The Pennsylvania State University

The Graduate School

Department of Crop and Soil Sciences

CROP INTENSIFICATION EFFECTS ON FORAGE YIELDS AND THE WATER BALANCE IN SOUTHEASTERN PENNSYLVANIA

A Dissertation in

Soil Science

by

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ABSTRACT

Double cropping is increasingly common on Pennsylvania dairy farms as farmers struggle to produce enough feed and fiber for their cattle. This research studied the effect of using a winter small grain (rye: *Secale cereale* L. and barley: *Hordeum vulgare* L.) on main crop silage yields and soil water balance in no till. A continuous alfalfa treatment was added for comparative purposes. The components of the water balance measured were precipitation, runoff, drainage, and soil water content. Crop evapotranspiration was estimated using the Penman-Monteith method. Small grains harvested for silage were planted in the fall following the harvest of the main crops. Corn (*Zea mays* L.) silage and soybean (*Glycine max* L.) whole-plant yields were not affected by double cropping. Total annual silage yields increased with double cropping compared to single cropping. Double cropping did not reduce runoff any more than single cropping rotations. Runoff was more affected by climatic conditions than by management practices such as crop intensification. Low antecedent soil moisture and low rainfall intensity were the influencing factors in this study. Drainage was no different in double cropping, single cropping and alfalfa (*Medicago sativa* L.) rotations except on a few dates when drainage in alfalfa was lower than in single cropping. Double cropping did not affect soil water content compared to single cropping. However, alfalfa lowered soil water content during a dry season compared to double and single cropping. Crop evapotranspiration was increased by double cropping during the fall and spring seasons. The water balance showed a likely over-estimation of drainage and possibly crop evapotranspiration. Double cropping offers the potential to increase annual silage yields without affecting the water balance in Southeastern Pennsylvania.

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INTRODUCTION

Rationale

The main source of year to year crop yield fluctuations in Pennsylvania is rainfall variability, even in this humid climate (Tzilkowski et al., 2002). This variability causes concerns about productivity and food security, and in dry years farmers struggle to produce enough feed for their cattle. At the same time, many farmers in southeastern Pennsylvania are expanding the area of double cropped corn silage (*Zea mays* L.) or soybean (*Glycine max* L.) after small grains since it allows a more efficient use of land and water resources (Harrington et al., 2001). This recent trend on dairy farms in Pennsylvania may potentially increase drought risks and reduce crop yield, runoff and groundwater recharge. This research addresses these drought risks by studying crop yield and the components of the water balance (runoff, drainage, soil water content, and evapotranspiration) during double cropping.

Literature Review

Yields

Rotational effects on crop yields vary depending on regional climates and soils. In areas with deep fertile soils such as the Corn Belt, both double and single crop practices are adopted by farmers. Corn and soybean are also double cropped in Southeastern USA. Commonly, soybean is double cropped with winter wheat. Double cropping became a common sequential practice in southeastern Pennsylvania in the late 1970s. The most frequent double cropping combination in Southeastern Pennsylvania is soybean after winter barley (*Hordeum vulgare* L.) or winter wheat (*Triticum aestivum* L.) for grain.

Soybean is usually selected because it retains good quality despite reduced yields caused by early frost, and for its ability to withstand drought (Lovell, 1983). Corn is also used in double cropping in Southeastern Pennsylvania. However, Lovell (1983) indicated that low soil moisture and rainfall during the pollination period for corn were the rule rather than the exception. Early harvested varieties were usually selected for the winter crop (small grain) so that the summer crop could be planted as soon as possible. In addition to barley and wheat, rye (*Secale cereale* L.) is a common winter cereal and typically grows under cooler temperatures than winter wheat or winter barley. It can produce more vegetative biomass than other winter cereals from late fall through early spring (Hanaway et al., 1983; Watson et al., 1993; Moyer and Coffey, 2000). Using a double crop in the winter in addition to the main crop in the summer had the potential to double silage yields.

Corn and soybean for grain or silage were frequently used as main growing season summer crops. A study in the Corn Belt region of the U.S. in the early 1970s showed that corn silage and corn grain yields decreased when planted after rye or oats (*Avena sativa chinensis* L.) for silage (Helsel and Wedin, 1981). The yield decrease was caused by a shorter growing season. Similarly, soybean yields were higher in a monoculture compared to when planted after rye silage. Because oats have a late harvest date, soybean yields were poor when planted after oats. Late planting often resulted in light stands due to poor germination and seedling growth (Helsel and Wedin, 1981). Murdock and Wells (1978) found that, in Kentucky, corn silage yields were higher in the monoculture than when double cropped. In addition, corn yields after barley silage were 25 % higher than after oats (Murdock and Wells, 1978). In Idaho, corn silage dry matter yields decreased when planted into stubble of winter forages (spring and winter wheat) (Brown, 2006). A recent study in Japan showed that double cropping corn with Italian ryegrass (*Lolium multiflorum*) decreased yield variability of corn silage (Idota and Ishii, 2007). In another double cropping study, corn silage yields were decreased when ryelage harvesting was delayed. When ryelage was harvested at heading, corn silage yields were higher than when ryelage was harvested one week and two weeks after heading (Yoshihira et al., 2007).

Soybean has been more successfully double cropped than corn in the Southeastern United States. Camper et al. (1972) found that soybean planted on June 30th in Eastern Virginia achieved a high yield and quality. They concluded that short-seasoned corn hybrids planted in late June could be profitable when grown after barley silage in Eastern Virginia. In Oklahoma, soybean forage yields were decreased in a winter wheat double cropping system (MacKown et al., 2007).

A double cropped study of corn silage following small grain silage (barley or oats) in Kentucky showed that dry matter yields of the combined two crops (corn and small grain) averaged 26% higher than that in the corn silage monoculture. The date of maturity at small grain harvest affected corn yields. For higher annual silage yields, "a small grain should be close to the soft dough maturity stage by corn planting time" (Murdock and Wells, 1978). In Idaho, annual double crop (winter forage and silage corn) dry matter yield did not consistently differ in three years from corn alone (Brown, 2006). However, a study in Japan showed that annual corn and rye silage yields were higher than single cropped corn silage (Yoshihira et al., 2007).

Runoff

Runoff occurs on sloping land when the intensity of precipitation exceeds the soil's infiltration rate (Hillel, 1998; Schwab et al., 1993). Many factors contribute to the generation of surface runoff: precipitation amount and intensity, topography and slope, geology and groundwater level, land cover, soil characteristics, irrigation, and snowmelt (Kleinman et al., 2006; Sporre, 2001; Gburek and Sharpley, 1998, Troeh et al, 2004). One of the pioneers in the research of runoff and erosion losses, a German physicist named Wollny, reported in the late 1800s that vegetative cover reduced runoff and soil erosion (Baver, 1938). He found that corn was more effective in intercepting rainfall than soybean or oats, and that alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) were more effective in intercepting rainfall than peas (*Pisum* L.), beans (*Phaseolus* L.), or vetch (*Vicia* DC.). Findings showed that including cover crops as a conservation practice in agricultural management lessens runoff to a greater extent than leaving the soil bare (Troeh et al., 2004). Crop rotations were found to provide more continuous soil cover than monocultures which helped reduce runoff. Small grains protected the soil surface from rainfall impact more than row crops as the plants grew faster and were planted closer to each other. Forage crops produced an even thicker soil cover than small grains, thus producing better runoff control (Troeh et al., 2004). Research has shown that it is possible to reduce runoff on crop lands by minimizing the amount of time that the soil is bare (Hartwig and Ammon, 2002; Joyce et al., 2002; Gregory et al., 2005). Van Vliet et al (1997) demonstrated that winter barley lowered runoff losses a significant extent; mean annual runoff was reduced by 43% between 1991 and 1994, compared to the control treatment without barley cover. Studies assessing nutrient soil loss and runoff demonstrate the benefits of using winter cover crops followed by corn or soybean (Kessavalou and Walters, 1999; McDowell and Sharpley, 2002).

Drainage

Drainage or percolation is the water that moves through the soil profile to depths below the root zone towards groundwater. Studies carried out on fallow (fallow, wheat and pea) versus cropped (mustard *Brassica* L., wheat and pea) annual rotations in Australia showed that groundwater recharge was greater under the fallow rotation (6.7 mm/year) than under the non-fallow rotation (4.0 mm/year) (O'Connell *et al*., 2003). The more water is consumed by crops, the less potential drainage water is available for groundwater recharge, assuming other losses are constant. Although some studies conclude that double cropping may increase infiltration and drainage through increased soil macroporosity and earthworm activity (Tomlin et al., 1995; Dunn and Phillips, 1991; Lund and Elkins, 1978; Farahani et al., 1998), it is more likely that intensified cropping systems will decrease groundwater recharge in southeastern Pennsylvania. Crops sown throughout the year limit the amount of water reaching below the root zone, unless rainfall exceeds plant requirements, transpiration and soil water evaporation. Studies assessing nutrient leaching have shown that cover crops sequester mobile nutrients such as nitrate, thereby inferring a diminishing volume of water reaching groundwater (Rasse et al., 2000; Staver and Brinsfield, 1998; Brandi-Dohn et al., 1997).

Soil Water Content

Soil water content is the quantity of water that is stored in the soil. It is defined as the volume of liquid water per volume of soil. Adding a winter crop to a summer cash crop can have a positive, neutral, or negative effect on soil water content. The winter crop can improve soil water conditions by increasing organic matter content and improving soil structure, resulting in increased infiltration of rainfall, increased water holding capacity, and higher soil water contents (Unger and Vigil, 1998; Gregory et al., 2005). The higher organic matter content increases absorptive surface areas in the soil, thus improving the soil water holding capacity and soil water storage (Gregory et al., 2005). By its shading, a winter crop can create a humid micro-environment below the canopy which results in lower soil water evaporation (Unger and Vigil, 1998). Fallow systems in California caused more soil water loss than double cropped systems (Joyce et al., 2002), and winter cover improved soil water storage for the subsequent crop. Greater soil water contents at 0.6 m in corn after rye compared to single cropped corn (and winter fallow) were found in a silt loam in Virginia (Moschler et al., 1967).

Conversely, a winter crop can consume soil water and lose it through transpiration, resulting in decreased soil water content (Smith et al., 1987). Water depletion by a winter crop can be detrimental in semi arid regions such as the Great Plains where precipitation is limited and irrigation is not used for the main crop (Unger and Vigil, 1998). In a Colorado study by Nielsen and Vigil (2005), legume crops (Austrian winter pea, *Pisum sativum* L.subsp. *sativum* var. *arvense* (L.) Poir.; spring field pea, *P. sativum* L.; black lentil, *Lens culinaris* Medikus; hairy vetch, *Vicia villosa* Roth) replaced fallow in a wheat-fallow rotation. They found that the longer the double crop season, the lower the soil water content at main crop planting time.

Crop Evapotranspiration

Evapotranspiration is the combination of soil water evaporation and plant transpiration. Crop evapotranspiration is a multiple of reference evapotranspiration ET_o such that $ET_c = K \times ET_o$ where K is one or more crop coefficients. K integrates the differences in evaporation and transpiration between field crops and the reference crop surface in the single crop coefficient approach.

There are various methods used to estimate ET_o (Smith et al., 1996; Brandi-Dohrn et al., 1996; Jemison and Fox, 1992; Louie et al., 2000). In 1990, the FAO recommended the use of the Penman-Monteith estimation method as the standard method (Allen et al., 1998). ET_o expresses the evaporation power of the atmosphere.

Adding a winter crop to the main summer crop increases annual evapotranspiration caused by higher transpiration (Dabney et al., 2001; Dabney, 1998). However, double cropping may decrease evaporation in the spring due to the shaded soil surface. Higher humidity and condensation below the canopy result in a lower water vapor movement from the soil to the air (Bond and Willis, 1969; Unger and Vigil, 1998).

Objectives

The objectives of this study were to assess the effects of small grain double cropping on main crop yields (corn silage and soybean grain) and total annual yields (main crops plus small grains for silage), on runoff, drainage, soil water content, crop evapotranspiration, and the complete water balance in southeastern Pennsylvania.

Hypotheses

In this study, the focus was on corn silage and soybean grain yields under both single cropped and double cropped systems with ryelage or barley silage. It was hypothesized that main crop yields will decrease with double cropping, whereas total annual yields (two crops combined) will increase. Double cropping was expected to decrease runoff. Since the study was located in a relatively warm location prone to drought, drainage was expected to be reduced by double cropping. In addition, it was hypothesized that soil water contents at main crop planting and during the main crop growing season (summer) will be negatively affected by double cropping. Finally, double cropping was expected to increase annual crop evapotranspiration rates compared to single cropping.

MATERIALS AND METHODS

Location

The field plots are located near Landisville in southeastern Pennsylvania at the Pennsylvania State University Southeast Research and Extension Center (latitude: 40.05 N, longitude: 76.24 W, elevation: 125 m). The soil is mapped as a Hagerstown silt loam but its main features (color, texture, depth, rock fragments) are characteristic of an alluvial soil such as Nolin or Newark, both of which are found on the banks of Chickies Creek. A portion of this creek is located approximately 50 m south of the plots (Custer, 1985, sheet 39). The average annual precipitation is 1041 mm (N.C.D.C., 2006).

Field Plots – Description

Corn, soybean, rye, barley, and alfalfa were rotated as illustrated in Fig. 1. Plots were 3 m wide by 9 m long. These eight treatments were arranged in a randomized complete block with four replicates. The blocks were perpendicular to the slope. Crop planting and establishment dates depended on harvest dates of the preceding crop. Table 1 shows the management practices used in the rotations including crop varieties, populations, tillage, planting and harvest dates, fertilizer and pesticide amounts and dates applied.

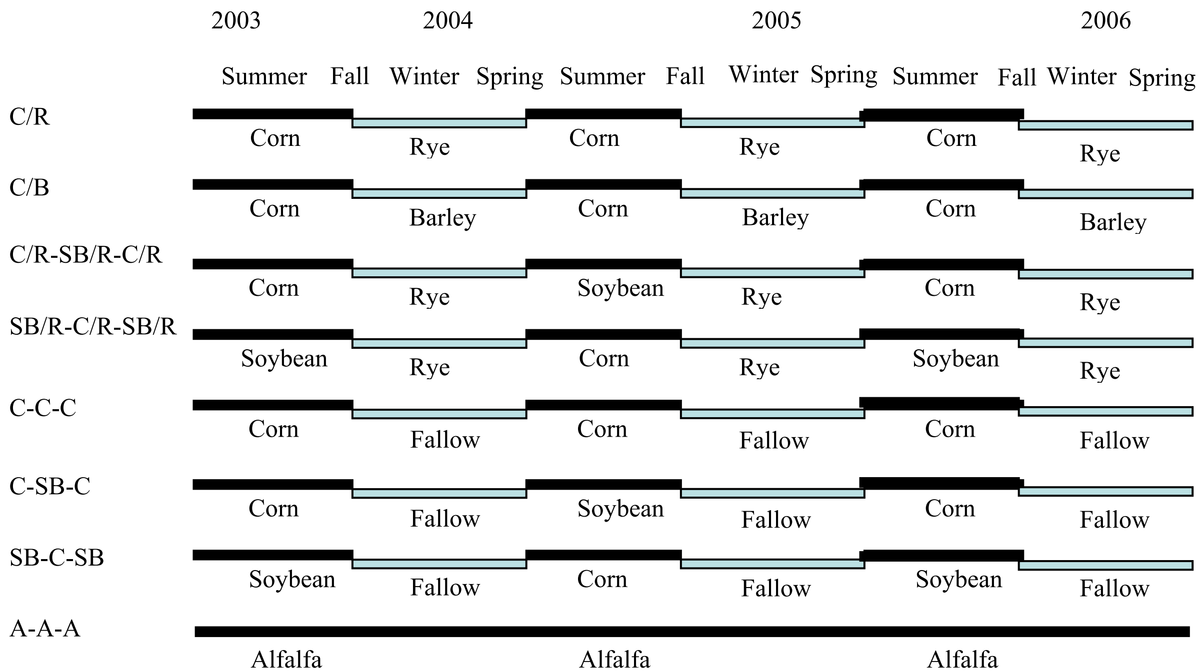

Fig. 1: Timing of the crop rotations. C/R: corn double cropped with rye, C/B: Corn double cropped with barley, C/R-SB/R-C/R and SB/R-C/R-SB/R: corn and soybean rotations double cropped with rye, C-C-C: single cropped corn, C-SB-C and SB-C-SB: single cropped corn and soybean rotations, A-A-A: perennial alfalfa.

Corn		2003	2004	2005	2006
Tillage		Chisel	---------- None ---------		
Variety			DKC64-11 RR2/YGCB		
Planting date					
	single	6-Jun	28-Apr	20-Apr	
	double cropped	6-Jun	7-May	9-May	
Population ppha			69,000		
Amm. nitrate at planting					
	rate		33% 180 kg/ha		
Herbicide	Roundup	19-Jun	22-Apr	10-May	
				25-Jun	
Harvest					
	single	26-Sep	1-Sep	29-Aug	
	double cropped	29-Sep	13-Sep	7-Sep	

Alfalfa		2003	2004	2005	2006
Tillage		Chisel	---------- None ---------		
Variety			WL 357 HQ		
Seeding rate			20 kg/ha		
Planting time		5-May			
Herbicide	raptor	19-Jun	0	0	
Insecticide	warrior	27-Jun	21-Jun	27-Jun	
	warrior	6-Aug	26-Jul	5-Aug	
	velpar		20-Mar		
Harvest			6-May	5-May	
			9-Jun	9-Jun	
		25-Jul	8-Jul	13-Jul	
		28-Aug	6-Aug	9-Aug	
		30-Sep	21-Sep	8-Sep	

Soybean		2003	2004	2005	2006
Tillage		Chisel	---------- None ---------		
Variety			Pioneer 93B68 RR		
Planting time		12-Jun	30-May	31-May	
Population ppha			494,000		
Herbicide	Roundup	19-Jun	22-Apr	10-May	
				25-Jun	
Harvest		13-Oct	20-Oct	20-Oct	

Barley		2003	2004	2005	2006
Tillage		Chisel	---------- None ---------		
Variety		Pennco	Pennco	Barsoy	Barsoy
Seeding rate			108 kg/ha		
Planting time		3-Oct	16-Sep	14-Sep	
	Amm. nitrate top dress		24-Mar	22-Mar	
	Rate		33% at 45 kg/ha		
Harvest			6-May	9-May	9-May

Rye		2003	2004	2005	2006
Tillage		Chisel	---------- None ---------		
Variety		-------------------- not stated -----------------			
Seeding rate			125 kg/ha		
Planting after corn		3-Oct	16-Sep	14-Sep	
Planting after SB		21-Oct	27-Oct	27-Oct	
Amm. nitrate top dress			24-Mar	22-Mar	
	rate		33% at 45 kg/ha		
Harvest			6-May	9-May	9-May

Table 1: Corn, soybean, alfalfa, rye, and barley management information (population, tillage dates, planting dates, harvest dates, fertilizer and pesticide timing and amount).

Particle Size Analysis

Core samples collected for bulk density determination and neutron probe calibrations were used for this analysis (Fig. 2). Samples were taken from three locations between the four blocks, and at six depths (0.18, 0.49, 0.79, 1.10, 1.40, and 1.70 m). They were sieved and particle size distribution of the soil material finer than 2 mm in diameter was determined using the Pipette Method (Thurman et al., 1994). The hydrogen peroxide and candling treatments were omitted due to low soil organic matter and salt content (Poteet, 2005; Gee and Bauder, 1982).

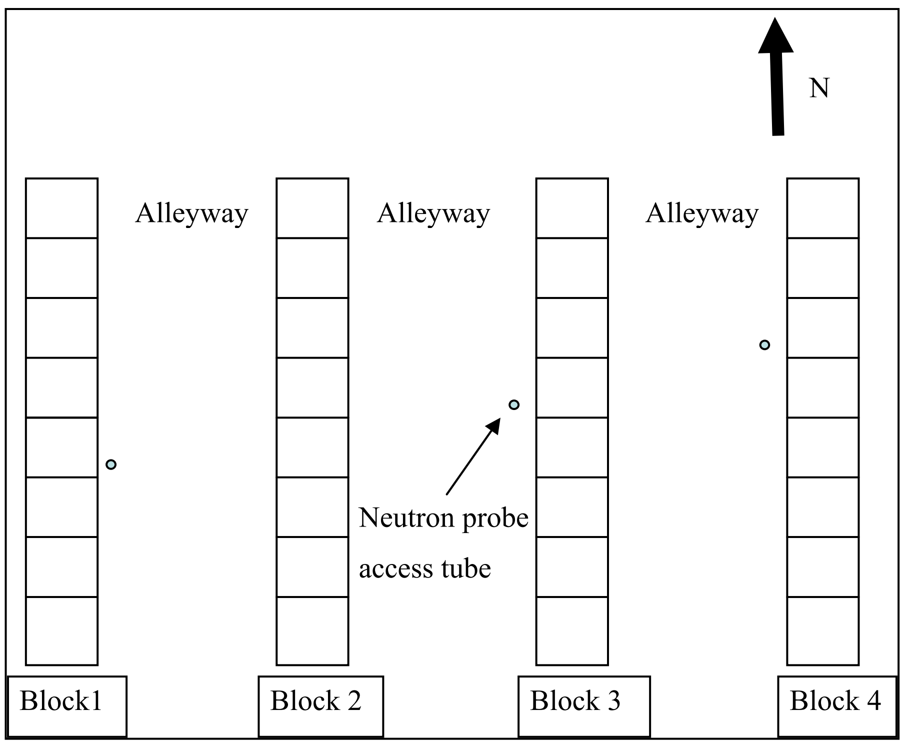

Fig. 2: Location of the access tubes and core sampling for the calibration of the neutron probe. The alleyways were grassed and 9 m wide.

Crops

Corn

In 2003, both double and single cropped corn crops (0.76 m rows) were planted on 6 June and were harvested on 26 September (Table 1). In 2004 and 2005, single cropped corn was planted on 28 April and 20 April and harvested on 1 September and 29 August, respectively. Double cropped corn was planted on 7 May 2004 and 9 May 2005 and harvested on 13 September 2004 and 7 September 2005. A 15-cm corn stubble was left on the soil surface. Nitrogen fertilizer was applied at planting at a rate of 180 kg/ha of ammonium nitrate (33%) (Table 1).

Soybean

All soybean crops (0.38 m rows) were planted on 12 June, 30 May and 31 May in 2003, 2004 and 2005, respectively. They were harvested on 13 October in 2003 and 20 October in 2004 and 2005 (Table 1).

Small Grains

Rye and barley double cropped with corn were planted (0.20 m rows) on 3 October, 16 September, and 14 September in 2003, 2004, and 2005, respectively. Rye double cropped with soybean was planted on 21 October 2003 and on 27 October in 2004 and 2005. Ammonium nitrate was top dressed on all small grains on 24 March 2004 and 22 March 2005 (Table 1).

Alfalfa

Alfalfa was planted on 5 May 2003. There were three cuttings in 2003 and five cuttings in 2004 and 2005 (Table 1). Being a perennial, alfalfa was present all year round for three years, and therefore represented an extreme case of double cropping. When comparing rotations throughout this study, the alfalfa will be referred to as the alfalfa rotation.

Yield Measurements

Small grain silage and alfalfa silage were measured for the entire plot area at harvest. Corn silage yields were measured as follows: one corn row was harvested by hand, leaving stubble 0.20 m tall. Plant counts and weights were taken, as well as row length. Corn yields were calculated for one row then converted to yield in Mg/ha. Soybean grain yields were measured using a 1.2 m wide harvester for the middle three rows, and grain yields were converted to whole-plant (above ground) yields using a harvest index of 0.44 (Bradford et al., 2005). Alfalfa yields were measured using a forage harvester.

Crop Moisture Content Analysis

Moisture content was measured similarly for corn, soybean and small grains: a sample of fresh crop was weighed, dried at 70^{o} C for 48 hours then weighed dry. All yields were calculated on a dry matter basis.

Precipitation

Three sources of precipitation data were used for this study. The closest source was located at the research plots. A second source was located at the Penn State South

East Research and Extension Centre (SEREC) about 500 m west of the research plots. Since comparisons between these two data sets did not always show consistent values, a third data set was acquired from the Lancaster Airport weather station (Federal Aviation Administration) located approximately 11 km east of the research plots. Rainfall intensities used in this study were collected at Lancaster Airport (Pennsylvania State Climatologist, 2006).

Research Plots

Precipitation measurements at the research plots were made using a Watchdog Tipping Bucket Rain Gauge (Spectrum Technologies, Inc., East-Plainfield, Illinois). It recorded rainfall hourly in 0.254 mm increments. This instrument was not designed to measure snowfall, and its function during freezing temperatures was given particular attention. Authors have documented the underestimation of tipping bucket rain gauges in high intensity events (>100 mm/hr) and the overestimation of rainfall at lower intensities (<50 mm/hr) (Vasvári, 2005; Molini et al., 2005). Causes range from water retention between tips, water loss (splash), blockages, wetting, evaporation, wind effects, position, and shelter (Upton and Rahimi, 2003).

Penn State SEREC (Farm House)

The weather station at SEREC is a cooperative reporting site for the National Weather Service. Cumulative precipitation for the previous 24 hours was measured at 4pm every day using a standard rain gauge. A graduated stick was used to measure the depth of the water in the rain gauge container. Snowfall was measured daily as the depth of accumulation on a board at ground level. Water content of the snow collected in the rain gauge was determined after melting.

Lancaster Airport

The weather station at Lancaster Airport is an Automated Surface Observing System (ASOS), also categorized as a level 1 weather station. Precipitation data were obtained from the Pennsylvania State Climatologist (Pennsylvania State Climatologist, 2006). Hourly data were reported and measured according to standard precipitation measurement procedures.

Calibration

Early in the data collection period, the Watchdog Tipping Bucket was generally consistent with SEREC precipitation data. Fig. 3 shows a high correlation between the data in both locations (R^2 = 0.86) during the first three full months of data collection (May through July 2004). This shows that when the tipping bucket worked properly, its values were comparable to SEREC data. It also shows that when the tipping bucket was not functioning, replacing its data with that of SEREC was an acceptable solution.

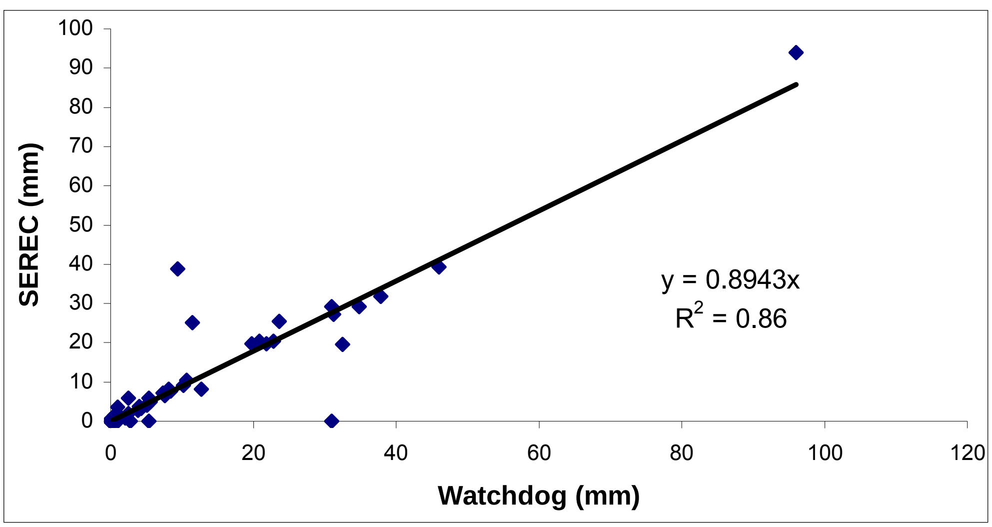

Fig. 3: Rainfall in mm at SEREC plotted against Watchdog data between May and July 2004.

Hierarchical Procedure

Since the watchdog tipping bucket rain gauge was the closest to the research site, its values were given priority and considered valid and handled as follows:

1- Plotting SEREC versus watchdog data over the first three months (May – July 2004) showed that the tipping bucket rain gauge overestimated the SEREC rain gauge by (1/0.8943 -1)100 = 11.8% (Fig. 3). Since the literature indicated that tipping bucket rain gauges overestimated actual rainfall, the regression equation developed in Fig. 1 (y = 0.8943 x) was used to correct all Watchdog data.

2- Where Watchdog data were collected during freezing (fr) or snow (sn), SEREC data were used.

3- In October, November and December 2005 Watchdog data were unavailable due to a failed battery, and SEREC data were used.

4- Relative differences ($\Delta A/\bar{A}$) between corrected Watchdog and SEREC data were calculated for each day (formula: $\Delta A/\bar{A}$ = |Watchdog day i – SEREC day i| * 100 / mean) (Lamb and Combrie, 1993). Relative differences lower than 10 % were not considered important, and corrected Watchdog data were accepted and used (Knight, 2006).

5- Relative differences higher than 10% were given particular attention:

   a. The daily absolute difference between SEREC and the corrected Watchdog data were calculated. Corrected Watchdog data were used when absolute differences were lower than 3 mm (Lamb and Combrie, 1993).

   b. When relative differences exceeded 10% and absolute differences exceeded 3 mm, corrected Watchdog data were rejected in favor of SEREC data. An exception was made during the summer seasons (June to August) when thunderstorms were likely to be localized, rainfall more convective, and precipitation values could differ between the two close locations. Absolute differences up to 5 mm were acceptable, in which cases corrected Watchdog data were used. The Watchdog tipping bucket was not checked for mechanical sources of error, which is the reason a low difference of 5 mm was chosen despite possibilities that higher differences could have occurred during the summer.

Runoff

Runoff plots were located at the down-slope edge of each experimental treatment plot (Fig. 4). The plots were installed in March 2004 using three metal barriers: two of which were 1.22 by 0.15 m and one was 0.76 by 0.15 m. Each barrier was hammered 75 mm into the soil. On the lower side, a 0.76 m long aluminum roof gutter was installed to collect the runoff and channel it to a 122-liter trash can. During planting and harvesting, the runoff plots were dismantled. The metal sidings and gutters were taken out of the soil and the runoff collection containers were covered with an approximately 0.60 m by 0.60 m steel plate. The planter/harvester moved over the 3 by 9 m plots once, then the metal barriers and gutters were reinstalled. The runoff plots were maintained regularly by ensuring that the metal barriers forming them were well connected, especially after planting. Plant debris and soil obstructing the flow of water into the containers were cleaned from the gutters at two week intervals as part of the data collection procedures.

In 2003, the area illustrated as bare in Fig. 4 was planted with the same crop as the adjacent main plot. However, this area was not planted in subsequent years in order to ensure easier access to the lysimeters. Weeds developed in the unplanted areas during the second and third year and were sprayed at the same time as the main plots. Grass was planted in the alleyways between the replications (blocks), and it was mowed as necessary.

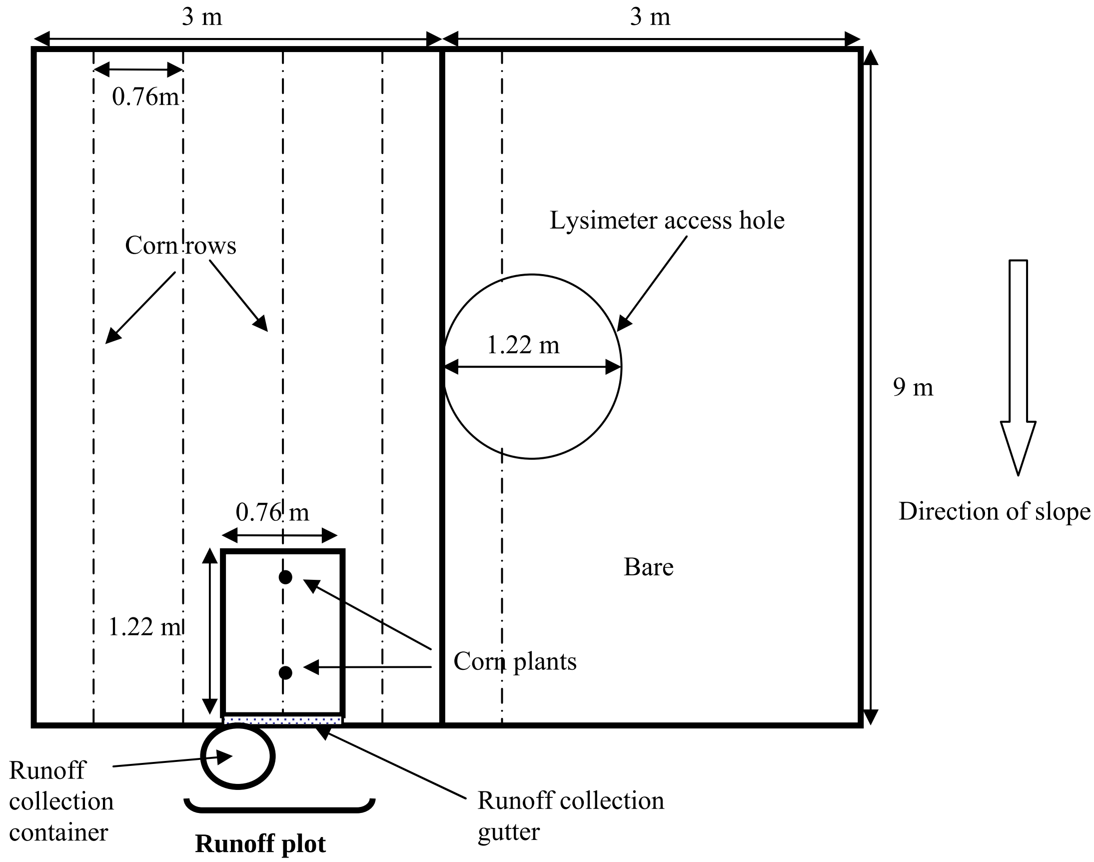

Fig. 4: Location and design of runoff plots.

Fig. 5 shows a general layout of the plot area, and arrows point to the direction of the slope. The area sloped uphill to the north of the research plots and a stream (Chickies Creek) was located approximately 50 m south of the plots. The alleyway between blocks 1 and 2 was a channel for surface water to reach the stream. In the plot area, the slopes ranged from 0.5 to 1% in the North-South direction, and from 1 to 3% in the East-West direction. Block 4 was at the highest position (up-slope), the alleyway between replications 1 and 2 was the lowest position in the landscape (toe-slope), and the overall slope was 1 to 2% between the two positions.

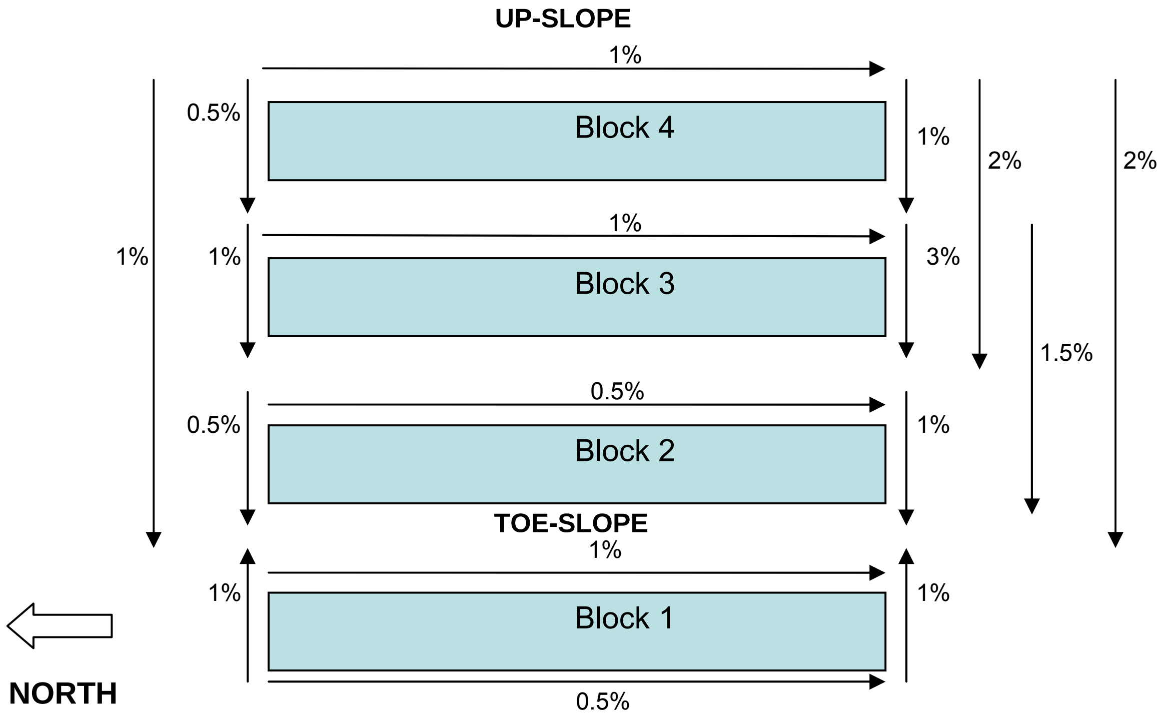

Fig. 5: Slopes and landscape positions of the replications (blocks) and the plots within the replications.

In June, July and August 2004 there were intense rainfall events that caused flooding of most of the runoff and lysimeter plots in blocks 1 and 2. The runoff water caused by these events entered the runoff collection holes and containers from the North, causing the containers to float. We were not able to record values during this time. This prompted us to redesign the runoff collection holes. Culverts were installed in each hole outside the collection containers to keep the soil from collapsing in the hole; gravel was placed in the holes under the containers in order to increase infiltration; a circular steel barrier was driven 75 mm into the soil around the culvert (on the outside) in order to prevent water from entering the runoff collection holes from outside the runoff plots. Metal plates were installed on either side of the gutters to channel runoff away from the runoff collection holes.

Runoff was measured between April 2004 and March 2006 at regular two-week intervals as well as after rainfall events likely to cause runoff. Runoff from snowmelt was included in the annual totals.

Statistical analyses were done using SAS (SAS Institute, 2006). A non-parametric data analysis for randomized complete block design (Friedman's test) was performed at the 5% significance level (SAS Institute, 2006). The repeated measures' procedure (SAS Institute, 2006) was used to assess the effects of rotations over time.

Drainage

Set Up

Drainage water was collected using passive capillary wick samplers (PCAPS) or lysimeters. The 2.44 m deep lysimeter pits were excavated in March 2003 using a commercial 1.22 m diameter drill from the McKinney Drilling Company (Colmar, PA). High Density Polyethylene corrugated plastic culverts were installed in the 32 pits as a support structure to keep the walls from collapsing. Inside the culverts, at 1.65 m deep, a 0.38 m by 0.38 m window was cut out of the culverts to access the lysimeters. Horizontal access holes 0.76 m deep were excavated using hand shovels, and plywood boxes (0.38 m by 0.38 m by 0.76 m) were installed to ensure safety while installing and maintaining the lysimeters. The latter were installed so that the wick surface was firmly in contact with the roof of the access hole. The depth of the lysimeter access hole was below the root zone so that the water sampled by the lysimeters was contributing to groundwater recharge. In previous studies, lysimeters were installed between 0.60 m and 2 m deep (Zhu et al., 2002; Landon et al., 1999; Louie et al., 2000).

Lysimeter design was adapted from that published by Holder et al. (1991). The lysimeters were constructed using two 0.30 by 0.30 m pressure-treated plywood support plates, connected by turn-buckles and threaded rods at the four corners to allow vertical adjustment of the upper plates (Fig. 6). Above the top plate was a 12 mm thick sheet of plexiglass topped with wick material that collected soil water from the overlying soil horizon. Wicks were 9.5 mm in diameter, 20-strand fiberglass rope (stock no. 1381) supplied by Pepperell Braiding Co., East Pepperell, MA (Knutson and Selker, 1994). Hydrophobic manufacturing chemicals were removed from the wicks by combustion at 400°C for 3 hours (Knutson et al., 1993). Individual wick strands were frayed using dissecting probes and small thumbtacks to increase the surface area and improve the absorptive capacity. Wick strands were spread evenly over the plexiglass plate. Spaces between strands were filled with extra wick material to achieve nearly 100 % cover of the plexiglass plate surface.

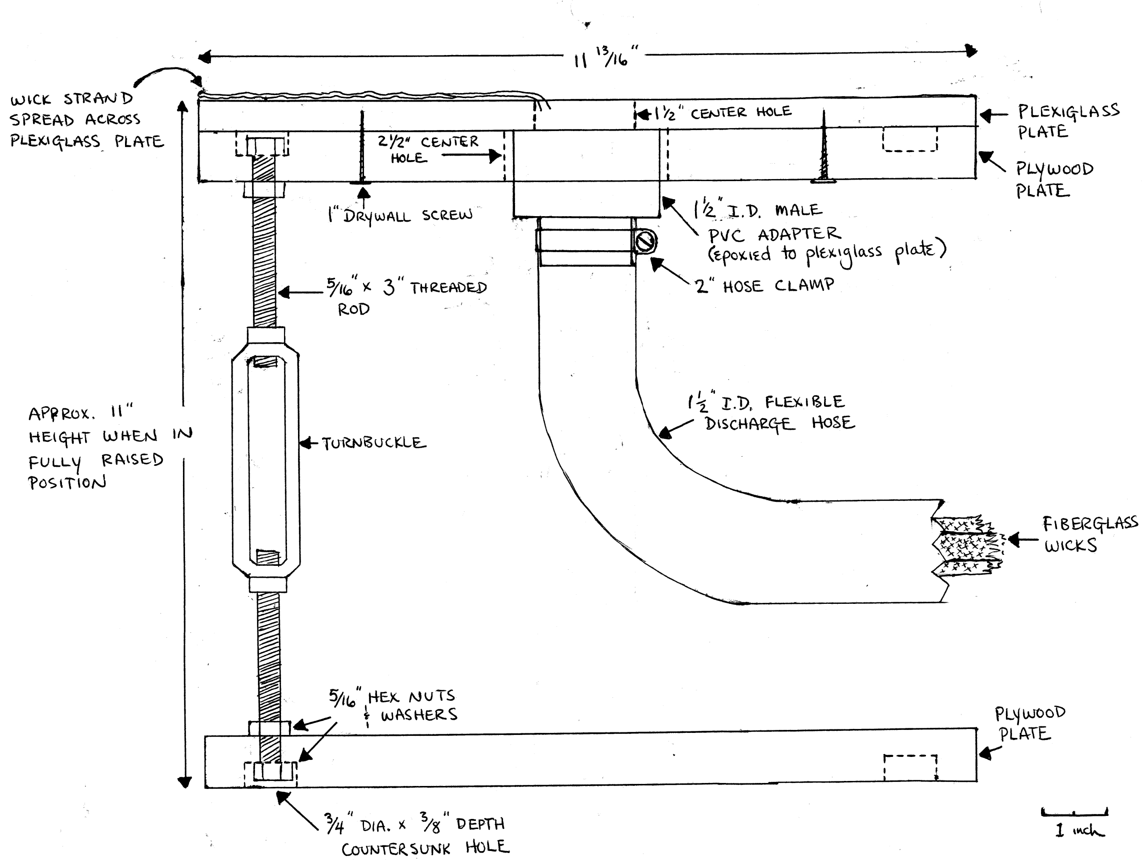

Fig. 6: Cross section of a wick lysimeter in construction. Units are in inches. Design by John Toth (Toth, 2003).

The number of wicks used needed to approximately match the in situ hydraulic conductivity. In order to avoid the disturbance of the native flow regime, the pressure at the top of the wick should match the pressure of the soil for any soil water flux. Six wicks were used for each lysimeter, based on previous work matching the hydraulic conductivity of the wick with that of the soil horizon containing the lysimeters (Jabro et al., 1996; Knutson and Selker, 1994). A previous study showed that six wicks matched the hydraulic conductivity of a local Hagerstown soil (Goyne et al., 2000). The length of the wick fiber was 1.60 m, due to the dimensions of the sampling system, and its height (hydraulic head) was 0.50 m. It follows that the moisture potential applied by the wick was approximately – 0.50 m H_2O (Fig. 7). Measurements of the water collected were taken every two weeks.

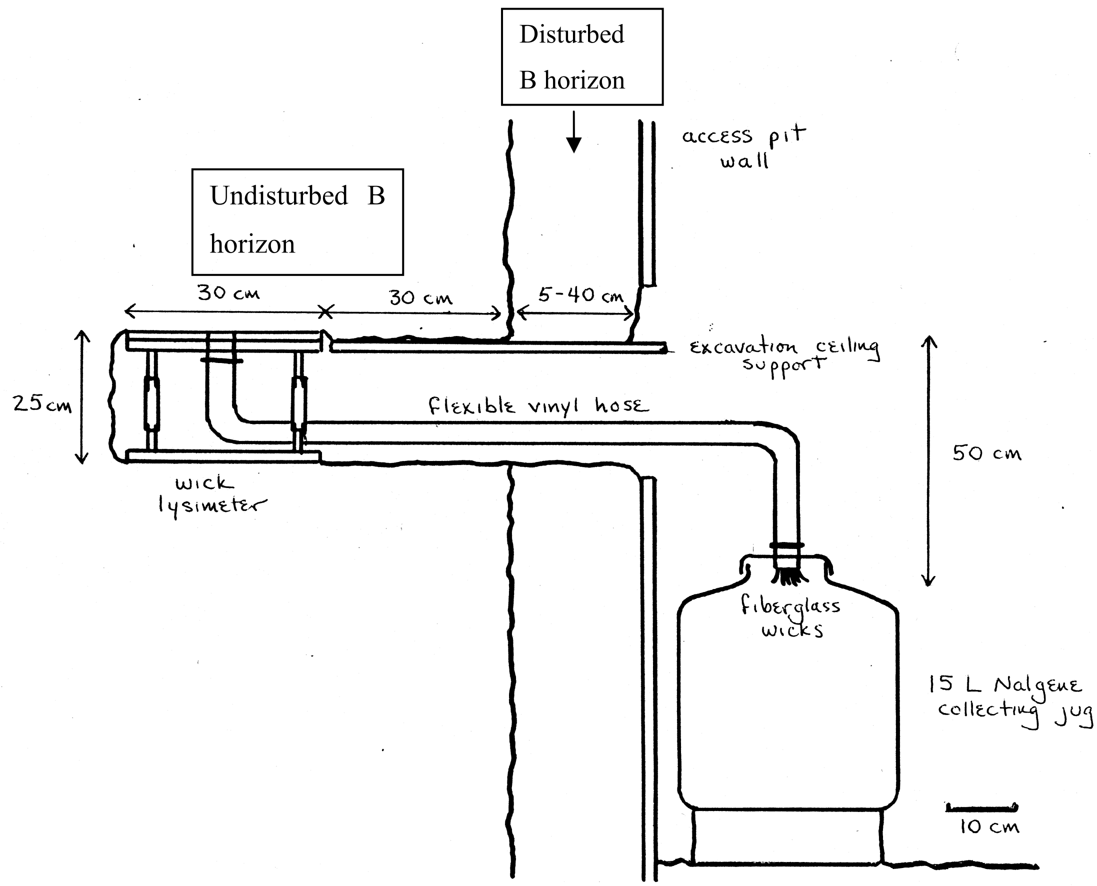

Fig. 7: Diagram of wick lysimeters installed and collecting drainage. Courtesy of John Toth (Toth, 2003).

Due to proximity of bedrock, the lysimeters in block 2 rotation A-A-A (alfalfa) and block 3 rotation C/R (double cropped corn and rye) were not installed. A few lysimeters were replaced or installed later than others. The first measurement of the newly installed/replaced lysimeters (low values) was not included in this analysis.

Statistical Analyses

A rank transformation normalized the data on individual dates and a general linear model (SAS GLM) was used to assess significance between rotation ranks (SAS Institute, 2006). The data were studied further in order to eliminate plot-specific phenomena. A plot by plot calibration was carried out to determine a correction factor per plot.

Most of the calibrated data were ranked, normalized, and analyzed using SAS GLM. Non-parametric statistics for randomized complete block designs (Friedman test) were used where the data were not normalized. To assess effect over time, repeated measures were also performed.

Soil Water Content

Soil water content was measured weekly between October 2003 and 2005, and every two weeks between November 2005 and March 2006 using a neutron probe (Campbell Pacific Nuclear International, Inc., Martinez, CA, USA, model 503DR1.5). Access tubes (38 mm diameter galvanized steel schedule 40) were installed in every plot using a tractor-mounted Giddings hydraulic soil sampling and coring machine (#15-TS Model GSRTS, Giddings Machine Company Inc., Windsor, Colorado). Measurements were taken in every plot at a depth of 0.18, 0.49, 0.79, 1.10, 1.40, and 1.70 m.

Neutron Probe Calibration (additional details of factory, laboratory, and field calibrations are in Appendix E)

For reliable neutron probe measurements, field and laboratory calibrations were sought and compared to the factory calibration. The decision was made to use the laboratory calibration. Please see Appendix E for methods, results and conclusion of the neutron probe calibration.

Crop Evapotranspiration

Reference Crop Evapotranspiration

Reference crop evapotranspiration (ET_o) represents the evapotranspiration from a standardized well-watered grass reference surface with a fixed crop height (0.12 m), albedo (0.23) and surface resistance (70 s/m) and was estimated by the Penman–Monteith equation (Allen et al., 1998). ET_o was approximated using CROPWAT: a decision support system developed by the Food and Agriculture Organisation (FAO) to calculate crop and irrigation requirements using the Penman-Monteith equation (Smith, 1992). The following weather parameters were needed in CROPWAT: solar radiation, minimum and maximum air temperature, relative humidity, and wind speed. They were collected at the Lancaster Airport weather station (Pennsylvania State Climatologist, 2006).

Crop Evapotranspiration

Crop evapotranspiration (ET_c) was estimated using the single crop coefficient method

$$ET_c = K_c ET_o \qquad [1]$$

where ET_c is in mm/day, K_c is the crop coefficient (dimensionless), and ET_o is the reference crop evapotranspiration in mm/day. Monthly ET_c was estimated by multiplying the crop coefficients by monthly ET_o. K_c changes with the development stage of the crop: $K_{c\ ini}$ refers to the initial crop stage where there is 10% or less soil cover. $K_{c\ dev}$ represents the crop developmental stage when its cover increases from 10% to 100%. $K_{c\ mid}$ refers to the crop maturity stage at 100% soil cover, and $K_{c\ end}$ is the crop senescence stage. The four K_c coefficients ($K_{c\ ini}$, $K_{c\ dev}$, $K_{c\ mid}$, and $K_{c\ end}$) were calculated as shown in Zhu et al. (2002) and Allen et al. (1998). The Leaf Area Index (LAI) was used to quantify soil plant cover during the growing seasons. LAI is the ratio of total upper leaf surface of a crop divided by the surface area of the land on which the crop grows. LAI was measured weekly during the growing season using a LI-COR LAI-2000 Plant Canopy Analyzer (LI-COR Biosciences, 2007). When LAI was ≥ 1, full canopy cover was assumed and $K_{c\ mid}$ stage was reached. When LAI was 0.1, 10% canopy cover and $K_{c\ ini}$ stage were assumed.

Alfalfa multiple cuttings in the summer result in several sets of coefficients (Kc ini – Kc end). Allen et al. (1998) recommends averaging the coefficients to produce a single alfalfa Kc curve for the season.

Winter Crop Evapotranspiration

During the winter months when there was plant cover on the soil surface, a crop residue cover adjustment factor K_r was added to Eq. [1] and

$$ET_c = K_c K_r ET_o \qquad [2]$$

where $K_r = 0.5\ K_{c\ ini}$. The values of $K_{c\ ini}$ were reduced by 5% for each 10% of soil surface covered by the crop (Zhu et al., 2002; Allen et al., 1998). Where residues covered almost 100% of the plots (rye, barley, and alfalfa), $K_{c\ ini}$ was reduced by 50%. Where residues covered almost 80% of the plots (soybean) and 50% of the plots (corn silage), $K_{c\ ini}$ was reduced by 40% and 25% respectively (Eck and Brown, 2004).

During the months where the soil was snow-covered, the albedo term of the ET_o equation (Allen et al., 1998) was increased to 0.5 indicating that less shortwave energy was available (Allen et al., 1998). During the months where the soil was bare (single cropped rotations in the winter), K_c was replaced by $K_{c\ ini}$ as it is mostly affected by soil evaporation at the early crop stage (less than 10% ground cover).

Crop Water Stress

Low precipitation in summer 2005 may have caused crop water stress. The effect of soil water stress on crops was described by adding the coefficient K_s in Eq. [1] (Allen et al., 1998) and the evapotranspiration adjusted for water stress became:

$$ET_{c\,adj} = K_c K_s ET_o \qquad [3]$$

When soil water content was at or above the readily available water content (RAW), it was assumed there was no water stress and K_s equaled one. RAW is a proportion of the total available water content (TAW), and the relationship is described by the equation RAW = p TAW where p is the fraction of total available water that can be depleted from the root zone before the crop experiences water stress. A value of 0.5 for p is commonly used for many crops (Allen et al., 1998) and was used in this study.

TAW is the difference between water contents at field capacity and at wilting point. Field capacity was determined by water content from measurements during wet periods and water content at wilting point was estimated using the ROSETTA computer program (Schaap et al., 2001). This program predicts parameters of the van Genuchten equation for a water retention curve. It was run using sand, silt and clay percentages taken from the field data (for more detail, see Appendix F).

RESULTS

Particle Size Analysis and Soil Series

The soil textures varied among the locations (Table 2). The soil was a deep silt loam between blocks 1 and 2, the lowest topographical location, reaching 1.70 m deep. Further up slope between blocks 2 and 3, the silt loam reached 0.49 m deep and was underlain by loam between 0.79 m and 1.10 m deep. At the highest topographical location (between blocks 3 and 4), the soil was a silt loam at 0.18 m depth and was underlain by sandy loam at 0.49 m and 0.79 m, and by loam at 1.10 m.

Table 2: Particle size analysis results for three locations and six depths (0.18, 0.49, 0.79, 1.10, 1.40, and 1.70 m).

Location	Depth (m)	Sand %	Clay %	Silt %	Texture
Between blocks 1-2	0.18	19.3	10.8	69.8	silt loam
	0.49	18.0	15.8	66.2	silt loam
	0.79	22.0	20.7	57.3	silt loam
	1.10	25.2	20.3	54.4	silt loam
	1.40	19.3	19.3	61.5	silt loam
	1.70	19.6	16.2	64.2	silt loam
Between blocks 2-3	0.18	22.5	13.3	64.2	silt loam
	0.49	29.8	18.9	51.3	silt loam
	0.79	35.3	18.9	45.8	loam
	1.10	36.5	15.7	47.8	loam
	1.40	†	†	†	†
	1.70	†	†	†	†
Between blocks 3-4	0.18	33.8	11.8	54.5	silt loam
	0.49	55.6	12.6	31.8	sandy loam
	0.79	56.6	11.4	32.0	sandy loam
	1.10	46.9	12.2	40.9	loam
	1.40	†	†	†	†
	1.70	†	†	†	†

† Samples were not taken at these depths due to proximity to bedrock.

Although the soil was mapped as a Hagerstown silt loam, it lacked the characteristics of a typical Hagerstown soil such as a red (2.5YR) B_t horizon in the subsurface and limestone fragments. The subsurface horizon was brown (10YR), the textures were silt loam, with some loam and sandy loam (up to 1.70 m), alongside mica gneiss and mica schist rock fragments. This is descriptive of a transitional soil representative of the Nolin and Newark series, both found along the bank of Chickies Creek. Our plots are likely on the interface between Newark/Nolin alluvium and Hagerstown residuum, with local alluvium from upslope A_p horizons (Ciolkosz, 2005).

Yields

Corn Silage

During the three years of the study (2003-05), double and single cropped corn silage yields did not differ (Table 3). Mean yields were 16.9, 18.3, and 15.2 Mg dry matter (DM) /ha/yr in 2003, 2004, and 2005 respectively.

Soybean Biomass

Soybean was harvested as grain (see values between parentheses in Table 3) and converted to biomass using a harvest index equal to 0.44 (Bradford et al., 2005) in order to simulate total annual above-ground yields to compare with the other crops. There were no differences in yields between double and single cropping of soybean in 2003 and 2005. However, in 2004 double cropped soybean yielded higher than single cropped soybean probably as a result of severe ground hog damage to the soybean plants early in the season (June 2004).

Small Grain Silage

Barley and rye silage yields were similar in 2004 (Table 3). In 2005, rye in the double cropped rotation involving soybean (SB/R-C/R-SB/R) showed higher yields after corn (8.9 Mg DM/Ha) than rye in the double cropped rotation (C/R-SB/R-C/R) after soybean (5.6 Mg DM/Ha). In addition, barley after corn produced lower yields (3.7 Mg DM/Ha) than rye after corn (7.1 Mg DM/Ha).

Alfalfa

Alfalfa annual biomass yields averaged 16 Mg DM/Ha.

Total Annual Silage

In 2003, without small grains, total silage yields are for corn, soybean and alfalfa yields. The corn rotations produced more silage biomass (17 Mg DM/ha) than the soybean rotations (8.5 Mg DM/ha). Corn and alfalfa yields did not differ. In 2004, double cropped rye and corn yielded higher (22.9 and 24.0 Mg DM/ha) than single cropped corn (19.5 and 20.5 Mg DM/ha). Single cropped corn after soybean (SB-C-SB) was not different than double cropped corn and barley (21.3 Mg DM/ha). Continuous corn yield was no different than corn following soybean. Double cropped soybean with rye (10.6 Mg DM/ha) yielded higher than single cropped soybean (4.2 Mg DM/ha). Alfalfa yields (16.5 Mg DM/ha) were lower than corn single and double cropped yields, and higher than soybean single or double cropped yields. In 2005, corn yields with rye were higher (22.6 and 20.8 Mg DM/ha) than single cropped corn, whether continuous (15.0 Mg DM/ha) or after soybean (15.7 Mg DM/ha). Similarly, soybean and rye double cropped yields were higher (17.9 Mg DM/ha) than single cropped soybean (8.7 Mg DM/ha). Afalfa yields (16.5 Mg DM/ha) were lower than double cropped corn and rye yields, but were no different from double cropped corn and barley yields, double cropped soybean and rye yields, or single cropped corn yields. Alfalfa yields were higher than single cropped soybean yields.

Table 3: Corn, soybean, small grain, alfalfa and total silage yields (Mg of dry matter (DM)/ha) in 2003, 2004 and 2005 on the research plots. Letters beside values indicate statistical differences between rotations (within crops). Values between parentheses indicate actual grain yields in Mg/ha. Underlined crops in a rotation indicate the crops corresponding with yields.

Year	Rotations	Corn	Soybean†	Small Grains	Alfalfa	Total
		----------	----------	Mg DM/ha	----------	----------
2003	C/R	17.1 a				17.1 a
	C/B	16.9 a				16.9 a
	C/R-SB/R-C/R	16.9 a				16.9 a
	SB/R-C/R-SB/R		8.8 (3.9) a			8.8 b
	C-C-C	16.9 a				16.9 a
	C-SB-C	16.9 a				16.9 a
	SB-C-SB		8.2 (3.6) a			8.2 b
	A-A-A				15.0	15.0 a
	Protected Fisher LSD	NS	NS			2.8

Year	Rotations	Corn	Soybean†	Small Grains	Alfalfa	Total
		----------	----------	Mg DM/ha	----------	----------
2004	C/R	16.9 a		6.0 a		22.9 a
	C/B	16.1 a		5.2 a		21.3 b
	C/R-SB/R-C/R		4.6 (2.0) a	5.9 a		10.5 e
	SB/R-C/R-SB/R	18.4 a		5.6 a		24.0 a
	C-C-C	19.5 a				19.5 c
	C-SB-C		4.1 (1.8) b			4.1 f
	SB-C-SB	20.5 a				20.5 bc
	A-A-A				16.5	16.5 d
	Protected Fisher LSD	NS	0.5	NS		1.4

Year	Rotations	Corn	Soybean†	Small Grains	Alfalfa	Total
		----------	----------	Mg DM/ha	----------	----------
2005	C/R	15.5 a		7.1 ab		22.6 a
	C/B	14.4 a		3.7 c		18.1 bc
	C/R-SB/R-C/R	15.3 a		5.6 bc		20.8 ab
	SB/R-C/R-SB/R		9.0 (4.0) a	8.9 a		17.9 bc
	C-C-C	15.0 a				15.0 c
	C-SB-C	15.7 a				15.7 c
	SB-C-SB		8.7 (3.8) a			8.7 d
	A-A-A				16.5	16.5 c
	Protected Fisher LSD	NS	NS	2.1		3.2

† Actual soybean grain yields are reported between parentheses.

Precipitation and Temperature

Complete precipitation and temperature data are available in Appendix B Parts 1 and 2. Snowfall contributed 4.2% and 2.3% to the total precipitation in 2004-05 and 2005-06, respectively. The 2004 growing season total precipitation was 1147 mm, a wet season, while the 2005 growing season total precipitation was 641.5 mm, a dry season (Table 4).

Although Lancaster Airport was located approximately 11 kms east of the research plots, rainfall intensities (obtained from rainfall amounts over time) were consistent with our runoff data during stratiform storms (long duration and spatially uniform), and therefore were considered relevant information.

A comparison between temperature and precipitation measured at SEREC and at Lancaster Airport showed that temperature changed up to 2% and precipitation changed up to 40% from one location to the other.

Runoff

Initial Data Analysis and Statistics

Complete runoff data are available in Appendix C. Individual runoff values per plot were compared to total precipitation that occurred during the runoff accumulation period. Runoff values that exceeded precipitation were considered erroneous and were not included in this analysis.

Because of many zero data points, the data did not follow a normal distribution and the regular transformations (log, ln, exponential, and inverse) did not normalize it (Shapiro-Wilk statistic was small and the hypothesis that the data followed a normal distribution was rejected ($p<0.05$)). Due to the high variability of the runoff data, outliers were identified as those values exceeding three standard deviations from the mean, recognizing that standard deviations are only valid for normally distributed data. No statistical differences were identified (Table 4) with or without outliers using either parametric or nonparametric methods. Since non-parametric statistics using ranks do not require the magnitudes of the observations, no outliers were eliminated in the results shown in Table 4.

Runoff Results

Runoff data were given particular attention after planting and harvesting, and it was concluded that runoff was not inflated by plot dismantlement during that time. Table 4 shows runoff averaged over blocks for each of the 53 events and for every rotation. In addition, overall totals were calculated and shown in Table 4 for two growing seasons (summer 2004 and 2005) as well as over two annual periods (April 2004 – March 2005 and April 2005 – March 2006) and over the cumulative time period (April 2004 – March 2006).

Table 4: Precipitation and mean runoff (mm) summed over the period between the date of interest and the previous date. Collections were made from 9 April 2004 to 20 March 2006. Means are shown for all rotations since there were no statistical differences (at 5%). The rotations are double cropped corn and rye (C/R-C/R-C/R), corn and barley (C/B-C/B-C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R), single cropped corn (C-C-C), corn and soybeans (C-SB-C and SB-C-SB), and alfalfa (A-A-A).

Precipitation (mm) †		35.6	64.1	33.6	10.9	37.0	12.7	85.4	58.8	61.6	100.0
Date	9-Apr-04	14-Apr-04	27-Apr-04	4-May-04	13-May-04	20-May-04	30-May-04	7-Jun-04	16-Jun-04	18-Jun-04	13-Jul-04
Rotation	--- mm ---										
C/R	0	3	0	0	0	0	0	0	0	0	0
C/B	0	3	0	0	0	0	0	0	8	23	29
C/R-SB/R-C/R	0	5	0	0	0	0	0	0	4	50	15
SB/R-C/R-SB/R	0	4	0	0	0	0	0	0	0	25	26
C-C-C	0	4	1	6	0	7	0	2	8	28	24
C-SB-C	0	4	1	1	0	6	0	1	15	49	17
SB-C-SB	0	3	0	0	0	9	0	0	0	‡	37
A-A-A	0	4	0	0	0	0	0	0	4	0	8
Mean	0	4	0	1	0	3	0	0	5	25	19
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	§	N.S.

† Precipitation is summed over the period between the date of interest and the previous date.

‡ Unavailable data due to flooding.

§ Significance not evaluated due to 50% or more data points missing.

N.S. = no differences between treatments at the 0.05 significance level. N.A. = not applicable.

Table 4: Continued.

Precipitation (mm)	44.7	146.3	84.4	92.6	110.8	84.1	47.3	36.9	90.6	13.6	25.9
Date	16-Jul-04	2-Aug-04	16-Aug-04	27-Aug-04	20-Sep-04	29-Sep-04	20-Oct-04	11-Nov-04	2-Dec-04	9-Dec-04	15-Dec-04
Rotation	----------	----------	----------	----------	----------	mm	----------	----------	----------	----------	----------
C/R	2	1	0	3	25	6	1	0	1	0	1
C/B	0	41	21	73	48	13	2	1	8	1	3
C/R-SB/R-C/R	0	4	7	29	1	4	1	0	1	0	0
SB/R-C/R-SB/R	17	46	25	12	34	23	3	0	2	0	3
C-C-C	7	33	39	‡	20	65	6	0	1	1	0
C-SB-C	17	16	44	9	5	10	1	0	1	0	0
SB-C-SB	4	48	37	52	45	0	0	0	0	0	0
A-A-A	9	1	2	13	8	10	1	0	22	0	0
Mean	7	24	22	27	23	16	2	0	4	0	1
Significance	§	§	§	§	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

‡ Unavailable data due to flooding.
§ Significance not evaluated due to 50% or more data points missing.

Table 4: Continued.

Precipitation (mm)	22.1	27.5	73.9	36.8	24.3	62.3	5.6	87.7	54.6	26.6	14.7
Date	29-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05	16-Feb-05	2-Mar-05	17-Mar-05	29-Mar-05	4-Apr-05	28-Apr-05	12-May-05
Rotation						mm					
C/R-C/R-C/R	0	0	0	0	0	0	2	2	1	0	0
C/B-C/B-C/B	1	0	1	0	0	0	1	2	7	2	0
C/R-SB/R-C/R	0	0	0	0	0	0	1	1	0	0	0
SB/R-C/R-SB/R	1	1	2	0	0	0	2	3	2	3	0
C-C-C	3	2	7	0	0	0	1	2	3	0	0
C-SB-C	0	0	2	0	0	0	1	3	0	1	0
SB-C-SB	0	0	1	0	0	0	1	14	0	0	0
A-A-A	1	2	8	0	0	0	1	6	10	7	3
Mean	1	1	3	0	0	0	1	4	3	2	1
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 4: Continued.

Precipitation (mm)	16.9	29.2	0.7	49.8	15.8	66.5	28.2	11.4	19.8	0.0	0.0
Date	27-May-05	9-Jun-05	23-Jun-05	30-Jun-05	6-Jul-05	11-Jul-05	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05
Rotation	--- mm ---										
C/R-C/R-C/R	0	0	0	5	1	3	0	0	1	0	0
C/B-C/B-C/B	0	0	0	6	0	1	0	0	0	0	0
C/R-SB/R-C/R	0	0	0	20	0	1	0	0	0	0	0
SB/R-C/R-SB/R	1	1	0	16	1	6	0	0	1	0	0
C-C-C	0	1	0	4	2	9	3	2	1	0	0
C-SB-C	0	0	0	15	2	9	2	0	0	0	0
SB-C-SB	0	0	0	18	3	20	1	1	1	0	0
A-A-A	1	1	0	1	2	11	1	3	1	0	0
Mean	0	0	0	11	1	8	1	1	1	0	0
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 4: Continued.

Precipitation (mm)	12.4	159.5	77.5	7.9	50.0	32.5	67.8	55.5	65.0	44.6	5.8
Date	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06
Rotation	-- mm --										
C/R-C/R-C/R	0	7	0	0	1	0	0	1	1	1	0
C/B-C/B-C/B	0	3	2	0	1	0	0	0	0	1	0
C/R-SB/R-C/R	0	5	0	0	0	0	1	0	0	0	0
SB/R-C/R-SB/R	1	14	1	0	0	2	1	0	3	4	0
C-C-C	0	17	3	0	1	1	0	2	3	1	0
C-SB-C	0	5	0	0	0	0	1	1	0	3	0
SB-C-SB	0	4	0	0	0	0	2	0	0	4	0
A-A-A	0	13	1	0	12	2	0	4	2	2	0
Mean	0	8	1	0	2	1	1	1	1	2	0
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 4: Continued.

Precipitation (mm)	7.4	11.1	1147	641.5	1617.1	931.3	2548.4
Date	8-Mar-06	20-Mar-06	Growing Season 04	Growing Season 05	Apr04-Mar05	Apr05-Mar06	Apr04-Mar06
Rotation				---------- mm ----------			
C/R	0	0	44	19	49	22	72
C/B	0	0	264	23	280	25	305
C/R-SB/R-C/R	0	0	94	26	96	27	124
SB/R-C/R-SB/R	0	0	216	48	231	59	290
C-C-C	0	0	249	47	266	54	320
C-SB-C	0	0	197	36	204	41	244
SB-C-SB	0	0	238	50	255	57	312
A-A-A	1	1	60	68	99	80	180
Mean	0	0	170	40	185	46	231
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Coefficients of variation ranged between 33 and 426% for all runoff events. There were no differences between rotations using the Friedman test at the 5% level of significance when runoff was summed over the two growing seasons (summers 2004 and 2005) (Table 4). Mean runoff in the growing season of 2004 was 332% greater than in 2005. Over the two annual periods (April 2004 – March 2005 and April 2005 – March 2006) there were no differences between rotations at the 5% significance level (Table 4). The mean runoff for Apr04-Mar05 (185 mm) was 302% higher than the mean runoff for Apr05-Mar06 (46 mm). Precipitation was 74% higher in the Apr04-Mar05 period compared to the Apr05-Mar06 period. Overall cumulative runoff was no different between rotations either, and the mean was 231 mm (Table 4).

Although the runoff data did not follow a normal distribution, repeated measures statistical analysis was used to determine the effect of measurements over time. It showed that time was a significant factor ($p<0.05$). The differences in rainfall amounts and intensities between the events caused differences among runoff responses. The interaction between rotations and time was assessed and found to be significant ($p<0.05$). Consequently, rotation runoff responses changed over time despite receiving the same precipitation events. This significant interaction effect lead to the evaluation of runoff on an event by event basis. Per event, there were no differences at the 5% significance level between the eight rotations, and the means varied between 0 and 27 mm (Table 4). In trying to explain the similarities between rotations on an event basis, follow the runoff reactions of two rotations: C-C-C and C-SB-C over time (Table 4). Runoff for the C-C-C rotation was similar to that of the C-SB-C rotation on 9, 14 and 27 April 2004 (Table 4). However, on 4 May 2004 runoff was 6 mm for C-C-C but did not change for C-SB-C (1 mm). Later, runoff in those two rotations was not different until 16 June 2004 when runoff in C-C-C was 8 mm whereas that of C-SB-C was 15 mm. A month later on 13 July, C-C-C runoff was 24 mm whereas C-SB-C runoff was only 17 mm. There was no typical runoff reaction between the two rotations, and there were frequent inconsistencies in rises and falls of runoff among all rotations which led to there being no significant differences in runoff between rotations on an event basis.

In another analysis, the proportion of events that produced runoff was calculated. The number of non-zero runoff collections was divided by the total number of runoff collections (Table 5). The proportions varied between 25% and 47%. The Friedman test showed that the rotations were not different from each other at the 5% significance level.

Table 5: Percent runoff higher than zero mm: the number of non-zero runoff events divided by the total number of observations made for runoff.

Rotations	Proportion of Runoff Occurrences %
C-R	32
C-B	38
C-R-SB-R-C-R	25
SB-R-C-R-SB-R	38
C-C-C	46
C-SB-C	36
SB-C-SB	32
A-A-A	47
Significance	N.S.

Calculating runoff as a percentage of precipitation enables a decrease in the variability of the data. This was performed for events that produced runoff amounts above zero for at least 50% of the plots. The statistical analysis (Friedman test) showed no differences between the rotations (Table 6). Mean percentages ranged from 4 to 21% of precipitation as runoff. Higher runoff occurred during summer (June and July 2005) and fall (September 2004). In most cases, high runoff was directly correlated with high rainfall intensities. The highest runoff percent of precipitation (20 September 2004) was caused by an event with a maximum intensity of 20 mm/hr. Higher maximum intensities observed on 30 June 2005 (23 mm/12 minutes) also resulted in 21% of precipitation running off the plots. Overall most of the runoff values were not large, indicating that the vegetation and soil captured most of the rainfall.

Table 6: Runoff as a percentage of precipitation for selected events. Dates (events) where 50% or more of the plots had zero runoff were not included in this table.

Precipitation (mm)	35.6	110.8	84.1	47.3	87.7	54.6	49.8	66.5	159.5
Date	14-Apr-04	20-Sep-04	29-Sep-04	20-Oct-04	29-Mar-05	4-Apr-05	30-Jun-05	11-Jul-05	12-Oct-05
Rotation					%				
C-R	10	23	7	1	2	1	10	4	4
C-B	9	44	15	5	3	14	12	1	2
C-R-SB-R-C-R	13	1	4	1	1	0	40	1	3
SB-R-C-R-SB-C	12	31	28	6	4	3	31	10	9
C-C-C	10	18	77	12	2	6	9	14	10
C-SB-C	11	5	12	2	3	0	31	14	3
SB-C-SB	9	41	0	1	16	1	36	30	2
A-A-A	11	8	11	3	7	17	1	17	8
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Mean	11	21	19	4	5	5	21	11	5
Max intensities (mm/hr)†	8	20	17	4	7	12	115‡	73‡	24‡

N.S. = non-significant at the 5% level.

† Source: Lancaster Airport weather station (11 kms away from plots).

‡ These intensity values were as follows: 23 mm/12 minutes, 28 mm/23 min, and 13 mm/32 min.

Drainage

Initial Data Analysis and Statistics

Drainage data (see Appendix D Table 25 for complete drainage data) did not follow a normal distribution (Shapiro-Wilk test $p<0.05$), nor did several transformations of the data (log, exponential, inverse, square root, and rank). Both parametric and non parametric statistics will be reported recognizing that the underlying assumptions of normality have been violated. Non-parametric statistics were used when the data did not follow a normal distribution.

Calibrated drainage data (see Appendix D Table 26 for complete calibrated drainage data) for overall and seasonal totals did not follow a normal distribution, except cumulative data for summer 2004, winter 2003-04 and winter 2005-06. Out of the 62 individual dates, only 18 showed normality. In order to normalize the rest of the calibrated data, transformations were studied using the SAS univariate procedure, and none were found to normalize the data. Looking at individual dates, ranking normalized most calibrated drainage data. Those with many zeros (summer 2005) were not normalized and the Friedman test for randomized complete block designs was used in these cases. The repeated measures statistical test was used to assess the effect of rotations on drainage over time.

Plot Calibrations

Since some plots were found to produce a high drainage value across all dates whereas other plots produced low drainage across all dates, a coefficient was devised similar to that used by Zhu et al. (2002) for each lysimeter in order to remove the local drainage effect. The objective was to find a time of year when the soil was moist and nearly at a steady state following relatively high precipitation when drainage was occurring in every plot. In order to choose a time of year for this calibration, a series of dates were studied and the following conditions were sought:

- Minimum rotation effect
    - Low evapotranspiration (early to mid spring and in late fall)
    - No field disturbances (soil or crop management such as harvesting, planting, cutting)
- No water loss through runoff (see runoff data in Appendix C)
- No freezing temperatures that would inhibit soil water movement (see temperature data in Appendix B part 2)
- No snow cover or potential standing water (see precipitation data in Appendix B part 1)
- No thawing that would inflate drainage. Thawing was suspected when drainage exceeded precipitation within the 2 week measurement period (see drainage data in Appendix D).
- Moderate precipitation during the two-week period (Appendix B part 1)
- Drainage occurring in all plots (no zero data values – see drainage data in Appendix D)

Table 7 includes data for some potential dates that were used to determine the suitability of those dates for the calculation of a calibration coefficient. For every date, total precipitation and the temperature range for the previous two-week period, corresponding to the drainage collection period, are shown. The "freezing" column describes the number of days during the drainage collection period when temperatures fell below 0 degrees C. The sixth column indicates whether snow accumulation was present by indicating the amount of snowfall. Thawing was determined during the two weeks prior to the measurement by comparing drainage collection with precipitation. When spring drainage exceeded rainfall in many of the plots, thawing was considered prevailing. The eighth column presents the number of missing or null drainage values for each date. Such values rule out the calculation of the coefficients for those plots (coefficient for plot 1 = drainage for plot 1 / precipitation). The runoff column indicates whether runoff was collected by giving the mean value measured on the specified date. A range of values denotes that runoff was not collected on that date, and describes the amounts of runoff collected before and after that date. Evapotranspiration (ET) was classified as “0” during the winter months when at least 10 days of freezing temperatures occurred. A “low” ET signifies between 2 and 10 freezing days, and a “moderate” ET signifies less than 2 days of freezing temperatures occurred during the two-week period. The field management column indicates whether planting or harvesting took place. Any such soil surface disturbances were plot specific and needed to be eliminated from the choice of dates for a calibration coefficient. The decision column designates a “yes” if the corresponding date satisfied most of the above criteria and a “no” if not. A “no” decision was justified in the reason column.

Table 7: Data on potential dates for the drainage calibration coefficients. Criteria for decision-making included precipitation (mm), temperature (C), number of freezing days, snowfall (mm), thawing, number of missing or zero drainage values, runoff (mm), estimated ET, and field management. Decision and justification for each potential date is also shown.

Season	Date	Precip.	Temp.	Freezing	Snow	Thawing	Zeros or missing	Runoff	Estimated ET	Field Management	Decision	Reasons
		mm	^{o}C	Days	mm			mm				
	5-Mar-04	7.87	-7 to 20	11	1	Yes	2	No data	0	--	No	low precipitation, thawing
	19-Mar-04	52.83	-6 to 18	8	13	Yes	2	No data	Low	--	No	snow cover, thawing
Spring 04	2-Apr-04	27.94	-8 to 23	4	No	Yes	2	No data	Low	--	No	low precipitation, thawing
	16-Apr-04	46.00	-2 to 20	5	No	Yes	2	0	Low	--	Yes	
	28-Apr-04	66.10	1 to 31	No	No	No	1	0-1	Moderate	Corn planting	No	high ET and planting
	28-Oct-04	25.40	-2 to 17	2	No	No	1	0	Moderate	Rye planting	Yes	
	11-Nov-04	28.01	-6 to 21	3	No	No	1	0	Low	--	Yes	
Fall 04	24-Nov-04	28.40	-5 to 16	4	No	No	1	0-4	Low	--	Yes	
	9-Dec-04	75.69	-7 to 18	9	No	No	0	0	Low	--	Yes	
	22-Dec-04	26.40	-15 to 11	9	No	No	0	1	Low	--	No	Low temperatures
	2-Mar-05	62.37	-14 to 7	13	36	Yes	1	0	0	--	No	Snow cover
	17-Mar-05	5.60	-17 to 19	15	0.3	Yes	1	1	0	--	No	Low precipitation
Spring 05	31-Mar-05	87.70	-6 to 17	4	No	Yes	1	3-4	Low	--	Yes	
	14-Apr-05	55.40	-1 to 27	2	No	No	1	2-3	Moderate	--	Yes	
	28-Apr-05	25.86	-4 to 28	2	No	No	2	2	Moderate	Corn planting	Yes	
	28-Oct-05	77.47	2 to 24	0	No	No	9	1	Moderate	Rye planting	No	Low drainage
Fall 05	10-Nov-05	7.87	-2 to 23	4	No	No	12	0	Low	--	No	Low drainage
	23-Nov-05	50.04	-7 to 21	8	No	No	4	2	Low	--	No	Low drainage
	22-Feb-06	5.80	-18 to 13	14	No	Yes	2	0	0	--	No	Low temperatures
Spring 06	8-Mar-06	7.40	-11 to 12	6	No	Yes	2	0	Low	--	No	Low precipitation
	20-Mar-06	11.13	-6 to 26	3	No	No	3	0	Low	--	No	Low precipitation

Table 8 presents the eight chosen dates from Table 7. Each column contains the coefficients for each of the 32 plots. The coefficients were calculated as the ratio of amount of drainage in each plot to the amount of precipitation for that two-week collection period. In addition, the mean and standard deviation (SD), calculated from the six pre-selected dates (in the big box in Table 8), were determined in order to help choose a single calibration date. The following is an example computation of the coefficient for plot 1-1 (block 1 rotation 1, i.e. rotation C/R in block 1) on 16 April 2004. Precipitation between 3 April 2004 (one day after previous drainage measurement) and 16 April 2004 was 46 mm (Appendix B Table 22). Drainage collected on 16 April 2004 on plot 1-1 was 100 mm (Appendix D Table 25). The ratio of 100 to 46 is 2.17 (Table 8). All coefficients in Table 8 were computed using this method.

The first and last dates (16 April 2004 and 28 April 2005) were eliminated due to a higher number of zero values than all other dates. For the six remaining possible dates, the means and standard deviations of each plot were used to invalidate more dates. The columns corresponding to 28 October 2004 and 14 April 2005 contain a higher number of outliers, rendering them unsound. Of the remaining four dates, 9 December 2004 was chosen because it had the least number of missing/zero values. Moreover, calibration coefficients for this date were closely related to the mean coefficients of the 32 plots over the selected dates.

Table 8: Dates chosen from Table 7 and the corresponding calibration coefficients per plot (calculated as the ratio of the amount of drainage per plot to the amount of precipitation). Mean and standard deviations (SD) helped in choosing a single date for the data calibration. Plot 1-2 is plot two in block one.

Plot	16-Apr-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	31-Mar-05	14-Apr-05	28-Apr-05	Mean†	SD†
1-1	2.17	2.45	2.61	2.04	2.69	2.32	**0.75**	1.00	2.14	0.72
1-2	0.07	**0.28**	0.18	0.11	0.07	0.07	0.12	0.17	0.14	0.08
1-3	2.19	**3.06**	2.45	2.05	2.56	2.32	**0.84**	0.23	2.21	0.75
1-4	1.07	0.43	0.39	0.35	0.44	0.39	**3.33**	0.25	0.89	1.19
1-5	0.00	0.35	0.32	**0.22**	**0.60**	0.38	0.27	0.19	0.36	0.13
1-6	0.56	0.63	0.66	0.50	0.31	**0.18**	**0.74**	0.34	0.50	0.22
1-7	1.81	**1.72**	1.55	**1.16**	1.38	**1.14**	1.44	0.71	1.40	0.23
1-8	0.94	0.47	0.45	0.64	**1.03**	‡	**0.07**	0.47	0.53	0.35
2-1	0.43	0.93	1.17	1.09	0.87	0.59	**0.04**	0.81	0.78	0.42
2-2	0.76	**1.32**	1.12	0.93	0.73	0.39	**0.09**	0.61	0.76	0.46
2-3	1.05	**0.81**	0.68	0.55	0.52	0.40	**0.36**	0.11	0.55	0.17
2-4	0.63	0.57	0.64	0.54	0.55	0.74	**0.04**	0.29	0.51	0.24
2-5	0.80	0.70	0.95	0.85	0.67	**0.45**	**0.98**	0.60	0.76	0.20
2-6	1.79	2.28	**2.80**	2.53	1.64	1.06	**0.63**	1.67	1.82	0.86
2-7	0.22	0.56	0.51	**0.42**	**0.70**	**0.42**	**0.72**	0.29	0.56	0.13
2-8										

Coefficients in individual small boxes: zero or missing value

Dates in one large box: these 6 dates are possibilities as they have fewer zeros or missing values

Underlined coefficients: outliers (means ± 2 SD)

Bold — In bold: outliers (mean ± SD)

† These calculations were obtained from the six dates selected in the big box.

‡ Missing value: collection can tipped over and spilled contents.

Table 8: Continued.

Plot	16-Apr-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	31-Mar-05	14-Apr-05	28-Apr-05	Mean†	SD†
3-1	0.88	0.28	0.55	0.16	0.79	0.75	**0.93**	0.00	0.57	0.30
3-2										
3-3	0.07	0.08	0.08	**0.03**	0.15	**0.22**	**0.23**	0.03	0.13	0.08
3-4	1.30	**0.64**	0.85	0.81	1.21	1.29	**1.92**	0.51	1.12	0.46
3-5	0.31	0.29	0.33	0.27	**0.15**	0.19	**0.42**	0.28	0.27	0.10
3-6	0.19	**0.25**	0.12	‡	0.17	0.17	**0.00**	0.14	0.14	0.09
3-7	0.00	**0.00**	**0.00**	0.09	0.07	0.10	**0.13**	0.00	0.06	0.05
3-8	0.45	0.29	0.37	0.39	0.98	1.02	**1.75**	0.39	0.80	0.56
4-1	0.38	0.51	0.55	0.47	0.53	0.49	**0.80**	0.30	0.56	0.12
4-2	0.48	0.58	0.77	0.66	1.22	1.15	**1.90**	0.52	1.05	0.49
4-3	0.26	**0.53**	0.32	**0.21**	0.34	0.26	0.31	0.13	0.33	0.11
4-4	1.03	**0.77**	1.07	0.90	**1.54**	1.07	**1.70**	0.51	1.18	0.37
4-5	2.41	3.39	3.65	2.84	**2.12**	**1.84**	3.67	2.91	2.92	0.79
4-6	0.74	**0.43**	**0.74**	0.63	0.64	**0.49**	**0.75**	0.27	0.61	0.13
4-7	0.49	1.79	1.81	1.49	**1.13**	**0.87**	1.69	1.17	1.46	0.39
4-8	0.42	0.31	0.33	0.36	0.52	0.43	**0.70**	0.27	0.44	0.15

Coefficients in individual small boxes: zero or missing value

Dates in one large box: these 6 dates are possibilities as they have fewer zeros or missing values

Underlined coefficients: outliers (means ± 2 SD)

Bold In bold: outliers (mean ± SD)

† These calculations were obtained from the six dates selected in the big box.

‡ Missing value: collection can tipped over and spilled contents.

Impact of Rotations on Uncalibrated Drainage

Table 9 presents the mean drainage (mm) collected over a two-week period ending on the indicated date. Values for each rotation were averaged over blocks for the two-week period, as well as for season totals, annual totals, and the overall total. Collection dates span from November 2003 to March 2006. The repeated measures' statistical test showed that rotations were not significantly different when averaged over time ($p=0.122$). The rotation by time interaction was not significant ($p=0.999$). However, time was a significant factor ($p<0.0001$) and so individual dates were given particular attention. Both parametric (GLM) and non-parametric (Friedman) statistical tests showed that there were no statistical differences between rotations at the 5% significance level for the totals and for most of the individual measurements (Table 9). Drainage means ranged from less than 1 mm for most of the 2005 growing season to 87 mm on 13 January 2006 during the non-growing season. Significant differences between rotations were observed on 9 June 2005 (Friedman test: $p=0.025$) and on 23 November 2005 (proc GLM: $p=0.047$) (Table 9). Drainage on 9 June 2005 was highest in single cropped corn (C-C-C), and higher than all four double cropped rotations (Table 9). Drainage in two of three single cropped rotations (C-SB-C and SB-C-SB) was no different from all four double cropped rotations. Alfalfa was no different from double cropping or two of three single cropped rotations (C-SB-C and SB-C-SB). Drainage on 23 November 2005 for the four double cropped rotations was no different from the three single cropped rotations. The alfalfa drainage was no different from that in three out of the four double cropped rotations, but it was significantly lower than the three single cropped rotations (Table 9).

Table 9: Mean drainage (mm) collected over the two weeks prior to the date of measurement.

Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04
Rotation											
C/R	36	64	115	94	34	11	8	4	35	53	45
C/B	24	31	39	45	15	8	2	1	5	17	19
C/R-SB/R-C/R	27	43	68	71	28	9	3	17	37	43	33
SB/R-C/R-SB/R	44	58	111	88	29	12	6	21	19	48	36
C-C-C	49	43	58	73	32	13	14	13	27	48	37
C-SB-C	35	40	52	60	23	9	8	3	16	29	20
SB-C-SB	40	44	73	75	28	9	15	10	31	41	37
A-A-A	55	55	98	117	32	3	13	13	16	45	33
Mean	39	47	77	78	28	9	8	10	23	40	32
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.A.: Not applicable. Less than 50% data available.
N.S.: Non significant differences between rotations at the 5% level.

Date	16-Apr-04	28-Ap-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04
Rotation											
C/R	44	33	21	9	17	70	15	72	23	19	58
C/B	20	17	13	8	10	43	12	16	13	9	20
C/R-SB/R-C/R	41	31	11	9	18	76	6	47	47	11	21
SB/R-C/R-SB/R	46	34	27	10	11	115	11	42	†	†	32
C-C-C	40	43	52	34	19	101	23	39	†	†	46
C-SB-C	38	36	40	20	18	42	23	47	†	†	44
SB-C-SB	29	40	38	17	11	62	12	20	43	30	29
A-A-A	28	25	21	9	1	17	8	11	19	19	22
Mean	36	32	28	14	13	66	14	37	29	18	34
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.A.	N.A.	N.S.

† Missing data.
N.A.: Not applicable. Less than 50% data available.
N.S.: Non significant differences between rotations at the 5% level.

Table 9: Continued.

Date	16-Sep-04	30-Sep-04	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05
Rotation											
C/R	4	50	22	26	34	27	92	57	45	82	9
C/B	3	46	34	18	19	16	51	35	23	40	15
C/R-SB/R-C/R	3	11	54	28	25	20	68	44	35	64	7
SB/R-C/R-SB/R	0	39	34	15	21	18	71	49	34	74	16
C-C-C	13	72	93	30	37	30	67	49	40	64	24
C-SB-C	7	25	21	23	30	35	52	39	32	44	11
SB-C-SB	1	46	34	26	27	22	62	42	36	56	14
A-A-A	3	47	33	9	11	13	64	42	28	48	7
Mean	4	42	41	22	25	23	66	45	34	59	13
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Date	16-Feb-05	2-Mar-05	17-Mar-05	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05
Rotation											
C/R	23	40	50	91	35	14	3	0	0 b	0	0
C/B	11	22	24	47	39	11	3	1	0 b	0	1
C/R-SB/R-C/R	9	26	36	70	24	3	1	0	0 b	0	0
SB/R-C/R-SB/R	14	33	47	77	97	10	1	0	0 b	0	0
C-C-C	26	43	48	63	74	26	12	6	2 a	1	0
C-SB-C	11	23	30	42	29	16	7	2	1 b	1	1
SB-C-SB	24	30	35	55	55	14	5	0	1 ab	0	2
A-A-A	17	26	39	64	46	10	1	0	0 b	0	0
Mean	17	30	39	64	50	13	4	1	1	0	1
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.

N.S.: Non significant differences between rotations at the 5% level.
* Significant differences between rotations at the 5% level.

Table 9: Continued.

Date	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
Rotation											
C/R	23	3	0	0	0	0	0	13	14	16 bc	49
C/B	15	3	1	0	0	0	0	10	11	11 bc	25
C/R-SB/R-C/R	4	1	0	0	0	0	0	23	7	21 abc	40
SB/R-C/R-SB/R	21	2	0	1	0	0	0	19	19	42 a	53
C-C-C	16	5	1	0	0	0	0	26	26	27 ab	47
C-SB-C	15	2	0	0	0	0	0	11	12	21 ab	33
SB-C-SB	35	5	0	1	0	0	0	18	10	23 ab	29
A-A-A	0	0	0	0	0	0	0	0	0	0 c	6
Mean	16	3	0	0	0	0	0	15	12	20	35
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.

Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06	Nov03-Mar06	Apr04-Mar05	Apr05-Mar06	G.S. ‡ 04
Rotation											
C/R	55	103	87	94	40	20	6	2109	1079	576	590
C/B	28	60	44	46	19	11	6	1135	605	344	336
C/R-SB/R-C/R	50	77	70	67	27	6	2	1622	852	424	493
SB/R-C/R-SB/R	54	109	82	84	34	18	8	1993	905	653	490
C-C-C	45	94	68	66	40	24	15	2121	1131	621	708
C-SB-C	29	67	47	47	29	16	9	1421	752	393	468
SB-C-SB	30	74	49	44	17	11	5	1678	882	429	526
A-A-A	29	111	42	75	35	20	7	1489	662	381	328
Mean	40	87	61	65	30	16	7	1696	858	478	493
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	NS	NS	NS	NS

N.S.: Non significant differences between rotations at the 5% level.
* Significant differences between rotations (5% level). Values followed by similar letters are not statistically different.
‡ G.S.=growing season: April through November.

Table 9: Continued.

Date	G.S. ‡ 05	N.G.S.§ 03-04	N.G.S.§ 04-05	N.G.S.§ 05-06
Rotation				
C/R	121	453	489	455
C/B	105	187	269	239
C/R-SB/R-C/R	86	345	359	338
SB/R-C/R-SB/R	212	435	415	441
C-C-C	223	369	422	398
C-SB-C	118	276	284	275
SB-C-SB	169	368	356	259
A-A-A	57	446	334	325
Mean	136	360	366	341
Significance	NS	NS	NS	NS

N.S.: Non significant differences between rotations at the 5% level.
‡ G.S.=growing season: April through November.
§ N.G.S.=non-growing season: December through March.

Impact of Rotations on Calibrated Drainage

Mean calibrated drainage depths (mm) using the 9 December 2004 coefficients (Table 8) to adjust for spatial variability are shown in Table 10. The following is an example of the computation of calibrated drainage for an individual plot for rotation C/R on 13 November 2003 for block 1 (plot 1-1). Uncalibrated drainage was 79 mm (Appendix D Table 25), and the coefficient for plot 1-1 was 2.69 (Table 8). Calibrated drainage was calculated by dividing uncalibrated drainage by the coefficient. This resulted in a calibrated drainage of 29 mm (Appendix D Table 26).

Most two-week periods did not show differences between rotations. Mean calibrated drainage values ranged from zero to 104 mm. The highest drainage was collected during the non-growing season (December-March) and the lowest during the growing seasons (April-November). Seven out of 62 dates showed differences between rotations at the 5% significance level. In every case, single cropped corn (C-C-C) resulted in one of the highest drainage values (Table 10). During the wet growing season (2004), total drainage values were not different between rotations. However, during the dry growing season (2005), total values show that drainage in single cropped corn (C-C-C) was higher than two of four double cropped rotations (C/R and C/R-SB/R-C/R) (Table 10). Nonetheless, drainage in two double cropped rotations C/B (207 mm) and SB/R-C/R-SB/R (283 mm) was no different than in two single cropped rotations C-C-C (266 mm) and SB-C-SB (200 mm). Also drainage in C/R and C/R-SB/R-C/R was no different than in C-SB-C. Drainage in alfalfa was lower than in all single cropped rotations and in two of four double cropped rotations (Table 10).

Individual dates show that on 13 May 2004, drainage values in the three single cropped rotations were not statistically different from each other at the 5% level, and were not different from drainage in alfalfa. However, three of four double cropped rotations (C/R, C/B, and C/R-SB/R-C/R) had lower drainage than all three single cropped rotations (Table 10). On 7 July 2004, drainage in two of three single-cropped rotations (C-C-C and C-SB-C) was no different (34 mm) than three of four double cropped rotations (C/R, C/B, and SB/R-C/R-SB/R) (Table 10). Drainage in alfalfa (9 mm) was no different then three of four double cropped rotations (C/R, C/R-SB/R-C/R, and SB/R-C/R-SB/R) and one single cropped rotation (SB-C-SB). On 17 March 2005, the highest drainage (55 mm) occurred in single cropped corn (C-C-C). It was not different from two of four double cropped rotations (C/R and SB/R-C/R-SB/R) or from alfalfa. On 12 May 2005, highest drainage was collected in the three single cropped rotations. Drainage in single cropped corn (C-C-C) was higher than in the four double cropped rotations. Drainage in the four double cropped rotations was no different from that in alfalfa. On 23 November 2005, drainage in three of four double cropped rotations was not different from all single cropped rotations. Drainage in alfalfa was lower than all single cropped rotations and two of four double cropped rotations. Drainage on 8 March 2006 showed no difference between three single cropped rotations, alfalfa and three of four double cropped rotations (Table 10).

Table 10: Mean calibrated drainage (mm) collected over the two weeks prior to the date of measurement.

Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04	16-Apr-04
Rotation												
C/R	23	42	102	83	25	8	7	6	24	40	32	36
C/B	25	36	41	48	16	9	3	14	7	20	46	38
C/R-SB/R-C/R	23	39	108	79	34	8	5	7	20	50	40	48
SB/R-C/R-SB/R	50	75	149	107	36	12	7	16	22	57	44	61
C-C-C	65	56	90	103	38	11	17	42	42	70	48	52
C-SB-C	59	63	91	101	39	12	23	17	31	51	23	59
SB-C-SB	63	60	126	138	48	9	36	30	68	50	35	24
A-A-A	68	67	125	144	41	3	17	16	17	49	39	33
Mean	47	55	104	100	35	9	14	19	29	48	38	44
Significance†	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.N.	N.S.	N.S.	N.S.	N.S.	N.S.

Date	28-Apr-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04	16-Sep-04	30-Sep-04
Rotation												
C/R	28	20 bc	9	14	109	14 bc	48	43	36	46	2	84
C/B	38	14 c	9	22	35	36 a	49	10	7	53	5	38
C/R-SB/R-C/R	36	20 bc	16	28	80	10 c	69	136	32	29	6	38
SB/R-C/R-SB/R	41	28 ab	12	13	85	13 bc	66	‡	‡	51	0	33
C-C-C	51	63 a	48	28	138	34 ab	62	‡	‡	63	21	78
C-SB-C	59	60 a	26	27	100	34 ab	78	‡	‡	71	16	38
SB-C-SB	37	42 a	17	10	93	12 c	30	38	27	34	2	85
A-A-A	30	26 ab	11	1	24	9 c	12	35	35	29	3	61
Mean	40	34	19	18	83	20	52	53	27	47	7	57
Significance	N.S	*	N.S.	N.S.	N.S.	*	N.S.	N.A.	N.A.	N.S.	N.N.	N.S.

†N.S. non significant at the 5% level. N.N. data not normal: did not follow a normal distribution. N.A. not applicable: significance not evaluated due to 50% or more data points missing.
‡Missing values due to floods.
*Significant at the 5% level.

Table 10: Continued.

Date	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05	16-Feb-05	2-Mar-05	17-Mar-05
Rotation					§							
C/R	42	21	28	22	76	49	38	65	11	17	33	40 abc
C/B	28	52	43	32	76	55	29	48	27	13	34	37 bc
C/R-SB/R-C/R	33	31	26	19	76	45	32	62	34	10	26	33 c
SB/R-C/R-SB/R	24	19	24	21	76	53	41	80	17	18	36	53 a
C-C-C	121	33	42	34	76	54	43	83	23	33	50	55 a
C-SB-C	33	35	40	39	76	54	34	57	15	11	26	34 c
SB-C-SB	42	23	24	29	76	47	41	98	14	30	32	39 bc
A-A-A	43	11	14	16	76	50	35	57	10	21	31	46 a
Mean	46	28	30	27	76	51	37	69	19	19	33	42
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*

Date	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05
Rotation												
C/R	75	42	12	3 bc	0	0	0	0	18	3	0	0
C/B	71	62	31	3 bc	1	0	0	8	33	11	13	0
C/R-SB/R-C/R	86	48	6	2 bc	0	0	0	0	2	0	0	1
SB/R-C/R-SB/R	87	142	12	2 c	0	0	0	0	21	2	0	0
C-C-C	76	90	29	17 a	5	6	2	0	23	11	2	0
C-SB-C	66	55	22	10 abc	2	3	2	4	28	4	1	0
SB-C-SB	80	76	13	9 ab	0	1	0	2	33	5	0	8
A-A-A	82	59	12	1 c	0	0	0	0	0	0	0	0
Mean	78	72	17	6	1	1	1	2	20	4	2	1
Significance	N.S.	N.S.	N.S.	*	N.N.	N.N.	N.N.	N.N.	N.S.	N.N.	N.N.	N.N.

§ 9 Dec 2004 was used to calibrate all other dates.
N.S. no significance at the 5% level.
* Significance at the 5% level.
N.N. data did not follow a normal distribution.

Table 10: Continued.

Date	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06
Rotation												
C/R	0	0	0	15	15	16 bc	39	46	87	67	74	33
C/B	0	5	0	11	12	18 bc	32	35	73	55	54	19
C/R-SB/R-C/R	0	0	0	33	5	20 ab	31	42	86	76	62	21
SB/R-C/R-SB/R	0	0	0	23	18	62 a	66	64	135	100	105	41
C-C-C	0	2	0	28	19	31 ab	45	44	104	81	74	45
C-SB-C	0	0	0	21	11	31 ab	45	40	112	77	71	37
SB-C-SB	0	0	0	21	8	25 b	25	43	70	98	48	15
A-A-A	0	0	0	0	0	0 c	6	35	138	56	89	42
Mean	0	1	0	19	11	25	36	44	101	76	72	32
Significance	N.A.	N.N.	N.N.	N.N.	N.N.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Date	8-Mar-06	20-Mar-06	Nov03-Mar06	Apr04-Mar05	Apr05-Mar06	G.S.¶ 04	G.S.¶ 05	N.G.S.# 03-04	N.G.S.# 04-05	N.G.S.#05-06
Rotation										
C/R	16 ab	6 ab	1886	1035	492	633	124 cd	359	326	368
C/B	15 bc	6 ab	1665	949	497	559	207 ab	219	314	290
C/R-SB/R-C/R	6 c	3 b	1917	1099	445	696	117 cd	373	328	327
SB/R-C/R-SB/R	23 ab	10 a	2356	997	827	536	283 a	532	385	544
C-C-C	26 ab	16 a	2642	1407	700	915	266 ab	534	417	434
C-SB-C	18 ab	10 a	2202	1110	604	737	194 bc	487	298	409
SB-C-SB	12 bc	4 ab	2202	1058	516	602	200 ab	628	380	315
A-A-A	24 a	9 a	1859	841	471	432	72 d	547	333	399
Mean	17	8	2091	1062	569	639	183	460	348	386
Significance	*	*	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.

N.A. significance was not evaluated due to 50% or more data missing. N.N. data did not follow a normal distribution. N.S. non-significance at the 5% level. * Significance at the 5% level. ¶ G.S.=growing season: April to November. # N.G.S.=non-growing season: December to March.

In addition to individual dates, drainage was summed over periods of time to check the significance of cumulative data, and was analyzed for statistical significance at the 5% level. Using raw drainage data (Table 9), only one time interval (28 October to 23 November 2005) showed significance (p=0.031) and was given particular attention. Table 11 presents summed drainage during this time for every rotation. Highest drainage was found in all single cropped rotations and two double cropped rotations (corn/rye: 43 mm and soybean/rye-corn/rye-soybean/rye: 80 mm), and none were significantly different from each other (Table 11). Drainage in all single cropped rotations was no different from all double cropped rotations. However, drainage in alfalfa (0 mm) was significantly lower than that in all single cropped rotations, but was no different from that in three double cropped rotations (corn/rye, corn/barley, and corn/rye-soybean/rye-corn/rye) (Table 11).

Table 11: Mean drainage (mm) from Table 8 summed over the period 28 October to 23 November 2005 for the rotations corn/rye (C/R), corn/barley (C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R), single cropped corn (C-C-C), corn and soybeans (C-SB-C and SB-C-SB), and alfalfa (A-A-A).

Rotation	Drainage (mm)
C/R	43 abc
C/B	31 bc
C/R-SB/R-C/R	51 ab
SB/R-C/R-SB/R	80 a
C-C-C	79 ab
C-SB-C	44 ab
SB-C-SB	52 ab
A-A-A	0 c

Calibrated drainage (Table 10) was also analyzed for summed drainage, and four time periods showed significant differences between rotations at the 5% level: spring 2004, spring 2005, fall 2005, and winter 2006. Table 12 shows calibrated drainage values for the rotations during these intervals. In May 2004, the sum of calibrated drainage on 13^{th} and 27^{th} was significant (p=0.024). Highest calibrated drainage was found in all three single cropped rotations, alfalfa, and one double cropped rotation (SB/R-C/R-SB/R) and none were different from each other, however they were all higher than drainage in C/B (Table 12). Single cropped corn had higher calibrated drainage than three of four double cropped rotations (C/R, C/B, and C/R-SB/R-C/R) (Table 12). In addition, two of three single cropped rotations (C-C-C and C-SB-C) produced higher calibrated drainage than two of four double cropped rotations (C/R and C/B). All three single cropped rotations produced higher calibrated drainage than double cropped C/B (Table 12).

In May 2005, the sum of calibrated drainage on 12th and 27^{th} was significant (p=0.024). Highest calibrated drainage was also produced by the three single cropped rotations and they were not statistically different from one another at the 5% level, however they were higher than that in alfalfa (Table 12). Two of three single cropped rotations (C-C-C and C-SB-C) had higher calibrated drainage than one double cropped rotation (SB/R-C/R-SB/R). Only single cropped corn had higher calibrated drainage than all four double cropped rotations (Table 12).

During fall 2005, summed calibrated drainage showed significant differences between rotations. Between 12 October and 7 December 2005 (p=0.039), calibrated drainage in all three single cropped rotations were no different from that in three of four double cropped rotations (C/R, C/B, and C/R-SB/R-C/R). Drainage in alfalfa was no different from that in three of four double cropped rotations, but was significantly lower than that in two single cropped rotations (C-C-C and C-SB-C) (Table 12).

Between 10 November and 23 December 2005 (p=0.023), calibrated drainage in all three single cropped rotations was also no different from that in three of four double cropped rotations (C/R, C/B, and C/R-SB/R-C/R) (Table 12). Calibrated drainage in alfalfa was no different from that in two single cropped rotations (C-SB-C and SB-C-SB) and in three afore mentioned double cropped rotations. In addition, calibrated drainage in double cropped soybean and corn (SB/R-C/R-SB/R) was significantly higher than that of all rotations except single cropped corn (C-C-C) (Table 12).

Between 22 February and 20 March (p=0.041), two of three single cropped rotations (C-C-C and C-SB-C) had calibrated drainage that was no different than that in two of four double cropped rotations (SB/R-C/R-SB/R and C/R) (Table 12). In addition, calibrated drainage in two of three single cropped rotations (C-SB-C and SB-C-SB) was no different than that in three of four double cropped rotations (C/R, C/B, and C/R-SB/R-C/R). Calibrated drainage in alfalfa was not different from that in three of four double cropped rotations (C/R, C/B, and SB/R-C/R-SB/R) and in two of three single cropped rotations (C-C-C and C-SB-C) (Table 12).

Table 12: Calibrated drainage (mm) in spring 2004, 2005, fall 2005, and winter 2006 when differences between rotations were statistically significant (5%).

	Spring 2004	Spring 2005	-------- Fall 2005 -------		Winter 2006
	13 and 27	12 and 27	12 Oct –	10 Nov –	22 Feb –
Date	May 04	May 05	7 Dec 05	23-Dec-05	20 Mar 06
Rotations	-- mm --				
C/R	29 cd	3 bcd	85 bc	116 bc	55 abc
C/B	23 d	4 bcd	72 bc	97 bc	41 bc
C/R-SB/R-C/R	36 bcd	3 bcd	89 bc	98 bc	30 c
SB/R-C/R-SB/R	40 abc	2 cd	170 a	210 a	74 ab
C-C-C	111 a	22 a	123 ab	139 ab	87 a
C-SB-C	86 ab	12 ab	108 ab	127 bc	65 abc
SB-C-SB	59 abc	10 abc	79 bc	101 bc	31 c
A-A-A	37 abc	1 d	6 c	42 c	75 ab

Soil Water Content

Soil water content data were collected between October 2003 and May 2006 (see Appendix E Part 2 for complete soil water content data). Table 13 shows two example sets of mean volumetric soil water content data for 18 June 2004 (wet period) and 5 October 2005 (dry period) at six depths (0.18, 0.49, 0.79, 1.10, 1.40, and 1.70 m).

Table 13: Soil water content (m^3m^{-3}) for each rotation and depth on a day during the wet period (18 June 2004) and a day during the dry period (5 October 2005).

		------------------------ Depth (m) ----------------------					
Date	**Rotation**	**0.18**	**0.49**	**0.79**	**1.10**	**1.40**	**1.70**
18-Jun-04	C/R	0.343	0.344	0.335	0.301	0.293	0.285
	C/B	0.343	0.354	0.331	0.335	0.303	0.289
	C/R-SB/R-C/R	0.342	0.356	0.335	0.283	0.259	0.290
	SB/R-C/R-SB/R	0.336	0.334	0.321	0.310	0.309	0.287
	C-C-C	0.336	0.345	0.330	0.320	0.313	0.298
	C-SB-C	0.347	0.347	0.333	0.316	0.281	0.291
	SB-C-SB	0.337	0.339	0.314	0.303	0.300	0.306
	A-A-A	0.335	0.327	0.327	0.323	0.304	0.326
5-Oct-05	C/R	0.200	0.249	0.253	0.246	0.249	0.242
	C/B	0.186	0.247	0.248	0.278	0.235	0.255
	C/R-SB/R-C/R	0.206	0.250	0.247	0.228	0.220	0.253
	SB/R-C/R-SB/R	0.198	0.217	0.233	0.253	0.258	0.261
	C-C-C	0.217	0.259	0.262	0.281	0.250	0.267
	C-SB-C	0.220	0.267	0.268	0.262	0.224	0.265
	SB-C-SB	0.176	0.229	0.221	0.250	0.261	0.265
	A-A-A	0.180	0.200	0.192	0.200	0.192	0.243

The data did not follow a normal distribution and were transformed by an elevation to the third power prior to statistical analyses. Averaged over months, over depths, and over rotation types, Fig. 8 represents volumetric soil water content for double cropped, single cropped, and alfalfa rotations. Double cropped rotations include four rotations: corn/rye (C/R), corn/barley (C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), and soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R). Single cropped rotations include corn-corn-corn (C-C-C), corn-soybean-corn (C-SB-C) and soybean-corn-soybean (SB-C-SB). Results on individual rotations are shown later.

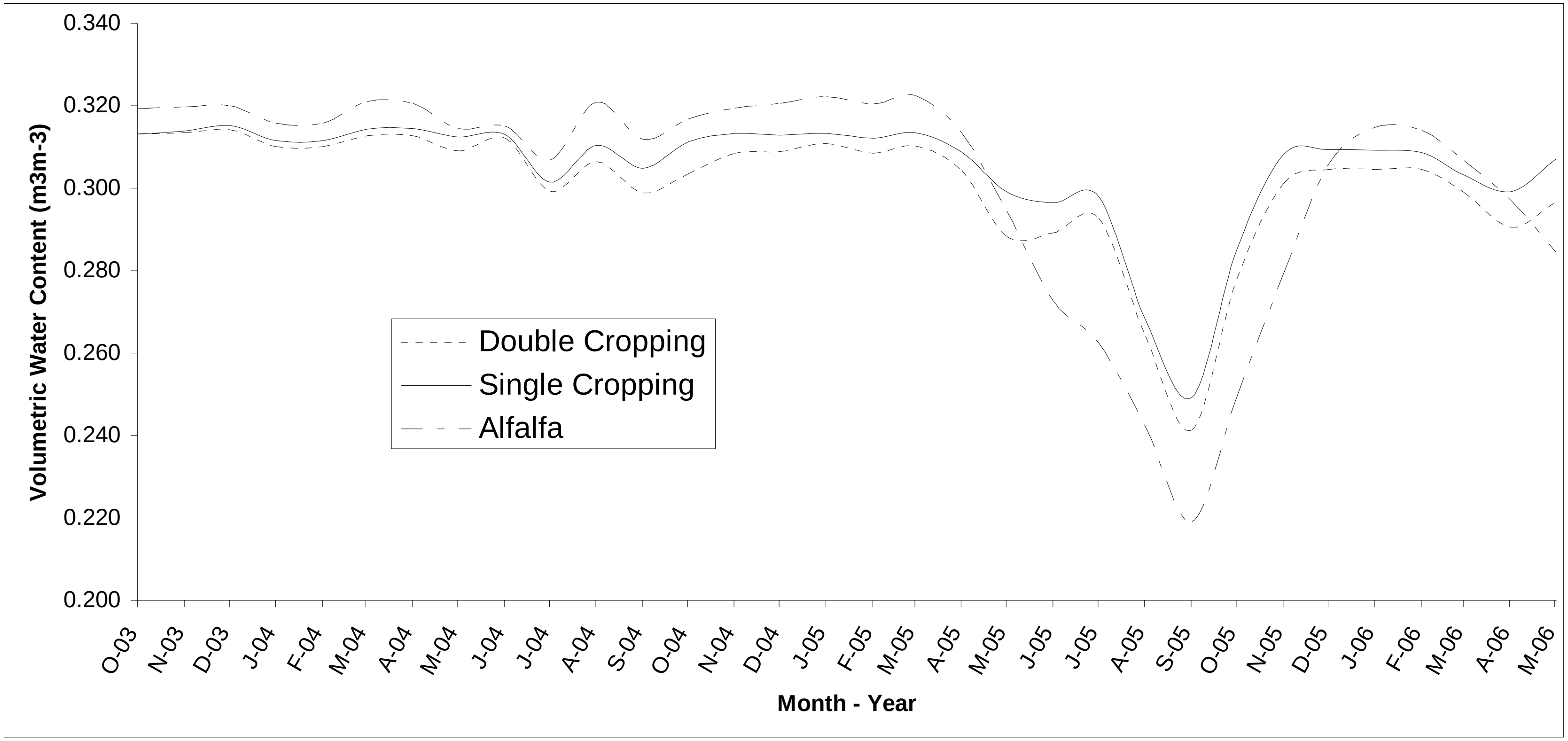

Fig. 8: Volumetric soil water content (m^3m^{-3}) over time, averaged over rotations, depths, and individual dates within a month, between October 2003 and May 2006. Double cropping is the average of four double cropped rotations (C/R, C/B, C/R-SB/R-C/R, and SB/R-C/R-SB/R), and single cropping is the average of three single cropped rotations (C-C-C, C-SB-C, and SB-C-SB).

Soil water contents averaged over depth, time, and rotation types (double/single cropping and alfalfa) showed a mean of 0.303 m^3m^{-3}. Between October 2003 and March 2005, soil water averaged 0.313 m^3m^{-3} and means ranged between 0.299 m^3m^{-3} and 0.323 m^3m^{-3}. In spring 2005, soil water contents started to drop (Fig. 8). Between April and October 2005, soil water contents averaged 0.277 m^3m^{-3} and means ranged between 0.219 m^3m^{-3} (September 05) and 0.313 m^3m^{-3} (April 05). In winter and spring 2006, soil water contents increased with a mean of 0.302 m^3m^{-3} (Fig. 8).

The analysis of variance of the rotation types (double, single, and alfalfa), seasons (Fall 03 to Spring 06), and rotation type by season interaction showed that soil water contents of the three rotation types averaged over depths were not different at the 5% significance level (Fig.8). However, there were differences in the interaction between seasons and rotation types. In summer and fall 2005, soil water content of the alfalfa rotation was lower than in both double and single cropped rotations while the opposite was true for October 2003 to March 2005 (Fig. 8).

The analysis of variance was also conducted over time with individual depths. The sources of variation included rotation type, depth, rotation type by depth interaction, season, rotation type by season interaction, depth by season interaction, and finally rotation type by depth by season interaction. All these effects were significant ($p<0.05$) except rotation type and the rotation type by depth interaction. Although rotation type was not significant alone, it was significant when combined with season and depth by season interaction.

Table 14 shows the significant differences between rotation types in the three-way interactions. All the significant differences involved the alfalfa rotation (Table 14). Double and single cropping were not different at the 5% level (Table 14). At 0.49 m deep, soil water content in the alfalfa rotation was lower than in single cropping in summer and fall 05 and in spring 06 (Table 14). In summer 05, the driest season, soil water content in the alfalfa rotation was also lower than in double cropping (Table 14). At 0.79 m, differences were recorded in summer and fall 2005 where soil water content in the alfalfa rotation was lower than in double and single cropping (Table 14). At 1.10 and 1.40 m depths, soil water content in the alfalfa rotation was lower than in double and single cropping during fall 2005 (Table 14). However, at 1.70 m, soil water content in the alfalfa rotation was higher than in double cropping in winter 03-04 and spring 04 (Table 14). Between summer 04 and spring 05, soil water content in the alfalfa rotation was higher than in both double and single cropping (Table 14).

Table 14: Results of statistical analyses showing three-way interactions of depth, season, and rotation type on soil water contents (DC: double cropping, SC: single cropping, and A: alfalfa cropping).

Effects	Depth (m)	Season	Differences ($p < 0.05$)
Rotation Type x Depth x Season	0.49	Summer 05	A < DC, SC
	0.49	Fall 05	A < SC
	0.49	Spring 06	A < SC
	0.79	Summer, fall 05	A < DC, SC
	1.10	Fall 05	A < DC, SC
	1.40	Fall 05	A < DC, SC
	1.70	Winter 03-04, Spring 04	A > DC
	1.70	Summer 04 – Spring 05	A > DC, SC

At main crop planting and combining values over months (March, April, and May of 2004, 2005, and 2006), there were no differences in soil water contents averaged over depths and months between the three rotation types. However, there was an interaction effect between rotation type and month. In March 2005, soil water content under alfalfa was higher than in double cropping. In May 2006, soil water content under alfalfa was lower than in single cropping (Fig. 8).

At main crop planting in spring, and on individual dates in April and May, results averaged over depths show that there were no differences in soil water content between rotation types in 2004, in 2005, and in 2006. There was no interaction effect between rotation types and individual dates in spring 2005. In spring 2006, the interaction between dates and rotation types was significant ($p<0.0001$). In April and May 2006, soil water content in single cropping was higher than in double cropping (Fig. 8). In May 2006, soil water content in the alfalfa rotation was lower than in double and single cropping (Fig. 8).

At main crop harvesting in fall, and on individual dates in October and November, results show that there were no differences in soil water content between rotation types in 2004. In fall 2005, however, rotation type was a significant factor (p=0.0011). Over all dates in fall 2005, soil water content in the alfalfa rotation was lower than both double and single cropping (Fig. 8). There were no interaction effects between rotation type and individual dates in fall 2004 and 2005.

The statistical results using the eight rotations and six depths were similar to those averaging over rotation types. Rotation and its interaction with depth were not significant factors, but its interaction with season was significant at the 5% level. The results of this significant interaction are shown in Table 15. The rotation by season interaction results (averaged over depths) were limited to fall 2004, summer 2005, and fall 2005, and all the differences involved the alfalfa rotation, except in fall 2004 (Table 15). In fall 2004, soil water content in the alfalfa rotation was higher than in double cropped C/R-SB/R-C/R. In addition, soil water content in SB/R-C/R-SB/R was higher than in C/R-SB/R-C/R (Table 15). During the dry season (summer 2005), however, soil water content in the alfalfa rotation was lower than in two double cropped rotations (C/B and SB/R-C/R-SB/R) and all single cropped rotations. During fall 2005, soil water content in the alfalfa rotation was lower than in double cropped C/B and in all single cropped rotations (Table 15).

Table 15: Results of statistical analyses showing the two-way interaction effects of rotation and season on soil water contents (A: alfalfa rotation, C/R-SB/R-C/R: corn/rye-soybean/rye-corn/rye, SB/R-C/R-SB/R: soybean/rye-corn/rye-soybean/rye, C/B: corn/barley, and SC: single cropped rotations).

Effects	Depth	Season	Differences ($p < 0.05$)
Rotation x Season	Averaged	Fall 2004	A > C/R-SB/R-C/R
			SB/R-C/R-SB/R > C/R-SB/R-C/R
	Averaged	Summer 2005	A < C/B, SB/R-C/R-SB/R
			A < all SC
	Averaged	Fall 2005	A < C/B, all SC

Crop Evapotranspiration

Calculated crop evapotranspiration (ET_c in mm/day) over time is shown in Fig. 9 (see Appendix F for calculation details). Double crop average represents the average of the four double cropped rotations: C/R, C/B, C/R-SB/R-C/R, and SB/R-C/R-SB/R). Single crop average is the average of the three single cropped rotations (C-C-C, C-SB-C, and SB-C-SB). Alfalfa ET_c was averaged over the growing season (see methods' section) to include the cutting effects. ET_c for double cropping ranged between 0.38 and 6.45 mm/day in December and August 2005, respectively, with a mean of 2.57 mm/day. ET_c for single cropping ranged between 0.53 and 6.45 mm/day in December and August 2005, respectively, with a mean of 2.42 mm/day. ET_c for alfalfa ranged between 0.38 and 6.26 mm/day in December and June 2005, respectively, with a mean of 2.74 mm/day (Fig. 9).

During the three fall seasons of 2003-04-05, single cropping ET_c decreased while double cropping ET_c increased as the winter rye and barley developed (Fig. 9). In November 2003, double cropping ET_c increased 0.10 mm/day while single cropping ET_c decreased 0.51 mm/day (Fig. 9). In fall 2004, double cropping ET_c remained at 1.82 mm/day between October and November 2004, whereas single cropping ET_c decreased from 1.76 to 1.16 mm/day (Fig. 9). Similarly in November 2005, double cropping ET_c increased 0.11 mm/day whereas single cropping ET_c decreased 0.88 mm/day (Fig. 9).

During the winter, single cropping ET_c was higher than double cropping and alfalfa ET_c (Fig. 9). Following the period of winter dormancy, temperatures increased in April and the rye, barley and alfalfa resumed their growth. ET_c of rye and barley reached 4.79 and 5.79 mm/day in April 2004 and April 2005, respectively (Fig. 9). In April 2004 and 2005, double cropping ET_c was 1.77 and 3.02 mm/day higher than single cropping ET_c, respectively. In addition, between April and May 2004, single cropping ET_c increased 0.75 mm/day while between April and May 2005 it increased 0.26 mm/day (Fig. 9).

After spring harvest, double cropping ET_c decreased. Corn and soybean were planted and ET_c for double and single cropping increased simultaneously to reach a peak in July 2004 (6.33 and 6.24 mm/day, respectively) and in August 2005 (6.45 mm/day). The peaks reached in 2005 were higher than those reached in 2004. In September, the end of the main crop season was attained and both double and single cropping ET_c decreased until the rye and barley were planted again.

Alfalfa ET_c decreased in the fall but remained higher than single cropping ET_c (Fig. 9). During the winter, alfalfa ET_c was lower than single cropping ET_c. Alfalfa ET_c increased in the spring and summer to reach a peak of 5.74 and 6.26 mm/day in June 2004 and June 2005, respectively (Fig. 9), then it decreased until the dormant winter season.

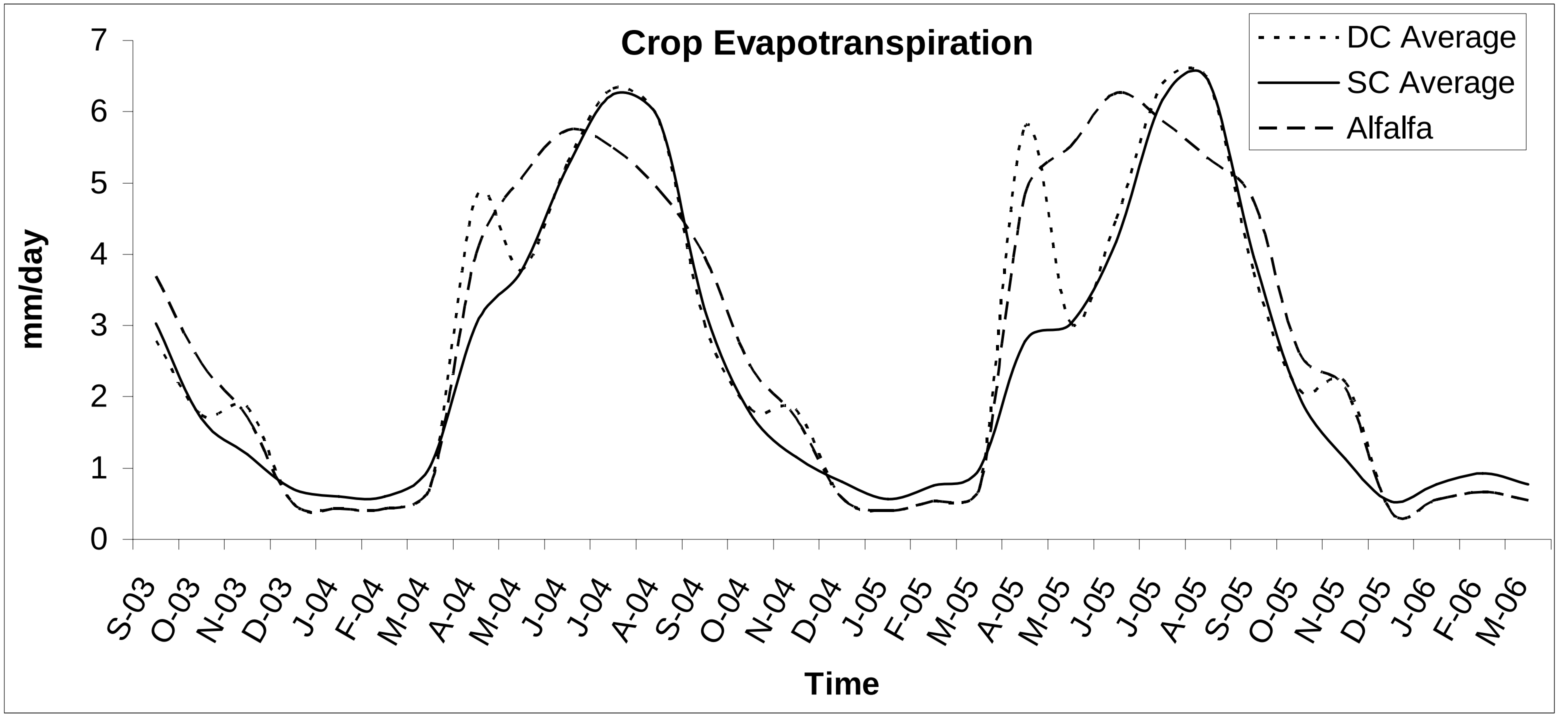

Fig. 9: Monthly crop evapotranspiration in mm/day. DC Average is the average of the four double cropped rotations: C/B, C/R, C/R-SB/R-C/R, and SB/R-C/R-SB/R. SC Average is the average of the three single cropped rotations: C-C-C, C-SB-C, and SB-C-SB.

Water Balance

Table 16 shows the monthly total components of the water balance between April 2004 and March 2006 for the three rotation types: double cropping averaged over the four double cropped rotations, single cropping averaged for the three single cropped rotations, and for alfalfa. The last three columns contain monthly values for the water balance for every rotation type determined using the following equation:

$$P - R - D - ETc - \Delta SWC = 0 \quad [4]$$

where P is precipitation, R is runoff, D is drainage, ETc is crop evapotranspiration, and ΔSWC is the change in soil water content betweeen the beginning and the end of each month: final – initial water content.

Table 16: Monthly components of the water balance (mm) between April 2004 and March 2006 for the three rotation types: double cropping (DC: average of C/R, C/B, C/R-SB/R-C/R, and SB/R-C/R-SB/R), single cropping (SC: average of C-C-C, C-SB-C, and SB-C-SB), and A: alfalfa. P is precipitation, R is runoff, D is calibrated drainage, ETc is crop evapotranspiration, and SWC is soil water content.

Year	Month	P	R	D			ETc			SWC change			P-R-D-ETc -SWC change		
				DC	SC	A	DC	SC	A	DC	SC	A	DC	SC	A
		mm													
2004	April	138	4	122	122	122	144	91	120	-7	-5	-6	-125	-75	-104
	May	92	4	39	73	45	117	117	157	-8	-14	-28	-60	-88	-85
	June	211	30	101	101	101	159	157	172	-17	-11	-1	-61	-66	-91
	July	231	26	70	78	61	196	194	170	16	15	25	-77	-82	-51
	August	235	73	80	80	80	182	182	152	-16	-13	-14	-85	-87	-56
	September	201	40	110	110	110	91	97	119	27	34	34	-67	-79	-101
	October	62	2	74	74	74	57	55	75	-9	-12	-21	-61	-56	-69
	November	88	0	57	57	57	55	35	51	14	11	20	-38	-15	-40
	December	81	6	127	127	127	18	25	18	-18	-21	-23	-52	-57	-48
2005	January	133	3	105	105	105	12	17	12	-7	-7	-6	19	14	19
	February	74	0	38	38	38	15	21	15	18	19	25	3	-4	-4
	March	111	5	118	120	124	22	31	22	6	7	1	-41	-52	-41
	April	89	5	89	89	89	174	83	145	-30	-28	-30	-148	-60	-119
	May	33	1	4	13	2	94	94	171	-18	-10	-49	-46	-64	-92
	June	70	11	2	2	2	135	125	188	13	4	-31	-91	-73	-100
	July	122	10	22	22	22	198	191	182	-23	-22	-18	-85	-80	-74
	August	20	1	6	6	6	200	200	166	-66	-66	-49	-122	-122	-105
	September	12	0	2	2	2	112	119	142	-12	-6	-38	-90	-102	-95
	October	237	9	19	19	19	65	62	81	107	105	115	36	41	12
	November	80	2	29	29	0	66	34	63	14	11	43	-30	4	-28
	December	95	1	80	80	80	12	17	12	-2	-4	31	5	1	-29

Table 16: Continued.

Year	Month	P	R	D			ETc			SWC change			P-R-D-ETc -SWC change		
				DC	SC	A	DC	SC	A	DC	SC	A	DC	SC	A
		mm													
2006	January	115	2	177	177	177	17	24	17	1	0	6	-83	-89	-88
	February	40	2	104	104	104	19	26	19	-6	-6	-8	-79	-86	-77
	March	18	0	21	29	33	17	17	24	-18	-11	-21	-2	-16	-18
Total		2588	240	1596	1658	1580	2176	2014	2294	-41	-30	-42	-1382	-1293	-1483

Cumulative precipitation and runoff between April 2004 and March 2006 were 2588 and 240 mm, respectively (Table 16). Cumulative drainage for the rotation types differed on certain dates (Table 10) and totals ranged between 1580 and 1658 mm (Table 16). Cumulative crop evapotranspiration (ETc) totals ranged between 2014 and 2294 mm for the three rotation types. Soil water content change was measured as the difference between final and initial water content per month, and multiplied by depth (1850 mm) to convert to depth of water. Negative values indicate lower final than initial water content, thus describing a decline in soil water content. Between April 2004 and March 2006, there was a decline in soil water content of only 41, 30, and 42 mm for double, single and alfalfa rotations, respectively (Table 16). Water balance values (Eq. [4]) are in the last three columns of Table 16. Negative values indicate that precipitation was lower than the sum of runoff, drainage, ETc, and soil water content change. The water balance shows a cumulative error of 1382, 1293, and 1483 mm of water for double, single and alfalfa rotations, respectively (Table 16). In double cropping, runoff, drainage, ETc, and soil water change were higher than precipitation by 1382 mm (Table 16). Similarly, in single cropping and alfalfa, runoff, drainage, ETc, and soil water content change were higher than precipitation by 1293 and 1483 mm, respectively (Table 16). Monthly balance values for double cropping show a negative water balance in most months except in January, February, and December 2005 when inputs exceeded outputs by 19, 3, and 5 mm, respectively (Table 16). In single cropping, outputs exceeded inputs except in January, October, November, and December 2005. Similarly, in alfalfa, outputs exceeded inputs except in January and October 2005.

DISCUSSION

Yields

Corn silage yields showed no difference between double and single cropping systems. Mean yields were 16.9, 18.3, and 15.2 Mg dry matter (DM) / ha in 2003, 2004, and 2005, respectively (Table 3 in results' section). These were comparable to 16.8, 18.6, and 15.7 Mg DM/ha in 2003, 2004, and 2005 respectively, reported by Roth et al. (2005).

Soybean yields did not differ whether double or single cropped in 2003 and 2005. Estimated whole-plant yields averaged 8.5 and 8.8 Mg DM/ha in 2003 and 2005, respectively (Table 3 results' section). Antle et al. (2005) found mean yields (converted to whole-plant yields using a harvest index of 0.44) of 8.4 and 7.8 in 2003 and 2005, respectively. In 2004, soybean yields averaged 50% lower than in 2003 and 2005. Ground hog activity was noticed soon after seedling emergence in June 2004 and many plants disappeared. In addition, a number of extreme rainfall events in summer 2004 caused flooding and possible disturbance of seedlings and young plants.

Although studies in the west and mid-west indicated lower main crop yields with double cropping (Helsel and Wedin, 1981; Murdock and Wells, 1978; Brown, 2006; MacKown et al., 2007), the growing season in Southeastern PA was long enough so that the 19-day difference in planting between double and single cropping did not affect whole-plant yields.

Small grain yields were not different in 2004. However, in 2005, rye planted after corn in SB/R-C/R-SB/C had higher yields than rye after soybean in C/R-SB/R-C/R (Table 3 in results' section). Rye after corn was planted on 16 September 2004, while rye after soybean was planted on 27 October 2004 (Table 1 in methods' section). There was a difference of 41 days between the two rye crops. Consequently, the earlier-planted rye produced more tillers by the onset of winter dormancy than the later-planted rye, and this allowed for more ryelage biomass in the spring. Barley (after corn) yields were not different from ryelage after soybean, but were lower than ryelage after corn. The wet soils at barley planting (September 2004) affected barley germination and growth but did not affect rye germination and growth. According to Rayburn (1995), winter rye is better adapted than winter barley to wet soils.

Corn produced more silage biomass than soybean, resulting in more annual silage yields in the corn rotations in 2003. In 2004 and 2005, small grains were added to the total annual silage yields. Double cropped corn with rye showed higher silage yields than single cropped corn. In the soybean rotations, the small grain (rye) significantly increased annual biomass compared to single cropped soybean. In 2005, low yields of soybean (relative to corn) and barley (relative to rye) resulted in no differences between double cropped soybean with rye and corn with barley (Table 3 in results' section).

Runoff

A study by Kibler et al. (1977) used "effective precipitation" to assess runoff at various locations around Pennsylvania over a period of 10 years between 1961 and 1975. Effective precipitation was defined as the ratio of precipitation that infiltrated over total precipitation. Consequently, "1-effective precipitation" equals runoff and was termed the "runoff factor". The 10-year documented monthly runoff factors in Lancaster and surrounding counties were compared with those determined from this 2-year study (Table 17).

Table 17: Mean runoff factors (1-effective precipitation) (%) as calculated in Kibler et al. (1977) for 6 locations in and surrounding Lancaster county over 10 years. Columns "Landisville 2004" and "Landisville 2005" show measured percent runoff for each year (runoff summed over each month divided by monthly precipitation, this ratio multiplied by 100).

Station	Berks	Chester 1†	Chester 2†	Lebanon	York	Lancaster	Landisville 2004‡	Landisville 2005‡
Month	-- % Runoff --							
April	36	25	29	8	29	12	4	6
May	20	15	22	9	15	9	4	3
June	14	7	21	9	17	13	8§	14
July	15	8	13	11	14	16	19§	9
August	13	9	16	5	9	16	23§	6
September	16	5	14	7	22	6	23	2

Source: Kibler et al. (1977)

† These are two separate locations in Chester county

‡ Data from present study

§ Missing data in this value due to floods.

The measured values (Landisville 2004 and 2005 in Table 17) were similar to values from Kibler et al. (1977) for Lancaster and surrounding counties during the growing season. For instance, in September the documented mean 10-year runoff factors ranged from 5% to 22% compared to our values ranging from 2 to 23% for the two year period. Overall the 10-year values ranged from 5 to 36% compared to our 2-year measured values ranging from 2 to 23%, although some might have been higher since values collected in June, July and August 2004 contained missing values due to floods that damaged the runoff collection areas.

Although no data from our plots are available to confirm the following statements, it is widely accepted that no tillage systems combined with a winter soil cover on a medium textured soil improves the soil structure and aggregate stability, allowing for better water infiltration (Troeh et al., 2004). Permeability depends on pore space between the soil peds. New pores are formed as new roots and living organisms force themselves through the soil profile, leading to the improvement of soil permeability with more plants and no tillage (Troeh et al., 2004). In addition, freezing and thawing of the soil surface during the winter months influences soil surface physical properties by affecting soil structure and permeability. Soil particles shift due to ice formation, and soil aggregates cling to each other with organic bonding agents (Troeh et al., 2004). According to Lehrsch (1998), maximum aggregate stability is observed after 2 or 3 freeze-thaw cycles. This increases the soil water infiltration rates, irrespective of the cropping system used.

The curve number technique can be used to estimate the amount of precipitation that could potentially cause direct surface runoff. The runoff curve number was calculated for the mapping unit of interest: Nolin (Ne) soil in Lancaster County has an estimated available water capacity of 0.23 mm of water per mm of soil (Custer, 1985). Soil cores showed that our soil was at least 1.83 m deep in many places, therefore had a potential maximum retention of 421 mm of water. The curve number equation ($CN = 1000 / (10+S)$ (U.S.D.A.-S.C.S., 1972), where CN is curve number and S is potential maximum retention in inches, showed that for a soil 1.83 m deep the curve number was 37. The relationship between accumulated direct runoff, precipitation and potential maximum retention (Fig. 10) indicates that for this soil at least 88 mm (reported in graph as 3.5 inches) of rain needed to fall in order for direct runoff to occur. Table 4 (methods' section) shows that only six precipitation events exceeded 88 mm, and average runoff ranged from 0 to 27 mm (Table 4 results' section). All other precipitation events did not produce runoff higher than 25 mm.

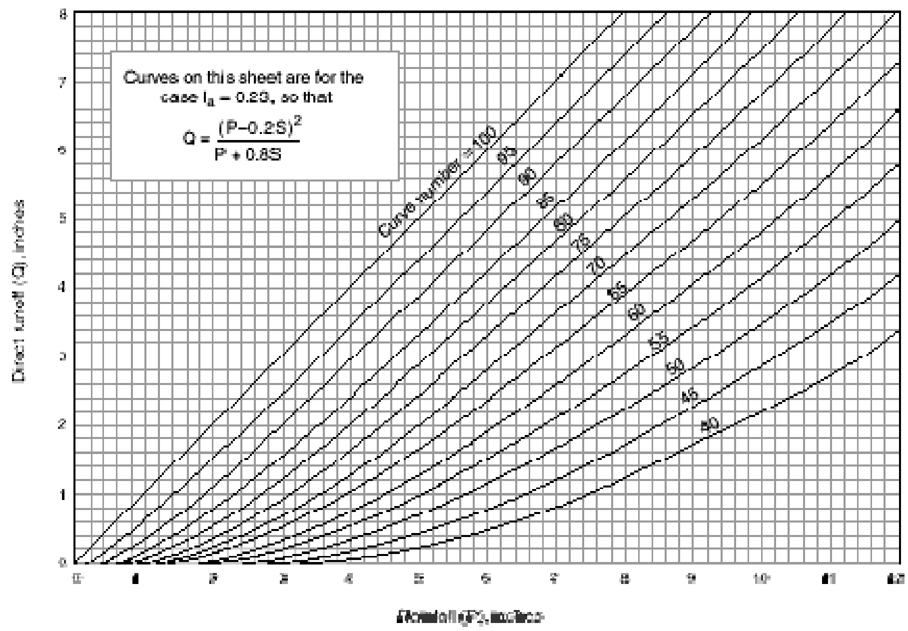

Fig. 10: Direct runoff depth as predicted using rainfall and runoff curve numbers (U.S.D.A.-S.C.S., 1986).

However, high rainfall amount alone does not necessarily generate runoff. For example on 18 June 2004 there was 61.6 mm of rainfall and 25 mm of runoff, on 12 October 2005 there was 159.5 mm of rainfall and 8 mm of runoff. The discrepancies between precipitation amounts and runoff indicate that other factors influence runoff generation.

Since the majority of runoff and erosion in the northeastern US occurs during high intensity storm events (Srinivasan, 2000; Sporre, 2001), we will limit our discussion to such events. According to the American Meteorological Society (2000), average storms in Pennsylvania produce rainfall of the following intensities: 25.2 to 28.8 mm/hr, 28.8 to 39.6 mm/hr, 39.6 to 43.2 mm/hr, and 43.2 to 50.4 mm/hr for 2, 5, 10 and 25-year return periods, respectively. On the other hand, the Lancaster County soil survey estimated minimum saturated hydraulic conductivity for the Nolin soil series is 15 mm/hr

(Custer, 1985). In this discussion we will consider high intensity rainfall events potentially producing runoff as those exceeding 15 mm/hr.

The potential for surface runoff increases with, among other conditions, less soil vegetative cover. In winter of 2003-04, the single cropped rotation plots were bare for 218 days (26 September 2003 to 28 April 2004) compared to 5 days for double cropped corn with rye/barley (29 September to 3 October 2003 and 6 to 7 May 2004). Similarly, in 2004-05 silage was removed in early September and single cropped rotations remained bare for 232 days (1 Sept 04 to 20 Apr 05) whereas double cropped rotations remained bare for 3 days in September 2004 (Table 1 in methods' section). The potential for runoff to occur is higher during these time periods when the soil surface was bare.

During these periods, there are critical times that could potentially cause higher runoff than others in southeastern PA: during late fall when high intensity localized summer storms are still frequent, and in early spring when the soil is thawing. Let us focus on these two critical time slots. Table 18 summarizes these critical time zones, documenting storms with relatively high precipitation that were likely to generate runoff.

Table 18: Storm dates, precipitation amounts (mm) (Appendix B Part 1), maximum and mean precipitation intensities (mm/hr) and duration (hr) measured at Lancaster Airport (Source: Pennsylvania State Climatologist, 2006).

Month/Year	Day	Precipitation	Max Intensity†	Mean Intensity†	Duration†
		mm	--------------mm/hr	-------------	hr
2003					
October	15	41.1	13.0	4.0	8.0
	29, 30	114.8	5.1	1.6	42.0
Nov	19, 20	32.5	11.0	2.4	14.0
2004					
April	26	44.1	17.5	2.5	17.0
May	3	31.1	8.6	0.8	10.0
June	5, 6	72.7	4.0	1.1	25.0
June	11	27.9	8.9	1.2	21.0
June	18	41.1	32.2	14.3	3.0
July	12	85.9	11.9	4.5	14.0
	14	25.1	13.2	6.7	4.0
July	23	27.7	18.8	4.7	5.0
August	1	53.8	10.9	3.2	8.0
	13	44.3	10.9	4.4	10.0
	21	44.7	17.2	6.9	3.0
	23	36.1	m	m	m
September	18	101.1	20.3	6.5	13.0
	28	55.9	16.7	5.0	9.0
	29	28.2	§	§	§
November	28	35.4	9.6	3.5	10.0
2005					
March	23	35.6	6.1	2.3	15.0
	28	37.6	6.7	2.2	18.0
April	2	44.5	12.2	2.1	26.0
June	30	49.8	195.0‡	53.0	2.6
July	8	56.9	69.7‡	12.0	14.5
October	7, 8	149.6	61.0‡	12.0	34.4
	25	22.6	6.1‡	2.0	21.1
December	16	34.5	22.2‡	5.0	14.0

† Source: LNS weather station. Duration is not always continuous.
‡195 mm/hr was recorded as 16.2 mm in 5 minutes, 69.7 as 8mm in 7 minutes; 61 as 4mm in 4 minutes; 6.1 as 1.5 in 15 minutes; 22.17 as 4mm in 11 minutes
m are missing values. There was no rainfall at Lancaster Airport on these days.
§ These intensities were not considered applicable to our plots as they did not correspond to stratiform storm

During the spring season (April – May); i.e. before and shortly after main summer crop planting, canopy cover was low so that little interception of precipitation occurred before reaching the soil surface. During spring 2004, 44.1 mm rain fell on 26 April (Table 18), and no runoff was measured (27 April in Table 4 results' section). In the double cropped plots, the small grains were not yet harvested (Table 1 methods' section) and acted as a shield to the soil, thus limiting runoff generation. In the single cropped plots, however, the bare soil surface did not produce significant runoff (Table 4 results' section). The maximum intensity for this storm (17.5 mm/hr during one hour) (table 18) exceeded the runoff generating threshold of 15 mm/hr. However, the mean intensity for this storm was 2.5 mm/hr for 17 hours. With a maximum slope of 3%, the excess water may have ponded on the soil surface before infiltrating the soil profile. Thus no runoff was observed during this storm. There were no other storms exceeding the maximum intensity threshold and no significant runoff measured in spring 2004. Although rainfall intensities were measured 11 kms away from the research plots (at Lancaster Airport), localized summer convective storms are not frequent at this time of year. Errors in rainfall intensities were limited.

During spring 2005, the highest rainfall amounts occurred on 28 March (37.6 mm) and on 2 April (44.5 mm), and maximum intensities did not exceed 12.2 mm/hr. This was below the 15 mm/hr threshold and resulted in no significant runoff collected (Table 4 results' section).

Another potential window for runoff was during the fall season after summer crop harvest (single cropping) and before full double crop cover. In October and November 2003, maximum intensities did not exceed 15 mm/hr. Runoff was not measured as runoff plots were not yet installed. In late September 2004, over 185 mm rainfall was recorded (Table 18) causing the highest runoff collection measured (Table 4 results' section). Maximum rainfall intensities reached 20.3 mm/hr and 16.7 mm/hr on 18 and 28 September respectively (Table 18). 21% and 19% of precipitation that fell during the intervals 27 August to 20 September and 20-29 September, respectively, was captured as runoff (Table 4 results' section). After the floods of July and August 2004, soil moisture was relatively high, limiting its water infiltration capacity (Bruce et al., 1976).

In fall 2005, over 149 mm of rainfall (Table 18) was recorded in early October (7-9th) but an average of 8 mm runoff was measured (Table 4 results' section). The rainfall intensity of 61 mm/hr was measured as 4 mm/hr in 4 minutes, and the average intensity was 12 mm/hr for 34 hours. The average intensity was lower than the soil's threshold. In addition, summer 2005 was drier than average with approximately a third of the precipitation in summer 2004 (Table 4 results' section). The average temperature was 21^{o}C in both years. Consequently, this rainfall amount was readily absorbed by the dry soil.

There were few residues left after corn and soybean harvest in September and October. Thus, the soil was not protected from intense rain storms in the single cropped rotations and was likely to produce runoff in the fall and spring. However, only low intensity storms took place throughout the experiment (where mean intensities and most maximum intensities remained below 15 mm/hr): in May and early June 2004, in November 2004 and in March 2005. The rate of rainfall usually did not exceed that of infiltration, and there was no excess water on the soil surface. Despite relatively long duration of the storms, little runoff was generated and the difference in runoff potential among rotations was not realised.

The spatial variability in this field data was also a factor in the lack of significant differences between rotations. Although blocking accounted for part of the variability, mainly topographic elevation differences, there were variations in soil texture, structure, surface moisture levels, and initial infiltrability that potentially occurred within blocks. As stated by Kleinman et al. (2006) and Kleinman (2006), we found that in the short time frame of this experiment that runoff generating processes were more influenced by rainfall intensity and antecedent soil moisture than by management. Furthermore, plot sizes are an important factor influencing runoff results. According to Wauchope and Burgoa (1995), a runoff study where plot sizes do not exceed a few square meters only describes isolated processes and cannot result in concluding statements regarding the effect of tillage or cropping systems. They suggested that effective research on runoff on agricultural fields needed to be undertaken on plots that were at least one hectare in size.

Drainage

Drainage did not differ between rotations over the study period, aside from a few exceptions. Fig. 11 and 12 show mean raw drainage measurements (Fig. 11) and calibrated measurements (Fig. 12) over time. All the rotations were averaged and the mean was used when no differences between them were statistically significant at the 5% level. Both figures show similar trends over time. In spite of the calibration procedure, only a few more significant differences were obtained in the calibrated data (Fig. 12) when compared to the raw data (Fig. 11). The calibration reduced some of the variability of the data, especially where significant differences between rotations were found in Fig. 12 and not in Fig. 11, but was not successful in completely eliminating it. Since the overall trends were identical in both figures, and the only significant differences in fall 2005 of the raw data were also found significant in the calibrated data, the discussion shall be based on Fig. 12.

The highest drainage peaks were reached during the dormant season, on 27 December 2003 (112 mm) and on 13 January 2006 (110 mm) (Fig. 12). The data show that 58% of total drainage between April 2004 and March 2005 occurred during the non-growing season (November to March). Similarly, 78% of total drainage between April 05 and March 06 occurred during the non-growing season. Water losses through plant uptake were negligible during the non-growing season, and water accumulated in the soil profile until the threshold for gravitational drainage was exceeded resulting in elevated drainage volumes. Similar results were also found in a 5-year lysimeter study in central Pennsylvania (Zhu et al., 2002).

The duration of the peaks was largest during the non-growing season and drainage was continuously high. In spring 2004, drainage peaks (16-49 mm) lasted between February and May (Fig. 12, B1). In the dormant season of 2004-05, peaks (17-74 mm) lasted between October and February (B2). Drainage increased again in February 2005 for a peak (16-79 mm) lasting until late April 2005 (B3). Similarly in fall/winter 2006 high drainage (13-110 mm) lasted between November 2005 and March 2006 (B4). Comparatively, summer peaks were much lower or non-existent in 2005 (Fig. 12). The peaks in summer 2004 are due to extreme rainfall events. Overall, the mean drainage was

65 % of total precipitation between November 2003 and March 2006, compared to 62% found in Zhu et al. (2002).

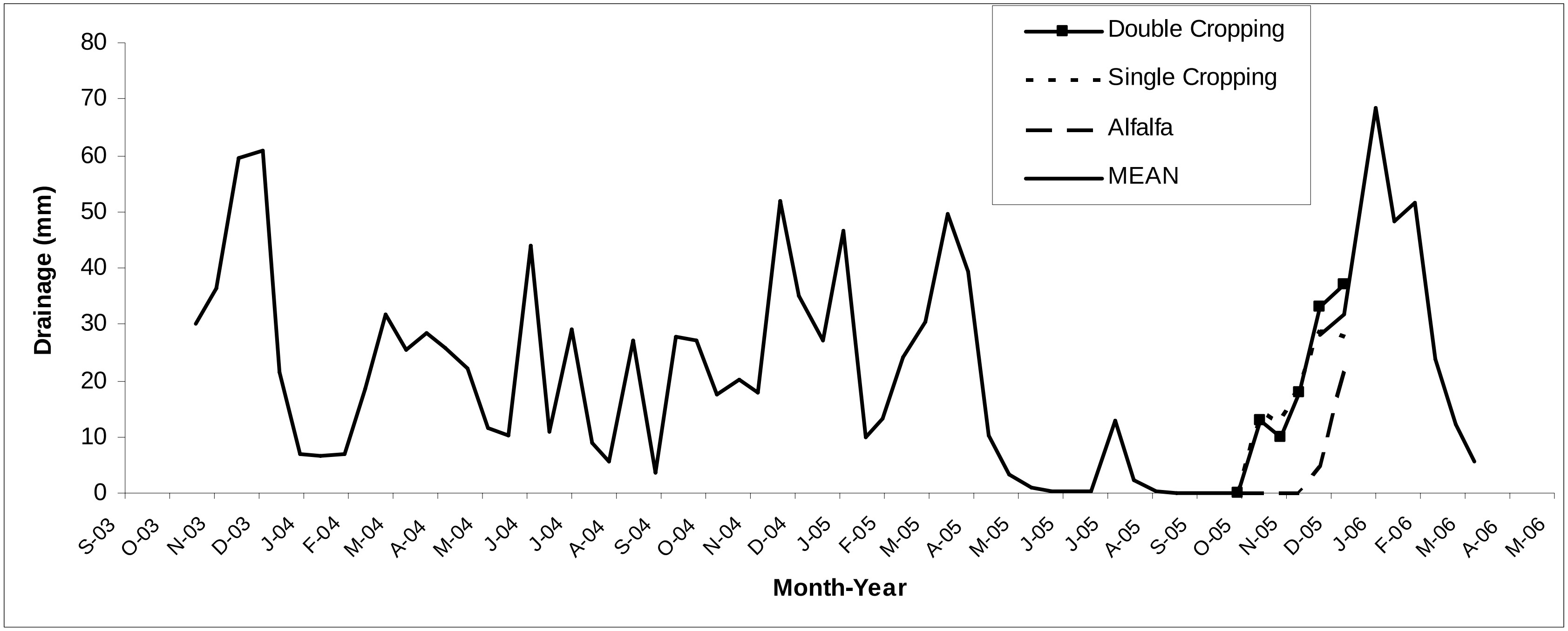

Fig. 11: Mean drainage (mm) for double cropped rotations (corn/rye, corn/barley, corn/rye/soybean/rye/corn/rye, and soybean/rye/corn/rye/soybean/rye), single cropped rotations (corn, corn/soybean, and soybean/corn), and alfalfa measured every two weeks between November 2003 and March 2006.

For most of the studied period, there were no differences between rotations. Smith et al. (1987) compared the effects of winter cover and winter fallow on soil water and concluded that field variability often made it impossible to detect treatment effects. This is also the case in our study. As documented by other authors (Zhu et al., 2002), some lysimeters consistently yielded lower or higher drainage than others. For instance, corn/barley in block 1 (mean 2 mm), corn/rye-soybean/rye-corn/rye in block 3 (mean 3 mm), and soybean-corn-soybean in block 3 (mean 3 mm) often had low drainage, whereas corn/rye, corn/rye-soybean/rye-corn/rye in block 1 (respective means 73 and 70 mm), and corn-corn-corn in block 4 (mean 83 mm) yielded high amounts of drainage (Appendix D Table 25). This indicates there might be preferential water flow paths occurring around the lysimeters that channel water towards the lysimeters (high collections) or away from it (low collections). For instance, sand lenses laterally traversing a soil profile can interrupt the downward flow of water towards the lysimeters and change its course, resulting in low drainage collections. On the other hand, soil water that would normally flow downwards a few feet away from the lysimeters might encounter a sand lens that would channel it towards the lysimeters, causing continuous collection of preferential flow and an over estimation of drainage. In our plots, sandy loam horizons were identified between 60 and 90 cm deep overlain by silt loam surface horizons. The potential occurrence of preferential flow caused by sand lenses could have occurred. Other authors have found high variability in drainage measurements using lysimeters (O'Connell et al., 2003) and highly variable collection efficiencies and high coefficients of variation (Zhu et al., 2002; Louie et al., 2000). The calibration procedure described in the method's section was an attempt to minimize such variability in our data analysis.

Variability in this data is also related to the tension produced by the lysimeters. The lysimeters measured drainage at matric potentials ranging from 0 to – 0.5 m. Any water that was held in the soil at higher tensions (more negative) was not collected. If field capacity was at a matric potential of – 0.5 m, then the lysimeters collected water until the soil reached field capacity and we neither over-estimated nor under-estimated drainage. If the tension applied was higher than that of the soil surrounding the wick lysimeters, soil water would flow towards the lysimeters from all directions and we would over-estimate drainage. Similarly, if the tension applied was lower than that of the surrounding soil, soil water would potentially bypass the lysimeter resulting in an under-estimation of drainage. The fact that little drainage was collected in summer compared to fall and spring indicates that soil water tension varied during our experiment. There were times when soil tension around the lysimeters exceeded - 0.5 m (summer) and times when there was a lower tension (winter). In situ, soil water tension is not constant over time. Using a constant continual suction when conditions are not continuous causes a change in soil water flow and results in over or under-estimation of drainage. By repeatedly collecting over or under-estimations of drainage, we ultimately generated a high variation in the data. Cochran et al. (1970) observed that applying a constant continual suction increased the variation in leachate volumes collected from lysimeters in different horizons with different water retention and flow properties.

Research has shown that the fallow winter season might not be a long enough time period to allow differences to emerge between drainage in fallow and cropped rotations. According to O'Connell et al. (2003), although drainage increased during wet periods, its increase was not significant due to short fallow seasons, especially in relatively dry years when rainfall was below average. In a simulation study over 42 years, Fischer et al. (1990) demonstrated that a longer fallow period produced wetter soil profiles and more drainage than a short fallow system. Zhang et al. (1999), while studying the impact of agronomic practices on groundwater recharge in southeastern Australia, also stressed the importance of the amount of time that agronomic practices had been in place, noting that a period of at least 10 years was required for changes in land management to have impacts on recharge.

In spite of the variability, differences between rotations were significant on a few dates. In the following data analysis, a generalization was adopted. If three out of four double cropped rotations were significantly different from another rotation, then double cropping was considered significantly different from that rotation. Similarly, when two out of three single cropped rotations were significantly different from another rotation, single cropping was considered significantly different from that rotation.

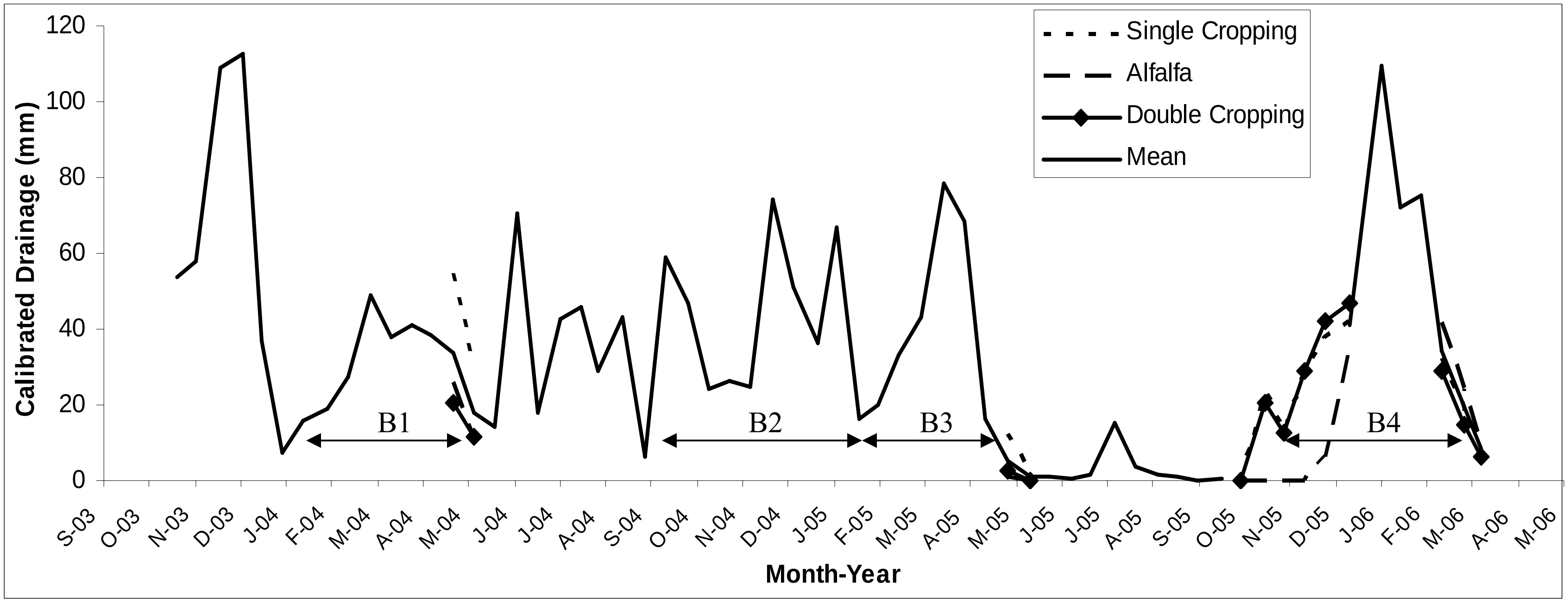

Fig. 12: Mean calibrated drainage (mm) for double cropped rotations (corn/rye, corn/barley, corn/rye/soybean/rye/corn/rye, and soybean/rye/corn/rye/soybean/rye), single cropped rotations (corn, corn/soybean, and soybean/corn), and alfalfa rotations measured every two weeks between November 2003 and March 2006. B1-B4 are measures of peak calibrated drainage duration. Differences during individual events (two-week intervals) are not shown in this figure.

Fig. 12 shows four time periods with significant differences: spring 2004, spring 2005, fall 2005, and spring 2006. Table 19 summarizes the results, in chronological order, of drainage during these times for both actual and calibrated data. Drainage in both alfalfa and double cropping rotations were frequently found to be significantly lower than single cropping and more specifically, in some cases, significantly lower than single cropped corn.

Table 19: Dates when drainage (actual and calibrated) showed significant differences ($p<0.05$) between rotations. DC: double cropping, SC: single cropping, and A: alfalfa. The "<" sign describes "significantly lower than". Double cropping was significantly lower than another rotation if three double cropped rotations were significantly lower than that rotation. Similarly, single cropping was significantly lower than another rotation if two single cropped rotations were significantly lower than that rotation.

Date	Significance
Actual Drainage	
28 Oct. to 23 Nov. 05	A < SC
Calibrated Drainage	
13 May 04	DC < SC
7 July 04	A < SC
12 May 05	A < C-C-C DC < C-C-C A < SC
27 May 05	A < SC DC < C-C-C
12 Oct. to 7 Dec. 05	A < SC
8 to 20 Mar. 06	DC < C-C-C

Drainage in alfalfa was significantly lower than single cropped rotations in summer 2004, spring 2005, and fall 2005 (Table 19 and Fig. 12). For the two-week interval ending on 7 July 2004, drainage in alfalfa (9 mm) was significantly lower than that in corn and soybean plots of single cropped corn (34 mm) and corn-soybean-corn (34 mm). During that time, both corn and soybeans were approaching their peak growth and therefore had high transpiration rates.

Comparatively, alfalfa which was harvested on 8 June 2004, had fully grown by 7 July and had a full vegetative cover which was again harvested on 8 July (Table 1 methods' section). Soil water content results averaged over depth (Fig. 8 of results' section) show no difference between alfalfa and single cropped rotations in summer 2004. Moreover, crop evapotranspiration results (Fig. 9 of results' section) show that by the end of June 2004 alfalfa lost more water to ETc than single cropping. Between 19 June and 7 July, only 8.4 mm rain was measured (Appendix B Table 22) and drainage decreased dramatically from 70 mm on 24 June to 18 mm on 7 July (Fig. 12). Apparently, the deep rooted legume had taken up more soil water than corn and soybean in the single cropped rotations.

In spring 2005, drainage in alfalfa was significantly lower than single cropped rotations and single cropped corn in particular (Table 19). The preceeding two months were warm with temperatures reaching 19^{o}C in March and 28^{o}C in April (Appendix B Table 23), and soil water was lost through evapotranspiration in alfalfa over more than two months (March to May). During that time, the single cropped plots were bare until corn was planted on 20 April. Water was stored in the soil profile of the bare plots and was available for drainage after reaching field capacity.

At the end of summer 2005, corn was harvested on 29 August (single cropped) and 7 September (double cropped). Barley and rye were planted on 14 September in the double cropped plots, but the single cropped plots remained bare until corn was planted again in spring 2006. Alfalfa was harvested on 9 August and 9 September 2005 (Table 1 methods' section). Before the soil froze, the alfalfa crops continued to transpire and take up soil water, lowering the potential for drainage losses during the fall. Meanwhile, the bare single cropped plots received precipitation and accumulated water in the soil profile, increasing the potential for drainage losses. Although it was a dry summer (32 mm rainfall in August and September 2005 – see Appendix B Table 22) and the soil profile did not drain until soil water reached field capacity at the end of October (Table 10 results' section), the amount of water uptake by alfalfa significantly lowered drainage losses compared to the bare plots (Table 19). This was accentuated by the deep alfalfa rooting system.

In this study, more differences between rotations occurred after a dry season than after a wet season. In summer and fall 2004 when the soil was close to saturation, there were no significant differences between the rotations (except during a dry spell in June/July 2004), whereas in fall 2005 after a dry summer, alfalfa significantly reduced drainage compared to single cropped rotations. This indicates that the effects of double cropping on drainage are more substantial in low rainfall conditions.

Drainage in double cropped rotations was significantly lower than that in single cropped rotations, and in particular lower than single cropped corn in May 2004 and 2005 and March 2006 (Table 19). The small grains were harvested in early May, but had been taking up soil water since March, therefore lowering soil water storage in the profile. The single cropped plots were bare and therefore stored more water in the soil profile, causing higher drainage losses. A study in southern Australia demonstrated that alfalfa perennial pastures reduced drainage compared to annual pastures (subterranean clover) (Ward et al., 2001). O'Connell et al. (2003) also found that drainage was lower in non-fallow rotations compared to fallow rotations. Although the soil water content data showed no difference between double and single cropping (Fig. 8 results' section), the soil water content values for single cropping were always slightly higher than for double cropping. This insignificant difference resulted in significant drainage differences between the two cropping systems. The higher sensitivity of drainage data is due to the fact that every individual event (two-week interval) was analysed separately, while weekly soil water content data were converted to monthly and seasonal intervals before being analysed for rotational differences.

Soil Water Content

Averaged over depths, soil water content in fall 2004 and winter 2004-05 was higher in the alfalfa rotation compared to double cropping (Fig. 8 results' section). Although soil water in the double cropped plots was taken up by the main crop during the summer 2004 until its harvest and was further depleted by the small grains in fall 2004, soil water was also taken up by the alfalfa rotation over summer and fall until winter dormancy. Therefore water content was expected to decline in relatively equal amounts in both double cropping and alfalfa. The calculated crop evapotranspiration data showed that cumulative ETc in alfalfa and double cropping between April and November 2004 was 1017 and 1000 mm, respectively (Table 16 results' section). Alfalfa lost more cumulative ETc in eight months than double cropping (17 mm), resulting in a lower soil water content in fall and winter 2004-05 in alfalfa than in double cropping. The fact that soil water content in alfalfa was higher than in double cropping is not clear. The water content mean over time (fall-winter 20004-05) shows a difference of 0.012 m^3m^{-3} between double cropping and alfalfa (Fig. 8), which is relatively small. This difference may be the result of an artifact in location of the alfalfa and the double cropped plots in relation to soil depth and textures. For instance, there may be a soil lens with higher clay content in the alfalfa plots that enable the measurement of higher water contents compared to coarser textures in the double cropped plots.

In summer and fall 2005, soil water content averaged over depth in the alfalfa rotation was lower than in both double and single cropping (Fig. 8 results' section). Higher temperatures and lower rainfall in summer and fall 2005 increased the drought risk for all crops. However, alfalfa is a tolerant perennial which can continue some growth during mild drought (Blevins and Barker, 2007). While the single cropping rotations were bare, alfalfa continued to grow and take up soil water. The deeper alfalfa rooting system allowed for higher soil water uptake than in double or single cropping, especially in drier soil surface conditions compared to summer and fall 2004.

Fig. 13 shows results of the three-way interaction between three rotation types (double, single, and alfalfa rotations), eleven seasons (fall 03 through spring 06), and six depths (0.18 to 1.70 m deep) (see Table 14 in results' section). The seasonal interaction showed that above 1.70 m soil water content in the alfalfa rotation was lower than in double and single cropping in summer, fall 05, and spring 06. In summer 05, precipitation was low and air temperature was high such that the soil surface was dry. Cumulative ETc between April and November 2005 showed that alfalfa lost more water through evapotranspiration (1138 mm) than double (1044 mm) and single cropping (909 mm) (Table 16 in results' section). In addition, cumulative drainage between April and November 2005 showed lower drainage in alfalfa (142 mm) than in double (172 mm) or single cropping (182 mm) (Table 16 in results' section), also indicating a lower soil water content. These effects were apparent as deep as 1.40 m and lasted until spring 06 at 0.49 m deep. However, at 1.70 m, soil water content in the alfalfa rotation was higher than in double and single cropping. This occurred only during the wet period (winter 03-04 through spring 05). During this time, most of the soil water was taken up at shallower depths, where alfalfa root density is greatest and the effective alfalfa root zone is located. As the upper soil dried (summer and fall 2005), the plants needed to utilize soil water at deeper layers and the root zone of active soil water extraction moved down (Shaeffer et al., 1988). The soil water content was no longer different between rotations at 1.70 m after spring 05.

	Fall 03	Win 03-04	Spr 04	Sum 04	Fall 04	Win 04-05	Spr 05	Sum 05	Fall 05	Win 05-06	Spr 06
0.18m											
0.49m								A<DC A<SC	A<SC		A<SC
0.79m								A<DC A<SC	A<DC A<SC		
1.10m									A<DC A<SC		
1.40m									A<DC A<SC		
1.70m		A>DC	A>DC	A>DC A>SC	A>DC A>SC	A>DC A>SC	A>DC A>SC				

Fig. 13: Soil water content results of three-way interaction analyses between three rotation types (A: alfalfa, DC: double cropping, SC: single cropping), eleven seasons (fall 03 to spring 06), and six depths (0.18 to 1.70 m).

The three-way interactions between depths, rotation types and seasons showed that there were no significant differences in soil water content between double and single cropped rotations, whether at individual depths, seasons, and rotations, or averaged (Tables 14 and 15 in results' section). Winter small grains did not affect the soil physical properties enough to cause a significant difference in soil water content compared to having a fallow winter (single cropping). McVay et al. (1989) found no differences in percent stable aggregates between having a winter crop (crimson clover, hairy vetch, wheat) and a winter fallow, thus minimizing the potential for enhanced infiltration, hydraulic conductivity and soil water retention. Folorunso et al. (1992) also reported no differences at the 5% level in infiltration rates between double cropping and winter fallow. Many soil horizons in our plots were sandy loam where water may not have been retained as well as in finer textures. Oquist et al. (2006) found no differences in water retention at coarse textures between alternative (legume/grain rotations, no till, manure use) and conventional (corn/soybean rotations, and synthetic fertilizers) cropping systems.

In April and May 2006, however, using individual dates at planting time, soil water content in double cropping was lower than in single cropping. After two years double cropping, this was the only time that a significant difference occurred in soil water content between double and single cropping. As Nielsen and Vigil (2005) suggested, differences may not appear in the first few years. This indicates two possible conclusions. This effect only occurred once over the study period and therefore is not showing a definite pattern. However, this effect occurred at the end of the study, alerting to the possibility of a pattern occurring in a long term study. Despite the long term benefits of double cropping such as the accumulation of organic matter, increased soil water holding capacity, enhanced aggregate stability and hydraulic conductivity leading to potentially better soil water storage (Gregory et al., 2005; Smith et al., 1987), there is a balance to be reached between the inputs and outputs of soil water over time. With abundant precipitation in spring 2004 and 2005, double cropping did not affect soil water content at planting time. In spring 2006, however, after an extremely dry summer in 2005, double cropping negatively affected soil water content, supporting farmers' concerns of high water use by a double crop during dry spells.

Crop Evapotranspiration

Table 20 summarises ET_c results. Rye and barley planted in the fall increased double cropping ET_c in both fall and spring. In the winter, double cropping ET_c was lower than single cropping ET_c (Table 20). The rye and barley were dormant in the winter and no transpiration occurred. However, evaporation was higher in the single cropped plots due to the lower residue cover. This was reflected by the higher crop coefficients in single cropping than in double cropping (see Appendix F Tables 37-43 for crop coefficients). Mean Kc winter values for single cropping ranged between 0.42 and 0.66 (Appendix F). These values are comparable to 0.50 which was found to adequately predict non-growing season evapotranspiration in Northern Utah (Allen, 1996).

In spring 2004 (April to May), single cropping ET_c increased by 0.75 mm/day compared to double cropping ET_c whereas in spring 2005 (April to May) it only increased by 0.26 mm/day (Fig. 9 in results' section). This is due to a later corn planting date in 2005 compared to 2004. Double cropped corn was planted 9 and 19 days after single cropped corn in 2004 and 2005, respectively (Table 1 in methods' section).

During the summer seasons, double and single cropping ET_c increased simultaneously and reached a higher peak in 2005 than in 2004 (Fig. 9). Maximum temperatures were 28 and 30^{o}C in summers of 2004 and 2005, respectively (Fig. 14), and higher temperatures contributed to higher ET_c. In addition, summer precipitation was double the 30-year average in 2004 and half the 30-year average in 2005 (Fig. 14). A drier and warmer summer in 2005 than 2004 resulted in higher ET_c.

In the fall seasons, alfalfa ET_c was higher than single cropping ET_c. The actively growing alfalfa took up soil water and transpired, and soil water evaporated from the soil surface. The single cropped plots contained dead vegetation that did not transpire and reduced soil evaporation, resulting in a lower ET_c. In the winter, as with double cropping ET_c, the crop coefficient used to calculate ET_c was lower for alfalfa than for single cropping due to more surface vegetation cover in alfalfa and in the double cropped rotations than in the single cropped rotations (Tables 37-43 in Appendix F). The average winter crop coefficient for alfalfa (0.40) is comparable to 0.50 recommended by Allen (1996). Other studies have shown that surface mulch, dormant vegetation or crop residues reduce soil evaporation (Bond and Willis, 1969; Frye et al., 1988; Unger and Vigil, 1998; Allen et al., 1998).

In the summer, alfalfa ET_c was lower than double and single cropping ET_c. When the effects of the individual cutting periods were averaged, only a single value for Kc needed to be employed for the whole season. According to Allen et al. (1998), this value is no higher than 80% of the Kc value that represents full ground cover (available in Table 12 page 112 of Allen et al., 1998), which resulted in lower ET_c values than double and single cropping.

Table 20: Crop evapotranspiration of single, double and alfalfa cropping systems.

Season	**ET_c**
Single (SC) and Double Cropping (DC)	
Fall	DC > SC
Winter	DC < SC
Spring	DC > SC
April-May 2004	SC > DC by 0.75 mm/day
April-May 2005	SC > DC by 0.26 mm/day
Summer	DC = SC
Alfalfa (A)	
Fall	A > SC
Winter	A < SC
Summer	A < DC, SC

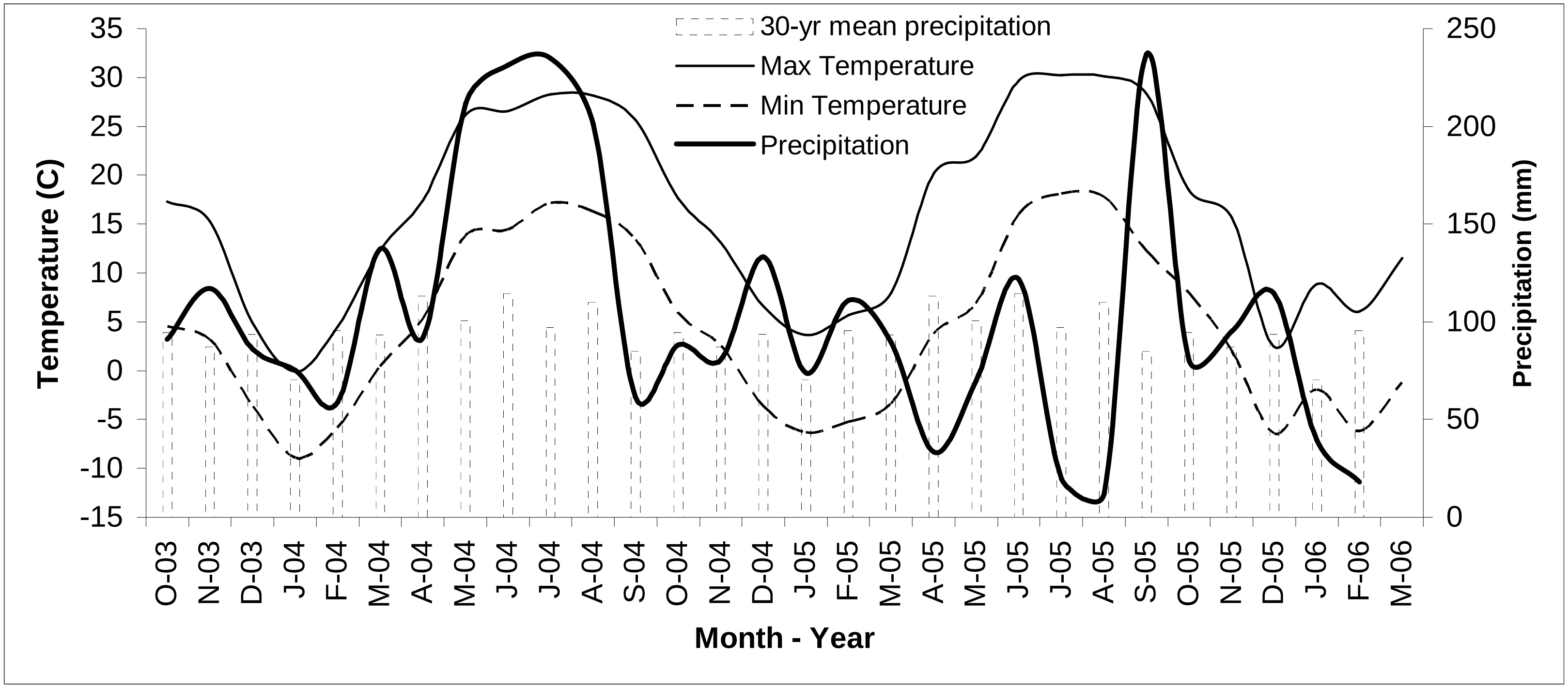

Fig. 14: Minimum and maximum temperatures (^{o}C), actual and 30-year average precipitation (mm) from September 2003 to March 2006 in the research plots.

Water Balance

The reasons for Eq. [4] not being satisfied are discussed in this section. Precipitation was measured using a tipping bucket, and when the latter was not performing well data was retrieved from two weather stations (see precipitation results). The errors associated with precipitation were addressed using the procedure described in the precipitation results' section, and their likely effect on the balance is minimal.

Runoff measurement was corrected to avoid an over estimation in summer 2004 in the plot re-design. In addition, the gutters were cleaned regularly and maintained level with the soil surface to minimise runoff under-estimations. Actual measurements were made using a 2000 mL graduated cylinder (minimum reading 50 mL). The low values of runoff indicate that runoff is not likely a major contributor to the water balance errors.

Drainage was calibrated in order to account for localized differences between individual lysimeters. Some drainage values exceeded precipitation and therefore may have contributed to the balance errors observed in Table 16 (results' section). For instance, in October and December 2004 drainage was 12 and 46 mm higher than precipitation. Similarly, drainage was higher than precipitation in March 2005 and January to March 2006. While many of the values exceeding precipitation occurred during the cold seasons (Table 16 results' section) when snow accumulation and melting or freezing and thawing of the soil may have impacted drainage, the values exceeding precipitation suggest periods of over-estimation and it seems likely that drainage was over-estimated most of the time in this study. A constant continual tension of 0.5 m at 1.65 m may have resulted in over-estimations of water volumes flowing through the soil profile.

Crop evapotranspiration (ETc) was calculated using the Penman-Monteith estimation method (Allen et al., 1998). Cumulative ETc values were 412, 574, and 294 mm lower than precipitation for double, single, and alfalfa rotations, respectively (Table 16 results' section), leaving little room for the remaining components of the water balance. Many values exceeded precipitation, especially between May and September 2005 (Table 16 results' section). An increase in ETc suggests a decrease in drainage, runoff, and soil water content (Table 16 results' section). There was a negative change in soil water content in April, May, July, August, and September 2005 (Table 16 results' section). However, the difference did not offset the high increase in ETc, suggesting possible over-estimations of ETc. ETc values were also high in summer 2004, indicating that the Penman-Monteith method may be overestimating crop evapotranspiration when used in our field conditions. Calculating reference crop evapotranspiration assumed a hypothetical well-watered and well-fertilized grass surface (Allen et al., 1998) responding only to climatic parameters. Crop evapotranspiration was estimated under standard conditions: disease-free and well-fertilized crops grown in large fields under optimum water conditions, and achieving full production under the climatic conditions. The field plots in this study were not large (3 m by 9 m) and soil water content was not optimum. Yield data showed that corn yields in 2004 and 2005 averaged 18 and 15 Mg DM/ha, respectively (Table 3 results' section). Higher air temperatures and lower rainfall caused lower yields in 2005 than 2004, which infers lower soil water availability and crop transpiration rates. However, total available water (TAW) and readily available water (RAW) calculations suggested that a water stress coefficient was not needed in calculating ETc (see Appendix F for calculations). The relation between TAW and RAW was assumed to be p=0.5 (see methods' section). Since the fraction p is a function of the evaporation power of the atmosphere, p changes with ETc. In hot and dry weather conditions where ETc is high (>8 mm/day), p may be 10-25% lower than the values suggested by Allen et al. (1998) and the soil may be relatively wet when crop stress starts to occur (Allen et al., 1998). A lower p value increases the soil water content threshold for stress. The higher atmospheric evaporative demand in summer 2005 may have warranted a lower p value than in summer 2004, and the soil water content stress threshold may have been reached with p lower than 0.5. In addition, the ETc calculations assumed that roots reached 1.85 m in all rotations. This may not have been true. Adjusting for root depths would have lowered the estimate of RAW and TAW to have included a water stress coefficient in the ETc calculations. Moreover, soil water field capacity and wilting points were needed to calculate TAW. Field capacity was obtained by averaging soil water contents during the wet period between October 2003 and March 2005 (methods and Appendix F). Wilting point was obtained using the computer program ROSETTA (Schaap et al., 2001) to estimate parameters of the van Genuchten equation from measured percent sand, silt, and clay (methods and Appendix F). These estimations of field capacity and wilting point may have also resulted in over-estimated ETc values.

Soil water content change values ranged from -66 to 115 mm, however the means were -2, -1, and -2 mm for double, single, and alfalfa rotations, respectively (Table 16 results' section). The cumulative total change showed the lowest absolute values compared to the other four components of the water balance: -41, -30, and -42 mm for double, single, and alfalfa rotations, respectively (Table 16 results' section). The low means and cumulative totals suggest that soil water content change did not contribute significantly to the cumulative water balance error.

To this date and to the best of my knowledge, no study was found to have measured the five components of the water balance. Louie et al. (2000) assumed no runoff and soil water content change in water balance calculations. Brandi-Dohrn et al. (1996) did not quantify runoff in a water balance used to validate soil water flux obtained using lysimeters. Russell and Ewel (1985) assumed runoff and evapotranspiration to be negligible in a study of water flow during large storms. Wessolek et al. (2008) did not include runoff in a water balance simulation to study percolation behavior. The difficulties of field measurements in long-term rotation studies often lead to the development of assumptions in order to simplify procedures. In this study, although all the components were determined, whether measured or calculated, the overall balance equation was not satisfied. Further water balance research is needed to overcome the shortages of this study.

Conclusions and Recommendations

Double cropping did not affect main crop whole-plant (above ground) yields in 2004 and 2005. Total annual silage yields increased with double cropping compared to single cropping.

Double cropping did not reduce runoff any more than single cropping rotations. Our data showed that runoff amounts were more affected by climatic conditions than by management practices such as crop intensification. High antecedent soil moisture and low rainfall intensity were the influencing factors in this study. Low slope, no tillage, and medium texture may have contributed to higher infiltration rates, thus potentially minimizing runoff losses.

During most of the studied period, and despite the drainage data calibration, our hypotheses were rejected and there were no significant differences in drainage between double cropped, alfalfa, and single cropped rotations. Nevertheless, on the few dates when statistical differences were found between rotations, our hypotheses were verified. Drainage in alfalfa was lower than that in single cropping rotations due to plant water uptake during the fall and spring and loss of water to transpiration. Drainage in double cropped rotations was also significantly lower than that in single cropped rotations, particularly single cropped corn, in the spring season. Using a wick tension at -0.5 m might have over-estimated the volume of drainage collected during the humid season and under-estimated drainage collected during the dry season. The constant continuous tension likely increased the variability of the drainage data, making it difficult to find differences between the rotations. In the future, soil water tension should be measured under natural conditions outside the lysimeter simultaneously at the depth of the lysimeter and a variable tension lysimeter should be used that is as close to the in-situ conditions as possible. Brye et al. (1999) have developed and demonstrated such a lysimeter that continuously adjusts its tension to that of the soil surrounding it.

Double cropping did not affect soil water content compared to single cropping, and the hypothesis was rejected during both the wet and dry seasons. However, alfalfa lowered soil water content during the dry season compared to double and single cropping.

Crop evapotranspiration was increased by double cropping during the fall and spring seasons. The water balance showed a likely over-estimation in the ETc calculations during summer 2004 and 2005 using the Penman-Monteith estimation method.

Comparing results of the wet year (2004) with those of the dry year (2005), differences were more acute after a dry period, supporting farmers' concern that double cropping may result in exacerbated water deficiencies. However, in this study, these detrimental conditions only occurred briefly in the spring before being offset by rainfall events.

Appendix A

Plot Layout

20 ft

30 ft

	6	4	5	2	8	1	7	3
Plot #	401	402	403	404	405	406	407	408
	1	6	4	3	8	2	7	5
Plot #	301	302	303	304	305	306	307	308
	5	1	3	4	2	8	6	7
Plot #	201	202	203	204	205	206	207	208
	2	3	6	5	7	1	8	4
Plot #	101	102	103	104	105	106	107	108

30 ft

N

Rotations:

1- C/R
2- C/B
3- C/R-SB/R-C/R
4- SB/R-C/R-SB/R
5- C-C-C
6- C-SB-C
7- SB-C-SB
8- A-A-A

Appendix B

Part 1 - Precipitation Data

Table 21: Precipitation (mm of liquid) between September 2003 and March 2004 at the Southeast Research and Extension Center (SEREC). Numbers followed by “sn” indicate precipitation in the form of snow.

Day	SEREC Sep-03	SEREC Oct-03	SEREC Nov-03	SEREC Dec-03		SEREC Jan-04		SEREC Feb-04		SEREC Mar-04	
1	0.8	2.5	0.0	0.0		0.0		0.0		0.0	
2	63.5	0.0	0.0	0.0		2.8		0.0		0.0	
3	7.4	0.0	0.0	0.0		0.5		18.5		0.0	
4	12.2	9.4	0.0	0.0		1.8		0.0		3.3	
5	0.0	0.0	5.6	14.2	sn	13.2		0.0		0.0	
6	0.0	0.0	3.8	21.6	sn	0.0		45.0	sn	12.2	
7	0.0	0.0	3.8	0.0		0.0		7.1		0.0	
8	0.0	0.0	0.0	0.0		0.0		0.0		5.3	
9	0.0	0.0	0.0	0.0		0.0		0.0		0.0	
10	0.0	0.0	0.0	1.8		0.0		0.0		1.0	
11	0.0	0.0	0.8	32.0		0.0		0.0		0.0	
12	0.0	0.0	7.6	0.0		0.0		0.0		0.0	
13	14.2	0.0	0.0	0.0		0.0		0.0		0.0	
14	5.6	1.5	0.0	15.2	sn	0.0		0.0		0.0	
15	5.3	41.1	0.0	4.1		3.0	sn	0.0		0.0	
16	0.0	0.0	0.0	0.0		0.0		0.0		17.0	sn
17	0.0	2.0	5.3	14.5		0.0		0.0		2.8	sn
18	0.5	6.4	0.0	0.0		28.2	sn	0.0		0.0	
19	28.4	0.0	18.5	0.0		0.0		0.0		14.5	sn
20	0.0	0.0	14.0	0.0		0.0		0.0		0.0	
21	0.0	0.0	0.0	0.0		0.0		0.0		0.0	
22	0.0	0.3	0.0	0.0		0.0		0.0		0.0	
23	56.6	0.0	0.0	0.0		0.0		0.0		0.0	
24	0.0	0.0	0.0	12.2		8.4	sn	4.6	sn	0.0	
25	0.0	0.0	0.0	0.0		0.0		0.0		0.3	
26	13.7	0.0	0.0	0.0		18.8	sn	0.0		0.0	
27	0.0	35.3	0.0	0.0		0.8		0.0		1.8	
28	2.0	2.0	14.0	0.0		8.4	sn	0.0		0.0	
29	1.5	27.7	17.5	0.0		0.0		0.0		0.0	
30	0.0	51.8	0.0	1.5		0.0				0.0	
31		0		0		0				0.508	

Table 22: Precipitation (mm of liquid) between April 2004 and March 2006 at the experimental site (Watchdog), the Southeast Research and Extension Center (SEREC), and the Lancaster Airport. The column headed “Corrected Watchdog” resulted from an error in screening and calibration process (see methods’ section for details). The column headed “FINAL” contains the data used for the study. The symbols †, fr, sn, and ‡ indicate data unavailable, freezing temperatures, snowfall, and data unavailable due to a low battery, respectively.

Apr-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	†		20.6	22.1	20.6
2	†		4.8	1.8	4.8
3	†		1.3	3.3	1.3
4	†		6.9	6.4	6.9
5	†		0.0	0.3	0.0
6	†		0.0	0.0	0.0
7	†		0.0	0.0	0.0
8	†		2.0	0.0	2.0
9	0.0	0.0	2.5	4.3	0.0
10	fr		0.0	0.0	0.0
11	0.0	0.0	0.5	0.0	0.0
12	4.6	4.1	3.6	0.5	4.1
13	28.7	25.7	19.1	20.3	19.1
14	14.0	12.5	12.7	15.7	12.5
15	0.3	0.2	0.0	0.3	0.2
16	fr		0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	1.8	1.6	1.5	2.8	1.6
22	0.0	0.0	0.0	0.0	0.0
23	1.5	1.4	1.3	0.8	1.4
24	14.5	12.9	13.0	15.7	12.9
25	2.5	2.3	2.3	1.5	2.3
26	49.3	44.1	41.9	46.5	44.1
27	1.8	1.6	1.8	5.6	1.6
28	2.5	2.3	0.3	0.3	2.3
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0

Table 22: Continued

May-04 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.5	0.0
3	34.8	31.1	29.2	14.5	31.1
4	0.3	0.2	0.0	1.0	0.2
5	1.0	0.9	0.0	0.0	0.9
6	0.5	0.5	1.5	4.8	0.5
7	5.6	5.0	5.1	0.0	5.0
8	0.0	0.0	0.0	4.1	0.0
9	0.0	0.0	0.0	0.0	0.0
10	5.1	4.5	4.1	11.7	4.5
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	5.3	4.8	5.8	0.5	4.8
16	10.2	9.1	9.1	11.2	9.1
17	2.8	2.5	0.0	0.0	2.5
18	1.0	0.9	3.6	0.3	0.9
19	21.8	19.5	19.8	11.7	19.5
20	0.3	0.2	0.5	3.6	0.2
21	1.3	1.1	1.3	0.8	1.1
22	0.5	0.5	1.0	0.0	0.5
23	0.0	0.0	0.0	0.0	0.0
24	4.1	3.6	3.8	0.8	3.6
25	0.0	0.0	0.0	0.0	0.0
26	8.4	7.5	7.6	6.1	7.5
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	5.3	4.8	0.0	0.3	0.0

Table 22: Continued.

Jun-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	5.6	5.0	4.8	7.6	5.0
2	7.4	6.6	7.1	5.8	6.6
3	1.3	1.1	1.3	1.0	1.1
4	0.0	0.0	0.0	0.0	0.0
5	37.8	33.8	31.8	8.9	33.8
6	9.4	8.4	38.9	17.8	38.9
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	31.2	27.9	27.2	23.4	27.9
12	1.0	0.9	1.3	2.8	0.9
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	20.8	18.6	20.3	12.4	18.6
16	12.7	11.4	8.1	23.4	11.4
17	22.9	20.4	20.3	0.0	20.4
18	46.0	41.1	39.4	42.9	41.1
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.8	0.7	0.8	0.0	0.7
23	0.5	0.5	0.5	1.8	0.5
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.8	0.7	0.8	1.0	0.7
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	4.3	3.9	3.3	3.3	3.9
30	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Jul-04 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.0	0.0
2	0.5	0.5	0.5	13.0	0.5
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.3	0.0
6	0.0	0.0	0.0	0.0	0.0
7	2.5	2.3	5.8	0.0	2.3
8	3.8	3.4	2.8	30.0	3.4
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	96.0	85.9	94.0	26.2	85.9
13	2.5	2.3	2.0	37.1	2.3
14	11.4	10.2	25.1	0.3	25.1
15	32.5	29.1	19.6	27.2	19.6
16	0.0	0.0	0.5	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	8.1	7.3	8.1	5.3	7.3
19	2.0	1.8	0.8	9.7	1.8
20	7.6	6.8	6.6	0.5	6.8
21	31.0	27.7	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	31.0	27.7	29.2	5.6	27.7
24	10.7	9.5	10.4	19.1	9.5
25	0.5	0.5	0.0	0.0	0.5
26	0.0	0.0	0.3	0.0	0.0
27	19.8	17.7	19.8	1.0	17.7
28	23.6	21.1	25.4	12.4	21.1
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Aug-04 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	54.1	48.4	53.8	25.7	53.8
2	0.0	0.0	0.0	0.0	0.0
3	24.6	22.0	18.0	16.3	22.0
4	0.0	0.0	0.0	26.9	0.0
5	20.1	17.9	16.3	0.0	17.9
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	4.1	3.6	4.6	3.8	3.6
12	0.0	0.0	0.0	0.0	0.0
13	49.5	44.3	44.7	49.0	44.3
14	0.0	0.0	0.0	0.0	0.0
15	0.5	0.5	0.8	0.0	0.5
16	0.0	0.0	0.0	0.3	0.0
17	0.3	0.2	0.0	0.0	0.2
18	0.0	0.0	0.0	0.0	0.0
19	2.5	2.3	2.3	2.0	2.3
20	10.4	9.3	10.9	1.8	9.3
21	44.2	39.5	44.7	5.3	44.7
22	0.0	0.0	0.0	17.5	0.0
23	0.0	0.0	36.1	0.3	36.1
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Sep-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.3	0.2	0.0	0.0	0.2
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.3	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	3.6	3.2	3.8	0.8	3.2
9	2.8	2.5	6.4	4.3	6.4
10	0.0	0.0	0.5	0.8	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.3	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.3	0.0
16	0.0	0.0	1.0	1.5	0.0
17	0.0	0.0	0.8	0.3	0.0
18	2.3	2.0	101.1	86.6	101.1
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.3	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	55.9	2.0	55.9
29	1.0	0.9	28.2	45.7	28.2
30	0.0	0.0	6.1	0.5	6.1

Table 22: Continued.

Oct-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.3	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	3.3	0.3	3.3
4	0.0	0.0	0.0	0.3	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	21.3	14.2	21.3
15	0.0	0.0	1.3	0.0	0.0
16	0.0	0.0	3.8	4.1	3.8
17	0.0	0.0	0.0	2.0	0.0
18	fr		0.8	0.0	0.8
19	0.0	0.0	11.9	15.5	11.9
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	5.6	3.8	5.6
22	0.0	0.0	3.3	2.8	3.3
23	fr		0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.5	0.5	11.4	5.8	11.4
31	0.0	0.0	0.0	0.3	0.0

Table 22: Continued.

Nov-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	fr		15.7	2.8	15.7
5	1.0	0.9	2.0	18.3	0.9
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	fr		0.0	0.0	0.0
10	fr		0.0	0.0	0.0
11	fr		0.0	0.0	0.0
12	0.5	0.5	15.7	8.4	15.7
13	0.3	0.2	4.3	8.9	4.3
14	fr		0.0	0.0	0.0
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	fr		0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	3.8	2.8	3.8
21	0.0	0.0	4.6	5.8	4.6
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.5	0.5	0.0
24	0.0	0.0	2.5	1.0	0.0
25	14.5	12.9	7.6	5.1	7.6
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	39.6	35.4	36.8	35.8	35.4
29	fr		0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Dec-04

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	81.0	72.5	19.1	17.8	19.1
2	fr		0.0	0.0	0.0
3	fr		0.0	0.0	0.0
4	fr		0.0	0.0	0.0
5	fr		0.0	0.0	0.0
6	fr		0.5	0.0	0.5
7	10.2	9.1	9.4	4.8	9.1
8	0.8	0.7	0.5	4.8	0.7
9	fr		3.3	0.0	3.3
10	24.4	21.8	23.6	14.2	21.8
11	3.6	3.2	1.5	15.7	3.2
12	0.0	0.0	0.0	0.0	0.0
13	1.0	0.9	0.8	0.5	0.9
14	fr		0.0	0.0	0.0
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	fr		0.0	0.0	0.0
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.5	0.0	0.5
21	fr		0.0	0.0	0.0
22	fr		0.0	0.0	0.0
23	13.7	12.3	20.8	2.5	20.8
24	fr		0.8	19.3	0.8
25	fr		0.0	0.0	0.0
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr		0.0	0.0	0.0
29	fr		0.0	0.0	0.0
30	fr		0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Jan-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.0	0.0	0.0
2	fr		0.5	0.3	0.5
3	fr		0.8	0.0	0.8
4	1.0	0.9	2.0	2.0	0.9
5	0.5	0.5	15.7	11.4	15.7
6	0.5	0.5	9.1	6.9	9.1
7	0.5	0.5	0.3	0.5	0.5
8	fr		13.5	10.7	13.5
9	fr		0.0	0.5	0.0
10	fr		0.0	0.0	0.0
11	fr		5.8	0.0	5.8
12	0.8	0.7	8.6	7.4	8.6
13	0.5	0.5	0.3	0.0	0.5
14	2.0	1.8	35.8	34.0	35.8
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	fr, sn		1.3	0.3	1.3
18	fr		0.0	0.0	0.0
19	fr, sn		7.9	0.0	7.9
20	fr, sn		0.5	0.3	0.5
21	fr		0.0	0.0	0.0
22	fr, sn		22.6	0.0	22.6
23	fr, sn		0.8	5.3	0.8
24	fr, sn		3.0	0.0	3.0
25	fr, sn		0.3	0.3	0.3
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr		0.0	0.0	0.0
29	fr		0.0	0.0	0.0
30	fr, sn		5.1	1.3	5.1
31	fr		0.0	0.0	0.0

Table 22: Continued.

Feb-05 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.0	0.0	0.0
2	fr		0.0	0.0	0.0
3	fr		0.0	0.0	0.0
4	fr, sn		5.1	0.3	5.1
5	fr		0.0	0.0	0.0
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	fr		0.0	0.0	0.0
9	0.3	0.2	0.0	0.3	0.2
10	3.3	3.0	0.3	1.3	3.0
11	fr		0.0	0.0	0.0
12	fr		0.0	0.0	0.0
13	fr		0.0	0.0	0.0
14	fr, sn		8.6	0.8	8.6
15	1.8	1.6	7.4	14.0	7.4
16	0.8	0.7	5.1	0.0	5.1
17	fr, sn		0.5	4.1	0.5
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.0	0.0	0.0
21	fr, sn		8.9	5.3	8.9
22	1.3	1.1	0.0	0.0	1.1
23	fr		0.0	1.8	0.0
24	fr, sn		6.9	0.0	6.9
25	fr, sn		18.3	3.8	18.3
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr, sn		8.9	0.0	8.9

Table 22: Continued.

Mar-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr, sn		17.8	7.4	17.8
2	fr		0.0	0.0	0.0
3	fr		0.0	0.0	0.0
4	fr		0.0	0.0	0.0
5	fr		0.0	0.0	0.0
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	fr, sn		5.6	5.6	5.6
9	fr		0.0	0.0	0.0
10	fr		0.0	0.0	0.0
11	fr		0.0	0.0	0.0
12	fr		0.0	0.0	0.0
13	fr		0.0	0.0	0.0
14	fr		0.0	0.0	0.0
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	fr		0.0	0.0	0.0
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	2.5	2.3	2.0	2.3	2.3
21	0.3	0.2	3.0	4.3	0.2
22	fr		0.0	0.0	0.0
23	5.1	4.5	35.6	16.8	35.6
24	5.3	4.8	3.0	18.8	4.8
25	6.4	5.7	0.0	0.0	0.0
26	fr		0.0	0.0	0.0
27	6.6	5.9	0.0	0.0	0.0
28	2.5	2.3	37.6	10.4	37.6
29	8.1	7.3	6.9	29.2	7.3
30	9.1	8.2	0.0	0.0	0.0
31	20.1	17.9	0.0	0.0	0.0

Table 22: Continued.

Apr-05 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	4.8	4.3	0.0	0.0	0.0
2	0.8	0.7	44.5	21.3	44.5
3	1.3	1.1	9.9	33.5	9.9
4	fr		0.3	0.0	0.3
5	fr		0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	9.1	8.2	0.8	11.2	0.8
9	0.0	0.0	0.0	0.0	0.0
10	fr		0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	fr		0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	fr		0.0	0.0	0.0
18	0.5	0.5	0.0	0.0	0.5
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.5	0.5	0.5	0.0	0.5
23	12.4	11.1	12.7	13.5	11.1
24	15.5	13.9	10.4	10.9	10.4
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	2.5	2.3	1.5	2.5	2.3
28	1.3	1.1	0.0	0.0	1.1
29	0.0	0.0	0.0	0.0	0.0
30	9.1	8.2	9.7	9.4	8.2

Table 22: Continued.

May-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	4.1	3.6	3.6	0.0	3.6
2	0.5	0.5	0.8	0.0	0.5
3	fr		1.0	1.5	1.0
4	0.0	0.0	0.0	0.0	0.0
5	fr		0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	1.5	1.4	0.0	0.0	1.4
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.3	0.3	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.5	0.5	1.8	0.3	0.5
16	0.5	0.5	3.6	5.3	3.6
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.3	0.2	0.0	0.0	0.2
20	0.0	0.0	7.4	3.6	7.4
21	0.0	0.0	0.0	2.8	0.0
22	0.3	0.2	0.5	0.3	0.2
23	0.0	0.0	0.3	0.5	0.0
24	0.0	0.0	5.1	0.3	5.1
25	0.0	0.0	1.0	1.8	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	9.9	0.0	9.9
29	0.0	0.0	0.0	7.9	0.0
30	0.0	0.0	0.3	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Jun-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	3.6	2.0	0.0
4	0.0	0.0	3.6	5.3	0.0
5	0.0	0.0	0.3	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	19.3	105.4	19.3
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.5	1.3	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	1.3	1.8	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.5	0.0	0.0
17	0.5	0.5	0.0	0.0	0.5
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.3	0.2	0.0	0.0	0.2
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	2.8	3.3	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.8	0.7	49.8	25.7	49.8

Table 22: Continued.

Jul-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	1.3	0.3	0.0
2	0.0	0.0	0.0	2.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	2.3	2.0	5.1	1.0	2.0
6	0.8	0.7	13.7	20.6	13.7
7	0.0	0.0	9.7	0.0	9.7
8	4.3	3.9	56.9	79.5	56.9
9	0.0	0.0	0.3	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	9.1	5.1	9.1
16	0.0	0.0	9.7	1.8	9.7
17	0.0	0.0	9.4	41.1	9.4
18	0.0	0.0	0.0	8.6	0.0
19	0.0	0.0	0.3	0.0	0.0
20	0.0	0.0	0.8	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	1.8	4.6	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	11.4	10.4	11.4
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.5	0.3	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Aug-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	2.3	0.8	0.0
8	0.0	0.0	0.3	0.0	0.0
9	0.0	0.0	6.1	6.9	6.1
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	4.8	4.6	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	13.7	4.8	13.7
17	0.0	0.0	1.8	8.6	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	3.8	1.8	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.3	0.0	0.0
28	0.0	0.0	2.8	8.6	0.0
29	0.0	0.0	2.3	0.3	0.0
30	0.0	0.0	1.5	0.0	0.0
31	0.0	0.0	0.5	0.3	0.0

Table 22: Continued.

Sep-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0	0.0	0.0	0.8	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.3	8.6	0.0
16	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	12.4	5.6	12.4
18	0.0	0.0	0.0	1.5	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.5	0.0	0.0
27	0.0	0.0	2.5	3.8	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	1.0	0.5	0.0
30	0.0	0.0	0.0	0.0	0.0

Table 22: Continued.

Oct-05 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	0.0		0.0	0.0	0.0
2	‡		0.0	0.0	0.0
3	‡		0.0	0.0	0.0
4	‡		0.0	0.0	0.0
5	‡		0.0	0.0	0.0
6	‡		0.3	0.0	0.3
7	‡		85.3	6.1	85.3
8	‡		64.3	86.9	64.3
9	‡		8.9	27.2	8.9
10	‡		0.3	0.0	0.3
11	‡		0.0	0.0	0.0
12	‡		0.5	0.0	0.5
13	‡		9.9	10.9	9.9
14	‡		3.8	1.0	3.8
15	‡		0.3	0.3	0.3
16	‡		0.0	0.0	0.0
17	‡		0.0	0.0	0.0
18	‡		0.0	0.0	0.0
19	‡		0.0	0.0	0.0
20	‡		0.0	0.0	0.0
21	‡		7.9	6.4	7.9
22	‡		20.3	14.2	20.3
23	‡		8.1	10.9	8.1
24	‡		0.3	0.0	0.3
25	‡		22.6	17.5	22.6
26	‡		4.1	4.3	4.1
27	‡		0.3	0.3	0.3
28	‡		0.0	0.0	0.0
29	fr		0.0	0.0	0.0
30	‡		0.0	0.0	0.0
31	fr		0.0	0.0	0.0

Table 22: Continued.

Nov-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.0	0.0	0.0
2	‡		0.8	0.3	0.8
3	fr		0.0	0.0	0.0
4	‡		0.0	0.0	0.0
5	‡		0.0	0.0	0.0
6	‡		0.0	0.0	0.0
7	‡		6.9	3.8	6.9
8	fr		0.0	0.0	0.0
9	‡		0.3	0.0	0.3
10	‡		0.0	0.5	0.0
11	fr		0.0	0.0	0.0
12	fr		0.0	0.0	0.0
13	‡		0.0	0.0	0.0
14	‡		0.0	0.0	0.0
15	‡		0.8	0.8	0.8
16	‡		18.3	0.0	18.3
17	fr		10.9	28.7	10.9
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.0	0.0	0.0
21	fr		0.0	0.0	0.0
22	‡		20.1	20.6	20.1
23	fr		0.0	0.0	0.0
24	‡		0.0	0.5	0.0
25	‡		0.0	0.5	0.0
26	‡		0.0	0.0	0.0
27	‡		0.5	0.0	0.5
28	‡		0.0	0.5	0.0
29	‡		2.5	0.0	2.5
30	‡		19.3	0.3	19.3

Table 22: Continued.

Dec-05

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.0	0.0	0.0
2	fr		0.0	0.0	0.0
3	fr		0.0	0.0	0.0
4	fr, sn		10.2	5.6	10.2
5	fr		0.0	0.0	0.0
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	fr		0.0	0.0	0.0
9	fr, sn		29.5	10.9	29.5
10	fr		0.0	0.0	0.0
11	fr		0.0	0.0	0.0
12	fr, sn		0.8	0.0	0.8
13	fr		0.0	0.0	0.0
14	fr		0.0	0.0	0.0
15	fr, sn		3.0	0.0	3.0
16	fr		34.5	33.3	34.5
17	‡		0.0	0.0	0.0
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.0	0.0	0.0
21	fr		0.0	0.0	0.0
22	fr		0.0	0.0	0.0
23	fr		0.0	0.0	0.0
24	fr		0.0	0.0	0.0
25	fr		6.9	‡	6.9
26	‡		2.5	0.8	2.5
27	‡		0.0	0.0	0.0
28	fr		0.0	0.0	0.0
29	‡		6.1	3.6	6.1
30	‡		0.0	2.5	0.0
31	fr		1.8	0.0	1.8

Table 22: Continued.

Jan-06

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.3	2.8	0.3
2	fr		29.5	0.0	29.5
3	5.1	4.5	0.0	31.0	0.0
4	0.5	0.5	0.0	0.0	0.5
5	0.3	0.2	0.0	0.0	0.2
6	0.3	0.2	0.0	0.0	0.2
7	fr		0.0	0.0	0.0
8	fr		0.0	0.0	0.0
9	fr		0.0	0.0	0.0
10	fr		0.0	0.0	0.0
11	fr		7.6	0.0	7.6
12	fr		0.0	8.1	0.0
13	fr		0.0	0.0	0.0
14	1.5	1.4	10.4	5.3	10.4
15	fr		0.0	0.5	0.0
16	fr		0.0	0.0	0.0
17	fr		0.0	0.0	0.0
18	6.9	6.1	33.0	25.9	33.0
19	fr		0.0	0.3	0.0
20	fr		0.0	0.0	0.0
21	fr		0.0	0.0	0.0
22	fr		0.0	0.0	0.0
23	fr		20.3	17.5	20.3
24	fr		0.0	0.5	0.0
25	4.8	4.3	1.3	0.0	1.3
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr		0.0	0.0	0.0
29	fr		2.8	0.0	2.8
30	0.3	0.2	0.5	2.3	0.2
31	9.4	8.4	10.4	6.6	8.4

Table 22: Continued.

Feb-06 Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	1.5	1.4	0.0	0.0	1.4
2	fr		0.0	0.0	0.0
3	9.4	8.4	17.3	16.5	17.3
4	6.1	5.5	4.8	0.0	5.5
5	fr		9.1	8.4	9.1
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	fr		0.0	0.0	0.0
9	fr		0.0	0.0	0.0
10	fr		0.0	0.0	0.0
11	fr		0.0	0.0	0.0
12	fr		5.8	3.8	5.8
13	fr		0.0	0.0	0.0
14	fr		0.0	0.0	0.0
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	9.9	8.9	0.0	0.8	0.0
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.0	0.0	0.0
21	fr		0.0	0.0	0.0
22	fr		0.0	0.0	0.0
23	fr		0.5	1.0	0.5
24	fr		0.0	0.5	0.0
25	fr		0.0	0.0	0.0
26	fr		0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr		0.0	0.0	0.0

Table 22: Continued.

Mar-06

Day	Watchdog	Corrected Watchdog	SEREC	Lancaster Airport	FINAL
1	fr		0.0	0.0	0.0
2	fr		6.9	2.3	6.9
3	fr		0.0	5.1	0.0
4	fr		0.0	0.0	0.0
5	fr		0.0	0.0	0.0
6	fr		0.0	0.0	0.0
7	fr		0.0	0.0	0.0
8	fr		0.0	0.0	0.0
9	0.3	0.2	0.3	0.0	0.2
10	1.0	0.9	0.0	0.0	0.9
11	0.0	0.0	0.0	0.0	0.0
12	11.2	10.0	11.7	13.5	10.0
13	0.0	0.0	0.0	1.0	0.0
14	4.1	3.6	0.0	0.3	0.0
15	fr		0.0	0.0	0.0
16	fr		0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	fr		0.0	0.0	0.0
19	fr		0.0	0.0	0.0
20	fr		0.0	0.0	0.0
21	fr		0.0	0.0	0.0
22	fr		0.0	0.0	0.0
23	fr		0.0	0.0	0.0
24	fr		0.0	0.0	0.0
25	0.3	0.2	0.0	0.0	0.2
26	0.0	0.0	0.0	0.0	0.0
27	fr		0.0	0.0	0.0
28	fr		0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	fr		0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0

Part 2 - Temperature Data

Table 23: Minimum and maximum temperatures (measured at the Southeast Research and Extension Center) in ^{o}C from October 2003 to March 2006. Missing data is indicated by “m”.

Month/Year	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
																	^{o}C															
Sep-03	Max	24	26	21	24	23	24	25	27	25	23	25	25	24	28	27	23	24	23	24	24	23	24	23	23	26	23	26	26	20	17	
	Min	18	17	16	19	14	9	9	12	17	9	10	14	16	19	17	12	9	11	17	14	13	16	17	7	10	15	16	14	9	3	
Oct-03	Max	17	13	14	14	13	16	19	23	23	24	23	23	23	21	16	18	14	13	16	17	23	22	9	11	13	19	18	13	12	18	19
	Min	6	3	-1	3	2	2	0	7	7	8	9	7	6	6	12	1	8	6	4	0	8	9	3	-3	-2	7	11	0	8	1	3
Nov-03	Max	24	24	27	26	24	16	14	14	6	9	11	12	14	7	11	12	13	12	20	14	18	18	15	16	16	7	11	16	m	m	
	Min	6	10	9	11	7	12	9	2	-7	-8	-2	8	4	1	1	-1	6	0	9	7	-1	1	2	5	-2	-3	m	-2	m	m	
Dec-03	Max	m	3	1	2	1	-3	-3	0	2	4	13	6	1	1	3	8	6	1	1	3	m	12	14	13	5	4	8	9	9	9	10
	Min	m	m	-7	-7	-2	-4	-7	-9	-11	-3	3	1	-5	-4	-2	-6	-1	-3	-6	-5	-7	m	1	5	-3	-3	-1	-7	-4	-1	-4
Jan-04	Max	8	7	14	12	12	5	5	-1	-2	-8	-2	2	6	3	-6	-6	-2	1	-1	-4	-4	3	2	-7	-7	-8	-6	-4	-4	-6	-6
	Min	-2	-2	3	6	2	-2	-9	-7	-8	-17	-17	-6	0	-12	-13	-14	-11	-5	-8	-7	-13	-14	-13	-13	-23	-11	-10	-9	-16	-10	-13
Feb-04	Max	-1	0	2	3	1	1	3	2	4	7	6	4	3	3	3	-2	2	3	8	8	8	6	6	5	3	5	8	13	15	-18	
	Min	-16	-20	-10	-1	-10	-3	0	-8	-10	-4	-2	-5	-4	-4	-6	-12	-9	-6	-3	-3	-1	1	-4	-4	-5	-7	-4	-4	-4	-18	
Mar-04	Max	16	20	19	12	12	18	18	12	7	7	12	11	6	7	13	13	2	6	6	12	9	5	8	16	13	23	22	22	17	12	9
	Min	-3	2	-1	6	7	8	5	3	-3	-3	-3	-2	2	-6	0	-2	-2	-3	0	-5	4	-4	-8	-6	6	6	5	5	2	1	3
Apr-04	Max	13	13	11	9	7	13	20	20	16	16	16	9	4	11	14	17	27	29	31	22	21	23	23	23	18	14	17	16	26	26	
	Min	6	6	5	2	-2	-2	3	-1	5	-1	4	5	4	7	3	-2	4	7	9	14	10	12	11	11	8	8	7	1	4	8	

Table 23: Continued.

Month/Year	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		°C																														
May-04	Max	27	26	25	15	19	22	26	22	26	29	28	31	31	29	31	29	28	27	27	21	26	29	31	30	30	28	26	26	26	23	21
	Min	12	18	7	4	4	4	11	9	8	13	16	16	16	18	17	18	16	17	17	15	19	16	18	19	16	17	17	19	10	9	13
Jun-04	Max	24	25	24	24	21	18	28	29	32	32	26	22	23	29	31	31	30	29	29	21	26	28	28	29	29	27	26	26	24	28	
	Min	14	12	13	10	12	12	16	13	16	19	14	10	11	17	17	19	21	19	18	11	9	18	18	14	17	18	9	11	13	11	
Jul-04	Max	28	30	30	27	32	32	29	29	28	27	29	23	26	27	27	28	29	20	28	31	32	31	29	27	22	28	28	29	31	31	31
	Min	13	16	15	17	21	19	17	18	16	12	16	20	19	18	16	14	14	19	18	16	15	18	21	18	18	17	19	21	14	18	22
Aug-04	Max	31	31	31	31	30	23	21	27	28	29	28	28	27	25	27	28	28	27	29	32	31	23	27	28	27	27	29	31	31	31	28
	Min	21	20	18	19	18	12	11	9	9	16	17	19	19	14	18	15	13	16	18	17	20	11	12	14	18	16	18	17	19	20	20
Sep-04	Max	26	26	26	29	31	27	26	26	27	26	25	26	28	28	27	25	25	24	20	21	26	27	28	28	26	25	24	23	21	22	
	Min	12	13	12	13	14	12	16	18	22	15	12	13	13	13	13	18	18	14	6	5	8	9	12	13	12	14	12	18	16	14	
Oct-04	Max	24	24	20	23	23	23	24	25	24	21	16	17	17	16	17	17	13	14	14	11	11	13	13	12	13	14	17	15	15	21	23
	Min	6	6	8	5	6	1	3	5	8	11	8	2	1	9	9	8	3	-2	9	9	9	8	-1	2	8	9	3	3	5	12	9
Nov-04	Max	16	19	19	11	11	16	21	19	7	8	13	12	7	8	15	16	13	14	16	14	15	13	10	14	18	7	10	13	7	9	
	Min	8	7	10	-1	6	0	0	2	-4	-6	0	3	2	-4	-5	-3	-1	7	3	8	8	3	7	9	11	-2	-1	8	-2	1	
Dec-04	Max	11	8	7	7	11	9	6	14	10	8	10	6	7	3	2	7	5	7	6	2	1	11	15	9	-2	-1	-2	0	10	8	12
	Min	6	-3	-6	-7	-4	-3	3	3	-1	5	2	2	2	-1	-8	-9	-1	-8	-6	-15	-12	-6	2	-3	-10	-11	-8	-13	-4	-2	2

Table 23: Continued.

Month/Year	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		°C																														
Jan-05	Max	17	12	12	10	8	8	4	6	7	8	8	6	16	17	4	0	-1	-1	-7	-2	-3	-3	-8	-7	0	3	3	-5	-2	2	2
	Min	-2	-3	-3	7	3	1	1	0	0	-1	-2	2	4	2	-6	-6	-8	-12	-13	-9	-14	-21	-13	-17	-8	-3	-16	-18	-19	-5	-16
Feb-05	Max	3	3	2	6	10	10	9	12	12	12	3	7	6	6	13	13	7	1	0	3	3	7	7	4	-1	4	1	0	-18	-18	
	Min	-17	-17	-9	-2	-3	-7	-7	-1	1	1	-4	-4	-4	-2	1	1	-3	-6	-10	-7	-2	0	-1	-4	-13	-14	-9	-4	-18	-18	
Mar-05	Max	2	2	-1	1	3	10	19	17	-1	1	6	7	6	5	6	7	8	11	12	11	8	12	12	6	7	8	8	8	14	17	16
	Min	-6	-3	-7	-17	-13	-9	-2	-5	-9	-11	-3	-6	-5	-4	-6	-7	-4	-6	-4	3	3	-3	2	0	3	-2	4	2	7	1	2
Apr-05	Max	17	17	12	15	18	27	27	23	19	22	23	18	18	20	20	17	23	23	27	28	28	18	21	20	11	21	21	19	16	17	
	Min	6	6	2	0	-1	4	9	10	2	0	6	2	-1	1	2	-4	-2	3	4	9	10	3	7	4	2	1	11	4	3	10	
May-05	Max	17	16	14	14	17	17	21	22	26	26	30	29	20	28	28	23	18	21	23	23	22	22	21	18	13	25	27	27	23	23	26
	Min	9	1	-1	4	-1	4	2	6	6	7	10	13	2	10	16	10	5	5	5	9	5	8	9	11	8	11	6	11	9	7	7
Jun-05	Max	26	27	23	23	30	33	31	33	31	31	32	32	33	33	33	30	24	24	23	24	28	29	29	31	34	34	32	34	31	33	
	Min	9	11	13	16	13	17	17	18	18	22	20	19	20	21	22	16	10	11	13	12	11	14	8	13	16	17	20	21	22	19	
Jul-05	Max	32	28	29	30	28	29	29	24	29	31	32	33	34	28	28	28	29	32	31	29	33	32	29	29	32	34	34	34	29	30	29
	Min	20	19	13	16	19	19	19	17	14	14	14	17	19	22	21	22	22	22	22	20	17	19	19	13	19	19	19	16	14	17	18
Aug-05	Max	30	32	32	34	35	31	31	28	28	30	32	34	36	36	28	28	28	29	29	29	32	31	28	26	27	28	27	27	29	28	31
	Min	17	17	19	19	19	18	18	20	19	17	18	19	21	21	21	19	16	14	19	20	21	13	12	11	9	13	17	19	18	21	24

Table 23: Continued.

Month/Year	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		°C																														
Sep-05	Max	30	32	31	27	28	27	28	30	29	28	28	32	33	33	30	31	30	28	29	29	28	30	30	29	22	25	24	25	24	21	
	Min	12	12	11	12	9	9	8	7	13	12	7	7	10	12	19	21	19	13	13	18	11	8	16	16	17	19	16	3	16	2	
Oct-05	Max	25	27	27	25	26	26	26	21	14	17	17	18	15	20	23	20	17	23	24	23	10	10	14	13	11	12	10	10	10	17	21
	Min	2	6	6	10	18	13	20	14	10	13	14	12	11	14	11	10	9	6	3	9	8	8	6	3	5	4	2	2	-1	1	-2
Nov-05	Max	22	18	21	22	m	23	19	16	16	17	10	16	18	16	17	21	9	3	9	15	13	8	6	m	m	m	m	19	19	18	
	Min	0	4	-2	1	m	3	4	-1	10	7	-2	-4	1	4	4	9	-1	-4	-7	-5	-2	4	-3	m	m	m	m	8	15	4	
Dec-05	Max	6	4	1	1	1	1	-1	-1	0	-1	2	2	-2	-7	-3	4	m	4	2	0	-1	3	11	10	4	6	6	7	7	7	2
	Min	-3	-1	-5	-3	-4	-5	-8	-11	-8	-18	-14	-5	-18	-22	-18	-3	m	-7	-7	-10	-11	-3	-3	-3	-6	1	2	-3	6	2	-3
Jan-06	Max	6	4	4	4	7	6	2	6	16	14	8	15	12	15	4	0	2	17	9	17	16	11	4	9	8	2	6	13	10	16	13
	Min	-1	-3	3	1	3	1	-7	-1	-2	-1	-2	-1	-1	4	-6	-8	-6	2	-5	-2	-2	-6	0	-4	1	-4	-9	-6	-3	1	4
Feb-06	Max	5	11	14	14	14	4	3	2	1	2	3	3	0	5	10	11	13	4	-3	2	6	5	8	7	12	12	0	2			
	Min	1	-3	5	1	-1	-1	-3	-6	-7	-8	-4	-4	-18	-15	-15	-6	2	-12	-12	-9	-11	-7	0	-4	-7	-7	-10	-11			
Mar-06	Max	7	7	1	6	8	8	6	9	15	23	19	17	26	25	7	10	8	8	7	7	6	6	9	7	8	9	13	15	17	20	21
	Min	-4	-7	-4	-4	-4	-4	-4	-8	3	8	1	9	6	6	0	0	1	-5	-4	-6	-8	-8	-5	-2	1	1	-4	-3	4	-3	10

Appendix C

Runoff Data (mm)

Table 24: Total runoff (mm) collected between the day indicated and the previous date (to the left). The precipitation for the sampling period is above the day indicated. There are four replications and eight rotations: corn/rye (C/R), corn/barley (C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R), corn-corn-corn (C-C-C), corn-soybean-corn (C-SB-C), soybean-corn-soybean (SB-C-SB), and alfalfa (A-A-A). The symbols † and ‡ indicate data eliminated due to floating trash cans, and data eliminated due to extreme values (higher than precipitation), respectively. The construction of the new runoff plots were finalized on 30 Sept.04.

Precipitation (mm)			35.6	64.1	33.6	10.9	37	12.7	85.4	58.8	61.6
Replications	Date	9-Apr-04	14-Apr-04	27-Apr-04	4-May-04	13-May-04	20-May-04	30-May-04	7-Jun-04	16-Jun-04	18-Jun-04
	Rotations										
1	C/R	0	3	0	0	0	0	0	0	0	†
	C/B	0	3	0	0	0	0	0	0	0	†
	C/R-SB/R-C/R	0	3	0	0	0	0	0	0	0	†
	SB/R-C/R-SB/R	0	3	0	0	0	0	0	0	0	0
	C-C-C	0	3	0	0	0	2	0	0	1	42
	C-SB-C	0	4	0	0	0	1	0	0	†	†
	SB-C-SB	0	4	0	2	0	3	0	1	1	†
	A-A-A	0	4	0	0	0	0	0	0	0	†
2	C/R	0	3	0	0	0	‡	0	0	†	†
	C/B	0	2	0	0	0	0	0	0	0	‡
	C/R-SB/R-C/R	1	9	1	0	0	0	0	0	†	0
	SB/R-C/R-SB/R	0	3	0	0	0	0	0	0	0	‡
	C-C-C	0	4	0	0	0	‡	1	0	0	†
	C-SB-C	0	3	0	1	0	4	0	0	7	†
	SB-C-SB	0	2	0	0	0	3	0	0	0	†
	A-A-A	0	4	0	0	0	0	0	0	2	†

Table 24: Continued.

Precipitation (mm)			35.6	64.1	33.6	10.9	37	12.7	85.4	58.8	61.6
Replications	Date	9-Apr-04	14-Apr-04	27-Apr-04	4-May-04	13-May-04	20-May-04	30-May-04	7-Jun-04	16-Jun-04	18-Jun-04
3	C/R	0	4	0	0	0	0	0	0	0	†
	C/B	0	4	0	0	0	0	0	0	0	23
	C/R-SB/R-C/R	0	3	0	0	0	0	0	0	12	50
	SB/R-C/R-SB/R	0	7	0	0	0	0	0	0	1	51
	C-C-C	0	4	4	22	0	20	0	7	33	‡
	C-SB-C	0	4	3	4	0	19	0	3	28	49
	SB-C-SB	0	3	0	0	0	‡	0	0	†	†
	A-A-A	0	4	0	0	0	0	0	0	0	0
4	C/R	0	4	0	0	0	0	0	0	0	0
	C/B	0	4	1	0	0	2	0	0	33	‡
	C/R-SB/R-C/R	0	3	0	0	0	0	0	0	0	†
	SB/R-C/R-SB/R	0	4	1	0	0	0	0	0	0	†
	C-C-C	0	4	0	0	0	1	0	0	0	14
	C-SB-C	0	4	2	1	0	1	0	0	10	‡
	SB-C-SB	0	4	1	0	0	20	0	0	0	‡
	A-A-A	0	3	0	1	0	0	0	0	13	‡

Table 24: Continued.

Precipitation (mm)		100	44.7	146.3	84.4	92.6	110.8	84.1	47.3	36.9	90.6
Replications	Date	13-Jul-04	16-Jul-04	2-Aug-04	16-Aug-04	27-Aug-04	20-Sep-04	29-Sep-04	20-Oct-04	11-Nov-04	2-Dec-04
	Rotations										
1	C/R	†	†	†	†	†	†	‡	0	1	0
	C/B	0	†	†	†	†	56	‡	7	0	0
	C/R-SB/R-C/R	0	†	†	†	†	4	‡	1	0	3
	SB/R-C/R-SB/R	1	†	†	†	†	16	‡	0	0	0
	C-C-C	2	†	†	†	†	33	‡	4	1	4
	C-SB-C	†	†	†	†	†	11	‡	0	0	0
	SB-C-SB	1	†	†	†	†	‡	‡	0	0	0
	A-A-A	5	†	†	†	†	32	19	0	0	81
2	C/R	†	†	†	†	†	69	‡	0	0	0
	C/B	†	†	†	†	†	15	6	0	0	0
	C/R-SB/R-C/R	†	†	†	†	†	1	‡	0	0	0
	SB/R-C/R-SB/R	†	†	†	†	†	70	‡	0	0	0
	C-C-C	†	†	†	†	†	0	‡	7	0	0
	C-SB-C	†	†	†	†	†	0	‡	1	0	3
	SB-C-SB	†	†	†	†	†	3	0	0	0	0
	A-A-A	†	†	†	†	†	0	11	4	0	5

Table 24: Continued.

Precipitation (mm)		100	44.7	146.3	84.4	92.6	110.8	84.1	47.3	36.9	90.6
Replications	Date	13-Jul-04	16-Jul-04	2-Aug-04	16-Aug-04	27-Aug-04	20-Sep-04	29-Sep-04	20-Oct-04	11-Nov-04	2-Dec-04
3	C/R	0	4	3	0	7	3	8	0	0	1
	C/B	0	0	24	21	73	13	19	2	1	0
	C/R-SB/R-C/R	45	‡	9	13	58	0	3	1	0	0
	SB/R-C/R-SB/R	45	17	22	22	12	3	3	7	1	4
	C-C-C	69	‡	59	55	‡	28	65	9	0	0
	C-SB-C	17	17	12	42	9	1	9	2	0	0
	SB-C-SB	‡	4	2	39	37	60	‡	1	0	1
	A-A-A	1	0	0	0	0	0	1	1	0	0
4	C/R	0	0	0	0	0	4	5	2	1	1
	C/B	86	‡	59	‡	‡	110	‡	1	3	31
	C/R-SB/R-C/R	0	0	0	0	0	1	4	0	0	0
	SB/R-C/R-SB/R	30	‡	70	28	‡	47	44	5	0	5
	C-C-C	2	7	6	23	‡	‡	‡	2	1	0
	C-SB-C	‡	‡	19	47	‡	10	10	1	0	0
	SB-C-SB	73	‡	94	34	68	73	‡	0	0	0
	A-A-A	17	17	2	3	26	1	7	0	0	0

Table 24: Continued.

Precipitation (mm)		13.6	25.9	22.1	27.5	73.9	36.8	24.3	62.3	5.6	87.7
Replications	Date	9-Dec-04	15-Dec-04	29-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05	16-Feb-05	2-Mar-05	17-Mar-05	29-Mar-05
	Rotations										
1	C/R	0	0	0	0	0	0	0	0	0	0
	C/B	1	1	0	0	0	0	0	0	0	1
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	1	2
	SB/R-C/R-SB/R	0	0	0	0	0	0	0	0	0	0
	C-C-C	3	0	0	0	0	0	0	0	‡	3
	C-SB-C	0	0	0	0	0	0	0	0	2	0
	SB-C-SB	0	0	0	0	0	0	0	0	0	0
	A-A-A	0	0	0	2	0	0	0	0	0	7
2	C/R	0	0	0	0	0	0	0	0	4	0
	C/B	0	0	1	0	0	0	0	0	0	1
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	2	0
	SB/R-C/R-SB/R	0	0	0	0	0	0	0	0	2	0
	C-C-C	0	0	0	0	2	0	0	0	0	1
	C-SB-C	2	0	1	0	9	0	0	0	0	5
	SB-C-SB	0	0	0	0	0	0	0	0	0	0
	A-A-A	0	1	3	7	30	0	0	0	‡	17

Table 24: Continued.

Precipitation (mm)		13.6	25.9	22.1	27.5	73.9	36.8	24.3	62.3	5.6	87.7
Replications	Date	9-Dec-04	15-Dec-04	29-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05	16-Feb-05	2-Mar-05	17-Mar-05	29-Mar-05
3	C/R	0	1	0	1	0	0	0	0	3	5
	C/B	0	0	0	0	1	0	0	0	0	3
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	0	1
	SB/R-C/R-SB/R	1	3	3	1	0	0	0	0	4	4
	C-C-C	0	0	13	7	27	0	0	0	3	5
	C-SB-C	0	0	0	0	0	0	0	0	0	5
	SB-C-SB	0	1	1	0	5	0	0	0	1	52
	A-A-A	0	0	0	0	0	0	0	0	0	0
4	C/R	0	0	1	1	0	0	0	0	2	3
	C/B	1	10	2	2	2	0	0	0	2	6
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	1	9	1	3	8	0	0	0	3	9
	C-C-C	0	0	0	0	0	0	0	0	0	0
	C-SB-C	0	0	0	0	0	0	0	0	0	0
	SB-C-SB	0	0	0	0	1	0	0	0	2	5
	A-A-A	0	0	0	1	0	0	0	0	2	1

Table 24: Continued.

Precipitation (mm)		54.6	26.6	14.7	16.9	29.2	0.7	49.8	15.8	66.5	28.2
Replications	Date	4-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	30-Jun-05	6-Jul-05	11-Jul-05	22-Jul-05
	Rotations										
1	C/R	0	0	0	0	0	0	12	0	3	0
	C/B	27	1	0	0	0	0	2	1	1	0
	C/R-SB/R-C/R	1	0	0	0	0	0	10	1	2	0
	SB/R-C/R-SB/R	0	0	0	0	0	0	4	0	0	0
	C-C-C	0	0	0	0	0	0	4	0	1	0
	C-SB-C	0	0	0	0	0	0	10	1	0	7
	SB-C-SB	0	0	0	0	0	0	32	4	55	0
	A-A-A	21	22	11	0	0	0	0	4	22	0
2	C/R	0	0	0	0	0	0	0	0	0	0
	C/B	0	0	0	0	0	0	1	0	1	0
	C/R-SB/R-C/R	0	0	0	0	0	0	1	0	1	0
	SB/R-C/R-SB/R	0	0	0	1	0	0	2	1	0	0
	C-C-C	2	0	0	0	2	0	4	0	10	2
	C-SB-C	0	2	2	0	0	0	19	7	33	0
	SB-C-SB	0	0	0	0	0	0	0	0	0	0
	A-A-A	17	7	3	1	0	0	3	6	22	2

Table 24: Continued.

Precipitation (mm)		54.6	26.6	14.7	16.9	29.2	0.7	49.8	15.8	66.5	28.2
Replications	Date	4-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	30-Jun-05	6-Jul-05	11-Jul-05	22-Jul-05
3	C/R	1	0	0	0	0	0	8	1	4	0
	C/B	0	0	0	0	0	0	1	0	0	0
	C/R-SB/R-C/R	0	0	0	0	0	0	25	0	1	0
	SB/R-C/R-SB/R	2	1	1	0	3	0	23	4	22	0
	C-C-C	10	1	0	1	1	0	4	0	1	0
	C-SB-C	‡	0	0	0	0	0	7	0	0	0
	SB-C-SB	1	1	0	0	0	0	22	9	‡	4
	A-A-A	0	0	0	0	0	0	0	0	0	0
4	C/R	2	0	0	0	0	0	1	1	4	1
	C/B	2	5	0	0	0	0	19	0	1	0
	C/R-SB/R-C/R	0	0	0	0	0	0	43	0	0	0
	SB/R-C/R-SB/R	4	13	0	2	3	0	33	0	4	0
	C-C-C	0	1	1	1	0	0	‡	6	26	9
	C-SB-C	0	2	0	0	0	0	25	1	3	0
	SB-C-SB	1	0	0	0	0	0	17	0	6	0
	A-A-A	0	1	0	5	2	0	0	0	1	3

Table 24: Continued.

Precipitation (mm)		11.4	19.8	0	0	12.4	159.5	77.5	7.9	50	32.5
Replications	Date	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
	Rotations										
1	C/R	0	0	0	0	0	0	0	0	0	0
	C/B	0	0	0	0	0	1	8	0	3	0
	C/R-SB/R-C/R	0	0	0	0	0	6	0	0	0	0
	SB/R-C/R-SB/R	0	0	0	0	0	0	0	0	0	0
	C-C-C	0	0	0	0	0	5	0	0	1	0
	C-SB-C	1	0	0	0	0	1	0	0	0	0
	SB-C-SB	0	0	0	0	0	4	0	0	0	0
	A-A-A	9	‡	‡	0	0	1	2	0	32	2
2	C/R	0	1	0	0	1	13	1	0	0	0
	C/B	0	0	0	0	0	2	1	0	0	0
	C/R-SB/R-C/R	0	0	0	0	0	8	0	0	0	0
	SB/R-C/R-SB/R	0	0	0	0	0	0	0	0	0	0
	C-C-C	8	0	‡	0	0	5	0	0	0	0
	C-SB-C	0	0	0	0	0	0	0	0	0	0
	SB-C-SB	0	0	0	0	0	0	0	0	0	0
	A-A-A	0	0	0	0	0	44	1	0	16	4

Table 24: Continued.

Precipitation (mm)		11.4	19.8	0	0	12.4	159.5	77.5	7.9	50	32.5
Replications	Date	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
3	C/R	0	1	0	0	0	8	0	0	2	1
	C/B	0	0	0	0	0	10	1	0	0	1
	C/R-SB/R-C/R	0	0	0	0	0	4	1	0	0	0
	SB/R-C/R-SB/R	0	0	0	0	1	16	1	0	0	1
	C-C-C	0	0	0	0	0	13	1	0	1	0
	C-SB-C	0	0	0	0	0	19	0	0	0	0
	SB-C-SB	3	5	0	0	0	9	1	0	1	1
	A-A-A	2	0	0	0	0	4	0	0	0	0
4	C/R	0	2	0	0	0	5	1	0	2	0
	C/B	0	0	0	0	0	0	0	0	0	0
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	0	4	‡	0	3	40	4	1	0	7
	C-C-C	1	2	‡	0	1	43	9	0	3	2
	C-SB-C	0	0	0	0	0	0	1	0	0	0
	SB-C-SB	0	0	0	0	0	2	0	0	0	0
	A-A-A	0	4	0	0	0	3	0	0	0	0

Table 24: Continued.

Precipitation (mm)		67.8	55.5	65	44.6	5.8	7.4	11.1
Replications	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06
	Rotations							
1	C/R	0	0	0	0	0	0	0
	C/B	0	0	0	0	0	0	0
	C/R-SB/R-C/R	0	0	1	0	0	0	0
	SB/R-C/R-SB/R	2	0	0	0	0	0	0
	C-C-C	0	0	0	0	0	0	0
	C-SB-C	0	0	2	1	0	1	0
	SB-C-SB	0	0	0	0	0	0	0
	A-A-A	1	2	1	1	0	3	4
2	C/R	0	0	0	0	0	0	0
	C/B	0	0	0	1	0	0	0
	C/R-SB/R-C/R	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	0	0	0	0	0	0	0
	C-C-C	0	5	4	3	0	0	0
	C-SB-C	0	0	0	0	0	0	0
	SB-C-SB	0	0	0	0	0	0	0
	A-A-A	1	15	5	5	0	0	0

Table 24: Continued.

Precipitation (mm)		67.8	55.5	65	44.6	5.8	7.4	11.1
Replications	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06
3	C/R	0	2	3	3	0	0	1
	C/B	0	0	0	2	0	0	0
	C/R-SB/R-C/R	2	1	0	0	0	0	0
	SB/R-C/R-SB/R	0	0	0	2	0	0	0
	C-C-C	0	1	2	2	0	0	0
	C-SB-C	2	2	0	8	0	0	0
	SB-C-SB	8	0	1	15	0	0	0
	A-A-A	0	0	2	1	0	0	0
4	C/R	0	0	0	3	0	0	0
	C/B	0	0	0	2	0	0	0
	C/R-SB/R-C/R	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	0	0	14	13	1	1	0
	C-C-C	2	0	5	1	0	0	0
	C-SB-C	1	1	0	1	0	0	0
	SB-C-SB	0	0	0	3	0	0	0
	A-A-A	0	0	0	0	0	0	1

Appendix D

Drainage Data

Table 25: Drainage data (mm) collected between the day indicated and the previous date (to the left). The precipitation for the sampling period is above the day indicated. There are four replications and eight rotations: corn/rye (C/R), corn/barley (C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R), corn-corn-corn (C-C-C), corn-soybean-corn (C-SB-C), soybean-corn-soybean (SB-C-SB), and alfalfa (A-A-A). The symbols †, ‡, §, ¶, and # indicate new lysimeter installed on previous measurement date, ice in container, collection container tipped due to high water table or soil/mud, values lost due to floods in summer 2004, wicks and hose destroyed by rats/mice, respectively. The symbols ††, ‡‡, §§, ¶¶, and ## indicate standard deviation, coefficient of variation, March-April, growing season, and non-growing season. There were no lysimeters installed in A-A-A of replication 2 and C/B of replication 3.

Precipitation in mm		21.59	37.85	101.09	45.97	19.81	31.24	54.86	52.07	7.87	52.83	27.94
Replication	Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04
	Rotation											
1	C/R	79	144	203	160	70	21	17	§	104	135	120
	C/B	0	†	0	0	0	0	0	2	0	0	6
	C/R-SB/R-C/R	69	105	149	203	57	25	6	50	132	101	76
	SB/R-C/R-SB/R	21	43	103	60	21	2	6	§	16	36	33
	C-C-C	4	4	6	5	1	0	1	§	5	†	19
	C-SB-C	19	20	25	26	13	7	8	§	18	17	0
	SB-C-SB	25	40	73	61	34	9	11	§	59	70	43
	A-A-A	32	34	71	64	16	3	8	§	14	64	39
2	C/R							†	§	4	18	16
	C/B	32	39	49	57	24	17	4	§	14	34	33
	C/R-SB/R-C/R			†	32	45	11	0	§	14	54	40
	SB/R-C/R-SB/R	34	58	107	72	26	11	2	§	8	31	22
	C-C-C	38	40	48	69	27	14	12	§	56	41	32
	C-SB-C	84	95	112	135	60	28	10	§	38	70	66
	SB-C-SB	34	50	103	79	18	5	36	§	14	34	22
	A-A-A											

Table 25: Continued.

Precipitation in mm		21.59	37.85	101.09	45.97	19.81	31.24	54.86	52.07	7.87	52.83	27.94
Replication	Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04
3	C/R	21	29	60	67	16	6	5	4	18	37	28
	C/B											
	C/R-SB/R-C/R	1	1	28	10	1	0	1	0	0	2	3
	SB/R-C/R-SB/R	63	73	117	105	34	15	12	33	21	64	42
	C-C-C	20	15	30	31	10	‡	4	11	9	16	10
	C-SB-C	16	14	25	27	11	1	10	6	6	14	6
	SB-C-SB	7	5	14	18	6	‡	5	3	12	4	†
	A-A-A	92	90	138	197	52	‡	17	20	28	59	41
4	C/R	7	19	82	55	15	5	4	4	15	21	16
	C/B	39	23	68	79	20	6	2	0	2	17	18
	C/R-SB/R-C/R	11	23	28	37	8	1	4	0	1	14	12
	SB/R-C/R-SB/R	60	59	116	114	35	20	2	9	31	59	47
	C-C-C	133	114	146	188	88	25	37	15	41	87	86
	C-SB-C	19	29	46	54	11	2	4	0	3	14	10
	SB-C-SB	96	81	102	142	54	15	8	18	41	55	47
	A-A-A	41	39	86	88	29	‡	13	6	5	12	19

Table 25: Continued.

Precipitation in mm		46	66.1	42.25	49.7	85.4	121.5	7.24	152.1	170.35	48.38	92.8
Replication	Date	16-Apr-04	28-Ap-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04
	Rotation											
1	C/R	100	70	37	14	35	¶	28	203	¶	¶	133
	C/B	3	4	0	0	2	¶	5	7	¶	¶	6
	C/R-SB/R-C/R	101	81	18	6	29	177	7	84	¶	¶	47
	SB/R-C/R-SB/R	49	22	10	6	7	¶	6	47	¶	¶	31
	C-C-C	0	3	2	2	2	¶	8	8	¶	¶	30
	C-SB-C	26	26	31	18	19	¶	19	29	¶	¶	30
	SB-C-SB	83	73	41	19	15	¶	15	0	¶	¶	33
	A-A-A	43	35	27	13	3	¶	12	14	¶	¶	7
2	C/R	20	16	16	14	11	¶	16	52	¶	¶	55
	C/B	35	26	20	17	22	¶	22	38	¶	¶	47
	C/R-SB/R-C/R	48	30	18	25	29	¶	12	79	¶	¶	20
	SB/R-C/R-SB/R	29	28	18	10	9	¶	11	65	¶	¶	59
	C-C-C	37	35	40	51	26	¶	18	124	¶	¶	53
	C-SB-C	82	72	87	52	45	¶	55	97	¶	¶	98
	SB-C-SB	10	30	31	16	6	¶	11	72	¶	¶	63
	A-A-A											

Table 25: Continued.

Precipitation in mm		46	66.1	42.25	49.7	85.4	121.5	7.24	152.1	170.35	48.38	92.8
Replication	Date	16-Apr-04	28-Ap-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04
3	C/R	41	30	15	3	11	76	7	12	¶	¶	19
	C/B											
	C/R-SB/R-C/R	3	4	3	1	1	6	0	3	¶	¶	4
	SB/R-C/R-SB/R	60	37	37	13	16	113	14	29	¶	¶	11
	C-C-C	14	13	17	12	7	28	10	6	¶	¶	12
	C-SB-C	9	8	5	0	2	16	3	15	¶	¶	12
	SB-C-SB	0	0	2	0	0	6	0	1	¶	¶	0
	A-A-A	21	21	22	6	0	22	6	16	¶	¶	39
4	C/R	17	15	15	7	9	64	9	23	23	19	26
	C/B	22	20	19	7	5	43	9	4	13	9	7
	C/R-SB/R-C/R	12	10	7	3	14	45	5	24	47	11	11
	SB/R-C/R-SB/R	48	50	42	9	11	117	13	24	¶	¶	29
	C-C-C	111	119	147	71	43	174	56	16	¶	¶	91
	C-SB-C	34	40	36	10	4	69	13	48	¶	¶	35
	SB-C-SB	23	57	80	34	23	119	22	7	43	30	22
	A-A-A	19	19	15	7	0	13	4	3	19	19	21

Table 25: Continued.

Precipitation in mm		9.5	191.3	24.6	25.4	28.01	28.4	75.69	26.4	49.12	73.86	36.85
Replication	Date	16-Sep-04	30-Sep-04	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05
	Rotation											
1	C/R	16	¶	¶	62	73	58	203	113	94	183	11
	C/B	0	¶	¶	7	5	3	5	4	1	2	3
	C/R-SB/R-C/R	4	¶	150	78	69	58	194	126	106	203	0
	SB/R-C/R-SB/R	0	¶	¶	11	11	10	34	23	21	35	5
	C-C-C	7	¶	140	9	9	6	45	25	17	42	4
	C-SB-C	12	¶	¶	16	19	14	23	15	13	17	7
	SB-C-SB	2	¶	¶	44	43	33	104	73	59	102	16
	A-A-A	8	¶	¶	12	13	18	78	46	33	36	9
2	C/R	0	¶	¶	24	33	31	66	50	35	56	8
	C/B	10	¶	¶	34	31	26	55	39	37	45	18
	C/R-SB/R-C/R	7	¶	¶	21	19	16	39	28	22	28	2
	SB/R-C/R-SB/R	0	¶	¶	15	18	15	42	31	26	48	14
	C-C-C	14	¶	¶	18	26	24	51	34	28	47	16
	C-SB-C	14	¶	¶	58	78	72	124	93	91	102	22
	SB-C-SB	3	¶	¶	14	14	12	53	33	30	37	11
	A-A-A											

Table 25: Continued.

Precipitation in mm		9.5	191.3	24.6	25.4	28.01	28.4	75.69	26.4	49.12	73.86	36.85
Replication	Date	16-Sep-04	30-Sep-04	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05
3	C/R	0	35	¶	7	15	5	60	39	36	63	3
	C/B											
	C/R-SB/R-C/R	0	3	2	2	2	1	11	4	2	11	16
	SB/R-C/R-SB/R	0	41	24	16	24	23	91	69	50	110	22
	C-C-C	6	10	10	7	9	8	11	9	8	18	4
	C-SB-C	2	¶	¶	6	3	#	13	9	0	6	†
	SB-C-SB	0	6	2	0	0	3	5	2	2	14	0
	A-A-A	0	64	46	7	10	11	74	50	27	80	0
4	C/R	0	66	22	13	16	13	40	26	17	25	14
	C/B	0	46	34	15	22	19	92	63	30	75	25
	C/R-SB/R-C/R	2	20	8	14	9	6	26	16	11	15	9
	SB/R-C/R-SB/R	0	59	43	20	30	26	117	73	40	103	22
	C-C-C	26	140	128	86	102	81	160	128	106	151	71
	C-SB-C	0	25	21	11	21	18	49	39	25	51	6
	SB-C-SB	0	85	67	45	51	42	85	61	52	73	30
	A-A-A	0	29	20	8	9	10	40	28	24	28	12

Table 25: Continued.

Precipitation in mm		24.26	62.37	5.6	87.7	55.4	25.86	14.65	16.91	29.2	0.68	65.56
Replication	Date	16-Feb-05	2-Mar-05	17-Mar-05	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05
	Rotation											
1	C/R	62	89	115	203	42	26	5	0	0	0	0
	C/B	0	2	3	6	7	4	0	0	0	0	2
	C/R-SB/R-C/R	22	78	110	203	46	6	2	2	1	1	0
	SB/R-C/R-SB/R	14	17	22	34	184	6	1	0	0	0	0
	C-C-C	11	17	26	33	15	5	3	0	1	0	1
	C-SB-C	7	13	13	16	41	9	6	1	4	3	3
	SB-C-SB	36	44	58	100	80	18	8	0	1	0	1
	A-A-A	17	27	51	§	4	12	1	0	0	0	0
2	C/R	17	38	38	51	2	21	5	0	1	0	0
	C/B	21	28	31	34	5	16	7	2	0	0	1
	C/R-SB/R-C/R	10	14	21	35	20	3	0	0	0	0	0
	SB/R-C/R-SB/R	7	18	36	65	2	8	2	0	0	0	0
	C-C-C	19	28	36	39	54	16	9	7	2	0	0
	C-SB-C	36	65	74	93	35	43	20	8	0	0	1
	SB-C-SB	21	18	26	37	40	8	3	0	2	0	6
	A-A-A											

Table 25: Continued.

Precipitation in mm		24.26	62.37	5.6	87.7	55.4	25.86	14.65	16.91	29.2	0.68	65.56
Replication	Date	16-Feb-05	2-Mar-05	17-Mar-05	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05
3	C/R	2	13	27	66	51	0	0	0	0	0	0
	C/B											
	C/R-SB/R-C/R	0	2	3	20	13	1	1	0	0	0	0
	SB/R-C/R-SB/R	26	46	68	113	106	13	2	0	0	0	0
	C-C-C	8	11	10	17	23	7	5	0	3	1	0
	C-SB-C	0	0	0	15	0	4	1	0	0	0	1
	SB-C-SB	2	1	2	9	7	0	1	0	0	0	0
	A-A-A	19	34	42	90	97	10	0	0	0	0	0
4	C/R	11	21	20	43	44	8	1	0	0	0	0
	C/B	11	37	38	101	105	13	1	0	0	0	0
	C/R-SB/R-C/R	5	11	11	23	17	3	1	0	0	0	0
	SB/R-C/R-SB/R	10	51	63	94	94	13	0	0	0	0	0
	C-C-C	65	115	119	161	203	75	33	17	3	2	1
	C-SB-C	0	13	33	43	41	7	0	0	0	0	0
	SB-C-SB	37	57	54	76	94	30	8	1	0	0	0
	A-A-A	15	18	25	38	39	7	1	0	0	0	0

Table 25: Continued.

Precipitation in mm		94.74	11.4	19.81	0	0	12.4	159.51	77.47	7.87	50.04	32.55
Replication	Date	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
	Rotation											
1	C/R	46	5	0	0	1	0	0	0	10	23	102
	C/B	4	2	3	0	0	1	0	0	0	1	1
	C/R-SB/R-C/R	14	3	1	0	0	0	0	41	22	59	127
	SB/R-C/R-SB/R	2	0	0	0	0	0	0	11	0	53	45
	C-C-C	16	0	3	0	0	0	1	35	9	12	26
	C-SB-C	12	4	1	0	0	0	0	4	0	10	9
	SB-C-SB	50	5	0	0	0	0	0	61	23	63	68
	A-A-A	0	0	0	0	0	0	0	0	0	0	7
2	C/R	26	7	0	0	0	0	0	20	25	14	42
	C/B	23	7	0	0	0	0	0	14	17	24	34
	C/R-SB/R-C/R	0	0	0	0	0	0	0	32	6	17	23
	SB/R-C/R-SB/R	20	2	0	0	0	0	0	15	17	37	39
	C-C-C	10	4	1	0	0	0	0	23	18	28	37
	C-SB-C	37	4	0	0	0	0	0	19	33	43	71
	SB-C-SB	31	2	0	0	0	0	0	0	0	16	18
	A-A-A											

Table 25: Continued.

Precipitation in mm		94.74	11.4	19.81	0	0	12.4	159.51	77.47	7.87	50.04	32.55
Replication	Date	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
3	C/R	19	0	0	0	0	0	0	30	15	26	43
	C/B											
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	15	6	0	2	0	0	0	40	30	45	62
	C-C-C	5	5	0	0	0	1	0	0	0	5	3
	C-SB-C	9	0	0	0	0	0	0	6	0	5	7
	SB-C-SB	0	0	0	2	0	0	0	2	0	1	0
	A-A-A	0	0	0	0	0	0	0	0	0	0	11
4	C/R	1	0	1	0	0	0	0	0	4	2	8
	C/B	19	2	0	0	0	0	0	15	15	7	41
	C/R-SB/R-C/R	1	0	0	1	0	0	0	18	0	8	11
	SB/R-C/R-SB/R	46	2	0	0	0	0	0	11	27	34	64
	C-C-C	34	11	0	1	0	0	0	45	76	65	121
	C-SB-C	0	0	0	0	0	0	0	16	15	26	43
	SB-C-SB	59	13	0	0	0	0	0	10	17	14	28
	A-A-A	0	0	0	0	0	0	0	0	0	0	0

Table 25: Continued.

Precipitation in mm		67.82	55.52	65	44.66	5.8	7.4	11.13			
Replication	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06	Means	Max	Min
	Rotation										
1	C/R	116	203	203	203	84	47	10	73	203	0
	C/B	1	2	2	2	0	1	0	2	7	0
	C/R-SB/R-C/R	154	203	203	203	87	17	5	70	203	0
	SB/R-C/R-SB/R	38	84	66	71	30	15	5	24	184	0
	C-C-C	25	58	33	33	11	3	2	14	140	0
	C-SB-C	12	22	15	12	8	5	4	13	41	0
	SB-C-SB	75	194	104	87	25	17	9	41	194	0
	A-A-A	39	113	73	73	29	18	8	22	113	0
2	C/R	44	85	57	61	37	20	9	24	85	0
	C/B	37	69	46	44	22	16	9	24	69	0
	C/R-SB/R-C/R	28	59	39	35	11	5	3	19	79	0
	SB/R-C/R-SB/R	39	82	56	64	19	14	9	24	107	0
	C-C-C	43	102	61	49	31	16	9	30	124	0
	C-SB-C	67	135	93	97	69	43	26	55	135	0
	SB-C-SB	17	41	24	26	10	6	4	21	103	0
	A-A-A										

Table 25: Continued.

Precipitation in mm		67.82	55.52	65	44.66	5.8	7.4	11.13			
Replication	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06	Means	Max	Min
3	C/R	39	91	67	91	27	6	3	23	91	0
	C/B										
	C/R-SB/R-C/R	1	6	10	5	2	0	0	3	28	0
	SB/R-C/R-SB/R	59	143	108	95	42	21	10	41	143	0
	C-C-C	3	10	14	13	9	6	4	9	31	0
	C-SB-C	5	29	18	15	5	2	1	7	29	0
	SB-C-SB	5	2	16	2	0	0	0	3	18	0
	A-A-A	29	127	3	108	53	26	7	32	197	0
4	C/R	22	32	22	19	13	8	3	16	82	0
	C/B	45	109	84	93	34	15	7	27	109	0
	C/R-SB/R-C/R	15	37	29	23	7	2	2	11	47	0
	SB/R-C/R-SB/R	80	129	97	105	44	23	6	40	129	0
	C-C-C	107	203	161	170	110	71	46	83	203	0
	C-SB-C	33	81	62	64	35	12	4	21	81	0
	SB-C-SB	23	58	53	61	33	22	7	40	142	0
	A-A-A	20	92	49	44	22	15	7	18	92	0

Table 25: Continued.

Precipitation in mm				2994	1659	931	1111	347	404	548	585
Replication	Date	SD††	CV‡‡	Total	2004-05§§	2005-06§§	GS## 04	GS## 05	NGS¶¶ 03-04	NGS¶¶ 04-05	NGS¶¶ 05-06
	Rotation										
1	C/R	69	95	4082	2023	1126	757	124	932	1267	1002
	C/B	2	113	109	75	32	34	22	2	41	11
	C/R-SB/R-C/R	68	98	4124	2027	1199	630	77	898	1397	1122
	SB/R-C/R-SB/R	32	131	1369	449	613	211	194	308	237	419
	C-C-C	22	156	782	465	292	81	43	26	384	249
	C-SB-C	10	74	718	383	182	211	84	152	173	99
	SB-C-SB	38	93	2309	1037	889	324	164	383	713	725
	A-A-A	26	116	1225	541	378	201	17	306	340	362
2	C/R	21	91	1162	661	478	215	63	23	446	415
	C/B	17	71	1332	669	394	269	60	269	400	334
	C/R-SB/R-C/R	18	96	1002	564	281	309	23	156	256	258
	SB/R-C/R-SB/R	24	101	1372	600	423	266	33	350	334	390
	C-C-C	25	81	1728	864	519	496	103	345	368	416
	C-SB-C	38	70	3053	1576	844	668	149	633	908	695
	SB-C-SB	22	102	1197	572	253	264	92	373	307	161
	A-A-A										

Table 25: Continued.

Precipitation in mm				2994	1659	931	1111	347	404	548	585
Replication	Date	SD††	CV‡‡	Total	2004-05§§	2005-06§§	GS## 04	GS## 05	NGS¶¶ 03-04	NGS¶¶ 04-05	NGS¶¶ 05-06
3	C/R	25	107	1384	609	511	274	71	263	335	440
	C/B										
	C/R-SB/R-C/R	5	168	191	107	39	30	15	45	76	25
	SB/R-C/R-SB/R	38	93	2432	1096	798	413	145	537	683	653
	C-C-C	7	80	537	274	117	146	50	146	129	67
	C-SB-C	7	111	369	131	108	78	15	130	53	93
	SB-C-SB	4	150	170	56	40	14	11	74	41	29
	A-A-A	42	128	1911	746	471	257	107	694	489	364
4	C/R	17	107	1006	590	188	310	55	227	280	133
	C/B	30	114	1643	781	605	219	141	257	561	464
	C/R-SB/R-C/R	11	103	688	386	175	223	23	127	163	152
	SB/R-C/R-SB/R	38	94	2421	1139	777	449	155	505	690	621
	C-C-C	58	70	4983	2554	1556	1081	380	873	1473	1176
	C-SB-C	21	99	1272	651	439	323	48	181	329	391
	SB-C-SB	33	83	2465	1322	532	591	206	611	731	327
	A-A-A	21	120	1078	463	295	188	46	321	274	249

Table 26: Calibrated drainage (mm) collected between the day indicated and the previous date (to the left). The precipitation for the sampling period is above the day indicated. There are four replications and eight rotations: corn/rye (C/R), corn/barley (C/B), corn/rye-soybean/rye-corn/rye (C/R-SB/R-C/R), soybean/rye-corn/rye-soybean/rye (SB/R-C/R-SB/R), corn-corn-corn (C-C-C), corn-soybean-corn (C-SB-C), soybean-corn-soybean (SB-C-SB), and alfalfa (A-A-A). The symbols †, ‡, §, ¶, and # indicate new lysimeter installed on previous measurement date, ice in container, collection container tipped due to high water table or soil/mud, values lost due to floods in summer 2004, wicks and hose destroyed by rats/mice, respectively. The symbols ††, ‡‡, §§, ¶¶, and ## indicate standard deviation, coefficient of variation, March-April, growing season, and non-growing season. There were no lysimeters installed in A-A-A of replication 2 and C/B of replication 3.

Replication	Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04
	Rotation											
1	C/R	29	54	76	60	26	8	6	§	39	50	45
	C/B	0	†	0	0	0	0	0	27	0	0	79
	C/R-SB/R-C/R	27	41	58	79	22	10	2	20	52	39	30
	SB/R-C/R-SB/R	47	97	232	135	47	3	15	§	36	82	73
	C-C-C	6	7	10	8	2	0	2	§	8	†	31
	C-SB-C	63	64	81	85	41	22	25	§	60	55	0
	SB-C-SB	18	29	53	44	25	7	8	§	43	50	31
	A-A-A	31	33	69	62	15	3	7	§	14	62	38
2	C/R							†	§	5	21	18
	C/B	43	53	66	79	33	23	6	§	19	46	46
	C/R-SB/R-C/R				62	86	22	0	§	26	103	77
	SB/R-C/R-SB/R	61	105	192	131	48	20	3	§	15	56	39
	C-C-C	56	60	72	103	40	20	19	§	83	62	48
	C-SB-C	51	58	69	82	36	17	6	§	23	43	40
	SB-C-SB	49	72	148	113	26	6	51	§	19	49	32
	A-A-A											

Table 26: Continued.

Replication	Date	13-Nov-03	26-Nov-03	11-Dec-03	27-Dec-03	8-Jan-04	21-Jan-04	4-Feb-04	20-Feb-04	5-Mar-04	19-Mar-04	2-Apr-04
3	C/R	26	37	77	86	20	7	6	5	23	48	35
	C/B											
	C/R-SB/R-C/R	9	7	186	66	6	0	6	0	0	16	19
	SB/R-C/R-SB/R	52	60	97	87	28	12	10	27	17	53	35
	C-C-C	135	104	209	212	70	‡	30	77	59	107	70
	C-SB-C	93	83	144	155	61	7	56	35	35	83	34
	SB-C-SB	101	66	211	270	95	‡	77	44	175	52	†
	A-A-A	94	92	141	202	53	‡	17	21	29	60	42
4	C/R	14	35	154	104	28	10	8	7	28	40	31
	C/B	32	19	56	65	16	5	2	0	2	14	15
	C/R-SB/R-C/R	33	68	80	107	23	2	13	0	4	41	35
	SB/R-C/R-SB/R	39	38	75	74	23	13	1	6	20	38	30
	C-C-C	63	54	69	89	42	12	17	7	19	41	41
	C-SB-C	30	46	71	83	16	2	6	0	5	22	16
	SB-C-SB	85	71	90	126	48	13	7	16	37	49	41
	A-A-A	79	75	165	168	56	‡	25	12	9	24	37

Table 26: Continued.

Replication	Date	16-Apr-04	28-Ap-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04
	Rotation											
1	C/R	37	26	14	5	13	¶	11	76	¶	¶	49
	C/B	48	62	0	0	33	¶	73	94	¶	¶	88
	C/R-SB/R-C/R	39	32	7	2	11	69	3	33	¶	¶	18
	SB/R-C/R-SB/R	111	49	22	15	16	¶	15	107	¶	¶	70
	C-C-C	0	5	4	3	3	¶	13	13	¶	¶	50
	C-SB-C	83	86	102	59	61	¶	62	95	¶	¶	99
	SB-C-SB	60	53	30	14	11	¶	11	0	¶	¶	24
	A-A-A	42	34	26	13	3	¶	11	13	¶	¶	6
2	C/R	23	18	18	16	13	¶	19	60	¶	¶	63
	C/B	48	36	27	23	30	¶	29	51	¶	¶	65
	C/R-SB/R-C/R	93	59	35	48	55	¶	23	152	¶	¶	38
	SB/R-C/R-SB/R	53	51	33	18	16	¶	19	117	¶	¶	106
	C-C-C	55	52	59	76	39	¶	27	184	¶	¶	79
	C-SB-C	50	44	53	32	28	¶	33	59	¶	¶	60
	SB-C-SB	15	43	44	22	9	¶	16	103	¶	¶	91
	A-A-A											

Table 26: Continued.

Replication	Date	16-Apr-04	28-Ap-04	13-May-04	27-May-04	9-Jun-04	24-Jun-04	7-Jul-04	22-Jul-04	5-Aug-04	16-Aug-04	1-Sep-04
3	C/R	52	38	19	4	14	96	8	15	¶	¶	24
	C/B											
	C/R-SB/R-C/R	23	24	19	4	4	40	0	21	¶	¶	29
	SB/R-C/R-SB/R	49	31	30	11	13	93	11	24	¶	¶	9
	C-C-C	99	91	118	80	49	193	69	43	¶	¶	82
	C-SB-C	50	45	30	0	12	92	20	85	¶	¶	69
	SB-C-SB	0	0	22	0	0	82	0	13	¶	¶	0
	A-A-A	21	22	23	6	0	22	7	16	¶	¶	40
4	C/R	33	29	29	13	18	121	17	43	43	36	49
	C/B	18	16	16	6	4	35	7	3	10	7	6
	C/R-SB/R-C/R	35	30	19	9	39	131	15	69	136	32	31
	SB/R-C/R-SB/R	31	32	27	6	7	76	9	16	¶	¶	19
	C-C-C	52	56	69	34	20	82	27	8	¶	¶	43
	C-SB-C	53	62	55	15	6	107	20	74	¶	¶	54
	SB-C-SB	20	51	71	30	20	105	19	6	38	27	20
	A-A-A	37	35	29	14	0	26	8	7	35	35	40

Table 26: Continued.

Replication	Date	16-Sep-04	30-Sep-04	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05
	Rotation											
1	C/R	6	¶	¶	23	27	22	76	42	35	68	4
	C/B	0	¶	¶	98	70	45	76	62	11	23	36
	C/R-SB/R-C/R	2	¶	59	30	27	23	76	49	42	79	0
	SB/R-C/R-SB/R	0	¶	¶	25	25	22	76	52	48	78	12
	C-C-C	12	¶	232	15	15	10	76	42	28	70	7
	C-SB-C	41	¶	¶	52	60	46	76	50	42	56	22
	SB-C-SB	2	¶	¶	32	32	24	76	53	43	74	12
	A-A-A	8	¶	¶	12	12	18	76	45	32	35	8
2	C/R	0	¶	¶	27	37	35	76	57	40	64	9
	C/B	14	¶	¶	46	43	36	76	53	51	61	25
	C/R-SB/R-C/R	14	¶	¶	40	37	30	76	55	43	54	5
	SB/R-C/R-SB/R	0	28	¶	26	32	28	76	56	47	86	25
	C-C-C	21	99	¶	26	39	36	76	51	42	70	24
	C-SB-C	8	¶	¶	35	48	44	76	56	56	62	13
	SB-C-SB	5	¶	¶	21	20	17	76	47	43	53	16
	A-A-A											

Table 26: Continued.

Replication	Date	16-Sep-04	30-Sep-04	14-Oct-04	28-Oct-04	11-Nov-04	24-Nov-04	9-Dec-04	22-Dec-04	7-Jan-05	20-Jan-05	4-Feb-05
3	C/R	0	44	¶	9	19	6	76	49	45	80	3
	C/B											
	C/R-SB/R-C/R	0	19	16	13	16	6	76	27	11	73	104
	SB/R-C/R-SB/R	0	34	20	13	20	19	76	57	41	91	18
	C-C-C	40	69	70	50	64	52	76	63	53	122	28
	C-SB-C	14	¶	¶	37	19	#	76	51	0	32	†
	SB-C-SB	0	95	25	0	0	38	76	33	32	199	0
	A-A-A	0	65	47	7	11	11	76	51	27	82	0
4	C/R	0	124	42	24	29	25	76	48	32	47	26
	C/B	0	38	28	12	18	15	76	52	25	62	20
	C/R-SB/R-C/R	7	57	23	39	26	18	76	48	33	42	26
	SB/R-C/R-SB/R	0	39	28	13	19	17	76	47	26	67	14
	C-C-C	12	66	60	41	48	38	76	60	50	71	33
	C-SB-C	0	38	33	17	32	28	76	60	39	80	9
	SB-C-SB	0	76	59	40	45	37	76	54	46	65	27
	A-A-A	0	56	39	15	18	19	76	54	46	53	22

Table 26: Continued.

Replication	Date	16-Feb-05	2-Mar-05	17-Mar-05	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05
	Rotation											
1	C/R	23	33	43	76	16	10	2	0	0	0	0
	C/B	0	35	36	82	94	61	0	0	0	0	21
	C/R-SB/R-C/R	9	30	43	79	18	2	1	1	0	0	0
	SB/R-C/R-SB/R	31	38	50	78	415	14	2	0	0	0	0
	C-C-C	19	28	43	55	25	8	4	0	2	0	1
	C-SB-C	22	42	41	53	133	29	21	3	13	9	9
	SB-C-SB	26	32	42	72	58	13	6	0	1	0	1
	A-A-A	16	26	49	§	4	12	1	0	0	0	0
2	C/R	20	44	43	59	2	24	6	0	1	0	0
	C/B	29	38	43	47	6	21	9	2	0	0	1
	C/R-SB/R-C/R	18	27	40	68	38	5	1	0	0	0	0
	SB/R-C/R-SB/R	12	33	64	116	4	14	3	0	0	0	0
	C-C-C	29	42	54	58	81	23	14	11	3	0	0
	C-SB-C	22	40	45	57	21	26	12	5	0	0	1
	SB-C-SB	31	26	37	53	57	11	5	0	3	0	8
	A-A-A											

Table 26: Continued.

Replication	Date	16-Feb-05	2-Mar-05	17-Mar-05	31-Mar-05	14-Apr-05	28-Apr-05	12-May-05	27-May-05	9-Jun-05	23-Jun-05	6-Jul-05
3	C/R	3	17	35	84	65	0	1	0	0	0	0
	C/B											
	C/R-SB/R-C/R	0	16	19	130	86	6	6	0	0	0	0
	SB/R-C/R-SB/R	22	38	57	94	88	11	2	0	0	0	0
	C-C-C	53	74	67	114	159	50	36	0	19	6	0
	C-SB-C	0	0	0	88	0	21	6	0	0	0	7
	SB-C-SB	30	19	28	126	104	0	19	0	0	0	0
	A-A-A	19	34	43	92	99	10	0	0	0	0	0
4	C/R	21	39	38	80	83	15	3	0	0	0	1
	C/B	9	30	32	83	87	11	1	0	0	0	0
	C/R-SB/R-C/R	15	31	31	66	50	10	2	0	0	0	0
	SB/R-C/R-SB/R	6	33	41	61	61	9	0	0	0	0	0
	C-C-C	31	54	56	76	96	35	15	8	2	1	1
	C-SB-C	0	20	51	67	64	11	0	0	0	0	0
	SB-C-SB	33	50	47	67	83	27	7	1	0	0	0
	A-A-A	28	34	47	73	74	14	1	0	0	0	0

Table 26: Continued.

Replication	Date	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
	Rotation											
1	C/R	17	2	0	0	0	0	0	0	4	8	38
	C/B	51	21	39	0	0	15	0	0	0	15	15
	C/R-SB/R-C/R	6	1	0	0	0	0	0	16	9	23	50
	SB/R-C/R-SB/R	5	0	0	0	0	0	0	25	0	120	102
	C-C-C	26	0	5	0	0	0	2	58	14	20	44
	C-SB-C	39	14	3	0	0	0	0	14	0	32	29
	SB-C-SB	36	4	0	0	0	0	0	44	16	46	49
	A-A-A	0	0	0	0	0	0	0	0	0	0	7
2	C/R	30	8	0	0	0	0	0	23	29	17	48
	C/B	32	9	0	0	0	0	0	19	24	33	47
	C/R-SB/R-C/R	0	0	0	0	0	0	0	62	12	34	45
	SB/R-C/R-SB/R	35	3	0	0	0	0	0	28	31	68	71
	C-C-C	15	6	2	0	0	0	0	34	27	42	56
	C-SB-C	23	2	0	0	0	0	0	12	20	26	43
	SB-C-SB	44	3	0	0	0	0	0	0	0	22	26
	A-A-A											

Table 26: Continued.

Replication	Date	22-Jul-05	4-Aug-05	19-Aug-05	1-Sep-05	14-Sep-05	30-Sep-05	12-Oct-05	28-Oct-05	10-Nov-05	23-Nov-05	7-Dec-05
3	C/R	25	0	0	0	0	0	0	39	19	34	55
	C/B											
	C/R-SB/R-C/R	0	0	0	0	0	0	0	0	0	0	0
	SB/R-C/R-SB/R	12	5	0	2	0	0	0	33	25	37	51
	C-C-C	34	33	0	0	0	9	0	0	0	31	21
	C-SB-C	51	0	0	0	0	0	0	35	0	26	40
	SB-C-SB	0	0	0	32	0	0	0	32	0	19	0
	A-A-A	0	0	0	0	0	0	0	0	0	0	11
4	C/R	1	0	1	0	0	0	0	0	7	4	15
	C/B	15	2	0	0	0	0	0	12	13	5	34
	C/R-SB/R-C/R	3	0	0	3	0	0	0	53	0	23	31
	SB/R-C/R-SB/R	30	1	0	0	0	0	0	7	17	22	42
	C-C-C	16	5	0	1	0	0	0	21	36	30	57
	C-SB-C	0	0	0	0	0	0	0	24	23	41	67
	SB-C-SB	52	12	0	0	0	0	0	9	15	12	25
	A-A-A	0	0	0	0	0	0	0	0	0	0	0

Table 26: Continued.

Replication	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06	Mean	Max	Min
	Rotation										
1	C/R	43	76	76	76	31	17	4	26	76	0
	C/B	18	35	33	24	0	12	0	27	98	0
	C/R-SB/R-C/R	60	79	79	79	34	7	2	26	79	0
	SB/R-C/R-SB/R	85	189	148	160	68	34	12	55	415	0
	C-C-C	42	97	56	54	18	6	4	22	232	0
	C-SB-C	37	70	48	38	25	16	12	41	133	0
	SB-C-SB	54	140	75	63	18	12	6	29	140	0
	A-A-A	38	109	71	71	29	18	8	21	109	0
2	C/R	50	97	65	70	42	23	10	26	97	0
	C/B	51	95	63	61	31	22	13	32	95	0
	C/R-SB/R-C/R	54	113	74	67	20	9	5	36	152	0
	SB/R-C/R-SB/R	69	147	101	115	34	24	16	43	192	0
	C-C-C	64	152	91	72	46	23	13	45	184	0
	C-SB-C	41	82	56	59	42	26	16	32	82	0
	SB-C-SB	24	59	34	38	14	8	5	30	148	0
	A-A-A										

Table 26: Continued.

Replication	Date	23-Dec-05	13-Jan-06	25-Jan-06	8-Feb-06	22-Feb-06	8-Mar-06	20-Mar-06	Mean	Max	Min
3	C/R	50	116	84	116	34	8	4	29	116	0
	C/B										
	C/R-SB/R-C/R	9	42	66	35	11	0	0	20	186	0
	SB/R-C/R-SB/R	49	118	89	78	34	17	8	33	118	0
	C-C-C	19	71	99	88	65	42	24	62	212	0
	C-SB-C	30	170	105	87	26	12	6	37	170	0
	SB-C-SB	73	28	237	36	0	6	0	42	270	0
	A-A-A	30	130	3	110	54	27	7	32	202	0
4	C/R	42	60	41	36	24	15	6	30	154	0
	C/B	37	89	69	76	28	12	6	21	89	0
	C/R-SB/R-C/R	44	109	85	66	20	7	5	32	136	0
	SB/R-C/R-SB/R	52	84	63	68	28	15	4	25	84	0
	C-C-C	51	96	76	80	52	34	22	39	96	0
	C-SB-C	51	126	97	99	54	19	6	32	126	0
	SB-C-SB	21	52	47	54	29	20	6	35	126	0
	A-A-A	38	176	94	85	42	28	13	33	176	0

Table 26: Continued.

Replication	Date	SD††	CV‡‡	TOTAL	2004-05§§	2005-06§§	GS¶¶ 04	GS¶¶ 05	NGS## 03-04	NGS## 04-05	NGS## 05-06
	Rotation										
1	C/R	25	95	1443	677	419	282	46	347	396	373
	C/B	31	116	1458	975	456	477	303	27	498	153
	C/R-SB/R-C/R	26	99	1535	716	468	246	30	351	470	438
	SB/R-C/R-SB/R	73	133	3010	935	1381	476	437	694	459	944
	C-C-C	36	161	1228	699	486	135	72	43	564	415
	C-SB-C	31	75	2262	1172	594	686	272	496	486	322
	SB-C-SB	27	94	1598	676	644	235	119	277	441	526
	A-A-A	24	117	1111	448	367	195	16	296	253	350
2	C/R	24	91	1255	682	547	247	72	26	435	475
	C/B	23	71	1746	839	539	368	82	368	471	457
	C/R-SB/R-C/R	35	97	1849	1008	540	593	44	300	415	496
	SB/R-C/R-SB/R	44	103	2398	1006	762	480	59	631	526	703
	C-C-C	37	82	2498	1211	773	739	154	514	472	620
	C-SB-C	23	70	1784	885	514	407	91	386	477	424
	SB-C-SB	31	104	1642	745	363	379	132	535	365	231
	A-A-A										

Table 26: Continued.

Replication	Date	SD††	CV‡‡	TOTAL	2004-05§§	2005-06§§	GS¶¶ 04	GS¶¶ 05	NGS## 03-04	NGS## 04-05	NGS## 05-06
3	C/R	31	108	1681	698	649	348	90	334	350	559
	C/B			0							
	C/R-SB/R-C/R	35	173	1189	632	260	202	97	297	430	163
	SB/R-C/R-SB/R	31	94	1936	831	661	341	120	444	490	541
	C-C-C	51	81	3624	1814	807	1003	346	1004	810	461
	C-SB-C	42	113	2053	678	624	450	86	751	228	538
	SB-C-SB	65	153	2417	741	585	211	155	1091	530	430
	A-A-A	43	131	1880	688	482	263	110	711	424	372
4	C/R	33	109	1815	1034	354	583	103	427	451	251
	C/B	24	115	1276	566	498	181	116	211	386	382
	C/R-SB/R-C/R	33	104	1924	1045	510	647	67	369	397	443
	SB/R-C/R-SB/R	24	94	1493	663	503	291	101	327	371	403
	C-C-C	27	71	2276	1129	734	510	179	412	619	555
	C-SB-C	32	101	1903	937	684	502	75	282	435	608
	SB-C-SB	29	84	2107	1095	471	523	182	541	572	289
	A-A-A	40	122	1985	809	564	360	88	613	449	475

Appendix E

Soil Water Content

Part 1 - Neutron Probe Calibration Information

This section describes the procedures used for the field and laboratory neutron probe calibrations. A comparison with the factory calibration equation, results, and decision are also described in this section.

Field Calibration

Site selection: Due to soil variability and slope, three calibration locations were chosen (Fig. 15). One access tube was installed in each of the three alleyways, and three to four soil cores (50.8 mm diameter and 1.22 m deep) were taken at approximately 0.7 m from the access tube so as not to affect neutron probe readings. The cores were taken at location 1 (between blocks 1 and 2), location 2 (between blocks 2 and 3), and location 3 (between blocks 3 and 4) (Fig. 15). The cores were used for gravimetric soil water and bulk density measurements.

Soil sample collection for water content and bulk density: The soil cores were collected on three dates: 24 September 2004, 9 June 2005, and 9 August 2005. The first date corresponded to a wet dataset, whereas the last two dates corresponded to points at various soil drying stages. After collection, the cores were transported to the SEREC laboratory. Intact soil samples were taken from each soil core at 0.18, 0.49, 0.79, 1.10, 1.40, and 1.70 m deep, corresponding to the depths of the neutron probe measurements. Sample length and diameter were measured to the mm using a ruler and used for volume calculations. Weights were measured wet and oven-dried (48 hours at 105 ^{o}C). In August

2005, several diameter measurements were taken per sample, whereas in September 2004 and June 2005 the sample diameters were assumed equal to the inner diameter of the core sampler (50.8 mm). Bulk density was determined by dividing the mass of the soil sample by its volume. Volumetric water content was determined by multiplying bulk density by gravimetric water content.

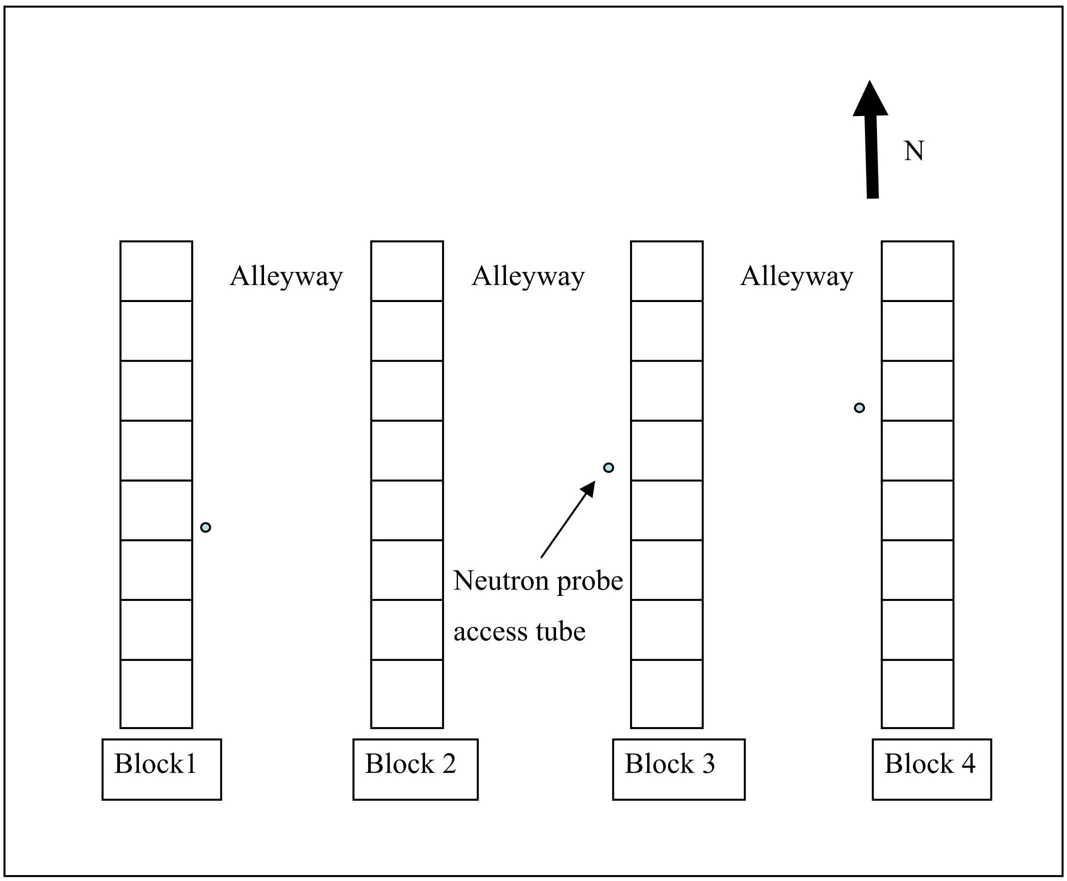

Fig. 15: Location of the access tubes and core sampling for the calibration of the neutron probe. The alleyways were grassed and 9 m wide.

Results: The bulk densities calculated using the field calibration data collected in September 2004 resulted in 90% negative air-filled porosities (Table 27). This describes soil samples with more water than total pore space and indicates errors probably caused by the assumption about sample radii. In June and August 2005 (Table 18 and Table 29 respectively), bulk density measurements showed only two extreme values in June (Table 18 location 1 cores 1 and 2) and none in August. In both cases, the lower water contents masked any potential problems as negative air-filled porosities were less likely and errors could have occurred.

Table 27: Gravimetric water content, bulk density (BD), total porosity, volumetric water content, and air-filled porosity for each soil sample at 6 depths and 3 locations in September 2004. Location 1 is between blocks 1 and 2, location 2 is between blocks 2 and 3, and location 3 is between blocks 3 and 4. Missing values are due to extremely dry soil or destroyed samples.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric $m^3 m^{-3}$	Air filled Porosity
1	1	0.18	0.335	1.47	0.444	0.493	-0.049
		0.49	0.494	1.15	0.566	0.567	-0.001
		0.79	0.332	1.62	0.387	0.539	-0.152
		1.10	0.349	1.61	0.394	0.560	-0.165
		1.40	0.322	1.58	0.405	0.507	-0.102
		1.70	0.327	1.76	0.337	0.575	-0.238
	2	0.18	0.340	1.36	0.488	0.461	0.027
		0.49	0.382	1.21	0.545	0.461	0.084
		0.79	0.334	1.54	0.418	0.515	-0.097
		1.10	0.339	1.54	0.418	0.523	-0.106
		1.40	0.339	1.47	0.445	0.498	-0.054
		1.70	0.320	1.67	0.370	0.534	-0.164
	3	0.18	0.407	1.33	0.499	0.540	-0.041
		0.49	0.315	1.53	0.424	0.481	-0.057
		0.79	0.308	1.72	0.349	0.530	-0.181
		1.10	0.291	1.64	0.383	0.476	-0.093
		1.40	0.310	2.12	0.201	0.656	-0.454
		1.70	0.266	2.26	0.149	0.600	-0.451

Table 27: Continued.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric m^3m^{-3}	Air filled Porosity
2	1	0.18	0.352	1.36	0.485	0.480	0.005
		0.49	0.280	1.74	0.343	0.487	-0.144
		0.79	0.265	1.76	0.336	0.467	-0.131
		1.10	0.248	1.76	0.337	0.435	-0.099
		1.40	0.261	1.58	0.405	0.412	-0.007
		1.70					
	2	0.18	0.259	1.95	0.263	0.506	-0.243
		0.49	0.234	2.06	0.222	0.482	-0.260
		0.79	0.259	2.12	0.201	0.548	-0.347
		1.10	0.231	2.16	0.184	0.499	-0.314
		1.40					
		1.70					
	3	0.18	0.236	1.88	0.289	0.444	-0.155
		0.49	0.295	1.72	0.351	0.508	-0.157
		0.79	0.255	2.01	0.241	0.512	-0.271
		1.10	0.276	1.84	0.304	0.509	-0.205
		1.40					
		1.70					
	4	0.18	0.242	1.90	0.282	0.460	-0.178
		0.49	0.255	2.03	0.233	0.518	-0.285
		0.79	0.238	1.69	0.363	0.401	-0.038
		1.10					
		1.40					
		1.70					

Table 27: Continued.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric m^{3}m^{-3}	Air filled Porosity
3	1	0.18	0.292	1.82	0.313	0.531	-0.218
		0.49	0.258	1.75	0.339	0.452	-0.113
		0.79	0.271	1.82	0.313	0.494	-0.181
		1.10	0.303	1.78	0.329	0.539	-0.209
		1.40	0.294	1.71	0.353	0.504	-0.151
		1.70	0.339	1.88	0.290	0.638	-0.348
	2	0.18	0.248	1.64	0.382	0.406	-0.025
		0.49	0.263	1.53	0.422	0.404	0.018
		0.79	0.281	1.69	0.361	0.477	-0.116
		1.10	0.286	1.71	0.355	0.489	-0.134
		1.40	0.242				
		1.70					
	3	0.18	0.247	1.77	0.333	0.437	-0.104
		0.49	0.243	2.03	0.233	0.495	-0.262
		0.79	0.288	1.85	0.303	0.532	-0.229
		1.10	0.281	1.87	0.295	0.525	-0.230
		1.40	0.255	1.45	0.454	0.368	0.086
		1.70	0.253	1.72	0.350	0.435	-0.085

Table 18: Gravimetric water content, bulk density (BD), total porosity, volumetric water content, and air-filled porosity for each soil sample at 6 depths and 3 locations in June 2005. Location 1 is between blocks 1 and 2, location 2 is between blocks 2 and 3, and location 3 is between blocks 3 and 4. Missing values are due to extremely dry soil or destroyed samples.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric $m^3 m^{-3}$	Air filled Porosity
1	1	0.18	0.230	1.08	0.591	0.249	0.342
		0.49	0.230	1.20	0.546	0.277	0.269
		0.79	0.244	1.24	0.532	0.302	0.230
		1.10	0.242	1.32	0.501	0.320	0.181
		1.40	0.207	1.38	0.480	0.285	0.194
		1.70	0.204	2.12	0.199	0.433	-0.234
	2	0.18	0.133	1.26	0.524	0.167	0.357
		0.49	0.116	1.28	0.517	0.148	0.369
		0.79	0.145				
		1.10	0.134	2.01	0.243	0.269	-0.026
		1.40	0.214				
		1.70	0.221				
	3	0.18	0.225	1.19	0.550	0.268	0.283
		0.49	0.220	1.09	0.589	0.239	0.349
		0.79	0.208	1.23	0.535	0.257	0.278
		1.10	0.230	1.39	0.474	0.321	0.153
		1.40	0.240	1.33	0.500	0.317	0.182
		1.70	0.231	1.23	0.537	0.283	0.254

Table 28: Continued.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric m^{3}m^{-3}	Air filled Porosity
2	1	0.18	0.134	1.22	0.541	0.163	0.379
		0.49	0.136	1.25	0.527	0.171	0.356
		0.79	0.172	1.38	0.479	0.237	0.242
		1.10	0.146	1.64	0.383	0.238	0.145
		1.40					
		1.70					
	2	0.18	0.156	1.26	0.524	0.197	0.328
		0.49	0.161	1.23	0.535	0.198	0.337
		0.79	0.130	1.13	0.573	0.148	0.425
		1.10	0.165				
		1.40					
		1.70					
	3	0.18	0.214	1.30	0.511	0.278	0.233
		0.49	0.205	1.12	0.578	0.229	0.348
		0.79	0.203	1.49	0.439	0.302	0.137
		1.10	0.201	1.42	0.465	0.285	0.180
		1.40					
		1.70					
3	1	0.18	0.157	1.64	0.381	0.257	0.124
		0.49	0.104	1.43	0.461	0.148	0.313
		0.79	0.120	1.72	0.351	0.207	0.144
		1.10	0.112	1.52	0.426	0.171	0.255
		1.40	0.178	1.53	0.422	0.273	0.148
		1.70					
	2	0.18	0.169	1.48	0.441	0.250	0.191
		0.49	0.124	1.31	0.505	0.163	0.342
		0.79	0.101	1.59	0.399	0.160	0.239
		1.10	0.149	1.58	0.404	0.236	0.168
		1.40					
		1.70					
	3	0.18	0.150	1.38	0.480	0.207	0.273
		0.49	0.104				
		0.79	0.129				
		1.10	0.175				
		1.40					
		1.70					

Table 29: Gravimetric water content, bulk density (BD), total porosity, volumetric water content, and air-filled porosity for each soil sample at 6 depths and 3 locations in August 2005. Location 1 is between blocks 1 and 2, location 2 is between blocks 2 and 3, and location 3 is between blocks 3 and 4. Missing values are due to extremely dry soil or destroyed samples.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric m^{3}m^{-3}	Air filled Porosity
1	1	0.18	0.185	1.33	0.496	0.247	0.249
		0.49	0.145	1.65	0.376	0.240	0.136
		0.79	0.176	1.70	0.359	0.299	0.060
		1.10	0.153	1.70	0.357	0.260	0.097
		1.40	0.174	1.48	0.442	0.257	0.185
		1.70					
	2	0.18	0.185	1.44	0.457	0.266	0.191
		0.49	0.182	1.50	0.434	0.272	0.161
		0.79	0.150	1.79	0.323	0.270	0.053
		1.10	0.169	1.71	0.355	0.289	0.067
		1.40	0.238	1.59	0.399	0.379	0.020
		1.70	0.173	1.61	0.392	0.278	0.114
	3	0.18	0.179	1.35	0.491	0.242	0.249
		0.49	0.174	1.30	0.510	0.225	0.285
		0.79	0.173	1.45	0.454	0.250	0.204
		1.10	0.231				
		1.40	0.200	1.46	0.449	0.292	0.157
		1.70	0.214	1.44	0.458	0.308	0.150
2	1	0.18	0.113	1.72	0.351	0.195	0.156
		0.49	0.145	1.67	0.368	0.243	0.125
		0.79	0.182				
		1.10	0.140	1.56	0.413	0.218	0.194
		1.40	0.042				
		1.70	0.118				
	2	0.18	0.105	1.55	0.414	0.163	0.251
		0.49	0.140	1.69	0.362	0.236	0.125
		0.79					
		1.10					
		1.40					
		1.70					
	3	0.18	0.142	1.60	0.397	0.227	0.170
		0.49	0.136	1.55	0.413	0.212	0.202
		0.79	0.144				
		1.10					
		1.40					
		1.70					

Table 29: Continued.

Location	Core	Depth m	Gravimetric kg water/kg dry soil	BD (Mg m^{-3})	Porosity	Volumetric m^{3}m^{-3}	Air filled Porosity
3	1	0.18	0.130	1.60	0.395	0.208	0.187
		0.49	0.116	1.56	0.411	0.181	0.230
		0.79	0.128	1.51	0.430	0.193	0.236
		1.10	0.116	1.74	0.342	0.203	0.139
		1.40	0.085	1.41	0.468	0.120	0.349
		1.70					
	2	0.18	0.129	1.56	0.411	0.201	0.211
		0.49	0.127	1.57	0.407	0.199	0.207
		0.79	0.165	1.45	0.453	0.239	0.214
		1.10	0.134	1.65	0.377	0.221	0.156
		1.40					
		1.70					
	3	0.18	0.133	1.58	0.402	0.211	0.191
		0.49	0.112	1.47	0.446	0.164	0.282
		0.79	0.136	1.52	0.425	0.208	0.217
		1.10	0.072	1.59	0.400	0.115	0.285
		1.40	0.149	1.61	0.391	0.240	0.151
		1.70					

If the September 2004 samples were saturated, their air-filled porosities should have been zero. Using a zero air-filled porosity, back calculations indicated that diameters needed to be between 48.6 and 61.3 mm instead of 50.8 mm. Since sample diameters were not measured in September and June, they were considered the biggest source of error in the field calibration on those two dates. In an effort to correct for the diameter error, the bulk densities measured in August where sampled diameters were measured were used for the September data but still produced 48% negative air-filled porosities (Table 30).

Table 30: Bulk densities (BD) measured in August 2005 used to calculate new porosities and volumetric water contents for September 2004. Missing values are due to extremely dry soil or destroyed samples.

Location	Core	Depth m	BD Mg m^{-3}	Porosity	Volumetric m^{3}m^{-3}	Air filled porosity
1	1	0.18	1.33	0.496	0.447	0.050
		0.49	1.65	0.376	0.817	-0.441
		0.79	1.70	0.359	0.563	-0.204
		1.10	1.70	0.357	0.594	-0.236
		1.40	1.48	0.442	0.476	-0.034
		1.70				
	2	0.18	1.44	0.457	0.489	-0.032
		0.49	1.50	0.434	0.573	-0.140
		0.79	1.79	0.323	0.599	-0.276
		1.10	1.71	0.355	0.579	-0.224
		1.40	1.59	0.399	0.539	-0.140
		1.70	1.61	0.392	0.515	-0.123
	3	0.18	1.35	0.491	0.548	-0.057
		0.49	1.30	0.510	0.409	0.101
		0.79	1.45	0.454	0.445	0.010
		1.10				
		1.40	1.46	0.449	0.452	-0.003
		1.70	1.44	0.458	0.382	0.076
2	1	0.18	1.72	0.351	0.605	-0.255
		0.49	1.67	0.368	0.468	-0.099
		0.79				
		1.10	1.56	0.413	0.385	0.027
		1.40				
		1.70				
	2	0.18	1.55	0.414	0.402	0.012
		0.49	1.69	0.362	0.396	-0.034
		0.79				
		1.10				
		1.40				
		1.70				
	3	0.18	1.60	0.397	0.376	0.021
		0.49	1.55	0.413	0.459	-0.045
		0.79				
		1.10				
		1.40				
		1.70				

Table 30: Continued.

Location	Core	Depth m	BD Mg m^{-3}	Porosity	Volumetric m^3m^{-3}	Air filled porosity
3	1	0.18	1.60	0.395	0.468	-0.073
		0.49	1.56	0.411	0.403	0.008
		0.79	1.51	0.430	0.410	0.020
		1.10	1.74	0.342	0.529	-0.187
		1.40	1.41	0.468	0.414	0.054
		1.70				
	2	0.18	1.56	0.411	0.387	0.024
		0.49	1.57	0.407	0.414	-0.008
		0.79	1.45	0.453	0.408	0.044
		1.10	1.65	0.377	0.472	-0.095
		1.40				
		1.70				
	3	0.18	1.58	0.402	0.392	0.010
		0.49	1.47	0.446	0.357	0.089
		0.79	1.52	0.425	0.439	-0.015
		1.10	1.59	0.400	0.447	-0.047
		1.40	1.61	0.391	0.411	-0.020
		1.70				

Using the average sample diameter (54 mm) measured in August 2005, 56% of the air-filled porosities were negative in September 2004. The mode of the diameters measured in August (57 mm) resulted in 18% negative air-filled porosities in September. With a diameter of 57 mm in September and June and the resulting bulk densities, the equation linking count ratio to calculated volumetric water content (Fig. 16) became

$$\theta v = 0.5376CR - 0.355 \qquad [1]$$

where θv is volumetric water content (m^3m^{-3}) and CR is count ratio (count divided by standard count).

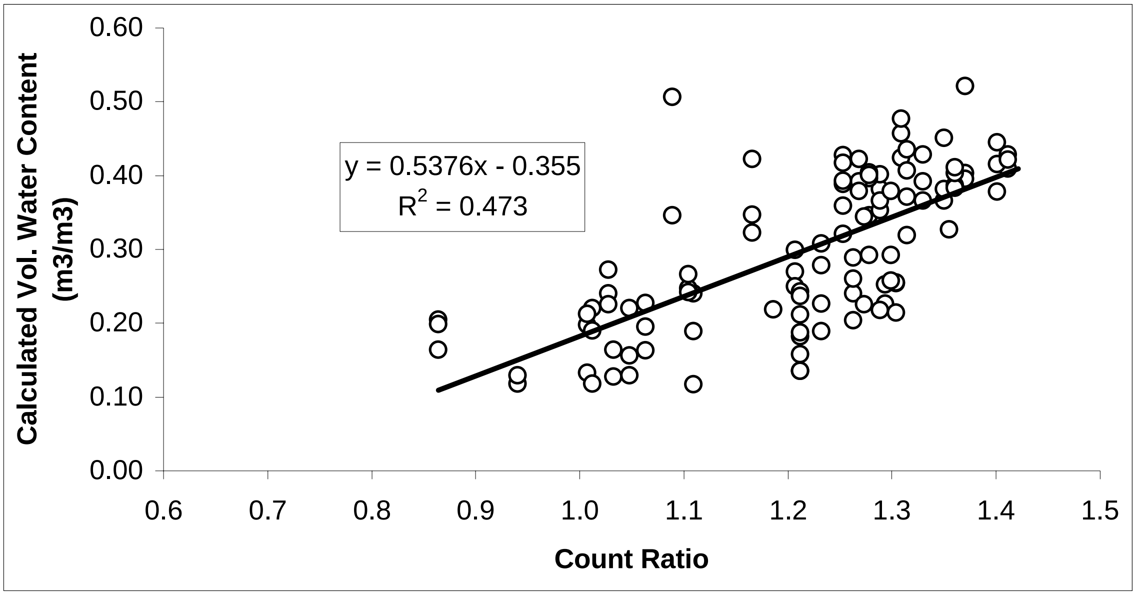

Fig. 16: Count ratio and calculated volumetric water contents of all field calibration data using adjusted diameters.

Factory Calibration

Using sand-filled containers, the neutron probe manufacturer determined calibration equations based on the type of metal used for the access tube. The following equation was the factory calibration linking volumetric water content to neutron probe count ratio for galvanized steel pipes

$$\theta v = 0.2933CR - 0.0132 \quad [2]$$

where θv is volumetric water content (m^3m^{-3}) and CR is count ratio.

Laboratory Calibration

Two 208-liter oil drums were filled with fine sand by uniformly compacting every layer around a central access tube. The steel access tube was 0.889 m tall and 38 mm in diameter and was placed in the center of the drums with a stopper on either side to prevent water from entering. Samples of sand were taken for initial water content, and one of the containers was saturated with water. Neutron probe readings were taken at 24 hour intervals until the values steadied.

The volume of sand in the calibration containers was 0.213 m^3. Corrected for the access tube, the volume of sand was 0.212 m^3. The sand weight was measured on the truck before and after unloading it into the containers. Total moist sand weight was 308 kg in each container. The gravimetric soil water measurements indicated an initial mean water content of 0.0383 kg water /kg soil which was used to calculate the mass of dry sand (296.7 kg per container) and bulk density (1.40 $Mg.m^{-3}$). Gravimetric water contents were converted to volumetric water content using bulk density. The relationship between neutron counts and calculated volumetric water contents is shown in Fig. 17.

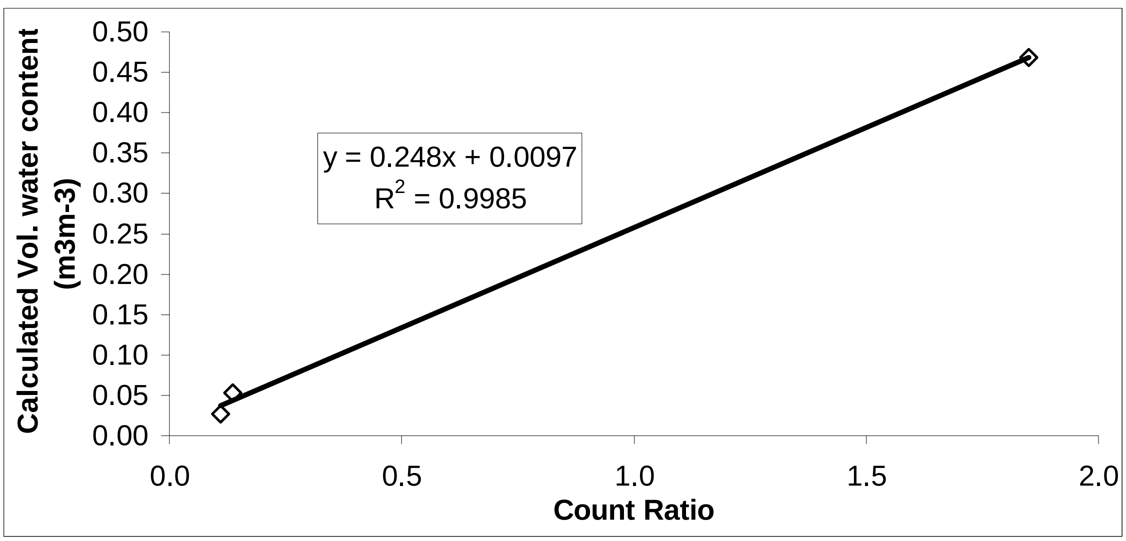

Fig. 17: Calculated volumetric water contents shown as a function of count ratio for the neutron probe in the laboratory.

The laboratory calibration equation generated by regression was

$$\theta v = 0.248CR + 0.0097 \quad [3]$$

where θv is volumetric water content (m^3m^{-3}) and CR is count ratio.

Discussion

Eq. [3] (the laboratory calibration) was closely related to the adjusted factory calibration (Eq. [2]) and to those described in Hignett and Evett (2002).

Fig. 18 shows predicted soil water contents using the field calibration equation (Eq. [1]) as a function of measured soil water content on all three dates. The measured data was used to determine the calibration equation, which in turn was used to calculate predicted water content from neutron probe counts. The relationship between them (dashed lines) was not a one-to-one relationship (full line), indicating that the neutron probe count ratios produced different water contents from the measured values (Fig. 18). Thus the field calibration equation does not rightly represent the neutron probe readings. The variation in soil texture between depths indicates that a separate equation for each texture is more appropriate than one equation for all depths.

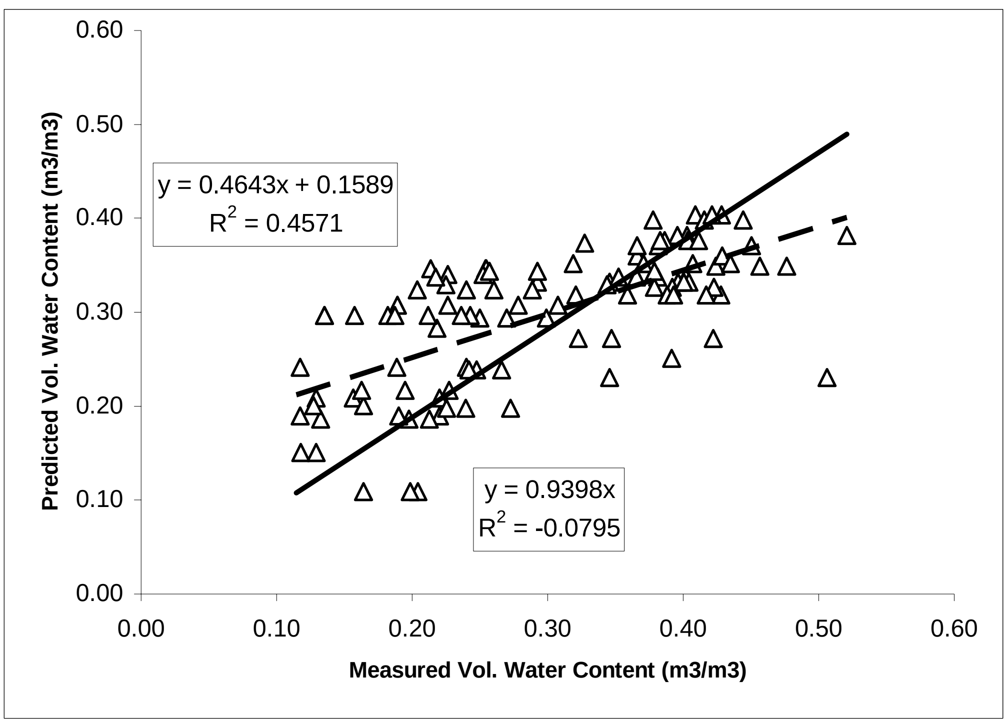

Fig. 18: Predicted soil water content using the field calibration equation as a function of measured soil water content in m^3m^{-3} on all three dates. The full line passes through zero and the dashed line is the best fit to the data.

Field calibration count ratios ranged between 0.86 and 1.42. Using the field calibration equation (Eq. [1]), the large slope (0.5376) and intercept (-0.355) caused negative volumetric soil water contents in dry conditions using actual field measurements (Table 31). A count ratio of 0.39 produced a water content of -0.145 and 0.106 $m^3.m^{-3}$ using the field and the sand calibration, respectively (Table 31). Using the field calibration, water content remained negative up to a count ratio of 0.67.

Table 31: Three selected dates illustrating the range in soil water contents calculated using the field and sand calibration equations.

Date	22-Sep-04	10-Aug-05	14-Sep-05
Days after rainfall	4 days after 101 mm	1 day after 6 mm	29 days after 14 mm
Count Ratio (CR)	0.39-1.49	0.46-1.39	0.50-1.37
Theta with sand calibration (m^3m^{-3})	0.106-0.379	0.124-0.354	0.134-0.349
Theta with field calibration (m^3m^{-3})	-0.145-0.446	-0.108-0.392	-0.086-0.382

Consequently, the field calibration equation cannot be used to calibrate the data where count ratios are lower than 0.67. We hypothesized that if we measured lower count ratios during the field calibration, both the slope and intercept of the equation would be smaller, thus eliminating negative volumetric water contents. This hypothesis was confirmed when we increased the range of count ratios to include an arbitrary data point with a low count ratio CR=0.39 and theta=0.087$m^3.m^{-3}$. The field calibration equation became $\theta v = 0.2404CR - 0.04118$ (R^2=0.3664) which is closely related to the sand (Eq. [3]) and factory calibration equations (Eq. [2]).

When the field calibration equation was forced through zero, the equation became $\theta v = 0.2489CR$ (R^2=0.335) which is also similar to the sand/factory calibration equations (Fig. 19).

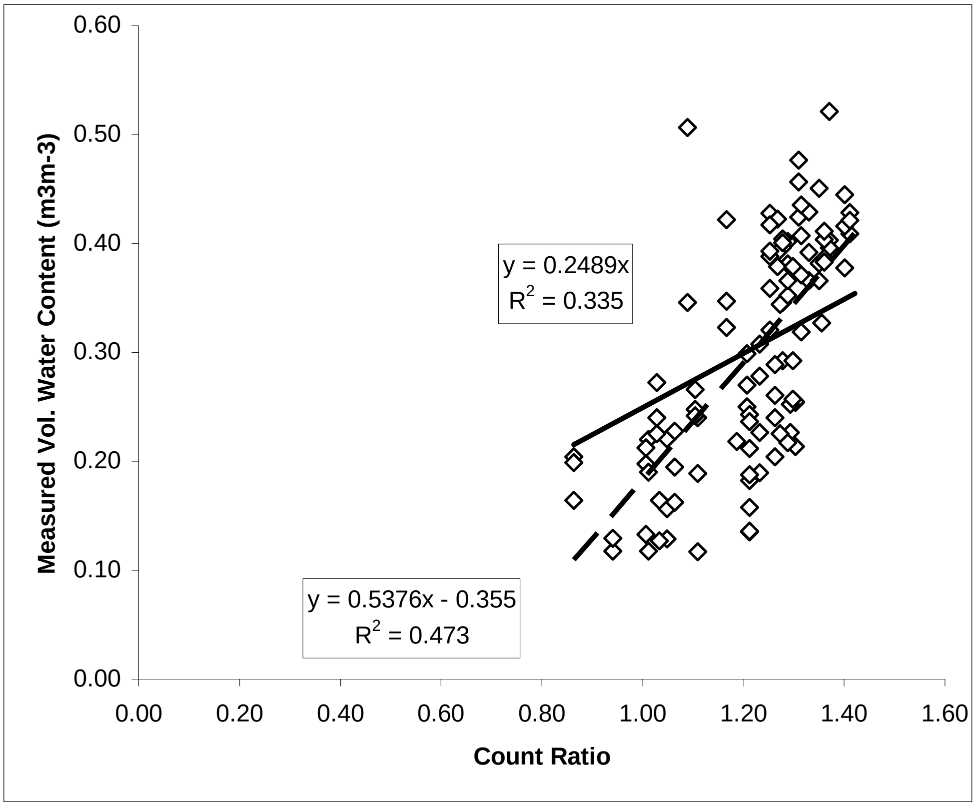

Fig. 19: Measured volumetric water contents as a function of count ratios. Regression lines are shown for the original equation and best fit (dashed line) and for the equation passing through zero (full line).

Soils containing non-water hydrogens and minerals that affect neutron thermalization produce a calibration equation with a lower slope than soils without such elements (Evett et al., 2002). Since the field soils contained more clays (non-water hydrogens) than the sand/factory soils used in the calibrations (for particle size data see Appendix F), the field calibration should have produced a lower slope than both the sand and factory equations. This further demonstrates errors in the field calibration.

Several errors in the field calibration caused Eq. [1] to have a high slope and intercept. Firstly, the gravimetric samples were taken 0.7 m away from the access tube used to measure neutron counts. One access tube was used to measure counts for several surrounding gravimetric locations. This distance was chosen in order not to influence the counts when taking cores around the access tube. However, the neutron counts were taken too far from the samples and were likely not representative due to extensive soil variability. According to Hignett and Evett (2002), soil samples need to be 0.10 m from the neutron count location (access tube). Secondly, the gravimetric samples were impacted by measurement procedures, namely sample length and diameter measurements. Diameter measurement errors caused erroneous bulk densities and negative air-filled porosities.

The field calibration equation was not used due to a high slope and intercept producing negative soil water contents in dry conditions. Adjusting this equation with low values from the data resulted in slopes and intercepts similar to those found in the sand and factory calibrations. Consequently, the decision was made to use the sand calibration equation (Eq. [3]) to analyze the soil water content data measured using the neutron probe.

Part 2 - Soil Water Content Data

Table 32: Volumetric soil water content data (m^3m^{-3}) measured at six depths (0.18, 0.49, 0.79, 1.10, 1.40 and 1.70 m) for eight rotations: four double cropped rotations (corn/rye, corn/barley, corn/rye-soybean/rye-corn/rye, and soybean/rye-corn/rye-soybean/rye), three single cropped rotations (corn-corn-corn, corn-soybean-corn, and soybean-corn-soybean), and a perennial rotation (alfalfa) over time.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
23-Oct-03	C/R	0.333	0.337	0.324	0.294	0.287	0.256
	C/B	0.330	0.345	0.328	0.329	0.289	0.283
	C/R-SB/R-C/R	0.342	0.352	0.336	0.281	0.269	0.288
	SB/R-C/R-SB/R	0.331	0.331	0.323	0.308	0.289	0.265
	C-C-C	0.333	0.338	0.327	0.310	0.291	0.283
	C-SB-C	0.337	0.345	0.332	0.309	0.259	0.285
	SB-C-SB	0.318	0.324	0.306	0.293	0.302	0.300
	A-A-A	0.317	0.320	0.321	0.322	0.299	0.315
30-Oct-03	C/R	0.340	0.339	0.332	0.298	0.297	0.269
	C/B	0.339	0.348	0.332	0.329	0.303	0.294
	C/R-SB/R-C/R	0.350	0.354	0.339	0.285	0.268	0.289
	SB/R-C/R-SB/R	0.339	0.337	0.322	0.313	0.294	0.276
	C-C-C	0.338	0.341	0.329	0.317	0.303	0.292
	C-SB-C	0.338	0.344	0.332	0.318	0.274	0.292
	SB-C-SB	0.324	0.326	0.307	0.298	0.306	0.299
	A-A-A	0.327	0.327	0.330	0.322	0.308	0.324
7-Nov-03	C/R	0.344	0.339	0.328	0.297	0.291	0.261
	C/B	0.340	0.346	0.333	0.326	0.293	0.285
	C/R-SB/R-C/R	0.351	0.354	0.339	0.287	0.268	0.287
	SB/R-C/R-SB/R	0.342	0.337	0.327	0.314	0.295	0.270
	C-C-C	0.343	0.342	0.325	0.316	0.298	0.282
	C-SB-C	0.346	0.344	0.334	0.310	0.264	0.286
	SB-C-SB	0.329	0.325	0.307	0.295	0.303	0.298
	A-A-A	0.332	0.322	0.327	0.323	0.302	0.316
15-Nov-03	C/R	0.335	0.338	0.331	0.291	0.288	0.260
	C/B	0.336	0.347	0.326	0.328	0.288	0.285
	C/R-SB/R-C/R	0.343	0.350	0.336	0.286	0.264	0.284
	SB/R-C/R-SB/R	0.333	0.336	0.320	0.309	0.290	0.269
	C-C-C	0.333	0.342	0.324	0.315	0.294	0.284
	C-SB-C	0.340	0.342	0.328	0.309	0.261	0.281
	SB-C-SB	0.324	0.320	0.304	0.299	0.299	0.290
	A-A-A	0.324	0.320	0.326	0.317	0.299	0.313

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
26-Nov-03	C/R	0.345	0.336	0.330	0.296	0.281	0.264
	C/B	0.344	0.345	0.330	0.332	0.296	0.285
	C/R-SB/R-C/R	0.350	0.352	0.337	0.284	0.269	0.289
	SB/R-C/R-SB/R	0.338	0.337	0.324	0.307	0.294	0.274
	C-C-C	0.342	0.342	0.328	0.317	0.296	0.289
	C-SB-C	0.344	0.348	0.336	0.312	0.267	0.288
	SB-C-SB	0.345	0.345	0.316	0.300	0.298	0.298
	A-A-A	0.331	0.325	0.329	0.325	0.304	0.318
4-Dec-03	C/R	0.340	0.344	0.330	0.299	0.291	0.263
	C/B	0.334	0.343	0.332	0.331	0.293	0.290
	C/R-SB/R-C/R	0.344	0.351	0.338	0.286	0.269	0.289
	SB/R-C/R-SB/R	0.330	0.337	0.327	0.310	0.293	0.273
	C-C-C	0.331	0.342	0.329	0.316	0.300	0.291
	C-SB-C	0.331	0.348	0.336	0.311	0.266	0.287
	SB-C-SB	0.334	0.338	0.317	0.302	0.305	0.297
	A-A-A	0.322	0.323	0.326	0.320	0.302	0.319
12-Dec-03	C/R	0.341	0.340	0.328	0.298	0.297	0.271
	C/B	0.343	0.345	0.333	0.333	0.300	0.291
	C/R-SB/R-C/R	0.350	0.352	0.336	0.283	0.273	0.291
	SB/R-C/R-SB/R	0.339	0.336	0.325	0.309	0.307	0.293
	C-C-C	0.339	0.340	0.330	0.314	0.306	0.292
	C-SB-C	0.343	0.344	0.333	0.313	0.278	0.294
	SB-C-SB	0.343	0.334	0.316	0.302	0.304	0.302
	A-A-A	0.335	0.324	0.332	0.322	0.309	0.323
20-Dec-03	C/R	0.331	0.334	0.326	0.295	0.288	0.267
	C/B	0.333	0.345	0.328	0.326	0.296	0.287
	C/R-SB/R-C/R	0.345	0.349	0.330	0.281	0.265	0.280
	SB/R-C/R-SB/R	0.330	0.329	0.318	0.303	0.300	0.284
	C-C-C	0.332	0.333	0.325	0.314	0.294	0.285
	C-SB-C	0.334	0.340	0.327	0.311	0.269	0.290
	SB-C-SB	0.331	0.336	0.313	0.303	0.298	0.294
	A-A-A	0.323	0.321	0.324	0.318	0.304	0.316
27-Dec-03	C/R	0.341	0.335	0.330	0.297	0.292	0.261
	C/B	0.337	0.346	0.329	0.331	0.295	0.284
	C/R-SB/R-C/R	0.347	0.353	0.341	0.284	0.268	0.288
	SB/R-C/R-SB/R	0.334	0.334	0.320	0.310	0.301	0.283
	C-C-C	0.337	0.341	0.322	0.317	0.296	0.288
	C-SB-C	0.339	0.342	0.327	0.311	0.269	0.286
	SB-C-SB	0.335	0.336	0.315	0.300	0.297	0.295
	A-A-A	0.327	0.323	0.330	0.321	0.302	0.316

Table 32: Continued.

Date	Rotation	---------- Depth (m) ---------- 0.18	0.49	0.79	1.10	1.40	1.70
1-Jan-04	C/R	0.338	0.336	0.326	0.296	0.287	0.259
	C/B	0.335	0.346	0.324	0.326	0.291	0.282
	C/R-SB/R-C/R	0.340	0.347	0.340	0.280	0.265	0.285
	SB/R-C/R-SB/R	0.329	0.332	0.315	0.299	0.297	0.280
	C-C-C	0.333	0.336	0.323	0.314	0.291	0.283
	C-SB-C	0.338	0.343	0.329	0.313	0.266	0.286
	SB-C-SB	0.336	0.336	0.313	0.302	0.296	0.293
	A-A-A	0.327	0.317	0.328	0.320	0.298	0.315
9-Jan-04	C/R	0.336	0.340	0.331	0.296	0.291	0.264
	C/B	0.332	0.348	0.331	0.334	0.298	0.287
	C/R-SB/R-C/R	0.341	0.355	0.340	0.291	0.267	0.288
	SB/R-C/R-SB/R	0.329	0.336	0.323	0.307	0.302	0.284
	C-C-C	0.331	0.342	0.329	0.320	0.296	0.291
	C-SB-C	0.341	0.343	0.331	0.314	0.270	0.286
	SB-C-SB	0.331	0.338	0.320	0.303	0.303	0.296
	A-A-A	0.320	0.324	0.330	0.323	0.301	0.320
15-Jan-04	C/R	0.318	0.335	0.324	0.296	0.286	0.261
	C/B	0.318	0.338	0.327	0.328	0.289	0.284
	C/R-SB/R-C/R	0.325	0.347	0.337	0.290	0.269	0.288
	SB/R-C/R-SB/R	0.316	0.332	0.319	0.306	0.304	0.282
	C-C-C	0.320	0.342	0.330	0.319	0.297	0.293
	C-SB-C	0.320	0.343	0.330	0.310	0.268	0.285
	SB-C-SB	0.315	0.334	0.317	0.301	0.298	0.292
	A-A-A	0.306	0.319	0.324	0.322	0.299	0.318
21-Jan-04	C/R	0.323	0.336	0.330	0.294	0.287	0.260
	C/B	0.326	0.340	0.327	0.332	0.292	0.286
	C/R-SB/R-C/R	0.328	0.345	0.338	0.287	0.266	0.290
	SB/R-C/R-SB/R	0.323	0.329	0.321	0.307	0.299	0.278
	C-C-C	0.324	0.337	0.328	0.316	0.298	0.287
	C-SB-C	0.325	0.338	0.329	0.310	0.260	0.288
	SB-C-SB	0.319	0.327	0.316	0.301	0.295	0.295
	A-A-A	0.312	0.315	0.328	0.325	0.304	0.316
31-Jan-04	C/R	0.330	0.326	0.319	0.288	0.280	0.250
	C/B	0.341	0.333	0.322	0.326	0.278	0.282
	C/R-SB/R-C/R	0.337	0.336	0.333	0.283	0.263	0.283
	SB/R-C/R-SB/R	0.332	0.321	0.314	0.300	0.295	0.276
	C-C-C	0.337	0.325	0.321	0.311	0.291	0.282
	C-SB-C	0.334	0.330	0.326	0.307	0.256	0.280
	SB-C-SB	0.325	0.319	0.306	0.298	0.291	0.286
	A-A-A	0.315	0.306	0.321	0.313	0.291	0.316

Table 32: Continued.

		---------------------------------- Depth (m) ----------------------------------					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
3-Mar-04	C/R	0.346	0.344	0.327	0.289	0.291	0.259
	C/B	0.339	0.341	0.330	0.327	0.285	0.281
	C/R-SB/R-C/R	0.345	0.352	0.336	0.282	0.273	0.290
	SB/R-C/R-SB/R	0.339	0.328	0.317	0.313	0.310	0.278
	C-C-C	0.340	0.341	0.332	0.317	0.302	0.308
	C-SB-C	0.344	0.345	0.333	0.311	0.265	0.287
	SB-C-SB	0.340	0.336	0.315	0.299	0.298	0.300
	A-A-A	0.340	0.327	0.327	0.323	0.298	0.318
11-Mar-04	C/R	0.343	0.337	0.327	0.296	0.290	0.261
	C/B	0.340	0.343	0.328	0.328	0.292	0.287
	C/R-SB/R-C/R	0.347	0.349	0.333	0.282	0.268	0.288
	SB/R-C/R-SB/R	0.335	0.331	0.320	0.308	0.309	0.284
	C-C-C	0.334	0.336	0.328	0.317	0.296	0.290
	C-SB-C	0.342	0.342	0.329	0.312	0.263	0.285
	SB-C-SB	0.334	0.334	0.315	0.303	0.298	0.300
	A-A-A	0.334	0.325	0.329	0.322	0.303	0.321
18-Mar-04	C/R	0.337	0.335	0.328	0.292	0.283	0.259
	C/B	0.334	0.343	0.325	0.327	0.286	0.281
	C/R-SB/R-C/R	0.352	0.350	0.335	0.282	0.267	0.290
	SB/R-C/R-SB/R	0.334	0.332	0.320	0.307	0.316	0.287
	C-C-C	0.333	0.334	0.328	0.320	0.298	0.288
	C-SB-C	0.343	0.337	0.327	0.309	0.264	0.285
	SB-C-SB	0.338	0.333	0.315	0.299	0.297	0.312
	A-A-A	0.333	0.323	0.326	0.323	0.300	0.317
24-Mar-04	C/R	0.332	0.339	0.330	0.294	0.287	0.261
	C/B	0.329	0.339	0.326	0.328	0.292	0.283
	C/R-SB/R-C/R	0.335	0.346	0.335	0.284	0.267	0.288
	SB/R-C/R-SB/R	0.324	0.330	0.319	0.309	0.310	0.280
	C-C-C	0.324	0.338	0.327	0.317	0.296	0.283
	C-SB-C	0.327	0.337	0.329	0.311	0.266	0.286
	SB-C-SB	0.326	0.330	0.317	0.296	0.298	0.294
	A-A-A	0.323	0.323	0.325	0.327	0.300	0.317
3-Apr-04	C/R	0.345	0.343	0.331	0.291	0.286	0.256
	C/B	0.340	0.345	0.330	0.328	0.289	0.286
	C/R-SB/R-C/R	0.349	0.355	0.337	0.285	0.268	0.284
	SB/R-C/R-SB/R	0.342	0.334	0.322	0.305	0.307	0.283
	C-C-C	0.342	0.343	0.325	0.315	0.296	0.292
	C-SB-C	0.346	0.347	0.331	0.309	0.263	0.288
	SB-C-SB	0.338	0.338	0.316	0.302	0.298	0.295
	A-A-A	0.340	0.325	0.330	0.322	0.299	0.318

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
7-Apr-04	C/R	0.337	0.344	0.333	0.294	0.288	0.259
	C/B	0.335	0.344	0.331	0.332	0.287	0.284
	C/R-SB/R-C/R	0.346	0.355	0.337	0.285	0.273	0.291
	SB/R-C/R-SB/R	0.331	0.331	0.320	0.311	0.311	0.283
	C-C-C	0.328	0.342	0.329	0.320	0.302	0.288
	C-SB-C	0.339	0.341	0.327	0.313	0.269	0.287
	SB-C-SB	0.333	0.335	0.317	0.303	0.298	0.300
	A-A-A	0.330	0.324	0.328	0.328	0.299	0.317
15-Apr-04	C/R	0.342	0.339	0.336	0.295	0.297	0.264
	C/B	0.340	0.348	0.334	0.332	0.296	0.290
	C/R-SB/R-C/R	0.345	0.354	0.336	0.283	0.269	0.287
	SB/R-C/R-SB/R	0.334	0.328	0.322	0.309	0.310	0.284
	C-C-C	0.338	0.340	0.328	0.313	0.304	0.289
	C-SB-C	0.345	0.342	0.333	0.311	0.272	0.289
	SB-C-SB	0.332	0.341	0.317	0.302	0.299	0.305
	A-A-A	0.336	0.325	0.332	0.324	0.302	0.319
22-Apr-04	C/R	0.314	0.337	0.331	0.298	0.288	0.259
	C/B	0.305	0.342	0.330	0.333	0.295	0.287
	C/R-SB/R-C/R	0.324	0.353	0.336	0.283	0.271	0.284
	SB/R-C/R-SB/R	0.310	0.327	0.319	0.310	0.309	0.283
	C-C-C	0.309	0.338	0.331	0.315	0.302	0.290
	C-SB-C	0.322	0.340	0.333	0.313	0.268	0.288
	SB-C-SB	0.316	0.333	0.317	0.298	0.298	0.301
	A-A-A	0.306	0.317	0.329	0.326	0.304	0.323
29-Apr-04	C/R	0.330	0.335	0.328	0.293	0.288	0.258
	C/B	0.324	0.339	0.328	0.329	0.287	0.284
	C/R-SB/R-C/R	0.337	0.350	0.331	0.282	0.268	0.282
	SB/R-C/R-SB/R	0.327	0.326	0.318	0.310	0.304	0.282
	C-C-C	0.326	0.338	0.325	0.314	0.296	0.288
	C-SB-C	0.335	0.340	0.328	0.313	0.272	0.290
	SB-C-SB	0.331	0.333	0.317	0.299	0.294	0.300
	A-A-A	0.327	0.322	0.325	0.325	0.301	0.315
6-May-04	C/R	0.328	0.333	0.328	0.294	0.287	0.265
	C/B	0.326	0.339	0.325	0.327	0.294	0.282
	C/R-SB/R-C/R	0.334	0.347	0.337	0.280	0.270	0.284
	SB/R-C/R-SB/R	0.320	0.324	0.318	0.304	0.304	0.279
	C-C-C	0.330	0.340	0.331	0.317	0.301	0.290
	C-SB-C	0.337	0.342	0.328	0.312	0.267	0.288
	SB-C-SB	0.333	0.336	0.313	0.304	0.296	0.304
	A-A-A	0.326	0.318	0.326	0.319	0.299	0.317

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
14-May-04	C/R	0.321	0.336	0.328	0.292	0.284	0.256
	C/B	0.312	0.339	0.324	0.323	0.284	0.280
	C/R-SB/R-C/R	0.324	0.348	0.333	0.283	0.269	0.284
	SB/R-C/R-SB/R	0.313	0.330	0.318	0.303	0.304	0.275
	C-C-C	0.311	0.336	0.330	0.315	0.297	0.289
	C-SB-C	0.324	0.342	0.328	0.310	0.264	0.286
	SB-C-SB	0.315	0.332	0.319	0.300	0.295	0.299
	A-A-A	0.309	0.319	0.321	0.317	0.294	0.319
20-May-04	C/R	0.340	0.338	0.325	0.289	0.285	0.271
	C/B	0.334	0.341	0.327	0.324	0.284	0.275
	C/R-SB/R-C/R	0.340	0.352	0.336	0.282	0.271	0.289
	SB/R-C/R-SB/R	0.325	0.333	0.317	0.307	0.308	0.279
	C-C-C	0.323	0.338	0.326	0.317	0.294	0.285
	C-SB-C	0.338	0.345	0.332	0.308	0.262	0.284
	SB-C-SB	0.335	0.342	0.319	0.305	0.295	0.302
	A-A-A	0.326	0.313	0.327	0.320	0.294	0.317
28-May-04	C/R	0.328	0.343	0.330	0.289	0.279	0.265
	C/B	0.324	0.343	0.324	0.327	0.285	0.274
	C/R-SB/R-C/R	0.332	0.348	0.334	0.281	0.266	0.284
	SB/R-C/R-SB/R	0.324	0.330	0.316	0.303	0.300	0.274
	C-C-C	0.312	0.337	0.326	0.311	0.296	0.286
	C-SB-C	0.331	0.339	0.330	0.310	0.257	0.285
	SB-C-SB	0.319	0.331	0.314	0.301	0.294	0.301
	A-A-A	0.307	0.305	0.321	0.320	0.292	0.321
2-Jun-04	C/R	0.323	0.335	0.325	0.290	0.280	0.260
	C/B	0.315	0.335	0.321	0.322	0.284	0.275
	C/R-SB/R-C/R	0.328	0.346	0.333	0.280	0.268	0.283
	SB/R-C/R-SB/R	0.317	0.326	0.315	0.305	0.302	0.277
	C-C-C	0.303	0.333	0.321	0.309	0.291	0.285
	C-SB-C	0.326	0.342	0.324	0.305	0.255	0.281
	SB-C-SB	0.312	0.323	0.311	0.298	0.293	0.291
	A-A-A	0.298	0.299	0.313	0.312	0.288	0.314
10-Jun-04	C/R	0.331	0.341	0.334	0.298	0.288	0.267
	C/B	0.326	0.346	0.327	0.333	0.290	0.281
	C/R-SB/R-C/R	0.342	0.354	0.338	0.285	0.270	0.290
	SB/R-C/R-SB/R	0.328	0.333	0.325	0.307	0.306	0.283
	C-C-C	0.317	0.338	0.325	0.319	0.294	0.288
	C-SB-C	0.338	0.345	0.331	0.313	0.262	0.289
	SB-C-SB	0.321	0.333	0.317	0.302	0.292	0.299
	A-A-A	0.327	0.309	0.315	0.317	0.291	0.318

Table 32: Continued.

		---------------------------------- Depth (m) ----------------------------------					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
18-Jun-04	C/R	0.343	0.344	0.335	0.301	0.293	0.285
	C/B	0.343	0.354	0.331	0.335	0.303	0.289
	C/R-SB/R-C/R	0.342	0.356	0.335	0.283	0.259	0.290
	SB/R-C/R-SB/R	0.336	0.334	0.321	0.310	0.309	0.287
	C-C-C	0.336	0.345	0.330	0.320	0.313	0.298
	C-SB-C	0.347	0.347	0.333	0.316	0.281	0.291
	SB-C-SB	0.337	0.339	0.314	0.303	0.300	0.306
	A-A-A	0.335	0.327	0.327	0.323	0.304	0.326
23-Jun-04	C/R	0.315	0.342	0.333	0.296	0.291	0.277
	C/B	0.309	0.345	0.329	0.328	0.296	0.288
	C/R-SB/R-C/R	0.329	0.354	0.332	0.283	0.263	0.285
	SB/R-C/R-SB/R	0.314	0.332	0.325	0.310	0.308	0.287
	C-C-C	0.306	0.338	0.332	0.321	0.301	0.291
	C-SB-C	0.333	0.346	0.332	0.315	0.270	0.291
	SB-C-SB	0.313	0.336	0.317	0.302	0.302	0.304
	A-A-A	0.319	0.319	0.329	0.325	0.298	0.325
1-Jul-04	C/R	0.266	0.324	0.326	0.287	0.284	0.268
	C/B	0.260	0.327	0.320	0.328	0.287	0.284
	C/R-SB/R-C/R	0.299	0.342	0.330	0.277	0.256	0.281
	SB/R-C/R-SB/R	0.270	0.312	0.313	0.306	0.305	0.275
	C-C-C	0.258	0.314	0.323	0.317	0.294	0.290
	C-SB-C	0.308	0.339	0.330	0.307	0.259	0.284
	SB-C-SB	0.268	0.307	0.312	0.298	0.292	0.299
	A-A-A	0.277	0.299	0.319	0.314	0.289	0.321
7-8 jul 2004	C/R	0.235	0.317	0.317	0.286	0.281	0.262
	C/B	0.228	0.310	0.312	0.320	0.284	0.275
	C/R-SB/R-C/R	0.282	0.332	0.333	0.277	0.258	0.279
	SB/R-C/R-SB/R	0.244	0.294	0.304	0.301	0.304	0.276
	C-C-C	0.227	0.285	0.309	0.316	0.293	0.282
	C-SB-C	0.289	0.331	0.325	0.304	0.254	0.283
	SB-C-SB	0.237	0.282	0.298	0.295	0.290	0.296
	A-A-A	0.252	0.279	0.304	0.312	0.287	0.318
13-Jul-04	C/R	0.333	0.326	0.319	0.293	0.294	0.286
	C/B	0.316	0.321	0.315	0.328	0.288	0.289
	C/R-SB/R-C/R	0.309	0.340	0.325	0.278	0.235	0.273
	SB/R-C/R-SB/R	0.318	0.312	0.325	0.332	0.312	0.289
	C-C-C	0.304	0.301	0.315	0.319	0.293	0.286
	C-SB-C	0.343	0.341	0.333	0.314	0.264	0.288
	SB-C-SB	0.323	0.331	0.321	0.306	0.301	0.294
	A-A-A	0.321	0.317	0.319	0.321	0.293	0.320

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
21-Jul-04	C/R	0.330	0.328	0.322	0.291	0.287	0.275
	C/B	0.322	0.334	0.319	0.326	0.285	0.287
	C/R-SB/R-C/R	0.304	0.333	0.327	0.273	0.250	0.271
	SB/R-C/R-SB/R	0.316	0.312	0.321	0.326	0.308	0.287
	C-C-C	0.315	0.311	0.312	0.312	0.287	0.284
	C-SB-C	0.335	0.339	0.324	0.312	0.266	0.285
	SB-C-SB	0.320	0.329	0.320	0.303	0.295	0.290
	A-A-A	0.324	0.318	0.322	0.322	0.298	0.316
12-Aug-04	C/R	0.311	0.325	0.329	0.292	0.288	0.295
	C/B	0.303	0.331	0.322	0.327	0.292	0.294
	C/R-SB/R-C/R	0.285	0.331	0.323	0.276	0.251	0.283
	SB/R-C/R-SB/R	0.297	0.312	0.324	0.329	0.312	0.288
	C-C-C	0.302	0.326	0.324	0.314	0.295	0.289
	C-SB-C	0.319	0.338	0.330	0.310	0.266	0.292
	SB-C-SB	0.297	0.324	0.325	0.308	0.300	0.303
	A-A-A	0.321	0.327	0.328	0.324	0.298	0.324
17-Aug-04	C/R	0.322	0.329	0.326	0.293	0.291	0.295
	C/B	0.321	0.336	0.324	0.331	0.293	0.290
	C/R-SB/R-C/R	0.289	0.330	0.324	0.273	0.247	0.280
	SB/R-C/R-SB/R	0.311	0.317	0.326	0.327	0.312	0.287
	C-C-C	0.315	0.329	0.326	0.315	0.293	0.286
	C-SB-C	0.330	0.348	0.327	0.312	0.264	0.285
	SB-C-SB	0.306	0.322	0.324	0.303	0.299	0.300
	A-A-A	0.322	0.331	0.324	0.324	0.300	0.322
26-Aug-04	C/R	0.320	0.328	0.328	0.294	0.292	0.295
	C/B	0.321	0.335	0.326	0.330	0.291	0.292
	C/R-SB/R-C/R	0.286	0.328	0.321	0.273	0.250	0.279
	SB/R-C/R-SB/R	0.311	0.318	0.328	0.326	0.312	0.290
	C-C-C	0.313	0.332	0.327	0.314	0.295	0.291
	C-SB-C	0.329	0.341	0.331	0.313	0.266	0.290
	SB-C-SB	0.305	0.324	0.324	0.309	0.300	0.304
	A-A-A	0.321	0.326	0.330	0.327	0.304	0.323
1-Sep-04	C/R	0.294	0.318	0.319	0.290	0.283	0.279
	C/B	0.291	0.324	0.320	0.323	0.286	0.286
	C/R-SB/R-C/R	0.262	0.316	0.321	0.272	0.243	0.276
	SB/R-C/R-SB/R	0.285	0.305	0.321	0.325	0.306	0.281
	C-C-C	0.291	0.319	0.316	0.314	0.291	0.287
	C-SB-C	0.300	0.328	0.324	0.308	0.259	0.281
	SB-C-SB	0.279	0.304	0.317	0.301	0.291	0.302
	A-A-A	0.292	0.311	0.319	0.322	0.296	0.316

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
10-Sep-04	C/R	0.286	0.316	0.312	0.283	0.285	0.279
	C/B	0.278	0.314	0.312	0.323	0.283	0.285
	C/R-SB/R-C/R	0.246	0.301	0.310	0.268	0.245	0.275
	SB/R-C/R-SB/R	0.276	0.300	0.320	0.323	0.305	0.285
	C-C-C	0.297	0.320	0.316	0.314	0.287	0.283
	C-SB-C	0.279	0.318	0.318	0.303	0.258	0.287
	SB-C-SB	0.281	0.308	0.320	0.300	0.293	0.299
	A-A-A	0.278	0.300	0.318	0.318	0.288	0.321
15-Sep-04	C/R	0.283	0.316	0.316	0.285	0.278	0.273
	C/B	0.275	0.314	0.307	0.319	0.277	0.285
	C/R-SB/R-C/R	0.236	0.294	0.305	0.265	0.244	0.293
	SB/R-C/R-SB/R	0.279	0.301	0.314	0.318	0.300	0.282
	C-C-C	0.295	0.319	0.315	0.314	0.286	0.283
	C-SB-C	0.269	0.310	0.313	0.299	0.253	0.281
	SB-C-SB	0.272	0.309	0.318	0.298	0.290	0.292
	A-A-A	0.269	0.296	0.309	0.316	0.290	0.314
22-Sep-04	C/R	0.330	0.334	0.319	0.292	0.289	0.286
	C/B	0.326	0.337	0.324	0.326	0.285	0.287
	C/R-SB/R-C/R	0.271	0.304	0.308	0.263	0.240	0.274
	SB/R-C/R-SB/R	0.315	0.323	0.330	0.328	0.311	0.287
	C-C-C	0.327	0.335	0.326	0.314	0.290	0.287
	C-SB-C	0.334	0.335	0.320	0.304	0.259	0.286
	SB-C-SB	0.312	0.326	0.329	0.302	0.298	0.303
	A-A-A	0.329	0.326	0.321	0.321	0.300	0.324
29-Sep-04	C/R	0.335	0.337	0.326	0.295	0.296	0.329
	C/B	0.329	0.342	0.324	0.329	0.300	0.303
	C/R-SB/R-C/R	0.279	0.299	0.318	0.260	0.248	0.291
	SB/R-C/R-SB/R	0.320	0.324	0.333	0.326	0.312	0.326
	C-C-C	0.330	0.340	0.330	0.319	0.303	0.317
	C-SB-C	0.343	0.341	0.328	0.311	0.277	0.307
	SB-C-SB	0.321	0.329	0.329	0.305	0.304	0.305
	A-A-A	0.338	0.329	0.328	0.327	0.304	0.339
6-Oct-04	C/R	0.330	0.333	0.326	0.294	0.284	0.286
	C/B	0.322	0.339	0.323	0.327	0.293	0.289
	C/R-SB/R-C/R	0.275	0.286	0.318	0.261	0.242	0.272
	SB/R-C/R-SB/R	0.310	0.323	0.327	0.328	0.314	0.285
	C-C-C	0.322	0.335	0.327	0.316	0.294	0.288
	C-SB-C	0.335	0.335	0.325	0.308	0.262	0.288
	SB-C-SB	0.309	0.325	0.328	0.307	0.298	0.305
	A-A-A	0.325	0.322	0.323	0.318	0.301	0.322

Table 32: Continued.

		---------------------------------- Depth (m) ----------------------------------					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
12-Oct-04	C/R	0.317	0.330	0.326	0.293	0.286	0.281
	C/B	0.311	0.335	0.325	0.322	0.290	0.289
	C/R-SB/R-C/R	0.271	0.289	0.317	0.264	0.245	0.269
	SB/R-C/R-SB/R	0.302	0.317	0.329	0.328	0.311	0.289
	C-C-C	0.312	0.335	0.327	0.315	0.293	0.288
	C-SB-C	0.334	0.341	0.328	0.305	0.258	0.285
	SB-C-SB	0.297	0.326	0.329	0.305	0.296	0.302
	A-A-A	0.313	0.318	0.319	0.317	0.292	0.320
20-Oct-04	C/R	0.339	0.334	0.326	0.290	0.282	0.276
	C/B	0.333	0.341	0.329	0.328	0.287	0.284
	C/R-SB/R-C/R	0.279	0.295	0.324	0.266	0.244	0.271
	SB/R-C/R-SB/R	0.323	0.326	0.330	0.328	0.307	0.286
	C-C-C	0.326	0.336	0.327	0.316	0.287	0.284
	C-SB-C	0.340	0.338	0.327	0.310	0.260	0.285
	SB-C-SB	0.318	0.331	0.329	0.310	0.296	0.298
	A-A-A	0.337	0.326	0.319	0.320	0.291	0.318
27-Oct-04	C/R	0.331	0.335	0.325	0.289	0.286	0.277
	C/B	0.330	0.344	0.327	0.324	0.289	0.283
	C/R-SB/R-C/R	0.280	0.290	0.317	0.262	0.244	0.269
	SB/R-C/R-SB/R	0.316	0.321	0.331	0.328	0.314	0.282
	C-C-C	0.328	0.335	0.322	0.313	0.289	0.282
	C-SB-C	0.342	0.342	0.321	0.309	0.263	0.288
	SB-C-SB	0.313	0.335	0.328	0.304	0.294	0.300
	A-A-A	0.330	0.325	0.320	0.318	0.290	0.318
3-Nov-04	C/R	0.335	0.334	0.327	0.288	0.286	0.279
	C/B	0.331	0.340	0.326	0.327	0.287	0.286
	C/R-SB/R-C/R	0.311	0.330	0.318	0.262	0.241	0.265
	SB/R-C/R-SB/R	0.313	0.321	0.332	0.328	0.307	0.282
	C-C-C	0.329	0.334	0.326	0.315	0.293	0.283
	C-SB-C	0.344	0.339	0.322	0.310	0.260	0.286
	SB-C-SB	0.312	0.327	0.330	0.310	0.298	0.302
	A-A-A	0.329	0.322	0.322	0.319	0.291	0.314
10-Nov-04	C/R	0.330	0.338	0.328	0.292	0.289	0.276
	C/B	0.333	0.343	0.330	0.330	0.292	0.288
	C/R-SB/R-C/R	0.318	0.338	0.322	0.266	0.247	0.273
	SB/R-C/R-SB/R	0.314	0.324	0.334	0.334	0.313	0.287
	C-C-C	0.325	0.342	0.327	0.325	0.296	0.289
	C-SB-C	0.343	0.343	0.328	0.313	0.265	0.290
	SB-C-SB	0.311	0.335	0.332	0.307	0.301	0.305
	A-A-A	0.337	0.327	0.324	0.326	0.295	0.320

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
17-Nov-04	C/R	0.336	0.334	0.328	0.296	0.285	0.278
	C/B	0.328	0.346	0.324	0.328	0.289	0.287
	C/R-SB/R-C/R	0.326	0.337	0.320	0.265	0.244	0.270
	SB/R-C/R-SB/R	0.314	0.319	0.331	0.330	0.309	0.288
	C-C-C	0.327	0.341	0.327	0.315	0.295	0.287
	C-SB-C	0.344	0.342	0.329	0.311	0.265	0.288
	SB-C-SB	0.313	0.327	0.329	0.311	0.301	0.304
	A-A-A	0.333	0.327	0.330	0.322	0.295	0.319
24-Nov-04	C/R	0.334	0.331	0.325	0.291	0.288	0.278
	C/B	0.334	0.342	0.322	0.330	0.285	0.286
	C/R-SB/R-C/R	0.326	0.335	0.316	0.260	0.242	0.286
	SB/R-C/R-SB/R	0.318	0.317	0.332	0.328	0.308	0.281
	C-C-C	0.331	0.334	0.326	0.316	0.289	0.284
	C-SB-C	0.344	0.340	0.325	0.312	0.259	0.283
	SB-C-SB	0.314	0.328	0.328	0.304	0.292	0.299
	A-A-A	0.335	0.324	0.323	0.323	0.296	0.314
2-Dec-04	C/R	0.340	0.336	0.328	0.296	0.294	0.291
	C/B	0.337	0.344	0.332	0.332	0.300	0.296
	C/R-SB/R-C/R	0.339	0.339	0.322	0.264	0.248	0.274
	SB/R-C/R-SB/R	0.320	0.325	0.337	0.327	0.316	0.302
	C-C-C	0.333	0.340	0.332	0.317	0.299	0.294
	C-SB-C	0.344	0.342	0.333	0.316	0.271	0.293
	SB-C-SB	0.316	0.336	0.335	0.309	0.306	0.307
	A-A-A	0.339	0.333	0.332	0.324	0.306	0.327
8-Dec-04	C/R	0.338	0.330	0.328	0.291	0.291	0.281
	C/B	0.336	0.341	0.326	0.332	0.289	0.289
	C/R-SB/R-C/R	0.339	0.338	0.320	0.264	0.242	0.268
	SB/R-C/R-SB/R	0.317	0.326	0.334	0.332	0.309	0.284
	C-C-C	0.335	0.337	0.329	0.314	0.290	0.286
	C-SB-C	0.346	0.344	0.326	0.314	0.265	0.288
	SB-C-SB	0.323	0.327	0.328	0.306	0.304	0.304
	A-A-A	0.336	0.333	0.324	0.322	0.298	0.318
15-Dec-04	C/R	0.332	0.339	0.328	0.294	0.291	0.285
	C/B	0.336	0.343	0.329	0.330	0.296	0.291
	C/R-SB/R-C/R	0.342	0.337	0.321	0.265	0.248	0.270
	SB/R-C/R-SB/R	0.317	0.330	0.330	0.332	0.313	0.287
	C-C-C	0.330	0.346	0.330	0.318	0.291	0.288
	C-SB-C	0.345	0.338	0.327	0.314	0.264	0.290
	SB-C-SB	0.324	0.333	0.332	0.312	0.301	0.305
	A-A-A	0.333	0.330	0.327	0.325	0.298	0.324

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
22-Dec-04	C/R	0.319	0.329	0.323	0.289	0.283	0.278
	C/B	0.321	0.334	0.320	0.323	0.291	0.288
	C/R-SB/R-C/R	0.323	0.329	0.318	0.260	0.240	0.270
	SB/R-C/R-SB/R	0.297	0.319	0.330	0.327	0.307	0.282
	C-C-C	0.319	0.335	0.322	0.314	0.293	0.284
	C-SB-C	0.325	0.336	0.323	0.310	0.261	0.284
	SB-C-SB	0.303	0.324	0.324	0.304	0.299	0.298
	A-A-A	0.320	0.323	0.324	0.320	0.294	0.320
29-Dec-04	C/R	0.317	0.330	0.325	0.291	0.284	0.278
	C/B	0.311	0.335	0.323	0.328	0.292	0.289
	C/R-SB/R-C/R	0.316	0.331	0.316	0.258	0.244	0.271
	SB/R-C/R-SB/R	0.304	0.322	0.327	0.323	0.305	0.281
	C-C-C	0.306	0.334	0.324	0.314	0.290	0.282
	C-SB-C	0.322	0.337	0.324	0.305	0.262	0.284
	SB-C-SB	0.295	0.323	0.320	0.302	0.294	0.301
	A-A-A	0.315	0.319	0.319	0.318	0.298	0.318
7-Jan-05	C/R	0.341	0.339	0.329	0.298	0.293	0.287
	C/B	0.341	0.343	0.331	0.334	0.302	0.294
	C/R-SB/R-C/R	0.341	0.340	0.321	0.266	0.247	0.280
	SB/R-C/R-SB/R	0.325	0.329	0.337	0.334	0.311	0.294
	C-C-C	0.336	0.339	0.332	0.321	0.301	0.287
	C-SB-C	0.340	0.344	0.333	0.316	0.272	0.288
	SB-C-SB	0.323	0.330	0.330	0.309	0.303	0.310
	A-A-A	0.341	0.334	0.331	0.327	0.304	0.326
13-Jan-05	C/R	0.341	0.339	0.332	0.299	0.291	0.284
	C/B	0.335	0.345	0.328	0.332	0.297	0.293
	C/R-SB/R-C/R	0.343	0.341	0.318	0.267	0.247	0.275
	SB/R-C/R-SB/R	0.325	0.330	0.342	0.332	0.315	0.292
	C-C-C	0.335	0.340	0.330	0.317	0.299	0.295
	C-SB-C	0.346	0.346	0.325	0.316	0.267	0.291
	SB-C-SB	0.319	0.333	0.330	0.309	0.301	0.307
	A-A-A	0.338	0.330	0.330	0.327	0.305	0.324
20-Jan-05	C/R	0.325	0.338	0.326	0.295	0.291	0.283
	C/B	0.316	0.339	0.330	0.327	0.298	0.291
	C/R-SB/R-C/R	0.322	0.337	0.316	0.264	0.244	0.270
	SB/R-C/R-SB/R	0.311	0.323	0.330	0.327	0.312	0.288
	C-C-C	0.314	0.337	0.328	0.316	0.293	0.287
	C-SB-C	0.330	0.335	0.326	0.311	0.264	0.288
	SB-C-SB	0.301	0.326	0.327	0.305	0.296	0.302
	A-A-A	0.319	0.328	0.326	0.322	0.298	0.317

Table 32: Continued.

Date	Rotation	---------------------------------- Depth (m)					----------------------------------
		0.18	0.49	0.79	1.10	1.40	1.70
26-Jan-05	C/R	0.317	0.330	0.327	0.293	0.287	0.277
	C/B	0.311	0.336	0.326	0.331	0.290	0.294
	C/R-SB/R-C/R	0.316	0.336	0.317	0.264	0.243	0.272
	SB/R-C/R-SB/R	0.300	0.326	0.331	0.326	0.307	0.282
	C-C-C	0.307	0.332	0.328	0.314	0.293	0.284
	C-SB-C	0.317	0.339	0.329	0.307	0.261	0.284
	SB-C-SB	0.296	0.325	0.330	0.307	0.295	0.298
	A-A-A	0.312	0.324	0.326	0.325	0.297	0.320
2-Feb-05	C/R	0.304	0.326	0.322	0.292	0.283	0.270
	C/B	0.305	0.334	0.315	0.322	0.286	0.285
	C/R-SB/R-C/R	0.305	0.324	0.317	0.264	0.237	0.270
	SB/R-C/R-SB/R	0.297	0.315	0.324	0.323	0.306	0.280
	C-C-C	0.300	0.325	0.324	0.313	0.289	0.278
	C-SB-C	0.311	0.331	0.321	0.306	0.254	0.278
	SB-C-SB	0.288	0.318	0.325	0.301	0.293	0.295
	A-A-A	0.298	0.312	0.324	0.319	0.294	0.319
10-Feb-05	C/R	0.341	0.338	0.330	0.291	0.287	0.279
	C/B	0.343	0.344	0.329	0.330	0.290	0.295
	C/R-SB/R-C/R	0.350	0.342	0.318	0.265	0.228	0.264
	SB/R-C/R-SB/R	0.330	0.329	0.335	0.327	0.309	0.287
	C-C-C	0.339	0.340	0.331	0.322	0.292	0.285
	C-SB-C	0.344	0.345	0.328	0.312	0.264	0.283
	SB-C-SB	0.326	0.335	0.335	0.308	0.304	0.301
	A-A-A	0.342	0.331	0.327	0.324	0.298	0.325
16-Feb-05	C/R	0.341	0.335	0.325	0.295	0.288	0.277
	C/B	0.334	0.337	0.327	0.331	0.291	0.288
	C/R-SB/R-C/R	0.338	0.337	0.317	0.264	0.245	0.275
	SB/R-C/R-SB/R	0.324	0.324	0.332	0.328	0.313	0.293
	C-C-C	0.335	0.333	0.331	0.315	0.297	0.286
	C-SB-C	0.340	0.343	0.324	0.310	0.264	0.288
	SB-C-SB	0.316	0.333	0.330	0.309	0.302	0.302
	A-A-A	0.335	0.333	0.324	0.320	0.298	0.321
23-Feb-05	C/R	0.339	0.336	0.327	0.296	0.288	0.278
	C/B	0.336	0.343	0.329	0.330	0.290	0.287
	C/R-SB/R-C/R	0.347	0.339	0.318	0.269	0.243	0.271
	SB/R-C/R-SB/R	0.323	0.329	0.333	0.329	0.309	0.286
	C-C-C	0.334	0.337	0.332	0.316	0.293	0.287
	C-SB-C	0.343	0.343	0.326	0.310	0.263	0.290
	SB-C-SB	0.318	0.334	0.330	0.312	0.298	0.302
	A-A-A	0.338	0.333	0.325	0.323	0.302	0.324

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
4-Mar-05	C/R	0.332	0.337	0.326	0.293	0.288	0.277
	C/B	0.334	0.340	0.327	0.332	0.291	0.288
	C/R-SB/R-C/R	0.339	0.337	0.320	0.264	0.243	0.271
	SB/R-C/R-SB/R	0.323	0.326	0.333	0.329	0.311	0.285
	C-C-C	0.328	0.337	0.329	0.318	0.292	0.287
	C-SB-C	0.337	0.343	0.325	0.314	0.264	0.285
	SB-C-SB	0.314	0.331	0.327	0.311	0.298	0.300
	A-A-A	0.336	0.332	0.331	0.326	0.300	0.322
10-Mar-05	C/R	0.337	0.336	0.329	0.297	0.294	0.280
	C/B	0.330	0.338	0.330	0.331	0.298	0.293
	C/R-SB/R-C/R	0.337	0.338	0.318	0.261	0.244	0.272
	SB/R-C/R-SB/R	0.320	0.325	0.335	0.330	0.309	0.286
	C-C-C	0.325	0.337	0.328	0.318	0.297	0.287
	C-SB-C	0.339	0.340	0.328	0.317	0.267	0.289
	SB-C-SB	0.310	0.332	0.329	0.309	0.305	0.304
	A-A-A	0.332	0.331	0.328	0.323	0.303	0.324
16-Mar-05	C/R	0.336	0.332	0.327	0.292	0.288	0.276
	C/B	0.328	0.333	0.328	0.322	0.294	0.288
	C/R-SB/R-C/R	0.334	0.335	0.319	0.265	0.241	0.268
	SB/R-C/R-SB/R	0.315	0.322	0.330	0.325	0.307	0.287
	C-C-C	0.325	0.334	0.330	0.318	0.294	0.284
	C-SB-C	0.335	0.337	0.326	0.309	0.258	0.288
	SB-C-SB	0.307	0.328	0.328	0.307	0.298	0.298
	A-A-A	0.325	0.326	0.325	0.320	0.297	0.319
22-Mar-05	C/R	0.328	0.337	0.329	0.291	0.290	0.274
	C/B	0.324	0.339	0.326	0.329	0.290	0.287
	C/R-SB/R-C/R	0.333	0.336	0.318	0.264	0.241	0.267
	SB/R-C/R-SB/R	0.316	0.322	0.331	0.325	0.311	0.285
	C-C-C	0.321	0.337	0.324	0.318	0.290	0.284
	C-SB-C	0.335	0.338	0.324	0.312	0.260	0.287
	SB-C-SB	0.304	0.327	0.330	0.309	0.298	0.304
	A-A-A	0.327	0.325	0.330	0.322	0.297	0.324
30-Mar-05	C/R	0.341	0.337	0.330	0.296	0.294	0.287
	C/B	0.333	0.342	0.330	0.329	0.301	0.295
	C/R-SB/R-C/R	0.345	0.340	0.320	0.265	0.246	0.273
	SB/R-C/R-SB/R	0.325	0.328	0.337	0.328	0.311	0.289
	C-C-C	0.333	0.337	0.329	0.317	0.304	0.290
	C-SB-C	0.344	0.343	0.327	0.313	0.275	0.296
	SB-C-SB	0.318	0.332	0.329	0.313	0.301	0.305
	A-A-A	0.332	0.331	0.329	0.325	0.307	0.325

Table 32: Continued.

		---------------------------------- Depth (m) ----------------------------------					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
6-Apr-05	C/R	0.338	0.335	0.331	0.298	0.295	0.294
	C/B	0.335	0.346	0.329	0.329	0.301	0.312
	C/R-SB/R-C/R	0.341	0.340	0.319	0.266	0.249	0.315
	SB/R-C/R-SB/R	0.324	0.324	0.328	0.331	0.315	0.322
	C-C-C	0.338	0.339	0.332	0.322	0.309	0.298
	C-SB-C	0.343	0.344	0.332	0.313	0.268	0.314
	SB-C-SB	0.317	0.337	0.333	0.311	0.305	0.295
	A-A-A	0.338	0.331	0.329	0.324	0.307	0.301
13-Apr-05	C/R	0.316	0.335	0.327	0.292	0.289	0.277
	C/B	0.308	0.335	0.320	0.329	0.290	0.286
	C/R-SB/R-C/R	0.323	0.333	0.317	0.263	0.244	0.267
	SB/R-C/R-SB/R	0.304	0.320	0.330	0.325	0.309	0.286
	C-C-C	0.312	0.337	0.331	0.312	0.292	0.284
	C-SB-C	0.325	0.338	0.323	0.311	0.261	0.288
	SB-C-SB	0.302	0.328	0.329	0.304	0.298	0.299
	A-A-A	0.314	0.325	0.326	0.321	0.299	0.318
20-Apr-05	C/R	0.287	0.320	0.319	0.286	0.283	0.273
	C/B	0.277	0.329	0.319	0.324	0.287	0.284
	C/R-SB/R-C/R	0.298	0.324	0.318	0.258	0.242	0.270
	SB/R-C/R-SB/R	0.275	0.313	0.327	0.320	0.306	0.283
	C-C-C	0.294	0.331	0.325	0.314	0.288	0.280
	C-SB-C	0.310	0.336	0.326	0.309	0.258	0.282
	SB-C-SB	0.285	0.323	0.320	0.303	0.291	0.295
	A-A-A	0.281	0.308	0.323	0.316	0.292	0.316
27-Apr-05	C/R	0.308	0.328	0.321	0.313	0.278	0.295
	C/B	0.302	0.328	0.327	0.272	0.259	0.277
	C/R-SB/R-C/R	0.301	0.310	0.298	0.300	0.259	0.260
	SB/R-C/R-SB/R	0.280	0.313	0.329	0.322	0.286	0.273
	C-C-C	0.288	0.317	0.319	0.333	0.298	0.302
	C-SB-C	0.291	0.308	0.312	0.283	0.275	0.301
	SB-C-SB	0.282	0.318	0.324	0.301	0.296	0.287
	A-A-A	0.302	0.323	0.331	0.310	0.295	0.290
5-May-05	C/R	0.285	0.319	0.317	0.284	0.282	0.268
	C/B	0.284	0.320	0.314	0.325	0.283	0.287
	C/R-SB/R-C/R	0.290	0.310	0.310	0.258	0.240	0.270
	SB/R-C/R-SB/R	0.274	0.298	0.318	0.318	0.304	0.280
	C-C-C	0.303	0.325	0.321	0.318	0.284	0.283
	C-SB-C	0.320	0.333	0.323	0.308	0.258	0.283
	SB-C-SB	0.292	0.320	0.328	0.306	0.294	0.298
	A-A-A	0.284	0.297	0.312	0.315	0.290	0.317

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
11-May-05	C/R	0.270	0.307	0.309	0.276	0.281	0.268
	C/B	0.269	0.311	0.307	0.319	0.276	0.280
	C/R-SB/R-C/R	0.273	0.311	0.305	0.257	0.238	0.266
	SB/R-C/R-SB/R	0.264	0.295	0.314	0.315	0.302	0.277
	C-C-C	0.284	0.320	0.319	0.311	0.288	0.279
	C-SB-C	0.299	0.327	0.318	0.303	0.250	0.283
	SB-C-SB	0.280	0.316	0.321	0.298	0.288	0.295
	A-A-A	0.267	0.294	0.302	0.311	0.285	0.315
18-May-05	C/R	0.270	0.312	0.312	0.276	0.279	0.269
	C/B	0.267	0.314	0.305	0.318	0.277	0.279
	C/R-SB/R-C/R	0.276	0.307	0.307	0.261	0.238	0.266
	SB/R-C/R-SB/R	0.264	0.295	0.315	0.312	0.299	0.279
	C-C-C	0.272	0.318	0.316	0.308	0.283	0.278
	C-SB-C	0.295	0.326	0.318	0.303	0.251	0.280
	SB-C-SB	0.276	0.313	0.322	0.300	0.291	0.291
	A-A-A	0.265	0.286	0.303	0.310	0.282	0.309
26-May-05	C/R	0.272	0.311	0.310	0.275	0.274	0.261
	C/B	0.274	0.316	0.299	0.314	0.269	0.278
	C/R-SB/R-C/R	0.277	0.305	0.299	0.256	0.234	0.262
	SB/R-C/R-SB/R	0.265	0.297	0.314	0.309	0.298	0.276
	C-C-C	0.276	0.314	0.315	0.308	0.278	0.279
	C-SB-C	0.293	0.326	0.317	0.302	0.248	0.277
	SB-C-SB	0.274	0.311	0.319	0.298	0.290	0.292
	A-A-A	0.253	0.279	0.296	0.307	0.275	0.312
1-Jun-05	C/R	0.284	0.312	0.304	0.276	0.274	0.260
	C/B	0.279	0.317	0.302	0.317	0.270	0.276
	C/R-SB/R-C/R	0.286	0.307	0.302	0.257	0.234	0.263
	SB/R-C/R-SB/R	0.279	0.298	0.313	0.311	0.297	0.280
	C-C-C	0.284	0.316	0.316	0.312	0.278	0.278
	C-SB-C	0.302	0.326	0.315	0.298	0.247	0.279
	SB-C-SB	0.283	0.315	0.312	0.296	0.290	0.291
	A-A-A	0.249	0.268	0.288	0.303	0.274	0.313
8-Jun-05	C/R	0.301	0.312	0.307	0.275	0.271	0.260
	C/B	0.295	0.319	0.302	0.311	0.270	0.276
	C/R-SB/R-C/R	0.303	0.311	0.298	0.254	0.235	0.260
	SB/R-C/R-SB/R	0.294	0.299	0.311	0.308	0.294	0.276
	C-C-C	0.300	0.317	0.311	0.307	0.278	0.276
	C-SB-C	0.312	0.325	0.316	0.296	0.246	0.278
	SB-C-SB	0.294	0.312	0.313	0.296	0.290	0.289
	A-A-A	0.250	0.259	0.278	0.295	0.268	0.309

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
15-Jun-05	C/R	0.298	0.317	0.313	0.272	0.275	0.261
	C/B	0.286	0.315	0.300	0.312	0.268	0.275
	C/R-SB/R-C/R	0.299	0.313	0.301	0.253	0.233	0.262
	SB/R-C/R-SB/R	0.285	0.303	0.313	0.310	0.292	0.277
	C-C-C	0.291	0.315	0.316	0.307	0.276	0.278
	C-SB-C	0.304	0.327	0.316	0.293	0.246	0.278
	SB-C-SB	0.284	0.313	0.320	0.294	0.287	0.289
	A-A-A	0.246	0.258	0.275	0.294	0.268	0.309
22-Jun-05	C/R	0.281	0.317	0.308	0.273	0.272	0.257
	C/B	0.276	0.314	0.303	0.315	0.265	0.275
	C/R-SB/R-C/R	0.287	0.310	0.301	0.252	0.235	0.262
	SB/R-C/R-SB/R	0.278	0.301	0.310	0.307	0.291	0.274
	C-C-C	0.282	0.318	0.310	0.307	0.276	0.275
	C-SB-C	0.294	0.324	0.314	0.292	0.245	0.276
	SB-C-SB	0.269	0.315	0.313	0.295	0.285	0.289
	A-A-A	0.228	0.250	0.258	0.284	0.261	0.300
30-Jun-05	C/R	0.319	0.317	0.309	0.276	0.276	0.306
	C/B	0.296	0.315	0.301	0.311	0.265	0.272
	C/R-SB/R-C/R	0.322	0.323	0.300	0.253	0.239	0.281
	SB/R-C/R-SB/R	0.290	0.308	0.316	0.309	0.291	0.275
	C-C-C	0.299	0.313	0.309	0.307	0.274	0.277
	C-SB-C	0.324	0.326	0.317	0.293	0.246	0.278
	SB-C-SB	0.294	0.330	0.317	0.298	0.286	0.290
	A-A-A	0.275	0.250	0.240	0.271	0.259	0.300
6-Jul-05	C/R	0.301	0.315	0.308	0.275	0.272	0.262
	C/B	0.286	0.316	0.301	0.312	0.265	0.275
	C/R-SB/R-C/R	0.310	0.316	0.302	0.254	0.237	0.263
	SB/R-C/R-SB/R	0.286	0.302	0.318	0.309	0.288	0.274
	C-C-C	0.286	0.314	0.310	0.305	0.273	0.277
	C-SB-C	0.304	0.325	0.310	0.292	0.244	0.276
	SB-C-SB	0.287	0.324	0.316	0.293	0.282	0.287
	A-A-A	0.253	0.234	0.237	0.265	0.245	0.292
13-Jul-05	C/R	0.305	0.330	0.319	0.283	0.279	0.265
	C/B	0.302	0.331	0.314	0.318	0.273	0.277
	C/R-SB/R-C/R	0.315	0.327	0.310	0.260	0.243	0.264
	SB/R-C/R-SB/R	0.297	0.321	0.329	0.319	0.297	0.277
	C-C-C	0.304	0.331	0.321	0.313	0.282	0.276
	C-SB-C	0.315	0.334	0.319	0.305	0.253	0.278
	SB-C-SB	0.286	0.331	0.324	0.300	0.292	0.294
	A-A-A	0.304	0.261	0.241	0.259	0.240	0.286

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
20-Jul-05	C/R	0.303	0.325	0.318	0.281	0.277	0.261
	C/B	0.298	0.325	0.314	0.320	0.272	0.279
	C/R-SB/R-C/R	0.316	0.317	0.311	0.259	0.241	0.266
	SB/R-C/R-SB/R	0.300	0.316	0.327	0.317	0.302	0.278
	C-C-C	0.300	0.324	0.322	0.313	0.280	0.278
	C-SB-C	0.317	0.330	0.321	0.305	0.254	0.278
	SB-C-SB	0.295	0.328	0.322	0.298	0.290	0.292
	A-A-A	0.315	0.265	0.248	0.263	0.244	0.292
28-Jul-05	C/R	0.269	0.313	0.312	0.279	0.275	0.264
	C/B	0.256	0.309	0.304	0.319	0.266	0.276
	C/R-SB/R-C/R	0.278	0.307	0.309	0.255	0.238	0.265
	SB/R-C/R-SB/R	0.270	0.302	0.321	0.313	0.298	0.276
	C-C-C	0.269	0.307	0.309	0.310	0.276	0.281
	C-SB-C	0.279	0.318	0.313	0.303	0.249	0.277
	SB-C-SB	0.259	0.305	0.315	0.296	0.288	0.294
	A-A-A	0.274	0.252	0.241	0.263	0.240	0.287
3-Aug-05	C/R	0.243	0.299	0.306	0.279	0.277	0.260
	C/B	0.229	0.299	0.299	0.313	0.274	0.277
	C/R-SB/R-C/R	0.252	0.289	0.296	0.251	0.240	0.265
	SB/R-C/R-SB/R	0.243	0.291	0.305	0.310	0.297	0.278
	C-C-C	0.244	0.290	0.300	0.307	0.274	0.278
	C-SB-C	0.255	0.308	0.304	0.295	0.247	0.281
	SB-C-SB	0.234	0.293	0.306	0.294	0.286	0.290
	A-A-A	0.243	0.242	0.238	0.260	0.240	0.290
10-Aug-05	C/R	0.222	0.281	0.292	0.268	0.268	0.257
	C/B	0.205	0.274	0.283	0.308	0.262	0.275
	C/R-SB/R-C/R	0.226	0.272	0.282	0.246	0.231	0.262
	SB/R-C/R-SB/R	0.230	0.265	0.297	0.303	0.288	0.276
	C-C-C	0.223	0.268	0.286	0.296	0.271	0.271
	C-SB-C	0.234	0.288	0.294	0.280	0.236	0.271
	SB-C-SB	0.216	0.270	0.289	0.285	0.278	0.283
	A-A-A	0.221	0.229	0.226	0.250	0.232	0.277
18-Aug-05	C/R	0.217	0.269	0.279	0.267	0.269	0.256
	C/B	0.201	0.258	0.271	0.302	0.260	0.272
	C/R-SB/R-C/R	0.225	0.266	0.275	0.239	0.234	0.260
	SB/R-C/R-SB/R	0.229	0.248	0.283	0.293	0.286	0.272
	C-C-C	0.215	0.264	0.272	0.298	0.264	0.272
	C-SB-C	0.228	0.279	0.280	0.278	0.235	0.275
	SB-C-SB	0.207	0.260	0.272	0.277	0.280	0.284
	A-A-A	0.226	0.232	0.228	0.248	0.227	0.280

Table 32: Continued.

		---------- Depth (m) ----------					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
24-Aug-05	C/R	0.209	0.259	0.274	0.261	0.266	0.253
	C/B	0.192	0.253	0.265	0.298	0.256	0.268
	C/R-SB/R-C/R	0.217	0.254	0.265	0.237	0.227	0.260
	SB/R-C/R-SB/R	0.217	0.240	0.267	0.285	0.282	0.272
	C-C-C	0.209	0.258	0.265	0.292	0.265	0.270
	C-SB-C	0.221	0.272	0.274	0.274	0.232	0.274
	SB-C-SB	0.197	0.250	0.254	0.270	0.275	0.284
	A-A-A	0.218	0.229	0.227	0.243	0.227	0.276
1-Sep-05	C/R	0.203	0.252	0.261	0.256	0.258	0.253
	C/B	0.189	0.249	0.255	0.293	0.251	0.269
	C/R-SB/R-C/R	0.210	0.249	0.252	0.234	0.224	0.258
	SB/R-C/R-SB/R	0.208	0.227	0.248	0.274	0.269	0.271
	C-C-C	0.212	0.251	0.260	0.288	0.262	0.270
	C-SB-C	0.220	0.264	0.265	0.265	0.229	0.270
	SB-C-SB	0.189	0.239	0.235	0.264	0.268	0.276
	A-A-A	0.210	0.220	0.219	0.238	0.218	0.272
7-Sep-05	C/R	0.193	0.247	0.250	0.250	0.260	0.253
	C/B	0.188	0.244	0.244	0.282	0.250	0.264
	C/R-SB/R-C/R	0.205	0.241	0.246	0.224	0.220	0.257
	SB/R-C/R-SB/R	0.199	0.216	0.238	0.260	0.266	0.267
	C-C-C	0.212	0.251	0.259	0.286	0.259	0.272
	C-SB-C	0.219	0.266	0.266	0.265	0.227	0.268
	SB-C-SB	0.179	0.230	0.224	0.257	0.262	0.278
	A-A-A	0.196	0.213	0.213	0.222	0.213	0.265
14-Sep-05	C/R	0.195	0.249	0.255	0.246	0.254	0.249
	C/B	0.187	0.251	0.247	0.282	0.247	0.261
	C/R-SB/R-C/R	0.206	0.243	0.243	0.228	0.220	0.256
	SB/R-C/R-SB/R	0.198	0.213	0.228	0.251	0.261	0.271
	C-C-C	0.212	0.256	0.262	0.284	0.260	0.269
	C-SB-C	0.220	0.266	0.271	0.264	0.228	0.265
	SB-C-SB	0.176	0.226	0.223	0.250	0.259	0.273
	A-A-A	0.194	0.214	0.204	0.217	0.212	0.262
28-Sep-05	C/R	0.202	0.249	0.256	0.249	0.251	0.249
	C/B	0.193	0.247	0.247	0.281	0.240	0.258
	C/R-SB/R-C/R	0.208	0.249	0.246	0.226	0.221	0.254
	SB/R-C/R-SB/R	0.199	0.219	0.229	0.254	0.258	0.264
	C-C-C	0.214	0.259	0.263	0.282	0.252	0.271
	C-SB-C	0.223	0.265	0.270	0.263	0.227	0.266
	SB-C-SB	0.178	0.231	0.226	0.252	0.256	0.269
	A-A-A	0.192	0.203	0.198	0.208	0.204	0.251

Table 32: Continued.

		Depth (m)					
Date	Rotation	0.18	0.49	0.79	1.10	1.40	1.70
5-Oct-05	C/R	0.200	0.249	0.253	0.246	0.249	0.242
	C/B	0.186	0.247	0.248	0.278	0.235	0.255
	C/R-SB/R-C/R	0.206	0.250	0.247	0.228	0.220	0.253
	SB/R-C/R-SB/R	0.198	0.217	0.233	0.253	0.258	0.261
	C-C-C	0.217	0.259	0.262	0.281	0.250	0.267
	C-SB-C	0.220	0.267	0.268	0.262	0.224	0.265
	SB-C-SB	0.176	0.229	0.221	0.250	0.261	0.265
	A-A-A	0.180	0.200	0.192	0.200	0.192	0.243
12-Oct-05	C/R	0.327	0.325	0.305	0.257	0.253	0.252
	C/B	0.327	0.332	0.299	0.293	0.242	0.258
	C/R-SB/R-C/R	0.329	0.329	0.300	0.241	0.227	0.258
	SB/R-C/R-SB/R	0.320	0.322	0.292	0.267	0.264	0.273
	C-C-C	0.322	0.322	0.291	0.293	0.260	0.273
	C-SB-C	0.339	0.331	0.313	0.279	0.229	0.271
	SB-C-SB	0.324	0.344	0.294	0.266	0.260	0.272
	A-A-A	0.336	0.308	0.262	0.223	0.214	0.244
20-Oct-05	C/R	0.317	0.324	0.307	0.259	0.249	0.246
	C/B	0.311	0.330	0.306	0.298	0.244	0.256
	C/R-SB/R-C/R	0.317	0.327	0.305	0.244	0.226	0.256
	SB/R-C/R-SB/R	0.306	0.314	0.303	0.265	0.260	0.266
	C-C-C	0.309	0.325	0.301	0.295	0.259	0.269
	C-SB-C	0.323	0.333	0.313	0.283	0.227	0.264
	SB-C-SB	0.313	0.341	0.302	0.264	0.255	0.270
	A-A-A	0.315	0.300	0.258	0.219	0.205	0.241
26-Oct-05	C/R	0.330	0.333	0.321	0.284	0.276	0.252
	C/B	0.330	0.334	0.319	0.324	0.282	0.268
	C/R-SB/R-C/R	0.335	0.332	0.316	0.260	0.240	0.269
	SB/R-C/R-SB/R	0.321	0.323	0.330	0.314	0.271	0.272
	C-C-C	0.333	0.335	0.317	0.309	0.282	0.279
	C-SB-C	0.336	0.338	0.316	0.307	0.257	0.279
	SB-C-SB	0.324	0.351	0.324	0.295	0.289	0.288
	A-A-A	0.343	0.326	0.301	0.238	0.206	0.242
2-Nov-05	C/R	0.319	0.327	0.316	0.283	0.281	0.263
	C/B	0.318	0.329	0.314	0.318	0.279	0.270
	C/R-SB/R-C/R	0.320	0.327	0.312	0.256	0.241	0.261
	SB/R-C/R-SB/R	0.308	0.316	0.325	0.309	0.281	0.271
	C-C-C	0.317	0.328	0.315	0.307	0.281	0.278
	C-SB-C	0.324	0.334	0.320	0.302	0.250	0.283
	SB-C-SB	0.313	0.340	0.325	0.297	0.286	0.290
	A-A-A	0.323	0.310	0.300	0.252	0.206	0.239

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
23-Nov-05	C/R	0.335	0.332	0.319	0.289	0.279	0.266
	C/B	0.329	0.338	0.318	0.327	0.279	0.279
	C/R-SB/R-C/R	0.332	0.333	0.315	0.258	0.243	0.268
	SB/R-C/R-SB/R	0.316	0.325	0.325	0.316	0.302	0.283
	C-C-C	0.323	0.331	0.314	0.309	0.288	0.283
	C-SB-C	0.336	0.340	0.321	0.309	0.261	0.287
	SB-C-SB	0.324	0.345	0.325	0.305	0.299	0.304
	A-A-A	0.336	0.321	0.312	0.285	0.224	0.244
7-Dec-05	C/R	0.332	0.331	0.320	0.288	0.289	0.277
	C/B	0.325	0.335	0.320	0.323	0.285	0.283
	C/R-SB/R-C/R	0.335	0.331	0.315	0.259	0.244	0.269
	SB/R-C/R-SB/R	0.315	0.322	0.331	0.318	0.304	0.288
	C-C-C	0.325	0.329	0.320	0.313	0.284	0.281
	C-SB-C	0.336	0.341	0.318	0.307	0.259	0.289
	SB-C-SB	0.322	0.342	0.327	0.302	0.295	0.299
	A-A-A	0.336	0.324	0.316	0.314	0.263	0.264
23-Dec-05	C/R	0.325	0.328	0.318	0.286	0.290	0.277
	C/B	0.322	0.331	0.320	0.324	0.287	0.281
	C/R-SB/R-C/R	0.329	0.328	0.313	0.255	0.241	0.267
	SB/R-C/R-SB/R	0.308	0.316	0.327	0.318	0.306	0.284
	C-C-C	0.322	0.329	0.313	0.305	0.287	0.281
	C-SB-C	0.334	0.332	0.317	0.307	0.261	0.286
	SB-C-SB	0.314	0.342	0.324	0.299	0.294	0.299
	A-A-A	0.328	0.316	0.316	0.313	0.291	0.289
12-Jan-06	C/R	0.330	0.327	0.321	0.290	0.286	0.272
	C/B	0.328	0.334	0.315	0.322	0.292	0.284
	C/R-SB/R-C/R	0.338	0.328	0.312	0.257	0.242	0.269
	SB/R-C/R-SB/R	0.311	0.318	0.327	0.320	0.301	0.282
	C-C-C	0.325	0.333	0.318	0.310	0.284	0.283
	C-SB-C	0.337	0.333	0.318	0.306	0.255	0.282
	SB-C-SB	0.320	0.337	0.327	0.305	0.296	0.300
	A-A-A	0.342	0.318	0.316	0.315	0.295	0.301
27-Jan-06	C/R	0.332	0.331	0.318	0.288	0.284	0.283
	C/B	0.323	0.332	0.315	0.324	0.292	0.286
	C/R-SB/R-C/R	0.330	0.329	0.312	0.254	0.243	0.267
	SB/R-C/R-SB/R	0.310	0.318	0.327	0.318	0.306	0.287
	C-C-C	0.323	0.327	0.316	0.307	0.290	0.281
	C-SB-C	0.333	0.332	0.322	0.307	0.262	0.286
	SB-C-SB	0.316	0.337	0.324	0.302	0.297	0.299
	A-A-A	0.337	0.320	0.315	0.317	0.300	0.300

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
22-Feb-06	C/R	0.328	0.329	0.323	0.288	0.290	0.279
	C/B	0.321	0.331	0.319	0.324	0.293	0.283
	C/R-SB/R-C/R	0.330	0.328	0.313	0.258	0.244	0.268
	SB/R-C/R-SB/R	0.307	0.320	0.323	0.319	0.306	0.286
	C-C-C	0.315	0.332	0.318	0.310	0.286	0.282
	C-SB-C	0.331	0.339	0.321	0.310	0.263	0.285
	SB-C-SB	0.308	0.341	0.322	0.302	0.295	0.298
	A-A-A	0.327	0.322	0.316	0.319	0.299	0.301
8-Mar-06	C/R	0.320	0.321	0.312	0.284	0.278	0.268
	C/B	0.312	0.331	0.317	0.319	0.282	0.276
	C/R-SB/R-C/R	0.323	0.323	0.308	0.254	0.243	0.261
	SB/R-C/R-SB/R	0.300	0.314	0.325	0.313	0.301	0.282
	C-C-C	0.310	0.322	0.314	0.304	0.283	0.276
	C-SB-C	0.322	0.333	0.313	0.301	0.250	0.281
	SB-C-SB	0.303	0.329	0.318	0.304	0.289	0.295
	A-A-A	0.318	0.310	0.312	0.310	0.294	0.297
20-Mar-06	C/R	0.319	0.326	0.318	0.284	0.281	0.270
	C/B	0.312	0.325	0.312	0.323	0.284	0.278
	C/R-SB/R-C/R	0.321	0.324	0.310	0.258	0.242	0.261
	SB/R-C/R-SB/R	0.301	0.315	0.323	0.316	0.301	0.277
	C-C-C	0.309	0.326	0.319	0.308	0.281	0.279
	C-SB-C	0.324	0.333	0.316	0.304	0.251	0.278
	SB-C-SB	0.301	0.337	0.316	0.303	0.291	0.292
	A-A-A	0.311	0.310	0.313	0.312	0.291	0.302
6-Apr-06	C/R	0.294	0.312	0.314	0.282	0.279	0.265
	C/B	0.294	0.318	0.310	0.317	0.277	0.279
	C/R-SB/R-C/R	0.296	0.312	0.307	0.250	0.239	0.264
	SB/R-C/R-SB/R	0.290	0.302	0.316	0.311	0.300	0.281
	C-C-C	0.295	0.322	0.311	0.311	0.280	0.276
	C-SB-C	0.309	0.329	0.314	0.302	0.249	0.279
	SB-C-SB	0.291	0.326	0.319	0.301	0.289	0.288
	A-A-A	0.290	0.300	0.308	0.311	0.285	0.302
17-Apr-06	C/R	0.292	0.312	0.306	0.276	0.276	0.264
	C/B	0.292	0.318	0.302	0.313	0.276	0.273
	C/R-SB/R-C/R	0.292	0.305	0.300	0.251	0.239	0.262
	SB/R-C/R-SB/R	0.290	0.305	0.315	0.305	0.294	0.279
	C-C-C	0.303	0.314	0.310	0.311	0.278	0.279
	C-SB-C	0.309	0.324	0.312	0.297	0.243	0.277
	SB-C-SB	0.296	0.327	0.320	0.300	0.286	0.289
	A-A-A	0.291	0.294	0.299	0.304	0.285	0.296

Table 32: Continued.

Date	Rotation	---------- Depth (m) ----------					
		0.18	0.49	0.79	1.10	1.40	1.70
16-May-06	C/R	0.336	0.325	0.306	0.271	0.269	0.257
	C/B	0.333	0.333	0.307	0.314	0.267	0.268
	C/R-SB/R-C/R	0.338	0.325	0.302	0.249	0.237	0.260
	SB/R-C/R-SB/R	0.315	0.319	0.322	0.305	0.288	0.275
	C-C-C	0.333	0.330	0.311	0.309	0.277	0.276
	C-SB-C	0.339	0.333	0.316	0.302	0.250	0.281
	SB-C-SB	0.317	0.343	0.323	0.302	0.292	0.293
	A-A-A	0.299	0.275	0.280	0.291	0.270	0.292

Appendix F

Crop Evapotranspiration

Crop Water Stress Coefficient Determination

Fig. 8 of soil water content results shows a relatively constant average soil water content (0.313 m^3m^{-3}) between October 2003 and March 2005. Since this value was the average amount of water retained in the soil during that time, it was used as the water content value for field capacity. Wilting point water contents were calculated using the parameters of the van Genuchten equation produced by ROSETTA (Schaap et al., 2001), and the mean value was 0.0801 m^3m^{-3}. Subsequently, the total available water (TAW) was 0.233 m^3m^{-3} and the readily available water (RAW) was 0.116 m^3m^{-3} (see methods' section). The soil water content threshold at which the plant starts to experience water stress is the water content at field capacity minus RAW, and that is 0.197 m^3m^{-3}. Fig. 8 of soil water content results showed a low value of 0.219 m^3m^{-3} in October 2005 for alfalfa. This value was higher than the water stress threshold 0.197 m^3m^{-3}, indicating that the crops did not suffer water stress. Therefore, the water stress coefficient K_s was not included in the calculations of crop evapotranspiration ET_c.

Crop Evapotranspiration Data

Table 33: Crop planting and harvest dates, and total length (days) of growing seasons for corn (C) double and single cropped, soybean (SB), rye, and barley in 2003-04, 2004-05, and 2005-06.

Single C Dates	Apr	May	June	July	Aug	Sept	TOTAL
	---------------------- Days --------------------						
6june-26 sept03	0	0	23	31	31	25	110
28Apr-1Sept04	2	31	30	31	31	0	125
20Apr-29Aug05	10	31	30	31	28	0	130

Single SB Dates	May	June	July	Aug	Sept	Oct	Total
	------------------------ Days -------------------------						
12june-13Oct03	0	18	31	31	30	12	122
30May-20Oct04	1	30	31	31	30	19	142
31May-20Oct05	0	30	31	31	30	19	141

Double C Dates	May	June	July	Aug	Sept	Total
	-------------------- Days --------------------					
6June-29Sept03	0	23	31	31	28	113
7May-13Sept04	24	30	31	31	12	128
9May-7Sept05	22	30	31	31	6	120

Barley/Rye after C	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
	------------------------------------ Days ---------------------------------------									
3Oct-6May04	0	28	9	0	0	0	7	30	5	79
16Sept-9May05	14	31	9	0	0	0	0	14	8	76

Rye after SB	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
	---------------------------------- Days ------------------------------------								
21Oct-6May04	10	9	0	0	0	7	30	5	61
27Oct-9May05	4	9	0	0	0	12	14	8	47

Table 34: First frost dates in fall of 2003 and 2004 and late frost dates in spring of 2004 and 2005.

Frost dates	First -4C	Last -4C
Fall 2003	9-Nov	
Spring 2004		24-Mar
Fall 2004	9-Nov	
Spring 2005		19-Mar
Fall 2005	12-Nov	

The temperature at which a plant reaches dormant stage is -4C (Allen et al., 1998)
Source of temperature data: see Appendix B

Table 35: Lengths (days) of the initial, development, mid and end stages for corn, soybean, rye and barley in 2003, 2004, and 2005. SB is soybean.

Crop Stage Lengths	Lini	Ldev	Lmid	Lend	Total
	---------------------------- Days -----------------------------				
Single Corn 03	30	30	30	20	110
Single Corn 04	30	30	30	35	125
Single Corn 05	30	30	30	40	130
Single/Double SB 03	20	30	60	12	122
Single/Double SB 04	20	30	60	32	142
Single/Double SB 05	20	30	60	31	141
Double Corn 03	30	30	30	23	113
Double Corn 04	30	30	30	38	128
Double Corn 05	30	30	30	30	120
Barley/Rye04 after corn	20	15	44	0	79
Barley/Rye05 after corn	20	15	41	0	76
Rye 04 after SB	20	15	26	0	61
Rye 05 after SB	20	15	12	0	47

Data estimated using values in Allen et al. (1998) and field observations.

Table 36: The components of the equation used to calculate the crop coefficient (Kc initial) for each month between September 2003 and March 2006 (See Zhu et al., 2002 for the equation). ETo values were estimated using the Penman-Monteith equation (CROPWAT in Smith, 1992). Iw is the interval between precipitation events (days).

Year	Month	ETo mm/day	Iw days	Iw (1.15 ETo) A	10 sqrt (ETo) B	exp (-A/B)	1-exp	num	denom	Kc initial
2003	Sept	3.90	3.33	14.95	19.75	0.469	0.531	10.49	13.00	0.807
	Oct	2.56	5.17	15.21	16.00	0.386	0.614	9.82	13.23	0.742
	Nov	1.91	3.33	7.32	13.82	0.589	0.411	5.68	6.37	0.893
	Dec	1.14	4.43	5.81	10.68	0.581	0.419	4.48	5.05	0.887
2004	Jan	0.99	5.17	5.88	9.95	0.554	0.446	4.44	5.12	0.868
	Feb	1.12	7.25	9.34	10.58	0.414	0.586	6.20	8.12	0.764
	Mar	2.02	6.20	14.40	14.21	0.363	0.637	9.05	12.52	0.723
	Apr	3.90	3.75	16.82	19.75	0.427	0.573	11.32	14.63	0.774
	May	5.23	3.88	23.31	22.87	0.361	0.639	14.62	20.27	0.721
	Jun	5.95	3.00	20.53	24.39	0.431	0.569	13.88	17.85	0.777
	Jul	5.80	3.10	20.68	24.08	0.424	0.576	13.88	17.98	0.772
	Aug	5.21	3.88	23.22	22.83	0.362	0.638	14.57	20.19	0.722
	Sept	4.19	5.00	24.09	20.47	0.308	0.692	14.16	20.95	0.676
	Oct	2.56	4.43	13.04	16.00	0.443	0.557	8.92	11.34	0.787
	Nov	1.85	4.29	9.12	13.60	0.512	0.488	6.64	7.93	0.838
	Dec	1.40	5.17	8.32	11.83	0.495	0.505	5.97	7.23	0.826

When there was snow cover, ETo was estimated using an albedo of 0.5 (instead of 0.23).

Table 36: Continued.

Year	Month	ETo	Iw	Iw (1.15 ETo)	10 sqrt (ETo)	exp (-A/B)	1-exp	num	denom	Kc initial
		mm/day	days	A	B					
2005	Jan	0.82	3.10	2.92	9.06	0.724	0.276	2.50	2.54	0.983
	Feb	1.12	3.11	4.01	10.58	0.685	0.315	3.34	3.48	0.957
	Mar	1.78	5.17	10.58	13.34	0.453	0.547	7.30	9.20	0.794
	Apr	4.63	6.00	31.95	21.52	0.227	0.773	16.64	27.78	0.599
	May	5.38	6.20	38.36	23.19	0.191	0.809	18.76	33.36	0.562
	June	6.40	15.00	110.40	25.30	0.013	0.987	24.98	96.00	0.260
	July	6.20	4.43	31.58	24.90	0.281	0.719	17.89	27.46	0.652
	Aug	5.62	15.50	100.18	23.71	0.015	0.985	23.36	87.11	0.268
	Sept	4.83	30.00	166.64	21.98	0.001	0.999	21.97	144.90	0.152
	Oct	2.68	3.10	9.55	16.37	0.558	0.442	7.24	8.31	0.871
	Nov	2.26	6.00	15.59	15.03	0.354	0.646	9.71	13.56	0.716
	Dec	0.86	5.17	5.11	9.27	0.576	0.424	3.93	4.44	0.884
2006	Jan	1.33	5.17	7.90	11.53	0.504	0.496	5.72	6.87	0.832
	Feb	1.91	7.00	15.38	13.82	0.329	0.671	9.28	13.37	0.694
	Mar	3.16	15.50	56.33	17.78	0.042	0.958	17.03	48.98	0.348

When there was snow cover, ETo was estimated using an albedo of 0.5 (instead of 0.23).

Table 37: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the corn/rye and corn/barley double cropped rotations. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin.

Year	Month	Crop	Corn Stages	Rye/Bar stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	ETo mm/day	Kc	ETc mm/day
2003	Sept	CORN	Kc end		0.807				0.6	0.57	2.9	61	2	3.90	0.57	2.23
	Oct	RYE/Barley		Kc ini	0.742						2.8	52		2.56	0.74	1.90
	Nov	RYE/Barley		Kc dev	0.893	1.00					3.4	56		1.91	1.00	1.90
	Dec	RYE/Barley		Kc winter	0.887						4.4	50		1.14	0.44	0.51
2004	Jan	RYE/Barley		Kc winter	0.868						4.7	47		0.99	0.43	0.43
	Feb	RYE/Barley		Kc winter	0.764						3.5	44		1.12	0.38	0.43
	Mar	RYE/Barley		Kc winter	0.723						4.0	41		2.02	0.36	0.73
	Apr	RYE/Barley		Kc mid	0.774		1.15	1.23			4.0	46	1	3.90	1.23	4.79
	May	CORN	Kc ini		0.721						3.1	56		5.23	0.72	3.77
	Jun	CORN	Kc dev		0.777	0.93					2.6	49		5.95	0.93	5.50
	Jul	CORN	Kc mid		0.772		1.15	1.13			2.5	55	2	5.80	1.13	6.58
	Aug	CORN	Kc mid		0.722		1.15	1.13			2.3	55	2	5.21	1.13	5.87
	Sept	CORN	Kc end		0.676				0.60	0.59	2.5	54	2	4.19	0.59	2.45
	Oct	RYE/Barley		Kc ini	0.787						2.5	54		2.56	0.79	2.01
	Nov	RYE/Barley		Kc dev	0.838	1.03					3.3	50		1.85	1.03	1.91
	Dec	RYE/Barley		Kc winter	0.826						3.7	50		1.40	0.41	0.58

Table 37: Continued.

Year	Month	Crop	Corn Stages	Rye/Bar stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	ETo mm/day	Kc	ETc mm/day
2005	Jan	RYE/Barley		Kc winter	0.983						3.5	55		0.82	0.49	0.40
	Feb	RYE/Barley		Kc winter	0.957						3.2	45		1.12	0.48	0.54
	Mar	RYE/Barley		Kc winter	0.794						4.1	44		1.78	0.40	0.71
	Apr	RYE/Barley		Kc mid	0.599		1.15	1.25			3.7	33	1	4.63	1.25	5.79
	May	CORN	Kc ini		0.562						3.3	36		5.38	0.56	3.03
	Jun	CORN	Kc dev		0.260	0.85					2.9	49		6.40	0.85	5.44
	Jul	CORN	Kc mid		0.652		1.15	1.14			2.4	53	2	6.20	1.14	7.05
	Aug	CORN	Kc mid		0.268		1.15	1.15			2.2	48	2	5.62	1.15	6.45
	Sept	CORN	Kc end		0.152				0.60	0.64	2.4	38	2	4.83	0.64	3.09
	Oct	RYE/Barley		Kc ini	0.871						3.2	54		2.68	0.87	2.33
	Nov	RYE/Barley		Kc dev	0.716	1.06					3.4	43		2.26	1.06	2.40
	Dec	RYE/Barley		WinterKc	0.884						3.4	47		0.86	0.44	0.38
2006	Jan	RYE/Barley		winter Kc	0.832						3.6	49		1.33	0.42	0.55
	Feb	RYE/Barley		winter Kc	0.694						4.3	41		1.91	0.35	0.66
	Mar	RYE/Barley		winter Kc	0.348						4.3	33		3.16	0.17	0.55

Table 38: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the corn/rye-soybean/rye-corn/rye double cropped rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin. SB is soybean.

Year	Month	Crop	SB Stages	rye stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	Kc	ETo mm/day	ETc
2003	Sept	CORN	Kc end		0.807				0.6	0.57	2.9	61	2	0.57	3.90	2.23
	Oct	RYE		Kc ini	0.742						2.8	52		0.74	2.56	1.90
	Nov	RYE		Kc dev	0.893	1.00					3.4	56	1	1.00	1.91	1.90
	Dec	RYE		Kc winter	0.887						4.4	50		0.44	1.14	0.51
2004	Jan	RYE		Kc winter	0.868						4.7	47		0.43	0.99	0.43
	Feb	RYE		Kc winter	0.764						3.5	44		0.38	1.12	0.43
	Mar	RYE		Kc winter	0.723						4.0	41		0.36	2.02	0.73
	Apr	RYE		Kc mid	0.774		1.15	1.23			4.0	46	1	1.23	3.90	4.79
	May	bare soil		Kc ini	0.721						3.1	56		0.72	5.23	3.77
	Jun	SB	Kc ini		0.777						2.6	49		0.78	5.95	4.63
	Jul	SB	Kc dev		0.772	0.96					2.5	55		0.96	5.80	5.57
	Aug	SB	Kc mid		0.722		1.15	1.14			2.3	55	0.8	1.14	5.21	5.91
	Sept	SB	Kc mid		0.676		1.15	1.15			2.5	54	0.8	1.15	4.19	4.80
	Oct	SB	Kc end		0.787				0.5	0.49	2.5	54	0.8	0.49	2.56	1.25
	Nov	RYE		Kc ini	0.838						3.3	50		0.84	1.85	1.55
	Dec	RYE		Kc winter	0.826						3.7	50		0.41	1.40	0.58

Table 38: Continued.

Year	Month	Crop	SB Stages	rye stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
											m/s	%	m		mm/day	
2005	Jan	RYE		Kc winter	0.983						3.5	55		0.49	0.82	0.40
	Feb	RYE		Kc winter	0.957						3.2	45		0.48	1.12	0.54
	Mar	RYE		Kc winter	0.794						4.1	44		0.40	1.78	0.71
	Apr	RYE		Kc mid	0.599		1.15	1.25			3.7	33	1	1.25	4.63	5.79
	May	CORN	Kc ini		0.562		1.15	1.23			3.3	36	1	0.56	5.38	3.03
	Jun	CORN	Kc dev		0.260	0.85					2.9	49		0.85	6.40	5.44
	Jul	CORN	Kc mid		0.652		1.15	1.14			2.4	53	2	1.14	6.20	7.05
	Aug	CORN	Kc mid		0.268	.	1.15	1.15			2.2	48	2	1.15	5.62	6.45
	Sept	CORN	Kc end		0.152				0.60	0.64	2.4	38	2	0.64	4.83	3.09
	Oct	RYE	Kc ini		0.871						3.2	54		0.87	2.68	2.33
	Nov	RYE	Kc dev		0.716	1.06					3.4	43		1.06	2.26	2.40
	Dec	RYE	Kc winter		0.884						3.4	47		0.44	0.86	0.38
2006	Jan	RYE	Kc winter		0.832						3.6	49		0.42	1.33	0.55
	Feb	RYE	Kc winter		0.694						4.3	41		0.35	1.91	0.66
	Mar	RYE	Kc winter		0.348						4.3	33		0.17	3.16	0.55

Table 39: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the soybean/rye-corn/rye-soybean/rye double cropped rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin. SB is soybean.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
										m/s	%	m		mm/day	
2003	Sept	SB	Kc mid	0.807		1.15	1.14			2.9	61	0.8	1.14	3.90	4.45
	Oct	SB	Kc end	0.742				0.5	0.50	2.8	52	0.8	0.50	2.56	1.29
	Nov	RYE	Kc ini	0.893						3.4	56	1	0.89	1.91	1.71
	Dec	RYE	Kc winter	0.887						4.4	50		0.44	1.14	0.51
2004	Jan	RYE	Kc winter	0.868						4.7	47		0.43	0.99	0.43
	Feb	RYE	Kc winter	0.764						3.5	44		0.38	1.12	0.43
	Mar	RYE	Kc winter	0.723						4.0	41		0.36	2.02	0.73
	Apr	RYE	Kc mid	0.774		1.15	1.23			4.0	46	1	1.23	3.90	4.79
	May	CORN	Kc ini	0.721						3.1	56		0.72	5.23	3.77
	Jun	CORN	Kc dev	0.777	0.93					2.6	49		0.93	5.95	5.53
	Jul	CORN	Kc mid	0.772		1.15	1.13			2.5	55	2	1.13	5.80	6.58
	Aug	CORN	Kc mid	0.722		1.15	1.13			2.3	55	2	1.13	5.21	5.87
	Sept	CORN	Kc end	0.676				0.6	0.59	2.5	54	2	0.59	4.19	2.45
	Oct	RYE	Kc ini	0.787						2.5	54		0.79	2.56	2.01
	Nov	RYE	Kc dev	0.838	1.03					3.3	50		1.03	1.85	1.91
	Dec	RYE	Kc winter	0.826						3.7	50		0.41	1.40	0.58

Table 39: Continued.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
										m/s	%	m		mm/day	
2005	Jan	RYE	Kc winter	0.983						3.5	55		0.49	0.82	0.40
	Feb	RYE	Kc winter	0.957						3.2	45		0.48	1.12	0.54
	Mar	RYE	Kc winter	0.794						4.1	44		0.40	1.78	0.71
	Apr	RYE	Kc mid	0.599		1.15	1.25			3.7	33	1	1.25	4.63	5.79
	May	Bare soil	Kc ini	0.562						3.3	36		0.56	5.38	3.03
	Jun	SB	Kc ini	0.260						2.9	49		0.26	6.40	1.67
	Jul	SB	Kc dev	0.652	0.71					2.4	53		0.71	6.20	4.40
	Aug	SB	Kc mid	0.268	.	1.15	1.15			2.2	48	0.8	1.15	5.62	6.46
	Sept	SB	Kc mid	0.152		1.15	1.19			2.4	38	0.8	1.19	4.83	5.73
	Oct	SB	Kc end	0.871				0.5	0.51	3.2	54	0.8	0.51	2.68	1.36
	Nov	RYE	Kc ini	0.716						3.4	43		0.72	2.26	1.62
	Dec	RYE	Kc winter	0.884						3.4	47		0.44	0.86	0.38
2006	Jan	RYE	Kc winter	0.832						3.6	49		0.42	1.33	0.55
	Feb	RYE	Kc winter	0.694						4.3	41		0.35	1.91	0.66
	Mar	RYE	Kc winter	0.348						4.3	33		0.17	3.16	0.55

Table 40: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the corn-corn-corn single cropped rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin.

Year	Month	Crop	stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	Kc	ETo mm/day	ETc
2003	Sept	CORN	Kc end	0.807				0.6	0.57	2.9	61	2	0.57	3.90	2.23
	Oct	bare soil	Kc ini	0.742						2.8	52		0.74	2.56	1.90
	Nov		Kc winter	0.893						3.4	56		0.67	1.91	1.28
	Dec		Kc winter	0.887						4.4	50		0.67	1.14	0.76
2004	Jan		Kc winter	0.868						4.7	47		0.65	0.99	0.64
	Feb		Kc winter	0.764						3.5	44		0.57	1.12	0.64
	Mar		Kc winter	0.723						4.0	41		0.54	2.02	1.10
	Apr	Bare soil	Kc ini	0.774						4.0	46		0.77	3.90	3.02
	May	CORN	Kc ini	0.721						3.1	56		0.72	5.23	3.77
	Jun	CORN	Kc dev	0.777	0.93					2.6	49		0.93	5.95	5.53
	Jul	CORN	Kc mid	0.772		1.15	1.13			2.5	55	2	1.13	5.80	6.58
	Aug	CORN	Kc mid	0.722		1.15	1.13			2.3	55	2	1.13	5.21	5.87
	Sept	CORN	Kc end	0.676				0.60	0.59	2.5	54	2	0.59	4.19	2.45
	Oct	bare soil	Kc ini	0.787						2.5	54		0.79	2.56	2.01
	Nov		Kc winter	0.838						3.3	50		0.63	1.85	1.16
	Dec		Kc winter	0.826						3.7	50		0.62	1.40	0.87

Table 40: Continued.

Year	Month	Crop	stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	Kc	ETo mm/day	ETc
2005	Jan		Kc winter	0.983						3.5	55		0.74	0.82	0.60
	Feb		Kc winter	0.957						3.2	45		0.72	1.12	0.80
	Mar		Kc winter	0.794						4.1	44		0.60	1.78	1.06
	Apr	bare soil	Kc ini	0.599		1.15	1.25			3.7	33	1	0.60	4.63	2.77
	May	CORN	Kc ini	0.562						3.3	36		0.56	5.38	3.03
	Jun	CORN	Kc dev	0.260	0.85					2.9	49		0.85	6.40	5.44
	Jul	CORN	Kc mid	0.652		1.15	1.14			2.4	53	2	1.14	6.20	7.05
	Aug	CORN	Kc mid	0.268		1.15	1.15			2.2	48	2	1.15	5.62	6.45
	Sept	CORN	Kc end	0.152				0.60	0.64	2.4	38	2	0.64	4.83	3.09
	Oct	bare soil	Kc ini	0.871						3.2	54		0.87	2.68	2.33
	Nov		Kc winter	0.716						3.4	43		0.54	2.26	1.21
	Dec		Kc winter	0.884						3.4	47		0.66	0.86	0.57
2006	Jan		Kc winter	0.832						3.6	49		0.62	1.33	0.83
	Feb		Kc winter	0.694						4.3	41		0.52	1.91	0.99
	Mar		Kc winter	0.348						4.3	33		0.26	3.16	0.82

Table 41: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the corn-soybean-corn single cropped rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin. SB is soybean.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	Kc	ETo mm/day	ETc mm/day
2003	Sept	CORN	Kc end	0.807				0.6	0.57	2.9	61	2	0.57	3.90	2.23
	Oct	Bare soil	Kc ini	0.742						2.8	52		0.74	2.56	1.90
	Nov		Kc winter	0.893						3.4	56		0.67	1.91	1.28
	Dec		Kc winter	0.887						4.4	50		0.67	1.14	0.76
2004	Jan		Kc winter	0.868						4.7	47		0.65	0.99	0.64
	Feb		Kc winter	0.764						3.5	44		0.57	1.12	0.64
	Mar		Kc winter	0.723						4.0	41		0.54	2.02	1.10
	Apr	Bare soil	Kc ini	0.774						4.0	46		0.77	3.90	3.02
	May	Bare soil	Kc ini	0.721						3.1	56		0.72	5.23	3.77
	Jun	SB	Kc ini	0.777						2.6	49		0.78	5.95	4.63
	Jul	SB	Kc dev	0.772	0.96					2.5	55	0.8	0.96	5.80	5.57
	Aug	SB	Kc mid	0.722		1.15	1.14			2.3	55	0.8	1.14	5.21	5.91
	Sept	SB	Kc mid	0.676		1.15	1.15			2.5	54	0.8	1.15	4.19	4.80
	Oct	SB	Kc end	0.787				0.50	0.49	2.5	54	0.8	0.49	2.56	1.25
	Nov		Kc winter	0.838						3.3	50		0.63	1.85	1.16
	Dec		Kc winter	0.826						3.7	50		0.50	1.40	0.69

Table 41: Continued.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
										m/s	%	m		mm/day	
2005	Jan		Kc winter	0.983						3.5	55		0.59	0.82	0.48
	Feb		Kc winter	0.957						3.2	45		0.57	1.12	0.64
	Mar		Kc winter	0.794						4.1	44		0.48	1.78	0.85
	Apr	Bare soil	Kc ini	0.599						3.7	33		0.60	4.63	2.77
	May	CORN	Kc ini	0.562						3.3	36		0.56	5.38	3.03
	Jun	CORN	Kc dev	0.260	0.85					2.9	49		0.85	6.40	5.44
	Jul	CORN	Kc mid	0.652		1.15	1.14			2.4	53	2	1.14	6.20	7.05
	Aug	CORN	Kc mid	0.268		1.15	1.15			2.2	48	2	1.15	5.62	6.45
	Sept	CORN	Kc end	0.152				0.60	0.64	2.4	38	2	0.64	4.83	3.09
	Oct	Bare soil	Kc ini	0.871						3.2	54		0.87	2.68	2.33
	Nov		Kc winter	0.716						3.4	43		0.54	2.26	1.21
	Dec		Kc winter	0.884						3.4	47		0.66	0.86	0.57
2006	Jan		Kc winter	0.832						3.6	49		0.62	1.33	0.83
	Feb		Kc winter	0.694						4.3	41		0.52	1.91	0.99
	Mar		Kc winter	0.348						4.3	33		0.26	3.16	0.82

Table 42: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the soybean-corn-soybean single cropped rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin. SB is soybean.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
										m/s	%	m		mm/day	
2003	Sept	SB	Kc mid	0.807		1.15	1.18			2.9	61	0.8	1.18	3.90	4.62
	Oct	SB	Kc end	0.742				0.5	0.50	2.8	52	0.8	0.50	2.56	1.29
	Nov		Kc winter	0.893						3.4	56		0.54	1.91	1.02
	Dec		Kc winter	0.887						4.4	50		0.53	1.14	0.61
2004	Jan		Kc winter	0.868						4.7	47		0.52	0.99	0.52
	Feb		Kc winter	0.764						3.5	44		0.46	1.12	0.51
	Mar		Kc winter	0.723						4.0	41		0.43	2.02	0.88
	Apr	Bare soil	Kc ini	0.774						4.0	46		0.77	3.90	3.02
	May	CORN	Kc ini	0.721						3.1	56		0.72	5.23	3.77
	Jun	CORN	Kc dev	0.777	0.93					2.6	49		0.93	5.95	5.53
	Jul	CORN	Kc mid	0.772		1.15	1.13			2.5	55	2	1.13	5.80	6.58
	Aug	CORN	Kc mid	0.722		1.15	1.13			2.3	55	2	1.13	5.21	5.87
	Sept	CORN	Kc end	0.676				0.60	0.59	2.5	54	2	0.59	4.19	2.45
	Oct	Bare soil	Kc ini	0.787						2.5	54		0.79	2.56	2.01
	Nov		Kc winter	0.838						3.3	50		0.63	1.85	1.16
	Dec		Kc winter	0.826						3.7	50		0.62	1.40	0.87

Table 42: Continued.

Year	Month	Crop	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
										m/s	%	m		mm/day	
2005	Jan		Kc winter	0.983						3.5	55		0.74	0.82	0.60
	Feb		Kc winter	0.957						3.2	45		0.72	1.12	0.80
	Mar		Kc winter	0.794						4.1	44		0.60	1.78	1.06
	Apr	Bare soil	Kc ini	0.599						3.7	33		0.60	4.63	2.77
	May	Bare soil	Kc ini	0.562						3.3	36		0.56	5.38	3.03
	Jun	SB	Kc ini	0.260						2.9	49		0.26	6.40	1.67
	Jul	SB	Kc dev	0.652	0.71					2.4	53		0.71	6.20	4.40
	Aug	SB	Kc mid	0.268		1.15	1.15			2.2	48	0.8	1.15	5.62	6.46
	Sept	SB	Kc mid	0.152		1.15	1.19			2.4	38	0.8	1.19	4.83	5.73
	Oct	SB	Kc end	0.871				0.50	0.51	3.2	54	0.8	0.51	2.68	1.36
	Nov		Kc winter	0.716						3.4	43		0.43	2.26	0.97
	Dec		Kc winter	0.884						3.4	47		0.53	0.86	0.46
2006	Jan		Kc winter	0.832						3.6	49		0.50	1.33	0.66
	Feb		Kc winter	0.694						4.3	41		0.42	1.91	0.80
	Mar		Kc winter	0.348						4.3	33		0.21	3.16	0.66

Table 43: Crop evapotranspiration (ETc) is calculated using monthly crop stages for the alfalfa rotation. Every stage is characterized by a crop coefficient (Kc initial, dev, mid, and end). Wind speed is u2, crop height is h, and minimum relative humidity is RHmin. SB is soybean.

Year	Month	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2	RH min	h	Kc	ETo	ETc
									m/s	%	m		mm/day	
2003	Sept	Kc mid	0.807		0.95	0.95			2.9	61	0.5	0.95	3.90	3.69
	Oct	Kc mid	0.742		0.95	0.96			2.8	52	0.5	0.96	2.56	2.47
	Nov	Kc end	0.893				0.90	0.91	3.4	56	0.5	0.89	1.91	1.71
	Dec	winter Kc	0.887						4.4	50		0.44	1.14	0.51
2004	Jan	winter Kc	0.868						4.7	47		0.43	0.99	0.43
	Feb	winter Kc	0.764						3.5	44		0.38	1.12	0.43
	Mar	winter Kc	0.723						4.0	41		0.36	2.02	0.73
	Apr	Kc mid	0.774		0.95	1.03			4.0	46	0.5	1.03	3.90	4.01
	May	Kc mid	0.721		0.95	0.97			3.1	56	0.5	0.97	5.23	5.06
	Jun	Kc mid	0.777		0.95	0.97			2.6	49	0.5	0.97	5.95	5.74
	Jul	Kc mid	0.772		0.95	0.95			2.5	55	0.5	0.95	5.80	5.49
	Aug	Kc mid	0.722		0.95	0.94			2.3	55	0.5	0.94	5.21	4.89
	Sept	Kc mid	0.676		0.95	0.95			2.5	54	0.5	0.95	4.19	3.97
	Oct	Kc mid	0.787		0.95	0.95			2.5	54	0.5	0.95	2.56	2.43
	Nov	Kc end	0.838				0.90	0.92	3.3	50	0.5	0.92	1.85	1.70
	Dec	winter Kc	0.826						3.7	50		0.41	1.40	0.58

Table 43: Continued.

Year	Month	Stages	Kc ini	Kc dev	Kc mid (table)	Kc mid	Kc end (table)	Kc end	u2 m/s	RH min %	h m	Kc	ETo mm/day	ETc mm/day
2005	Jan	winter Kc	0.983						3.5	55		0.49	0.82	0.40
	Feb	winter Kc	0.957						3.2	45		0.48	1.12	0.54
	Mar	winter Kc	0.794						4.1	44		0.40	1.78	0.71
	Apr	Kc mid	0.599		0.95	1.04			3.7	33	0.5	1.04	4.63	4.84
	May	Kc mid	0.562		0.95	1.02			3.3	36	0.5	1.02	5.38	5.51
	Jun	Kc mid	0.260		0.95	0.98			2.9	49	0.5	0.98	6.40	6.26
	Jul	Kc mid	0.652		0.95	0.95			2.4	53	0.5	0.95	6.20	5.87
	Aug	Kc mid	0.268		0.95	0.95			2.2	48	0.5	0.95	5.62	5.34
	Sept	Kc mid	0.152		0.95	0.98			2.4	38	0.5	0.98	4.83	4.75
	Oct	Kc mid	0.871		0.95	0.98			3.2	54	0.5	0.98	2.68	2.62
	Nov	Kc end	0.716				0.90	0.94	3.4	43	0.5	0.94	2.26	2.12
	Dec	winter Kc	0.884						3.4	47		0.44	0.86	0.38
2006	Jan	winter Kc	0.832						3.6	49		0.42	1.33	0.55
	Feb	winter Kc	0.694						4.3	41		0.35	1.91	0.66
	Mar	winter Kc	0.348						4.3	33		0.17	3.16	0.55

Table 44: Monthly ETc (mm/day) for double cropping (averaged over C/B, C/R, C/R-SB/R-C/R, and SB/R-C/R-SB/R), single cropping (averaged over C-C-C, C-SB-C, and SB-C-SB), and alfalfa.

Year	Time	Double cropping	Single Cropping	Alfalfa
		--------------------	mm/day	-------------------
2003	Sept	2.79	3.03	3.69
	Oct	1.75	1.70	2.47
	Nov	1.85	1.19	1.71
	Dec	0.51	0.71	0.51
2004	Jan	0.43	0.60	0.43
	Feb	0.43	0.60	0.43
	Mar	0.73	1.02	0.73
	Apr	4.79	3.02	4.01
	May	3.77	3.77	5.06
	June	5.29	5.23	5.74
	July	6.33	6.24	5.49
	Aug	5.88	5.88	4.89
	Sept	3.04	3.23	3.97
	Oct	1.82	1.76	2.43
	Nov	1.82	1.16	1.70
	Dec	0.58	0.81	0.58

Table 44: Continued.

Year	Time	Double cropping	Single Cropping	Alfalfa
		------------------- mm/day -------------------		
2005	Jan	0.40	0.56	0.40
	Feb	0.54	0.75	0.54
	Mar	0.71	0.99	0.71
	Apr	5.79	2.77	4.84
	May	3.03	3.03	5.51
	June	4.50	4.18	6.26
	July	6.39	6.17	5.87
	Aug	6.45	6.45	5.34
	Sept	3.75	3.97	4.75
	Oct	2.09	2.01	2.62
	Nov	2.20	1.13	2.12
	Dec	0.38	0.53	0.38
2006	Jan	0.55	0.78	0.55
	Feb	0.66	0.93	0.66
	Mar	0.55	0.77	0.55

LAI Data

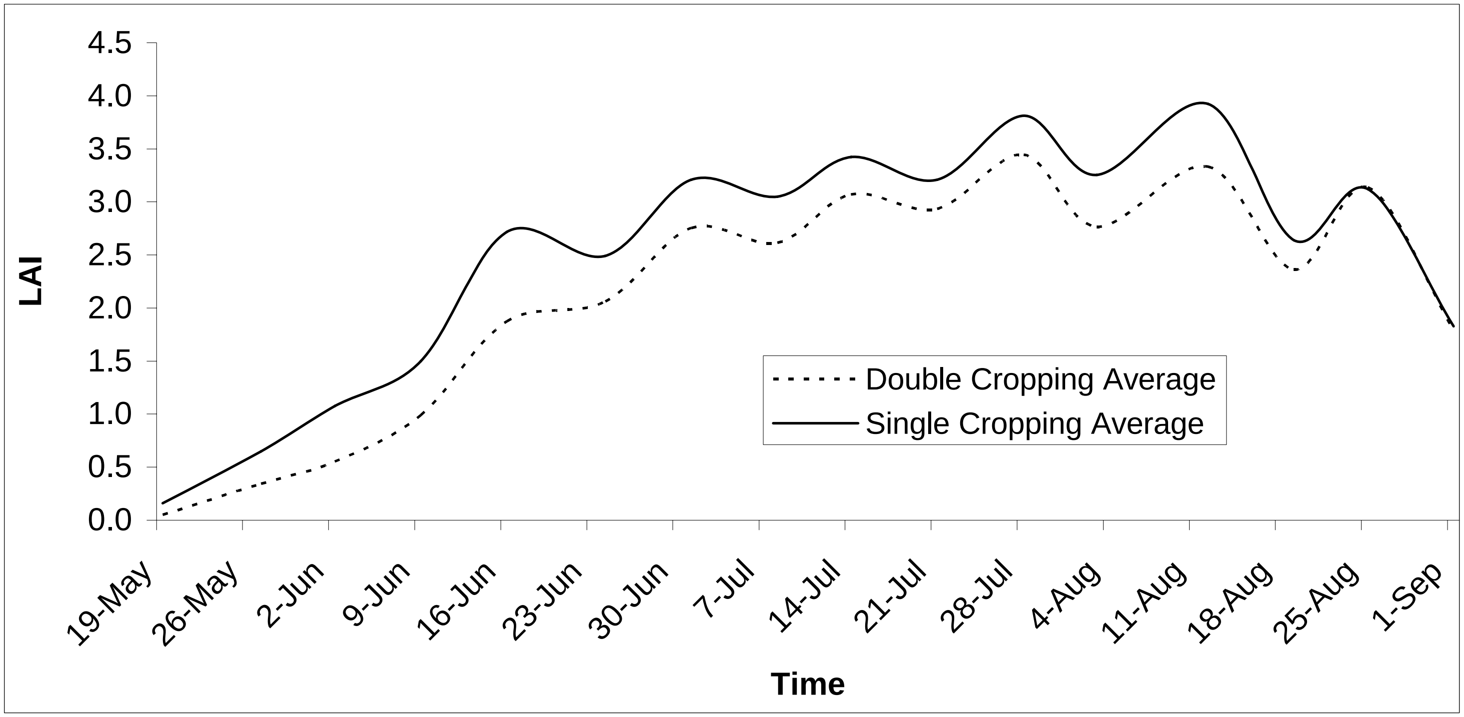

Fig. 20: Leaf Area Index (LAI) values for corn during the 2004 growing season for double and single cropped rotations.

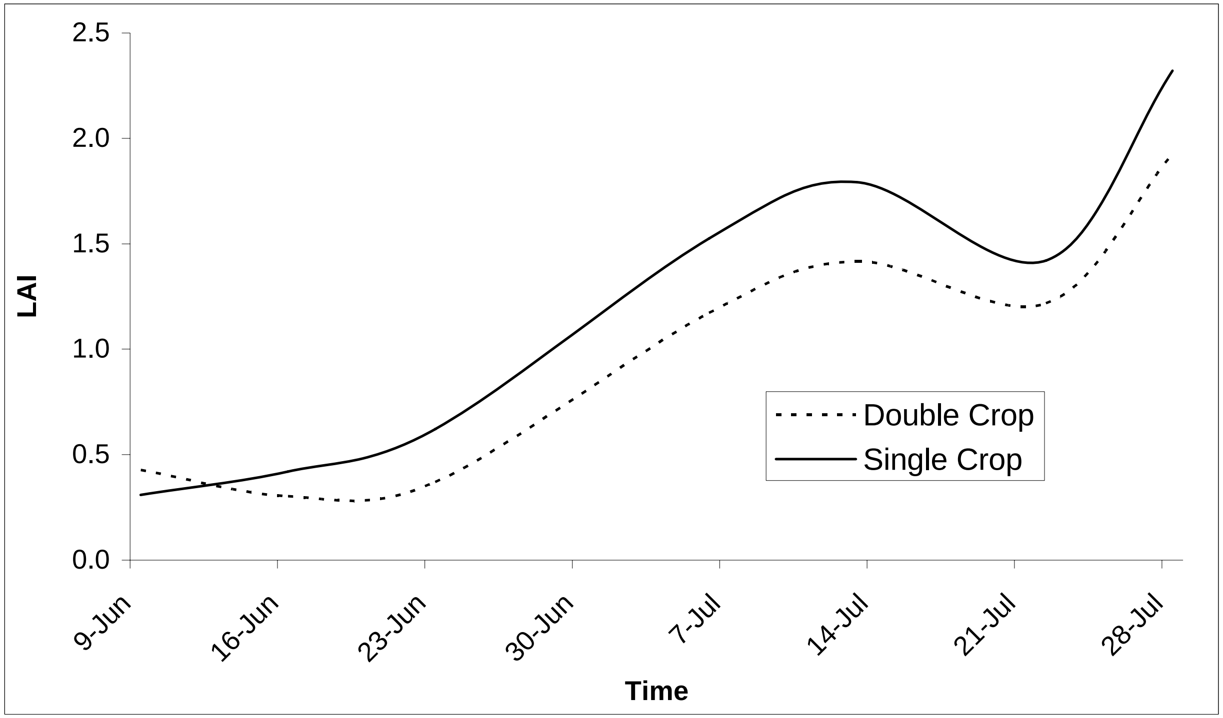

Fig. 21: Leaf Area Index (LAI) values for corn during the 2005 growing season for double and single cropped rotations.

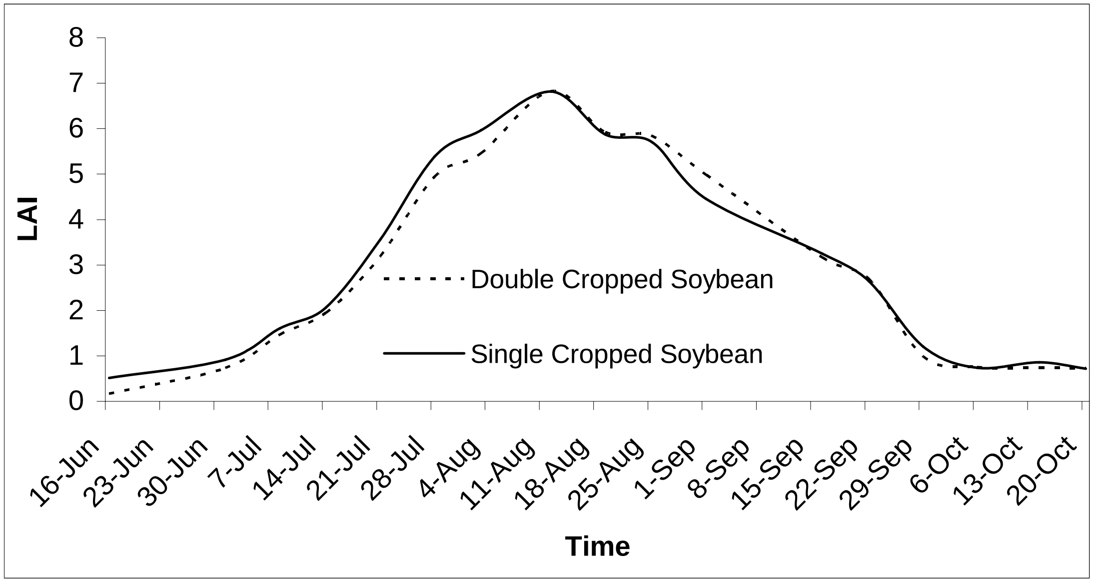

Fig. 22: Leaf Area Index (LAI) values for soybean during the 2004 growing season for double and single cropped rotations.

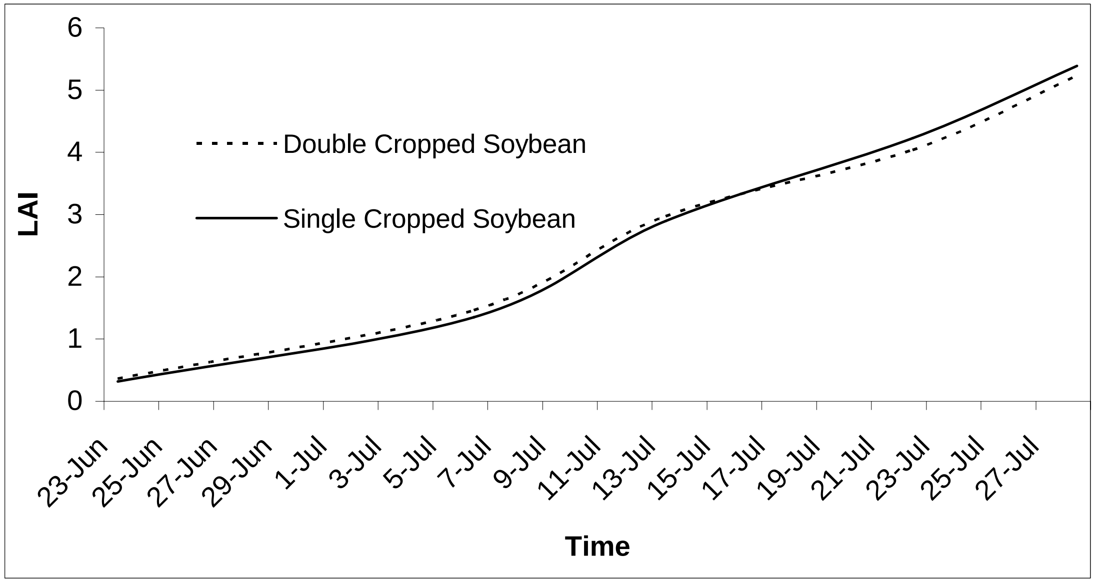

Fig. 23: Leaf Area Index (LAI) values for soybean during the 2005 growing season for double and single cropped rotations.

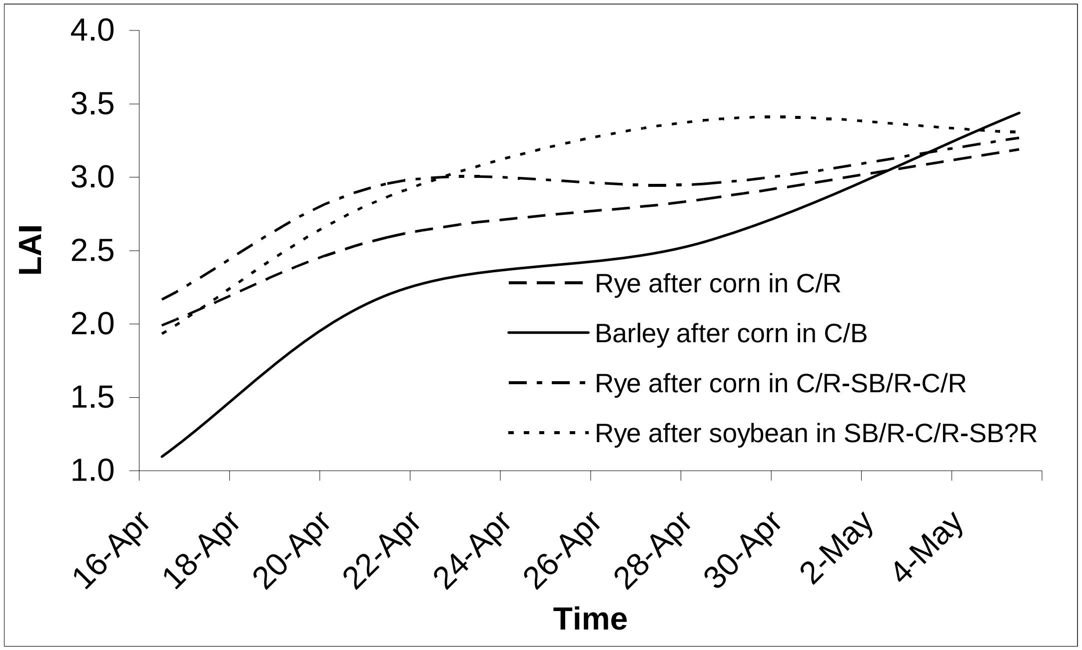

Fig. 24: Leaf Area Index (LAI) values for rye and barley during spring 2004.

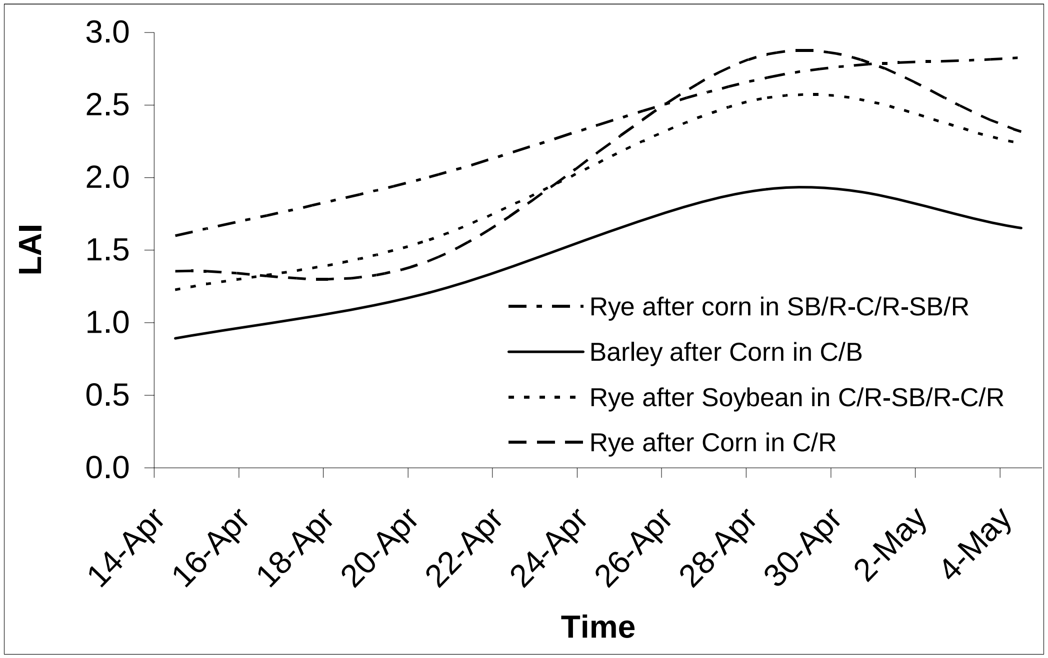

Fig. 25: Leaf Area Index (LAI) values for rye and barley during spring 2005.

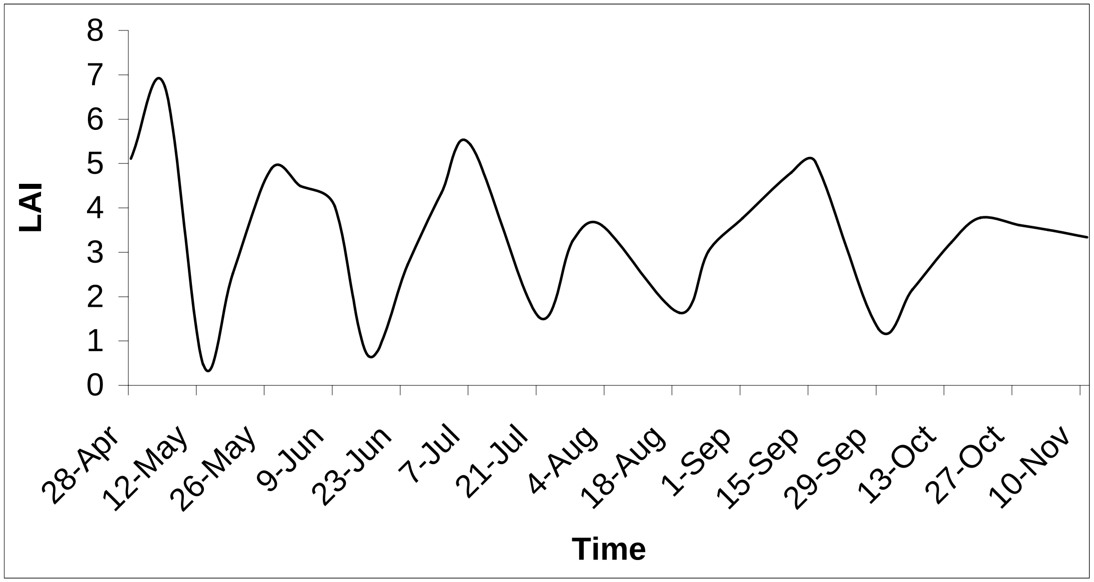

Fig. 26: Leaf Area Index (LAI) values for alfalfa during 2004.

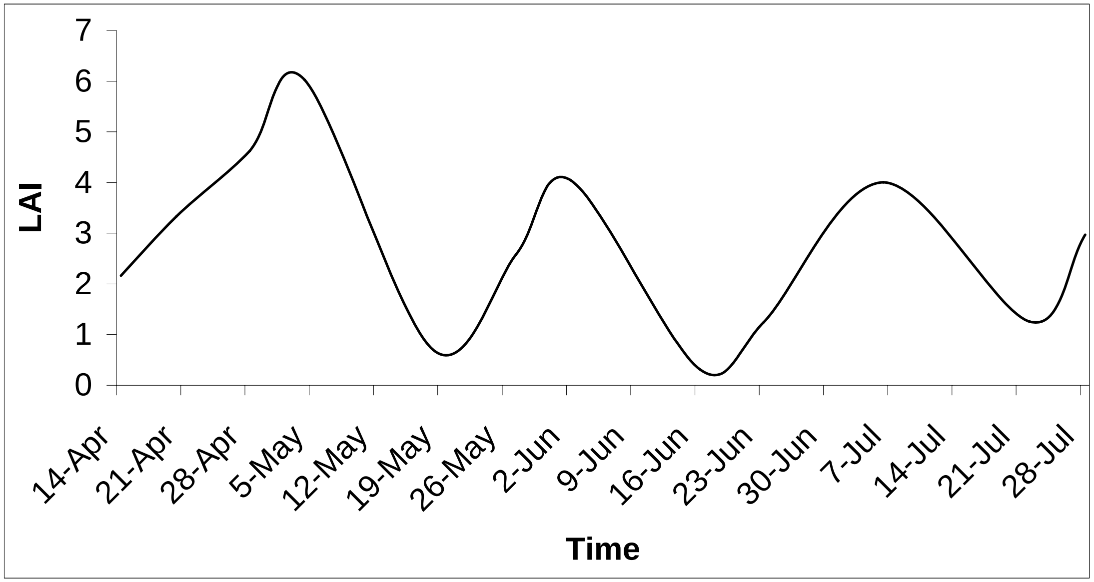

Fig. 27: Leaf Area Index (LAI) values for alfalfa during summer 2005.

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