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**Abstract.** This study analyses three key conservation practices adoption behavior for 266 farmers in eastern Washington. Results revealed (1) that multiple practice adopters contrast more sharply with non-adopters than do adopters of a single practice, and (2) single practice adopters differ more from zero practice adopters than from other farmers.

Keywords: adoption, conservation, logit, multiple adopters, single adopters, soil conservation, technology adoption, wind erosion,

**How Do Farmers Who Adopt Multiple Conservation Practices Differ from their Neighbors?**

Wind erosion has been a serious environmental problem in the inland Pacific Northwest (PNW) since settlers began cultivating the fine soils 120 years ago (Busacca et al., 1998). East sides of Washington and Oregon states lie in the rain shadow of the Cascade Mountains and receive only six to twenty inch (150 to 500mm) of annual precipitation. The region also experiences high wind. For example, a five-year study at Hermiston, Oregon showed that the wind speed exceeded 15 mi $hr^{-1}$ (24km $hr^{-1}$) 30% of the time during the period from March to June and 13% of the time during July through October (Papendick, 1998). Much of the soil in this region is relatively fine textured loess or weathered soils which are vulnerable to wind erosion.

On-farm damages has always been a major concern among agriculturalists in the dryland regions. More recently airborne dust pollution has attracted increasing attention due to off-site effects including damage to human health, traffic safety, industrial and household cleaning costs, and diminished recreational values (Veseth et al., 1994). Particulate matter (PM) 10 microns or smaller, and especially those 2.5 microns or less, in aerodynamic diameter (PM-10 and PM-2.5, respectively) are readily inhaled and can accumulate in lung tissues. These particulates have been related to heart and respiratory illness (Schwartz, 1996). Because agriculture is a major contributor to airborne pollutants in the PNW, it is important that research aid adoption of conservation practices that control wind borne dust to tolerable levels.

Three key practices for controlling wind erosion in eastern Washington are reduced tillage (no-till or min-till), continuous spring cropping and vegetative wind strips. Studies have shown their effectiveness in controlling on-site erosion as well as off-site damages; for example, adoption of continuous spring cropping was projected to reduce air borne dust by 95% compared to conventional tillage summer fallow (Lee, 1998). However, in east-central Washington, where wind erosion is most severe, even minimum tillage fallow is rarely used. For example, in Adams County, the heart of Washington's wheat (*Triticum aestivum L.*)-fallow area and most vulnerable to wind erosion, conventional tillage was still practiced on 88% of the cropland (CTIC, 1998).

Technology adoption has been a major part of the agricultural research agenda of economists and sociologists for several decades (Griliches, 1957; Jensen, 1982; Feder et al., 1985; Byerlee and de Polanco, 1986; Diebel et al., 1993; Ruttan, 1996). A considerable number of studies have focused on the adoption of soil conservation practices, with the majority directed to conservation tillage (Papendick and Miller, 1977; Dillman and Carlson, 1982; Ervin and Ervin, 1982; Lee and Stewart, 1983; Hansen et al., 1987; Napier and Camboni, 1993).

**Determinants of conservation practices adoption**

The literature on adoption is extensive and complex. For simplicity, we identify three "paradigms" which have emerged to explain conservation practice adoption (e.g., Ruttan, 1996; Wandel and Smithers, 2000; Feder and Umali, 1993; Nowak, 1987). The ***income paradigm*** assumes that farmers are profit maximizers and that the technology that increases net returns to the farm-firms will be adopted (Cary and Wilkinson, 1997). However, one of the major criticisms of this paradigm is that it fails to recognize heterogeneity among farmers' preferences (Nowak, 1987). Thus it fails to explain why certain profitable technologies are <u>not</u> adopted (Neill and Lee, 2001).

The ***utility paradigm*** asserts that producers make the adoption decision based on utility maximization rather than profit maximization (Rahm and Huffman, 1984; Caviglia and Kahn, 2001). In the utility paradigm, a producer responds to many factors beside income, including non-income factors such as environmental quality, social benefit, and/or altruism. For example, Smale et al. (1994) maximized net income and information over a multi period horizon. Bultena and Hoiberg (1983) used risk orientation, perceived erosion and perceived attitudes of other farmers, as well as their perception of other farmers' adoption, to explain adoption of conservation practices.

Many rural sociologists favor a third paradigm, the ***innovation-diffusion-adoption*** paradigm introduced by Rogers (1962), and used extensively since (e.g., Taylor and Miller, 1978). This paradigm emphasizes the role of information, risk factors, and the social position of the decision maker in the community. It portrays the innovation process as somewhat similar to the spread of an infectious disease among farm operators with different predispositions to accept change and to innovate (Feder and Umali, 1993). Thus, some researchers have provided evidence that availability of information to producers, and the level of education and experience of prospective adopters, are better determinants of adoption of new practices than income (Caviglia and Kahn, 2001). However, by itself, the diffusion paradigm provides inadequate attention to agent motivation and to model specification (Ruttan, 1996).

The current theoretical and empirical literature recognizes that adoption behavior is complex and often requires a blend of the income, utility and diffusion paradigms (Feder and Umali, 1993). Thus, researchers often include economic variables, social-cultural variables, as well as information variables in their studies (Nowak, 1987).

**Adopters and non-adopters**

Most prior empirical studies have divided farmers into two homogeneous groups - "adopters" and "non-adopters"(Lockeretz, 1990; Cary and Wilkinson, 1997). This approach tends to neglect the sequential process by which a farmer adopts different practices. Also, this approach relying on binomial adoption variables provides little discrimination on the extent and intensity of "adoption." (Lockeretz, 1990; Harper, 1991; Rikoon et al., 1996). Because there are frequently multiple conservation practices available to farm operators, placing all adopters of a single practice into one homogeneous category of "adopters" will not precisely discriminate the degree of innovativeness nor the amount of soil saved by adopters versus non-adopters. A non-adopter of wind strips, for example, may be using other practices such as no-till that are equally or more effective in controlling wind erosion. The multiple practice versus single practice versus zero practice categorization proposed in this study will normally be correlated with innovativeness, but it will not always be perfectly correlated with soil saved. However, our experience is that adopters of multiple practices will typically save more soil. In response to this problem, Napier et al. (2000) define an "adoption index" as a continuous adoption variable. However, while a continuous adoption variable provides a desirable theoretical solution, it may be difficult to apply in practice due to information limitations (Feder et al., 1985; Lockeretz, 1990).

In this study we provide a tractable compromise for empirical applications. To recognize some heterogeneity in soil savings among farmers, we partition the sample into three groups: zero practice adopters, single practice adopters and multiple practice adopters. This categorization is compatible with the innovation-adoption paradigm because farmers who are simultaneously using two or three conservation practices could reasonably be classified as more innovative than neighbors who are using zero or one practice.

**Objectives**

To help determine if farmers using different numbers of conservation practices are distinct identifiable groups, we test the following two hypotheses

1) Farm and farmer characteristics will differ more between adopters and non-adopters of conservation practices when adopters are defined as those who adopt multiple practices (multi-adopters) as opposed to those who adopt a single conservation practice (single adopters).
2) Farm and farmer characteristics will account for a greater difference between adopters and non-adopters of a particular conservation practice when non-adopters are defined as adopters of zero conservation practices (zero-adopters) as opposed to when they are defined as "all other farmers." "All other farmers" ("rest") includes both the zero adopters and farmers who have not adopted the particular practice but who may have adopted some other practice.

**Methods**

First we statistically compare the similarity of farm and farmer characteristics between single practice adopters and multiple practice adopters. The farms were divided into two groups, one for the single (multiple later) practice adopters, and the other for the zero practice adopters. The levels of farm characteristic variables for each group were assessed separately. T-tests were used to test the differences in means for all continuous characteristic variables, and Chi-square test were used to test the difference in frequency of occurrence for all categorical characteristic variables. The null hypothesis for each case is that there is no difference in a characteristic variable between single (multiple later) practice adopters and zero practice adopter.

Our second objective was to compare the ability of farm and farmer characteristics to predict differences between adopters and non-adopters of any practice when non-adopters are defined as farmers who do not adopt the specific practice versus farmers who do not adopt any practice. Logistic regression, an appropriate analytical tool to deal with a dichotomous criterion variable (Gujarati, 1992), was used for this comparison. The level of significance of coefficients for the same characteristics was compared across the two regression equations representing different non-adopter definitions. The dependent variable is described by a binary (zero-one) variable. Six types of adoption variables are defined (Table 1). SINGLE and MULTIPLE represent single and multiple practice adoption. NOTILL and CONTSP represent no-till and continuous spring cropping adoption. When these conservation practice variables are followed by "_ZERO", adopters are contrasted with zero practice adopters only, and when followed by "_REST", adopters are contrasted with the rest of the farmer sample.

The seven independent variables included in this study (Table 1) are drawn from all the three adoption paradigms. KNOWPM10 represents knowledge of a PM-10 educational program, which had been conducted in the region prior to the survey (Scott et al., 1997). This program communicated on-site and off-site damages from wind erosion and described potentially effective control practices. Consistent with the innovation and diffusion paradigm, the program is expected to have a positive correlation with the adoption of practices. EROSPROB represents an index of the number of the farmer's perceived on-site problems with wind erosion. Consistent with an environmental quality component of utility, it is expected to have a positive correlation with the adoption of practices. SIZE and %RENTED represent the number of acres farmed by the respondent and the percentage of farmland rented from farmers other than family members, respectively. SIZE may increase the financial capability of the farmer to implement conservation practices. Therefore, it is expected to contribute positively to the adoption of practices as larger farmers have the resources to be more risk-tolerant following the diffusion paradigm. %RENTED might vary negatively with adoption because a renter may not consider long run land degradation as much as an owner. AGE, EDUC and OFF-FARM represent age, level of education and magnitude of off-farm income of the farmer respectively. AGE is expected to have negative correlation because of a shorter expected economic payoff period from conservation practices for older farmers. Consistent with the diffusion paradigm, EDUC is expected to correlate positively with adoption of practices because it may help farmers better acquire new information and apply conservation technology. OFF-FARM could not be signed because it could either provide capital for conservation practices or dilute income incentives for conserving resources. KNOWPM10, EROSPROB, OFF-FARM and EDUC are measured as categorical variables. SIZE, %RENTED and AGE are continuous variables (Table 1).

**Data**

Data employed for this study were obtained through a telephone survey conducted in 1997. The survey included a random sample of dry land farmers from Adams, Benton, Douglas, Franklin, and Grant counties in east central Washington State (Scott et al. 1997). Data from a total of 266 respondents were included in the study. This included 59% of the original sampling frame, a relatively high final response rate for a telephone survey.

**Results and Discussion**

Figure 1 provides the percentage of farmers in each category: zero practice adopters, adopters of any one practice, and adopters of any combinations of practices. It shows that 60.5% of the 266 farmers used none of these conservation practices, and they are defined as zero practice adopters in this study. Only the remaining 39.5% were adopters of conservation practices. The single practice adopters include 12.8% of the 266 farms for CONTSP, 8.3% for NOTILL, and 4.5% for WINDST, which add up to 25.6%. Duel practice adopters shown by the overlapping areas in Figure 1 represent 9.8% of the 266 farms using NOTILL and CONTSP, 1.9% using CONTSP and WINDST, and 0.8% using WINDST and NOTILL, adding up to 12.5%. An additional 1.5% farms adopt all three practices. These results show 26% of the sample farms adopted CONTSP, followed by 20.3% for NOTILL, and 8.7% for WINDST.

Table 2 reports basic statistics for the responding farmers. These include the number of observations, range, mean and standard deviation for continuous variables, and percentage of each category for categorical variables utilized in this study. For example, consistent with Figure 1, out of 266 farmers about one fifth adopted no-till. The remaining farmers either adopted no conservation practice or other practices.

Table 3 evaluates the statistical difference of farm and farmer characteristics between adopters and non-adopters when adopters are defined as single practice adopters and multiple practice adopters. More specifically, Table 3 lists the probabilities of making type-I error that is rejecting that the means are equal for adopters and non-adopters when they are actually equal. Almost all probabilities are smaller for the multiple practice adopters versus zero practice adopters than for the single practice adopters versus zero practice adopters. The only exception is EROSPROB. This shows heterogeneity among adopters except that the variable measuring the perception of erosion on the farm does not go along the cluster of attributes that discriminate among heterogeneous adopter categories.

At the 10% critical level, the T and chi-square tests show no statistically significant differences between the characteristics of single practice adopters and zero practice adopters (Table 3 ). Only SIZE approaches significance with a 0.13 probability level. In contrast, both SIZE and EDUC statistically differ at the 0.04 and 0.10 level between multiple practice and zero practice adopters. All variables conform to expected signs. Adoption theorists have argued that innovators or early adopters are likely to have more financial resources, exercise more opinion leadership and use broader sources of information (Rogers, 1962). The significance of SIZE at the 0.04 probability level might indicate greater financial resources among multiple adopters in this semi arid region where farm size varied greatly. Higher levels of EDUC might also facilitate information acquisition and use.

Table 4 presents results of four Logit regression models with estimated coefficients, their level of significance, and overall equation significance. Non-adopters are defined alternatively as zero practice adopters and "all other farmers." In all four models KNOWPM10, SIZE, OFF-FARM and EDUC are positively related to adoption, consistent with theory discussed in the method section. These results are also consistent with existing literature. Farm size was found to contribute positively and significantly to adoption (Feder et al., 1985; Rahm and Huffman, 1984; Lee and Stewart, 1983; Norris and Batie, 1987). Off-farm income was also found to be positively related to conservation tillage adoption (Norris and Batie, 1987; Nowak, 1987). Nowak (1987) favored the argument that farmer with more off-farm income have more flexibility to invest in practices than those with only farm income. In our case, the insignificant coefficient for off-farm income may be due to lack of off-farm employment opportunities in the study area. Education was also found to be significant and positive by Traore et al.(1998) and Gould et al. (1989).

%RENTED is negatively related to adoption but insignificantly, which is also consistent with theory. Renters have a shorter time horizon to benefit from the soil productivity payoffs from soil conservation. Traore et al. also reported insignificant impact of land ownership to adoption (1998).

EROSPROB is also negatively related to adoption but is insignificant. This shows that perception of the number of erosion problems was a weak determinant of adoption Previous studies had mixed results which concur with this conclusion. Perception of erosion problem was found positively related to the adoption sometimes (Norris and Batie, 1987), and negatively other times (Wandel and Smithers, 2000). Carry and Wilkinson 1997 found that environmental attitudes will not translate into pro-environmental behavior unless there are economical or other benefits associated with the behavior. In our case, insignificant but negative perception of erosion problem may be due to the respondent's recollection of erosion problems on the farm over the last 10 years.

The two models defining non-adopters as zero practice adopters display superior overall equation significance levels (Table 4). Furthermore, for all variables except for KNOWPM10 and AGE, the probability of type-I error is higher in NOTILL_REST than in NOTILL_ZERO. The results differ for the CONTSP model. The level of significance is higher in CONTSP_REST than in CONTSP_ZERO for SIZE and %RENTED. Coefficient significance levels are very similar for KNOWPM10, EROSPROB, and EDUC. However, significance of the overall equation clearly favors CONTSP_ZERO. The overall equation significance suggests NOTILL_ ZERO and CONTSP_ZERO are superior models supporting our second hypothesis.

The level of significance of %RENTED, OFF-FARM, AGE and EROSPROB range from 34% to 84% suggesting these variables have weak discriminating influence, in a multiple regression context, between adopters and non-adopters. KNOWPM10 and SIZE show the most consistent statistical significance at 0.05, 0.10, 0.15 levels (Table 4). Size of farm is beyond the control of conservation advocates, but it can be used as a targeting criterion for new conservation technologies.

**Conclusions**

This study revealed (1) that adopters of multiple conservation practices contrast more sharply with zero practice adopters than do adopters of a single conservation practice, and (2) adopters of a practice differ more from zero practice adopters than they do from all other (the "rest" of the) farmers. More specifically, it recognizes heterogeneity among "adopters" in conserving the soil. Multiple practice adopters are a distinct identifiable group who may play a key role as innovators who can influence neighbors to adopt effective soil conservation practices. The approach used in this study identifies innovativeness and adoption with soil conservation performance to a greater extent. It also provides a more rigorous definition of "non-adopters" by defining this group as zero-practice adopters. These distinctions were statistically significant in terms of farm size, education and knowledge of a conservation education program.

Results from this paper support the previous findings by sociologists that early adopters have more financial resources or larger farms (Feder et al., 1985; Rahm and Huffman, 1984; Lee and Stewart, 1983; Norris and Batie, 1987) and that education aids adoption (Caviglia and Kahn, 2001; Traore et al., 1998; Gould et al., 1989).

Comparatively speaking, variables drawn from innovation-adoption paradigm appear to outweigh those from the utility paradigm although there is overlap in linking variables to paradigms. Variables drawn from the income paradigm show mixed significance. Of course, the findings from this study could also be influenced by the particular agro-climatic characteristics of the study region. Similar research using these definitions of adoption and non-adoption is encouraged elsewhere.

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**Table 1. Variables in wind erosion control practices adoption models**

| Variable[1] | *Unit*[2] | Description | Paradigm |
|---|---|---|---|
| Dependent: | | | |
| NOTILL_REST | (1,0) | 1 if no-till or min-till, 0 otherwise | |
| NOTILL_ZERO | (1,0) | 1 if no-till or min-till, 0 for zero practices | |
| CONTSP_REST | (1,0) | 1 if continuous spring crop, 0 otherwise | |
| CONTSP_ ZERO | (1,0) | 1 if continuous spring crop, 0 for zero practices | |
| SINGLE | (1,0) | 1 if single practice, 0 for zero practices | |
| MULTIPLE | (1,0) | 1 if multiple practices, 0 for zero practices | |
| Independent: | | | |
| KNOWPM10 | (0,1,2,3) | 0 if not heard of PM-10, 1 if slightly knowledgeable, 2 if somewhat knowledgeable, and 3 if very knowledgeable. | Diffusion |
| EROSPROB | (0,1,2,3) | 0 if no problems with erosion in last 10 years, 1 if one to two problems, 2 if three to five problems, and 3 if more than five problems | Utility |
| SIZE | Acres[3] | Acres | Income |
| %RENTED | Percent | Percentage of farm land rented from other than family | Income |
| OFF-FARM | (1,2,3) | 1 if source of household income is mostly from farm, 2 if roughly same from farm or off-farm, and 3 if mostly off-farm | Income |
| EDUC | (0,1,2) | 0 if highest level of education is within secondary, 1 if some college or technical school, and 2 if college graduate | Diffusion |
| AGE | Years | Years | Income |

*1* Suffix REST and ZERO in the variable name denotes adopters are contrasted with rest of the farmer sample and zero practice adopters, respectively.
*2* Value for categorical variables.
*3* One acre =0.405 ha.

**Table 2. Descriptive statistics for all variables**

| **Variable**[1] | Value/ Unit | N | Statistics | | | | Max | Min |
|---|---|---|---|---|---|---|---|---|
| Categorical: | | | % of level 0 | ***% of level 1*** | ***% of level 2*** | ***% of level 3*** | | |
| NOTILL_REST | (1,0) | 266 | 80 | 20 | - | - | 1 | 0 |
| NOTILL_ZERO | (1,0) | 215 | 75 | 25 | - | - | 1 | 0 |
| CONTSP_REST | (1,0) | 266 | 74 | 26 | - | - | 1 | 0 |
| CONTSP_ZERO | (1,0) | 230 | 70 | 30 | - | - | 1 | 0 |
| SINGLE | (1,0) | 229 | 70 | 30 | - | - | 1 | 0 |
| MULTIPLE | (1,0) | 198 | 81 | 19 | - | - | 1 | 0 |
| KNOWPM10 | (0,1,2,3) | 266 | 27 | 24 | 40 | 9 | 3 | 0 |
| EROSPROB | (0,1,2,3) | 266 | 25 | 44 | 23 | 8 | 3 | 0 |
| OFF-FARM | (1,2,3) | 266 | - | 81 | 14 | 5 | 3 | 1 |
| EDUC | (0,1,2) | 266 | 27 | 42 | 31 | - | 2 | 0 |
| Continuous: | | | Mean | | ***SD***[2] | | | |
| SIZE | Acres[3] | 266 | 3,263 | | 2,593 | | 18,000 | 60 |
| %RENTED | Percent | 266 | 23.76 | | 30.53 | | 100 | 0 |
| AGE | Years | 266 | 53 | | 13 | | 86 | 26 |

*1* Suffix REST and ZERO in the variable name denote adopters are contrasted with rest of the farmer sample and zero practice adopters, respectively.
*2* Standard deviation.
*3* One acre = 0.405 ha.

**Table 3. Comparison of single and multiple practice adopters to zero practice adopters on the basis of probability of type I error**[1]

| *Variables* | Tests | Zero compared to single practice adopters (N=229) | | Zero compared to multiple practices adopters (N=198) | |
|---|---|---|---|---|---|
| | | Error | Direction[2] | Error | Direction[2] |
| SIZE | T-test | 0.13 | + | 0.04 | + |
| %RENTED | T-test | 0.92 | + | 0.56 | + |
| AGE | T-test | 0.74 | - | 0.54 | - |
| KNOWPM10 | chi-sq.test | 0.48 | + | 0.21 | + |
| EROSPROB | chi-sq.test | 0.26 | + | 0.44 | + |
| OFF-FARM | chi-sq.test | 0.98 | - | 0.91 | + |
| EDUC | chi-sq.test | 0.45 | + | 0.10 | + |

*1* The null hypothesis is there is no difference between adopters and zero practice adopters.
*2* Direction in which adopters differ from zero practice adopters. For continuous variables it is the comparison of means. For categorical variables it is comparison of percentage. All the categories of a variable are equally weighed for the comparison.

**Table 4. No-till and continuous spring cropping adoption regression coefficients when non-adopter is defined as all other farmers versus zero practice adopters.**

| *Variables* | **NOTILL _REST** | **NOTILL _ZERO** | **CONTSP _REST** | **CONTSP _ZERO** |
|---|---|---|---|---|
| KNOWPM10 | 0.322 | 0.316 | 0.226 | 0.232 |
| | (0.058)[1] | (0.069) | (0.136) | (0.137) |
| EROSPROB | -0.135 | -0.177 | -0.135 | -0.133 |
| | (0.468) | (0.345) | (0.424) | (0.431) |
| SIZE | 0.000162 | 0.000181 | 0.000086 | 0.000121 |
| | (0.006) | (0.005) | (0.124) | (0.047) |
| %RENTED | -0.00112 | -0.0016 | -0.00225 | -0.0029 |
| | (0.839) | (0.780) | (0.653) | (0.579) |
| OFF-FARM | 0.115 | 0.190 | 0.249 | 0.218 |
| | (0.712) | (0.566) | (0.353) | (0.428) |
| EDUC | 0.259 | 0.308 | 0.219 | 0.234 |
| | (0.261) | (0.198) | (0.288) | (0.289) |
| AGE | 0.00787 | 0.006 | -0.0121 | -0.00909 |
| | (0.584) | (0.689) | (0.348) | (0.494) |
| CONSTANT | -3.062 | -2.820 | -1.363 | -1.396 |
| | (0.005) | (0.013) | (0.148) | (0.152) |
| Equation Signif.(chi-sq) | (0.041) | (0.029) | (0.237) | (0.169) |

*1* Significance level in parentheses.

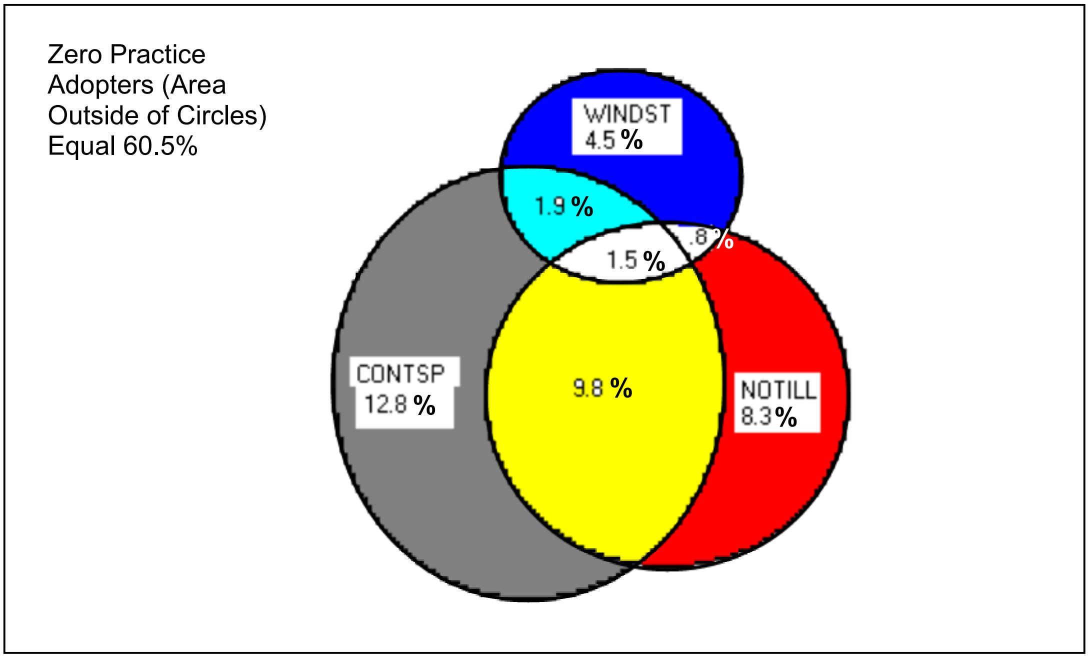


Figure 1. Percent of Total Respondents by Adoption Category