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ATTRIBUTES OF IDEAL SOIL SUBSTITUTES: RESULTS OF A SURVEY OF DEMAND SECTORS

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ABSTRACT---
This paper describes preferences for attributes of ideal soil substitutes reported by industry demand segments, and relates those attributes to willingness to pay for soil substitutes. Regression results on principal components indicate that concern over product stability, safety and environmental protection induce higher willingness to pay for ideal soil products.

-----KEY WORDS-----

compost, markets, principal components, product attributes

Attributes of Ideal Soil Substitutes: Results of a Survey of Demand Sectors

"Soil substitutes" are products that perform functions similar to soil, serving as a growth medium for plants, a filtering medium for precipitation, a host environment for biota and insects, and a support medium for structures. These products can be used in place of soil or added to soil to enhance one or more desirable characteristics, such as water-holding capacity, cation exchange capacity, soil tilth, particle retention or nutrient availability.   Existing products in wide use include topsoil, potting soil, peat moss, sphagnum moss, vermiculite, bark and wood chips. Organic-derived materials such as animal manures, sewage sludge, yard trimmings (grass clippings, leaves, tree trimmings), and sawmill byproducts (bark and wood chips) may be dried or composted and sold as replacements for existing products. Organic-based soil substitutes may also open new market niches by providing desirable features that existing products do not.

Transforming organic residuals into marketable resources may reduce disposal costs, produce revenues, and reduce environmental damage associated with disposal. Expectations about performance are critical to establishing markets for these products. Depending on feedstocks available and characteristics desired, soil substitutes may be formulated to target consumer needs (Willson). Software for process design to obtain desired outputs is available (Person and Shayya). The objective of this paper is to describe preferences for attributes of ideal soil substitutes reported by industry demand segments, and to relate those attributes to willingness to pay for soil products. This is the first research to address marketing characteristics in assessing desired attributes for soil substitutes. This information may be used by potential producers when evaluating local markets.

Data Collection for Attribute Ratings

Markets for soil substitutes vary by the planned uses for the products. Industry groupings in previous studies used this type of functional delineation (Laliburty; Perry, Towles, and Fletcher; Slivka *et al.*; Kashmanian; Sheehan; Segall and Alpert).

In this study, existing research on market segments and expert opinions of researchers, extension specialists and industry representatives were used to identify probable demand sectors. Twelve sectors were selected for evaluation: construction, florists, retail garden centers, golf courses, greenhouses, lawn care services, landscape maintenance and installation, nurseries, general retailers (hardware stores, supermarkets, discount chain stores), sod growers, wholesale suppliers, and vegetable growers. These sectors have been grouped as "horticultural" uses by Sheehan because their main interest in soil substitutes is using or selling them as a plant growth medium.

A questionnaire booklet was developed following recommendations on question format and survey design by Dillman. The introduction to the questionnaire described waste products as "animal manures, sewage sludge or yard waste." Respondents were assumed to have familiarity with some soil products made from organic materials. Thus, only brief descriptions for composting and drying, the usual forms for marketing, were provided.

Respondents were asked to conceptualize an ideal product and then rate the importance of a list of 47 characteristics for that product, given the choices "not at all," "slightly," "somewhat," "very," and "extremely." In the analysis, these answers were assigned integer values from 0 ("not at all") to 4 ("extremely"). The total number of responses varied slightly across the attributes because some respondents chose not to rate certain attributes. The attributes were selected to address concerns of the industry groups, based on previous studies (Laliburty; Perry, Towles, and

Fletcher; Slivka *et al.*; Kashmanian; Sheehan; Segall and Alpert). The attributes were presented in six categories - guaranteed chemical analysis, freedom from contaminants, aesthetic product specifications, handling characteristics, product costs, and manufacturer attributes.

Respondents were also asked whether they had purchased soil substitutes as defined by the survey in the previous year, whether they would purchase the ideal soil substitute, what price they would pay for their ideal soil substitute, whether the ideal product would replace or add to existing items, and which of six products - dried or composted manures, sewage sludge or yard waste - would be most acceptable to their customers. To account for the variety of industry groups, the price question was open-ended, allowing the respondent to fill in the units as well as the price. All other responses were interpreted as binary variables for analysis.

The survey questionnaire was mailed to 1,995 businesses in Michigan in July 1992, with postcard reminder and followup questionnaire sent in subsequent weeks. The sample was selected randomly from within the industry categories provided by the agencies. The number selected from each group reflected an estimate of the likelihood of market development for soil substitutes in the category, the need to obtain sufficient responses to be statistically representative of the group and to perform econometric analysis, and the overall budget for the survey. Of the 1,897 valid mailings, 775 respondents returned either partially or fully completed questionnaires, for an overall response rate of 40.8 percent.

Method of Analysis

For products that include both qualitative and quantifiable attributes, willingness to pay is affected by demand for attribute bundles. Attribute ratings reflect expectations about product performance. Suitability and quality are subjectively evaluated by consumers, who trade off price with attribute combinations. In previous studies, willingness to pay has not been linked to attributes, and attribute ratings have simply been summarized for each industry group, on the assumption that marketing is easiest addressed to identifiable sectors (Laliburty; Perry, Towles, and Fletcher; Slivka *et al.*; Kashmanian; Sheehan; Segall and Alpert). However, potential marketers of soil substitutes are typically limited to about a 50-mile radius within which transportation costs do not exceed net revenues (Slivka *et al.*). Realistically, a small-scale marketer such as a farmer composting manure may have few consumers in any one industry section within that radius. Thus, it would be helpful to establish general relationships that cut across industry groups. In this study, responses to the open-ended willingness to pay question were converted to a weight-based unit, PRICELB, measured in $/lb. and a volume-based unit, PRICECF, measured in $/cu. ft. These variables capture the main differences in product use by consumer groups, with attendant implications for the marketer's capital requirements. These are also consistent with the weight- and volume-based measures used for sales inventory by marketers of soil products (LaGasse).

PRICELB averaged $0.13/lb. for the 105 respondents in 12 industry groups who gave price as a weight-based value. The range on this variable was $0.003/lb. to $2.00/lb. For PRICECF, the mean was $0.88/cu.ft., ranging from $0.025/cu.ft. to $4.50/cu.ft. for the 180 respondents listing a volume-based willingness to pay. All other respondents either did not provide a price, gave an area-based willingness to pay or failed to answer other questions that disqualified their responses from the sample. Only the PRICELB variable was used in this paper, by way of demonstration of the method.

Another problem with the approach taken by previous researchers is that the attribute ranks are presente, but the latent factors are not statistically determined so the underlying concerns of the consumers are not made explicit (Laliburty; Kashmanian; Sheehan). The high degree of correlation among individual attributes makes regression analysis on the untransformed attribute ratings difficult to interpret due to multicollinearity. One transformation method to uncover latent variables is principal components (PC) analysis.

In PC analysis, the original data is transformed to an ordered set of uncorrelated vectors such that the first few vectors retain most of the variation present in all the original variables (Joliffe). Since the PC are ordered according to variance accounted for, components may be deleted from the set, reducing dimensionality without losing significant explanatory power of the variables. The PC are interpretable as the latent variables, and may be used in OLS estimation. The resulting estimates are biased, but variance is reduced. Joliffe provides details of statistical properties, transformation methods and examples of PC regression.

The general form of the model for this analysis was

$$\text{PRICELB} = \alpha + \beta_1\text{BOUGHT} + \beta_2\text{ADDITEM} + \beta_3\text{OLDITEM} + \beta_4\text{SLUDGE} + \beta_5\text{MANURE} + \sum_{i=1}^{k} \beta_{5+i} Z_i + \sum_{j=1}^{m} \beta_{k+j} W_j \tag{1}$$

where the named variables are binary representing previous year's purchase (BOUGHT), the addition of the ideal product to an existing line (ADDITEM), the replacement of an existing product with the ideal soil substitute (OLDITEM), whether the consumer's clients prefer sewage sludge (SLUDGE) or manure (MANURE) as a raw material for the ideal product. Z_i and W_j are PC vectors of latent variables of product characteristics (28 attributes from guaranteed chemical analysis, freedom from contaminants and aesthetic product specifications) and market factors (19 attributes from handling characteristics, product costs and manufacturer attributes). The PC were calculated and the OLS regressions were estimated using SHAZAM.

Results of Estimation

Table 1 shows the latent variables represented by the retained PCs for equation 1, and gives the percentage of total variance explained by each as well as an intepretation of the variable. For the two PC vectors, the retained components explain over 75 percent of the total variation in the original data vectors.

The interpretation of PCs is subjective, since the transformed components include portions of all variables, with the vectors orthogonal to each other. The components are between -1 and 1. Joliffe recommends examining only the signs of the largest components in the vector, including all those components whose absolute value is at least half as large as the absolute value of the biggest component. There are as many components in each vector as variables in the original data set. For example, the largest component in PC1:1 was 0.3286, so the signs of all components in the vector that are at least 0.1643 in absolute value should be considered.

The sign of the component itself may be positive or negative, and is usually the same for all components in the first vector. In subsequent vectors, the original data variables whose components have negative signs are contrasted with those associated with positive signs. The interpretation is made as a contrast between the variable combinations. For example, in PC1:2 macronutrient content is contrasted with soil structure. Here, the original variables that have negatively signed components were nitrogen, phosphorus and potassium. The positively signed components are associated with bulk density, moisture content, color, particle size, texture and age. PC1:2 accounts for 10% of the variation in the production specifications, so individuals who rate soil nutrients highly and soil structure lowly (and conversely) account for 10% of the remaining variation in the data. Interpreting this as a variable, PC1:2 could relate willingness to pay to the type of application of the soil substitute, whether structural or nutritional factors are more important.

Table 2 shows the regression results for equation 1. BOUGHT is significant and negative indicating that previous experience reduces the willingness to pay for soil substitutes purchased by weight. Since these units are often sold packaged, potential customers may feel the product qualities do not justify a higher price. SLUDGE is significant and positive, which indicates that these buyers do not exhibit the usual stigma against sludge as a raw material. This subsample is dominated by greenhouse, lawn care and landscape groups, who may be more knowledgeable about sludge or may believe it has better quality than other raw materials. This is suggested by the significant negative sign on MANURE.

Of the latent variables in Z_1, PC1:4 is positive and significant. From Table 1, the contrast is between losing macronutrients and accumulating contaminants as the waste ages. As concern over yard waste increases, the buyer is willing to pay more for the ideal product. PC1:5 and PC1:8 are both negative and significant, and both demonstrate a constrast with sludge problems:

temporary vs. uncorrectable and manures vs. sludge. The coefficients indicate that the more uncorrectable problems and the less confident the buyer is in the sludge-based product, the lower is the price paid for the ideal product. PC1:9 is also negative and signficant, and the contrast expressed on Table 1 is a measure of product decay with both negative (volatilization) and positive (soil structure and color) results. The buyer will pay less for the ideal product if the negative effects of product decay are a major concern.

PC1:11 is positive and significant, which suggests that if the contaminants that affect human health can be stabilized, the buyer will pay more for the soil substitute. PC1:12, PC1:17 and PC1:18 are all negative and significant. These components contrast various types of biological, chemical and physical problems in the soil product. Some of these problems are related to product immaturity and may be corrected with ageing, but some are concerns in the makeup of the product. In all cases, buyers pay less for products with suspicious chemical and biological attributes. PC1:19 is positive and significant. From Table 1, this component contrasts chemical stability with groundwater risk from leaching. If the ideal product is very stable, with properties that limit nutrient loss, then the buyer's willingness to pay is higher. PC1:23 is positive and significant, and is also related to nutrient contamination of groundwater, since it contrasts mobility and mineralization of nutrients. Again, if the ideal product can reduce this risk, the buyer will pay more for the product.

Market characteristics, W_j, are significant and positive for PC2:1, which represents all the pricing, cost and manufacturer variables except packaging and transportation. PC2:9, PC2:11, and PC2:18 are all significant and negative. From Table 2, PC2:9 expresses the tradeoff between buying a ready to use product and being uncertain about the validity of product claims. PC2:11

describes the trade off between taking advantage of discounts and other introductory offers with uncertainty about contracting with a new business. PC2:18 contrasts willingness to buy off-season for a discount with cost of hauling the product. These uncertainties work against willingness to pay. PC2:10 is positive and significant, and represents the cost and time savings of purchasing custom blended product with blending it oneself to obtain the exact product desired. The buyer pays more for the ideal product if a balance in these can be struck.

Conclusions

Industrial consumers of soil substitutes are more definitive about required attributes than are household consumers. Industrial consumers expect reliability and consistency in soil products. Their concern over contaminants, particularly those that cannot be corrected, and environmental risks complicates the preparation of soil products for this market. The potential marketer of soil substitutes from waste products must concentrate on product stability and safety to address these concerns. The industrial clients also want to reduce their uncertainty about the product's features and purchase a product that is not overly prepared. There is interest in blending the product to obtain the exact product for the situation. There may be some reluctance of these consumers to utilize unfamiliar outlets and products for soil substitutes, but attention to discounting and other price-related incentives can encourage new business.

Table 1. Interpretations for the Principal Components in the Subsample Purchasing by Weight

Component	Percentage of Total Variation	Elements Contrasted
Product Specifications (Z_i)		
PC1:1	27.74	All product characteristics, except odor and color
PC1:2	10.90	Macronutrient content with soil structure in all
PC1:3	8.94	Growth suitability with contaminants in all
PC1:4	5.49	Macronutrient loss with contaminants in yard waste
PC1:5	4.77	Temporary with uncorrectable problems in sludge
PC1:8	3.56	Problems in manures with problems in sludge
PC1:9	3.47	Nitrogen volatilization factors with ageing signs in all
PC1:11	2.57	Product stability with human health contaminants in all
PC1:12	2.44	Product maturity with nutrient loss in decay in all
PC1:17	1.44	Weed potential with uncorrectable problems in manure
PC1:18	1.33	Chemical contaminants with biological contaminants in all
PC1:19	1.18	Chemical stability with groundwater risk in all
PC1:22	0.98	Phosphorus runoff risk with potassium runoff risk in all
PC1:23	0.84	Nitrogen mobility with phosphorus mineralization in all
Market specifications (W_j)		
PC2:1	25.03	All market specifications, except packaging and delivery
PC2:2	11.27	Convenience and reliability of bagged with bulk and pots
PC2:3	9.69	Consistency of product with reasonably priced delivery
PC2:4	8.20	Amount of product preparation with ease of sampling
PC2:5	7.17	Value of reliability with availability of information
PC2:9	3.96	Preparation time saving with validity of product claims
PC2:10	3.78	Ease of blending with already custom blended
PC2:11	2.76	Chance to try out with concern over new business
PC2:13	2.22	Price with cost savings offered by manufacturer
PC2:16	1.35	Cost of adjusting pH with ease of blending
PC2:18	1.16	Discount with hauling charges

Table 2. Results of OLS Regression Explaining Price Per Pound of Soil Substitute

Variable	Coefficient	Variable	Coefficient
BOUGHT	-0.1375*	PC2:1	0.2457*
ADDITEM	0.0737	PC2:2	0.1118
OLDITEM	0.0245	PC2:3	-0.1463
SLUDGE	0.1497*	PC2:4	0.1918
MANURE	-0.0805*	PC2:5	0.0723
PC1:1	-0.0151	PC2:9	-0.3948*
PC1:2	0.0895	PC2:10	0.4328*
PC1:3	0.1431	PC2:11	-0.5110*
PC1:4	0.6954*	PC2:13	-0.3868
PC1:5	-0.6947*	PC2:16	-0.5471
PC1:8	-0.6962*	PC2:18	-0.8865*
PC1:9	-0.3525*	CONSTANT	0.1823
PC1:11	0.4380*		
PC1:12	-0.4762*		
PC1:17	-0.8081*	N = 105	
PC1:18	-0.6256*	R^2 = 0.5510	
PC1:19	0.6428*		
PC1:22	-0.6416		
PC1:23	1.0099*		

The dependent variable is PRICELB. Estimated coefficients marked with asterisks are significant at α=0.10 based on t-tests.

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