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The determinants of on-farm sewage sludge spreading

Douadia Bougherara¹, Gilles Grolleau², Naoufel Mzoughi³

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Abstract: The quantity of sewage sludge requiring disposal has been for several years increasing greatly in Europe because of the progressive implementation of the Urban Waste Water Treatment Directive 91/271/EEC. Land application and incineration are the two most widely used options for sewage sludge disposal. The benefits and costs of each option raised –and continues to raise– much debate. Besides, the spreading of sludge on agricultural soils is not recent. And yet, there is little econometric analysis of the determinants of industrial and urban sludge spreading. The aim of the paper is to provide policy makers with an overview of the determinants of sewage sludge spreading by farmers. We investigate variables pertaining to the farmer, to the farm (economic size and location) and also to the market for farm outputs. We use an exhaustive data base, the agricultural census in France coupled with location data such as distance to the nearest sewage sludge treatment facility, population density around the farm and environmental zoning.

Key words: Agricultural lands; Sewage Sludge; Waste.

JEL Classification Numbers: Q15; Q53.

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1. Introduction

Sewage sludge is the by-product of processes that clean our sewage before the cleaned water is discharged into waterways. Their safe disposal remains a challenging issue for governments, given that options are currently limited to land filling, incineration and land application. The quantity of sewage sludge requiring disposal has been for several years increasing greatly in Europe because of the progressive implementation of the Urban Waste Water Treatment Directive 91/271/EEC. In 2000, 6,900 and 700 millions of tons of dry solids sewage sludge were generated, respectively in the United States and in France with 41% and 50% going to land application (Renner, 2000). Moreover, the environmental pressures of environmental groups and the economic costs, associated with incineration and land filling, are part of what has led to increased focus on land application (Harrison et al., 2007). Sewage sludge is frequently considered either as a potentially dangerous waste costly to eliminate or as a cheap resource that can be applied on agricultural lands. Nevertheless, beyond this simple distinction, the reality is more complex with farmers frequently unfamiliar with the possible consequences of sewage sludge use. Indeed, sewage sludge can affect (either objectively or subjectively) soil quality, quality of food produced on these lands and ultimately human health with consequences on the land value, marketability of products and liability issues. For example, in France several food processors (e.g., Bonduelle, Vico) and retailers (e.g. Carrefour) refuse products coming from lands where sewage sludge has been spread or impose severe restrictions. Except some recent contributions (Krogmann et al., 2001; Refsgaard and Magnussen, 2006), little is known about the factors shaping the acceptance of sewage sludge by farmers. This paper aims at filling this gap by testing empirically whether several factors related to

economic, environmental and social considerations shape the farmers' acceptance of sewage sludge spreading.

The remainder of the paper is organized as follows. After a brief overview of the evolution of sewage sludge use on farm land (section 2), we introduce a model of sludge acceptance and describe the hypotheses to be tested in the analysis. The econometric methods in estimating the model are then described (section 3) before the presentation and discussion of results (section 4). In the conclusion (section 5), policy implications are stressed and directions for further research indicated.

2. Land application of sewage sludge: Conceptual framework and hypotheses

Land application of sewage sludge is not a new process. Sewage sludge has been applied on agricultural lands since more than 50 years, but with an important increase in recent years. Indeed, in addition to an increase in sludge production⁴, other disposals have been severely restricted (e.g., land filling) or forbidden (ocean dumping), making land application the main disposal in most developed countries. At the same time, there are on going scientific, social and political debates regarding land application of sewage sludge. Without purporting to be exhaustive, concerns include potential risks for humans, animals, the environment and possible economic social and legal issues for the farmer or landowner (Bamka et al., 1999). One of the main concerns is the long term build-up of heavy metals (e.g. cadmium, zinc, copper) in the soil that can over time damage agricultural soils and food quality. These issues remain controversial putting farmers in an uncomfortable position regarding acceptance of what can be considered either a cheap or free source of nutrients and for pH management or as a dangerous waste likely to harm (maybe at a long term horizon) the overall farm profitability. Indeed, accepting sewage sludge today may compromise future uses of the lands.

During the crop growing season, a farmer has to take numerous important decisions, including the decision to use sewage sludge or not. First, sewage sludge can be considered as a production input affecting the farmer's profit. From the farmer viewpoint, sewage sludge also affects on-farm environmental resources and health and is likely to constrain the future uses of lands. Indeed, the use of sewage sludge may alter land productivity and make the lands ineligible for the production of certain crops or for certain customers. The sewage sludge application can also make the land less attractive for purchase when compared to lands without sewage sludge. The farmer who is also a citizen and consumer may be concerned by the positive and negative environmental and health externalities caused by sewage sludge use on farmlands. Indeed, while sewage sludge use serves the society as a whole, it also generates harmful effects on the neighborhood such as nuisance odors. So, sewage sludge use is likely to affect both profit and other utility dimensions (Beach and Carlson, 1993).

The choice of factors hypothesized to influence producer's likelihood of applying sludge was based primarily on earlier research on innovation adoption. While several innovations considered in the related literature are advantageous from an environmental viewpoint, sewage sludge application has an uncertain and fuzzy status. On one side, it solves a waste problem for society at an attractive cost, and on the other side, the same society have a bad perception of lands and products where sewage sludge is used. By considering the related literature we formulate several hypotheses concerning the determinants of sewage sludge acceptance. These hypotheses can be broadly classified into four categories: factors related to farmers' characteristics, farms' characteristics (especially location) and market for farm output.

⁴ In some cases, the increase in sewage sludge is clearly related to tougher clean water regulations (Renner, 2000).

Farmers' characteristics

The operator age and education are frequently considered as reflecting a higher openness and learning capacity, making younger farmers more likely to use sewage sludge because they have a better understanding of the issues at stake. Older farmers on average have a lower level of education, have a shorter time horizon and may be less inclined to invest in innovative practices (Diederer et al., 2003).

H₋: The probability of accepting sewage sludge decreases with the age of the farmer, ceteris paribus.

H₋: The probability of applying sewage sludge increases with education, ceteris paribus.

Given that sludge is frequently perceived as an unsafe material because of heavy metals, pathogens and possible diseases (Krogmann et al., 2001). The presence of children can reinforce these concerns, making the concerned farmer less likely to apply sewage sludge on his lands.

H₋: The probability of applying sewage sludge decreases with the presence of children, ceteris paribus.

Farms' characteristics

Several studies show that larger production units are more likely to adopt innovations. Many innovations are characterized by fixed costs, for instance because some substantial investments in information gathering and learning are required. Scale economies, a more professional management and a larger capacity to bear risk makes larger firms more likely to innovate by applying sewage sludge (Diederer et al., 2003)

H₋: The probability of applying sewage sludge increases with farm size, ceteris paribus.

Renters have a shorter time horizon than owner-operators and are not the residual claimants of the land value. Consequently, renters are more likely to apply sewage sludge because they can benefit

from short term benefits (e.g., sewage sludge as a quasi free fertilizer) without incurring the disadvantages (e.g., concerns regarding end-land value) that are likely to arise only over the longer term (Soule et al., 2000).

H₋: The probability of accepting sewage sludge increases (respectively, decreases) with renter operator status (owner operator status), ceteris paribus.

Sludge is frequently an alternative for farmers without livestock and subsequent manure. We expect other land application like manure but also industrial sludge to have a negative impact on sewage sludge land application.

H₋: The probability of applying sewage sludge decreases with manure application on the farm.

The location of the farms can also have an impact on the decision to apply sewage sludge. The proximity of sewage sludge production make close farmers more likely to be approached. Indeed, sewage sludge producers want to decrease their operation costs and are more likely to canvass close farmers, making them more informed about sewage sludge application.

H₋: The probability of applying sewage sludge increases with closeness of sewage sludge production units, ceteris paribus.

Because of nuisance odors and the bad public perception of sewage sludge, farmers located in a dense neighborhood have a higher incentive not to apply sewage sludge.

H₋: The probability of applying sewage sludge decreases with dense neighborhood.

Market for farm output characteristics

Consumers that purchase products under specific signs of quality are frequently concerned with safety issues and sludge application is likely to be perceived as an incompatible input. In addition,

several manufacturers anticipate consumers' concerns and require products from lands where sewage sludge have not been applied.

H₋: The probability of applying sewage sludge decreases with productions under specific quality signs, ceteris paribus.

Given that sewage sludge use is likely to cause nuisance odors and other concerns among public, a closer contact with consumers (e.g., direct sale, farm tourism) is likely to decrease the probability of applying sludge.

H₋: The probability of accepting sewage sludge decreases with tourism activities and direct sale, ceteris paribus.

3. Modeling the decision to use or not sewage sludge

During the crop growing season, a farmer has to take numerous important decisions, including the decision to use or not sewage sludge. First, sewage sludge can be considered as a production input affecting the farmer's profit. From the farmer viewpoint, sewage sludge also affects on-farm environmental resources and health and is likely to constrain the future uses of lands. Indeed, the use of sewage sludge may alter land productivity and make the lands ineligible for the production of certain crops or for certain customers. The sewage sludge application can also make the land less attractive for purchase when compared to lands without sewage sludge. The farmer who is also a citizen and consumer may be concerned by the positive *and* negative environmental and health externalities caused by sewage sludge use on farmlands. Indeed, while sewage sludge use serves the society as a whole, it also generates harmful effects on the neighborhood such as nuisance odors. So, sewage sludge use is likely to affect both profit and utility (Beach and Carlson, 1993).

The adoption of an alternative technology is usually modeled as a choice between the *status quo* that is the already used technology (no use of sewage sludge) and the proposed one (use of sewage sludge). Farmers are assumed to make their decisions by choosing the alternative that maximizes their perceived utility (Fernandez-Cornejo et al., 1994; 2003). Thus, a farmer i is likely to adopt sewage sludge use if the utility of doing so, U_{i1} , is larger than the utility of not adopting, U_{i0} , that is, if $U_i^* = U_{i1} - U_{i0} > 0$. However, only the binary random variable I_i (taking the value of one if sewage sludge is applied and zero otherwise) is observed, as utility is unobservable:

$$I_i = \begin{cases} 1 & \text{if } U_{i1} > U_{i0} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Because utilities are not known to the analyst with certainty, they are treated as random variables. In the context of sewage sludge and dropping the subscript i for simplicity, we can write: $U_j = V_j + \varepsilon_j$, where V is the systematic component of U related to the profitability and other utility arguments of adopting ($j = 1$) and the profitability of not adopting ($j = 0$), and the random disturbance (ε) accounts for errors in perception and measurement, unobserved attributes and preferences, and instrumental variables. The probability of adopting is $P_1 = P(I = 1) = P(U^* > 0) = P(U_1 > U_0) = P(V_1 - V_0 > \varepsilon_0 - \varepsilon_1) = P(\varepsilon_0 - \varepsilon_1 < V_1 - V_0)$. Assuming that the stochastic components ε_0 and ε_1 are independently and identically distributed with a Weibull distribution, their difference follows a logistic distribution (Maddala, 1992). Assuming a linear utility function and that choice probabilities depend only on observed individual-specific characteristics (Judge et al., 1985), the relative odds of sewage sludge application are $P_1/P_0 = \exp(\alpha + \delta'Z)$, where the odds ratio (P_1/P_0) denotes the ratio of the probability of applying sewage sludge to the probability of not applying,

conditional on the vector Z of explanatory variables; α is the intercept parameter and δ_a is the vector of slope parameters. Taking the log of each side, the logit equation is:

$$\log (P_1/P_0) = \alpha + \delta'Z. \quad (2)$$

In the result section, we present two analyses. We first present the probability of using sewage sludge using a logistic regression as described above. Then, we model the decision on the number of hectare on which to spread sewage sludge.

4. Empirical analysis

4.1. Data description

We use the data from the agricultural census in 2000. We also use acknowledge the help of M. Hilal (INRA CESAER) in providing data on distance of farm to nearest sewage sludge supplier and population density around each farm. Finally, we use data from the Ministry of the Environment on environmental zoning.

4.2. Summary statistics

Tables 1 to 5 present some summary statistics on our variables classified according to the hypotheses in the preceding section. These tables also display the significance of Student t-tests aiming at comparing farms that spread urban sewage sludge and other farms. The symbol "***" means a 1% significance while "ns" means not significant.

	Whole sample			Only farms where no urban sewage sludge application			Only farms where urban sewage sludge application		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Area where sewage sludge application in hectares (<i>EFEPUR</i>)	663,807	9.27	180.86	658,901	0	0	4,906	1,253	1,692
Dummy (1 if <i>EFEPUR</i> >0, 0 otherwise) (<i>EFEPURbin</i>)	663,807	0.01	0.09	658,901	0	0	5,427	1	0

Table 1. Urban sewage sludge spreading variables

	Whole sample			Only farms where no urban sewage sludge application			Only farms where urban sewage sludge application		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age of farmer (<i>AGECEX</i>)***	663,807	49.58	13.24	658,901	49.61	13.25	4,906	44.34	9.64
Dummy indicating if farmer has no agricultural education (<i>NoAGREDUC</i>)***	664,328	0.54	0.50	658,901	0.54	0.50	4,906	0.26	0.44
Dummy indicating if farmer has only primary agricultural education (<i>PrimAGREDUC</i>)***	664,328	0.11	0.31	658,901	0.11	0.31	4,906	0.14	0.35
Dummy indicating if farmer has only secondary agricultural education (<i>SecondAGREDUC</i>)***	664,328	0.30	0.46	658,901	0.30	0.46	4,906	0.51	0.50
Dummy indicating if farmer has higher agricultural education (<i>SupAGREDUC</i>)***	664,328	0.05	0.22	658,901	0.05	0.22	4,906	0.09	0.28
Dummy indicating if farmer has no general education (<i>NoGENEDUC</i>)ns	664,328	0.02	0.13	658,901	0.02	0.13	4,906	0.01	0.12
Dummy indicating if farmer has only primary general education (<i>PrimGENEDUC</i>)***	664,328	0.46	0.50	658,901	0.46	0.50	4,906	0.39	0.49
Dummy indicating if farmer has only secondary general education (<i>SecondGENEDUC</i>)***	664,328	0.46	0.50	658,901	0.46	0.50	4,906	0.56	0.50
Dummy indicating if farmer has higher general education (<i>SupGENEDUC</i>)***	664,328	0.06	0.24	658,901	0.06	0.24	4,906	0.04	0.19

Table 2. Variables describing farmers

	Whole sample				Only farms where no urban sewage sludge application				Only farms where urban sewage sludge application			
	N	Mean	SD	Freq	N	Mean	SD	Freq	N	Mean	SD	Freq
UAA in hectares (<i>SAU</i>)***	658,735	4,469	5,867		653,636	4,430	5,837		4,860	9,540	7,432	
Economic size in € (<i>QMBS</i>)***	663,041	52,152	102,171		658,135	51,792	101,523		4,906	100,418	160,641	
#Farms/type												
Crop	165,611			28%	163,508			28%	2,103			46%
Dairy cattle	87,176			15%	85,730			15%	1,446			31%
Meat cattle	82,456			14%	82,344			14%	112			2%
Poultry/pig	22,618			4%	22,595			4%	23			0.5%
Vegetables	15,784			3%	15,774			3%	10			0.2%
Vineyards	117,609			20%	117,497			20%	112			2%
Area where manure application in hectares (<i>EFANIM</i>)***	663,807	787	1,681		658,901	781	1,675		4,906	1,594	2,209	
Area where industrial sewage sludge application in hectares (<i>EFIND</i>)***	663,807	7	155		658,901	7	152		4,906	43	368	
Area where other land application in hectares (<i>EFAUT</i>)***	663,807	32	362		658,901	31	360		4,906	95	531	
Dummy indicating if farm is engaged in a conservation program for reduction of pesticide use (<i>PHYTObin</i>)***	664,328	0.05	0.22		658,901	0.05	0.22		4,906	0.09	0.28	
Dummy indicating if farm is engaged in an agri-environmental program (<i>CTEbin</i>)***	664,328	0.01	0.10		658,901	0.01	0.10		4,906	0.02	0.13	

Table 3. Variables describing farms

	Whole sample			Only farms where no urban sewage sludge application			Only farms where urban sewage sludge application		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Distance to nearest sewage sludge supplier (<i>DIST_STEP</i>)***	664,328	2,784	2,454	658,901	2,788	2,456	4,906	2,162	1,997
Population density around farm at a 1000 meter distance (<i>DENS1000M</i>)***	664,271	100	301	658,876	99	281	4,905	129	202
Population density around farm at a 2500 meter distance (<i>DENS2500M</i>)***	664,285	101	289	658,884	100	274	4,905	132	201
Population density around farm at a 5000 meter distance (<i>DENS5000M</i>)***	664,308	104	267	658,901	102	255	4,906	137	189
Dummy (=1 if farm in a zone where high nitrogen application) (<i>ZESbinaire</i>)***	664,328	0.10	0.30	658,901	0.10	0.30	4,906	0.15	0.35
Dummy (=1 if area around farm is environmentally sensitive) (<i>VULN</i>)***	664,328	0.50	0.50	658,901	0.50	0.50	4,906	0.69	0.46
pH of soil around farm (<i>PH_MOY</i>)***	590,703	6.84	0.79	585,985	6.84	0.79	4,479	6.76	0.71

Table 4. Variables describing location of farms

	Whole sample			Only farms where no urban sewage sludge application			Only farms where urban sewage sludge application		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Dummy (=1 if one or more of the products is labeled organic) (<i>agbiobin</i>)***	664,328	0.01	0.11	658,901	0.01	0.11	4,906	0.00	0.06
Dummy (=1 if one or more of the products is labeled AOC) (<i>aocbin</i>)***	664,328	0.14	0.35	658,901	0.14	0.35	4,906	0.08	0.28
Dummy (=1 if one or more of the products is labeled "certificat de conformité") (<i>confobin</i>)***	664,328	0.03	0.17	658,901	0.03	0.17	4,906	0.05	0.21
Dummy (=1 if one or more of the products is labeled "Label Rouge") (<i>labelbin</i>)***	664,328	0.05	0.22	658,901	0.05	0.22	4,906	0.06	0.24
Dummy (=1 if one or more of the products has another quality label) (<i>autqualbin</i>)***	664,328	0.10	0.30	658,901	0.10	0.30	4,906	0.11	0.31
Dummy (=1 if food processing activities on the farm) (<i>TRFERMnum</i>)***	664,328	0.09	0.29	658,901	0.09	0.29	4,906	0.06	0.24
Dummy (=1 if direct sales to consumers on the farm) (<i>VENDIRnum</i>)***	664,328	0.15	0.36	658,901	0.15	0.36	4,906	0.14	0.35
Dummy (=1 if accommodation on the farm) (<i>HEBFERnum</i>)***	664,328	0.02	0.14	658,901	0.02	0.14	4,906	0.03	0.16
Dummy (=1 if restaurant on the farm) (<i>TOURESTnum</i>)ns	664,328	0.00	0.07	658,901	0.00	0.07	4,906	0.00	0.07

Table 5. Market variables

4.3. Modeling the decision to use sewage sludge

We perform a logistic regression on our data. Table 6 shows the estimated parameters. As for farmers' characteristics, as expected younger and more educated farmers have a higher probability of accepting urban sewage sludge. As for farms' characteristics, only the physical economic size plays a positive role. However, the probability of sewage sludge application increases manure and industrial sludge application. It may be because of some machinery that is used for manure and can be used for sewage sludge. Finally, farms that have a conservation program (less pesticides or agri-environmental schemes) are more likely to decide to spread sewage sludge. As for farm location variables, distance to sewage sludge supplier has a negative impact as expected. The signs of all the other variables are surprising (positive impact: population density, high nitrogen areas, environmentally sensitive areas; negative impact: soil pH). As for the market variables, the probability of using urban sewage sludge clearly decreases with quality labels (organic, AOC, Label Rouge). Having a food processing activity on the farm also decreases the probability of using sewage sludge. Some signs are surprising (positive sign: direct sales and accommodation on the farm).

Model	Logistic regression		OLS regression	
Dependent variable	EFEPURbin		EFEPUR	
	Estimated parameter	Pr>Khi2	Estimated parameter	Pr>t
Intercept	-4.6977 (0.2223)	***	3.2325 (3.2546)	ns
Farmers' characteristics				
<i>AGECEX</i>	-0.0155 (0.0017)	***	0.0559 (0.0231)	**
<i>PrimAGREDUC</i>	0.7314 (0.0516)	****	0.7628 (0.8177)	ns
<i>SecondAGREDUC</i>	0.7317 (0.0425)	***	1.5017 (0.6452)	**
<i>SupAGREDUC</i>	0.5718 (0.0668)	***	2.8541 (1.1594)	**
<i>PrimGENEDUC</i>	0.3348 (0.1300)	**	1.5477 (1.8466)	ns
<i>SecondGENEDUC</i>	0.2572 (0.1293)	**	2.0265 (1.8542)	ns
<i>SupGENEDUC</i>	-0.1911 (0.1537)	ns	0.8516 (2.0714)	ns
Farms' characteristics				
<i>SAU</i>	0.0001 (0.0000)	***	0.0025 (0.0001)	***
<i>QMBS</i>	0.0000 (0.0000)	ns	0.0000 (0.0000)	***
<i>EFANIM</i>	0.0000 (0.0000)	***	-0.0004 (0.0002)	**
<i>EFIND</i>	0.0001 (0.0000)	***	0.0128 (0.0015)	***
<i>EFAUT</i>	0.0000 (0.0000)	ns	0.0014 (0.0006)	***
<i>PHYTObin</i>	0.2251 (0.0553)	***	2.0712 (1.1029)	*
<i>CTEbin</i>	0.2091 (0.1193)	*	3.5930 (2.4100)	ns
Farm location variables				
<i>DIST_STEP</i>	-0.0002 (0.0000)	***	-0.0015 (0.0001)	***
<i>DENS1000M</i>	0.0009 (0.0000)	***	0.0197 (0.0016)	***
<i>ZESbinaire</i>	0.1238 (0.0477)	***	0.4645 (0.8644)	ns
<i>VULN</i>	0.5653 (0.0351)	***	3.5223 (0.5078)	***
<i>PH_MOY</i>	-0.0853 (0.0236)	***	-1.5174 (0.3410)	***
Market variables				
<i>agbiobin</i>	-1.6065 (0.2611)	***	-8.7870 (2.1943)	***
<i>aocbin</i>	-0.2525 (0.0596)	***	-1.9191 (0.7714)	**
<i>confobin</i>	-0.0336 (0.0729)	ns	-5.5177 (1.3854)	***
<i>labelbin</i>	-0.1207 (0.0643)	*	-5.9263 (1.1031)	***
<i>TRFERMnum</i>	-0.2614 (0.0745)	***	-2.1911 (1.0087)	**
<i>VENDIRnum</i>	0.1432 (0.0504)	***	1.6236 (0.7788)	**
<i>HEBFERnum</i>	0.3480 (0.0999)	***	5.4262 (1.7801)	***

Table 6. Econometric results on decision to apply urban sewage sludge (logistic regression) and decision on the area to spread (OLS regression).

4.4. Modeling the decision on the size of the area on which to spread sewage sludge

We also perform an OLS regression on our data to understand the decision of farmer on the area to spread with sewage sludge. The results are presented in Table 6.

As for farmers' characteristics, age has now a positive sign. Older farmers spread more hectares than younger ones. Education has a positive sign but only the agricultural education influences the 'how much' decision. Concerning the farms' characteristics, physical but also *economic* size plays a role on the 'how much' decision. Manure application has now a negative impact on the area to spread (substitution effect). The quantity of industrial sludge has a positive impact. Among the farms that have a conservation program, only the farms that have an agri-environmental scheme spread more sewage sludge. As for the farm location variables, results are similar to the logistic regression, except that the farm being in a high nitrogen area has no significant effect on the area spread. As for the market variables, we find that all quality labels have a negative impact on the 'how much decision'. Having a food processing activity on the farm also decreases the area where sewage sludge is spread. We also find surprising positive signs on direct sales and accommodation on the farm.

5. Conclusion

The aim of our study was to determine the factors that influence farmer's decision to use sewage sludge. We find that age and education of farmers play an important role and do not influence in the same way the decision to spread sewage sludge (effect of age negative and general and agricultural education play a role) and the decision of how much to spread (effect of age is positive and only agricultural education play a role). We find that economic size and distance to sewage sludge supplier are important variables. Finally, quality labels have a highly significant negative impact on the decision to apply sewage sludge but also on how much to apply.

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