302,414	112,214,301,403	106,211,312,413	105,207,309,412	114,201,313,405	104,213,314,408
Primary Tillage		Chisel Plow 11/26/90	Chisel Plow 11/26/90	Chisel Plow 11/26/90		Chisel Plow 11/26/90	Chisel Plow 11/26/90	
Secondary Tillage		Tilloll	Tilloll Tilloll	Tilloll Tilloll		Tilloll Pulvimulcher	Tilloll Tilloll	
Planting Date	5/30/90	4/26/91	5/11/91	5/11/91	5/30/90	4/26/91	5/11/91	5/30/90
Variety	Magnum III	Magnum III	Pioneer 3578	Pioneer 3578	Magnum III	Horicon-oats Magnum III-alf.	Pioneer 3578	Marathon-rd clov. Toro-timothy Badger-brome
Population	(5.3 lb/A reseed 4/2/91)	15.5 lb/A	32,000	32,000	(5.4 lb/A reseed 4/2/91)	15.5 lb/A alf. 64 lb/A oats	32,000	6.1 lb/A rd clov. 3.5 lb/A timothy 3.1 lb/A brome
Fertilizer		20 T/A manure 11/26/90	122 lb 82-0-0	122 lb 82-0-0		15 T/A manure 11/26/90	122 lb 82-0-0	10 T/A manure 5/29/90 11/26/90
Pesticides	None	Eptam 2 qt/A ppi	Bladex 2 lb/A Confidence 2 qt/A post Counter 15G 5 lb/A planter applied	Bladex 2 lb/A Confidence 2 qt/A post Counter 15G 5 lb/A planter applied			Counter 15G 5 lb/A planter applied	
Mechanical Weeding			No-till cult. 6/19/91	No-till cult. 6/19/91			Rotary hoe 5/20/91 No-till cult. 6/18/91	
Harvest	5/29/91 7/9/91 8/20/91	6/23/91	10/15/91	10/15/91	5/29/91 7/9/91 8/20/91	Oats 7/15/91 Straw 7/18/91 Alfalfa 8/26/91	10/15/91	5/29/91 8/20/91
Yield	.5 T DM/A	3.9 T DM/A	128 bu/A	131 bu/A	3.5 T DM/A	54 bu/A oats 1.1 T/A straw .5 T DM/A alf.	108 bu/A	3.4 T DM/A
1992 Crops	Alfalfa Hay	Alfalfa Hay	D.S. Alfalfa	Filler Corn	Corn	Alfalfa Hay	Oats/Alfalfa	Pasture

Appendix VI. A1. ARLINGTON RESEARCH STATION WICST - INPUT/OUTPUT DATA - Cash Grain Rotations - 1990

Crop	Continuous Corn	Filler Corn	Narrow Row Beans	Filler Corn	Wide Row Beans	Filler Corn
Rotation	R1	R2	R2	R3	R3	R3
Treatment	1	2	3	4	5	6
Plot #'s	109,204,306,412	108,206,310,408	101,214,303,401	104,201,301,402	106,202,307,411	102,212,313,407
Primary Tillage	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89
Secondary Tillage	Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher
Planting Date	5/1/90	5/1/90	5/15/90	5/1/90	5/15/90 soybean 9/12/90 wheat	5/1/90
Variety	DeKalb 547	DeKalb 547	Pioneer 9272	DeKalb 547	Pioneer 9272 Caldwell-wheat	DeKalb 547
Population	32,100	32,100	205,500	32,100	149,430 soybean 120 lb/A wheat	32,100
Fertilizer	100 lb 6-24-24 73 lb 82-0-0	104 lb 82-0-0	None	104 lb 82-0-0	None	104 lb 82-0-0
Pesticides	Atrazine 2 qt/A Lasso 2.5 qt/A preemerge Counter 15G 9 lb/A planter applied	2,4-D 1 pt/A post Counter 15G 9 lb/A planter applied	Treflan 1.5 pt/A Lexone DF .75 lb/A ppi	Counter 15G 9 lb/A planter applied	None	Counter 15G 9 lb/A planter applied
Mechanical Weeding	No-till cult. 6/18/90	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	None	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	Rotary hoe 5/24, 6/6/90 No-till cult. 6/16, 6/27/90	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90
Harvest	10/30/90	10/29/90	10/16/90	10/30/90	10/16/90	10/29/90
Yield	166 bu/A	155 bu/A	57 bu/A	148 bu/A	52 bu/A	150 bu/A
1991 Crops	Corn	Narrow Row Beans	Corn	Filler Corn	Wheat/ Red Clover	Wide Row Beans

Appendix VI. A2. ARLINGTON RESEARCH STATION WICST - INPUT/OUTPUT DATA - Forage Rotations - 1990

Crop	D. S. Alfalfa	Filler Corn	Filler Corn	Filler Corn	Oats/Alfalfa	Filler Corn	Filler Corn	Pasture
Rotation	R4	R4	R4	R4	R5	R5	R5	R6
Treatment	7	8	9	10	11	12	13	14
Plot #'s	111,209,305,409	113,210,311,414	105,203,308,406	107,205,309,404	110,208,304,413	103,213,314,410	114,211,312,403	112,207,303,405
Primary Tillage	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89	Chisel Plow 11/89
Secondary Tillage	Disk Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher	Disk Disk Soil Finisher
Planting Date	4/23/90	5/1/90	5/1/90	5/1/90	4/23/90	5/1/90	5/1/90	4/23/90
Variety	Magnum III	DeKalb 547	DeKalb 547	DeKalb 547	Horicon-oats Magnum III-alf.	DeKalb 547	DeKalb 547	Marathon-rd clov. Toro-timothy Badger-brome
Population	15 lb/A	32,100	32,100	32,100	70 lb/A oats 15 lb/A alfalfa	32,100	32,100	7 lb/A rd clov. 4 lb/A timothy 8 lb/A brome
Fertilizer	20 T/A manure 4/23/90 2 T/A lime 10/29/90	20 T/A manure 10/29/90 2 T/A lime 10/29/90	2 T/A lime 10/29/90	2 T/A lime 10/29/90	15 T/A manure 4/23/90 2 T/A lime 10/29/90	15 T/A manure 10/23/90 2 T/A lime 10/23/90	2 T/A lime 10/29/90	10 T/A manure 4/23/90 10/29/90
Pesticides	Eptam 2 qt/A ppi	2,4-D 1 pt/A post	None	None	None	None	None	None
Mechanical Weeding		Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90		Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	Rotary hoe 5/14,24, 6/8/90 No-till cult. 6/18, 6/20/90	
Harvest	7/3/90 8/14/90 10/24/90	10/29/90	10/30/90	10/30/90	6/25/90 oatlage 8/7/90 alfalfa 10/24/90	10/29/90	10/29/90	7/3/90 8/14/90 10/24/90
Yield	4.3 T DM/A	155 bu/A	146 bu/A	148 bu/A	2.1 T DM/A oat. 2.1 T DM/A alf.	151 bu/A	144 bu/A	4.0 T DM/A
1991 Crops	Alfalfa Hay	D.S. Alfalfa	Filler Corn	Filler Corn	Alfalfa Hay	Oats/Alfalfa	Filler Corn	Pasture

Appendix VI. B1. ARLINGTON RESEARCH STATION WICST - INPUT/OUTPUT DATA - Cash Grain Rotations - 1991

Crop	Continuous Corn	Narrow Row Beans	Corn	Filler Corn	Wheat/Red Clover	Wide Row Beans
Rotation	R1	R2	R2	R3	R3	R3
Treatment	1	2	3	4	5	6
Plot #'s	109,204,306,412	108,206,310,408	101,214,303,401	104,201,301,402	106,202,307,411	102,212,313,407
Primary Tillage	Chisel Plow 11/8/90	Chisel Plow 11/8/90	No-Till	Chisel Plow 11/8/90	None	Chisel Plow 11/8/90
Secondary Tillage	Disk Soil Finisher	Soil Finisher Soil Finisher	None	Disk Soil Finisher	None	Soil Finisher
Planting Date	4/27/91	5/15/91	4/27/91	4/27/91	9/12/90 wheat 3/26/91 clover	5/15/91 soybean 9/4/91 wheat
Variety	DeKalb 547	Pioneer 9272	DeKalb 547	DeKalb 547	Caldwell - wheat Arling. - rd clov.	Pioneer 9272 Caldwell - wheat
Population	32,100	234,000	32,100	32,100	120 lb/A wheat 12 lb/A clover	156,000 soybean 180 lb/A wheat
Fertilizer	100 lb/A 6-24-24 146 lb/A 82-0-0	None	100 lb/A 6-24-24 110 lb/A 82-0-0	128 lb 82-0-0	None	None
Pesticides	Lasso 2 qt/A Atrazine 1.5 qt/A preemerge Counter 15G 9 lb/A planter applied	Treflan 1.5 pt/A Lexone DF .5 lb/A ppi	Lasso 2 qt/A Bladex 2.5 qt/A preemerge Accent .67 oz/A post	Counter 15G 9 lb/A planter applied	None	None
Mechanical Weeding	No-till cult. 6/6/91	None	No-till cult. 6/6/91	Rotary hoe 5/9, 5/13/91 No-till cult. 5/30, 6/6/91	None	Rotary hoe 5/29/91 No-till cult. 6/6/91
Yield	160 bu/A	60 bu/A	185 bu/A	124 bu/A	64 bu/A	51 bu/A
1992 Crops	Corn	Corn	Narrow Row Beans	Wide Row Beans	Corn	Wheat/ Red Clover

Appendix VI. B2. ARLINGTON RESEARCH STATION WICST - INPUT/OUTPUT DATA - Forage Rotations - 1991

Crop	Est. Alfalfa	D. S. Alfalfa	Filler Corn	Filler Corn	Est. Alfalfa	Oats/Alfalfa	Filler Corn	Pasture
Rotation	R4	R4	R4	R4	R5	R5	R5	R6
Treatment	7	8	9	10	11	12	13	14
Plot #'s	111,209,305,409	113,210,311,414	105,203,308,406	107,205,309,404	110,208,304,413	103,213,314,410	114,211,312,403	112,207,302,405
Primary Tillage		Chisel Plow 11/8/90	Chisel Plow 11/8/90	Chisel Plow 11/8/90		Chisel Plow 11/8/90	Chisel Plow 11/8/90	
Secondary Tillage		Disk Soil Finisher	Disk Soil Finisher	Disk Soil Finisher		Disk Soil Finisher	Disk Soil Finisher	
Planting Date	4/23/90	4/8/91	4/27/91	4/27/91	4/23/90	4/8/91	4/27/91	4/23/90
Variety	Magnum III	Magnum III	DeKalb 547	DeKalb 547	Magnum III	Horicon-oats Magnum III-alf.	DeKalb 547	Marathon-rd clov. Toro-timothy Badger-brome
Population		15 lb/A	32,100	32,100		15 lb/A alfalfa 64 lb/A oats	32,100	7 lb/A rd clov. 4 lb/A timothy 8 lb/A brome
Fertilizer		20 T/A manure 10/29/90	128 lb 82-0-0 20 T/A manure 10/30/91	128 lb 82-0-0	15 T/A manure 10/31/91	15 T/A manure 10/23/90	128 lb 82-0-0 15 T/A manure 10/31/91	10 T/A manure 10/29/90 11/4/91
Pesticides	Malathion 1 qt/A 7/18/91	Eptam 2 qt/A ppi Malathion 1 qt/A 7/18/91	Lasso 2 qt/A Bladex 2.5 qt/A preemerge Counter 15G 9 lb/A planter applied	Lasso 2 qt/A Bladex 2.5 qt/A preemerge Counter 15G 9 lb/A planter applied			Counter 15G 9 lb/A planter applied	
Mechanical Weeding			No-till cult. 6/6/91	No-till cult. 6/6/91			Rotary hoe 5/9,13,21/91 No-till cult. 5/30, 6/6/91	
Harvest	6/4/91 7/10/91 8/15/91 10/23/91	6/19/91 7/29/91 8/28/91 10/23/91	10/3/91	10/3/91	6/4/91 7/10/91 8/15/91 10/23/91	Oats 7/16/91 Straw 7/19/91 Alfalfa 8/29/91	10/3/91	6/4/91 7/10/91 8/15/91
Yield	5.8 T DM/A	5.1 T DM/A	156 bu/A	160 bu/A	5.8 T DM/A	55 bu/A oats 1.0 T/A straw 1.4 T DM/A alf	124 bu/A	4.7 T DM/A
1992 Crops	Alfalfa Hay	Alfalfa Hay	D.S. Alfalfa	Filler Corn	Corn	Alfalfa Hay	Oats/Alfalfa	Pasture

Appendix VII. A.

Rotation: 1 (Continuous Corn)
Crop: Corn — Site: Arlington Res. Station
Year: 1990 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Corn	165.78	Bu	2.28	377.97
2.					0.00
3.					0.00
4.					0.00
5.	Total				$377.97

	II. Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (DK547)	0.40	Bag	73.00	29.29
2.	82-0-0	60.00	Lb	0.10	6.21
3.	6-24-24	100.00	Lb	0.08	8.15
4.	Atrazine	2.00	Qt	2.14	4.29
5.	Lasso	2.50	Qt	5.08	12.70
6.	Counter 15G	9.00	Lb	1.36	12.24
7.		0.00		0.00	0.00
8.		0.00		0.00	0.00
9.		0.00		0.00	0.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	165.78	Bu	0.17	28.53
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00	$	0.00	0.00
22.	Custom	1.00	$	0.00	0.00
23.	Fuel	6.05	Gal	0.80	4.84
24.	Repairs	1.00	$	6.47	6.47
25.	Interest	112.72	$	0.060	6.76
26.	Total				$119.48

III. Gross Margin ($/Acre) : (I5 - II26) — $258.48

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	30.67
2.	Labor 1.1 x 1.66 hrs. x 5.00 $/HR	9.11
3.	Total	$39.78

	V. Returns		
1.	Gross Returns	Line I5	$377.97
2.	Variable Costs	Line II26	119.48
3.	Gross Margins	Line V1 - V2	258.48
4.	Fixed Costs	Line IV3	39.78
5.	Returns to Labor, Management, & Land	Line V3 - IV1	227.81
6.	Returns to Management & Land	Line V5 - IV2	218.70

Appendix VII. B.

Rotation: 1 (Continuous Corn)
Crop: Corn — Site: Arlington Res. Station
Year: 1991 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Corn	159.98	Bu	2.14	342.35
2.					0.00
3.					0.00
4.					0.00
5.	Total				$342.35

	II. Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (DK547)	0.40	Bag	75.00	30.09
2.	82-0-0	120.00	Lb	0.11	12.72
3.	6-24-24	100.00	Lb	0.09	8.85
4.	Lasso	2.00	Qt	5.08	10.16
5.	Atrazine	1.50	Qt	2.59	3.89
6.	Counter	9.00	Lb	1.55	13.95
7.		0.00		0.00	0.00
8.		0.00		0.00	0.00
9.		0.00		0.00	0.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	159.98	Bu	0.07	11.97
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00	$	0.00	0.00
22.	Custom	1.00	$	0.00	0.00
23.	Fuel	5.51	Gal	0.80	4.41
24.	Repairs	1.00	$	6.68	6.68
25.	Interest	102.71	$	0.060	6.16
26.	Total				$108.87

III. Gross Margin ($/Acre) : $233.47
(I5 - II26)

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	30.20
2.	Labor 1.1 x 1.65 hrs. x 5.00 $/HR	9.08
3.	Total	$39.28

	V. Returns		
1.	Gross Returns	Line I5	$342.35
2.	Variable Costs	Line II26	108.87
3.	Gross Margins	Line V1 - V2	233.47
4.	Fixed Costs	Line IV3	39.28
5.	Returns to Labor, Management, & Land	Line V3 - IV1	203.27
6.	Returns to Management & Land	Line V5 - IV2	194.19

Appendix VII. C.

Rotation: 1 (Continuous Corn)

Crop: Corn — Site: Lakeland Ag. Complex

Year: 1990 — Plots: Average across 4 plots

I.	Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Corn @ 15%	163.63	Bu	2.28	373.06
2.					0.00
3.					0.00
4.					0.00
5.	Total				$373.06

II.	Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (Pioneer 3790)	0.40	Bag	70.25	28.10
2.	4-10-10	100.00	Lb	0.05	5.00
3.	82-0-0	150.00	Lb	0.10	14.33
4.	Ranger	1.50	Qt	9.06	13.59
5.	Counter 15G	9.00	Lb	1.44	12.93
6.	Attrex 9-0	2.00	Lb	1.87	3.74
7.	Confidence	2.00	Qt	5.13	10.25
8.	Custom Spray	1.00	Pass	3.50	3.50
9.	Custom Plant	1.00	Pass	8.25	8.25
10.	Lease NH3 Toolbar	1.00	Pass	0.31	0.31
11.	Custom Combine	1.00	Pass	21.00	21.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	163.63	Bu	0.14	23.07
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00		0.00	0.00
22.	Custom	1.00		0.00	0.00
23.	Fuel	5.38	Gal.	0.78	4.20
24.	Repairs	1.00	$	4.93	4.93
25.	Interest	153.20	$	0.060	9.19
26.	Total				$162.39

III.	Gross Margin ($/Acre) : (I5 - II26)	$210.67

IV.	Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	$19.18
2.	Labor 1.1 x 1.30 hrs. x 5.00 $/HR	7.15
3.	Total	$26.33

V.	Returns		
1.	Gross Returns	Line I5	$373.06
2.	Variable Costs	Line II26	162.39
3.	Gross Margins	Line V1 - V2	210.67
4.	Fixed Costs	Line IV3	26.33
5.	Returns to Labor, Management, & Land	Line V3 - IV1	191.49
6.	Returns to Management & Land	Line V5 - IV2	184.34

Appendix VII. D.

Rotation: 1 (Continuous Corn)
Crop: Corn — Site: Lakeland Ag. Complex
Year: 1991 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) : Product	Yield	Unit	Price	Dollars per acre
1.	Corn @ 15%	121.15	Bu	2.33	282.28
2.					0.00
3.					0.00
4.					0.00
5.	Total				$282.28

	II. Direct Costs ($/Acre) : Input	Amount	Unit	Price or Factor	Dollars per acre
1.	Seed (Pioneer 3578)	0.40	Bag	73.51	29.40
2.	4-10-10	100.00	Lb	0.06	5.75
3.	82-0-0	122.00	Lb	0.09	11.29
4.	Counter 15G	5.00	Lb	1.51	7.55
5.	Attrex 9-0	1.50	Lb	1.87	2.81
6.	Confidence	2.00	Qt	5.15	10.31
7.	Custom Plant	1.00	Pass	8.25	8.25
8.	Lease NH3 Toolbar	1.00	Pass	0.31	0.31
9.	Custom Combine	1.00	Pass	22.00	22.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	121.15	Bu	0.10	12.60
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00	$	0.00	0.00
22.	Custom	1.00	$	0.00	0.00
23.	Fuel	4.32	Gal	0.85	3.67
24.	Repairs	1.00	$	4.17	4.17
25.	Interest	118.10	$	0.060	7.09
26.	Total				$125.19

III. Gross Margin ($/Acre) : (I5 - II26) — $157.09

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	$14.93
2.	Labor 1.1 x 1.00 hrs. x 5.00 $/HR	5.50
3.	Total	$20.43

	V. Returns		
1.	Gross Returns	Line I5	$282.28
2.	Variable Costs	Line II26	125.19
3.	Gross Margins	Line V1 - V2	157.09
4.	Fixed Costs	Line IV3	20.43
5.	Returns to Labor, Management, & Land	Line V3 - IV1	142.16
6.	Returns to Management & Land	Line V5 - IV2	136.67

Appendix VII. E.

Rotation: 2 (Corn-Soybeans)
Crop: N.R. Soybeans — Site: Arlington Res. Station
Year: 1990 — Plots: Average across 4 plots

I.	Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Soybeans	56.68	Bu	5.96	337.78
2.					0.00
3.					0.00
4.					0.00
5.	Total				$337.78

II.	Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (Pioneer 9272)	60.00	Lb	0.26	15.60
2.	Lexone	0.75	Lb	21.70	16.28
3.	Treflan	1.50	Pt	3.13	4.69
4.		0.00		0.00	0.00
5.		0.00		0.00	0.00
6.		0.00		0.00	0.00
7.		0.00		0.00	0.00
8.		0.00		0.00	0.00
9.		0.00		0.00	0.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	0.00		0.00	0.00
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00	$	0.00	0.00
22.	Custom	1.00	$	0.00	0.00
23.	Fuel	3.45	Gal	0.78	2.69
24.	Repairs	1.00	$	3.54	3.54
25.	Interest	42.79	$	0.060	2.57
26.	Total				$45.36

III. Gross Margin ($/Acre) : (I5 - II26) — $292.42

IV.	Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	15.64
2.	Labor 1.1 x 1.18 hrs. x 5.00 $/HR	6.47
3.	Total	$22.11

V.	Returns		
1.	Gross Returns	Line I5	$337.78
2.	Variable Costs	Line II26	45.36
3.	Gross Margins	Line V1 - V2	292.42
4.	Fixed Costs	Line IV3	22.11
5.	Returns to Labor, Management, & Land	Line V3 - IV1	276.78
6.	Returns to Management & Land	Line V5 - IV2	270.31

Appendix VII. F.

Rotation: 2 (Corn-Soybeans)
Crop: N.R. Soybeans — Site: Lakeland Ag. Complex
Year: 1990 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Soybeans	52.78	Bu	5.96	314.57
2.					0.00
3.					0.00
4.					0.00
5.	Total				$314.57

	II. Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Pioneer	80.60	Lb	0.22	17.49
2.	Treflon	1.50	Pt	3.13	4.69
3.	Lexone	0.67	Lb	22.15	14.84
4.	Ranger	1.50	Qt	9.06	13.59
5.	Assure	15.00	Oz	0.61	9.18
6.	Crop Oil	0.38	Pt	0.35	0.13
7.	28%N	1.25	Gal	2.21	2.76
8.	Cus Spray	1.75	Pass	3.75	6.56
9.	Cus Grain Drill	1.00	Pass	8.63	8.63
10.	Cus Combine	0.75	Pass	15.75	11.81
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	0.00		0.00	0.00
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance			0.00	0.00
22.	Custom			0.00	0.00
23.	Fuel	2.99	Gal	0.78	2.33
24.	Repairs	1.00	$	2.60	2.60
25.	Interest	94.61	$	0.060	5.68
26.	Total				$100.29

III. Gross Margin ($/Acre) : (I5 - II26) — $214.28

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	9.36
2.	Labor 1.1 x 0.46 hrs. x 5.00 $/HR	2.54
3.	Total	$11.90

	V. Returns		
1.	Gross Returns	Line I5	$314.57
2.	Variable Costs	Line II26	100.29
3.	Gross Margins	Line V1 - V2	214.28
4.	Fixed Costs	Line IV3	11.90
5.	Returns to Labor, Management, & Land	Line V3 - IV1	204.92
6.	Returns to Management & Land	Line V5 - IV2	202.38

Appendix VII. G.

Rotation: 2 (Corn-Soybeans)
Crop: Corn — Site: Arlington Res. Station
Year: 1991 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Corn	184.65	Bu	2.14	395.15
2.					0.00
3.					0.00
4.					0.00
5.	Total				$395.15

	II. Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (DK 547)	0.40	Bag	75.00	30.09
2.	82-0-0	110.00	Lb	0.11	11.66
3.	6-24-24	100.00	Lb	0.09	8.90
4.	Lasso	2.00	Qt	5.08	10.16
5.	Bladex	2.50	Qt	4.25	10.63
6.	Accent	0.67	Oz	26.76	17.85
7.		0.00		0.00	0.00
8.		0.00		0.00	0.00
9.		0.00		0.00	0.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	184.65	Bu	0.07	12.98
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00		0.00	0.00
22.	Custom	1.00		0.00	0.00
23.	Fuel	3.31	Gal	0.80	2.65
24.	Repairs	1.00	$	4.64	4.64
25.	Interest	109.55	$	0.060	6.57
26.	Total				$116.13

III.	Gross Margin ($/Acre) : (I5 - II26)	$279.02

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	22.19
2.	Labor 1.1 x 0.96 hrs. x 5.00 $/HR	5.29
3.	Total	$27.48

	V. Returns		
1.	Gross Returns	Line I5	$395.15
2.	Variable Costs	Line II26	116.13
3.	Gross Margins	Line V1 - V2	279.02
4.	Fixed Costs	Line IV3	27.48
5.	Returns to Labor, Management, & Land	Line V3 - IV1	256.83
6.	Returns to Management & Land	Line V5 - IV2	251.55

Appendix VII. H.

Rotation: 2 (Corn-Soybeans)
Crop: N.R. Soybeans — Site: Arlington Res. Station
Year: 1991 — Plots: Average across 4 plots

I. Gross Returns ($/Acre) :				Dollars
Product	Yield	Unit	Price	per acre
1. Soybeans	60.38	Bu	5.27	318.18
2.				0.00
3.				0.00
4.				0.00
5. Total				$318.18

II. Direct Costs ($/Acre) :			Price or	Dollars
Input	Amount	Unit	Factor	per acre
1. Seed (P9272)	90.00	Lb	0.26	23.40
2. Lexone	0.50	Lb	22.15	11.08
3. Treflan	1.50	Pt	3.13	4.69
4.	0.00		0.00	0.00
5.	0.00		0.00	0.00
6.	0.00		0.00	0.00
7.	0.00		0.00	0.00
8.	0.00		0.00	0.00
9.	0.00		0.00	0.00
10.	0.00		0.00	0.00
11.	0.00		0.00	0.00
12.	0.00		0.00	0.00
13.	0.00		0.00	0.00
14.	0.00		0.00	0.00
15.	0.00		0.00	0.00
16.	0.00		0.00	0.00
17.	0.00		0.00	0.00
18. Drying	0.00		0.00	0.00
19. Storage	0.00		0.00	0.00
20. Marketing	0.00		0.00	0.00
21. Crop Insurance	1.00		0.00	0.00
22. Custom	1.00		0.00	0.00
23. Fuel	2.75	Gal	0.80	2.20
24. Repairs	1.00	$	3.22	3.22
25. Interest	44.58	$	0.060	2.67
26. Total				$47.26

III. Gross Margin ($/Acre) : (I5 - II26) — $270.92

IV. Fixed Costs ($/Acre) :	Dollars per acre
1. Equipment and Buildings - Depreciation and Interest	15.00
2. Labor 1.1 x 0.90 hrs. x 5.00 $/HR	4.95
3. Total	$19.95

V. Returns		
1. Gross Returns	Line I5	$318.18
2. Variable Costs	Line II26	47.26
3. Gross Margins	Line V1 - V2	270.92
4. Fixed Costs	Line IV3	19.95
5. Returns to Labor, Management, & Land	Line V3 - IV1	255.92
6. Returns to Management & Land	Line V5 - IV2	250.97

Appendix VII. I.

Rotation: 2 (Corn-Soybeans)

Crop: Corn — Site: Lakeland Ag. Complex

Year: 1991 — Plots: Average across 4 plots

	I. Gross Returns ($/Acre) :				Dollars
	Product	Yield	Unit	Price	per acre
1.	Corn @ 15.5%	144.70	Bu	2.33	337.15
2.					0.00
3.					0.00
4.					0.00
5.	Total				$337.15

	II. Direct Costs ($/Acre) :			Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (Pioneer 3578)	0.40	Bag	73.51	29.40
2.	9-23-30	100.00	Lb	0.06	6.10
3.	82-0-0	122.00	Lb	0.09	11.29
4.	Ranger	1.50	Qt	7.63	11.44
5.	Confidence	2.00	Qt	5.15	10.31
6.	Bladex 90 Df	2.00	Lb	5.04	10.08
7.	Custom Plant	1.00	Pass	8.25	8.25
8.	Lease NH3 Toolbar	1.00	Pass	0.31	0.31
9.	Custom Harvest	1.00	Pass	22.00	22.00
10.		0.00		0.00	0.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	144.70	Bu	0.10	15.05
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00		0.00	0.00
22.	Custom	1.00		0.00	0.00
23.	Fuel	2.59	Gal	0.78	2.02
24.	Repairs	1.00	$	2.47	2.47
25.	Interest	128.71	$	0.060	7.72
26.	Total				$136.44

III. Gross Margin ($/Acre) : (I5 - II26) — $200.71

	IV. Fixed Costs ($/Acre) :	Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	11.38
2.	Labor 1.1 x 0.93 hrs. x 5.00 $/HR	5.12
3.	Total	$16.50

	V. Returns		
1.	Gross Returns	Line I5	$337.15
2.	Variable Costs	Line II26	136.44
3.	Gross Margins	Line V1 - V2	200.71
4.	Fixed Costs	Line IV3	16.50
5.	Returns to Labor, Management, & Land	Line V3 - IV1	189.33
6.	Returns to Management & Land	Line V5 - IV2	184.22

Appendix VII. J.

Rotation: 2 (Corn-Soybeans)

Crop: N.R. Soybeans — Site: Lakeland Ag. Complex

Year: 1991 — Plots: Average across 4 plots

I. Gross Returns ($/Acre) :					Dollars per acre
	Product	Yield	Unit	Price	
1.	Soybeans	58.70	Bu	5.54	325.20
2.					0.00
3.					0.00
4.					0.00
5.	Total				$325.20

II. Direct Costs ($/Acre) :				Price or	Dollars
	Input	Amount	Unit	Factor	per acre
1.	Seed (Pioneer 9272)	83.70	Lb	0.27	22.26
2.	Inoculum	83.70	Lb	0.01	0.59
3.	Pinnicle	0.25	Oz	23.92	5.98
4.	Classic	0.25	Oz	16.26	4.07
5.	Crop Oil	1.00	Qt	0.92	0.92
6.	28% Nitrogen	1.00	Gal	1.75	1.75
7.	Assure	14.00	Oz	0.82	11.43
8.	Crop Oil	1.00	Qt	0.92	0.92
9.	Custom Drill	1.00	Pass	4.50	4.50
10.	Custom Harvest	1.00	Pass	22.00	22.00
11.		0.00		0.00	0.00
12.		0.00		0.00	0.00
13.		0.00		0.00	0.00
14.		0.00		0.00	0.00
15.		0.00		0.00	0.00
16.		0.00		0.00	0.00
17.		0.00		0.00	0.00
18.	Drying	0.00		0.00	0.00
19.	Storage	0.00		0.00	0.00
20.	Marketing	0.00		0.00	0.00
21.	Crop Insurance	1.00		0.00	0.00
22.	Custom	1.00		0.00	0.00
23.	Fuel	3.23	Gal	0.78	2.52
24.	Repairs	1.00	$	3.23	3.23
25.	Interest	80.17	$	0.060	4.81
26.	Total				$84.98

III. Gross Margin ($/Acre) : (I5 - II26) — $240.22

IV. Fixed Costs ($/Acre) :		Dollars per acre
1.	Equipment and Buildings - Depreciation and Interest	12.21
2.	Labor 1.1 x 0.90 hrs. x 5.00 $/HR	4.97
3.	Total	$17.18

V.	Returns		
1.	Gross Returns	Line I5	$325.20
2.	Variable Costs	Line II26	84.98
3.	Gross Margins	Line V1 - V2	240.22
4.	Fixed Costs	Line IV3	17.18
5.	Returns to Labor, Management, & Land	Line V3 - IV1	228.01
6.	Returns to Management & Land	Line V5 - IV2	223.04

Appendix VIII. Making the Economic Analysis of the WICST Useful

A. The economic analysis of the Wisconsin Integrated Cropping Systems Trials must appropriately account for costs and returns, reflect reality, and be useful. For reference, here is a summary of the issues and topics raised at the Advisory Board Annual Meeting January 16, 1992, when asked what they will look for in the economic analysis and how the economic analysis should be presented:

a) What prices should be assigned to the products? Harvest prices, or when? On the farm, or where? Prices "as is" or adjusted for moisture, etc? How should farmers' decisions to participate in federal farm programs be accounted for in the system analysis?
b) Should animal production be accounted for in the grazing trials? If so, how? What prices and costs?
c) What cost should be assigned manure?
d) Assignment of machinery costs requires assumptions about the size of the machinery and its annual use (i.e. about the size of the "farm").
e) Under what circumstances should it be assumed that custom machine operations were used, and machinery charges be based on custom rates (e.g. certain herbicide applications)?
f) What is the most appropriate way to charge for family labor? Should a charge or draw for family living expense be incorporated? Should the labor charge reflect the time of year? While the hours of machine operation in the field can be calculated from the data, how much overhead labor should be allocated to support the field time?
g) Should a charge be made for land so that the return to management is explicit?
h) What are the potential environmental costs? How should they be measured? How should they be valued?
i) Is there a use for enterprise analysis as well as system analysis?

B. Issues raised by the Advisory Board farmers in the Columbia County area at the WICST Systems Economics Evaluation Information Gathering Session 1, Arlington Research Station, February 19, 1992 were as follows:

1. The economic analysis of the Wisconsin Integrated Cropping Systems Trials must:
- appropriately account for costs and returns
- reflect reality
- be useful.

2. The purpose of the discussion at this session was to help that come about. What will you (farmers) look for in the economic analysis? What should be included? How should the analysis be presented?

Although this question was not directly addressed until the end of the session, the suggestions that were raised included the following:
- conduct the analysis on a whole-farm, cropping/animal systems basis, and
- include labor (more below), machinery investment cost recovery, and land costs on a whole-farm basis.

The basis for the discussion was the way in which the farmers in the group (B. Franz, N. Harris, and K. Hershleb) make decisions about crop mix, labor use, land acquisition, and machinery investments. Because the farmers in this group approach these decisions simultaneously, the underlying analysis should calculate a return from all enterprises to the fixed resources - labor and management, land, and machinery.

3. For reference and to focus the discussion, a summary of the issues and topics that had been raised at the Advisory Board Meeting January 16, 1992 was used. The comments under each letter are a draft summary of what occurred at the meeting on 2/19/92.

a) What prices should be assigned to the products? Harvest prices or when? On the farm or where? Prices "as is" or adjusted for moisture, etc?

This discussion addressed the question in three parts: cash grain, forages/corn grown in the animal cropping systems, and rotational grazing.

Cash Grain: Issues raised included when and at what moisture content the grain should be priced, where the price should be quoted, and how the drying costs should be determined. Suggested answers included pricing the grain at harvest at a standard moisture content (e.g., 15.5% for corn), using a local elevator for the price and drying charges on the closest day to when the grain is harvested.

Alfalfa in the Animal Systems: Issues raised included in what form the hay should be harvested (haylage vs. hay), what price to use, whether storage costs needed to be included, how the quality of the hay (measured in relative feed value) should be included, and whether the economics of these animal cropping systems should be evaluated as crops or as part of the dairy system. Suggested answers included using an average price for (all?) auctions the following winter at Johnson Creek and Lomira, accounting for the relative feed value by calculating the average price for hay within a range (say 15 points either way) surrounding the relative feed value of the harvested hay, evaluating the cropping systems using market values for the time being, and considering later addition of animal enterprises.

Corn and oats for grain pricing decisions were not discussed. Subject to hearing from the group, we assume that these would be priced as they are in the cash grain systems.

Rotational Grazing: Issues raised included whether the systems should be valued by rate of gain and economics of the dairy heifers that will use the system, by rate of gain and economics of other relevant livestock, by use in a dairy herd, or by an estimated market value similar to the method discussed for alfalfa in the animal cropping systems. The suggested answers tended to focus on animal performance and economics which raised additional questions about how the livestock should be valued at the beginning and ending of the grazing project. While we don't think a solution was suggested to livestock pricing, we did hear some suggestion that the animals be valued at market (beef) value; even though these are dairy replacement heifers. We need more feedback here. Finally, the group asked us to consider comparisons of the grazing system to confinement feeding systems.

b) What cost should be assigned to manure?

This discussion focused on the issues of manure nutrient value and application costs. The value issue is complicated by the relatively high soil test values on the Arlington Station. Although the nutrients in manure cannot be separated, the suggestion was that the nutrients be priced based on their commercial values. However, the nutrients would only have a value depending on whether or not a cash grain producer would have applied a given nutrient based on the plot's soil test. This particularly applies to phosphorus. Application costs would be based on commercial fertilizer application rates. This was suggested based on the assumption that manure had to be hauled and applied anyway as part of the dairy operation, and the commercial application costs would approximate the management costs of more field-specific fertilizer applications.

c) Assignment of machinery costs requires assumptions about the size of the machinery and its annual use (i.e. about the size of the "farm").

This issue is complicated and is somewhat related to the labor and land issues. Most of the discussion was focused on the cash grain system. At issue was how would we determine what size farm (acres) constitutes a representative farm (ideas included using a target salary level, calculating a per acre family living/salary draw, and then calculating acres -- $30,000 salary -> $30/acre -> 1,000 acres. The problem that the group encountered was the need to consider simultaneously the family living needs, machinery costs, and land costs. While no consensus was reached, the discussion focused on including the total machinery costs as one item (see 2 above) and to work with the farmer advisory groups to define the content, size (capacity), and value of the equipment line.

d) Under what circumstances should it be assumed that custom machine operations were used, and machinery charges be based on custom rates (e.g. certain herbicide applications)?

Issues raised included developing criteria for considering the use of custom machine operations instead of ownership. Discussion primarily addressed the economics, timing, and quality of custom services. Suggestions for the cash grain systems focused on identifying operations where custom rates would be significantly different from ownership costs. Only aerial seeding was identified by the group. Suggestions for the animal cropping systems focused additionally on staying below a target investment per acre and then looking for cost differences between custom and ownership. The only examples provided were grain planting and harvesting where relatively high investment items are used on few acres.

e) What is the appropriate rate to charge for labor? Should the labor charge reflect the time of year?

f) While the hours of machine operation in the field can be calculated from the data, how much overhead labor should be allocated to support the field time? Should a charge or draw for family living expense be incorporated?

Issues raised focused on the separation of labor from management, the relatively low wage rate, and how to account for all labor (field and overhead). Suggestions included either treating labor and management as a whole-farm item as discussed in 2 above, use at least a $10/hour wage rate if labor is to be accounted for in the individual enterprises, and to develop an estimate for total labor.

g) What are the potential environmental costs? How should they be measured? How should they be valued?

Issues raised included the basic question of whether certain systems should be penalized or credited for use or no use of pesticides and fertilizers and, if so, how should the values be determined. The group discussed the basic question at some length with an emphasis on such issues as relatively flat land and relatively deep water tables at the Arlington Station and whether changing practices would have any impact in the near term. Suggestions about valuing the environmental costs included change in land value due to soil erosion or nutrient or pesticide detection in the groundwater, using per unit costs from other sources (for example, $/ton of soil loss), estimates of value of reducing contaminants, and compliance costs such as those seen in the Atrazine Management Areas. In addition, the group was looking forward to the views of environmental and regulatory groups. Furthermore, the group suggested that the analysis include 3 Es: economics, energy, and the environment.

h) Is there a use for enterprise analysis as well as system analysis?

As we discussed in 2 above, it was suggested that the analysis be done on a systems basis with returns calculated 1) on a basis of returns to the fixed resources and 2) as a profit after all other costs have been met. While this should be adequate for the cash grain systems, concerns were raised about how this would be done on the animal systems where the fixed resources are shared by crop and livestock enterprises. In addition, while these systems are on large plots and use field machinery, it was noted that few farmers produce all of their crops on their farms in exactly the same rotation as those included in the study. The suggestion was made that we consider ways in which the systems could be combined to reflect what actually occurs on the farm.

i) Should a charge be made for land so that the return to management is explicit?

Land charges were considered to be a fixed resource, much like labor and machinery. It was suggested that local cash rents serve as a proxy for land costs -- noting that this only represented a 5% return to the investment -- and that land be treated as a fixed resource.

j) How should farmers' decisions to participate in federal farm programs be accounted for in the system analysis?

The group suggested that no farm commodity programs be included in the base analysis. It was noted that we could modify the analysis later to simulate what might have occurred with these programs.

k) Should animal production be accounted for in the grazing trials? If so, how? What prices and costs?

See section 3a for this discussion.

l) Other Issues:

- Should we include pest scouting costs in the analysis?
- Repairs from the Minnesota Cost Estimates are too high; what should we use?
- We need to make sure that all overhead expenses are included in the whole-farm analysis. These include all fuel, repairs, supplies, and taxes.
- More detail on labor would be useful including actual field work rates (although plot work may not be relevant), including all overhead labor hours, detailing these hours by season and possibly comparing them to available field days.