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LANDOWNERSHIP AND THE ADOPTION OF MINIMUM TILLAGE

Linda K. Lee

and

William H. Stewart*

*The authors are Assistant Professors of Agricultural Economics and Statistics, respectively, Oklahoma State University. The helpful comments of Dan Badger, Bruce Bullock, Francis Epplin, Glenn Knowles, Luther Tweeten and the anonymous Journal referees are gratefully acknowledged.

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Soil losses from water erosion recently are reported to be in excess of natural replacement rates on almost 25 percent of U.S. cropland (U.S. Department of Agriculture, p. 6). These losses may affect adversely the potential productivity of U.S. cropland as well as water quality in streams and rivers. Land tenure arrangements and farm size are among the landownership factors hypothesized to affect investments in soil conservation and thus soil erosion rates (Held and Clawson, pp. 253-282; Block, p. 21). If significant differences in soil conservation adoption occur among easily identified groups of landowners, this information could be useful in developing public policies to encourage soil conservation and reduce soil loss.

This paper assesses the relationships between landownership and the adoption of minimum tillage and residue management--practices that can on some soils be very effective in controlling soil loss and reducing total input costs (Crosson, pp. 4-14). Hypotheses about the effect of landownership on soil conservation investments are evaluated for their applicability to minimum tillage. National data relating landownership and minimum tillage practices are analyzed with a logit model and policy implications are discussed.

Factors Affecting Soil Conservation Decisions

Although rainfall, soil type, and slope greatly influence soil loss rates, management decisions can exacerbate or mitigate their effects. Soil management decisions at the farm level have been analyzed by maximizing expected net income over a planning horizon. An individual, it is postulated, calculates the income effect of a proposed conservation program over time and compares it to expected income over time without conservation measures. Within this framework, individuals whose land exhibits similar physical characteristics may reach different conservation decisions depending on their planning horizon and individual time preference or discount rates. A lower discount rate and a longer planning horizon tend to encourage conservation decisions by increasing the present value of expected net revenues and by allowing sufficient time to recoup conservation investments.

In addition to an operator's personal characteristics, such as age or education, landownership factors of farm size and land tenure have been hypothesized to influence planning horizons and discount rates. Small farm size is associated with low volume production, increased per unit costs, and low net farm incomes (Miller, Rodewald, McElroy). Low net farm income can lead small farm owners and operators to increase individual time preference rates. Market interest rates are often greater for low income groups because of increased risk and higher per unit administrative costs (Ciriacy-Wantrup, pp. 105, 162). In either case, higher discount rates may be used in evaluating conservation strategies, reducing the likelihood of conservation adoption.

Tenure arrangements that separate landownership from farm operation also can discourage soil conservation through short-term leases or inequitable sharing of the costs and benefits of conservation investments (Ciriacy-Wantrup, pp. 150-160).[1] In addition, it has been hypothesized that landlords, particularly absentee landlords, have a short planning horizon and a strong preference for current income at the expense of long-term soil conservation investments and hence, future soil quality (Timmons, p. 6). Bible extends this hypothesis by arguing that separation of landownership from farm operation with nonfamily corporate ownerships also can lead to short-term planning horizons and fewer conservation investments (pp. 207-208).

Researchers have supported some of these hypotheses about the impact of size and tenure on conservation investments with studies in small, relatively homogeneous areas with similar soils, climate and topography (Held and Clawson, pp. 253-282; Baron). Recent research, however, did not find hypothesized soil management differences among full-owner operators, landlords, nonfamily corporations, and family ownerships reflected in average soil loss rates among these groups at the national level (Lee). Furthermore, a study of the influence of absentee landowners on the use of erosion control practices by Palouse farmers reported that absentee landowners do not typically impose major obstacles to greater erosion control (Dillman and Carlson). None of these studies, however, directly address the relationships between land tenure and other landownership factors on the adoption of minimum tillage and crop residue management, hereafter referred to as minimum tillage.[2] There is considerable interest in minimum tillage as a cost minimizing conservation strategy now that capital investments in permanent soil conservation measures such as terraces are declining (Pavelis).

Minimum tillage adoption decisions may be analyzed in the same way as traditional soil conservation investments--maximization of expected net farm income over time. Within this framework, the decision to adopt minimum tillage is a complex one, depending on input prices and yield variations, among other factors. However, landownership factors also play a role in the adoption process. Small operating size could be an obstacle to minimum tillage adoption as well as other soil conservation investments through low volume production, increased per unit costs, and low net farm incomes as discussed earlier.

However, unlike traditional conservation investments, tenure arrangements that separate landownership from farm operation should not pose significant obstacles to minimum tillage adoption. Two characteristics of minimum tillage support this hypothesis: (a) the cost reduction potential of minimum tillage and (b) the independence of the tenant from the landowner in the adoption process under many leasing arrangements.

First, unlike other conservation investments, minimum tillage practices can be adopted for several objectives, including conservation of energy and labor as well as soil. Investments such as terraces tend to be uneconomical for many farmers, if only the direct benefits from terracing are considered (Mitchell, Brach, and Swanson). Minimum tillage and residue managment, however, can be effective cost reduction measures. As Crosson concludes, "...in areas with well-drained soils, adequate control of weeds with herbicides, and potential for double cropping, the economics clearly favor conservation tillage (p. 21)." Short-term planning horizons and high discount rates associated with separation of ownership from farm operation should not inhibit minimum tillage adoption where it has an immediate economic advantage.

Another fundamental difference between minimum tillage and traditional conservation investments is the landowner's role in the conservation decision making process. Traditional conservation measures such as terraces, grassed waterways, or gully controls are long-term investments that alter the land. They generally require the involvement of the landlord. Under these circumstances, where landownership and farm operation are separated, short-term leases and other tenure arrangements pose potential obstacles for conservation investments.

Investments in minimum tillage technologies, on the other hand, are closely associated with the operator, not the landowner. Minimum tillage equipment can be used by part-owners on both owned and rented land. Furthermore, the adoption of minimum tillage does not permanently alter the land, thus necessarily requiring the involvement of the landowner. If share leasing provisions require the landlord to pay part of the herbicide and/or pesticide costs of minimum tillage, the landlord could be more actively involved in the adoption decision than under cash leases. However, obstacles imposed by the separation of resource ownership from operation are generally less important for minimum tillage decisions than for land altering conservation investments.

Data and Analysis

Data for this study were obtained by merging the Soil Conservation Service's (SCS) 1977 National Resource Inventories (NRI) and the 1978 Landownership Survey of the National Resource Economics Division (NRED), Economic Research Service (ERS), U.S. Department of Agriculture (Lewis). The NRI was a two-stage, area-point sample of nonfederal U.S. land. Approximately 70,000 sampling units of generally 160 acres in size were selected. Within each sampling unit, information on land use and soil conservation, including minimum tillage, was collected on three selected points by SCS field staff according to national guidelines. Then SCS provided ERS the name and address of the owner of the first point in each sampling unit. Of the 70,000 original first points, names and addresses for private landowners were available for 52,000 points, and slightly more than 37,000 completed landownership questionnaires were obtained. The NRED survey collected information from the landowners about personal characteristics such as age, income, and education plus general information on size of landowner holdings, organizational structure, and tenure status. These data were merged with the NRI land use data.

The analysis conducted here focuses only on cultivated cropland, defined as land in row crops, close grown field crops, summer fallow, or rotation hay and pasture. There were 7,649 observations from the merged sample meeting these criteria. These 7,649 sampling units constitute a random sample from the population of all non-federal, cultivated cropland units in the contiguous 48 states during 1977-78.

For this population of land units we considered a cross-classification of five categorical variables: tenure status (full-owner operators, part-owner operators, nonoperator landlords), farm size (small, medium, large), erosion hazard (hazard, no hazard), region (10 farm production regions), and organizational structure (sole proprietors-family, nonfamily corporations, other).[3] See

Tables 1 and 3 for more specific definitions of these categories. Each cultivated cropland unit of the population could be classified into one of the 540 classifications possible from these five variables. For a given classification c, p_c is defined to be the proportion of all cultivated cropland units in classification c which have minimum tillage practices. Ideally, if the p_c were known, we could investigate the structure of the p_c to understand the relationship between the explanatory variables and minimum tillage adoption. However, in our case, we must take into account that the 7,649 observations are a random sample.

A simple approach would be to estimate each population p_c by $\hat{p}_c$, the observed proportion of sampled land units with minimum tillage practices in classification c. This would have 2 major drawbacks: the precision of estimating 540 parameters with only 7,649 observations would be very low, and such analysis would give no direct clue to any underlying structure between the explanatory variables and minimum tillage adoption. Equally unsatisfactory would be to consider the impact of each classification variable on minimum tillage one at a time in a two-way table. This would confound the effects of the variable at hand with those variables not considered.

The approach used here is to model the relationship of the explanatory variables and the minimum tillage rates with a linear model in the logit or log odds scale, i.e. log

$[p_c/(1-p_c)]$. This greatly reduces the number of parameters to be estimated and provides an interpretable structure for studying this data. Following Grizzle, Starmer, and Koch the analysis is done in a regression framework with the dependent variable log $[\hat{p}_c/(1-\hat{p}_c)]$ and dummy independent variables corresponding to the categories of the explanatory variables. Because the error variances are not constant across the independent variables, the parameters are estimated with weighted least squares (Forthofer and Lehnen, pp. 26-27).

The model is:

$$\log \frac{p_{ijkl}}{1-p_{ijkl}} = K + T_i + S_j + E_k + R_l + (ER)_{kl},$$

$$\sum_i T_i = \sum_j S_j = \sum_k E_k = \sum_l R_l = \sum_k (ER)_{kl} = \sum_l (ER)_{kl} = 0.$$

Here p_{ijkl} is the proportion of land units with minimum tillage practices occurring on land tenure status i, of farm size j, with erosion hazard k and from region l. The model has 24 free parameters: K, a constant; T_i, the main effect of tenure status i; S_j, the main effect of farm size j; E_k, the main effect of erosion hazard status k; R_l, the main effect of region l; and $(ER)_{kl}$, the interaction effect of erosion hazard status k with region l. Table 1 includes definitions and estimates of all model parameters along with standard errors of the estimators. These estimates may be substituted into the model equation to provide estimates of the p_{ijkl}, hereafter referred to as minimum tillage adoption rates. Further terms involving

Table 1. Parameter Estimates

Interpretation	Parameter	Estimate	Standard Error
Constant	K	- .056	.036
Main effects of tenure:			
Full-owner operators	T_1	- .114	.037
Part-owner operators	T_2	.072	.034
Nonoperator landlords	T_3	.042	.036
Main effects of size:			
$\leq$ 140 acres	S_1	- .161	.046
141 - 700 acres	S_2	- .015	.034
$\geq$ 700 acres	S_3	.176	.044
Main effects of erosion hazard:			
No erosion hazard	E_1	.218	.034
Erosion hazard	E_2	- .218	.034
Main effects of region:			
Appalachian	R_1	- .136	.106
Corn Belt	R_2	- .412	.055
Delta	R_3	.654	.171
Lake	R_4	-1.055	.078
Mountain	R_5	.117	.083
Northeast	R_6	- .265	.105
Northern Plains	R_7	.712	.058
Pacific	R_8	- .082	.112
Southeast	R_9	- .287	.116
Southern Plains	R_{10}	.752	.090

Table 1. Parameter Estimates, continued

Interpretation	Parameter	Estimate	Standard Error
Interaction effects of erosion hazard with region:			
No erosion hazard, Appalachian	ER_{11}	.234	.105
Erosion hazard, Appalachian	ER_{21}	- .234	.105
No erosion hazard, Corn Belt	ER_{12}	- .200	.054
Erosion hazard, Corn Belt	ER_{22}	.200	.054
No erosion hazard, Delta	ER_{13}	.558	.172
Erosion hazard, Delta	ER_{23}	- .558	.172
No erosion hazard, Lake	ER_{14}	- .066	.077
Erosion hazard, Lake	ER_{24}	.066	.077
No erosion hazard, Mountain	ER_{15}	- .265	.081
Erosion hazard, Mountain	ER_{25}	.265	.081
No erosion hazard, Northeast	ER_{16}	.266	.104
Erosion hazard, Northeast	ER_{26}	- .266	.104
No erosion hazard, Northern Plains	ER_{17}	- .110	.057
Erosion hazard, Northern Plains	ER_{27}	.110	.057
No erosion hazard, Pacific	ER_{18}	- .185	.111
Erosion hazard, Pacific	ER_{28}	.185	.111
No erosion hazard, Southeast	ER_{19}	- .273	.117
Erosion hazard, Southeast	ER_{29}	.273	.117
No erosion hazard, Southern Plains	$ER_{1,10}$	.040	.089
Erosion hazard, Southern Plains	$ER_{2,10}$	- .040	.089

interactions and the organizational structure variable were not included in this model because they were not found to be significantly different from zero (table 2). Insignificant terms are usually excluded in logit analysis to simplify the interpretation of results(Reynolds, p. 176).

The parameter estimates can be directly interpreted as the change in log odds resulting from changing one of the variables while keeping all the other variables constant. For example, comparing full-owner operators ($\hat{T}_1$=-.114) with nonoperator landlords ($\hat{T}_3$=.042), the log odds for landlord adoption rates would be estimated as .156 ($\hat{T}_3 - \hat{T}_1$) greater than the log odds for full-owner adoption rates when all other variables were the same. Specifically, the estimates of the log odds for adoption rates of full-owners and landlords on Corn Belt large farms with no erosion hazard are -.388 and -.232, respectively, a difference of .156 in log odds. Adoption rates derived from transforming the log odds are estimated as 40 percent for full-owners and 44 percent for landlords under the given conditions in the Corn Belt. Although in the logit scale differences between full-owners and landlords are estimated to be a constant .156 across all categories, transformed adoption rate differences across categories will not be constant.

Because of the interaction between erosion hazard and region, the term $(ER)_{kl}$ must be taken into account when considering the effect on log odds of changing either region

Table 2. Logit Analysis

Variables[a]	Degrees of Freedom	Chi-Square	Observed Significance Level (OSL)
Constant	1	2.42	.1195
Tenure	2	9.70	.0078
Farm Size	2	16.79	.0002
Erosion Hazard	1	41.23	.0001
Region	9	496.31	.0001
Erosion Hazard x Region	9	46.02	.0001
Goodness of Fit	155	155.95	.4635

[a]Significance tests for additional variables incorporated into the model are as follows:

Organizational Structure	2	.72	.6969
Tenure x Region	18	25.10	.1222
Tenure x Size	4	4.06	.3986
Tenure x Erosion Hazard	2	3.69	.1577
Size x Erosion Hazard	2	6.33	.0423
Size x Region	18	18.85	.4014

or erosion hazard. For example, the estimates of log odds in the Delta and Corn Belt differ by $\hat{R}_3+(\hat{ER})_{13}-[\hat{R}_2+(\hat{ER})_{12}]$ or 1.824 for nonerosive land but only $\hat{R}_3+(\hat{ER})_{23}-[\hat{R}_2+(\hat{ER})_{22}]$ or .308 for erosive land.

In Table 2, a chi-square statistic is reported for the significance of each variable of the model, after adjusting for the influence of the other variables. For example, the chi-square statistic of 9.70 for tenure tests the null hypothesis that $T_1=T_2=T_3=0$ (tenure status has no effect on minimum tillage adoption rates). The observed significance level (OSL) may be interpreted as the chance of sampling data with a larger chi-square than the observed 9.70, if, in fact, the null hypothesis were true. Values for the OSL less than .05 constitute evidence against the null hypothesis with the degree of evidence increasing as the OSL decreases. The OSL of .0078 indicates that, in this case, the null hypothesis should be rejected.

The goodness of fit statistic is used to determine if the proposed model is supported by the data. This is done by comparing adoption rates observed in the sample with adoption rates estimated from the model(Forthofer and Lehnen, pp. 46-48). If the differences between observed and estimated adoption rates can be reasonably attributed to sampling variability, then the estimated model is consistent with the data. Supposing the model to be true, then repeated drawings of new samples and calculations of the goodness of fit statistics would produce a chi-square distribution. The OSL is used to judge how the goodness of fit statistic calculated from the observed sample compares with this ideal sampling distribution. The OSL of .4635 means that, if the model were true, 46.36% of the samples would lead to larger chi-square values than the 155.95 calculated from the observed sample. In this case, the adoption rates observed in the sample are consistent with the model, since, if the model were true, we have observed a typical sample as evidenced by the fact that the observed chi-square statistic falls near the middle of the sampling distribution. Of course, there are other models which will also be consistent with the sampled data. But the adoption rates estimated from other consistent models must also be within sampling error of the observed adoption rates, and cannot be too much different from those estimated by our model.

Table 2 also includes chi-square tests for adding further parameters to the model. These test the null hypothesis that the proposed model holds against alternative hypotheses of models with additional nonzero parameters corresponding to log odds differences of the categories of other variables. There is little evidence for including any more interaction terms of tenure, size, erosion hazard, or region. Also the variable of organizational structure shows no significant impact on minimum tillage adoption rates after controlling for differences attributable to tenure, size, erosion hazard, and region.

Interpretation of Results

Differences in the adoption of minimum tillage among landowner tenure groups were found consistently across all regions, sizes of farms, and erosion hazards. The differences, however, do not appear to confirm usual hypotheses about the effect of separation of ownership and farm operation on soil conservation. Instead, adoption of minimum tillage is lowest among full-owner operators, those who operate only land that they own. Nationally, approximately 44 percent of full-owner operators used minimum tillage as opposed to 52 percent of part-owners and 51 percent of nonoperator landlords(see table 3 for definitions). Although tenants may be actually making the minimum tillage adoption decision, the discussion that follows refers to adoption by landlords because the data were collected by ownership units. Minimum tillage data were not provided by landlords, but collected by SCS field staff.

These raw percentages, which ignore all other factors, overstate the effect of tenure, since tenure is correlated with other explanatory variables. The logit model accounts for these intercorrelations by comparing minimum tillage adoption rates for the different tenure classes while holding size, erosion hazard, and region constant. For example, using the logit model, in the Corn Belt on farms of

Table 3. Estimated Minimum Tillage Adoption Rates for the Corn Belt Region by Tenure of the Owner, Size of Farm, and Land Quality

Land Quality	Erosion Hazard			No Erosion Hazard		
Size of Farm (acres)	$\leq$ 140	141-699	$\geq$ 700	$\leq$ 140	141-699	$\geq$ 700
	percent					
Landowner Tenure[a] Classification						
Full-owner operator[b]	32	35	40	33	36	40
Part-owner operator[c]	36	39	44	37	40	45
Nonoperator landlord[d]	35	39	43	36	40	44

[a]The land tenure classifications used in this paper were developed by USDA for the Landownership Survey (Lewis, p. 6).

[b]Those who operate land that they own, they do not rent land to or from others.

[c]Primarily those who operate land that they own and additional land that they rent, but also includes part-owners who rent out land and owners who operate only rented land.

[d]Those who do not operate any land but rent land to others.

less than 141 acres without erosion hazard, an estimated 33 percent of full-owner operators adopted minimum tillage on cultivated cropland (table 3). Approximately 37 percent of part-owner operators and 36 percent of nonoperator landlords, under these same conditions, also adopted minimum tillage. Using the logit model, paired comparisons between the tenure classes show full-owner operators are significantly different from both part-owners (OSL=.0027) and nonoperator landlords (OSL=.0167), but part-owners and nonoperator landlords are not significantly different (OSL=.6033).

One possible explanation is that differences in adoption by tenure of the landowner reflect the total acres worked by operators. The Landownership Survey used an ownership unit as the information base. Consequently, only land actually owned by part-owners or tenants was reported by these groups. Census data which use an operating unit concept, including land owned and operated as well as land rented from others, suggest that full-owners operate fewer acres than do part-owners and tenants. The 1978 average size of farm with harvested cropland was 74 acres for a full-owner, compared to 285 and 188 acres, respectively, for part-owners and tenants (U.S. Census of Agriculture). These statistics suggest that small operating size may be an inhibiting factor in minimum tillage adoption by full-owners. Further study, however, is needed to test this hypothesis.

Other research suggests that operator tenure may be related to the life cycle of the operator. Full-ownership rises and tenancy declines with age. Part-ownership rises through the 45 to 54 age bracket and then declines (Barry and Baker, p. 53). Thus, tenants and part-owners may be younger than full-owner operators, have longer planning horizons, and thus be more likely to adopt conservation measures. The potential interaction of operating size, operator age, and minimum tillage adoption requires further investigation.

Although leasing data were not included in the analysis, the tenure effect was significant across all regions, including those regions such as the Corn Belt where share leases are common. Furthermore, there was not a significant interaction effect between tenure and region. This suggests that leasing arrangements do not alter the basic relationship between tenure and minimum tillage adoption.

The results with respect to landowner farm size were consistent across regions, tenure groups, and land quality. The analysis supported the hypothesis that small farm size may inhibit adoption of minimum tillage on cultivated cropland. Nationally only 40 percent of small farms (less than 141 acres) compared to 47 percent of medium sized farms (141-700 acres) and 61 percent of larger farms (over 700 acres) use minimum tillage on cultivated cropland. As with tenure percentages, these statistics may overstate the effect of size.

Regional adoption rates by size can be estimated in the logit model (table 3). For example, in the Corn Belt, full-owner operators with less than 141 acres and an erosion hazard designation have an estimated 32 percent minimum tillage adoption rate on cultivated cropland. Corn Belt full-owner operators with 141-700 acres and an erosion hazard designation have an estimated adoption rate of 35 percent, compared to a 40 percent rate for similar but larger farms. Paired comparisons show small farms significantly different from medium size farms (OSL=.0319) and medium size farms significantly different from large farms (OSL=.0028).

The hypothesis that minimum tillage differences among landownership groups can be accounted for by land quality differentials or regional location is not supported by this analysis. Main effects of tenure and size are consistent across erosion hazards and various geographical regions. Not surprisingly, regional effects are most important in explaining minimum tillage adoption. Crops grown, yield reduction, erosion problems, as well as local attitudes may explain most of these regional adoption differences. Interaction effects between region and erosion hazard are included in the model because their joint effects are not constant across regions. The analysis indicates that, after accounting for tenure classification and size of farm, minimum tillage is slightly more likely to be adopted on nonerosive land than on erosive land in some regions. This suggests that soil conservation may be a secondary motivation in minimum tillage adoption.[4]

Conclusions

This analysis indicates that full-owner operators and landowners with small holdings have lower minimum tillage adoption rates on cultivated cropland than do other groups. If low incomes associated with small farm size are the reason, then cost-sharing, including chemical costs, may be necessary to further encourage conservation management decisions among these groups.

This study, however, does not address the costs and returns of such a strategy. If groups with higher adoption rates also have higher marginal propensities to adopt minimum tillage, then a cost effective strategy may be to target policies to groups where the adoption rates are already highest--landowners with large holdings, part-owners, and nonoperator owners. Further research is needed to determine among which groups public dollars may be spent most effectively.

This analysis did not find that nonfamily corporate structure significantly influences the adoption decision. The study results do suggest that personal characteristics and economic factors associated with farm operators should be further investigated as determinants of minimum tillage adoption. In many cases, the operator may have more influence than the landowner in the adoption decision.

The importance of the regional variables in analyzing the adoption of minimum tillage emphasizes the complexities of examining soil conservation from a national perspective. Applicability of minimum tillage varies from region to region, as do physical erosion problems, owner attitudes, crops, weed and pest problems, and leasing arrangements. Nevertheless, at the national and regional level, this analysis indicates that small operating size poses more of an obstacle to minimum tillage adoption than separation of ownership from farm operation.

Footnotes

[1] Share leases have been hypothesized by many to lead to less efficient resource allocation than other leasing arrangements. See Cheung for a review of this literature. Others (Dillman and Carlson) have hypothesized that cash leases leave decisions to the farm operator and encourage maximization of short-term productivity at the expense of soil conservation. There is little empirical evidence, however, that indicates one type of lease leads to lower levels of conservation investment than other leasing arrangements.

[2] Minimum or conservation tillage generally refers to any tillage system, including planting directly into untilled soil, that reduces loss of soil or water compared to unridged or clean tillage. Crop residue management is the use of that portion of the plant or crop left in the field after harvest for protection or improvement of soil (Soil Conservation Society of America, pp. 15g-16g).

[3] Data on net farm income, type of lease, landowner age and education were not available for the entire data set and were therefore excluded from the analysis. The farm size variable was converted from a continuous to a categorical variable for this analysis, possibly resulting in some loss of power to detect the effect of farm size on minimum tillage adoption rates.

[4]Higher minimum tillage adoption rates on nonerosive land also may reflect the possibility that observation of conservation measures on the land made an erosion hazard assessment by local SCS staff less likely.

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