IRRIGATION WATER SOURCES AND IRRIGATION APPLICATION METHODS USED BY U.S. NURSERY PRODUCERS

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, Orlando, Florida, 3-5 February 2013

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Abstract

We examined water sources and irrigation methods chosen by U.S. nursery plant producers using a nested multinomial fractional regression model. We used data collected from the National Nursery Survey (2009) to identify effects of different firm and sales characteristics on the fraction of water sources and irrigation methods used. We found that nursery location regions, sales of plant types, farm income and farm age were significant in determining the source of water use. Given the fraction of alternative water sources used, results indicated that use of computer, annual sales, region, and number of IPM practices used play important roles in the choice of irrigation methods used.

Key words: irrigation method, multinomial nested fractional regression, plant nursery, quasi Likelihood, water sources

JEL Classification: C1, C35, Q25,

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Water has been a scarce and valuable commodity throughout the U.S. because of its multiple competitive uses. As water gets scarcer, human consumption gets precedent over other uses. This creates contention among alternative users. Due to limited surface and groundwater availability, lately reclaimed/recaptured water use has been prevalent in nursery plant production (Malash et al., 2008) and in agricultural production overall. Reclaimed water is typically used in states like Florida and California where a large number of nursery operations are located. Other sources of water used in nursery plant production include natural, wells and piped water supply from municipal sources.

In outdoor nursery areas, a prevalent form of watering is through flooding or sub-irrigation(Clemson Cooperative Extension, 2013). Flooding causes significant loss of water as a result of evaporation and drainage. A drip irrigation method has been used in areas where water is scarce. Drip irrigation is expensive so nursery operators need to be convinced about its economic value before investing in this irrigation method. If water used in irrigation is saline (such as obtained from reclaimed source), the drip irrigation has additional benefits. Overhead irrigation system is the most common method in greenhouse as well as outdoor nursery areas. Unfortunately, overhead irrigation has high water inefficiency (as much as 80%). Generally speaking, each irrigation method has its own strengths and weaknesses. The choice of irrigation methods is determined by several factors (for example, intended plants, regional factors, and market channel and contract used by growers) but the ultimate goal is to minimize dry areas at the minimum cost.

The objective of this study is to use a nested multinomial fraction regression model to determine the quantitative estimates of factors affecting irrigation water source choice and irrigation method selections by nursery plant producers in the U.S. In the first step, we identify variables affecting water source selection. In the second step, we identify the irrigation method choice conditional on the water source chosen by nursery plant producers.

Method

Let's assume a nursery plant producer chooses to obtain water from different sources that make up the total portfolio of water use. These different water sources are well, recaptured water, city supplied water, and natural water. A nursery producer therefore chooses to use a fraction of water from each source and water use from all sources makes to 100% water used in the production process. The sources are not mutually exclusive as farmers can use multiple sources to fulfill their water needs. Suppose $Z = (z_1, z_2, \ldots, z_L)$ corresponds to L different water sources. These water sources supply a pool of water that farmers use to irrigate their nursery crops using one of the irrigation methods: drip, overhead, sub-irrigation and other. Nursery producers choose to use one irrigation method or all four of these methods. Let $Y = (y_1, y_2, \ldots, y_M)$ represent fraction of area (plant containers) irrigated using M irrigation method. Since the values associated with these variables are in fractions, they are limited to the closed interval [0,1]. An appropriate model should adjust the nature of fractional variables. A solution to deal with this type of variables is to use a nonlinear function satisfying $0 \leq g(.) \leq 1$, where $g(.)$ is nonlinear model proposed by Papke and Wooldridge (1996). Hence, the conditional mean of the dependent variable can be expressed as

$$E(y|x) = g(x\beta) \tag{1}$$

with x representing the matrix of independent variables and βrepresenting the parameters associated with these independent variables. A fractional model is specified using a logistic link with Bernoulli distribution. We estimate β by maximizing Bernoulli log-likelihood function given by

$$LL(\beta) = \sum_{i=1}^{N} y_i \log[g(x_i\beta] + (1 + y_i) \log[1 - g(x_i\beta)] \tag{2}$$

with N being the total number of nursery producers. The estimated parameter is consistent and asymptotically normal provided that $E(y|x)$ is correctly specified. Different approaches are discussed in the literature for univariate cases (Hinson et al., 2012; Papke and Wooldridge, 2008; Ramalho et al., 2011). These authors have proposed a fractional regression model on the basis of the logit conditional mean function and maximization of a quasi-likelihood function.

In our problem, water sources and irrigation methods used necessitate we estimate the model simultaneously using a multivariate specification. A recent manuscript by Murteira et al. (2012) has proposed generalization of a univariate specification shown in equation (1) to a multivariate specification with multinomial logit link and multivariate Bernoulli distributions[1].

[1] An alternative to logit link function and Bernoulli distribution is to use a beta distribution in which density values lies between 0 and 1, however this is less common compared to the quasi-likelihood maximum likelihood estimation. A recent paper by Ramalho et al. (2011) illustrated a different models and estimation procedure that can be used for multivariate fractional response variables with test procedure to check methodology and validity.

Let $E(Y|X) = G(X;\beta) = [G_1(X,\beta], \dots, G_M(X,\beta)]'$ be the m vector of conditional mean function with its components $E(y_m|X), m = 1, \dots, M,$ with $G_m = G_m(X,\beta)$. Here the conditional mean $0 < G_m < 1$ for all m and $\sum_m^M G_m = 1$.We use multinomial logit specification expressed as:

$$G_m = \frac{\exp(X_m\beta)}{\sum_{l=1}^{M}\exp(X_l\beta)}, m = 1, \dots, M \tag{3}$$

Nursery plants can be irrigated using any of the four irrigation methods that utilize water coming from any of the four sources. This can be presented as a nested structure shown in Figure 1. The nested logit model uses following structure

$$G_m = \frac{\exp\left[\frac{X_m\beta}{1+\eta_l}\right]\left\{\sum_{j\in S_l}\exp\left[\frac{X_j\beta}{1+\eta_l}\right]\right\}^{\eta_l}}{\sum_{k=1}^{L}\left\{\sum_{j\in S_l}\exp\left[\frac{X_j\beta}{1+\eta_l}\right]\right\}^{1+\eta_l}} \tag{4}$$

Here, S_l is a branch within the nested structure and l =1,…,4 as shown in figure 1. This expression is equivalent to the multinomial logit if $\eta_l = 0, l = 1, \dots, L$.

Let Y_m be the fraction of m^{th} component irrigation method used by a nursery producer which follows multivariate Bernoulli (MB) distribution (Murteira et al., 2012). The individual contribution of each i producer to the log-likelihood can be expressed as:

$$\log L_i(\beta) = \sum_{m=1}^{M} y_{im}\log G_{im} = \sum_{m=1}^{M-1} y_{im}\log\frac{G_{im}}{G_{iM}} + \log G_{iM}. \tag{5}$$

Here, $G_{iM} = 1 - \sum_{m=1}^{M-1} G_{im}$. Then the quasi-maximum likelihood (QML) estimator is estimated by maximizing log-likelihood of all nursery producers (N) as given below

$$LL(\beta) = \sum_{i=1}^{N}\log L_i(\beta). \tag{6}$$

The estimated parameter $\hat{\beta}$ is consistent and asymptotically normal regardless of the true conditional distribution of y, provided that G is correctly specified.

Data, Variables Used and Justification

Data for this analysis were obtained from the National Nursery Survey, 2009[2]. Data about sales, employment, product types and forms, market channels, production and marketing practices, regional trade, and other influencing factors were collected for the year 2008 using mail and e-mail surveys in 50 U.S. states. A list of nursery plant producers was taken from sources that included National Plant Health Board, departments of agriculture in each state, grower associations, and business databases. The Dillman (2000) protocol was used for design and implementation of surveys. The survey was sent to 15,000 producers by regular mail and to 1,900 producers in 12 states by email. A total of 3,044 valid responses was received for a 17% response rate. Of these responses, 312 were from the e-mail survey. Descriptive statistics of e-mail and mail survey respondents are similar[3] in nature so we analyzed the data that combines both email and mail survey respondents.

Our dependent variables for the first level of nested multinomial fractional regression are fraction of water source used: natural[4], recapture, municipal (city) and wells. Figure 2 shows that 56.2% nursery producers use well water making it the major source of water used in nursery production. Other sources of water such as natural,

[2] The 2009 National Nursery Survey was conducted by the Green Industry Research Consortium of University Horticulturists and Economists, organized as a multi-state project (S-1021) under the National Institute of Food and Agriculture at the U.S. Department of Agriculture.

[3] We use two sample mean comparison t-test for each variable and found that they are not significant.

[4] Natural source includes rain and river.

municipal and recapture are used by 26.4%, 19.6%, and 9.8% of nursery producers, respectively. Among irrigation application methods, most nursery producers (59.8%) use an overhead irrigation method. Other irrigation methods used are: drip (37.5% of nursery producers), other (18.3% of nursery producers) and sub-irrigation (ebb/flood) (3.86% of nursery producers). For each producer the sum of fractions is equal to one for water sources as well as for irrigation methods. Hodges et al. (2008) found that significant regional differences existed with respect to use of sources and irrigation methods. Based on the location of firms, we divided growing regions into five categories (Midwest, Northeast, Pacific, Southeast, and others) as defined in Table 2[5].

Plant types determine the amounts of water needed in the nursery plant production phase. For example, foliage plants need frequent applications of water using overhead irrigation method, but the drip method often is used. In addition, because firms specialize in production of different categories of plants (vines, annuals, trees etc.), sales volumes by plant category are used as explanatory variables in the model. Nursery plant producers use computers for functions such as accounting/cost analysis, inventory, financial investment analysis, and digital imaging for disease diagnosis (Hodges et al., 2010). Computer technology enables nursery producers to evaluate benefits of choice of irrigation sources and methods; hence the use of computer can be an important factor that determines the fraction of water from different sources and irrigation methods.

We expect farm size, as measured by total sales volume, to have effect on choice of water sources and irrigation methods by nursery producers. The literature suggests that

[5] The states corresponding to the regions categories are Midwest: IA, IL, MI, MN, MO, OH, and WI; Northeast: CT, DE, MA, ME, NH, NJ, NY, PA, RI, and VT; Pacific: AK, CA, HI, OR, and WA; Southeast: AL, FL, GA, MS, and SC; Others: AR, AZ, CO, ID, KS, KY, LA, MT, NC, ND, NE, NM, NV, OK, SD, TN, TX, UT, VA, WV, and WY.

operator's age is important in many economic choice decisions (Pandit et al., 2012; Paudel et al., 2013). Operator age was not available, so age of the firm was included.

The emergence of mass merchandisers as a dominant form of retail for nursery plants has led to a higher share of plants reported as sold through contracts. These contracts reduce risk in some senses, but also may increase risk. In the contract relationship, growers are expected to have the agreed upon number of plants available for shipment. However, if retail demand is not sufficient, the retailer does not order shipment and the grower must find other outlets for the material. Still, the contract relationship typically does encourage or require the grower to expand and to control costs diligently. We expect that firms selling through contracts are more likely to choose appropriate irrigation sources and methods to maximize production. Further, we expect that choice of irrigation sources and methods are associated with type of contracts, such as contract to other producers, contract to garden center and contract to mass merchandisers.

Market channel alternatives have contributed to the growth of ornamental plant sales in the United States (Hinson et al., 2012). Choice of a particular marketing channel may have implication on the quality expectation and cost component, thereby impacting choice of irrigation source and application method. Hodges et al. (2010) found that the landscape channel received the highest share of growers' sales.

We expect that different kinds of promotion increase sales of product of a firm. As sales increase, we expect that growers would move to more costly sources as more water is needed, linked to profitability based on the increased demand. We used number of trade shows attended in 2008 (trade), web site promotion expenses and trade show promotion expenses as variables impacting the choice of irrigation sources and methods. The choice of these explanatory variables is consistent with the study by Pandit et al. (2012) and Hinson et al. (2012). Explanatory variables and summary statistics are provided in Table 2.

Previous literature has shown that small and large nursery plant producers behave differently (Hinson et al., 2012). In order to address effect of farm size we use a farm income dummy in the model. A farm income variable is used with annual sales volume above $500000 per year with value 1 and 0 otherwise. A summary statistics and definition of dependent and independent variables are provided in Table 1.

Results and Discussion

Our data do not provide information on water source used (l) by each irrigation method (m); therefore we restricted parameters to have equal value for each irrigation method. Our interpretation for the second level equation is based on the fact that fraction of water used in each irrigation method comes from different sources. To estimate the nested multinomial fractional regression model, we chose natural source of water as the base in the first level and overhead as the base in the second level. We estimated equation (6) to identify important variables affecting water source and irrigation method choice. Wald statistics for the model is significant at the 1% level (Wald $stat = 109.7, \text{d.f.} = 22$) indicating that the system of equations has a good fit. The dissimilarity parameters given at the bottom of Table 4 are significant indicating that we need to jointly estimate the regression equations.

Water Sources

The parameters associated with factors affecting the first level or the fractions of water source used are given in Table 2, and their corresponding marginal effects are given in Table 3. The average marginal effects in Table 3 indicate that nursery producers in Midwest, Northeast and Other regions use 13%, 19% and 12% more water from well compared to the nursery producers from the Southeast region.[6]. In contrast, nursery producers in the Pacific region use 9% less water from well compared to the nursery producers from the Southeast region. Nursery producers located in the Northeast and Pacific regions use 2% and 1% less recaptured water compared to the producers in the Southeast region. Regional results also indicate that nursery producers in the Pacific region use municipal water the most, nursery producers from the Southeast region use natural water source the most, nursery producers located in the northeast use well water the most and the nursery producers in the southeast use the recaptured water the most. The result is consistent as Florida (in the Southeast region) is not only a large nursery plant producing state but also a leader in the reclaimed water use in the agriculture sector in the U.S(Martinez and Clark, 2013).

Higher sale of trees and shrubs (pg1) means nursery producers use more well water and less natural water. More sales of bedding plants (*pg2*) implies that nursery producer use less recaptured water. In contrast, higher sales of bedding plants mean that nursery producers use more municipal water. Further, higher sales of vines imply that nursery producers use more natural water.

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[6] In multinomial logit model the sign of the marginal effect (ME) may not be the same sign of regression coefficients. $\frac{\partial p_{ij}}{\partial x_j} = p_{ij}(\beta_j - \bar{\beta}_i$, and $\bar{\beta}_i = \sum_l p_{il}\beta_l$. For a variable$x$, the ME is positive if $\beta_j > \bar{\beta}_i$. We calculated average marginal effects as it aggregates the effect from all observations.

Results show that if producers are contracted to the garden center, they use 5.73% more municipal water than those who have not contracted to the garden center. Similarly, nursery producers contracted to mass merchandiser use 16.74% more wells water than who have not contracted to mass merchandisers, but opposite is true for the use of natural water. A thousand dollar increase in trade show expenses means that fraction natural water use rises by 0.0012%. If the age of farm increases by one year, the fraction of municipal water use increases by 0.0012 but contrarily the natural water use decreases by 0.0013.

We also find effects of market channels on the water source used. A one percent increase in share of market channels from landscape firm implies that use of fraction of well water increases by 0.0043. However, a one percent increases in share of sale through mass merchandiser means that use of municipal water decreases by 0.0014. If the nursery producer's farm income is higher than $500K, the fraction of recaptured water use is more by 3.19% than the nursery producer whose income is less than $500K. Further, we found that for nursery producers who have adopted more integrated pest management practices, the fraction of natural water use rises by 0.0059.

Irrigation Methods

The parameters estimated for the factors affecting the irrigation methods used by the U.S. nursery producer are given in Table4, and their corresponding marginal effects are given in Table 5. Our results show that nursery producers located in the Midwest and Other region use 2.53% and 1.8% more Other irrigation method compared to nursery producers located in the Southeast region, respectively. Further our results indicates that nursery producers who live in the Midwest region use 4.23% less drip irrigation and 0.399% less overhead irrigation method.

Higher sales of bedding plants (pg2) means nursery producers irrigate higher proportion of plants using Other irrigation method. Increase in sales of vines (pg3) means nursery producer irrigate higher amount of water using a drip irrigation method.

If the nursery producer contracted to mass merchandiser (*tcmm*), the fraction of Other irrigation method decreases by 1.3% compared to nursery producers who have not signed contract with mass merchandisers. We also found that higher trade show promotion expenses (*patss*) implies that nursery producers irrigate less using sub-surface irrigation method. If nursery producers use computers in their operation (*dcomp*), the fraction of drip irrigation use is higher by 1.80% compared to those who do not use computer. In contrast, we found Other irrigation and overhead irrigation methods use decreases by 1.38% and 0.24%, respectively.

According to our results, higher sales through mass merchandiser (*mm*) and re-wholesalers (*rw*) means nursery producer irrigate higher fraction of area with drip irrigation, and a lower fraction of area by other and overhead irrigation methods. If nursery producers have farm income (*farm income*) higher than $500,000 , they use other and overhead irrigation methods lesser by 1.23% and 0.19%, respectively, but sub-surface irrigation method higher by 0.57%. We found that as the number of IPM practices adopted by nursery producers increases, the fraction of area with other and overhead irrigation methods used decrease by 0.16 and 0.03 respectively. In contrast, water irrigated by drip irrigation method rises by 0.26.

Conclusions

We used a nested multinomial fractional regression model to analyze water sources and irrigation methods used by U.S. nursery producers. Fraction of irrigation sources chosen varies by regions as well as plant types. We found that nursery producers in the Pacific region use the highest fraction of municipal water compared to the nursery producers from other regions. Nursery producers who contracted to mass merchandisers use less water from natural resources. Older nursery firms use municipal water resources. Nursery producers with higher sales income are likely to use more recapture water as they are likely to be in Florida and California where water is in short supply. For a given fraction of water resource used, our results indicate that overhead irrigation method chosen in nursery plants were impacted by annual sales being more than $500 K (decreased), Midwest region (increased), use of computer (decreased), sales through mass merchandiser and landscape (decreased), and number of IPM practices used (decreased). For sub-irrigation method, we found that trade-show expenses (decreased) and annual sales being more than $500K (increased) are significant variables. The following variables affect the drip irrigation choice: Midwest region (decreased), use of computer (increased), sales through mass merchandiser and re-wholesalers (increased), bedding plant groups (decreased), vines (increased), and number of IPM used (increased). In case of other source of irrigation methods used, we found Midwest (increased), annual sales being greater than $500 K (decreases), Midwest region (increased), sales through mass merchandiser and re-wholesalers (decreased), and number of IPM practices adopted (decreased) are significant variables. The overall finding is that a proper choice of water sources and irrigation method helps to develop sustainable and profitable nursery operations and this choice is impacted by unique factors to the regions.

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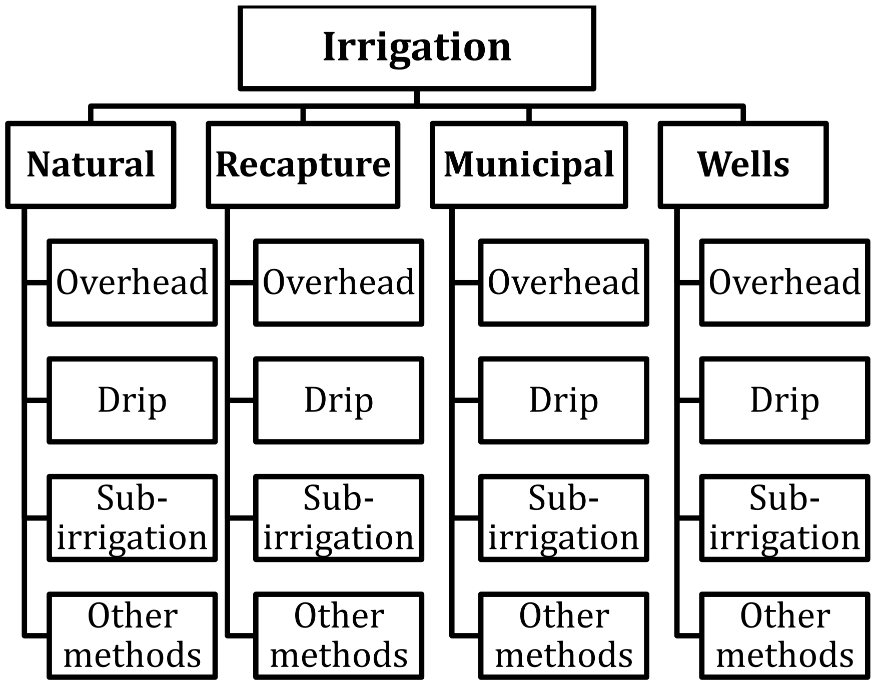

Figure 1. Nested structure of irrigation sources and application methods.

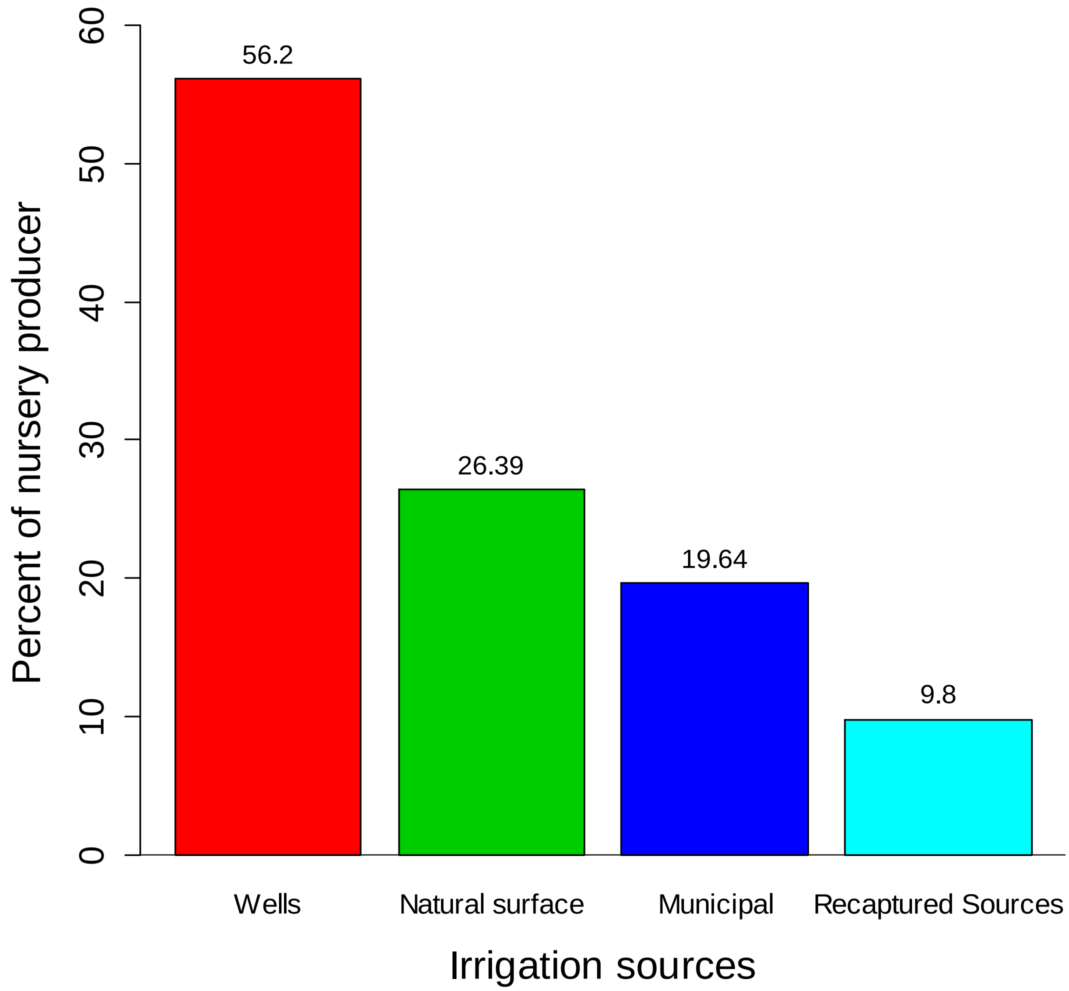

Figure 2: Irrigation water sources used by nursery producers in the U.S., 2008

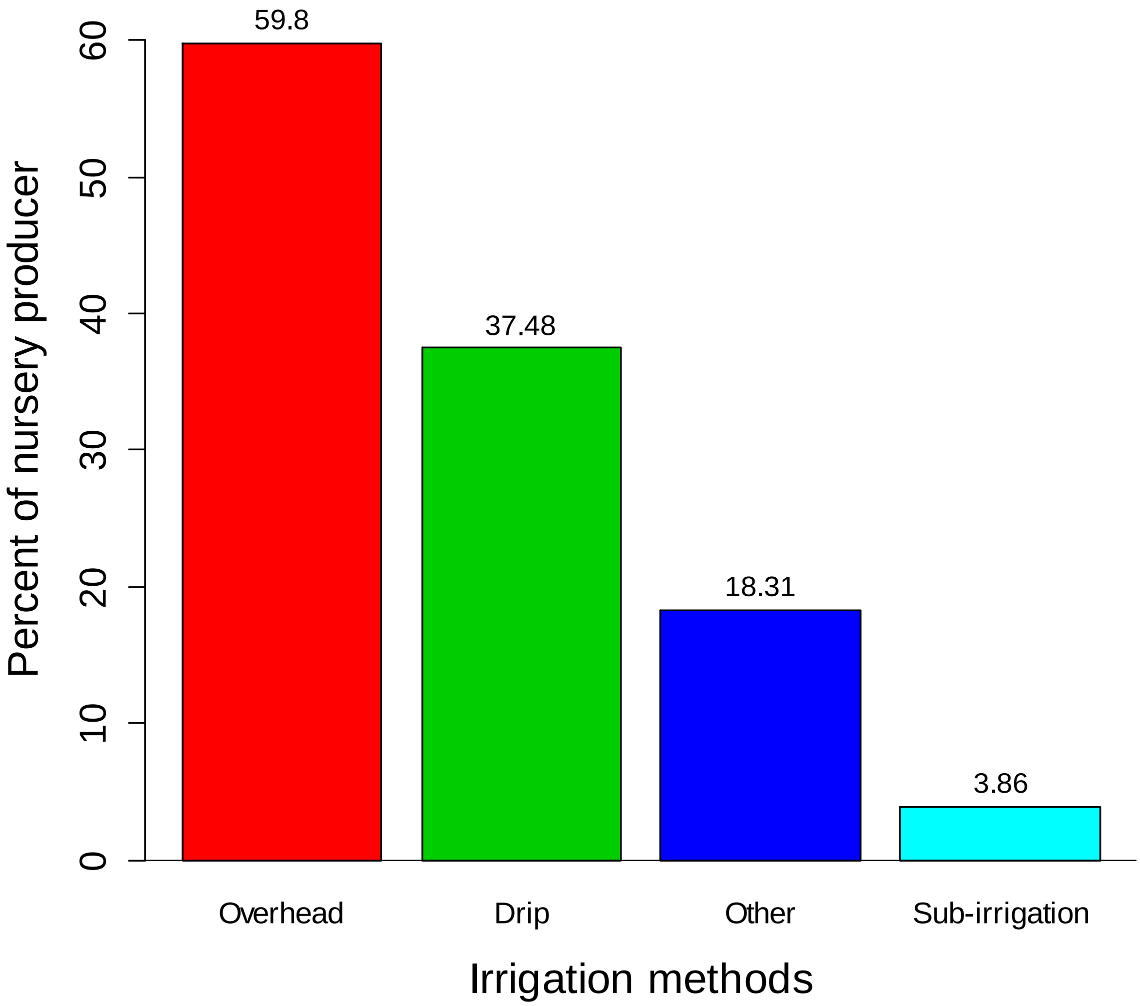

Figure 3: Irrigation application methods used by nursery producers in the U.S., 2008.

Table 1: Summary Statistics of variables

Variable name	Variable Definition	Mean	SD
Regions			
Midwest	Equals 1 if Midwest, otherwise 0	0.1604	0.3671
Northeast	Equals 1 if Northeast, otherwise 0	0.2144	0.4105
Pacific	Equals 1 if Pacific, otherwise 0	0.1428	0.3499
Southeast	Equals 1 if Southeast, otherwise 0	0.2320	0.4222
Plant Group			
pg1	Sales of trees/shrubs($00,000)	34.4819	42.9287
pg2	Sales of bedding plants($00,000)	11.5796	26.2431
pg3	Sales of vines($00,000)	11.5252	23.3794
pg4	Sales of foliage($00,000)	3.8453	16.8906
pg5	Sales of other($00,000)	36.3852	39.8742
Contracted production			
ctcts	Total sales under contract ($00,000)	8.7138	22.4995
tcgc	Contract to garden centers (1 if positive, otherwise 0)	0.0499	0.2177
tcmm	Contract to mass merchandisers (1 if positive, otherwise 0)	0.0217	0.1458
Kinds of promotions			
trade	Number of trade shows attended in 2008	1.2069	3.9585
pawsss	Website promotion expenses ($000)	7.8491	21.0558
patss	Trade show promotion expenses ($000)	6.3886	19.1403
Market Channels			
mm	Mass merchandiser (%)	2.2249	11.7337
gc	Garden Center (%)	16.1273	29.9293
ls	Landscape firms (%)	24.8406	36.4250
rw	Re-wholesalers (%)	18.0604	31.5661
others			
agef	Firm age (2008 minus year established)	22.8276	20.2791
dcomp	Computer management aids	0.5794	0.4937
farm income	Equal 1 if annual sale is greater than $500K, 0 otherwise	0.2672	0.4426
nipm	Number of integrated pest management used	6.8887	4.7335

Note: Total number of observation=2948.

Table 2. Parameter estimates for first level (irrigation sources)

Parameter	Wells	Recapture	Municipal
Constant	1.17280***	-1.95968***	-0.90809***
	(0.000)	(0.000)	(0.002)
Midwest	-0.89862***	-0.74129***	-0.22349
	(0.000)	(0.007)	(0.355)
Northeast	-1.00729***	-1.26519***	-0.97134***
	(0.000)	(0.000)	(0.000)
Pacific	0.03053	0.09382	1.84312***
	(0.876)	(0.762)	(0.000)
Other	-1.05882***	-0.50405**	0.33669
	(0.000)	(0.032)	(0.107)
pg1	-0.00457**	-0.00204	-0.00397*
	(0.013)	(0.483)	(0.067)
pg2	0.01399***	0.00118	0.02249***
	(0.000)	(0.808)	(0.000)
pg3	0.00718***	0.00124	0.00113
	(0.003)	(0.804)	(0.761)
pg4	0.01055**	0.00109	0.01152**
	(0.011)	(0.883)	(0.017)
pg5	0.00042	0.00024	0.00476**
	(0.828)	(0.938)	(0.034)
ctcts	-0.00156	-0.00648	-0.00370
	(0.475)	(0.105)	(0.207)
tcgc	-0.04898	-0.16199	0.37145
	(0.829)	(0.704)	(0.182)
tcmm	-0.97157***	-0.09768	-0.73963*
	(0.002)	(0.840)	(0.087)
trade	0.00019	0.01288	0.01431
	(0.985)	(0.129)	(0.192)
pawsss	-0.00117	-0.00342	0.00274
	(0.617)	(0.400)	(0.351)
patss	0.00143	0.00071	-0.01028**
	(0.549)	(0.844)	(0.016)
agef	-0.00231	0.00332	0.00807**
	(0.347)	(0.373)	(0.011)
dcomp	0.08300	0.33379	0.00828
	(0.443)	(0.102)	(0.956)

Table 2. Contd.

Parameter	Wells	Recapture	Municipal
mm	0.00006	-0.00654	-0.01183*
	(0.989)	(0.342)	(0.052)
gc	0.00025	0.00346	-0.00463**
	(0.891)	(0.276)	(0.044)
ls	-0.00181	-0.00446*	-0.00509***
	(0.208)	(0.073)	(0.008)
rw	-0.00213	-0.00473	-0.00897***
	(0.185)	(0.149)	(0.000)
farm income	0.13222	0.81730***	0.09219
	(0.257)	(0.000)	(0.557)
nipm	0.04620***	0.06508***	0.03746**
	(0.000)	(0.002)	(0.020)

Note: Value given in parenthesis are P-value. *, **, and *** represent parameters are significant at 0.10,0.05, and 0.01 level of significance.

Table 3. Marginal effects for first level (irrigation source)

Parameter	Wells	Recapture	Municipal	Natural
Midwest	0.13022***	-0.00848	0.05019*	-0.17192***
	(0.000)	(0.329)	(0.086)	(0.000)
Northeast	0.18579***	-0.01942***	-0.03356	-0.13281***
	(0.000)	(0.008)	(0.167)	(0.000)
Pacific	-0.09024***	-0.01409*	0.30629***	-0.20195***
	(0.000)	(0.086)	(0.000)	(0.000)
Other	0.11531***	-0.00055	0.14462***	-0.25938***
	(0.000)	(0.945)	(0.000)	(0.000)
pg1	0.00071**	0.00005	-0.00009	-0.00067*
	(0.011)	(0.639)	(0.691)	(0.059)
pg2	-0.00246***	-0.00044**	0.00163***	0.00126***
	(0.000)	(0.011)	(0.000)	(0.009)
pg3	-0.00092**	-0.00012	-0.00049	0.00153***
	(0.016)	(0.507)	(0.249)	(0.002)
pg4	-0.00168**	-0.00028	0.00054	0.00142**
	(0.012)	(0.279)	(0.209)	(0.035)
pg5	-0.00021	-0.00003	0.00057**	-0.00032
	(0.477)	(0.759)	(0.014)	(0.362)
ctcts	0.00038	-0.00020	-0.00029	0.00011
	(0.276)	(0.186)	(0.346)	(0.786)
tcgc	-0.00672	-0.00771	0.05730*	-0.04288
	(0.848)	(0.566)	(0.085)	(0.289)
tcmm	0.16046***	0.02597	-0.01903	-0.16740***
	(0.010)	(0.322)	(0.651)	(0.003)
trade	-0.00063	0.00041	0.00171	-0.00149
	(0.658)	(0.249)	(0.194)	(0.462)
pawsss	0.00009	-0.00013	0.00047	-0.00043
	(0.817)	(0.385)	(0.111)	(0.309)
patss	0.00016	0.00007	-0.00143***	0.00120**
	(0.681)	(0.594)	(0.004)	(0.018)
agef	-0.00002	0.00013	0.00120***	-0.00131***
	(0.959)	(0.336)	(0.000)	(0.005)
dcomp	-0.01365	0.01092	-0.00841	0.01114
	(0.427)	(0.119)	(0.610)	(0.597)

Table 3. Contd. (Irrigation source)

Parameter	Wells	Recapture	Municipal	Natural
mm	0.00045	-0.00018	-0.00146**	0.00119
	(0.509)	(0.467)	(0.024)	(0.131)
gc	0.00009	0.00017	-0.00063***	0.00038
	(0.754)	(0.159)	(0.007)	(0.255)
ls	0.00043*	-0.00010	-0.00046**	0.00013
	(0.053)	(0.275)	(0.030)	(0.648)
rw	0.00060**	-0.00008	-0.00092***	0.00039
	(0.016)	(0.533)	(0.000)	(0.211)
farm income	-0.02769	0.03191***	-0.00605	0.00183
	(0.118)	(0.000)	(0.716)	(0.933)
nipm	-0.00751***	0.00128*	0.00029	0.00594***
	(0.000)	(0.081)	(0.860)	(0.008)

Note: Value given in parenthesis are P-value. *, **, and *** represent parameters are significant at 0.10,0.05, and 0.01 level of significance.

Table 4. Parameters estimates second level (irrigation application methods)

Parameters	Other irrigation	Drip	Sub-irrigation
Constant	1.73699***	2.06977***	-1.02419
	(0.000)	(0.000)	(0.117)
Midwest	0.14375**	-0.62583***	-0.18698
	(0.014)	(0.002)	(0.701)
Northeast	0.07164	-0.27137	-0.13458
	(0.134)	(0.147)	(0.777)
Pacific	0.06845	-0.09471	-0.06565
	(0.245)	(0.596)	(0.883)
Other	0.09020*	-0.50808***	0.18139
	(0.096)	(0.004)	(0.648)
pg1	0.00028	-0.00455*	0.00068
	(0.883)	(0.080)	(0.844)
pg2	0.00132	-0.01394***	-0.00707
	(0.309)	(0.000)	(0.215)
pg3	-0.00590***	0.01636***	0.00788
	(0.003)	(0.000)	(0.324)
pg4	0.00049	-0.00149	-0.01891
	(0.802)	(0.714)	(0.209)
pg5	0.00107	-0.00956***	-0.00341
	(0.413)	(0.000)	(0.467)
ctcts	-0.00060	0.00187	0.00498
	(0.367)	(0.501)	(0.349)
tcgc	-0.06977	0.05787	0.77574
	(0.445)	(0.826)	(0.133)
tcmm	-0.45421	0.48423	0.88301
	(0.127)	(0.104)	(0.155)
trade	-0.00600	0.01221	0.01672*
	(0.176)	(0.165)	(0.086)
pawsss	0.00074	-0.00153	-0.01340*
	(0.190)	(0.567)	(0.090)
patss	0.00004	0.00210	-0.02082**
	(0.969)	(0.513)	(0.023)
agef	0.00061	-0.00425	-0.00684
	(0.209)	(0.206)	(0.414)
dcomp	-0.07011**	0.30061**	0.52538
	(0.012)	(0.032)	(0.107)

Table 4. Contd.

Parameters	Other irrigation	Drip	Sub-irrigation
mm	-0.00118	0.01025**	0.00331
	(0.389)	(0.043)	(0.769)
gc	-0.00033	0.00160	0.00184
	(0.349)	(0.422)	(0.679)
ls	-0.00009	0.00308*	-0.00169
	(0.841)	(0.082)	(0.716)
rw	-0.00156***	0.00738***	0.00467
	(0.008)	(0.000)	(0.334)
farm income	-0.08505**	0.22718	0.65436**
	(0.043)	(0.101)	(0.025)
nipm	-0.00740**	0.04170***	0.02688
	(0.034)	(0.004)	(0.406)

Note: Values given parenthesis are P-value. Dissimilarity parameters are: $\tau_1 = 1.229, \tau_2 = 1.228$, and $\tau_3 = 1.203$ with P-value$=$ 0.000 for all. *, **, and *** represent parameters are significant at 0.10,0.05, and 0.01 level of significance.

Table 5. Marginal effects second level (irrigation application methods)

Parameter	Other Irrigation	Drip	Sub-irrigation	Overhead
Midwest	0.02536***	-0.04230***	0.00087	0.00399***
	(0.003)	(0.001)	(0.857)	(0.004)
Northeast	0.01148	-0.01867	-0.00009	0.00180
	(0.142)	(0.127)	(0.985)	(0.192)
Pacific	0.00535	-0.00828	-0.00037	0.00029
	(0.479)	(0.488)	(0.931)	(0.822)
Other	0.01830**	-0.03561***	0.00439	0.00322***
	(0.014)	(0.001)	(0.328)	(0.007)
pg1	0.00015	-0.00029	0.00003	0.00004
	(0.146)	(0.107)	(0.469)	(0.153)
pg2	0.00052***	-0.00085***	0.00001	0.00011***
	(0.000)	(0.000)	(0.911)	(0.000)
pg3	-0.00073***	0.00120***	0.00001	-0.00010***
	(0.000)	(0.000)	(0.943)	(0.000)
pg4	0.00013	0.00002	-0.00017	0.00003
	(0.455)	(0.944)	(0.237)	(0.495)
pg5	0.00035***	-0.00060***	0.00002	0.00008***
	(0.000)	(0.000)	(0.709)	(0.001)
ctcts	-0.00010	0.00011	0.00004	-0.00002
	(0.390)	(0.564)	(0.442)	(0.457)
tcgc	-0.00730	-0.00061	0.00945	-0.00085
	(0.519)	(0.972)	(0.256)	(0.667)
tcmm	-0.03055**	0.03832	0.00889	-0.00257
	(0.029)	(0.101)	(0.412)	(0.291)
trade	-0.00063	0.00089	0.00011	-0.00007
	(0.111)	(0.202)	(0.304)	(0.159)
pawsss	0.00012	-0.00003	-0.00012	0.00002
	(0.276)	(0.859)	(0.114)	(0.359)
patss	0.00000	0.00027	-0.00021**	0.00000
	(0.972)	(0.227)	(0.021)	(0.986)
agef	0.00018	-0.00024	-0.00004	0.00004
	(0.158)	(0.256)	(0.579)	(0.195)
dcomp	-0.01384**	0.01807**	0.00349	-0.00246**
	(0.015)	(0.048)	(0.216)	(0.027)

Table 5. Contd.

Parameter	Other Irrigation	Drip	Sub-irrigation	Overhead
mm	-0.00038*	0.00065**	-0.00002	-0.00008**
	(0.074)	(0.049)	(0.840)	(0.032)
gc	-0.00007	0.00010	0.00001	-0.00001
	(0.367)	(0.440)	(0.821)	(0.427)
ls	-0.00010	0.00020*	-0.00003	-0.00002*
	(0.180)	(0.085)	(0.463)	(0.082)
rw	-0.00030***	0.00048***	0.00001	-0.00005***
	(0.000)	(0.000)	(0.848)	(0.000)
farm income	-0.01236**	0.01266	0.00576*	-0.00194*
	(0.036)	(0.182)	(0.088)	(0.066)
nipm	-0.00166***	0.00267***	0.00005	-0.00032***
	(0.004)	(0.005)	(0.871)	(0.003)

Note: Value given in parenthesis are P-value. *, **, and *** represent parameters are significant at 0.10,0.05, and 0.01 level of significance.