Economic and Resource Impacts of Policies to Increase Organic Carbon in Agricultural Soils

Aziz Bouzaher, Derald J. Holtkamp,
Randall Reese, and Jason Shogren

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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011

Aziz Bouzaher is an associate professor of economics and head, Resource and Environmental Policy Division, CARD; Derald J. Holtkamp is a CARD research associate; Randall Reese is a CARD research assistant; and Jason Shogren is an associate professor of economics, Iowa State University, and a visiting associate professor, Yale University.

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ABSTRACT

Economic impacts are evaluated for four agricultural policies intended to increase organic carbon stored in agricultural soils. Two policies are directed at changing agricultural practices on tillage and cover crops. The other two involve alternative land use scenarios under the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP).

Two economic simulation models are used. The Resource Adjustment Modeling System (RAMS), a linear programming model, is capable of evaluating an extensive set of crop production practices including tillage, cover crops, rotations, irrigation, and several conservation practices for U.S. corn and sorghum areas. RAMS provides short-run, region-specific results for producer income, resource use, erosion, and cropping patterns as well as information about the mix of agricultural practices. The alternative land use scenarios under CRP and WRP are evaluated by the Basic Linked System (BLS), an applied general equilibrium model capable of estimating the economic effects of changing land use patterns on the agricultural sector.

Several scenarios are considered for each of the four policies and the results are compared with a baseline set of outcomes. In most cases under the BLS, producers and consumers are worse off, so any increase in organic carbon stored in the soil must be weighed against the economic costs. Decreases in erosion and fertilizer use from higher levels of conservation tillage and cover crops must be included in the environmental side of the equation. For the CRP and WRP scenarios the costs of these programs are more than offset by savings from commodity program outlays.

ECONOMIC AND RESOURCE IMPACTS OF POLICIES TO INCREASE ORGANIC CARBON IN AGRICULTURAL SOILS

Recently there has been widespread documentation of increasing levels of CO_2 and other greenhouse gases in the atmosphere (Houghton et al., 1990). The balance of carbon stored in the atmospheric, terrestrial and oceanic pools is beginning to shift disproportionally toward the atmosphere leading to predictions of global climate change. It is estimated that agricultural soils store 1.5×10^{15} kilograms of carbon, twice the amount held in the atmosphere (Post et al., 1990). The agricultural activities carried out on any particular tract of land have a significant capacity to affect the amount of carbon stored in the soil. Policies designed to encourage or compel the adoption of practices or land use patterns that promote the buildup of soil organic carbon may affect reduced emissions of carbon gases as well as potential economic costs to producers and consumers. Depending upon their design and implementation, policies may have considerable regional and national impacts on agricultural profitability, land use patterns, soil erosion, and the use of pesticides and fertilizer. The purpose of this paper is to evaluate these impacts and to provide meaningful measures with which to evaluate both environmental and economic outcomes. Economic impacts are evaluated with two modeling systems: the Resource Adjustment Modeling System (RAMS) and the Basic Linked System (BLS). The work summarized here is part of the U.S. EPA Climate Change Program and involves the integration of RAMS and BLS with a soil organic formation model called CENTURY. The CENTURY model is operated by Aqua Terra Consultants and some key results are reported in this paper to facilitate the analysis of economic and environmental tradeoffs.

RAMS is a regional, comparative static, linear programming model of the crop production sector. The model objective is maximization of net returns to crop production. RAMS is designed for disaggregated analysis of agricultural and environmental policy and the results are used to estimate short-run adjustments in producer decisions about crops grown, input use, and cropping systems employed. The RAMS study region includes the major corn and sorghum producing areas of the United States. The strength of RAMS is in the extensive detail about agricultural practices with environmental ramifications.

The Basic Linked System of applied general equilibrium models (Abkin, 1985) is a large-scale computer simulation of the world agricultural economy. Unlike RAMS, BLS simulates the long-run behavior of agricultural production and commodity markets at the national and world levels and specifies interactions with nonagricultural markets. The rules governing these markets are consistent with microeconomic principles of general equilibrium and accommodate various policy regimes.

Two types of policies are evaluated in this paper. The first type, involving region-specific targeting of crop production practices, is evaluated by RAMS. The second type of policy, involving national shifts in land use patterns prompted by the Conservation Reserve (CRP) and Wetlands Reserve (WRP) Programs, is evaluated by BLS. BLS is better suited to analyze national policies, such as the CRP and WRP, for which international trade effects may be significant. While the scope of BLS is broad, it does not have RAMS's detail for specific production practices. RAMS is thus better suited for evaluation of targets on specific production practices.

Regionally targeted production practices include winter cover crops and conservation tillage. Winter cover crops are expected to increase soil organic carbon by expanding annual biomass production while conservation tillage is expected to increase soil organic carbon by minimizing soil disturbances. Shifts in land use patterns through CRP can have substantial impact on soil carbon levels even though increasing soil carbon levels was not a policy objective when the CRP was first authorized. The WRP examined here is intended as a carbon sequestering measure. The program targets bottomland suitable for hardwood tree growth, which has the potential for significant carbon benefits.

This paper discusses the RAMS and BLS models and their linkages to CENTURY. The policies and their implementation in the models are described and are followed by a review of the economic results of the policy analyses and key soil organic carbon results from CENTURY. Conclusions are presented to stimulate discussion and further research.

Models

RAMS

The Resource Adjustment Modeling System (RAMS) was developed in 1990 and 1991 by the Center for Agricultural and Rural Development (CARD). The system is geographically delineated by PAs, hydrological areas representing aggregated subareas defined by the water resources council (USWRC, 1970). The areas are small enough that the assumption of homogenous production across the area can reasonably be made. RAMS is interfaced with the CENTURY model through areas of crop production by crop, tillage, and rotation, and they are passed from RAMS to CENTURY.

Crop production is characterized in the model by activities that specify crop rotation, tillage, contour management, winter cover crops, and irrigation. Each activity is defined by a combination of these five dimensions.

Cover crops are included only for a subset of all crop sequences within each rotation. The subset depends on the geographic location of the PA. In general, the eligible sequences in any PA depend upon the time period in which cover crops can grow and on the scarcity of moisture. The RAMS study area is segregated into three regions for the purpose of defining cover crops. The northern one-third of the producing areas is considered unsuitable for cover crops and therefore it is excluded. The middle and southern thirds have cover crops defined but the subset is smaller in the middle third. Southern PAs typically have longer, and warmer, growing seasons allowing substantial growth of a winter cover crop. Some western PAs simply do not have enough water to support a commodity and a winter cover crop. The growing period for winter cover crops is greater following crops with early harvests and/or succeeding crops with late planting dates. (Cruse, 1992).

Winter cover crops not only improve the soil carbon content of the soil, they reduce soil erosion, fix nitrogen available to the subsequent crop in the case of hairy vetch, cost money to establish and, because of competition for moisture, reduce yields in the subsequent crop. Winter cover crop activities were modeled by adding new production activities with adjustments to each of these variables defined for the original RAMS activities. Because each of the variables is defined for rotations in RAMS, adjustments were weighted according to the share occupied by each crop sequence in the rotations.

Data needed to estimate cost adjustments are obtained from two sources. Machinery usage and costs are estimated from CARD budgets. Seeding rates are estimated from field data (Cruse, 1992) and prices for seed are obtained from *Agricultural Prices* (NASS, 1990).

Estimates of erosion reductions vary according to crop sequence and tillage. Reductions are estimated from two sources. When available, percentage differences in the C factors for land treated with a winter cover crop, versus untreated, are obtained from the Soil Conservation Service Field Office Technical Guides (SCS, 1991) and used to adjust the C factor used in the original calculation of erosion for the activity without winter cover. The alternative is to use rainfall erosion index curves, which measure the percentage of annual erosion occurring at each point in time to estimate the percentage of annual erosion occurring between harvest and planting of commodity crops (Wischmeier and Smith, 1965). This value is then adjusted by an estimate of the percent reduction in erosion due to the cover crop during that same time period. For example, if the rainfall erosion index curves indicate that 30 percent of annual erosion occurs between harvest and planting and that cover crops will reduce erosion by 50 percent between the harvest and planting dates, then the erosion reduction is 15 percent (50% of 30%). Normal planting and harvest date were taken from Burkhead et al. (1968).

Nitrogen carryover from hairy vetch, which is a nitrogen fixing legume, is estimated from reported field data. Carryover amounts of 55 pounds per acre in the middle region and 78 pound in the south are limited to use by the crop immediately succeeding the cover crop. Nitrogen in excess of the succeeding crop's demand is assumed lost.

Yield adjustment factors are estimated from field data when available. In cases where relevant field data were unavailable, yield impact estimates are based on information about water competition taken from the literature (Cruse, 1992).

The outcomes of the model include the indicators used to evaluate the economic costs and benefits as well as the production patterns that are fed to the CENTURY and DNDC models. Primary economic indicators include net returns to production, acreage planted, tillage practices, rotations, erosion, and fertilizer and herbicide use.

BLS

The BLS is characterized as a system of applied general equilibrium models. The term *applied general equilibrium* means that all behavior in the model derives from standard microeconomic assumptions about how markets work together. All commodities, markets, and regions are linked through prices and specific accounting rules: prices and quantities must be such that all markets clear and global commodity markets balance. BLS is also flexible enough to accommodate several specific agricultural, trade, and economic policies and to account for changes over time. Thus, when policies such as the CRP and WRP scenarios are included in the model, the impacts of those policies projected by BLS reflect (1) the domestic linkages among several agricultural markets and the nonagricultural market; (2) the dynamic effects in production, consumption, and trade over time; (3) the feedback from international markets, and (4) the influences of several national policies.

The U.S. submodel specifically accounts for 23 commodities, but this discussion is limited to the seven program crops and soybeans plus livestock. Results generated include annual projections of supply and utilization tables that identify production (including acreages, yields, and herd sizes), net exports, demands (human, feed, industrial, seed, waste, and stocks), retail prices, and consumer raw material prices. The BLS provides for this study annual estimates through 2030 of the items listed here, except for production costs and returns and government expenditures, which are estimated using the trends suggested by BLS.

Policies Evaluated with RAMS: Region-specific Targeting of Production Practices

The baseline for the RAMS model is the 1990 growing season. Commodity program parameters for the 1991 programs were used to reflect the new commodity programs of the 1990 farm bill. Input prices for 1989 were used. Crop inputs such as seed and fertilizer are often purchased in the previous year for tax purposes or because discounts are offered. Crop acreages are calibrated to 1990 data. Commodity prices were estimated as averages for the 1990 calendar year, using projected prices for the later months. Yields for 1990 were also estimated.

Alternatives

Targets for adoption of no-till and reduced tillage practices, together labeled *conservation tillage* are derived by altering the criteria for defining highly erodible land for conservation compliance purposes. Targeting of the most erosive land offers a dual benefit of reducing erosion and increasing storage of carbon in agricultural soils. Targets for planting of winter cover crops are based upon baseline areas of land planted to crops with early harvest dates, namely small grains and silage, followed by crops not seeded in the fall.[1] The objective is to select and promote situations where winter cover crops have the most opportunity to fix carbon. Targeting both conservation tillage and winter cover crops is accomplished by including a constraint in RAMS to force selection of activities meeting the appropriate criterion.

Conservation Tillage Targets. Modeling conservation compliance in RAMS for the baseline involved calculating of erodibility index[2] (EI) values for land in the National Resource Inventory

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[1]Crops seeded in the fall circumvent the need for establishing a winter cover crop. Fall seeded crops modeled include winter wheat, legume hay, and nonlegume hay.

[2]EI is equal to RKLS/T for water erosion. R,K,L and S are universal soil loss equation (USLE) coefficients and T is the theoretical amount of soil loss that if exceeded will lead to losses in productivity.

(NRI). Land with an erodibility index (EI) greater than 8 is considered highly erodible. Six *highly erodible land groups* (HELG) based on ranges of the estimated EI values are defined. Highly erodible land groups 1 through 5 enclose the range of EI from 9 to 43 in increments of 6. Land with an EI greater than 43 is included in the sixth HELG.

The C and P coefficients in the universal soil loss equation are indices of the crop grown and management practices used. Values for both coefficients were estimated for all of the production activities in RAMS and the product of the two is labeled the CP factor. Values of the CP factor for each activity in RAMS are evaluated for each group of highly erodible land. If EI $< 1/CP$, where EI is the average of the range for each HELG, the practice meets the conservation compliance requirements for that HELG.

For the present analysis, the sum of land falling into one of the six highly erodible land groups was used as the target for conservation tillage. This was modeled by constraining the sum of no-till plus reduced till to be equal to the amount of highly erodible land. The constraint may be satisfied by devoting cropland to either no-till or reduced tillage systems. Because the minimum EI for land to be considered highly erodible was reduced from 8 to 2, the amount of land considered highly erodible increases.

Four runs were performed to evaluate the sensitivity of the results to the size of the target and to different assumptions about relative yields. A single run was performed, assuming relative yields between tillage practices were essentially equal[3] for each of two targets based on EI values of 8 and 2. In addition, the same runs are performed assuming a 10 percent reduction in no-till yields and a 5 percent reduction for reduced till. The lower yields reflect yield losses that might be expected during the initial adoption period when producers are learning to use the conservation tillage systems (Cruse, 1992). Experience has shown that once producers gain sufficient management skill, yields equivalent to those with conventional tillage systems are attainable.

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[3]While yields in RAMS were estimated to reflect differences for different tillage practices, the estimation procedure used produced very similar yields for each of the four tillage practices.

Winter Cover Crops. Cover crop activities are created by inserting winter cover crops into previously defined production activities in RAMS. The cropping sequences are defined, in part, by a crop rotation that is merely a set of sequences in which crops are to be grown. Therefore, adding winter cover crops to a cropping system does not increase the amount of land required, only the intensity of its use.

To establish a target for winter cover crops the following question was posed. How many acres could be devoted to cover crops between the desired sequence of crops without altering the mix of cropping systems used under the baseline? Recall, the desired sequence of crops is small grains or silage followed by crops not seeded in the fall. Small grains include barley, oats, and spring and winter wheat. Silage includes both corn and sorghum silage. The area in the appropriate sequences was calculated from baseline results for each producing area in RAMS. These values are used as the winter cover crop target. About 5 percent of the cropped acreage in the study region is planted to these sequences under the baseline.

Policies Evaluated with the BLS: National Shifts in Land Use Patterns

Three alternative CRP scenarios and a targeted WRP scenario were analyzed using BLS to project their likely long-term economic impacts on the agriculture sector of the United States. The four scenarios are labeled CRP1, CRP2, CRP3, and WRP1. The three CRP scenarios each reflect different assumptions about the size of future CRP programs and about alternative uses of CRP land. Specifically, two alternative CRP proposals—a 40 million acre CRP (CRP2) and a 50 million acre CRP (CRP3)—are compared with a baseline scenario consisting of a 17.5 million acre CRP (CRP1), considered a likely outcome after current CRP contracts expire. A 5 million acre WRP targeted to bottomland capable of supporting hardwood tree growth is also analyzed and the results are compared with those obtained under the 17.5 million acre CRP baseline.

The CRP and WRP scenarios are implemented in BLS as additions (reductions) in acres planted to the several crops as land is retired from (enters) the reserve program being analyzed. In a particular simulation year, the model determines an initial estimate of acres planted to a crop, then the addition or reduction from the reserve program is made. Other variables in the model then adjust to this final acreage planted and the acres harvested of each crop are finally determined.

Baseline

All CRP and WRP scenarios assume that the present CRP program reaches its goal of 40 million acres by 1995. In the baseline scenario (CRP1) contracts begin to expire in 1996 according to historical sign-ups. Coverage would ultimately be maintained on 17.5 million acres to include (a) 2.7 million tree acres, (b) 8.3 million acres of environmentally sensitive grassland, and (c) 6.5 million acres of additional grassland. This means that by 2005, 17.5 million acres will have entered or remained in the CRP, and will remain there through the end of the study period. The remaining 22.5 million acres return to production according to patterns indicated by historical sign-ups.

Alternatives

CRP. In CRP2, all contracts in the current 40-million acre program are renewed indefinitely. It thus reflects current land use patterns. CRP3 is an expanded CRP of 50 million acres. It is modeled as CRP2 with an additional 10 million acres removed from crop production over the 10-year period from 1996 to 2005 at the rate of one million acres per year. Land is removed from production of the program crops and soybeans according to the average proportion of area reductions in a particular crop attributed to CRP in the last five years of the current CRP (1991-1995) as projected in the *FAPRI 1992 U.S. Agricultural Outlook*. Roughly 25 percent of the new 10 million acres is assumed to come from other crops.

Because no specific constraint exists on the total number of acres available to U.S. crop production in the model, there is no internal mechanism to determine the way in which CRP land will be used as CRP contracts expire. In other words, what proportion of old CRP acres will be planted to wheat, what proportion to corn, and so on. Similarly, the BLS cannot determine which crops will surrender land to a new CRP or WRP. It was thus necessary to supply estimated acreage changes to the model for each crop exogenously. Figure 1 shows how land enrolled in the scenarios might otherwise be used; that is, to what crops the land would otherwise have been planted. For the CRP scenarios, this distribution is based on the USDA estimates of area reductions from historical sign-ups.[4] While there are slight differences in the distribution of cropland in each CRP, wheat land makes up the largest portion in each program, about 30 percent. Corn and soybean acreages each make up about 12 percent of the total and other feed grain acreage (sorghum, oats, and barley) makes up about 18 percent. Cotton acreage is only 4 percent.

WRP. WRP1 is a 5 million acre reserve of wetlands consisting predominantly of drained bottomland currently planted to agricultural crops and is run in conjunction with CRP1. The potential crop-specific land content of the reserve was estimated using a national database of hydric soils for the United States obtained from the 1982 National Resource Inventory (NRI) and SOILS5 (SCS, 1985; SCS/ISSL, 1989). Land in the database was ranked according to USDA estimated easement and restoration costs (Heimlich et al., 1989) and the least costly 5 million acres were selected for the program.[5] About 40 percent of these acres are planted to soybeans and 28 percent to corn. The remainder comes mostly from wheat and other acreages. Not surprisingly, most of the land projected to enter the reserve is located in the Mississippi Delta and Southern states. Most of the remainder comes from the Midwest. The BLS, however, cannot discriminate between regions within the United States; all information in the system is on a national or global level.

Empirical Results

Estimates produced by RAMS for the region-specific targets on conservation tillage and winter cover crops are aggregated and summarized at the study region level.

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[4]These reductions are outlined in the FAPRI 1992 Outlook and based on estimates provided by USDA.

[5]Land only in states bordering or east of the Mississippi River was included because it was believed that very little bottomland in the western states had the suitable climate to support hardwood growth. All land planted in rice and all land in Florida were excluded from the database because of difficulty in determining the hydric nature of these soils. These exclusions had relatively little impact on the final make-up of the WRP.

Region-specific Targeting of Production Practices under the Baseline

Under the baseline, net returns to crop production defined as gross revenue less variable costs on all land in the study region is $19.165 billion or $88.53 per acre. A total of 216,481,000 acres are in crops. The major crop is corn for grain grown on 68.7 million acres or 32 percent of the total area in crops. Other principal crops include soybeans (44.2 million acres), legume hay (31.1 million acres), nonlegume hay (21.4 million acres), winter wheat (12.9 million acres) and spring wheat (10.3. million acres).

Nearly 70 percent of the crops are grown with conventional tillage. Forty-six percent (100.8 million acres) is plowed in the spring and 24 percent (50.6 million acres) is plowed in the fall. Reduced tillage is practiced on 27 percent (59.3 million acres) of the cropped area and no-till on nearly 3 percent (5.7 million acres). The dominant rotation in the study region is a corn-soybean rotation (CRN SOY). Twenty-four percent of the area is devoted to this rotation. Six other rotations are practiced on 5 to 9 percent of the total area. They include continuous corn (CRN), continuous legume hay (HLH), continuous nonlegume hay (NLH), corn-corn-soybean (CRN CRN SOY), corn-soybean-winter wheat (CRN SOY WWT) and summer fallow-spring wheat (SMF SWT). None of the cropland is treated with winter cover crops under the baseline.

Average fertilizer application rates for the macro nutrients are 54.91 pounds per acre of nitrogen, 34.53 pounds per acre of potassium, and 23.75 pounds per acre of phosphorous. In total, 11.9 billion pounds of nitrogen, 7.5 billion pounds of potassium, and 5.1 billion pounds of phosphorous are applied. In all cases, the units are pure nutrient equivalents (i.e, pounds of pure N, P and K). Soil erosion occurs at an average rate of 4.51 tons per acre or nearly one billion tons on all cropland in the study region.

Region-specific Targeting with Winter Cover Crops

A total of 11,365,190 acres or approximately 5 percent of all crop acres are treated with winter cover crops. Of those, 6,093,920 acres are planted to rye and 5,271,270 acres to hairy vetch. While establishing the cover crop in the fall costs money and yields of the crop planted the following spring are typically reduced, the costs are partially offset by nitrogen savings provided by hairy vetch. No other economic benefits are considered. Consequently, when winter cover crops are forced to be grown, average net returns are reduced by 1.18 percent or $1.05 per acre (Table 1). Establishment costs for cover crops range from $14 to $22 per acre and costs associated with lost yields are estimated at $5 to $15 per acre with 1991 commodity prices. Therefore, total costs per acre for establishing cover crops ranges from $19 to $37 per acre.

As mentioned earlier, about 5 percent of the cropland is treated with cover crops. Consequently, if no other adjustments in crop mix, tillage and rotations, for example, are made in response to the constraint, we would expect the average net returns per acre to decrease by about 5 percent of the establishment costs or by $0.95 to $1.85 per acre. The value estimated falls at the lower end of this range. While some savings are realized in nitrogen costs on the acres planted to hairy vetch, the low-end estimate probably also reflects adaptive behavior on the part of producers; that is, choosing the least-cost cover crops, changing the crop mix, choosing alternative tillage and rotation practices, and so forth.

Changes in the crop mix ranged from a 1.1 (8.81%) million acre increase in acres of wheat grown to a 1.2 (2.65%) million acre reduction in the area of soybeans grown (Table 2). In general, the areas of the crops targeted for cover crops either remained constant or experienced small increases. Increases were for corn silage (1.03%), oats (0.44%), sorghum silage (0.17%), and winter wheat. Reductions occurred in the area planted to the two major crops, corn (0.59%) and soybeans, and to nonlegume hay (0.17%).

Employment of conventional tillage with fall plowing decreases by 4 percent while conventional tillage with spring plowing increases by 2.2 percent (Table 3). This outcome is largely due to the inconsistency between fall plowing and establishing winter cover crops. The combination was simply prohibited in RAMS. Other adjustments included a 0.33 percent decrease in the use of reduced tillage. The major shift in crop rotations was a movement from planting a corn-soybean-winter wheat (CRN SOY WWT) rotation without cover crops in the baseline to one with winter cover crops (Table 4). Under the baseline 6 percent of total cropland was planted to the rotation. With the constraint on cover crops, 5.47 percent of the acres are planted to the same rotation but only 0.52 percent without cover crops, 1.27 percent with a rye winter cover and 3.68 percent with an hairy vetch winter cover. The other major rotations with cover crops are corn silage-soybean-3 years of legume hay (CSL SOY HLH HLH HLH), (1.17%) and sorghum-winter wheat (SRG WWT), (1.24%). The list of major rotations in the baseline, with the exception of corn-soybean-winter wheat, remains unchanged after the cover crop constraint is introduced.

Fertilizer application rates for all three macronutrients decline when winter cover crops are forced into the solution (Table 5). Nitrogen rates decline by 1.68 percent or 0.92 pounds per acre. In total, nearly 200 million fewer pounds of nitrogen are applied. The principal cause is likely the nitrogen supplied by the hairy vetch. Given about 2.4 percent of cropland is treated with hairy vetch with maximum[6] nitrogen savings of 55 pounds per acre in the middle region and 78 pounds per acre in the south, we might expect a savings of between 1.3 and 1.9 pounds per acre. The lower value estimated indicates that adjustments, such as the decrease in soybean acreage, may have offset some of the gains made by the hairy vetch. Lesser reduction in the amount of potassium (0.41%) and phosphorous (0.03%) are experienced. A reduction in soil erosion of 2.72 percent or 0.12 pounds per acre was also estimated (Table 6). Most of the savings is probably attributable to the winter cover crops but the shift from fall plowing to spring plowing under the conventional tillage systems might have contributed to the savings as well. Some of those savings are offset by the smaller area treated with reduced tillage systems.

Region-specific Targeting with Conservation Tillage

When no yield adjustment is assumed, average net returns per acre actually rise by \$0.67 per acre (0.76%) for the low target (EI=8) and \$4.06 per acre (5.35%) for the high target (EI=2) (Table 7). This outcome is a manifestation of the relative costs and yields in RAMS. While, as

[6]Because all of the nitrogen fixed by the hairy vetch is not always demanded by the succeeding crop and because any excess is not carried over to the next year, the values represent maximum savings of nitrogen.

mentioned in the previous section, yields are nearly equal across tillages, the costs of no-till and reduced tillage systems are lower. Lower machinery costs more than offset the higher chemical costs in these systems. Consequently, they are very attractive alternatives in RAMS. In the baseline the dilemma these circumstances create is handled with flexibility constraints,[7] which force the model to calibrate to observed historical patterns of tillage. Modeling higher conservation tillage targets demands that these constraints be dropped in favor of even higher levels of no-till and reduced tillage. Consequently, returns increase relative to the baseline. If yields with the conservation tillage systems are adjusted downward then net returns per acre fall by $3.02 (3.41%) per acre for the low target and $2.93 (3.31%) per acre for the high target. Clearly the lower costs associated with no-till and reduced tillage systems are not sufficient to offset the lower yields.

The pattern of shifts in crop acreages is rather cloudy and only a few generalizations are apparent. Soybeans, sorghum grain, and barley are the only crops to show increases from the baseline for both low and high targets under both yield assumptions (Table 8). Furthermore, the areas for these three crops increase more with the higher target and when lower yields for no-till and reduced tillage are assumed. For soybeans, with no yield adjustments, areas increase by 278,000 (0.63%) and 523,000 (1.18%) acres for the low and high target. With the yield adjustment, increases are 944,000 (2.14%) and 646,000 (1.46%) acres. For barley the respective changes are 130,000 (2.5%), 130,000 (2.5%), 306,000 (5.87%) and 307,000 (5.88%) acres. For sorghum grain the changes are 264,000 (5.39%), 593,000 (12.11%), 554,000 (11.32%) and 697,000 (14.25%) acres. Nonlegume hay and legume hay are the only crops to experience consistent area losses. Just as with soybeans, sorghum grain and barley, the changes are larger for the higher target and when lower yields for no-till and reduced tillage are assumed. The changes from the baseline in area planted to legume hay with no yield adjustment are 21,000 (0.07%) and 547,000 (1.76%) acres for the low and high targets. With the yield adjustment, the areas decrease by 320,000 (1.03%) and 823,000 (2.65%) acres for the

[7]Flexibility constraints are simply upper bounds on the areas of no-till and reduced tillage. A separate constraint is included for each tillage system.

low and high targets. The corresponding changes for nonlegume hay are 0.547 (2.56%), 3.088 (14.43%), 1.565 (7.32%), and 3.632 (16.98%) million acres. The outcomes suggest that no-till and reduced tillage systems favor soybeans, sorghum for grain, and barley relative to other crops. It is not surprising that increases in these crops come at the expense of nonlegume and legume hay because the small seed of these crops benefit more from a well-prepared seed-bed. One other interesting shift is the increase in summer fallow with the higher target. When no yield adjustments are made, 1.2 (17.17%) million more acres are summer fallowed and with yield adjustments, 0.9 (13.33%) million. Because no vegetation is grown during the fallow period, such an increase may have important implications for soil organic carbon levels.

The most striking outcomes are the percentage increases from the baseline in the area treated with no-till. The increase was as high as 905.37 percent or 51.3 million acres for the high target with no yield adjustment (Table 9). Other increases for no-till in descending order are 22.8 (401.42%) million acres for the high target with yield adjustments, 3.9 (69.13%) million acres for the low target without yield adjustments, and 2.7 (47.91%) million acres for the low target with yield adjustments. Increases for reduced till with no yield adjustments are 4.0 (6.77%) and 4.4 (7.46%) million acres for the low and high targets. With yield adjustments the increases are 5.2 (8.8%) and 33.0 (55.64%) million acres. Clearly no-till is favored over reduced till when a higher level of either is required. Only when a 10 percent yield reduction for no-till versus a 5 percent reduction for reduced tillage systems is assumed do the absolute acreage increases for reduced tillage exceed those for no-till. In all but one case, the percentage decreases in area treated with conventional tillage with fall plowing exceed those for conventional tillage with spring plowing. However, the absolute acreage decreases for spring plowing are always larger. With no yield adjustments, the decreases for the low and high targets are 1.1 (2.18%) and 22.4 (44.24%) million acres with fall plowing and 6.8 (6.78%) and 33.4 (33.07%) million with spring plowing. When yield adjustments are made the decreases for the low and high targets are 3.7 (7.23%) and 23.2 (45.73%) million acres with fall plowing and 4.3 (4.24%) and 32.6 (32.33%) million acres with spring plowing. The mix of crop rotations employed is relatively steady. The major rotations used in the baseline are also the major rotations for each of the policy runs (Table 10). With the exception of the corn-soybean (CRN SOY) rotation, no patterns are apparent and generalizations do not seem warranted. The corn-soybean (CRN SOY) rotation increases with the higher target and is higher when yield adjustments are made.

As with winter cover crop targets, fertilizer use and erosion are reduced when conservation tillage targets are included. Without yield adjustments, nitrogen rates decreases by 0.13 (0.22%) and 0.59 (1.07%) pounds per acre for the low and high targets (Table 11). When yield adjustments are considered, nitrogen rates go down by .69 (1.25%) and 0.19 (0.34%) for the low and high targets. Total savings of nitrogen are 28.1, 127.7, 149.4 and 41.1 million pounds respectively. Similar decreases are observed for the other macro nutrients, never exceeding 1.4 percent for potassium or 0.6 percent for phosphorous. Most of the savings in nitrogen can be attributed to the larger areas planted to soybeans and to more corn being grown in a corn-soybean rotation. Substantial decreases in erosion rates are estimated to occur. With no yield adjustments, erosion rates decrease by 0.14 (3.08%) and 1.55 (34.34%) tons per acre for the low and high targets (Table 12). With yield adjustments the corresponding reductions are 0.11 (2.58%) tons per acre and 1.03 (22.85%) tons per acre. Total soil savings in the region are 30.3, 335.5, 23.8, and 223.0 million tons.

National Shifts in Land Use Patterns under the Baseline

Baseline values for acres harvested of the program crops and soybeans are given at the top of Table 13 for the years 2010 and 2030. Note that over time, acres harvested of all these crops except cotton are anticipated to increase. Total acres harvested of these crops rises 8 percent from 266 million acres in 2010 to 286 million acres in 2030 due to underlying assumptions in the model about growth in the general economy and in crop production technology. The land use pattern in the baseline, on the other hand, remains about the same over time: corn accounts for about 32 percent of all acres in both years; wheat for 29 percent; soybeans for 23 percent; and barley, sorghum, and oats together account for about 10 percent of all acreage for these crops.

National Shifts under the CRP Scenarios

Table 14 gives the percentage changes from the baseline in crop acreages, yields, and crop producer prices for the years 2010 and 2030 for all scenarios. As expected, crop acreages in CRP2 and CRP3 are lower throughout the study period than under CRP1. In percentage terms, acres harvested of barley, sorghum, and oats are reduced the most, especially barley acres. This is due mostly to the high percentage of feed-grain acres idled by the present CRP program and the assumption that the new programs will generally reflect historic sign-ups. Of the major crops, soybean acreage is affected least by the increases in CRP coverage, primarily because a relatively small proportion of present soybean acres are idled in CRP. Total acreage does not fall by as much as the size of the CRPs, though. Under CRP2, total acreage is only 16.7 million acres lower than under CRP1 in 2010, even though the move from CRP1 to CRP2 ultimately removes 17.1 million acres from production. The difference is due primarily to farmers bringing previously unplanted land into production in response to the higher crop prices induced by the CRP acreage reductions over time. For CRP3, the gross reduction in acreage of these crops due to CRP is 24.6 million acres, but projected acreage planted actually falls by only 22.8 million acres.

The reductions in acreage are slightly offset by increases in yields on harvested acres of the major crops, except barley. The direction and magnitudes of these changes depend upon the responsiveness of farmers to changes in price expectations, the impact of changes in feed demands, and the rate of technological change (represented by time trends in BLS) for each crop. The net result is not at all surprising: production of all major crops is less in the larger CRP scenarios throughout the study period than in the 17.5 million acre CRP1. The relative differences between scenarios (in percentage terms) are seen most dramatically in feed grains. The smaller supply of these crops leads to higher producer prices for all major crops.

Beef production increases in both scenarios relative to CRP1 while production of pork, milk, poultry, and eggs falls. The increases in beef production are slightly higher under CRP3, but in both scenarios, the increases are on the order of only 1 to 2 percent. The increases reflect improved demand for beef and veal relative to CRP1. Pork production falls by 2.5 to 4 percent under CRP2 and by 4.2 to 5.8 percent under CRP2. The drops in poultry and egg production are relatively small in both scenarios, and milk production is barely changed compared with milk production under CRP1. All livestock producer prices increase in both scenarios but more so under CRP3 than under CRP2.

Consumption of wheat and coarse grain products falls under both scenarios by 1 to 2 percent, reflecting retail price increases of 2 to 5.5 percent in CRP2 and 3.6 to 7.4 percent in CRP3. Consumption of beef changes very little in either scenario even though retail prices for beef and veal increase slightly. In both scenarios, per capita consumption of other animal products (primarily pork, poultry, and fish) decreases by 1 to 2 percent. Consumption of dairy products, cotton, and tobacco are relatively unchanged between scenarios.

Projected changes in net production returns and government costs are given in Table 14 in constant dollar terms. Changes in net returns to production are estimated outside of the BLS, but are based upon recent (1989) data and the trends suggested by the BLS runs. In general crop producers gain, livestock producers lose, and net government costs fall relative to CRP1. The results indicate that in the long run, however, the industry as a whole does not gain from the larger programs relative to the 17.5 million acre program.

Higher grain prices in CRP2 and CRP3 boost net returns from crop production, excluding government payments, and lower net returns to livestock production relative to CRP1. Higher grain prices also lower government transfer payments for the crop programs (price supports, deficiency payments, etc.), more than offsetting the estimated increases in CRP payments. Thus, total government payments actually fall relative to CRP1. Crop producers benefit substantially from the larger CRP scenarios. The net gains to crop producers through transfer payments and production returns do not, however, fully compensate for declines in net returns to livestock production. The net result for the agriculture sector is a decline in industry net returns of $350 to $460 million per year. By comparison, the average U.S. net farm income from 1989 to 1991 was about $47 billion

(USDA, 1992). So these annual losses would probably amount to less than 1 percent of net farm income.

National Shifts under the WRP Scenario

The largest impacts on crop production due to the WRP will be for soybeans and corn. Indeed, the results show that acreages of these crops fall about 4 percent for soybeans and 2 percent for corn. Other feed-grain acreage also falls 1 percent. Cotton acreage falls by less than 1 percent while the other crops are relatively unaffected. Yields for all crops change very little, if at all. Soybean producer prices increase by about 3 percent and corn prices by about 1 percent. Other feed-grain prices can be expected to follow the changes in corn price, but wheat and rice prices rise by only small margins. Production of pork and poultry fall by 1 to 2 percent, while production of other livestock products is relatively unaffected. Consequently, producer prices for pork and poultry increase by about 1 to 2 percent while other livestock prices increase only slightly.

With respect to net farm income, much the same story holds for the WRP scenario as for the CRP scenarios: crop producers gain, government payments fall, and livestock producers absorb most of the costs to agriculture due to higher feed costs. The estimated cost of obtaining easements on WRP land is $1.4 billion, but this represents one-time payments based on the discounted present value of expected net returns to that land if it remained in production. There is thus no change in annual reserve program payments relative to CRP1, which is assumed to run in conjunction with the WRP. Because there are no additional reserve program payments, the annual projected costs to agriculture of WRP are much higher than under CRP2 and CRP3, about $700 million versus $350-$400, even though the reserve is smaller.

Environmental Results

Crop acreage and production practice outcomes from RAMS and BLS are passed to the CENTURY model used to predict soil organic carbon levels in yearly increments to the year 2030 by Aqua Terra Consultants (Donigian, et al. 1993). Presently, only results for alternative levels of CRP and the targeted levels of conservation tillage (with no yield adjustments for conservation tillage) and winter cover crops are available.

Soil organic carbon levels in 2030 are estimated assuming the crop production activities, estimated in RAMS for the baseline and each policy alternative, are practiced starting in the base year, 1990, and continuing every year through 2030. For targets on conservation tillage, projected soil organic carbon levels, for the study region as a whole, are relatively unchanged or lower compared with the levels estimated for the baseline in the year 2030. Under the baseline, soil organic carbon levels are projected to increase nearly 32 percent from 1990 to 2030. With the low and medium conservation tillage targets, soil carbon increases are also 32 percent. For the high conservation tillage target, the estimated increase is nearly 31 percent. With targeted levels of winter cover crops, soil organic carbon levels observed in 2030 are 34 percent higher than in 1990. The level observed is 7 percent higher in 2030 than that under the baseline.

For the CRP analysis, 1986 was considered the base year. Two alternatives were examined. Both assume CRP enrollment is at the maximum level (40 million acres nationally, 15 million acres in the RAMS study area) in the base year. The first alternative corresponds with the BLS baseline (CRP1) in that 44 percent of the CRP land is returned to production as the original contracts expire and 56 percent remains idled. The second alternative, corresponding with CRP2, assumes that all of the land enrolled in the CRP is re-enrolled upon expiration of the original contract. A third case that does not correspond with any of the BLS runs but provides a benchmark of comparison assumes that CRP never existed and that all of the land remained in production. Compared with this benchmark, soil organic carbon levels are 12 percent higher under the assumptions corresponding with the BLS baseline and 4 percent higher for CRP2. The higher value for the BLS baseline is a result of incorporating surface organic matter into the soil when the CRP land is converted back to cropping.[8]

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[8]CENTURY evaluates soil organic values in the top 20 cm of the soil profile and does not account for residue stored on the soil surface.

Conclusions

This paper presents an economic evaluation of several policies designed to promote the build-up of organic carbon in agricultural soils. It is part of a broader, integrated effort to evaluate both economic and environmental outcomes. Two economic models were employed to evaluate two types of policies. RAMS is used to evaluate region-specific targeting of conservation tillage and winter cover crops while BLS is used to evaluate changes in land use patterns caused by the CRP and WRP. Both RAMS and BLS are linked to CENTURY, a soil organic formation model, which estimates soil organic carbon levels over time under alternative assumptions about agricultural practices and land use.

For the targets on conservation tillage and winter cover crops, the results indicate that the economic cost to producers is not overwhelming. Measured in terms of changes in net returns to crop production, decreases are never more than 3.5 percent. The changes are sufficiently small that relatively minor changes in the assumptions about yields can produce increases in net returns. But, if increases in soil organic carbon are the only environmental indicators considered, only the targeted winter cover crop alternative is successful. In general, forcing higher levels of conservation tillage does not improve soil organic carbon levels in the top 20 centimeters of the soil profile. More benefits may be observed if the organic matter stored at the surface of the soil is added to that in the top 20 centimeters of soil. Other environmental benefits, however, are evident. For the targeted level of winter cover crops, nitrogen application rates are reduced by about 1.5 percent. Smaller but positive reductions are also observed for potassium and phosphorous. In addition, decreases in erosion per acre of nearly 3 percent occur. The results for the targeted levels of conservation tillage are more striking. Reductions of up to 34 percent in erosion rates are estimated. Results for fertilizer applications are similar to those for the targets on winter cover.

Under the alternative CRP and WRP scenarios, producers and consumers are worse off than under the baseline scenario. Therefore, 12 and 4 percent increases in soil organic carbon stored, under the CRP1 and CRP2 alternatives relative to the no CRP case, must be weighed against the economic costs. In assessing the impacts of the CRP and WRP policies, it is important to remember that the assumptions about the make up of each alternative reserve program—the amount of land idled from each crop—play an important role in determining the relative impacts within agriculture, for instance whether corn producers benefit more than wheat producers, or whether pork production is affected more heavily than beef production. Our assumptions about the distribution of cropland within the scenarios should reasonably approximate the most likely outcomes. The overall effects on agriculture, however, should not depend so much on the particular assumptions made within each scenario, and the trends reflected in the results should be fairly robust.

Economic analyses from two divergent models are presented in this paper. Each provides useful information about policy impacts. But individually neither can provide results with a broad range of temporal and geographic characteristics. Linking RAMS and BLS is one strategy that would provide opportunities to obtain a more comprehensive list of economic indicators. While both RAMS and BLS are linked to CENTURY, linking the two economic models together is more difficult. Several issues and obstacles must be resolved. Both models have several common parameters (e.g., commodity prices and crop acreages) that are either estimated or used as input. Decisions must be made about which parameters to pass and at what level of aggregation. Furthermore, inconsistencies regarding the fundamental assumptions underlying each model must be resolved.

Table 1. Average net returns, baseline versus targeted levels of winter cover crops

Baseline	Cover Crop	Change from Baseline
(dollars per acre)		(percent)
88.53	87.48	1.18

Table 2. Acres of crops grown, baseline versus targeted levels of winter cover crops

Crop	Baseline	Cover Crops	Change from Baseline
	(acres)		(percent)
Barley	5218290	5218290	0.00
Corn Grain	68674800	68271200	-0.59
Corn Silage	3906800	3947080	1.03
Cotton	1227560	1227560	0.00
Legume Hay	31108800	31113200	0.01
Nonlegume Hay	21398800	21362800	-0.17
Oats	4814450	4835820	0.44
Sorghum Grain	4893650	5305190	8.41
Sorghum Silage	57881	57982	0.17
Soybeans	44186400	43014700	-2.65
Summer Fallow	6761860	6761860	0.00
Sunflower	1048920	1048920	0.00
Spring Wheat	10317700	10317700	0.00
Winter Wheat	12865300	13998800	8.81

Table 3. Tillage practices, baseline versus targeted levels of winter cover crops

	Baseline	Cover Crops	Percentage Change from Baseline
	(acres)		(percent)
Conventional Tillage /Fall Plow	50662200	48638000	4.00
Conventional Tillage /Spring Plow	100837000	103056000	2.20
Reduced Tillage	59310500	59115900	-0.33
No-till	5670960	5670970	0.00

Table 4. Major rotations, percentage of total acres, baseline versus targeted levels of winter cover crops (acres)

Crop Rotation	Baseline	Cover Crops
	(percent of total acres)	
Continuous CRN	8.36	8.46
CRN CRN SOY	7.11	6.91
CRN SOY	23.87	23.28
CRN SOY WWT	6.00	0.52
SMF SWT	5.43	5.43
Continuous HLH	8.43	7.78
Continuous NLH	8.34	8.35
CRN SOY WWT(rye cover)	0.00	1.27
CSL SOY HLH HLH HLH (rye cover)	0.00	1.17
SRG WWT(rye cover)	0.00	1.24
CRN SOY WWT(vetch cover)	0.00	3.68

Key:

CRN = corn for grain
CSL = corn for silage
HLH = legume hay
NLH = nonlegume hay
SMF = summer fallow
SWT = spring wheat
SOY = soybeans
SRG = sorghum for grain
WWT = winter wheat

Table 5. Fertilizer applications rates, baseline versus targeted levels of winter cover crops

Fertilizer	Baseline	Cover Crops	Change from Baseline
	(pounds per acre)		(percent)
Nitrogen	54.81	53.89	-1.68
Potassium	34.53	34.39	-0.41
Phosphorous	23.75	23.74	-0.03

Table 6. Soil erosion rates, baseline versus target levels of winter cover crops

Baseline	Cover Crops	Change from Baseline
(tons per acre)		(percent)
4.51	4.39	-2.72

Table 7. Net returns per acre, baseline versus targeted levels of conservation tillage (dollars/acre)

	Tillage Targets				
	Baseline	Low-w/ Yield Adj	High-w/ Yield Adj	Low-w/ Yield Adj	High-wo/ Yield Adj
Dollars per acre	88.53	89.20	93.26	85.51	85.60
Percentage Change from Baseline		0.76%	5.35%	-3.41%	-3.31%

Table 8. Acres of crops grown, baseline versus targeted levels of conservation tillage

		Tillage Targets			
	Baseline	Low-w/ Yield Adj	High-w/ Yield Adj	Low-wo/ Yield Adj	High-wo/ Yield Adj
Barley	5218290	5348530	5348760	5524620	5525140
		2.50%	2.50%	5.87%	5.88%
Corn Grain	68674800	68759800	68831300	68444200	69360500
		0.12%	-0.23%	-0.34%	1.00%
Corn Silage	3906800	3923660	3733160	4030600	3735510
		-4.43%	-4.44%	3.17%	-4.38%
Cotton	1227560	1227560	1227560	1227560	1227560
		0.00%	0.00%	0.00%	0.00%
Legume Hay	31108800	31087900	30561100	30788200	30285000
		-1.07%	-1.76%	-1.03%	-2.65%
Nonlegume Hay	21398800	20851000	18310700	19833200	17766200
		-2.56%	-14.43%	-7.32%	-16.98%
Oats	4814450	4793190	5011560	4825860	504880
		-0.44%	4.09%	0.24%	4.81%
Sorghum Grain	4893650	5157650	5486170	5447810	5590920
		5.39%	12.11%	11.32%	14.25%
Sorghum Silage	57880.8	57533.7	57533.7	57679.2	57207.3
		-0.60%	-0.60%	-0.35%	-1.16%
Soybeans	44186400	44464600	44709900	45130500	44832300
		0.63%	1.18%	2.14%	1.46%
Summer Fallow	6761860	6761860	9722570	6763800	7663330
		0.00%	17.17%	0.03%	13.33%
Sunflower	1048920	1048920	1048920	1057430	1057430
		0.00%	0.00%	0.81%	0.81%
Spring Wheat	10317700	10317700	1030600	10176200	10189000
		0.00%	-0.11%	-1.37%	-1.25%
Winter Wheat	12865300	12681200	13925700	13173300	14145100
		-1.43%	8.24%	2.39%	9.95

Note: Percentage changes from baseline shown below estimated values.

Table 9. Tillage practices, baseline versus targeted levels of conservation tillage

		Tillage Targets			
		(percentage of total acres)			
	Baseline	Low - w/ Yield Adj	High - w/ Yield Adj	Low - wo/ Yield Adj	High - wo/ Yield Adj
Conventional Tillage/Fall Plow	50662200	49559100 -2.18%	28247300 -44.24%	46999100 -7.23%	27493300 -45.73%
Conventional Tillage/Spring Plow	100837000	94003800 -6.78%	67486500 -33.07%	96563800 -4.24%	68240300 -32.33%
Reduced Tillage	59310500	63326900 6.77%	63733100 7.460%	64529900 8.80%	92312200 55.64%
No-till	5670960	9591280 69.13%	57014300 905.37%	8388200 47.91%	28435200 401.42%

Note: Percentage changes from baseline shown below estimated values.

Table 10. Major rotations, percentage of total acres, baseline versus targeted levels of conservation tillage

		Tillage Targets			
	Baseline	Low-w/ Yield Adj	High-w/ Yield Adj	Low-wo/ Yield Adj	High-wo/ Yield Adj
		(percentage of total acres)			
Continuous CRN	8.36	8.37	7.96	8.42	8.71
CRN CRN SOY	7.11	7.22	7.13	6.03	6.39
CRN SOY	23.87	23.92	24.23	25.03	24.82
CRN SOY WWT	6.00	6.00	5.99	6.2	6.29
Continuous HLH	8.43	8.43	7.63	8.34	8.45
Continuous NLH	8.34	8.39	6.96	7.94	6.65

Key: CRN=corn for grain
HLH=legume hay
NLH=nonlegume hay
SMF=summer fallow
SWT=spring wheat
SOY=soybeans
WWT=winter wheat

Table 11. Fertilizer application rates, baseline versus targeted levels of conservation tillage

		Tillage Targets			
	Baseline	Low-w/ Yield Adj	High-w/ Yield Adj	Low-wo/ Yield Adj	High-wo/ Yield Adj
		(pounds per acre)			
Nitrogen	54.81	54.68	54.22	54.12	54.62
		-0.22	-1.07	-1.25	-0.34
Potassium	34.5321	34.52	34.15	34.39	34.07
		-0.03	-1.08	-0.40	-1.32
Phosphorous	23.74	23.73	23.60	23.71	23.68
		-0.07	-0.60	-0.16	-0.26

Note: Percentage changes from baseline shown below estimated values.

Table 12. Soil erosion rates, baseline versus targeted levels of conservation tillage

	Tillage Targets			
Baseline	Low-w/ Yield Adj	High-w/ Yield Adj	Low-wo/ Yield Adj	High-wo/ Yield Adj
4.51	4.37	2.96	4.40	3.48
	-3.08	-34.34	-2.58	-22.85

Note: Percentage changes from baseline shown below estimated values.

Table 13. Baseline and percentage changes in production indicators relative to CRP1, selected years

Year	Wheat	Rice	Corn	Other Grains	Soybeans	Cotton
CRP1			(million acres)			
2010	75.0	3.6	85.3	27.3	61.0	13.3
2030	81.6	4.5	91.1	29.8	65.7	13.0
CRP2			(percent change)			
Acres Harvested						
2010	-8.0	-2.0	-4.0	-15.0	-2.0	-6.8
2030	-7.0	-1.6	-5.0	-18.0	1.0	-7.3
Yields						
2010	0.2	1.4	0.3	-1.3	0.1	1.0
2030	0.3	1.2	0.3	-2.6	0.2	0.9
Producer Prices						
2010	4.1	1.0	5.6	5.6	3.1	1.0
2030	5.5	2.6	4.7	4.7	4.4	0.0
CRP3			(percent change)			
Acres Harvested						
2010	-10.0	-2.3	-6.0	-20.0	-5.0	-8.9
2030	-9.0	-1.8	-7.0	-28.0	-1.0	-9.5
Yields						
2010	0.3	1.6	0.4	-1.2	0.2	1.0
2030	0.3	1.3	0.4	-4.6	0.3	0.9
Producer Prices						
2010	5.3	1.2	7.6	7.6	6.2	1.4
2030	6.8	3.3	6.2	6.2	7.8	-0.3
WRP1			(percent change)			
Acres Harvested						
2010	0.0	0.0	-2.0	-1.0	-4.0	-0.7
2030	0.0	0.1	-2.0	-1.0	-3.0	-0.8
Yields						
2010	0.0	0.1	0.1	0.1	0.0	0.0
2030	0.0	0.0	0.0	-0.1	0.1	0.0
Producer Prices						
2010	0.8	0.2	1.4	1.4	3.4	0.3
2030	1.3	0.8	1.0	1.0	3.6	0.1

Table 14. Estimated changes from CRP1 in net producer returns, selected years

	Crop Production Net Returns	Program Payments	CRP Payments	Total Crop Net Returns	Livestock Net Returns	Agriculture Net Returns
			(million 1989 dollars)			
CRP2						
2010	1300	-2103	1035	232	-576	-345
2030	1950	-2498	1035	488	-838	-350
CRP3						
2010	1793	-2739	1519	573	-939	-366
2030	2660	-3254	1519	925	-1384	-459
WRP1						
2010	417	-373	0	44	-717	-673
2030	542	-393	0	149	-856	-708

APPENDIX A. Graphical Representation of Table Data

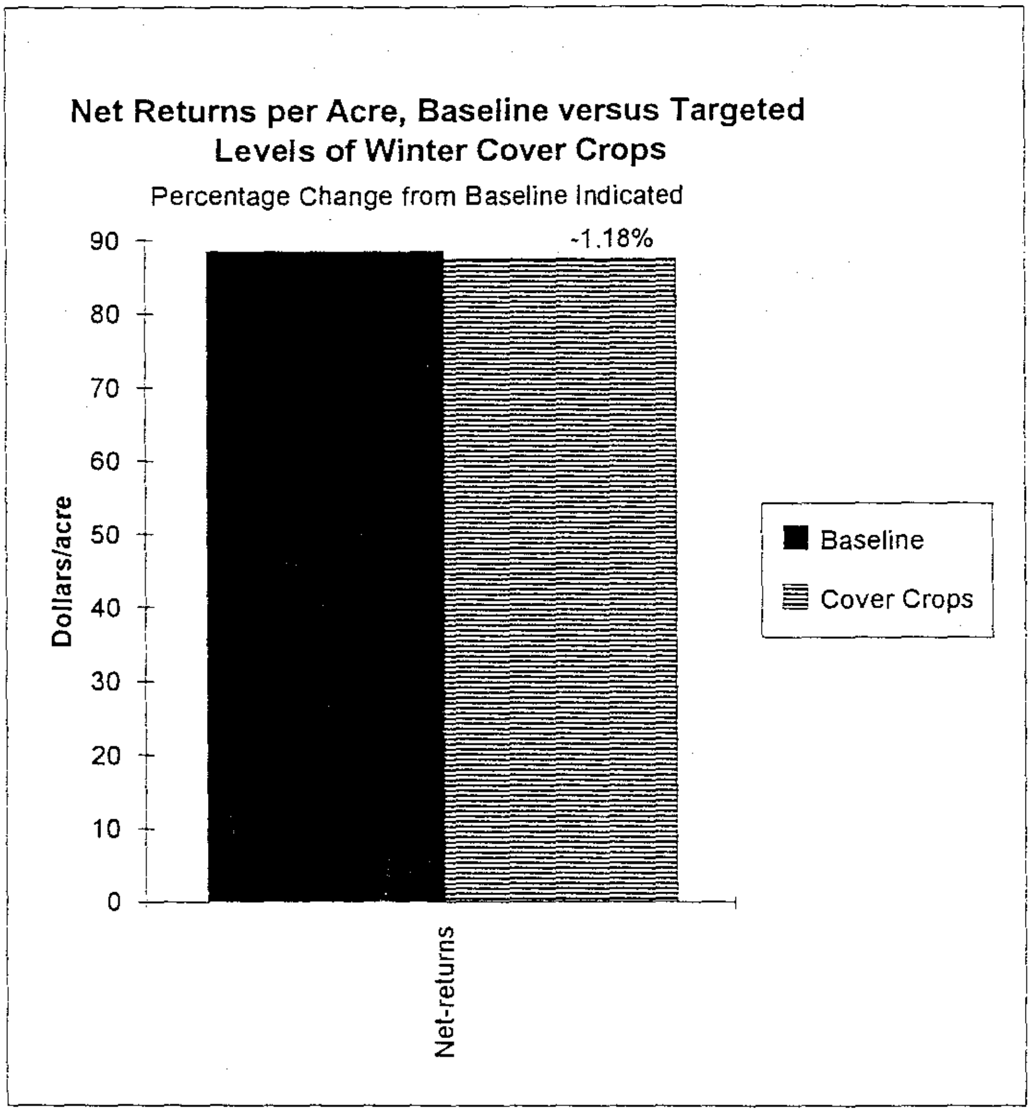
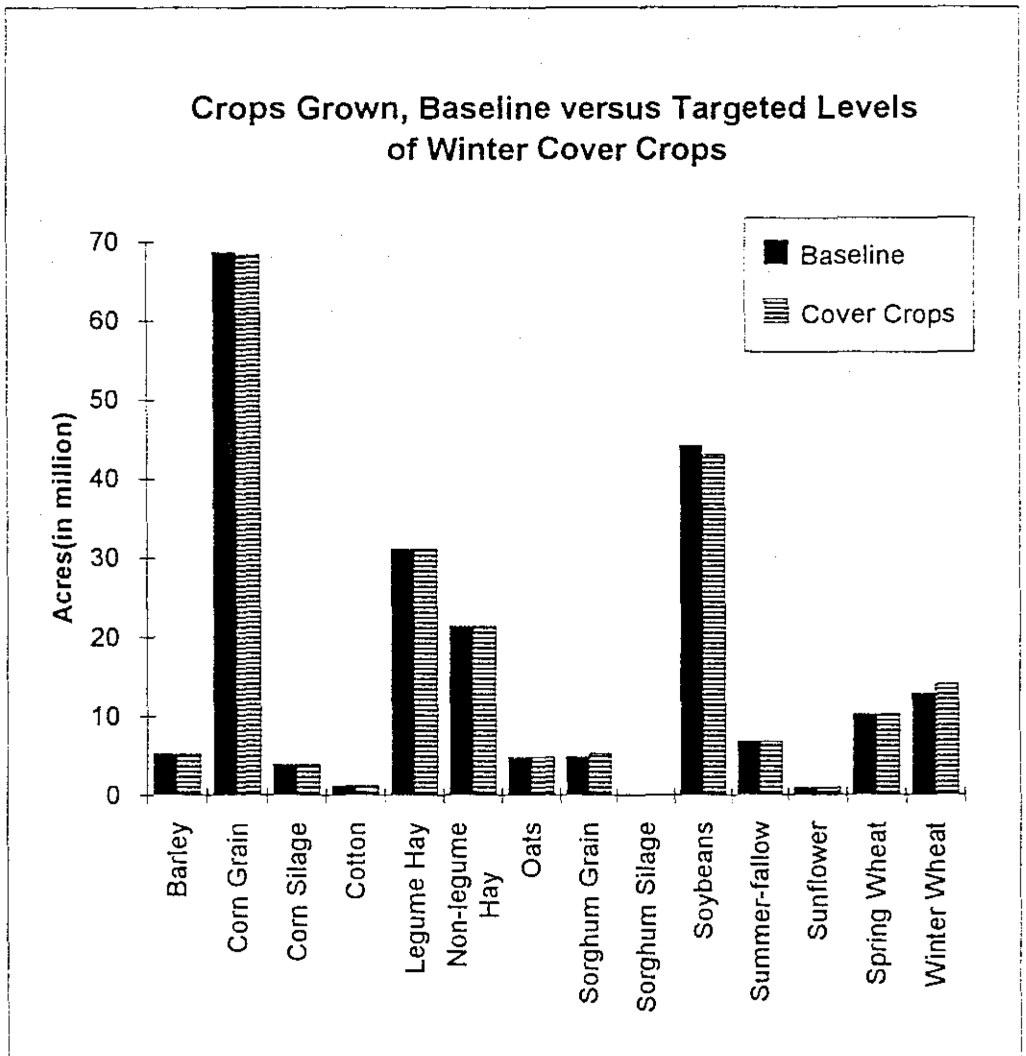


Figure A.1. (Corresponds with Table 1)



Percentage Change from Baseline		
	Baseline	Cover Crops
Barley	5.22	0.00%
Corn Grain	68.67	-0.59%
Corn Silage	3.91	1.03%
Cotton	1.23	0.00%
Legume Hay	31.11	0.01%
Non-legume Hay	21.4	-0.17%
Oats	4.82	0.44%
Sorghum Grain	4.89	8.41%
Sorghum Silage	0.058	0.17%
Soybeans	44.19	-2.65%
Summer Fallow	6.76	0.00%
Sunflower	1.05	0.00%
Spring Wheat	10.32	0.00%
Winter Wheat	12.87	8.81%

Figure A.2. (Table 2)

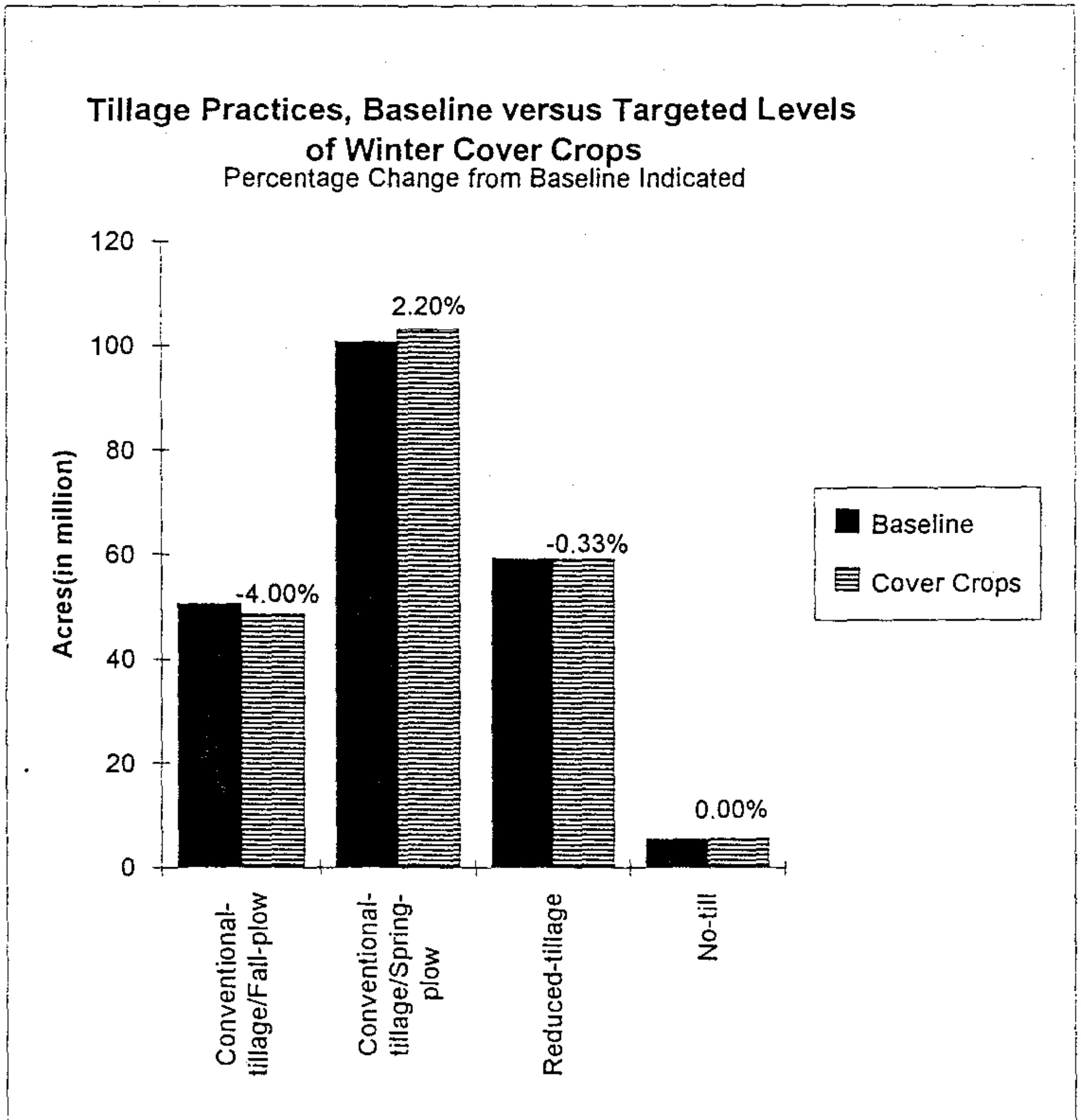
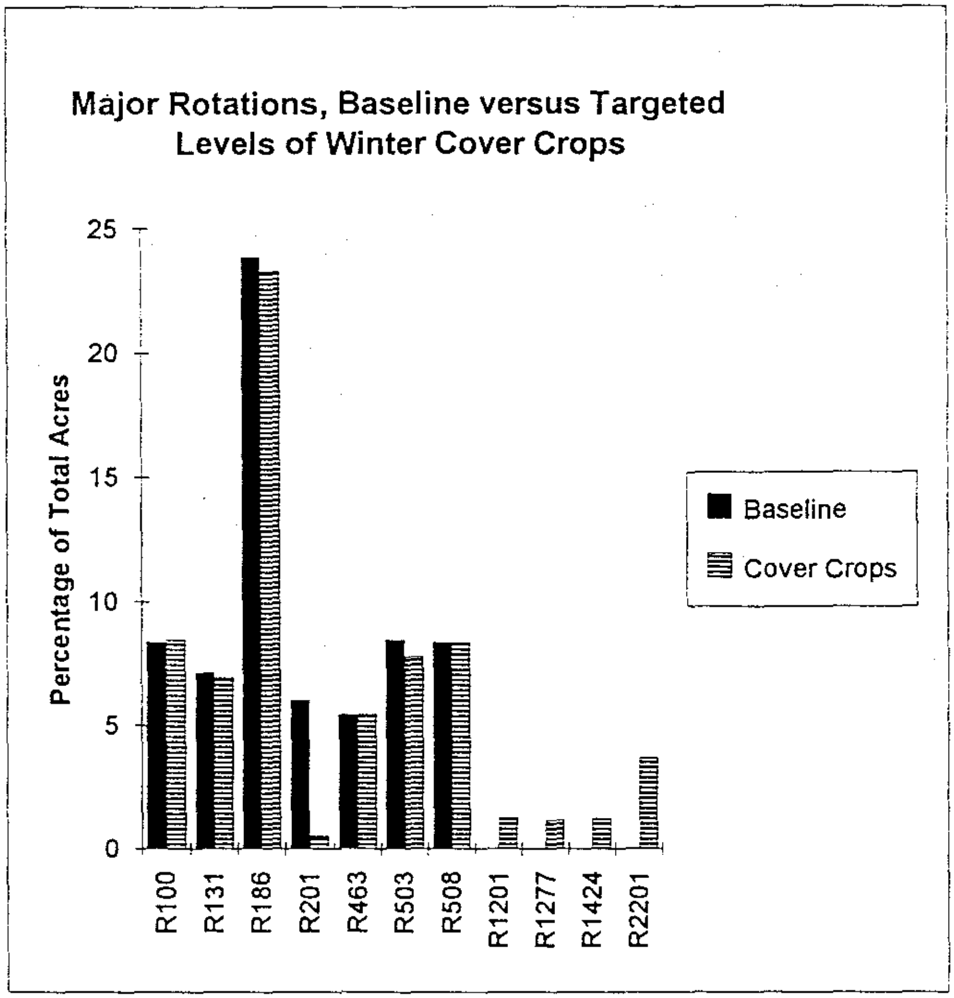


Figure A.3. (Table 3)



Key:

- R100 Continuous CRN
- R131 CRN CRN SOY
- R186 CRN SOY
- R201 CRN SOY WWT
- R463 SMF SWT
- R503 Continuous HLH
- R508 Continuous NLH
- R1201 CRN SOY WWT(rye cover)
- R1277 CSL SOY HLH HLH HLH(rye cover)
- R1424 SRG WWT(rye cover)
- R2201 CRN SOY WWT(vetch cover)

Where

- CRN: Corn grain
- SOY: Soybeans
- WWT: Winter wheat
- SMF: Summer fallow
- SWT: Spring wheat
- HLH: Legume hay
- NLH: Non-legume hay
- CSL: Corn silage
- SRG: Sorghum grain

Figure A.4. (Table 4)

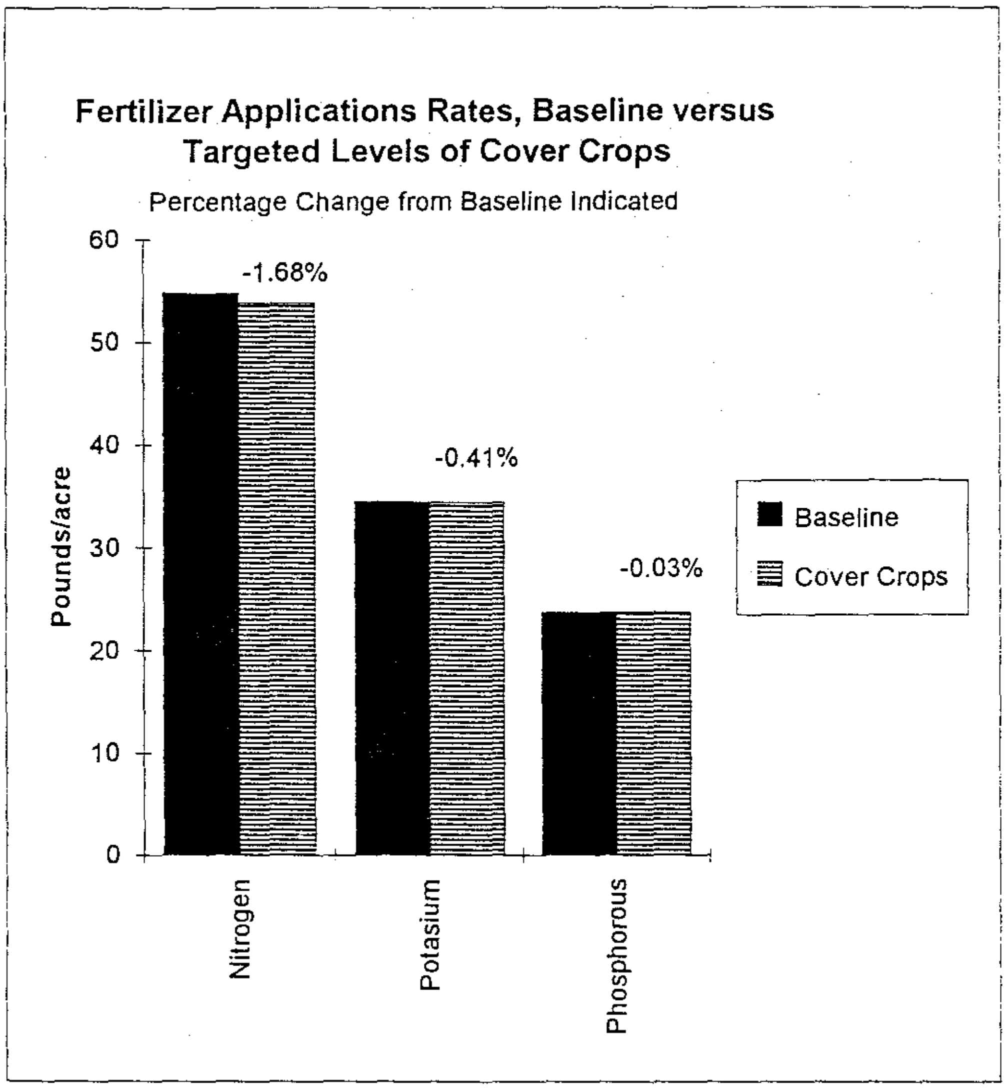


Figure A.5. (Table 5)

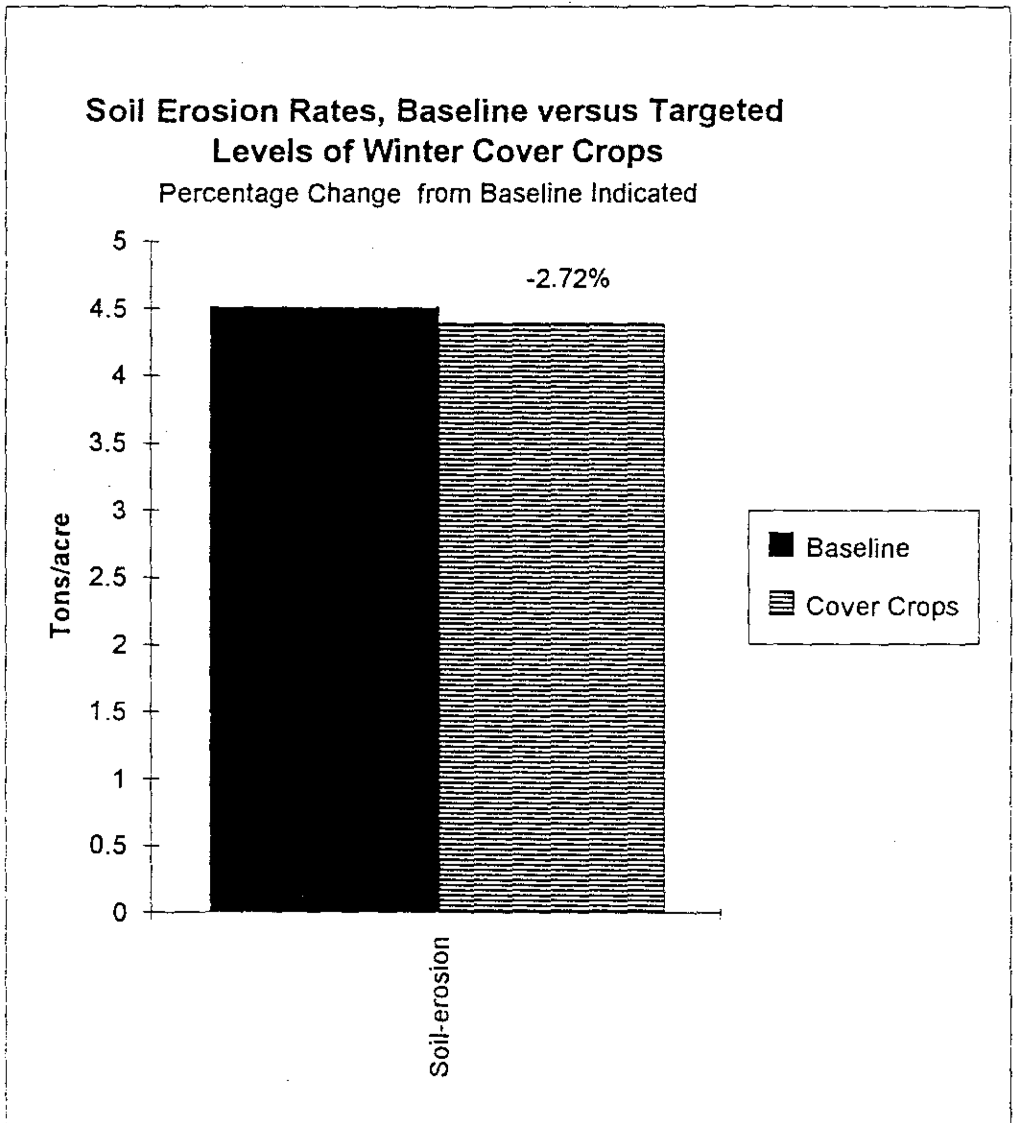
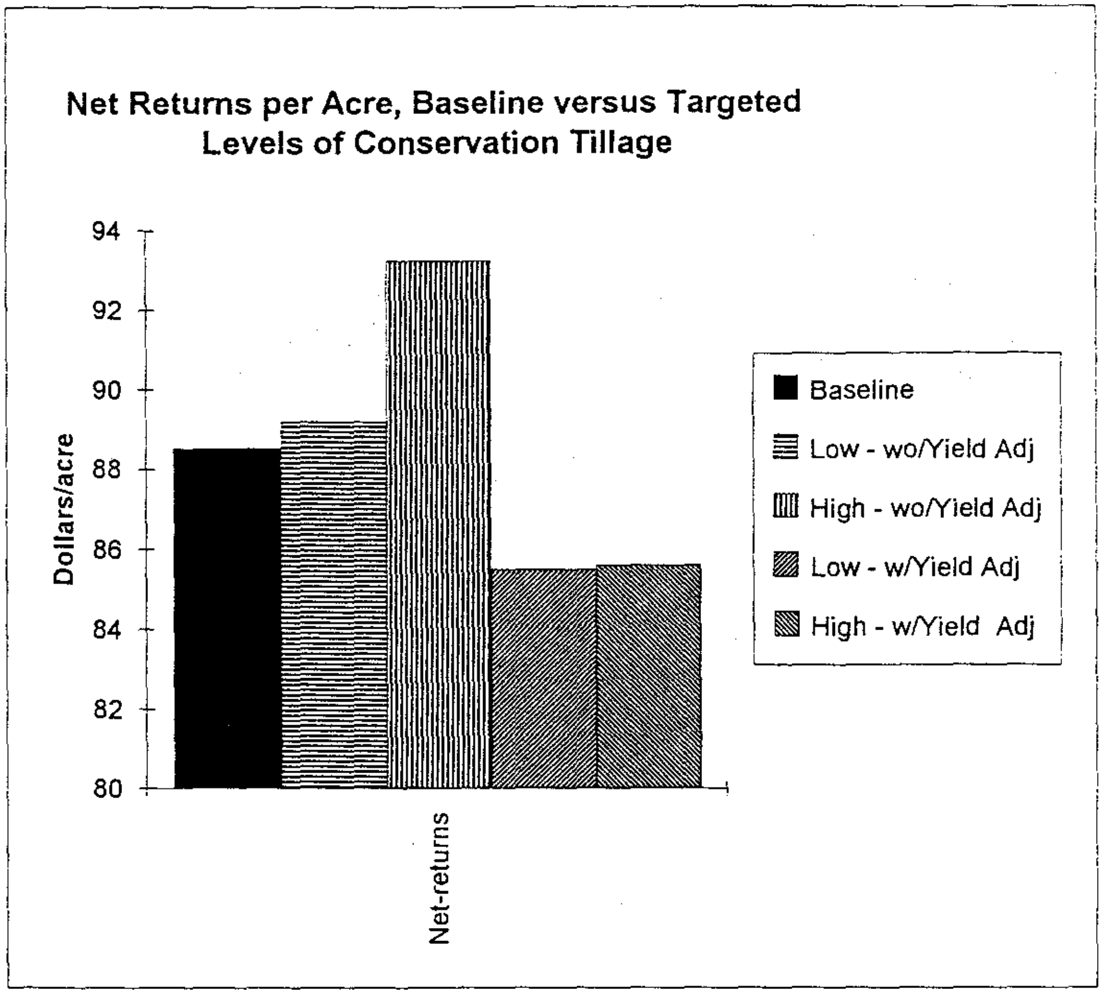
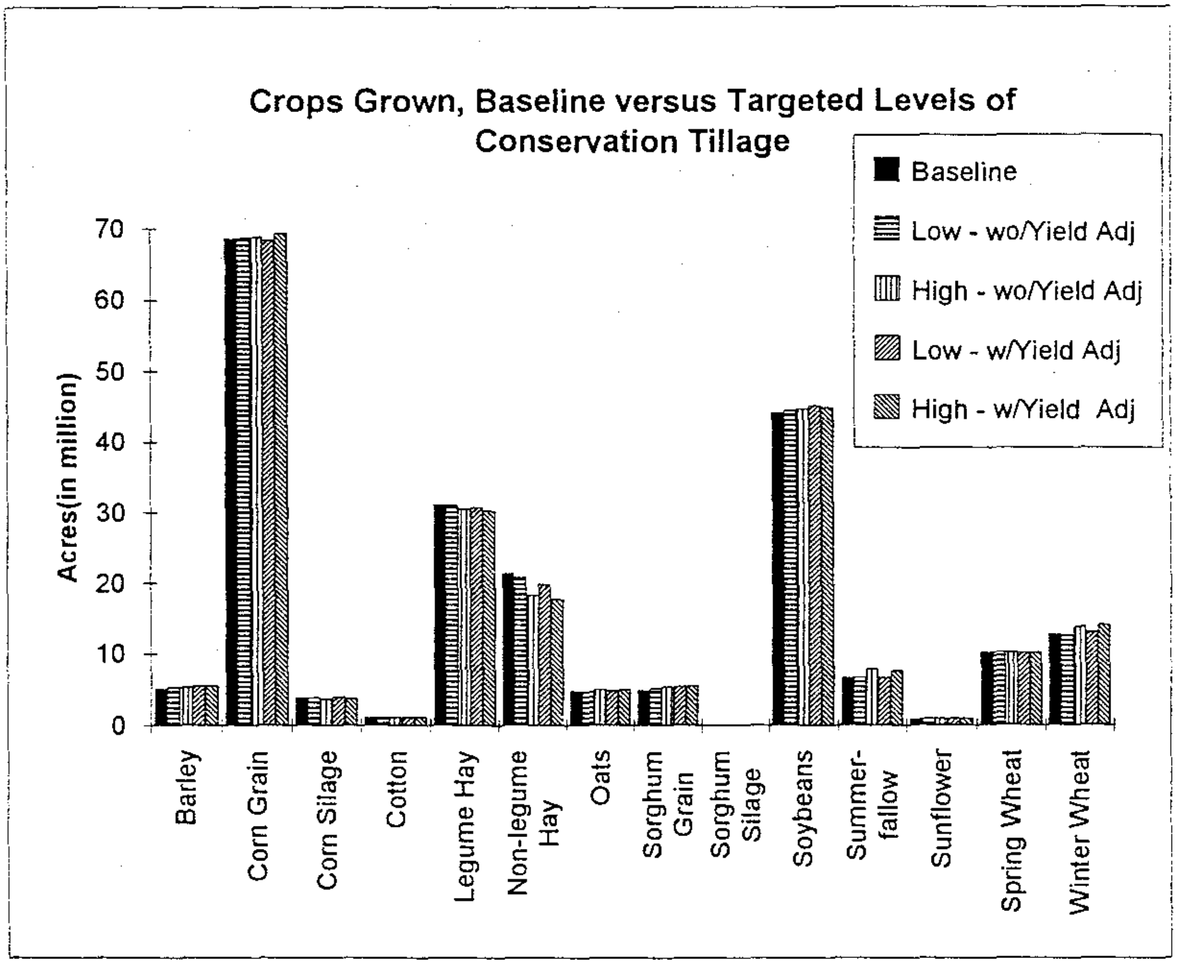


Figure A.6. (Table 6)



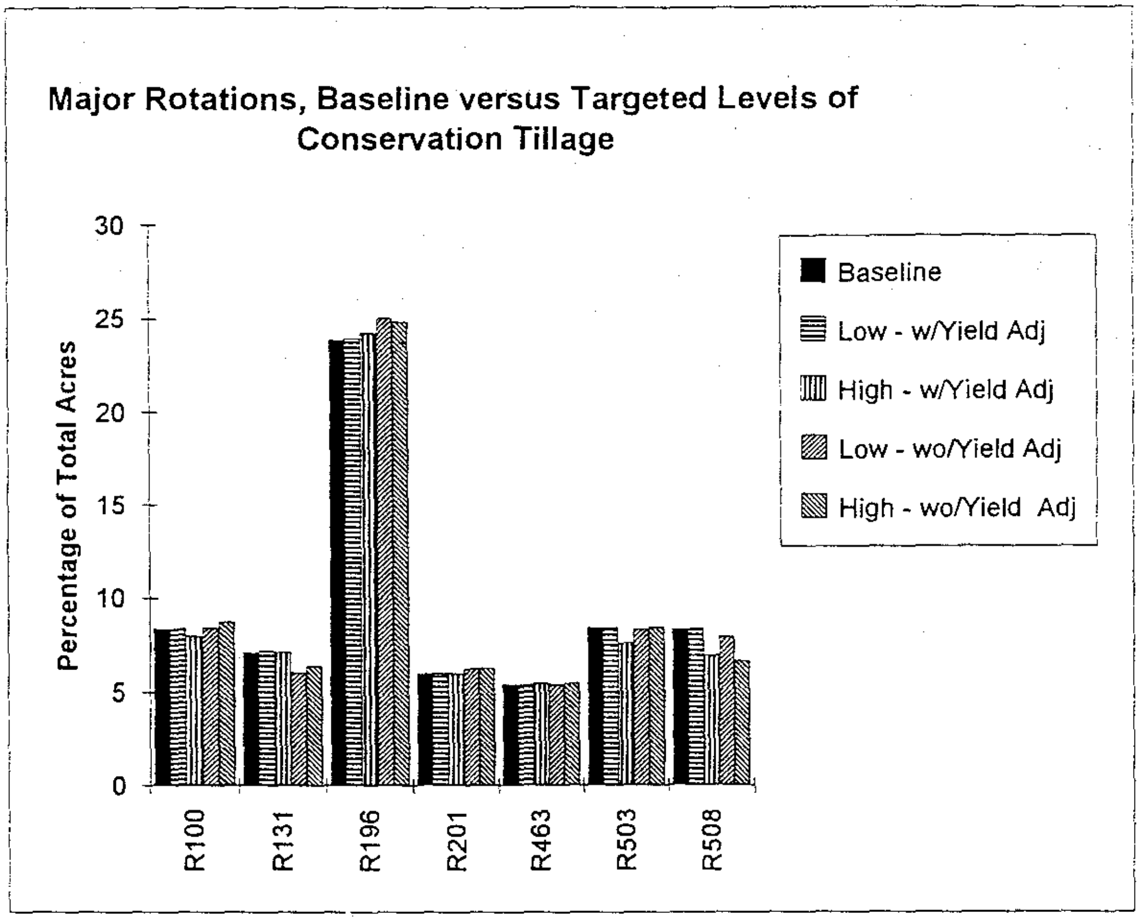
Percentage Change from Baseline				
Baseline	Tillage Targets			
	Low -wo/Yield Adj	High-wo/Yield Adj	Low -w/Yield Adj	High-w/Yield Adj
88.53	0.76%	5.53%	-3.41%	-3.31%

Figure A.7. (Table 7)



		Percentage Change from Baseline			
	Baseline	Tillage Targets			
		Low - wo/Yield Adj	High - wo/Yield Adj	Low - w/Yield Adj	High - w/Yield Adj
Barley	5.22	2.50%	2.50%	5.87%	5.88%
Corn Grain	68.67	0.12%	0.23%	-0.34%	1.00%
Corn Silage	3.91	0.43%	-4.44%	3.17%	-4.38%
Cotton	1.23	0.00%	0.00%	0.00%	0.00%
Legume Hay	31.11	-0.07%	-1.76%	-1.03%	-2.65%
Non-legume Hay	21.4	-2.56%	-14.43%	-7.23%	-16.98%
Oats	4.82	-0.44%	4.09%	0.24%	4.81%
Sorghum Grain	4.89	5.39%	12.11%	11.32%	14.25%
Sorghum Silage	0.058	-0.60%	-0.60%	-0.35%	-1.16%
Soybeans	44.19	0.63%	1.18%	2.14%	1.46%
Summer Fallow	6.76	0.00%	17.17%	0.03%	13.33%
Sunflower	1.05	0.00%	0.00%	0.81%	0.81%
Spring Wheat	10.32	0.00%	-0.11%	-1.37%	-1.25%
Winter Wheat	12.87	-1.43%	8.24%	2.39%	9.95%

Figure A.8. (Table 8)



Key:

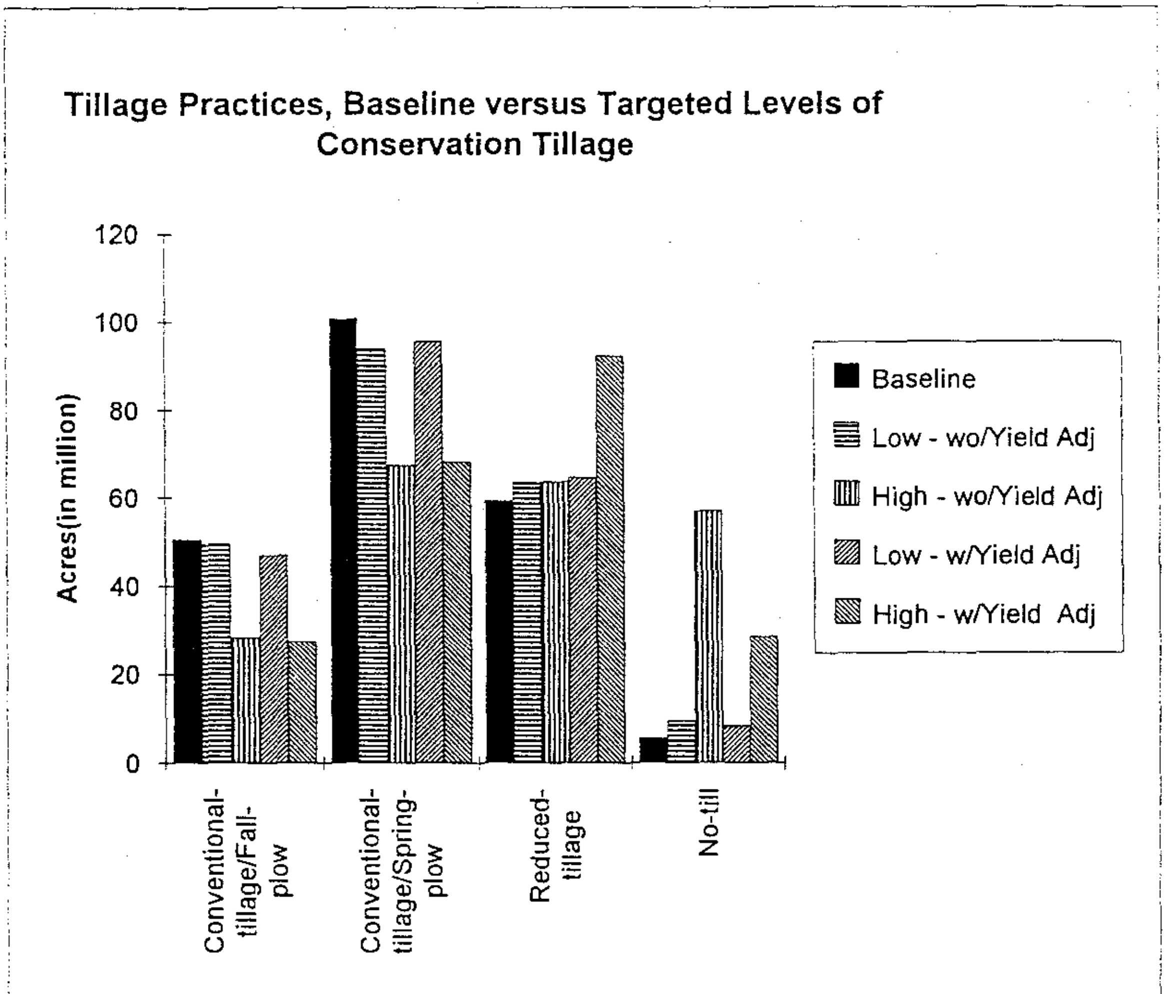
- **R100 Continuous CRN**
- **R131 CRN CRN SOY**
- **R186 CRN SOY**
- **R201 CRN SOY WWT**
- **R463 SMF SWT**
- **R503 Continuous HLH**
- **R508 Continuous NLH**

Where

- **CRN: Corn grain**
- **SOY: Soybeans**
- **WWT: Winter wheat**
- **SMF: Summer fallow**
- **SWT: Spring wheat**
- **HLH: Legume hay**
- **NLH: Non-legume hay**

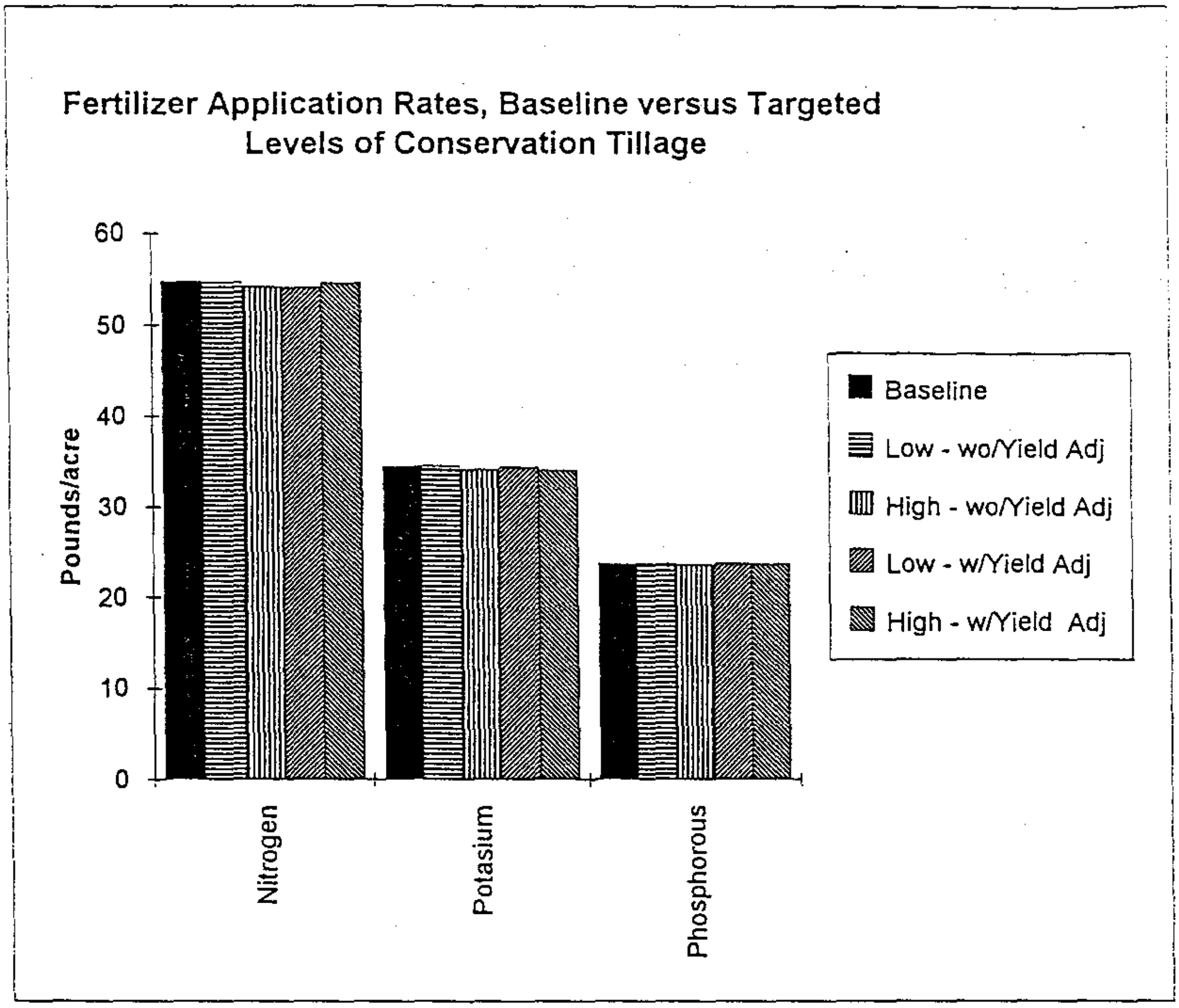
	Percentage Change from Baseline				
	Baseline	Tillage Targets			
		Low - w/Yield Adj	High - w/Yield Adj	Low - wo/Yield Adj	High - wo/Yield Adj
R100	8.36%	8.37%	7.96%	8.42%	8.71%
R131	7.11%	7.22%	7.13%	6.03%	6.39%
R196	23.87%	23.92%	24.23%	25.03%	24.82%
R201	6.00%	6.00%	5.99%	6.24%	6.29%
R463	5.43%	5.43%	5.49%	5.42%	5.49%
R503	8.43%	8.43%	7.63%	8.34%	8.45%
R508	8.34%	8.39%	6.96%	7.94%	6.65%

Figure A.9. (Table 9)



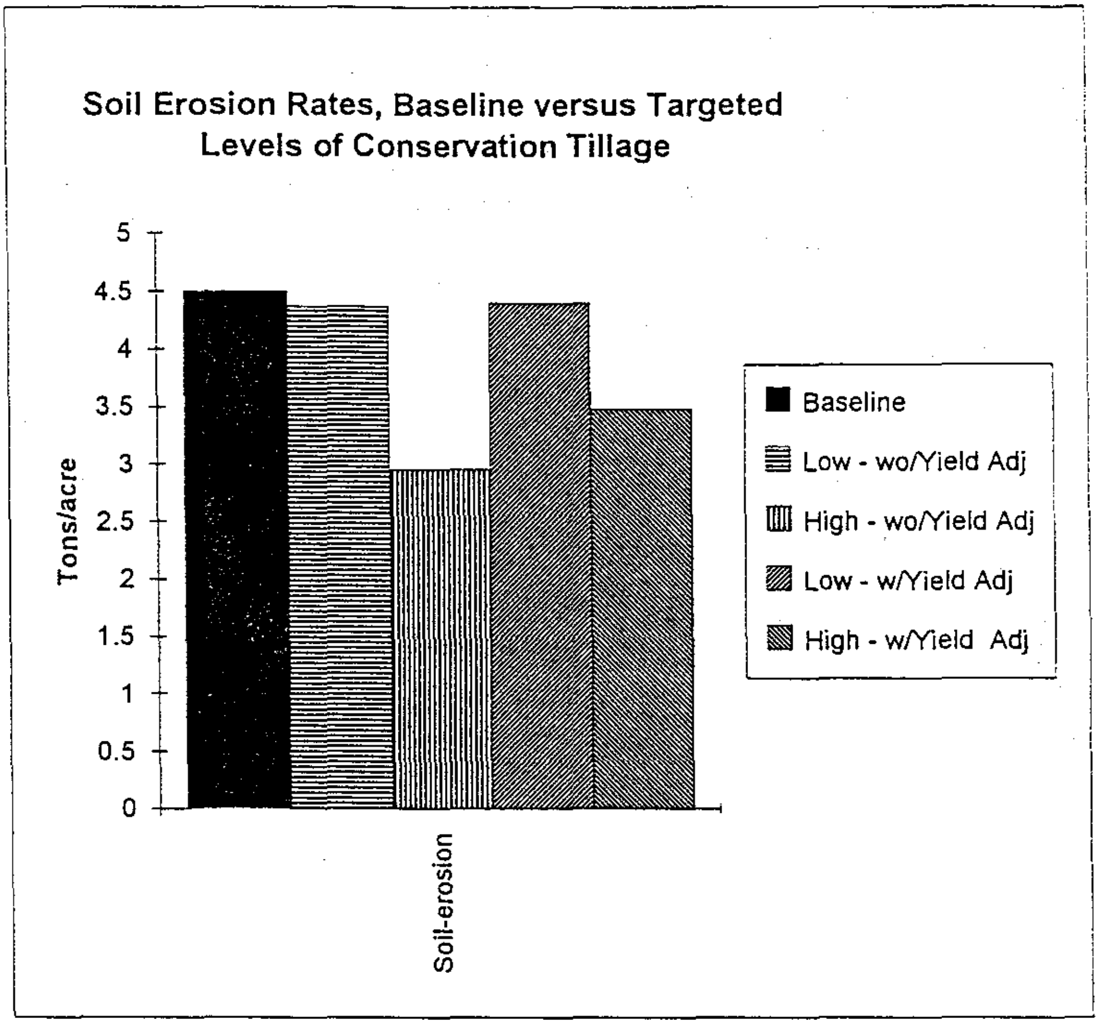
		Percentage Change from Baseline			
	Baseline	Tillage Targets			
		Low - wo/Yield Adj	High - wo/Yield Adj	Low - w/Yield Adj	High - w/Yield Adj
CT/Fall Plow	50.66	-2.18%	-44.24%	-7.23%	-45.73%
CT/Spring Plow	100.84	-6.78%	-33.07%	-4.24%	-32.33%
Reduced Tillage	59.31	6.77%	7.46%	8.80%	55.64%
No-till	5.67	69.13%	905.37%	47.91%	401.42%

Figure A.10. (Table 10)



		Percentage Change from Baseline			
	Baseline	Tillage Targets			
		Low - wo/Yield Adj	High - wo/Yield Adj	Low - w/Yield Adj	High - w/Yield Adj
Nitrogen	54.81	-0.22%	-1.07%	-1.25%	-0.34%
Potasium	34.53	-0.03%	-1.08%	-0.40%	-1.32%
Phosphorous	23.74	-0.07%	-0.60%	-0.16%	-0.26%

Figure A.11. (Table 11)



Percentage Change from Baseline				
Baseline	Tillage Targets			
	Low -wo/Yield Adj	High-wo/Yield Adj	Low -w/Yield Adj	High-w/Yield Adj
4.51	-3.08%	-34.34%	-2.58%	-22.85%

Figure A.12. (Table 12)

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