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Lars Lönnstedt and Björn Rosenquist (eds.)

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Creaming: a fast track to continuous cover forests?

Colin Price and Martin Price

Abstract
The premises for designing economic transformation to continuous cover forests might be: early revenue is preferable to delayed revenue; big trees make more money than medium-sized trees; fast growth may bring quality penalties; small trees cost money to remove; there is an opportunity cost in felling trees not at optimal rotation; in the temperate/boreal zone regeneration may need a large canopy gap; planting more trees costs more money; the long period of transformation is a bad thing if the target system is more profitable than the existing one. Early revenue is obtainable by premature clear felling, at lesser cost than by transformation,. Removing the largest trees from an even-aged crop gives net revenues early; minimises deviation from optimal felling size; provides gaps large enough for some but not excessive regeneration. Successive removal of the largest trees creates fully diverse size structure quickly. Subsequent fellings will also be of high value trees. Both the resulting forest, and the process of transformation, could be more profitable than alternative treatments. Preliminary results of time study and stand modelling support this provisional conclusion.

Introduction
The trouble with silvicultural experiments is that they are designed by silviculturists. Economists get to analyse them afterwards, and the first conclusion may be that *these were the wrong experiments*.

In the early third millennium, the Forestry Commission in Wales instituted research into how Wales's largely even-aged forests could achieve some form of continuous cover structure. This followed declaration of a forestry objective "to convert at least half of the National Assembly [i.e. state-owned] woodlands to continuous cover over the next 20 years …" (National Assembly of Wales, 2001). One component of the programme was to study economic factors, in a privately owned forest, with a view to evaluating what kind of financial inducements might be necessary and appropriate, to encourage transformation in the private sector.

Given the project's economic orientation, it was surprisingly difficult to include economic reasoning in the *design* of experimental treatments. Conventional small-group felling was an agreed treatment; as was selection of frame trees, with crown thinning undertaken to favour them. These are silvicultural treatments often considered in the UK when continuous cover forestry is discussed. The base-line treatment was to continue the pre-existing low thinning, eventually followed by clear cutting and even-aged regeneration. Yet it is far from clear what economic advantages conventional treatments offer over clear cutting, even once transformation of age structure is complete. On the contrary, they involve harvesting on a small scale and in a dispersed pattern, which might be expected to increase harvesting cost, with no guarantee that conditions for "free" natural regeneration would arise. Moreover, to transform the age-class structure entails felling part of the crop prematurely, and part beyond its economically optimal rotation, with important short-term costs.

If, instead, one sought treatments likely to be economically attractive both at the outset, and in the long term, what would be designed? This was the thinking that underlay what was, and still is, regarded as a subversive incursion into UK silviculture. This paper describes the theoretical argument, the experiments set up to test its validity, some preliminary results, and an economic evaluation based on simple but reasonable models of the treatments' future development. It builds on work presented in Price and Price (2006), using refined figures for operational costs.

Purposefully economic transformation

Premises from basic forest economics, for designing an economic transformation to continuous cover structure, might include these following.

- Because of the effect of discounting, early revenue is preferable to delayed revenue, particularly for private sector forest owners with cash flow problems.
- Felling big trees makes more money than felling the same total volume of medium-sized trees.
- Very fast-grown trees may not yield good quality timber.
- Small trees cost money to remove. Taking them out in thinnings increases investment in the crop.
- By definition, there is an opportunity cost in felling trees either before or after their optimal rotation.
- In windy climates and exposed conditions, trees may not survive long after they reach a critical height.
- In the temperate and boreal zones, a large canopy gap may be needed to encourage regeneration, except with the most shade-tolerant species.
- The more trees that are planted and tended, the more money it costs.
- Transformation takes a long time, which is a bad thing if the target system is more profitable than the existing one (though possibly be a good thing if, as may be the case, it is *less* profitable).

Early revenue and early clear cutting

Particularly in the private sector, cash flow constraints may require premature felling of some trees in an even-aged forest: transformation to continuous cover forestry has been considered beneficial/advocated on these grounds (Knoke & Plusczyk, 2001). But early cash flow (or regular cash flow, or flexible cash flow, as desired) can equally be achieved by rescheduling the clear felling of whole stands (Brazee, 2003). Hence such a treatment was included in the experiment.

The expectation is that early clear felling will be better than the “silvicultural” transformation treatments, both because of cost economies of working on a large scale, and because the most valuable (large) trees may be removed. The only treatment that is (definitionally) superior is felling at optimal rotation, but this does not provide the required early revenue.

The design of the creaming treatment

An economically optimal transformation may depend on the preferred final state. However, it is also possible that the costs and forgone revenue incurred in the transformation may make some alternative final state more desirable – or less undesirable. The argument defining an economically attractive final state might go something like this.

We want to take as high a proportion of yield as possible in big trees.

We don’t want to remove small thinnings *at all*: even if they could be sold. The reversed J-shaped curve of classical selection may have arisen from observation of natural forests. It may not be necessary for managed forests to replicate it. The traditional prescription for selection forestry, removal of volume from all size classes, and more trees from the smaller size classes, is anathema.

Wide spacing gives wide growth rings, high taper and poor strength qualities. In UK conditions, with the favoured species, fast growth may already be a barrier to premium markets. Even within an evenly spaced stand, larger diameter trees may be of low quality

(Meilby, pers.comm.). (However, where wind stability is a problem, wide spacing may be the only way to achieve desirable diameters before height becomes critical.)
So, we want to grow our big trees in *quite* competitive conditions, especially early in the rotation, when wide rings dimensional instability are likely to result from free growth …
… yet, to recap, without having to take out any more thinnings than necessary …
… except perhaps just a few to give us selection options …
… and at the same time we want big enough crowns late in the growth period, that a sufficient diameter is reached before wind damage becomes a problem.
And we don't want it to cost much.
This means that neither do we want to plant many trees (artificially), nor
… do we want too many to regenerate (naturally) – see 2. above, although …
… a gap big enough to encourage adequate regeneration is desirable.

Relative profitability, once in place

Once this regime is in place, it may be compared with a clear cutting regime in which all age-classes are represented in a normal age-class structure. The following figure shows the difference in capitalised profit between the regimes, at a range of harvesting and regeneration cost differentials. The basis for revenue is that felled trees are each of 1 m^3, at which size they obtain a price close to maximal per m^3. At plausible levels of cost differential, the creaming treatment is more profitable.

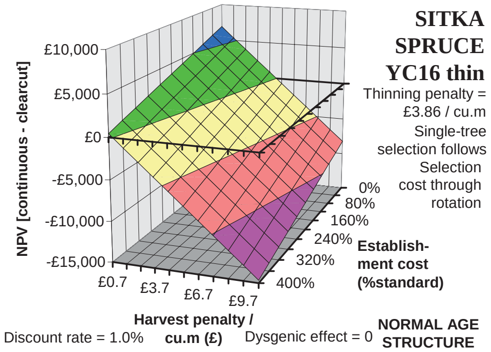

Figure 1. Continuous cover versus clear cutting – regime up and running

Note that, while the discount rate affects the land expectation value of both regimes, it does not affect their *relative* profitability. Both regimes provide a regular annual cash flow, and a constant difference of cash flow, whose capitalised value is inversely proportional to discount rate. This is displayed in figure 2. *The discount rate affects neither whether a regime is profitable or not, nor which of the regimes is the more profitable.*

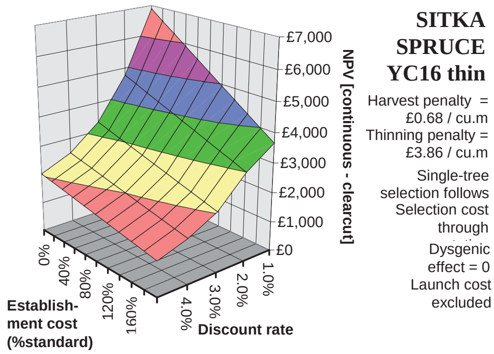

Figure 2: Effect of discount rate on profitabilities

Working the transformation

However, the discount rate may influence whether it is economically advantageous to *change* from clear cutting to continuous cover forestry. (It could also affect whether it is advantageous to change back, if continuous cover forestry turns out to be less profitable than clear cutting.)

Using the premises already discussed, what might be the most economically acceptable treatment, to move from an even-aged forest to one with a continuous cover structure? The following should be borne in mind.

We don't want it to cost much.

We do want it to yield substantial revenue …

… early rather than late.

On the way there, we don't want to take out trees too small, or leave them until too big.

And, on the assumption that the new regime is better than the old one once we get there (else why would we be going there anyway?), the sooner we're up and running, the better.

So, what do we do?

The answer is relatively simple. It corresponds to the earliest rule adopted by humanity for managing forests: take out trees of the size you want, when you want them. Nowadays this is contemptuously referred to by silviculturists and ecologists as "creaming" or "high-grading". Such a prescription also emerges from an economic approach to thinning even-aged stands: take out the biggest trees first, because they earn you the most money, and they are closest to their optimal rotation (Price, 1987, 1988).

So there is not much mysterious about it. It is just not a commonly advocated route to a silvicultural state characterised by obsession with long-term stand development and doing things as expensively as possible.

In practice, the rule used to identify trees for removal was not simply taking the largest trees in the plot, until the required reduction in basal area had been achieved. Because of irregularity of spatial distribution, this would have left substantial gaps in some places. Instead, the area was divided into cells of such a size that removing the largest tree per cell achieved the required reduction.

Relationship of this regime to target diameter cutting

Target diameter cutting is used elsewhere in the UK, including in transformation to continuous cover structure. In these cases, target diameter results from the technical limits of harvesting or processing machinery. The *economic* target is to achieve a suitable basal area for regeneration, by taking out the largest available trees. The economic target may also have a technical upper limit, but it may be smaller than that limit. We may fell also before economic target diameter is achieved in transformation. But once the regime is up and running, we do not want to take out anything below target (optimal) dimension. By contrast, in regular target diameter regimes, low thinning through most of the rotation may be a planned feature.

Possible dysgenic effects

If the largest trees are large because of genetic superiority, their removal early in the regeneration period will somewhat reduce the productivity of the successor trees. On the other hand, large size may simply result from accidental micro-site conditions giving initial competitive advantage. There are indeed indications that small trees grow faster (Zingg and Sterba, 2001). However, this may be for an already uneven-aged crop, where small trees have the physiological vigour characteristic of early middle life. The effect would not be replicated in single-aged crops where large trees may be large precisely because of inherent vigour.

Because of this possible dysgenic effect, part of the plot was replanted artificially in different patterns, one of which established two trees at the site of each "creamed" tree (but not of earlier removals) to give selection potential. This will eventually lead to a substantially smaller number of trees being planted over the transformation period than would be the case over a clear cutting rotation, but in several successive operations.

Note that, once the first regeneration cycle is complete, there is no further dysgenic effect. Although the trees felled continue to be the largest in the crop, they are large because they have been growing longest, not because of superior genetic quality. Maintaining genetic quality through the transformation period is the key.

The seal of disapproval

Significantly, passing silviculturists have referred to this treatment as "economic" thinning; which to silviculturists, it might be supposed, is a term of abuse. (Silvicultural thinning, of course, is purely for the benefit of the trees, or of silviculturists.) A footnote might be appended, that the "silvicultural" treatments were each given two replicates, whereas the two "economic" treatments were allowed only a single replicate – and that, only after a protracted struggle by this economist.

The problem of plot productivities

By misfortune, the experimental plots, which were judged to be uniform in a preliminary survey, turned out to have markedly different productivities. Group, frame-tree and low-thinning treatments had a mean productivity of $20\ m^3\ ha^{-1}\ year^{-1}$, creaming treatment only $16\ m^3\ ha^{-1}\ year^{-1}$ on one site type. Lower productivity was found on another site type, but no creaming plot was included. The premature clear cutting plot had a very high $26\ m^3\ ha^{-1}\ year^{-1}$ – which meant that felling was hardly premature in financial terms. In consequence of these differences, valid comparisons could only be made by modifying the actual results, to indicate what might have happened in a "synthetic stand" with the mean characteristics of the actual stands. The details of this process are not relevant to this paper's main theme, but it was and is being rigorously developed.

Time study results

Detailed time studies were made during the entire period of harvesting. The same two machines (a harvester and a forwarder) and the same two operators undertook all the work. The detail of the time study is given elsewhere. The mean costs per m3 for the different treatments are shown below.

Table 1: Cost of harvesting per m^3 for the experimental treatments

Treatment	Clear cutting	Low thinning	Group felling	Creaming
Cost/m^3	£9.14	£13.00	£12.40 (£11.80)	£9.82
Difference from clear cutting	–	£3.86	£3.26 (£2.66)	£0.68

The figures in parenthesis are estimates. The original group felling cost included the (high) cost for low thinning the area surrounding the groups. Separate figures for groups and surrounds have not yet been calculated.

Details of the volumes and prices net of harvesting cost for the product assortment obtained from each plot (see table 2) were used:
to derive a price–size relationship for long-term modelling;
to calculate short-term cash flows.

Table 2. Proportion of products (%), adjusted for differences in tree volume between plots; highest value products at top of column

Product (type, length)	Clear cutting	Low thinning	Group felling	Creaming
Log, 495 cm	69	57	53	68
Log, 315 cm	12	17	17	13
Bar, 375 cm	6	5	8	2
Bar, 254 cm	4	5	6	3
Stake	4	–	4	0
Pulp, 300 cm	5	16	12	14

Some further economic analyses

Extra cost and saved cost

The extra cost of harvesting in the smaller units and constrained working conditions of continuous cover forestry are not likely to be compensated by greater volume production (Price, 2003). In small group felling – which effectively fells a typical cross-section of tree sizes – it is unlikely that any price premium will exist. And such a premium, if it existed, would only arise at the end of a further growth cycle, from which its value would be discounted before comparison could be made with the harvesting cost penalties incurred in creating the group. Thus groups are not expected to produce larger revenue: they can only be justified by reduced cost of immediate establishment and subsequent protection.
With a measured harvest cost penalty of £3.26 (£2.66) / m^3, a hectare's worth of small plots would cost approximately £1500 (£1200) more to clear, compared with the same area of clear felling. Given an estimated cost of artificial regeneration of £1000 / ha, such a saving seems improbable!

The result of group fellings may not be *more* regeneration, but rather *more controlled* regeneration via management of light levels. This may save on respacing cost as might exist in clear cutting areas, where in UK conditions natural regeneration may fail, but may also appear in embarrassing and unpredictable abundance. However, reported figures of

£300–£500 per hectare for respacing suggest that this cost, too, is worth incurring, rather than the harvesting penalty of group felling.

On the other hand, the measured harvest cost penalty for creaming, £0.68 / m^3, is covered by the better product assortment, both in the long term and immediately. Neither is there any delay between incurring costs and realising higher revenue.

The transformation process

It was agreed between silviculturists and economists that the experimental transformation had begun too late. Already high costs and low revenues had been incurred in early low thinning. Moreover, given the constraint on long rotations imposed by wind hazard, there is little time to complete the first phase of transformation before the remaining crop will have to be cleared.

For this reason, the figures derived from the time study were used in a standard yield model adapted to allow NPV comparisons between clear cutting and:

a) group fellings at the measured harvest cost penalty, transformation being initiated at the least unprofitable time, the one minimising departure from optimal felling time;
b) transformation by creaming, starting at the same time, again using the measured harvest cost penalty.

In either case transformation was considered to be complete by the end of one clear cutting's rotation.

As expected, transformation to group felling would entail loss of profitability, unless there is some increase in revenue, as in figure 3. It is, however, difficult to envisage why revenue should increase under group felling.

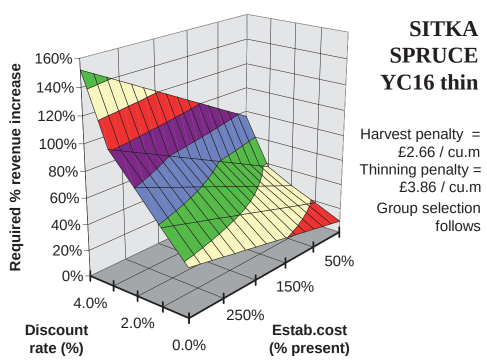

Figure 3. Required revenue gain to justify transformation by group felling.

To the losses incurred through the harvesting penalty, are added those caused by untimely felling. These are apparent in figure 4, in which no harvesting penalty has been applied. Where establishment costs are equal to those of clear cutting, nonetheless transformation incurs a loss, which disappears as the discount rate goes to zero: at this point, the short-term opportunity costs of transformation become insignificant, compared with the long-term equality between the two regimes: any regeneration cost advantage to group felling makes it (slightly) more profitable than clear cutting.

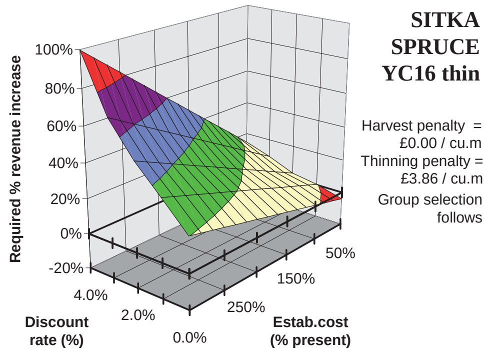

Figure 4. The same, but with no harvesting cost penalty.

Creaming treatment compared with clear cutting

By contrast, creaming transformation is superior to retaining the existing clear cutting regime under a broad range of conditions. Figure 5 shows the comparison between creaming transformation, and continuing with clear cutting, all costs of transformation now being included.

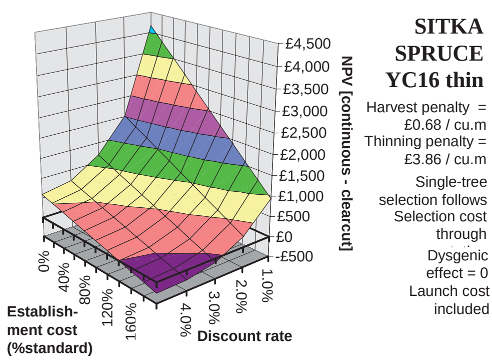

Figure 5. Costs, including those of transformation itself.

As can be seen, even at high discount rates, it is worth transforming using creaming, except with a much-greater-than-normal establishment cost.

Figure 6 shows the results, if there is a dysgenic effect, such that productivity drops by 20% as a result of the transformation.

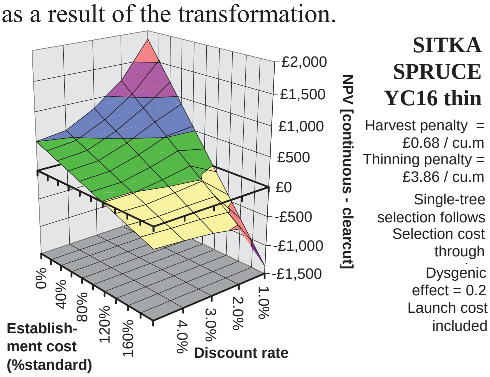

Figure 6. The same, but with a 20% dysgenic effect.

The positive results at a high discount rate indicate that in the short term (first cut) and medium term (during transformation) the transformation to continuous cover forestry offers greater profitability than clear cutting. By contrast, at low discount rates loss of long term productivity is more important than the immediate advantages of felling large trees, if establishment costs are no higher in the transformed system.

The dysgenic effect can be avoided by undertaking artificial regeneration. A preliminary time study has been undertaken, of artificial regeneration following creaming. One treatment was at a much lower density than the original, with a view to avoiding the need to take out small trees as thinnings. (In the ideal regime, there is no thinning as such: increase of light to the growing trees is achieved by felling trees of target size.) Artificial regeneration is only needed during transformation. Thereafter, removed trees are large because they are old, not because they are genetically superior.

Early revenue: the least-cost method

Suppose a forest owner wished to raise a certain extra amount of revenue in the short term, or at some specific point in time. It has been proposed that this can be achieved by initiating transformation to continuous cover forestry. It should now be clear that a creaming-based transformation may be able to do so at less cost than by felling small groups. But premature clear cutting offers a further option. Table 3 compares the cost of raising £10 000 by group cutting and premature felling, at various ages for the crop. The cost is calculated from the number of hectares that would have to be treated to reach the target amount of money, multiplied by the loss of NPV resulting from applying the treatment, rather than continuing with clear cutting on an optimal rotation. Costless regeneration following group felling is assumed. As creaming is superior to clear cutting anyway, under reasonable assumptions, no calculations have been made for it: a rational owner would wish to initiate it anyway, irrespective of the need for early revenue.

Table 3. The cost of raising £10 000 by initiating transformation at various crop ages

	Extra revenue generated per hectare (£)	Loss / ha (£) compared with clear cutting on optimum rotation (present value at age of obtaining revenue)	Hectares to treat to obtain £10 000	Overall loss (£)
At age 27				
Group felling	28	944	357	337 000
Premature clear cutting	860	3361	12	40 000
At age 37				
Group felling	260	854	38	32 000
Premature clear cutting	3750	1679	3	11 000

Even with favourable assumptions about regeneration cost, group felling is not the best option, and early in the rotation it results in unthinkable loss of profit. If creaming is, for some reason, not feasible or desirable, early clear cutting is a much less costly way of obtaining revenue, at all stages of the crop's life.

Conclusions

If an economically attractive silvicultural regime is wanted, it is best designed with economic considerations in mind. There may yet prove to be unforeseen or not-incorporated problems in the regimes designed for this experiment. However, such problems of innovation are unlikely to be either confirmed or circumvented, by resolutely refusing to do anything different from the regimes that have evolved within traditional silviculture.

In the foregoing, “economic” has been used in its confined sense, of having to do with the making of money. In the broader sense of the word, of course, externalities, distortions and distribution are also part of being “economic”. There are intertemporal distributional judgements embedded in discounting; an opportunity cost less than the market wage might favour some of the labour-intensive operations inherent in continuous cover forestry. Otherwise, distribution and distortion have doubtful relevance to this choice of silvicultural regime. But externalities, particularly environmental ones, have often been urged in favour of continuous cover forestry. There are, however, some arguments that suggest continuous cover forestry may have environmental disadvantages too (Price, 2003). For the private forest owner, sometimes struggling with low timber prices, the main question that may be asked about alleged non-market benefits is, how are they to be paid for? If a silvicultural regime has prospects of paying for itself in short and long term, as it appears creaming transformation may, the provision of environmental benefit to society becomes less of an issue.

Acknowledgements

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