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Land Improvements under Land Tenure Insecurity the Case of Liming in Finland

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Land Improvements under Land Tenure Insecurity
The case of Liming in Finland

Sami Myyrä and Kyösti Pietola[1]

Abstract: This article solves and characterizes optimal decision rules to invest in irreversible land improvements conditional on land tenure insecurity. Economic model is a normative dynamic programming model with known parameters for the one period returns and transition equations. The optimal decision rules for liming are solved numerically, conditional on alternative scenarios on the likelihood that the lease contract and, thus, farmer access to land is either renewed or expired. The model parameters represent Finnish soil quality and production conditions. The results suggest that irreversible liming decreases quickly and the yields decline gradually, when the farmer is confronted with land tenure insecurity caused by uncertain renewal of the lease contract. The results are confirmed via empirical results.

Keywords: Land tenure, Liming

1 INTRODUCTION

Economic literature analysing implications of land tenure insecurity focuses for the most part in developing countries. In these countries land tenure insecurity has large implications, not only on land improvements, but also on the household and society welfare as a whole. In many empirical studies the effects of land tenure insecurity could not, however, be strongly identified in these countries, because household access to farming inputs and output markets can be severely retarded by other institutional, financial, and economic factors than by land tenure insecurity alone (Holden and Hailu 2002).

Even if land tenure insecurity is not yet a dominating problem in rich countries it may become such, particularly in Less Favoured Areas (LFA), where production costs are high and yields are low. The trend towards more liberalized food market and internationally harmonized agricultural policies decrease Marginal Value Products (MVP) for agricultural inputs in the LFA areas, where farmer options to adjust to these trends are rare. There are good reasons to expect that in the LFA areas of Northern Europe land improvements may decrease below the socially optimal levels[2], if farmers are confronted with significant land tenure insecurity.

In Finland, for example, signals on market failures, caused by land tenure insecurity, are emerging. Liming has generally decreased, and it has decreased most in land parcels that have been cultivated under lease contracts (Kalkitusyhdistys 7.12.2004; Myyrä *et al.* 2003). The potential land tenure insecurity problem on leased land is becoming more and more extensive. In 1994 the share of land cultivated under a lease contract from the total land area in Finland was 18%. In 2004 the corresponding share was increased to 33% (Figure 1). The standard land lease contract in Finland is a short term contract with fixed duration and a fixed cash lease payment per year. They are typically made for 5 or 10 years. The average duration of lease contract is 6 years (Myyrä 2004).

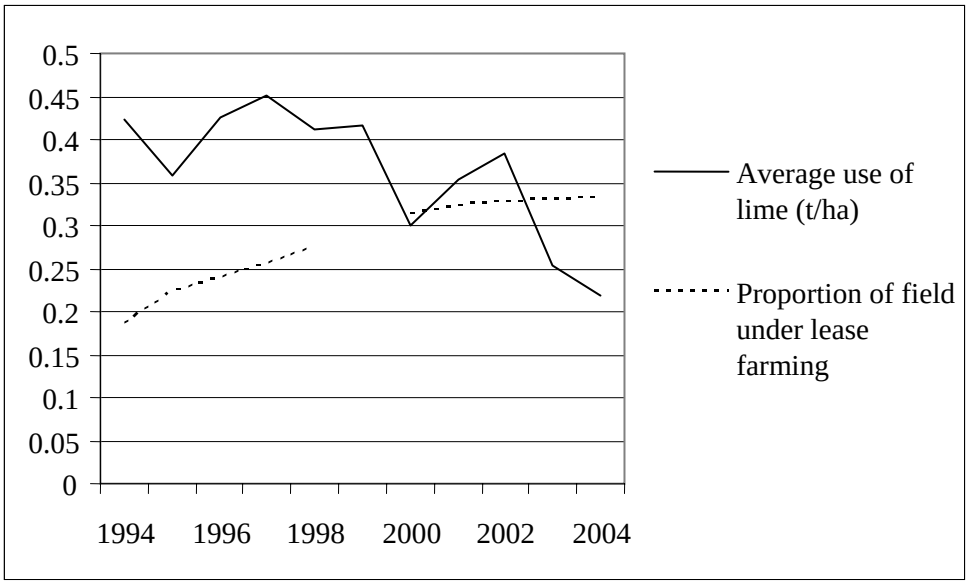


Figure 1. Lime application tonnes/ha and the proportion of arable land under lease farming in Finland during years 1994 – 2004 (Kalkitusyhdistys 7.12.2004; Yearbook of Farm Statistics 2003). Data for year 2004 is preliminary.

The goal of this paper is to describe the optimal liming applications on leased land under the Finnish production conditions, leasing institution and the Common Agricultural Policy (CAP). This is important, because liming represents a relatively long term land improvement that is

necessary to maintain land fertility and productivity of farming inputs. The soils of Finland have been formed from acidic rock and *pH* values in agricultural soils are commonly below the recommended level. Therefore, liming is one of the basic ameliorative measures used to maintain good yields. We focus on dynamic programming model described in section 2.

The discrepancy between the soil pH values of leased and farmer-owned land is tested for in observed data.

2 THE MODEL

We solve and characterize optimal decision rules to invest in liming conditional on land tenure insecurity. Economic model is a normative Dynamic Programming (DP) model with known parameters for the one period returns and transition equations. The decision rules are solved numerically conditional on alternative scenarios on the likelihood that the lease contract and, thus, farmer access to land is expired. The model parameters represent Finnish conditions and they are based on extensive number of field experiments.

2.1 The Bellman equation

The grain grower optimization problem is modelled as a recursive finite horizon (T) dynamic programming problem that is solved numerically by iterating on the following Bellman's equation (Bellman 1957):

$$V_t(z_t) = \max_{u_t} \left\{ R_t(z_t, u_t) + \beta E_t\left[V_{t+1}(z_{t+1}) \middle| \Omega_t \right] \right\}, \quad t = 0,1,\ldots,T \tag{1}$$

subject to

transition equations: $z_{t+1} = g(z_t, u_t)$, and

initial state: z_0 given

where the optimal value function (V_t) is the function of the current state vector (z_t); u_t is the control, *i.e.* the lime application (often also called as the decision rule or policy function); $R_t(.)$ is the one period net return function; β is the discount factor; and $E_t[.]$ is the conditional expectations operator, conditioned on current information (Ω_t). The optimal value function is constrained by the transition equations, in which $g(.)$ is a function. It determines the connection between the current state and control and the next period state. In practice this means how *pH* is changing between years when the lime is added on the field or the cultivation is continued without adding lime on the field. The optimal solution is pinned down by the initial state z_0. It has to be noticed that z_t and u_t have separate contributions to the net return, even if u_t has no direct effect on yield. This specification generalizes the models presented by Kennedy (1986).

The problem is normalized to one hectare and the crop grown is spring barley which is the most common cereal grown in Finland. The soil types are fine-textured *Vertic Cryaquept*[3] and medium-textured *Oxyaquic Eutrocryepts*[3]. The model represents land that has sufficient quality and the long run equilibrium is to keep soil *pH* status at satisfactory[4] levels from the society perspective, i.e. without land tenure insecurity. In more marginal land areas, the land tenure insecurity problem is not the only institutional factor that is decreasing the irreversible soil improvements in a high cost country with sparse rural population, such as Finland. The time horizon was set at 100 years which guaranteed that not only the decision

rules but also the stock variables converged. This is important to see the equilibrium *pH* levels conditional on different contract regimes.

Economic implications of land tenure insecurity are modelled through a sequence of fixed duration (τ) land leasing contracts. We simulate a five ($\tau=5$) and ten ($\tau=10$) year cash lease contracts, which are the standard durations for the lease contracts in Finland. Longer than 10 year contracts are forbidden by law (Maanvuokralaki).

The signed contract continues, and farmer has access to land, by certainty until the contract's next expiration date (in five years contracts: $t=n\tau$, for $n=1,2,3,\ldots,20$ and in ten years contracts: $t=n\tau$, for $n=1,2,3,\ldots,10$). At each expiration date $t=n\tau$, the continuation of the contract is uncertain and it is renewed by an exogenously[5] given probability $Prob_{n\tau}$. Because continuation and expiration are mutually exclusive, the probability that the lease contract expires is ($1-Prob_{n\tau}$) and, once the contract expires, the one period returns are assumed to stay at zero forever. Thus, the expiration is assumed irreversible so that, if the contract expires, it can never be renewed. Under these conditions, taking the expectations results in the Bellman equation

(2) $$V_t(z_t) = \max_{u_t} \left\{ R_t(z_t,u_t) + \beta Prob_t V_{t+1}(z_{t+1}) \right\}, \quad t = 0,1,\ldots,T$$

subject to $z_{t+1} = g(z_t, u_t)$

z_0 given , $T=100$

where $0 \leq Prob_t \leq 1$ for all $t=n\tau$, and $Prob_t=1$ otherwise.

The state vector (z_t) includes the measure of soil acidity (*pH*) and prices of outputs (p_t) and the price of the control variable (w_t). Prices are assumed deterministic such that the current prices prevail in the future. Thus, the transition equations for prices are simply

(3) $$p_t = p_{t+1} = \overline{p} \quad and \quad w_t = w_{t+1} = \overline{w}$$

The transition equation (*i.e.* the carry-over effect) for soil *pH* is defined separately in subsequent section.

The one period net return (R_t) is the difference between the one period revenue from selling the yield minus the expenditure of purchasing the control (liming). Because other factors are hold fixed in the analysis, they can be suppressed and the one period return function is:

(4) $$R_t(z_t,u_t) = p_t y(pH_t,u_t) - w_t u_t$$

where $y(pH_t,u_t)$ is a deterministic yield response function, specified below. The last term, $w_t u_t$ is the expenditure of using input *i.e.* lime.

2.2 Lime (L): yield response and carry-over

The liming control (u^l) is measured as tonnes per hectare (t/ha) and the stock of lime is measured in terms of soil *pH*. Liming has only an indirect effect on yield via soil *pH*. The yield response to the soil *pH* is described by Mitscherlich function, because it fits best to the data in Kemppainen *et al.* 1993. It also has some desirable features in the context of liming, like convergence on maximum and no diminishing phase[6]. The average yields of barley in years 2000-2004 in Finland were between 3,550 kg/ha and 3,210 kg/ha (Yearbook of Farm

Statistics 2003). Our estimated maximum 3,748 is on line with the average annual yields reported in the statistics. The yield function is:

(5) $$y(pH_t^l, u_t^l) = 3748 - 29147862\, e^{-3.85\, pH_t}$$

The transition equation describing the carry-over-effect and the effects of liming to the soil *pH* is (Kemppainen *et al.* 1993)

(6) $$pH_{t+1}^l = pH_{t+1} = 0.049\, u_t^l + pH_t - 0.015$$

With no liming, the average annual decay rate in the soil *pH* is 0.015 *pH*-points, which implies that annual amount of liming required for maintaining the existing *pH* level is in average 0.31 tonnes per hectare. With more demanding crops, more lime is needed to keep *pH* constant over time. The initial state is imposed at $pH_0 = 5.8$, which was estimated to be an average on leased plots in central and northern parts of Finland (Myyrä *et al.* 2003). The prices and the scope of the model are summarized in Table 1.

TABLE 1. Prices and the scope of the optimization problem.

Price of barley [a]	110 €/tonne
Price of lime [a]	22.69 €/tonne
if applied 1-3 tonnes/ha	42.69 €/tonne
if applied 4-15 tonnes/ha	33.61 €/tonne
Discount factor (β)	1/1.05
Time horizon (T)	100 years
Duration of single contracts (τ)	5 or 10 years

[a] The prices are at farm gate. The price of liming includes also distribution on the field because the standard is that the distribution is bough from a contractor and, therefore does not involve sunk cost from the farmer perspective. Distribution incurs extra cost per tonne at low application levels.

3 RESULTS

Liming is to some extent lumpy so that it is expensive to distribute small amounts of lime (see the price thresholds in Table 1). Therefore, if the initial soil *pH* is in biological target range, which is in our simulations 5.8, the land tenure insecurity does not make a difference in the optimal liming rules (Figure 1). It does not pay to distribute lime on land with *pH* level exceeding 5.5, except when the farmer access to land certainly continues, either through repeated contract renewals or land ownership. We have analysed crop farming and more precisely spring barley. More demanding crops would likely benefit from higher pH values.

Substantially high observed pH values (initial state) on leased plots can be explained by short history of leasing and the domestic price support regime before Finland entry in the EU. If we use a pre-entry price for barley (in year 1994), the socially optimal *pH* level will converge near to biological optimum. Also the reputation condition mentioned by Sjaastad and Bromley (1997) might be one explanation.

But when the initial *pH* level decreases, which is inevitable according our results, decisions to lime diversify according to the length of lease contract and uncertainty over continuation of the lease contract (Figures 2 and 3). If the contract is going to expire by certainty, it pays to lime at the beginning of a ten (five) year contract only if the soil *pH* is

below an extremely low value of 5.2 (5.1). If the odds are slightly in favour of contract renewal (*Probability of expire = 25%*) it pays to lime at the beginning of the ten (five) year contract if the soil *pH* is below 5.4 (5.3). Results show, that if the probability of expiration of contract is small, the date of liming is not important, but when the probability of expiration of contract is big, the only reasonable date for liming is the first year of contract. This is one disadvantage of short term contract which are competed by tenant continuously. Especially, when contract is short and likelihood for contract renewal decreases and the odds are in favour of contract termination, the soil *pH* is allowed to decrease below 5.25, which in the soil studies most commonly represents the fertility class "rather poor"[4]. This is below the biological optimum for barley.

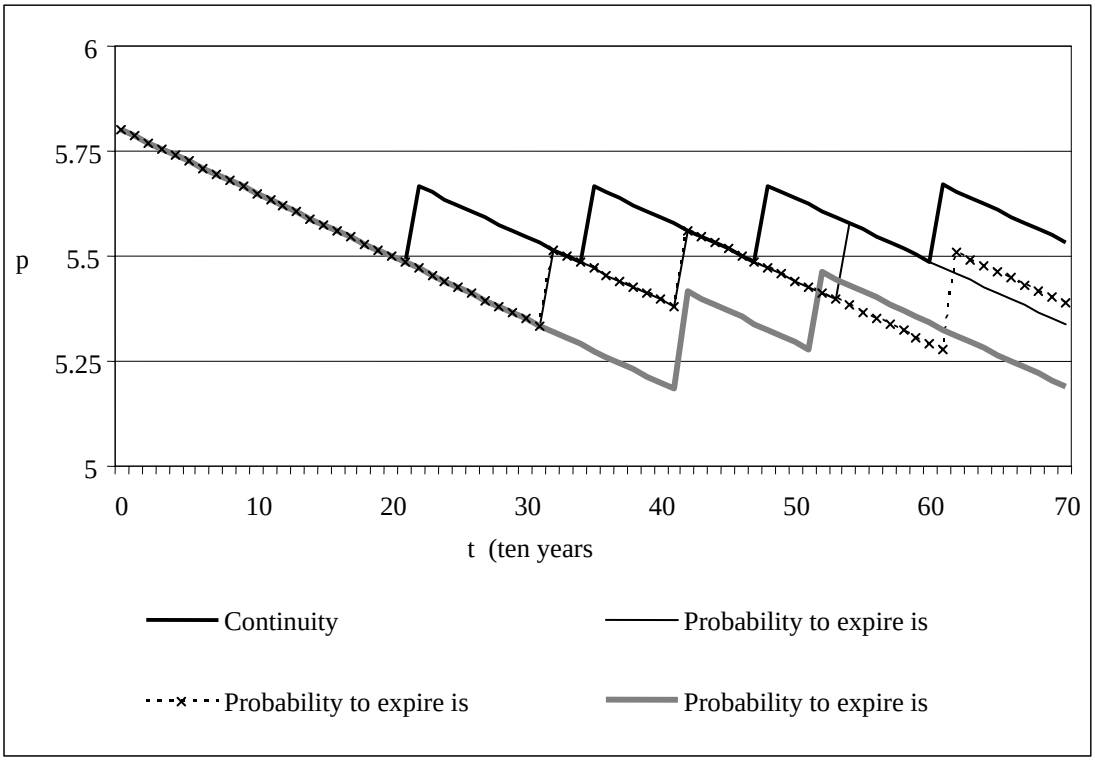


Figure 2. Development of soil *pH* in a sequence of ten year lease contracts conditional on alternative contract renewal probabilities. The upward sloping jumps in soil *pH* indicate points where lime is applied. Downward sloping line traces the soil *pH*, when lime is not applied.

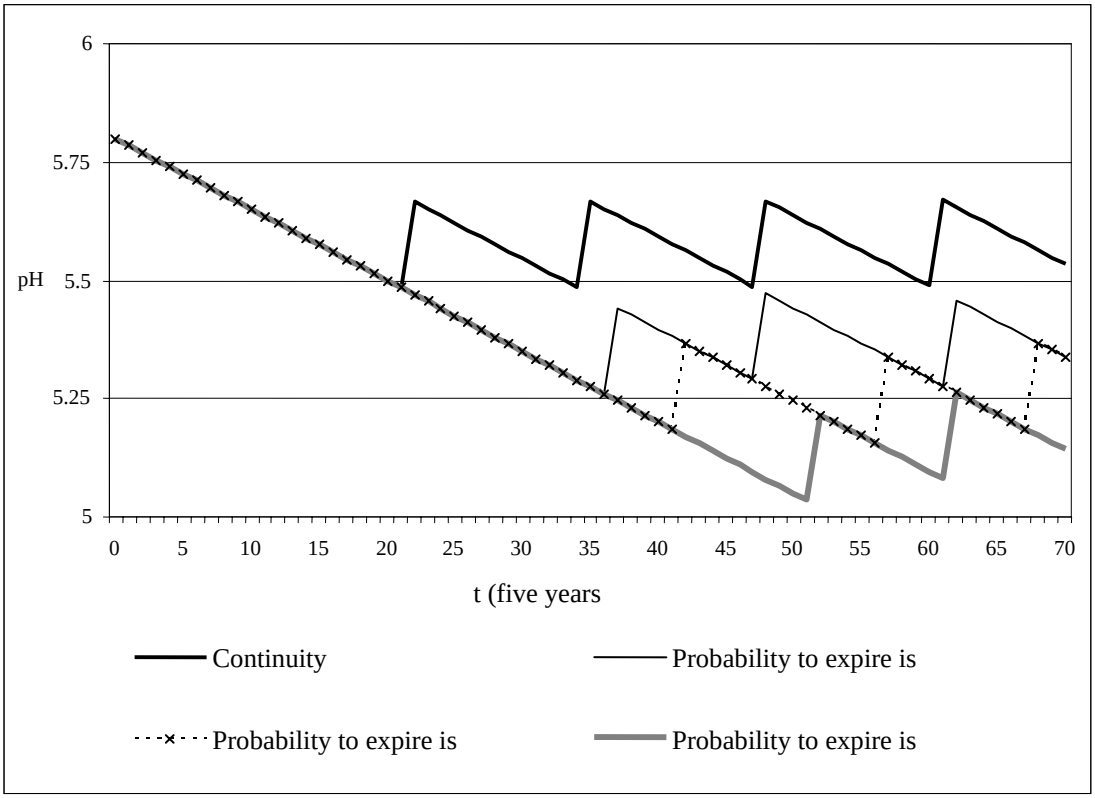
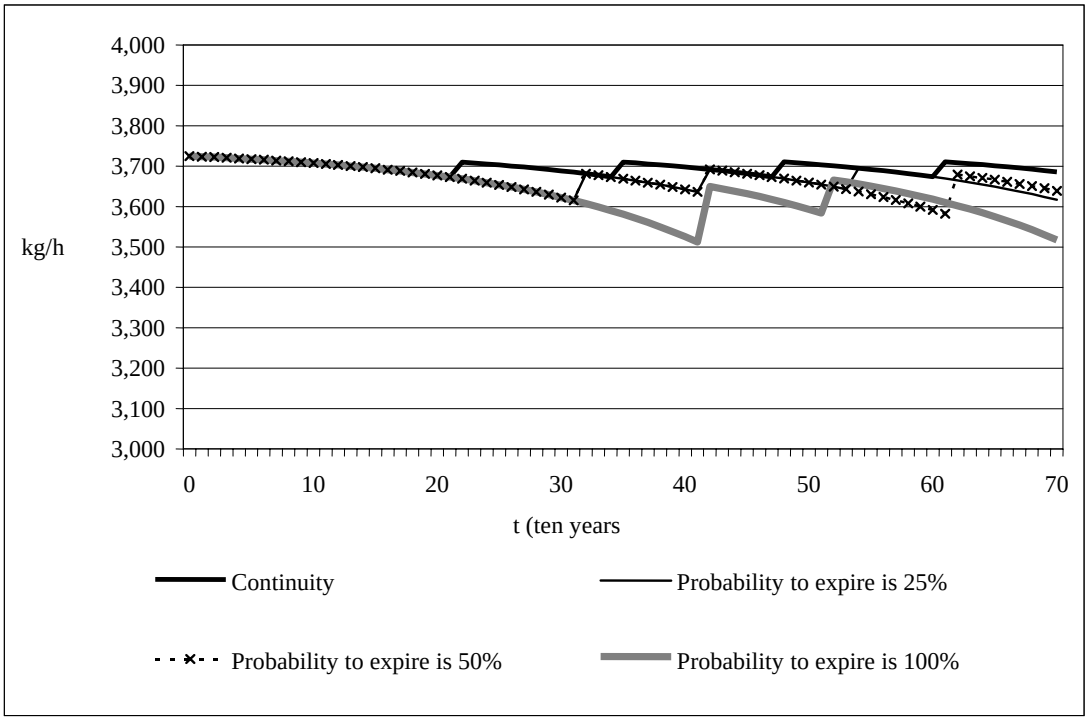


Figure 3. Development of soil *pH* in a sequence of five year lease contracts conditional on alternative contract renewal probabilities. The upward sloping jumps in soil *pH* indicate points where lime is applied. Downward sloping line traces the soil *pH*, when lime is not applied.

Neglected liming implies a gradual decrease in soil *pH*, which will eventually decrease yields (*ceteris paribus*). Figure 4 traces out patterns of consequent ten and five year contracts, which sum up to a 100 year period (only the first 70 years are drawn because the end of planning period is affecting to results on years 70-100). When the land has been cultivated under several subsequent lease contracts and the likelihood for contract renewal has been repeatedly at stake, the yield will start to decrease significantly and converge to around 3,600 kg/ha on ten years contracts and around 3,450 on five years contracts. The yield decrease from the 3,750 kg/ha steady state equilibrium without land tenure insecurity is 150-300 kg/ha and in relative terms 4-8 per cent. If the odds are slightly in favour of contract renewal (probapility to expire is 25%) the steady state yield will be decreased only by 100-150 kg/ha.



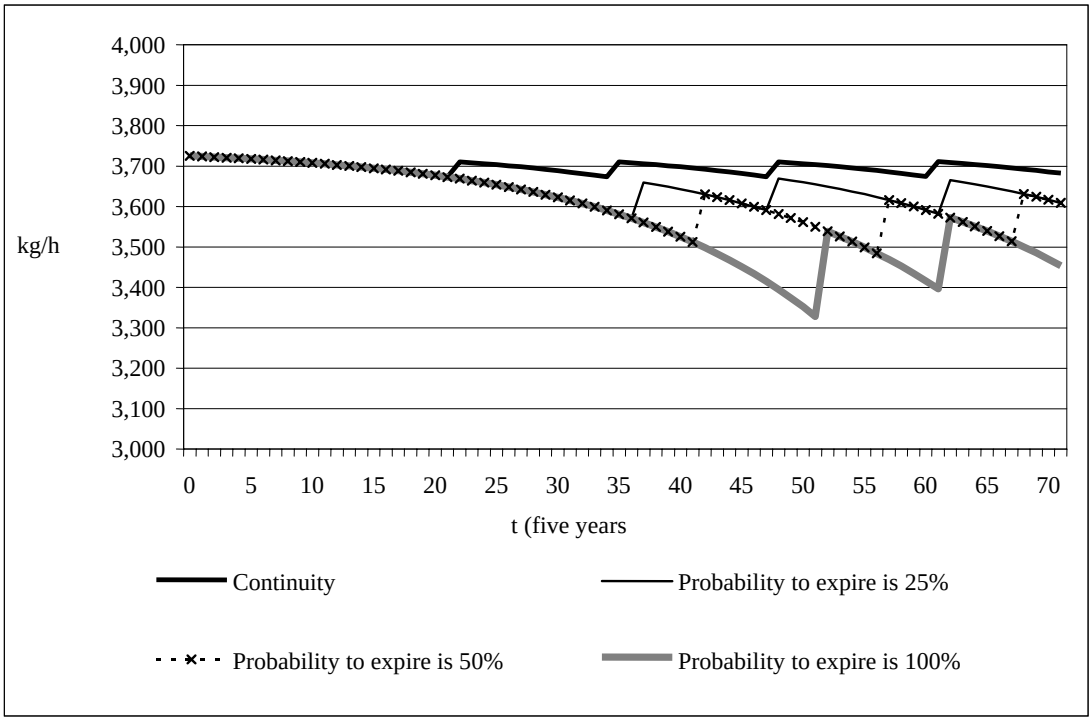


Figure 4. Predicted yield response to optimal liming under alternative probabilities for a expiration of each ten and five year lease contracts (*ceteris paribus*).

In our positive approaches[7], the insecurity problem has had statistically significant effects on the soil *pH.* The mean soil *pH* was estimated to be 0.2 *pH* units higher in the land owned by the farmer than in the land cultivated under a lease contract. In different parts and soil types in Finland, the mean soil *pH* for the owned parcels was higher than that of the leased parcels. However, the endpoints of the 95% confidence intervals for the mean implied that the true means of both land tenure status can be within the satisfactory class. The

measured mean soil pH values where substantially high, 6.0 in owner operated and 5.8 in tenant operated fields in central and northern parts of Finland.

There are a slight difference between the observed *pH* values and the predicted *pH* values, as predicted by the normative model. Nevertheless, the model predicts the discrepancy of *pH* values between the owner and tenant operated plots as it is also observed in the data. When we know that average duration of the lease contracts in Finland is six years, the result give signals that the average probability of renewing a lease contract with the same tenant is 50%. This conclusion can be made, even if we knew that the difference in observed *pH* values have partly formed under different price regime than our model is solved.

4. CONCLUDING REMARKS

The results of our normative dynamic programming model, solved with known parameters, highlight that the optimal decision rules on irreversible land improvements, with long pay-back periods, substantially diversify according to the extent of land tenure insecurity. Liming decreases below the optimum for the society, when the likelihood for contract renewal decreases and likelihood of having future access to land decreases. Therefore, the current tendency of gradually increasing share of land cultivated under short duration cash lease contracts poses a problem in maintaining land improvements that are sufficient for maximizing society welfare. This will finally turn into decreased yields and weakened supply for food. Further, the incentive problem caused by land tenure insecurity will hamper the efficiency of environmental programs to decrease nutrient runoffs since the standard is that implementing these programs requires irreversible investments on land with long payback periods.

The substantial implications, as suggested by our normative model, are supported by aggregate market behaviour. The demand for lime has been decreasing rapidly as the share of land cultivated under lease contracts has been increasing. It has to be noted, however, that the market trends have been affected also by other institutional and economic factors, such as decreasing Marginal Value Product for lime in 1995, when Finland joined EU.

Our results hold only to cash lease contracts where the likelihood of contract renewal is exogenous. The results do not generalize to repeated dynamic games, in which the reputation effect has significant implications to the optimal decision rules. Thus, our analysis does not account for the possibility that land improvements may be used to increase likelihood for contract renewal.

One of the main goals of CAP is to increase productivity in agriculture. The results signal that reaching this goal may be seriously hampered by gradually increasing land leasing unless the land tenure insecurity problem can be solved by better contract design in Finland.

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NOTES

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2. The socially optimal level of land improvements refers to a level, wich is reached in competitive markets equilibrium without land tenure insecurity (Mas-Coell et.al. 1995 p. 325-328). The social optimum gives the maximum welfare for society as a whole, including land onwners and tenants.

3. Soil taxonomy.

4. The class limits depend on the particle size distribution and the organic matter content of the soil.

5. This is a simplification of true life. In case of short duration fixed cash lease contracts which are common in Finland the reputation (performance and used farming practices like liming in earlier periods) of tenant might be crucial variable when land owner decides the next period's tenant. Unfortunately we don't have any empirical data on reputation effect to continuation of lease contract in case of developed countries like Finland. It has been shown that in some circumstances tenant might have incentives above to land owner to invest in land (Sjaastad and Bromley 1997). One important notice in our case is that tenant is not compensated of his efforts for land improvements (like liming) on expiration date if contract is not renewed.

6. In case of fertilization the lack of the diminishing phase is a disadvantage (Bäckman et al. 1997). The data that Kemppainen et al. (1993) have shown do not indicate that diminishing phase is needed, when relation between pH and yield is estimated.

7. Full description of used data and methods can be found from unpublished discussion paper: Myyrä, S., Ketoja, E., Yli-Halla, M., and Pietola, K. 2004. Land improvements under land tenure insecurity the case of pH and phosphate in Finland. MTT Agrifood Research Finland. Discussion papers 2004/3.