Cost Differences and Erosion Implications of No-Till and Conventional Tillage

A decision to change to no-till planting should include consideration of factors such as soil erosion hazard, planting equipment available, whether the weeds present can be controlled, whether a granular nematicide is required, the pH and fertility status of the soil, and the general level of management available.

These factors determine the importance of using no-till and strongly influence its agronomic and economic success. Many farmers have the choice of continuing with conventional tillage or making minimal changes in equipment and herbicides to allow no-till planting.

A change to no-till may reduce some input costs (fuel and labor) but usually increases pesticide costs and the need for quality labor. With the elimination of plowing and several secondary tillage operations the power and machinery requirement for a given acreage is reduced, as are related investment and ownership costs. This reduction in tillage work may permit more timely planting, extended years of equipment life, and the opportunity to make more efficient use of the labor available. Successful use of no-tillage systems has been clearly shown to greatly reduce the risk of soil erosion.

It is important to recognize the cost trade-offs between conventional tillage and no-tillage, especially in view of recent escalation of input prices and interest rates. This section will emphasize cost analyses for the production of corn and soybeans with a typical conventional tillage procedure versus several observed no-till procedures.

Estimation Methods and Assumptions Used

All estimates are based on a 400-acre operation (200 acres corn, 200 acres soybeans) using standard procedures of budget generation applied by agricultural economists. Budgets for conventional tillage include a medium-sized tractor (65 hp), a moderately-large tractor (115 or 140 hp), a chisel plow, disc, sprayer, rolling cultivator, rotary stalk chopper, combine, two-ton truck and pickup truck.

Unless otherwise noted, no-tillage budgets include the same equipment items except that the larger tractor, chisel plow, and rolling cultivator were excluded and the size of disc was reduced to be compatible with the power of the medium-sized tractor. Ten-year useful lives were assumed for field machines, a 5-year life for the pickup, and 8-year life for the truck.

All costs are based on 1981 price levels. Fertilizer and lime costs include custom spreading of typical maintenance rates for productive cropland and are the same for all tillage procedures. The following operations were assumed:

Conventional Tillage

For corn following soybeans-disc / chisel plow / disc / disc / plant / preemergence spray / postemergence spray / harvest / chop stalks / disc.

For soybeans following corn-disc / chisel plow / disc / disc / plant / preemergence spray / cultivate / harvest (leave residue over winter).

No-Tillage

For corn following soybeans-no-till plant / preemergence spray / postemergence spray / harvest / chop stalks / disc.

For soybeans following corn-no-till plant / preemergence spray / postemergence spray / harvest (leave residue over winter).

In all of the following budgets corn received a postemergence herbicide treatment valued at about $7 per acre when planted either conventionally or no-till. For soybeans, however, one cultivation was assumed with conventional tillage whereas a postemergence herbicide treatment valued at about $20/acre was used with no-till. In some weed situations less costly soybean postemergence herbicides may be more appropriate. No-till planted double-crop soybeans sometimes require less postemergence treatment than where tillage has been done. In other cases more than one treatment may be required.

Except where indicated otherwise the no-till budgets include the upper labeled rate of the contact herbicide Paraquat, a 33 percent increase in the rate of one preemergence herbicide over the rate used in conventional tillage, a 10 percent increase in the seeding rate, and slightly slower planting speed. A list of the major production inputs used in the budgets is presented in Table 4.

In all budgets corn residue is rotary chopped and then disced once in the fall with the intention of controlling insect and disease pests while leaving some residue exposed for erosion protection. Soybean residue is left untilled over winter. Crop rotation is assumed in all cases. These are generally considered to be sound residue management practices for production of these crops.

Three Cases Analyzed

Cost estimates and comparisons between tillage systems were made for three situations or "cases" differing in the type of planter used and no-tillage production procedures.

Case A assumes the modification of conventional flex-type, unit planters (addition of tool bar, fluted coulters, ribbed press wheels) to make a good no-tillage planter. An investment requirement of $1638 for these modifications to a 6-row planter was assumed. (The charge for modifying a John Deere "MaxEmerge" planter for no-till would be approximately 50% less than this but narrow rows for late planted soybeans might require double planting.) The complete no-till herbicide program outlined above was followed.

The Case A example is intended to have wide applicability to current farm conditions in all of North Carolina and neighboring states. Its applicability to a specific field would, of course, require adjustment for fertilization and pesticide use to fit that specific case.

The Case B example is a minimal-cost approach to no-till and is offered for comparison purposes primarily. *It is not intended to have widespread applicability.* In this case *no contact herbicide* is included and no change in preemergence herbicides is made. Only the seeding rate (10% increase) and planting speed (from 5 mph to 4 mph) are changed. A minimal 4-row planter modification charge of $250 was included. This example would apply to a farmer already owning a no-till planter which needs improvement or having purchased a set of used fluted coulters and miscellaneous parts needed to suitably modify his existing planter. Narrow row soybeans would require double planting in Case B.

It is recognized that some situations exist where the contact herbicide may not be needed but these must be selected very carefully since this savings in herbicide cost could often be greatly suprassed by the value of decreased crop yield. This case is only applicable to certain situations where corn is no-till planted into soybean residue early in the spring before any summer annual weeds have germinated and where all weed pressure is minimal. Early application of 2,4-D may also be required but is not included in this budget. Case B may also apply to infrequent cases of no-till, double-cropped soybeans planted into small grain residue where essentially no grass or broadleaf weeds have germinated.

Case C is a higher-investment approach which includes the same levels of contact, preemergence and postemergence herbicides, seeding rates and planting speed as used in Case A. In this comparison, however, a no-till ripper planter is used. It is assumed that the farmer's existing flex-type, unit planters will be remounted directly onto the no-till ripper unit and will be pulled by the same 140 hp tractor which would otherwise be used for conventional tillage operations. Because of the weight of this ripper-planter unit a lift assist wheel assembly is included. In this no-tillage budget the 65 hp tractor is retained and used primarily for spraying.

The Case C no-tillage approach should be viewed as more than traditional no-till planting because it provides in-row subsoiling as well as the capability of one-pass planting into most crop residue situations with resultant soil and moisture conservation benefits. However, the applicability of this example is considered greatest in certain soils of the Coastal Plain where yield increases from subsoiling may readily justify some added cost.

Cost Estimates

Based on the assumptions specified above, cost budgets were developed to compare chisel plow/disc land preparation with no-tillage for Cases A, B and C. Estimated annual per acre cost and fuel consumption for corn and soybean production are presented by case in Tables 5, 6 and 7, respectively.

For Case A-a widely applicable situation-the no-tillage procedure was less costly by $4.76/A for corn but more costly by $15.85/A for soybeans (Table 5). No-till permitted a total cost savings for machinery ownership, operation and labor of $20.30/A for corn and $22.06/A for soybeans. However, these savings were offset by cost increases for herbicide, seed and interest on operating capital totaling $15.54/A for no-till corn and $37.91/A for no-till soybeans. The notably high cost of no-tillage soybean herbicide was influenced by the costly postemergence treatment. In many cases this cost may be reduced where weeds present and careful management permit use of less expensive postemergence treatments. (One cultivation was assumed for clean-tillage soybeans.)

In Case B the total cost of no-tillage corn and soybeans (presented in Table 6) was reduced by $16-24/A compared with Case A, largely because standard no-tillage herbicides were left out. Compared with chisel/disc, no-till reduced the machine ownership, operating and labor costs by $22.07/A for corn and $28.40/A for soybeans. Although seed, herbicide and interest costs for no-till were still somewhat higher, the overall cost of no-till in Case B was $20.77 less for corn and $7.04 less for soybeans.

As in Case A, even greater cost savings would occur if less expensive postemergence weed control could be used for no-tillage soybeans. Clearly the cost savings of our Case B no-tillage would be helpful, but we again caution you that these procedures would not be widely applicable. Except under the conditions previously indicated, this procedure could result in significant yield reductions.

Use of a no-tillage ripper planter (Table 7), a larger tractor and allowance for use of both the 140 hp and 65 hp tractors in the Case C no-till budget pushed average machine ownership costs upward about $19/A compared with Case A. In Case C no-tillage allowed a savings in machine ownership, operation and labor costs of only $0.54/A for corn and $6.47/A for soybeans. The increased herbicide, seed and interest costs resulted in net increases of $15.06/A for no-tillage corn and $31.53/A for no-tillage soybeans compared with the chisel plow/disc treatment. As indicated previously, for much of the light, colored, sandy land of the Coastal Plain yield increases in response to this subsoiling technique are likely to more than pay for this increased cost-especially for corn.

Effect of Owning Unnecessary Equipment

Farmers who change to no-tillage planting are likely to find it difficult or impossible to sell larger tractors and tillage equipment which would provide excessive tillage capacity in a total no-tillage program. This may be due to unsuitability of no-till to a portion of acreage farmed or to certain crops grown (tobacco, peanuts, cotton). In many cases it may also be advantageous to maintain a diverse tillage program for periodic incorporation of lime, for pest management, or in the hope of increasing chances with adverse weather factors. With the same general assumptions as to acreage and procedures, keeping the 115 hp tractor and its matching chisel plow and disc would increase the annual per acre cost in Case A or Case B by $14.76 for no-tillage corn and $19.51 for no-tillage soybeans based on lo-year expected useful lives of these items.

Since hours of use of this larger equipment would decline as the no-tillage portion of the acreage increased, it may be desirable to assume an extended useful life expectancy of 20 years. This would reduce net increases in machinery ownership costs for Case A or Case B to $9.73/A for no-tillage corn and $13.41/A for no-tillage soybeans. In all of the above comparisons the chisel/disc procedure already included the use of the larger tractor and matching plow and disc as well as the smaller tractor.

Tillage Cost for Two-Year System

Some North Carolina farmers have successfully used a wheat-soybean-corn system which minimizes clean tillage, offers excellent erosion protection, makes maximum use of our summer growing season, and contributes to timeliness by reducing tillage trips and labor. For this comparison we used the same assumptions as in Case A above for planting corn and soybeans.

The system begins with a conventionally prepared seedbed for wheat, which is planted with a grain drill. The wheat received N topdressing and 2,4-D for weed control in the spring.

After wheat harvest a soybean double crop is planted by either conventional seedbed preparation (disc/disc/chisel plow/disc/plant) or by no-tillage planting. At harvest of the soybeans the residue is left over winter in either case. In the second year corn is planted by the same steps for conventional tillage versus being planted into soybean residue by no-tillage. This cost comparison is shown in Table 8.

As in the earlier comparisons for a single crop, substantial reduction in machinery ownership and operational costs and labor were nearly offset by increased costs of herbicides, seed and interest on production inputs. For the two year, three crop system no-tillage planting of the corn and soybeans resulted in a net cost decrease of $10.23/A as compared with the chisel/disc procedure.

Fuel Savings

Based on the same assumptions and utilizing standard guidelines established by Agricultural Engineers, the estimated fuel consumption for each of the above comparisons is given in Tables 5 through 8. Of course, the difference in direct fuel consumption was almost entirely in Diesel fuel used in the tractor and combine. Gasoline was consumed by trucks. A pickup was used to transport production materials to the farm and field and a 2-ton truck was used to transport water for spraying to the field and crop products from the field.

A meaningful comparison can be made by averaging the fuel consumed in producing an acre of corn and soybeans. In this manner no-tillage production resulted in an annual savings of 2.87 gal/acre in Case A, 3.12 gal/acre in Case B, and 2.32 gal/acre in Case C. For the two-year production of wheat, soybeans and corn the no-tillage procedure saved 5.64 gal/acre. These estimates closely resemble a recent analysis in Kentucky which reported an energy savings in machinery manufacture and fuel consumption of 3.9 gal. Diesel/acre for no-till corn and 3.4 gal. Diesel/acre for no-till soybeans as compared with conventional tillage.[1]

Yields

Any complete economic analysis of production practices must include the resulting yields. Here we have chosen to emphasize only a comparison of costs under several sets of assumptions. Knowing the differences in costs of production, one can readily estimate the yield differences (either increases or decreases) which would allow a change in tillage practices. Space does not permit rigorous comparison of expected yields under conventional versus no-tillage planting. It should be obvious, however, that the differences in total costs between the two tillage methods (Tables 5-8) are equivalent in value to yield differences of 1 to 8 bushels of corn/acre or 1 to 5 bushels of soybeans/acre. Inadequate plant population of corn or faulty weed, insect, or disease control in either crop can readily cause yield decreases of double or triple these amounts.

The importance of consistently achieving at least equal yields under no-till production as compared with conventional tillage cannot be over-emphasized. Test plot and farmer experience in North Carolina includes many cases of equal or slightly better yields with no-till but there also are cases of much lower no-till yields resulting from poor weed or insect control or inadequate stand establishment.

Since no-tillage production generally is nearly equal if not more costly, it is clear that nothing less than the best management should be devoted to this practice to maximize the chances for high yields. Specific suggestions for yield-saving techniques in no-tillage production are given in other sections of this publication.

Erosion and Water Quality Implications

Nationwide the estimated loss of soil by erosion from cropland is nearly 2 billion tons per year. In North Carolina it is estimated that 49 million tons of soil is lost from eroding cropland, which represents 64 percent of the total erosion occurring in the state.[2]

The water pollution costs of excessive erosion are difficult to quantify. These arise from losses of nutrients, organic material, pesticide and sediment. In the simplest case of reservoir sedimentation the cost per ton of sediment can be calculated. Nationally it has been estimated that $250 million is spent yearly removing sediment from streams, harbors and reservoirs. Flood damages related to excessive sedimentation are estimated at one billion dollars yearly.

There are additional costs due to loss of recreational, aesthetic and fishery benefits related to excessive sedimentation. These are real but difficult to quantify because the values are subjective. There are instances when public water supplies are damaged by eroding cropland, in which case the costs to society may be almost without limit.

Five studies of streams and rivers in the North Carolina Mountains and Piedmont have shown that soil sediment from cropland erosion was associated with a moderate (30%-60%) or severe (over 60%) reduction in the number of aquatic insects which form the basis of the food chain for many fishes.[3] These and similar studies suggest that a 30-60 percent reduction in aquatic life is common in most Piedmont and Mountain streams of North Carolina.

Excessive erosion also has direct costs to the farmer. Fertilizer nutrients move off the land in association with the runoff water and eroding sediments. In a recent report the value of N, P, K and lime included in transported sediments varied from $3.33 to $28.78 per eroded acre, depending upon assumptions as to fertility level of the soil and availability of the nutrients.[4] This was based upon an assumed soil loss of 14 tons/acre/year. This is a high rate of soil erosion, but is common in our Piedmont region. Average soil erosion is estimated at 10-15 tons/acre/year in 17 counties and at over 15 tons/acre/year in 11 counties.[5]

The characteristics of the topsoil have great influence on crop growth. In soils in which the subsoil is clayey, erosion exposes this material at the surface. Studies have shown that when such less favorable

Table 4
Production inputs assumed in all budgets except where otherwise indicated in the text.

Herbicides for Corn
- Lasso 4EC (1.5 qts clean till; 2.0 qts no-till)
- AAtrex 4L (1.25 qts clean till; 1.25 qts no-till)
- Paraquat 2CL (2.0 pts + surfactant in no-till)
- Evik 80W (1.25 lbs/A + surfactant in clean till and no-till)

Herbicides for Soybeans
- Lasso 4EC (1.5 qts clean till; 2.0 qts no-till)
- Lorox 4L (1 pt clean till; 1.5 pt no-till)
- Paraquat 2CL (2.0 pts + surfactant in no-till)
- Basagran 4SL (2.0 pts in no-till)

Insecticides - none [1]

Fungicides - none

Fertilizer - 20 lbs. N + 20 lbs. P_2O_5 + 120 lbs. K_2O preplant for corn and soybeans (bulk blended); 130 lbs. N (30% solution) layby for corn; 60 lbs. N (with 2,4-D) topdress for wheat; lime @ 1 T/A every three years.

Seed - Corn - 16 lbs./A; soybeans 0.8 bu/A certified seed (plus 10% for no-till)

Fuel Prices - Diesel - $l.05/gal; gasoline - $1.25/gal.

NOTE: Inclusion of these products and rates for budgeting purposes does not constitute a recommendation of these products or rates for any specific situation nor imply criticism of other similar products or rates by the N. C. Agricultural Extension Service.

[1] No soil insecticide was budgeted for corn planted either conventionally or in no-tillage, although under some circumstances it would be needed. If corn is planted no-till into relatively weed-free soybean residue without previous history of heavy infestation of seedling-attacking insects, the need for soil insecticides is generally no greater in no-till than conventional tillage. This was assumed in these examples.

Table 5
Estimated costs and fuel use per acre of chisel/disc versus no-till corn and soybeans in North Carolina, 1981. Case A.[1]

Item	Corn Chisel/disc	Corn No-till	Soybeans Chisel/disc	Soybeans No-till
Seed	$ 17.60	$ 19.36	$ 12.29	$ 13.82
Fertilizer and lime	76.21	76.21	45.35	45.35
Herbicides	17.84	30.94	11.74	45.95
Fuel, oil, lub. and repairs	25.11	21.34	15.86	12.79
Interest on operating capital @ 15 percent	8.85	9.53	6.31	8.48
Total operating costs	$145.61	$157.38	$ 91.55	$136.39
Labor @ $4/hour	14.52	12.85	8.30	6.44
Machinery ownership costs	75.49	60.63	50.20	33.07
Total costs	$235.62	$230.86	$150.05	$165.90
Fuel consumption (gallons):				
Gasoline-truck and pickup	3.90	3.90	1.45	1.85
Diesel-tractors and combine	8.63	5.88	6.53	3.54

[1] No-till planter developed by $1638 modification of flex-type planters (4-36” rows for corn; 6-24” rows for soybeans). Typical no-tillage herbicide program included.

Table 6
Estimated costs and fuel use per acre of chisel/disc versus no-till corn and soybeans in North Carolina, 1981. Case B.[1]

Item	Corn Chisel/disc	Corn No-till	Soybeans Chisel/disc	Soybeans No-till
Seed	$ 17.60	$ 19.36	$ 12.29	$ 13.82
Fertilizer and lime	76.21	76.21	45.35	45.35
Herbicides	17.84	17.84	11.74	30.47
Fuel, oil, lub. and repairs	24.83	20.70	15.59	10.27
Interest on operating capital @ 15 percent	8.83	8.37	6.29	7.39
Total operating costs	$145.31	$142.48	$ 91.26	$107.30
Labor @ $4/hour	14.44	12.77	8.22	5.19
Machinery ownership costs	74.78	58.51	49.49	29.44
Total costs	$234.53	$213.76	$148.97	$141.93
Fuel consumption (gallons):				
Gasoline-truck and pickup	3.90	3.90	1.45	1.45
Diesel--tractors and combine	8.63	5.88	6.53	3.05

[1] Minimum no-till planter modification cost assumed ($250); no contact herbicide, and no increase in pre-plant herbicide rates; postemergence herbicide included for chisel/disc and no-till corn and for no-till soybeans. Caution-these no-till procedures will result in yield reductions except in some specific situations described in the text.

soil material is exposed yields decline. Such conditions are predominant in sloping areas of the North Carolina Piedmont and certain areas of the Coastal Plain and Mountains.

Obviously there are many factors that should be accounted for in assessing the costs of excessive erosion and resultant water pollution. To realistically assess the pollution costs of erosion, each water resource must be evaluated individually. But it should be noted that in almost every case where this has been done the benefits of erosion control have exceeded the costs.

When no-tillage planting succeeds in establishment of a crop with satisfactory stand, vigorous growth and good weed and pest control there is greatly reduced risk of soil erosion than with most forms of conventional tillage. The erosion control value of cropping systems involving no-till is of major importance. Generally the greatest erosion protection results from a well-established sod crop or small grain cover crop on the land over the winter. Corn can then be no-tilled into the killed residue of this crop. Very effective erosion protection also is provided by small grain residue into which double-cropped soybeans are no-till planted.

Soybean residue after harvest provides limited erosion protection. However, from an erosion standpoint leaving it untilled overwinter is far preferable to fall tillage without a cover crop. If corn is no-till planted into soybean residue (as assumed in the preceding budgets) the vulnerability to erosion following spring tillage can be greatly reduced.

Special Advantages of No-Till

Some farm situations fit well with no-till. In the following examples the advantages of no-till may outweigh its increased costs and special considerations.

(1) If soil erosiveness and/or collection of sediment or fertilizers in adjacent ponds or streams is a key concern, then ,successful no-tillage production as often as possible in the cropping system should be a management goal. If factors such as johnsongrass or the need for lime or phosphorus prevent successful no-tillage planting, these conditions should be corrected. In some cases on hilly land no-till planting may actually increase the acreage of potentially useful cropland and avoid or reduce the cost of alternative erosion protection measures.

(2) Farm operations having insufficient large tractors and tillage equipment in relation to their acreage can benefit from the reduction in machinery required with no-till *if* high quality management at the field level can be provided. This also applies to farmers who have limited credit for investment in machinery. The annual credit required for increased production inputs with no-till is likely to be more readily available.

(3) Relatively small farm operations or those heavily involved in livestock but having small crop acreages simply cannot justify large machinery investment. No-till production helps to keep per-acre ownership costs more reasonable.

(4) Farm operations where labor is in short supply or is primarily devoted to livestock enterprises or off-farm employment can benefit from no-tillage *if* quality management is available. Besides the actual hours of labor saved with no-till production this practice often permits greater timeliness of planting. A special example of this is the planting of double-cropped soybeans immediately after harvesting the small grain, thus avoiding loss of soybean yield potential through planting delays required for conventional tillage.

Table 7
Estimated costs and fuel use per acre of chisel/disc versus no-till ripper planter for corn and soybeans in North Carolina, 1981. Case C.[1]

Item	Corn: Chisel/disc	Corn: No-till Ripper	Soybeans: Chisel/disc	Soybeans: No-till Ripper
Seed	$ 17.60	$ 19.36	$ 12.29	$ 13.82
Fertilizer and lime	76.21	76.21	45.35	45.35
Herbicides	17.84	30.94	11.74	45.95
Fuel, oil, lub. and repairs	24.44	22.10	16.38	14.32
Interest on operating capital @ 15 percent	8.81	9.95	6.34	8.60
Total operating costs	$144.90	$158.16	$ 92.10	$128.04
Labor @ $4/hour	13.67	12.07	7.50	6.44
Machinery ownership costs	78.71	82.11	52.41	49.06
Total costs	$237.28	$252.34	$152.01	$183.54
Fuel consumption (gallons):				
Gasoline-truck and pickup	3.90	3.90	1.45	1.85
Diesel-tractors and combine	8.65	6.59	7.23	4.65

[1] A 140 hp tractor is used for both chisel/disc and no-till ripper procedures. Both tillage programs also include a 65 hp tractor. Typical no-tillage herbicide program (same as in Case A) was included. For corn four 36" rows were used; for soybeans six 24" rows were used.

Table 8
Estimated costs and fuel use per acre for two-year, three crop system comparing chisel/disc versus no-till planted soybeans and corn. Both planting methods include conventionally seeded wheat with double-cropped soybeans followed by corn in the second year.[1]

Item	Wheat-Soybeans: Chisel/disc	Wheat-Soybeans: No-till	Corn: Chisel/disc	Corn: No-till	Total (3 crops): Chisel/disc	Total (3 crops): No-till
Seed	$ 25.82	$ 27.36	$ 17.60	$ 19.36	$ 43.42	$ 46.72
Fertilizer and lime	59.60	59.60	76.21	76.21	135.81	135.81
Herbicides	33.48	48.96	17.84	30.94	51.32	79.90
Fuel, oil, lub. and repairs	28.28	24.31	26.10	22.35	54.38	46.66
Interest on operating capital	10.21	11.01	8.87	9.54	19.08	20.55
Total operating costs	$157.39	$171.24	$146.62	$158.40	$304.01	$329.64
Labor @ $4/hour	14.32	12.12	14.52	12.85	28.84	24.97
Machinery ownership costs	65.50	48.99	65.09	49.61	130.59	98.60
Total costs	$237.21	$232.35	$226.23	$220.86	$463.44	$453.21
Fuel consumption (gallons):						
Gasoline-truck and pickup	3.67	3.67	3.90	3.90	7.57	7.57
Diesel-tractors and combine	9.32	6.43	8.63	5.88	17.95	12.31

[1] No-till planter developed by $1638 modification of flex-type planters (4-36" rows for corn; 6-24" rows for soybeans). Typical no-tillage herbicide program (same as in Case A) was included.

Footnotes

[1] No-Tillage Agriculture. R. E. Phillips, R. L. Blevins, G. W. Thomas, W. W. Frye, and S. H. Phillips, 1980. Science, Vol. 208, June 6.

[2] Erosion and Sediment Inventory of North Carolina. 1977. USDA-SCS.

[3] Biological Evaluation of Non-Point Source Pollutants in N. C. Streams and Rivers. D. R. Lenat, D. L. Penrose, and K. W. Eagleson, 1980. Biol. Series No. 102. NC-DNRCD-DEM.

[4] Economic and Production Effects of Soil Erosion. 1980. L. W. Murdock, W. W. Frye and R. L. Blevins, Proceedings of Southeastern Soil Erosion Control and Water Quality Workshop. Nashville, Tenn.

[5] Erosion and Sediment Inventory of N. C. 1977. USDA-SCS.