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The economics of surface grading of peat soils in northern Norway

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Preface

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The paper represents a step towards planned international publishing and is therefore written in English.

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Abstract

Farmers in northern Norway have experienced frequent winter damages of grassland, especially on flat areas and peat soils. The use of open ditches and surface grading has become the common method to drain such fields and for reclaiming new land with such characteristics. We designate this as surface grading in this paper. An investment analysis is carried out to explore the profitability of this method. This analysis indicates that the method is profitable from the farmers' point of view. However, the conclusions are sensitive to changes in crop yields and the value of the yields. The cost of a winter damage and thus an unplanned reseeding is high for young leys, but is small for leys approaching the optimal replacement age.

Samandrag

Gardbrukarar i Nord-Noreg har relativt ofte hatt overvintringsskade på eng, særleg på flate myrjordsareal. Opne grøfter og overflateforming har vorte ein vanleg måte for å drenere slike areal. Dette gjeld både ved nydyrking og ved drenering av tidlegare dyrka jord. Metoden er omtala som profilering. Ei investeringsanalyse er gjort for å undersøkje lønsemda ved denne metoden. Analysen indikerer at profilering er lønsamt, men analysen byggjer på mange usikre føresetnader. Lønsemda er spesielt avhengig av kva avling ein kan oppnå og verdien av avlinga. Kostnaden, eller det økonomiske tapet, ved vinterskade er størst på ung eng fordi denne skulle gje stor avling. Tapet er mindre på gammal eng fordi fornyinga fører til auke i venta avling åra etterpå.

1 Introduction

Grass production is the main agricultural land use in many parts of Norway. In northern Norway, i.e. the three counties of Nordland, Troms and Finnmark, as much as 94 per cent (89644 hectares (ha)) of agricultural land in use was under grass in 1999 (Statistics Norway 2001). The profitability of grassland is strongly correlated to the length of the ley periods (Hegrenes 1991). Winter damage of the ley is the main reason why the ley has to be reseeded in northern Norway. In the years 1975, 1978, 1985, 1995, and 1998 the grass ley was severely damaged on many farms in northern Norway. Andersen (1960) reported relatively high frequency of winter damage in some regions in northern Norway in the period 1922–59. Clearly, winter damage to grassland is a significant hazard in this area. The frequency of winter damage seems to be highest on flat areas and peat soils in regions with an unstable winter climate.

Frequent winter damage of the ley leads to variation in yields from year to year. This in turn leads to unstable farm income. The crop damage schemes can reduce some of the income effects of low yields. Two of these schemes are especially relevant to the analysis in this paper—the grants to repair and re-establish grassland after winter damage, and grants to buy roughages[1].

It is of interest both to the farmers and to the government to evaluate methods for reducing the problems connected with winter damage of grassland. The aim in this paper is to describe and evaluate such methods, mainly from the farmers' point of view[2]. We believe that the results are relevant to farmers deciding what to do with problematic flat fields on peat soils.

[1] The first mentioned scheme is intended to stimulate farmers to repair the damaged areas as soon as possible. In the county of Finnmark and in parts of Troms county the farmers' own risk is equal to the cost of re-establishing 15 per cent of the farms' total roughage area. In other parts of the country the farmers' own risk is equal to the cost of re-establishing 20 per cent of total roughage area. The latter grant is intended to finance extraordinary purchase of roughages in years of small crop yields. This scheme has an own risk of 22 per cent in Finnmark and part of Troms and 27 per cent in other parts of Norway.

[2] It is of course interesting and relevant to analyse the problem also from society's point of view. Because of positive and negative externalities of agriculture and the many subsidy schemes, a Norwegian analysis from society's point of view might be very different from an analysis from the farmers' point of view. An example of a potential negative effect is the down stream effects of

The paper is organised as follows. After this introduction we describe the problem in more detail and present some measures that might reduce the problem. From this description we conclude that a method called surface grading seems promising. We thereafter provide an investment analysis of surface grading. We also calculate costs of unplanned reseeding of grasses. The paper ends with a discussion of the results.

increased peak flows. Another example could be increased emission of carbondioxide when the peat soil is drained.

2 The problem

The problem of winter damage of grassland is most common on flat areas and peat soils in regions where the winter temperature varies around freezing point. Periods with temperature below freezing point and no or thin snow cover give frozen soil. Frozen peat soils have low water permeability after cycles of cold and mild periods, and the water will not infiltrate into the soil and underground drainage system. Surface water will freeze when a mild, rainy period is followed by cold weather. An ice cover might damage the ley, and the damage risk increases with the duration of the period with ice cover. In addition, most peat soils in northern Norway have low water permeability even in summertime, especially where the soil is worked by heavy agricultural machinery. There might be ponding at the surface after rainfall. Such fields are difficult to harvest due to low load-bearing capacity. The combination of a variable winter climate, flat areas and peat soils is rather common in northern Norway, for instance the Vesterålen region in Nordland county. A farmer having fields with the characteristics described above, is faced with at least three alternatives:

1. To drain the field with underground agricultural drainpipes (traditional drainage)
2. To use open ditches and to surface grade the field
3. To stop harvesting of the field and take it out of use

Use of open ditches and grading of the surface of peat soils has become the commonly used method for cultivation and reclamation of peat soils in northern Norway during the past two decades. The distance between the open parallel ditches is normally 40–50 metres, and the ditches are about one metre deep. The area between the open ditches is graded so as to create a slope of 4–5 per cent towards the open ditches. The surplus water is thereby drained off the surface. Net area is reduced by approximately 7 per cent because of the open ditches. For simplicity the method is subsequently referred to as “surface grading” in this paper.

The method has been found appropriate for reclaiming peatlands in areas with high precipitation which has been out of use for agricultural purposes because of poor drainage (Haraldsen et al. 1993). This method has also given high yields of grass on peat soils in areas with moderate to little precipitation in northern Norway (Haraldsen et al. 1995). Grading the surface of the peat soils reduces the problems of surface ponding which, in turn, has resulted in less winter damage on grassland and has increased the possible length of the ley periods. Aandahl et al. (1999) found that approximately 75 per cent of surface graded fields with peat soils in the Vesterålen region had leys of 7 years or older. Because many of them were established approximately ten years ago, few of them had been reseeded. These leys had survived years with severe winter damage on other flat, peat soil fields drained with agricultural drainpipes.

Practical experience and estimates by local advisers (see for instance Ryeng 1996) indicate that the investment costs are at least as high for traditional drainage as for surface grading. Because of low water permeability, traditional drainage with agricultural drainpipes will not provide efficient drainage of such fields, both during winter and summer. Preliminary estimates indicated that traditional drainage was not profitable in such cases as described in this paper. Therefore, we have concentrated on surface grading in the remainder of this paper, and the main alternatives are surface grading and not using the land[3].

An economic analysis of surface grading of peat soils in the Vesterålen region showed that the winter damage and length of the ley periods highly influenced the profitability of cultivating peat soils, and indicated that surface grading is profitable for the farmers (Lien et al. 1999). This paper is partly based on the same data, but another analytical method is applied.

[3] Because of area payments it will be profitable to keep some areas in use where the value of the crop is lower that the direct cost of cultivating that area. In such cases the cash flow is negative before taking the area payments into account. The increase in annual cash flow when such fields are surface graded will be larger than the cash flow (area payment not included) from a surface graded field. In such cases the profitability of surface grading is better than indicated in this paper.

3 Method

3.1 Choice of method

Both field experiments and practical experience indicate that yields are relatively high on surface graded fields. The growing season starts earlier, there are less operational problems, and the frequency of winter damage is reduced, compared with similar fields that are not surface graded. Therefore, surface grading might have effects on the whole distribution of profit. Portfolio analysis and the use of "the expected return-variance rule" (E–V rule) is one of the simplest models for the analysis of risky situations. In this paper we use a rather traditional investment analysis approach. By this approach we can derive information on necessary conditions for making surface grading profitable. By comparing information on the necessary conditions with available knowledge, the profitability of surface grading can then be gauged. In another paper we have used simulation optimisation to analyse the profitability of surface grading (Hegrenes et al. 2001). This makes it possible to compare the results of two methods.

The investment analysis might be formulated in many ways, and several criteria might be used as a basis for decision, for instance net present value (NPV) and internal rate of return (IRR). Ringøy (1984) used the IRR-criterion in an analysis of traditional draining. Eidman (1997) used after-tax IRR when analysing cropland draining in Minnesota. In some cases the NPV-criterion and the IRR-criterion might not give the same ranking of alternatives. Estimation of the internal rate of return is especially problematic when there are multiple changes of the sign of the cash flow; see for instance Copeland and Weston (1988: 31–36) for a comparison of NPV and IRR. As shown below, there are some years with a negative cash flow after surface grading. Therefore, we have chosen NPV as the main criterion for measuring profitability. Tax effects are not included.

We assume that the surface graded fields are used for grass production. It might be profitable to reseed the grass at some stage, even without any severe winter damage. We do not know a priori the optimal interval between the reseeding of grasses after grading. Therefore, we have estimated the NPV for many intervals. In order to be able to compare the results for different intervals, we have assumed stationarity; i.e. that the projects are replicated at constant scale an infinite number of times[4]. When assuming an infinite time we can compare projects with different lives because when their cash flow streams are replicated forever it is as if they had the same life (Copeland and Weston 1988: 49). In doing so we have applied the following formula:

$$NPV(N,\infty) = \left(\sum_{t=1}^{N} \frac{a_t}{(1+i)^t}\right) \frac{(1+i)^N}{(1+i)^N - 1} \qquad [1]$$

$\sum_{t=1}^{N} \frac{a_t}{(1+i)^t}$ is the NPV of an N-year investment project with an annual cash flow of a_t. $NPV(N,\infty)$ expresses the NPV of an N-year project replicated at constant scale an infinite number of times. The factor $[(1+i)^N/((1+i)^N-1)]$ is later in this paper referred to as the replication factor.

The costs of a damage to the ley are calculated as the difference between the NPV of the optimal frequency of re-establishing the ley and the NPV of any other frequency of replacement. This is explained in more detail in section 4.3.

Many uncertain assumptions have to be made in order to carry out the investment analysis. A rather simple sensitivity analysis is used to explore the effects on profitability of changes in some of the factors that are regarded as uncertain.

Haraldsen et al. (1993) report yields for surfaces graded fields in northern Norway. However, there is often a discrepancy between experimental results and practice, see for instance Dillon and Anderson (1990 chapter 8). There are also losses in the haymaking and silage making processes (e.g. Merry et al. 2000). Therefore, net crop yield available for sale or as feed for livestock is considerably lower than crop yield registered in field experiments. There is little information on this difference, and we have used available information to estimate yields that "look reasonable".

Reseeding of the leys might be regarded as a replacement problem, but it is not a major purpose in this paper to estimate optimal economic life of a grass ley. Instead we have assumed, rather arbitrarily, that the ley is reseeded every fifteen years if it is not reseeded earlier. However, the model produces some information on the economic life of leys.

3.2 Specification of the model

3.2.1 Investment in surface grading

Based on Aandahl et al. (1999), we assume that when two mechanical diggers work in cooperation, one hectare might be surface graded in 50–60 machine hours at a cost of approximately NOK[5] (Norwegian kroner) 24000, according to experience. Including costs for some additional work, for instance costs for a tractor road to the field, works to secure water outlets, and costs of harrowing the field that has been graded, we estimate the costs to NOK 30000 per ha. We assume that no yield can be harvested in the year of grading.

It is common practise to have one year with green fodder before the grass is seeded. On average the yield per ha of green fodder is 70–80 per cent of the yield of grassland in northern Norway (Hegrenes and Lien 1999). We have assumed that the net value (net cash flow) of the green fodder is NOK 2000 per ha per year. The year of surface grading is regarded as year

[4] Alternatively, we could have used the average return per year, which is the equivalent annuity when interest rate is positive. The ranking of the alternatives would be the same.

[5] On average for the year 2000, EUR 1 = NOK 8.11 (Norges Bank 2001)

“zero” in the investment analysis. The investment cost, including the value of one harvest of green fodder, is then calculated to be NOK 28095 per ha assuming 5 per cent interest rate.

3.2.2 Annual cash flows for surface graded fields

In spring two years after the surface grading, grasses are seeded with barley as a cover crop. The cash flow in the year of seeding is presented in Table 3.1. Because net area is reduced after surface grading, the cash flows are adjusted accordingly.

Table 3.1 Estimated costs for reseeding 1 ha of surface graded ley

	Quantity	Unit	Price		Total, NOK/ha
Seed, grass	20	kg/ha	40	NOK/kg	800
Seed, barley	60	kg/ha	4	NOK/kg	240
Lime	1000	kg/ha	0.37	NOK/kg	370
Labour input,	40	h/ha	100	NOK/h	4000
Machinery costs	35	h/ha	100	NOK/h	3500
Total					8910
Value of yield		4000 kg DM[1)] at NOK 1.65		NOK/ha	6600
Net expenses				NOK/ha	2310
Net expenses adjusted[2)]				NOK/ha	2148

1) Dry matter.
2) Adjusted because net harvested area is reduced by 7 per cent because of the open ditches.

The peat soils are normally acid, and acid precipitation and use of chemical fertilisers have acidification effects on the soil. Therefore, lime is commonly applied in the year of reseeding grassland, for instance 5 tons per ha if the grass is reseeded every five years, or 10 tons per ha every ten years. However, in this paper we have not assumed any fixed reseeding pattern. Therefore, we have assumed that 1 ton of lime is applied annually.

Some input prices are presented in Table 3.1 while other input prices are presented in Table 3.2 together with the price of the yield. The price level is assumed to represent the prevailing prices in the year 2000. The interest rate is assumed to be 5 per cent per annum, approximately equal to the average real interest rate on Government bonds with 10 years maturity. A labour cost of NOK 100 per hour is low compared with average wages in manufacturing industries (Statistics Norway 1999), but is relatively high compared with average wage earning capacity in agriculture. The latter was NOK 71.17 per hour in 1998 and NOK 62.95 per hour in 1999 on dairy farms in northern Norway, according to the Farm Business Survey (NILF 1999, 2000)[6].

Table 3.2 Assumed prices for calculating annual cash flows

Yield, NOK per kg dry matter (DM)	1.65
Fertiliser, NOK per kg	2.0
Preservatives, NOK per litre	20
Fuel, NOK per litre	3

[6] Most of the labour input is by farmers and family members. The “price” of this labour cannot be observed directly in a market. At present there are an outflow of labour from agriculture. We have assumed that in the long run, the labour income must be higher than the observed average at present, but lower than what might be earned elsewhere. Admittedly, NOK 100 per hour is a rather ad-hoc assumption.

Interest, % p.a.	5

In northern Norway, most of the grass is made into silage or used for pasture. We assume that the yield is made into silage. Most of the silage is used on the farm where it is produced, and there is a thin market for silage and other roughages. Therefore, the value of home-grown roughages cannot be observed in the market. However, one can expect that, because of transportation costs and other transaction costs, the price obtained when selling roughages is lower than the purchase price and that the on-farm use value lies somewhere between the two. As weather conditions tend to be the same in relatively large regions, many farms might simultaneously experience winter damage of grass leys. This could have an influence on the market for hay or silage. Therefore, it could be expected that the market value of the crops varies and is high when yields are small and low when yields are large, see for instance Johnson (1997). We have assumed a price of NOK 1.65 per kg DM. This is close to the prices of silage paid by farmers in northern Norway participating in the Farm Business in 1996 and 1998. It is also close to the balance sheet value of silage applied in the Norwegian Farm Business Survey (NILF 1999). There the price of roughages is based on the selling price of barley. The purchase price of barley was approximately NOK 2.50 per kg in northern Norway in the year 2000.

In Norway, there is an acreage subsidy payment for grassland and other roughages. The rates per ha depend on the area of grassland and other roughages, and vary by region. In most of northern Norway the payment is NOK 4400 per ha per year for less than 20 ha per holding, and NOK 2200 per ha for 20–40 ha per holding. There are no payments for more than 40 ha of grassland per holding. If a field is harvested both before and after surface grading, the surface grading has no influence on what the farmer receives in acreage payment. However, if the field is not in use before surface grading, the farmer receives more acreage payment as a result of the surface grading, as long as the total area for roughages is less than 40 ha. Because the rates vary with region and harvested area, and are frequently changed, the acreage payment is not included in the budgets. It is, however, taken into account when discussing the results.

The costs of preservatives, chemical fertilisers and variable machinery costs are assumed to be proportional, or close to proportional, to yield. Most farmers who consider surface grading have livestock, mainly cattle. The manure is commonly applied to the grassland, and the use of chemical fertiliser is reduced accordingly. However, as we have not modelled the livestock activities, we have estimated fertiliser costs as if only chemical fertilisers were applied.

The expected yield of grassland depends on the age of the ley. Results of Nesheim (1986) indicate higher yields on leys with an age of 1–5 years compared with older leys. This is also in accordance with results from the "Grassland survey in Norway" described in Haraldsen and Waag (1991). From this database we calculated average yield per ha dependent on age of the ley for fields in northern Norway. The number of observations for fields of each age varies between 109 for three years old fields to 8 for twelve years old fields. To find the "smoothed" yield curve dependent on age of the ley the estimated annual yields were regressed against age of ley. Assuming a quadratic function this gave the following equation (figures in parentheses indicate the standard deviation of the coefficients):

$$\underset{(389.3)}{6483.5} \underset{(135.8)}{-152.8c} + \underset{(10.2)}{4.0c^2} = Y \qquad [2]$$

where

Y = estimated grassland yield at age c, in kilograms of dry matter per hectare (kg DM/ha), c = age of ley, c = (1,..,12)

Equation 2 indicates that yields are falling until the ley is 19 years old, but the equation is statistically uncertain; the standard deviations of the estimated parameters are rather high. As there probably are few surface graded fields in this database, one might argue that the data are not representative of surface graded fields. In addition, it might be argued that some fields have an old grass ley because the yield has been high, while fields with more rapidly decreasing yields, have been reseeded and never became old. Therefore, there are reasons to believe that the estimated curve is too flat in the beginning. For these reasons we used some expert advice to construct an assumed curve that is falling more steeply in the first years than indicated by equation 2, but has no decrease in annual yield for leys seven years old or older, see Table 3.3.

Table 3.3 Assumed quantities of inputs and outputs, and cash flow; after grading

Year of rotation	1	2	3	4	5	6	7–14
Yield, kg DM per ha	7000	6500	6000	5500	5300	5100	5000
Fertiliser, kg per ha	750	700	670	620	600	600	600
Preservatives, litre per ha	49.0	45.5	42.0	38.5	37.1	35.7	35.0
Lime, kg per ha	1000	1000	1000	1000	1000	1000	1000
Fuel, litre per ha	80	75	70	65	60	60	60
Other variable machinery costs, NOK per ha	1400	1329	1257	1186	1157	1129	1114
Labour input, h per ha	27	26	25	24	23.5	23	22
Net cash flow (NCF), NOK	4360	3891	3383	2914	2746	2522	2486
NCF adjusted to net area[1)] NOK/ha	4055	3619	3520	3056	2888	2681	2312

1) Adjusted because net harvested area is reduced by 7 per cent because of the open ditches.

The average yield over a run of fourteen years is 5386 kg DM/ha. This is fairly close to the average of 5190 kg DM/ha found in Vesterålen (Lien et al. 1999). In the Farm Business Survey the yield of grass and pasture was on average approximately 2900 feed units milk (FUM) per ha in the period 1996–1998 in northern Norway (NILF 1997–1999). Assuming 1.3 kg DM per FUM this is a little less than 4000 kg DM/ha. Because this includes some pasture which normally has lower crop yields than grass for silage, and also includes some fields that might be older than assumed in the model, the yields used in the model and the yields estimated in the Farm Business Survey are fairly close. However, the model probably represents fields with somewhat higher than average yields.

We assume that the method and cost of re-establishing the ley are the same regardless of the reason why the field is reseeded. In all cases it is assumed that the field is ploughed and harrowed and then grass seed is sown with barley as a cover crop. The yield is harvested as silage. Table 3.1 gives the assumed data concerning reseeding of the grassland ley.

When peat soils are drained, the soil conversion process is speeded up. The soil surface might sink, the ditches become less deep, the banks of the open ditches may erode, and trees may grow there. The tree roots can hinder the water flow. Therefore, it seems plausible to assume a finite economic life of the investment, or to assume some maintenance costs. Lien et al. (1999) assumed an economic life of 20 years. We have assumed some maintenance work and that the investment has an infinite economic life. The first maintenance work is assumed to be carried out seventeen years after surface grading and then every fifteen years. This is assumed to be done regardless of the rotation pattern. The maintenance cost is set to NOK 5000 per ha. The present value of this (in year zero) is:

$$5000*(1.05^{15}/1.05^{15}-1)/1.05^{17} = 4203$$

Figure 3.1 is a summary of the cash flow for the year of surface grading (year 0) and the next 17 years. This would be the cash flow if the farmer choose to re-establish the ley fifteen years after the first seeding. A winter damage incident can make it profitable to re-establish the ley at an earlier stage. Because of the reduction in annual cash flow with increasing age of ley, it might be profitable to re-establish the ley more frequently even without any damage of the ley.

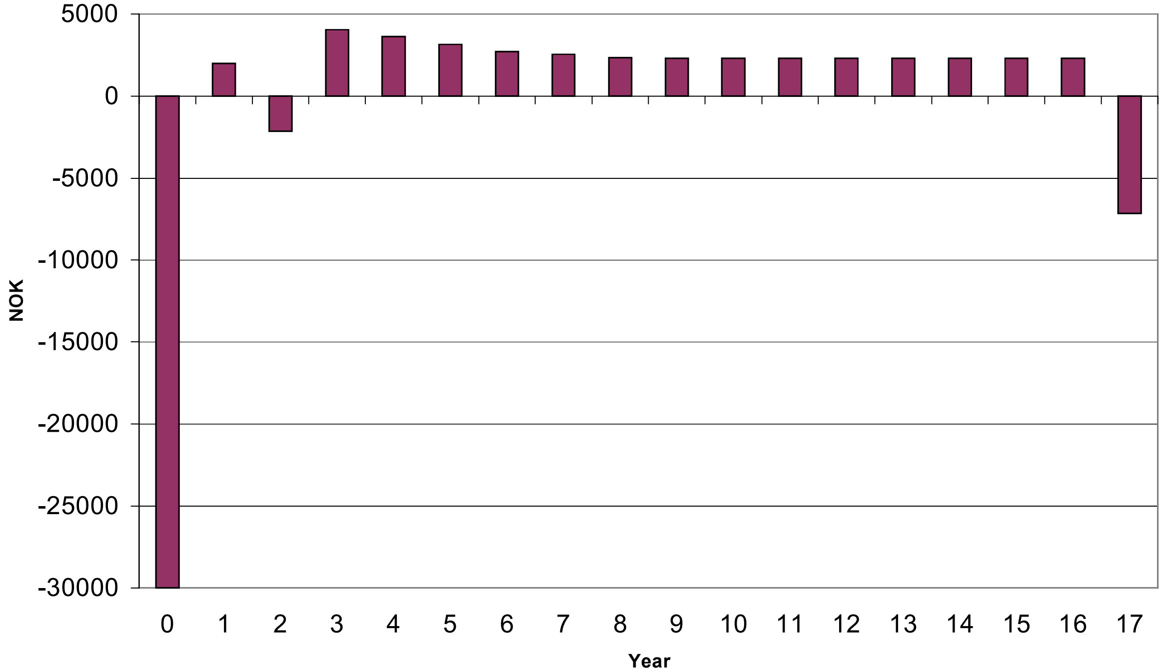

Figure 3.1 Estimated annual cash flows for a surface grading project, assuming surface grading in year 0, establishing of the first ley in year 2, and re-establishing the ley in year 17. NOK/ha

Following this presentation, there are four elements in the estimation of profitability of surface grading: (1) the investment cost in year 0 (=NOK 30000), (2) the net value of the green fodder in year 1 (=NOK 2000), (3) the value of the infinite grassland period, starting in year 2, and (4) the present value of the maintenance cost starting in year 17.

4 Results

4.1 Results with basic assumptions

Table 4.1gives some results for the grassland period, element (3) above (end of section 3.2.2). If grass is seeded in one year, then there is one year with a “normal” harvest and severe damage the second winter, the NPV of the two years would be: NOK (- 2148 + 4055/1.05) = NOK 1713. If this were replicated an infinite number of times, the present value would be NOK 18430. Table 4.1 gives the corresponding figures for periods of 2 to 15 years.

Table 4.1 Present value of one period and an infinite number of periods of grassland with different reseeding frequencies. NOK per hectare

Reseeding every	One period	Replication factor	Infinite period
2 years	1713	10.756	18430
3 years	4996	7.344	36691
4 years	7714	5.640	43507
5 years	9943	4.619	45934
6 years	11944	3.940	47065
7 years	13695	3.456	47335
8 years	15338	3.094	47461
9 years	16902	2.814	47560
10 years	18392	2.590	47638
11 years	19812	2.408	47702
12 years	21163	2.257	47755
13 years	22451	2.129	47800
14 years	23676	2.020	47838
15 years	24844	1.927	47871

Table 4.1 shows, for instance, that the discounted value of an infinite run of reseedings every 15 years is NOK 47871. But in practice the stream of benefits represented by this present value does not start until two years after surface grading, for which some costs are incurred. When taking all four elements mentioned at the end of section 3.2.2 into account, and assuming reseeding frequencies varying from 2 to 15 years, we get the figures in the "Basic" column in Table 4.2. With the basic assumptions, the ley has to last for at least two years (a reseeding every three years), in order to give a positive NPV. The NPV increases up to a reseeding frequency of 15 years, which is the maximum length assumed in the estimations.

Table 4.2 Net present values (NPV) of surface grading for basic assumptions, and effects on the NPV of changes in assumed value of some parameters. NOK per hectare

Reseeding every	Basic	Price of yield		Yield after grading		Interest rate	
		+10 %	-10 %	+10 %	-10 %	3 %	7 %
2 years	-15582	386	-31551	-6449	-24716	-7139	-19287
3 years	981	17911	-15948	12733	-10770	21252	-7781
4 years	7163	24234	-9907	19912	-5585	31783	-3463
5 years	9365	26255	-7526	22468	-3739	35442	-1892
6 years	10390	27075	-6295	23652	-2871	37095	-1141
7 years	10635	27102	-5831	23944	-2673	37398	-927
8 years	10750	27023	-5522	24066	-2565	37500	-813
9 years	10840	26962	-5283	24160	-2481	37580	-724
10 years	10911	26913	-5092	24236	-2414	37643	-653
11 years	10969	26873	-4936	24297	-2360	37695	-596
12 years	11017	26840	-4807	24348	-2315	37738	-549
13 years	11057	26812	-4698	24391	-2276	37775	-509
14 years	11092	26789	-4605	24427	-2244	37806	-475
15 years	11122	26768	-4525	24459	-2216	37833	-446

4.2 Sensitivity analysis

The results are based on some rather uncertain assumptions. It is therefore interesting to analyse how robust the results are under changes in the assumptions. To explore such questions, we have changed the following factors by plus and minus 10 per cent and kept the other factors unchanged:

- Costs of surface grading (investment costs)
- Yield per hectare after grading
- Price of yield.

In addition, we have also estimated one alternative with an interest rate of 3 per cent and one with an interest rate of 7 per cent.

We have chosen to study the effects of yield and price because these are the two single factors most important for the gross revenue. The effect of yield and price is linear. Therefore, the effect of a change of, for instance, 20 per cent in one of these factors is twice the effect of a 10 per cent change. The effect of changes in the interest rate is not proportional to the change.

The cost of grading enters the calculation only in year zero. A change in the grading cost has therefore a direct effect on the result, and an increase (decrease) in the cost of surface grading reduces (increases) the NPV by the same amount. A 10 per cent change in the cost of grading equals NOK 3000 and changes the NPV by the same amount but in the opposite direction for all length of leys.

Investment grants are one reason why investment costs might be lower than assumed. At present, the maximum grant is NOK 8000 per ha. Such a grant will significantly increase the profitability of surface grading (and other drainage projects).

If the value of the yield is 10 per cent (NOK 0.165 per kg DM) lower than assumed, the grading is not profitable, ceteris paribus. On the other hand, the profitability will be much improved at a 10 per cent higher price for roughage, and in this case reseeding intervals of seven years are optimal, though the differences are rather small between frequencies of six years or more.

As some costs are assumed to be proportional to the yield, the effect of a 10 per cent change in yield per ha is smaller than the effect of a 10 per cent change in the price of the yield, see Table 4.2.

Table 4.2 shows that a reduction in interest rate to 3 per cent has a more profound effect on NPV than an increase to 7 per cent. At 3 per cent interest rate the investment would be very profitable if there are at least three years between each reseeding. The investment would not be profitable even at reseeding intervals of fifteen years if the interest rate is 7 per cent.

If yields and prices were 3.5 per cent lower and interest rates were 3.5 per cent higher than in the basic alternative, the NPV would be only NOK 145 at a reseeding frequency of 15 years, and only frequencies of 13 years or more had a positive NPV.

The sensitivity analysis shows that the profitability is rather dependent on the chosen assumptions. Relatively small negative changes are enough to make the investment unprofitable, as long as we do not include the effect of the acreage payment.

4.3 The cost of unplanned reseeding

Let us say that a farmer experiences severe damage in the first year after seeding. If this damage had not occurred, the field would have been re-established when it was 15 years. The present value of this would have been NOK (47871+2148)*1.05 = NOK 52520. However, the process starts again because of the reseeding, and the NPV of the new process is estimated to be NOK 47871. The cost of severe winter damage in the first year is:

$$(47871+2148)1.05 - 47871 = 4649$$

By estimating the costs for different ages of the ley, we get the figures in Table 4.3. The table clearly shows, as expected, that damage to a young ley is more costly than damage to a ley that is close to the maximum replacement age of 15 years.

Table 4.3 Costs of an unplanned re-establishment of the ley. Basic assumptions. NOK

Age of ley	
1 year	4649
2 years	3018
3 years	1762
4 years	940
5 years	535
6 years	274
7 years	218
8 years	195
9 years	171
10 years	146
11 years	120
12 years	92
13 years	32

These results treat damage as a rare event that occurs only once in the (near) infinite time period. A pattern of recurring damage incidents might be more normal, but we have no means of knowing when they will occur. A simplification is to assume damage at fixed intervals. The cost of this can be found as the difference between the present value for reseeding every fifteen year and any other frequency of reseeding in Table 4.1. This too shows that winter damages more frequent than approximately every 5 years are rather costly.

5 Discussion

The financial analysis indicates that surface grading is profitable for farmers if the leys on surface graded fields last for at least 2 years, that is the leys have to be reseeded every 3 years. The profitability is improved the more lasting the ley is, at least up to fifteen years. Aandahl et al. (1999) found that 75 per cent of the surface graded fields in the Vesterålen region had leys of seven years or more. These leys had survived periodes with severe damages on similar non-graded fields in the same region. In addition, the variability in crop yield and financial result is lower after surface grading than it was before.

The area subsidy and the subsidy to re-establish leys are not taken into account in these estimations. The public crop disaster programme that includes several schemes, might reduce the farmers' financial burden of a winter damage of the grass ley. The main reason for not including this payments is that the crop disaster schemes are on a whole-farm basis while the profitability estimates are on a per hectare basis. We assumes that the total area is not necessarily surface graded. The omission of these grants means that we have overestimated the farmers' cost of a winter damage and the calculated NPVs are under-estimated.

The profitability analysis is based on many uncertain assumptions. The sensitivity analysis indicates that crop yield, value of the yield, and the interest rate all have substantial influence on the profitability of surface grading and are more decisive than the cost of the grading itself. Another observation from the sensitivity analysis is that the "optimal" length of the ley is only marginally influenced by changes in most of the assumptions as long as there are no severe damage. The occurrence of damages might be the single factor most decisive for when to reseed the ley. An unplanned reseeding close to the optimal replacement age of the ley does not incur any significant costs compared with the costs incurred if a young ley is damaged.

This sensitivity approach is very crude. Indications of the uncertainty concerning costs of grading and the yield after grading might be obtained by studying historic data. In the beginning of section 3.2.1 some information on the uncertainty with the investment costs are presented. Future prices are difficult to gauge. However, one might argue that Norwegian farmers cannot expect higher prices in the future than today, taking the present Norwegian agricultural policy and the tendency towards freer international trade in agricultural products into account. Therefore, it might be argued that reduced prices are more probable than increased prices, and that a 10 per cent reduction is potentially a small reduction.

This paper is based on conditions prevailing on some soil types in northern Norway. However, the results are relevant to other regions too where soil and climatic conditions and prices are similar to those described here. Therefore, it is not surprising to notice an increasing interest in the use of open ditches and land grading in other parts of Norway. Other countries have other conditions concerning natural conditions, market situation, and agricultural policy and the results cannot be applied generally.

Surface grading is an interesting method for improving fields that are in use but have frequent winter damage or are difficult to harvest due to low load-bearing capacity. The method is also of interest when reclaiming new land. In the first case, area payment has no influence on the profitability of surface grading. In the latter case, area payment increases the profitability of reclaiming new land. However, a farmer needs a special concession from the government in order to reclaim new land. Land reclamation is, therefore, not a very realistic option to many farmers.

If a field is surface graded, the cost of grading can be regarded as a sunk costs. Also, if the farmer stops harvesting the field, he would loose the acreage payment. Therefore, the economic conditions might worsen "quite a lot" before it is profitable to take surface graded farmland out of use.

Elsewhere (Hegrenes et al. 2001) we have analysed two other questions related to surface grading:

- What is the profitability of surface grading when the probability of winter damage is built into the investment model?
- How damaged can the ley be before it is profitable to reseed grasses?

Those analyses too indicate that surface grading is profitable in most cases. It is also indicated that it is profitable to re-seed a ley if it is so damaged that the farmer can expect to get only half the yield assumed in this paper. If the farmer can expect the yield to be more than half the "normal" yield, it is more profitable not to reseed the ley.

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