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The logging policy of private woodlot owners

An analysis of a data sample by means of the AID method

De enskilda skogsägarnas avverkningspolicy

En analys av ett datamaterial med hjälp av AID-metoden

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Abstract

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The aim of this study was to analyse a multivariate and non-experimental data sample to determine the factors that influence the logging policy of private woodlot owners in Sweden. The sample was obtained from interviews with some 2 000 woodlot owners. The method of analysis is known as the Automatic Interaction Detector (AID). For a given population, this method can be used to explain the variation in a criterion variable (dependent variable) through the use of a set of predictors (independent variables).

The study results establish that in the majority of cases the state of the forest is apparently the most important factor influencing the determination of the cut by the woodlot owners. However, other groupings are considered in the AID "trees", for example, according to whether or not the woodlot owner participates in forest management courses. Of interest here is that none of the following groupings is obtained: farm owners; forest estate owners; owners resident on their holdings; and owners not resident on their holdings. (For the purposes of this study, a farm owner is defined as a person managing a holding comprising both arable and forest land. A forest estate owner manages forest land only and may be either resident on the holding or not. The general term including both categories is private woodlot owners.)

Translator's note: Unless otherwise indicated, volumes expressed in cubic metres (m^3) in this report refer to gross volume outside bark.

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Summary

The aim of this study is to analyse a multivariate and non-experimental data sample to determine the factors that influence the logging policy of private woodlot owners in Sweden. The topical interest of this study is attributable to the fact that the total annual cut in Sweden at the beginning of the 1970's reached the same level of (and even exceeded) the annual increment in the forests. The private woodlot owners, who own about one half of the total area of forest land, therefore assumed a stronger position on the wood market. This implied that wood buyers had to consolidate their efforts to find suppliers. Because of this new situation, the authorities in Sweden are anxious to ensure that the requirement for sustained yield forestry can be satisfied in the future.

The method of analysis used is known as the Automatic Interaction Detector (AID). For a given population, this method can be used to explain the variation in a criterion variable (dependent variable) through the use of a set of predictors (independent variables). Briefly, the method operates such that the original population (sample) is divided into two subpopulations by means of one of the predictors. The division is made in such a way that certain classes, as defined by the predictor in question, will be included in one subpopulation and the remaining classes in the other. The criterion for a split is to maximize the variation between the groups. To determine the best possible split of subpopulations, the program examines every conceivable dichotomous split of a predictor in accordance with the above variance analysis criterion. This process continues until certain criteria specified by the program user can no longer be satisfied.

The data sample analysed includes 2203 private woodlot owners from all over Sweden with a minimum forest land area of 5.1 ha. This is a considerable reduction compared with the original sample (3632 holdings). The reasons for this are non-response, a subsequent change in the conditions concerning the holdings during the study period, and incomplete answers. Thus, no statistical generalizations may be made on the basis of the results, since the latter are primarily referrable to the holdings studied.

Two criterion variables are used in the analysis: a) the annual cut per hectare and b) the logging intensity. The predictors used are the location of the holdings, the area of arable and forest land, respectively, the state of the forests, the possession of livestock, the owner category (physical person or Estate of a deceased), place of residence and number of persons resident on the holding, and the sex, age, employment, education and membership of a forest owner association.

The results establish that the sample is not suitable for division into readily identifiable groups according to the two criterion variables. Seen as individual groups, farm owners and forest estate owners, owners resident on holdings or non-resident, men and women, young and old, and private persons and Estates reflect no significant differences in the annual cut per hectare nor in the logging intensity. However, variations within each group are *wide*. In contrast, the results establish that the state of the forest is an important factor affecting the logging policy of *all* categories of private woodlot owners.

1 Introduction

A project entitled "Forms of management of small forest holdings" is being pursued at the College of Forestry (see Drakenberg & Höök, 1975, for example). As part of the work of this project, a comprehensive sample of data was collected from private woodlot owners throughout Sweden. A parallel project entitled "An explanatory model for activities in small-scale forestry" has also been completed (Lönnstedt, 1974 a and b). Since there was every possibility of putting the experience gained from these two projects to good use, a project receiving financial support from the National Council for Forestry and Agricultural Research was initiated in 1975.

The aim of the study was to *analyse a multivariate and non-experimental data sample to determine the factors that influence the logging policy of private woodlot owners in Sweden.*

The topical interest of this study is attributable to the fact that the total annual cut in Sweden at the beginning of the 1970's reached the same level of (and even exceeded) the annual increment in the forests. The private woodlot owners, who own about one half of the total area of forest land in Sweden, therefore assumed a stronger position on the wood market. This implied that wood buyers had to consolidate their efforts to find suppliers. Because of this situation, the authorities in Sweden are anxious to influence the long-term supply and demand on the wood market in order to ensure that the requirement for sustained yield forestry can be satisfied in the future.

2 The AID method (Automatic Interaction Detector)

2.1 Selecting the method of analysis

When a sample comprises two variables and has been obtained by non-experimental methods, the production of tables is generally the simplest method of studying the interrelationships between the variables. The same method may be used when there are three variables. However, the difficulties increase in pace with an increase in the number of variables, since a further division of the sample into groups implies fewer observations in each class. Moreover, an inordinate amount of work is necessary in order to establish the existence or otherwise of interrelationships between the variables and the intervals at which these interrelationships apply.

In this situation researchers frequently turn to linear regression analysis. However, this method presuppopses that the variables included in the analysis:

a) have *linear* covariance
b) have additive covariance (i.e. there are no *interaction effects*[1])
c) have properties commensurate at least with *the interval scale.*

However, these prerequisites cannot generally be satisfied when the data are of a behavioural-science nature. The first two assumptions are particularly uncertain. Many of the relationships studied in the behavioural sciences are not only non-linear but frequently also non-monotonic, i.e. the relationships describe U-shaped or inverted-U-shaped curves. In such cases, methods intrinsically based on the assumption of linearity cannot be used. As regards the additivity assumption, there is often good reason within the behavioural sciences to assume the converse to be true, i.e. that various types of interaction effects exist between the variables.

In the present data sample, it is possible to assume that there exists a linear correlation between the variables that is an expression of the state of the forests on the holding on the one hand and of cuttings by the owner on the other. However, the correlation is scarcely a linear one for the majority of variables reflecting the owner and his holding. In the case of many of variables, the correlation is probably also non-monotonic.

It is extremely likely that interaction effects exist. This proposition can be elucidated by means of an example. For many farm owners, the forest is important from the viewpoints of income and employment. However, this does not apply to forest estate owners who are gainfully employed elsewhere and who, in addition, are not resident on the holding. In such cases, the livelihood of the owner is based on his salary at work. Consequently, felling operations will probably not be so regular.

As regards the requirement that the variables shall at least have the properties of the interval scale, no problems exist in this study in respect of the variables expressing fellings in the forests and the state of the forest on a holding. However, some of the variables reflecting the holder and the holding do not meet this requirement.

In summary, it may be said that the sample is multivariate and non-experimental. The sample is to be analysed to study which factors affect the logging policy of private woodlot owners. Tabular analysis is unsuitable for practical reasons. Multiple re-

[1] However, it is possible to adjust this in certain methods by means of additivity expressions.

gression analysis is also less suitable for the reasons given above.

Under these circumstances, the *AID method* was chosen. This method should be seen as an analysis strategy for descriptive statistics, which may be used, for a given population, to explain variations in a criterion variable (dependent variable) by means of a set of predictors (independent variables). The method allows for considerable freedom in the use of the predictors. It is thus possible to use variables that are nominal scale as well as continuous variables that must be divided into classes. A set of mutually exclusive observation classes are defined for each of the predictors. As regards the criterion variable, this should at least have the properties of the interval scale or be dichotomous.

The AID method was presented by Sonquist & Morgan in "The Detection of Interaction Effects" (1964). The book contains a comprehensive description of the method, illustrated by a number of examples. The method has also been discussed in "Multivariate Model Building" (Sonquist, 1970) and in "Multiple Classification Analysis" (Andrews, Morgan & Sonquist, 1967). An elaboration of the method is described in "Searching for Structure" (Sonquist, Baker & Morgan, 1971). In Sweden, Anita Gavatin-Avén, at the Department of Statistics at Stockholm University, has studied the technical aspects of the method, focusing particularly on significance problems (Gavatin-Avén, 1973, 1974). Both versions of the AID program are available at the Stockholm computer centre and are included in the OSIRIS II and III software packages. OSIRIS II was mainly used in this study.

In Sweden the method has been employed in many different fields including medicine, behavioural science and law. An earlier example dealing with market segmentation is discussed in Arpi (1967, 1971). Other examples include Tornstam (1973), in the field of anthropology and Emanuelsson (1974), in the pedagogic field.

2.2 Principles of the AID method

Briefly, the method operates such that the original population (sample) is divided into two subpopulations by means of one of the predictors. The division is made in such a way that certain classes, as defined by the predictor in question, will be included in one subpopulation and the remaining classes in the other. Of importance here is whether the predictor has been specified as free or monotonic. If the predictor is defined as *free,* this implies that the classes defined by the predictor may be freely divided on partitioning of the sample. (A free predictor with K classes can split a population $2^{K-1}-1$ ways.) The splitting of a population by means of a *monotonic* predictor implies that each of the two subpopulations will contain a sequence of variable values. (A monotonic predictor with K classes can split a population into two subpopulations in $K-1$ different ways.) Thus, to define a variable as free implies more possible splits when there are more than two classes than is the case with a monotonic variable. This gives rise to significance problems.

The criterion for a split is to maximize the variation between the groups (subpopulations). A high covariance between the groups means that the larger part of the variation in the criterion variable[2] in the original sample may be "explained" by means of the partitioning factors employed (predictors).

To determine the best possible split of subpopulations, the program examines every conceivable dichotomous split of a predictor in accordance with the above variance analysis criterion. This is performed for all of the specified predictors. The program then selects the dichotomous split which of *all* conceivable splits of *all* predictors best satisfies the above criterion and splits the population into two subpopulations accordingly.

[2] $\sum_i (Y_i-\overline{Y})^2$

where, Y_i is the i : th ($i=1, 2, \ldots n$) observed value of variable Y and

$\overline{Y}=\frac{\Sigma Y_i}{n}$

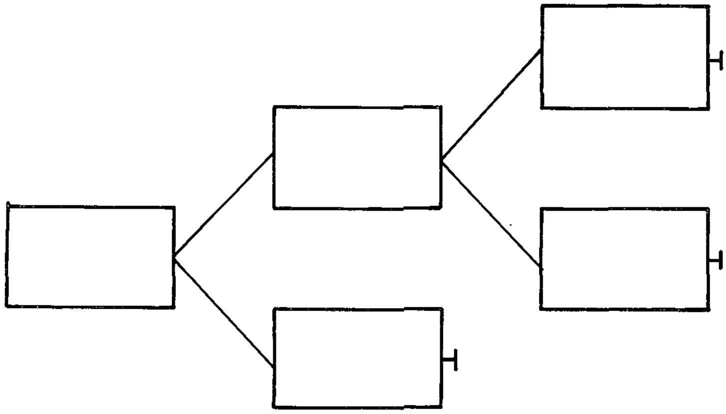


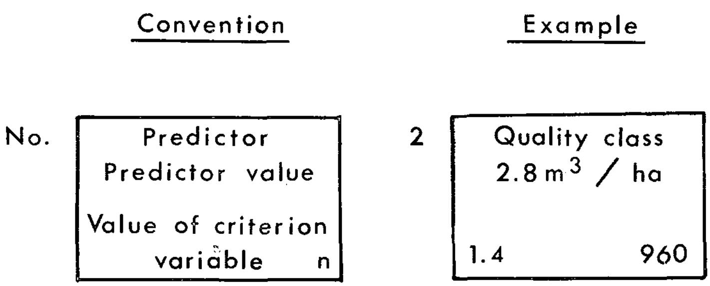
Figure 1. A typical AID tree.

The two subpopulations obtained as described above are then examined for conceivable splits and are split according to the same principles. However, for a split to be possible, it is necessary that the between-class sum of squares for the partition in question is larger than a constant that may be influenced by the program user (0.2 % in this study). In addition, the new subgroups resulting from a partition must contain at least one of the specified number of observations set by the program user (25 in this project). However, the significance tests are probably more decisive to the appearance of the binary or AID tree than these rules for stopping.

2.3 **The AID tree**

To supplement the above description, an example of the structure of an AID tree is presented in Figure 1.

In the subgroup boxes, the following conventions are used:



Predictor is the name given to that variable according to which a split has been made. The *value of the criterion variable* stated refers to the arithmetic mean value of the criterion variable in the subpopulation. The number of holdings studied (n) belonging to the subpopulation is also given. The *number* to the left of each box is merely a reference number to facilitate reference to a given subpopulation.

2.4 **Problems of significance**

Sonquist, Baker & Morgan in "Searching for Structure" (1971) state the following in this context:

"It should be obvious that if there are M different predictors of K subclasses each, if all are maintained in some logical order, each split looks at M (K − 1) possibilities and, by the time 25 such splits have been decided upon, the program has selected from among 25 M (K − 1). With 20 predictors of ten classes each, this is 4500. If any reordering is allowed, the number explodes. Hence there is no point asking about statistical significance or degrees of freedom."

However, in "The Detection of Interaction Effects", Sonquist & Morgan (1964) discuss the possibility of letting half of the investigation units in a sample determine the structure of the AID tree. The results obtained thereby are then tested on the other half of the sample. A drawback with this procedure is that considerable data are required.

In a law thesis (Saldeen, 1971), Eklund suggests that one of the predictors should be an arbitrary variable. Since splitting according to this variable is carried out, this and subsequent splits should be regarded as fortuitous (artefacts) and consequently able to be disregarded. The advantage of this method is that it is inexpensive and readily understood.

In another monograph (Sköldenberg, 1972), Eklund & Gavatin-Avén put forward a solution to the problem of significance, which is based on the Bonferroni difference. The solution involves an attempt to determine the risk of fortuitous splits—assuming that all mean differences have been derived at random. However, this solution results in an overestimation of the risk of fortuitous splits and, consequently, also to a certain extent of exaggerated cautiousness.

In her monograph, "Problems of significance in AID analysis" (1973), Gavatin-Avén deals with various approximation methods for estimating the probability of a fortuitous splitting of a population occurring according to a given predictor (both when free and monotonic) at a given step in an analysis. Gavatin-Avén establishes that the rules for stopping incorporated in the AID program should be such that it is possible to specify in advance the risk of a fortuitous split occurring at a given step in the analysis. This programming feature is theoretically possible. In the present project, the Gavatin-Avén method for testing the significance of results obtained has been employed. In addition, an arbitrary variable, comprising the last digit in the national registration number of the owner, has been included to enable an estimate to be made of the fortuitous variations existing in a predictor.

3 Analysis plan

3.1 The analysis sample

Selection

The original sample included 3855 holdings from all over Sweden with at least 5.1 ha of forest land. Holdings with more than 0.2 ha of arable land were obtained by means of a free, random sample taken from the register of holdings (dated 1971) of the Central Bureau of Statistics. The sample was divided into various forest area classes according to the total number of holdings and the total area of forest within the respective classes. Holdings with 0.2 ha or less of arable land were selected systematically according to the forest area. Consequently, the holdings were distributed in proportion to the area of forest (Drakenberg & Höök, 1975).

The selected private woodlot owners were visited and interviewed by forest rangers. The particulars obtained concerned the size of the holding and the state of the forest, logging operations in the holdings during the 1968/69—1972/73 logging seasons, the types of ownership, and the place of residence and employment situation of the owner (op. cit.).

However, the number of holdings that could be included in the analysis was reduced by a certain amount of non-response. The sample of data suitable for analysis was further reduced as a result of changes in conditions of the holdings and incomplete answers.

Non-response

Some of the holdings selected (43) were found to be owned by legal persons or to have a forest area of less than 5.1 ha. Thus, the sample had a certain degree of excess coverage, since these holdings did not belong to the target population. Accordingly, the actual sample consisted of 3632 holdings.

There was non-response in the case of 434 holdings (12 %). The principal reason for the non-response was the refusal of owners to answer or the fact that the forest rangers were unable to contact the owners. A subsequent study revealed that owners who had not supplied information differed from those who had in that a larger proportion of them were non-resident; a larger proportion of the number of holdings were also found to be the estates of deceased persons.

A change in the conditions of certain holdings

The particulars of logging operations refer to the 1968/69—1972/73 logging seasons. Data on the owners and holdings are from 1973. Consequently, the factors influencing logging policy may now be different owing to changes in ownership or in the area of holdings. To make it possible for a study to be made of the influence of the factors included in the investigation on annual cuts, the holdings affected by such changes have been excluded from the sample (728 holdings).

Other holdings excluded owing to possible changes are those that are referred to in the sample as *forest estates*,[1] but which according to particulars submitted by the owners have more than 3 head of cattle or agricultural operations accounting for more than 10 man-days. This category includes 212 units.

Another group of holdings (27) precluded from the sample are those for which the

[1] According to the sample, these holdings have 0.2 ha or less of arable land.

class of the forest has been calculated as an average value. This implies a change in area. Holdings for which the owners could not provide figures of the cuts for the logging seasons in question were also excluded (53). A possible reason may be that the owner acquired the holding during the period under investigation.

Incomplete answers

Owners who answered, "Don't know", or who failed to answer certain questions have also been excluded. In addition, holdings occurring twice in the sample have been combined in a single unit. Thus, the sample has accordingly been reduced by 88 holdings.

Conclusion

The number of holdings suitable for analysis amounts to 2203. This figure is considerably lower than the 3632 holdings included in the original sample. As a result, the statistical grounds are not sufficiently certain for any valid generalizations to be made. However, the results obtained are valid for the 2203 holdings. This is quite satisfactory since the objective of the analysis was to elucidate the factors influencing the logging policy of private woodlot owners.

3.2 **Criterion variables and predictors**

Types of variables

The AID method uses only two types of variables: a) a criterion (dependent) variable and b) predictors (independent variables) (Section 2). It is assumed that the predictors will explain the variation in the criterion variables.

Criterion variables

Two criterion variables occur in the study: a) the annual cut per hectare and b) the logging intensity. The cut per hectare is based on operations during the 1968/69—1972/73 seasons and on the area of forest land included in a holding. The logging intensity has been obtained by means of a comparison between the actual cuts and the potential cuts determined by consideration of the state of the forest (quality class equilibrium, average stocking level and percentages of large-dimension trees).

Details of the potential cut were obtained from "Logging Calculations, 1969" (Janz, 1970) which in turn was based on the National Forest Survey material. Thus, the procedure involved the calculation of the potential cut in a number of areas expressed as a function of the variables concerning the state of the forest (Andersson, 1977).

These functions are then used to calculate the potential cut for each individual holding. The potential cut calculated in this way for a group of holdings is probably fairly accurate since the random variations within the holdings probably cancel each other out. However, deviations may occur in respect of the estimated cut of a *given* holding. As mentioned earlier, the state of the forest is only described in terms of quality class, average stocking level and percentage of large-dimension trees; consequently, the estimated cut of a given holding is no more than *approximate.*

It should also be noted that the estimated cuts are based on the quantities and distribution implemented in Alternative C of "Logging Calculations, 1969". This alternative assumes that, during a 70-year period, the initial cuts will be large and then will gradually decrease. Alternative C was deemed to be the most realistic alternative at the time at which the calculations were made. This alternative therefore also takes the "small areas"[2] into account, which constituted a prerequisite for the calculations made.

The variables describing the state of the forest and which are also used in the construction of the criterion variable, logging intensity, may be regarded as predictors. The

[2] Parallelogram units used in earlier surveys at the College; the land area was divided into 480 such units.

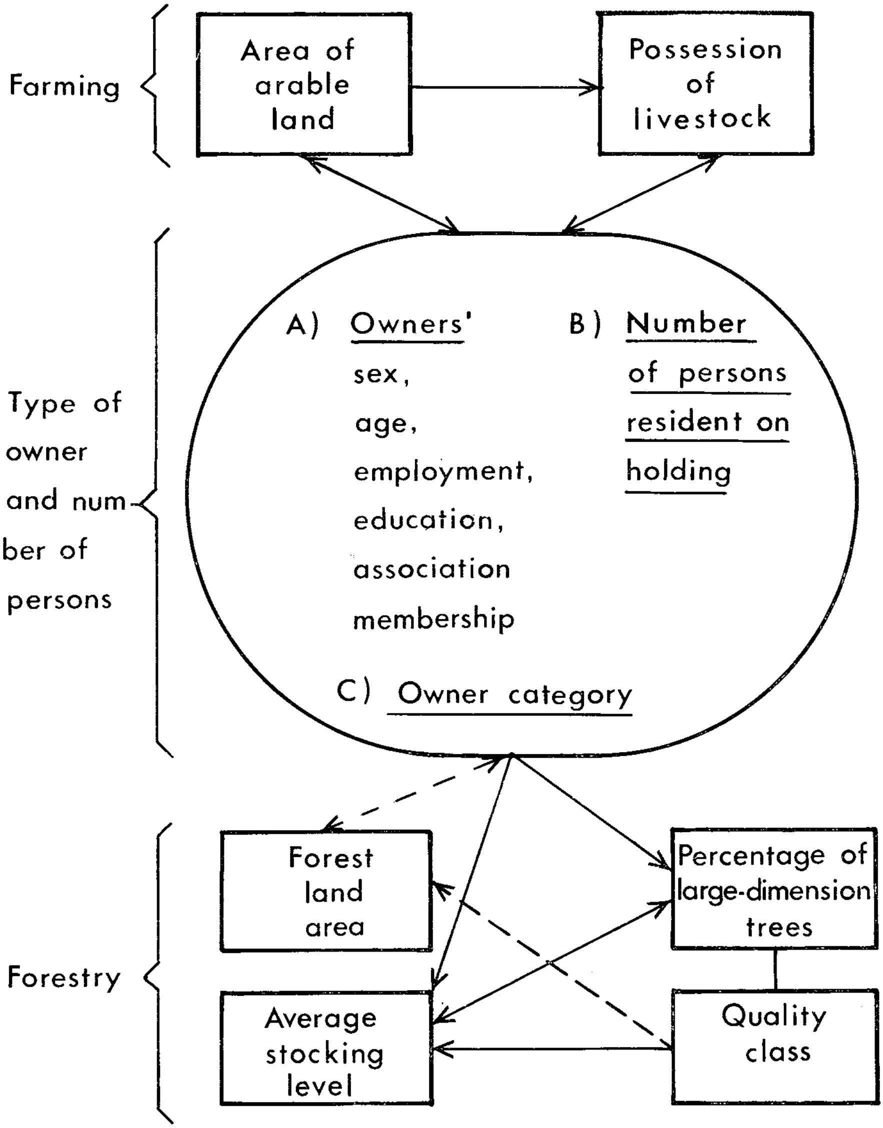


Figure 2. Variables included in the two groups of variables: a) location of holding, area and state of forest (or farm holding); b) type of owner and number of persons.

main implication of this is that these variables should be seen as an expression describing previous operations by the owner. If the variables describing the state of the forest are excluded from the predictors, deviations between the actual and the recommendable cut will be explained by the other predictors.

Predictors

The predictors used are the location of the holdings, the area of arable and forest land, respectively, the state of the forests, the possession of livestock, the owner category (physical person or Estate), place of residence and number of persons resident on the holding, and the sex, age, employment, education and membership of a forest owner association.

Figure 2 shows the probable correlation between the following predictor groups: 1) arable land area and possession of livestock on farms; 2) area of forest land and state of the forest; 3) type of owner and number of persons.[3] An idea of the state of the forest is obtained from consideration of the stocking level, the percentage of large-dimension trees and the quality class. Quite naturally, there is a positive correlation between the percentage of large-dimension trees and the quality class on the one hand, and the average stocking level on the other. The same also applies between the percentage of large-dimension trees and the quality class.

Many of the predictors are a direct or indirect expression of the state of the forest on the holding and the geographical location of the holding. This applies, for instance, to association membership and area of forest land. It is namely more usual in southern Sweden for owners to be members of a forest owner association. The area of forest land on holdings in this part of Sweden is generally also smaller (Drakenberg & Höök, 1975). Similarly, the state of the forest interacts with the regional variable.

The predictors which have been referred to the group, type of owner and number of persons, are shown in figure 2. It may be worth noting that the place of residence of the owner is indirectly apparent from the variable, number of persons resident on holdings.

There are several correlations between the predictor included in this group. For example, it is more usual for owners to be gainfully employed when they are non-resident on the holding. The sex and age of the owner are also of importance to whether or not the owner is gainfully employed. It is also more usual for owners to be members of a forest owner association or a forestry combine area if they are resident on the holding. A further example is the correlation existing between the education of the owner and his place of residence and age.

As regards predictors in the two main groups, there is a correlation between the area of arable land and the possession of livestock on the one hand, and the age, employment, education and association membership, and the number of persons resident on the holding, on the other. It may generally be said that older owners or owners gainfully employed elsewhere are to be found on small holdings. The number of persons resident on the holding is generally also smaller than in the case of large holdings. Moreover, there is also a tendency for such owners to have had a shorter period of education and for assocation membership (e.g. of a forest owner association) to be less common. It is common among owners who either have no arable land or who lease out arable land for them to be non-resident. Under certain conditions, there may also be an interaction between the area of forest land and the place of residence of the owner and whether or not he is gainfully employed elsewhere.

A third group of variables that has not been included in figure 2 is that defined as the owner's involvement in forestry. To this group are referred predictors which are expressions of the further education of the owner, the existence of a forestry plan for the holding and the participation in the forestry work by the owner and members of his family.

As far as the location of the holding is concerned, this predictor is not included in the figure either. This predictor interacts with both the farming and forestry variables. The site quality class and the state of the forest vary from one part of the country to another, which is also true of membership of a forestry combine area. The prospects for selling wood to a mill as well as road networks also vary. In addition, some regions are distinctly agricultural while others are clearly forestry regions.

[3] This classification is based on previous experience (Lönnstedt, 1974 b).

4 Results

During the period covered by the 1968/69–1972/73 logging seasons, the owners studied on the average carried out logging operations every other year. However, this average figure is misleading because there are two extreme groups which together embrace half of the number of private woodlot owners: owners logging frequently and infrequently, respectively. These groups are of the same size and, accordingly, each accounts for a quarter of the number of owners studied. But, not surprisingly, their shares of the area of forest land are not equivalent. Owners who carried on logging operations in all of the five years hold approximately 35 % of the area of private forest land, whereas owners who had no logging operations during the same period own no more than about 17 % of the area.

Of the total cut during this period, owners with frequent operations accounted for 50 % of the cut. During the 1969/70 and 1970/71 seasons, the cut attributable to these owners was some 15 % higher than during the other years. This can probably be explained by the windthrows occurring during the winter of 1969. In contrast, fluctuations in the general marketing conditions apparently have no appreciable influence on the cut of owners with frequent operations.

Thus, the remaining 50 % of the total cut during the five-year period is accounted for by the owners with occasional operations. About one half of these owners change their logging policy from year to year. In other words, this 50 % of the annual cut is attributable to those owners with occasional operations who actually logged during the season in question. In the following season, half of those who logged during the preceding year will be inactive; however, this will be compensated for by the fact that half of the owners who were inactive during the previous season will carry out logging this season.

These, of course, are average figures. Certain variations will be apparent if the correspondent shares are studied for each individual season. A certain pattern emerges such that slightly more than half of the owners with occasional operations will be active when prices are rising, and slightly less than half when prices are falling. However, the variations are relatively insignificant, amounting to approx. ± 4 % on the average.

It is also evident that an owner with occasional operations who has logged in two successive seasons will have smaller variations in the cut than a similar owner who logs during a given season but who was inactive the preceding year.

Characteristic of this latter group is that it accounts for a considerably larger cut per hectare (approx. 55 %) than the former group. Another feature is that the group has a lower average area of forest land than other owners with occasional operations. This explains the results to some extent.

It would certainly be interesting if it were possible to identify these different owner categories. In the remainder of this section, a study will be made using the AID method to determine what correlations exist in the sample between the factors included and the annual cut per hectare and the logging intensity, respectively.

4.1 The annual cut per hectare

The AID tree

As may be seen from the AID tree in figure 3, three of the splits were made according to the quality class to which the

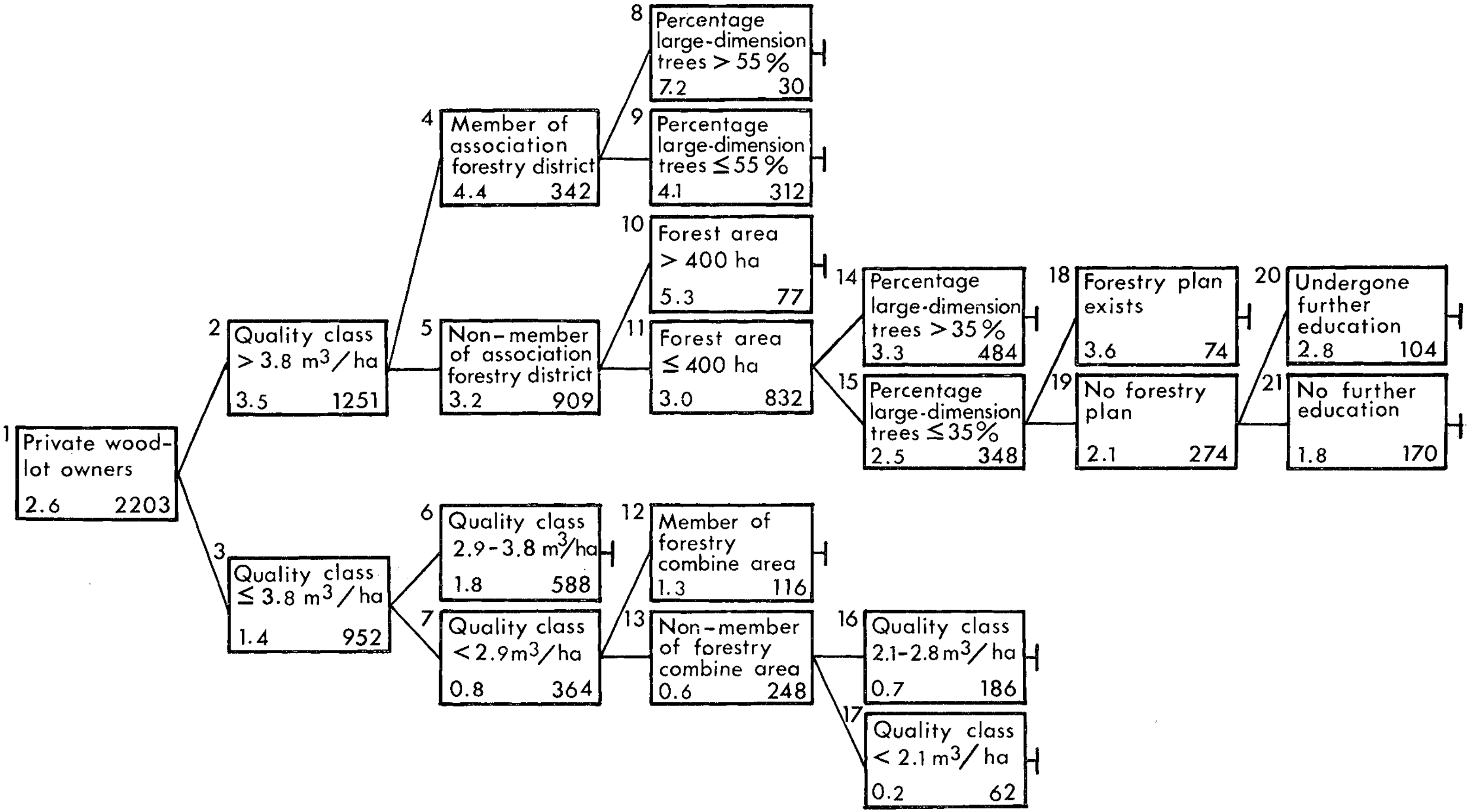


Figure 3. The AID tree when the actual average cut (m^3/ha) is the criterion variable.

forest land on the holding belongs. Another variable describing the state of the forest is the percentage of large-dimension trees. One split is made depending on the area of forest the holding includes. Other predictors in the AID tree are membership in an association forestry district, participation in a forestry combine, the existence of a forestry plan and further education.

Subgroups 1, 3 and 13

In view of the strong correlation existing between the *quality class* predictor and the annual cut per hectare, it is natural that the first split and two subsequent splits be made here. The correlation is most noticeable in the case of quality classes of up to 3.8 m^3/ha, which fact is also reflected by the AID tree.[1]

At a stretch, it may be said that this correlation and the effected splits demonstrate differences between Norrland on the one hand and Svealand and Götaland on the other. In Norrland, the quality class of the forest land in turn varies between coastal and inland areas, and again, as far as the inland area is concerned, depending on whether or not the land is situated above or below the reforestation limit.

The importance of the *region* to the annual cut per hectare is also apparent from the interaction between these two variables. In Norrland, the cut per hectare amounts to about 1.5 m^3 ($S=2.0$)[2] compared with 2.6 m^3 ($S=3.0$) in central Sweden and 3.6 m^3 ($S=3.3$) in southern Sweden. These differences in the cuts in the different regions and dependence on the quality class of the forests are quite logical; a lower potential yield implies—at least in time—a lower actual potential cut.

Subgroup 7

For holdings with forests belonging to a quality class lower than 2.9 m^3/ha,[3] a partition is made based on membership of a *forestry combine area.*[4] Forest owners belonging to a combine area have a somewhat higher annual cut per hectare (1.3 m^3; $S=1.0$) than non-affiliated owners (0.6 m^3; $S=1.5$). This may be interpreted such that it is a certain category of forest owner who joins a forestry combine area. However, the results may also reflect regional differences in the production capacity of the land since considerably fewer combine areas have been formed in the inland areas of Norrland than in areas on the coast (Lönnstedt & Ekholm, 1975). It may be mentioned that next to the predictor concerning membership of a forestry combine area, the most suitable predictor was quality class.

Subgroup 2

The variable demonstrating the strongest correlation with the annual cut per hectare for holdings with forests belonging to quality classes greater than 3.8 m^3[5] was that of membership in a forest owner association or, more precisely, in an *association forestry district.* Owners belonging to an association forestry district account for a considerably higher annual cut per hectare (4.4 m^3; $S=3.7$) than other members of forest owner associations (3.2 m^3; $S=3.3$).

The probable explanation for the difference between the groups is that it is a certain category of forest owner who joins an association forestry district (see above). This interpretation is supported by the fact that, next to membership in an association forestry district, the variable most suitable for splitting was that of *further education.*

[1] For the sake of comparison, it may be mentioned that the difference between the lowest and the highest values of the random variable is approx. 0.6 m^3/ha per annum.

[2] S designates the standard deviation within the group.

[3] These holdings are largely located in the inland areas of Norrbotten and Västerbotten, and in the mountain regions of Jämtland and Kopparberg.

[4] As from 1 July, 1974 subsidies under the heading of "Increased forest yields in Norrland" have been incorporated in subsidies for "Intensified silviculture in northern Sweden". The county forestry boards concerned decide whether forestry combine areas are a suitable form of organization or whether some other form in keeping with the purpose of the subsidies shall be applied.

[5] These holdings are largely located in central and southern Sweden.

Those owners who had not participated in forestry meetings organized by the associations had an annual cut per hectare of 2.9 m^3 (S = 3.1) compared with 4.0 m^3 (S = = 3.4) in the case of those who had.

Subgroup 4

A small group of owners with a larger cut than the others may be distinguished among the members of an association forestry district. This group is identified in the AID tree by its having a *percentage of large-dimension trees* greater than 55 % (7.2 m^3 as against 4.1 m^3; S = 5.8 and 3.3, respectively). Viewed against the entire sample, this variable demonstrates a strong correlation with the average cut. It should be noted in this context that the percentage of large-dimension trees is partially a reflection of the location of the holding, because the same limit for large-dimension trees is applied to the whole sample.

Subgroup 5

A small group of owners with larger cuts than the other owners may also be distinguished among non-members. These owners are characterized by the fact that their *area of forest land* includes more than 400 hectares (5.3 m^3 as against 3.0 m^3; S = 2.1 and 3.1, respectively). The next best split was obtained according to the existence or otherwise of a forestry plan for the holding. The annual cut per hectare for holdings with a forestry plan amounts to 4.3 m^3 (S = 3.0) compared with 2.8 m^3 (S = 3.0) for holdings for which no plans exist. This correlation is interesting because, once again, in common with membership of an association forestry district, it may be seen as an expression of the influence that various features of the forest owner can have on the annual cut. The forestry plan itself probably also affects the owner's logging decisions.

Subgroups 11, 15 and 19

Of the other non-members of an association forestry district, a division is made according to the *percentage of large-dimension trees.* Of forest owners with a low percentage of large-dimension trees ($\leqslant$ 35 %), *involvement in forestry* (further education, existence of forestry plan) is of importance to the size of the cut.

Variance reduction

The partitioning gave rise to a reduction in the total variation in the sample data of about 20 %. Large variations remain primarily within subgroups 6, 9 and 14 (74 % of the residual variance is contained in these subgroups). A study of the distribution of the criterion variable in these groups establishes that the criterion variable has a more even distribution than in the complementary subgroups (7, 8 and 15).

The relatively low reduction in variance is very interesting in consideration of the results and of the investigation. The results suggest that a number of factors (e.g. the correlation between the forest and arable land and place of residence of the owner) are of less importance to the size of the annual cut per hectare. In addition, the results suggest that the explanation for the variation in cut is to be found in other predictors than those studied in the analysis (see Lönnstedt, 1977). However, this supposition requires further study. This is achieved by a) regression analysis; b) weighting of the data; and c) adjustment of the skewed distribution of the criterion variable.[6]

The method of regression analysis used is known as *Multiple Classification Analysis* (MCA) and is included in the OSIRIS II and III software packages. An advantage of the MCA method is that it permits the use of predictors that are on nominal scales. Moreover, no linearity of relationships between the predictors and the criterion variable is required. However, the MCA method assumes that there are no interaction effects. Another drawback with the method is that the results easily adapt themselves

[6] About 35 % of the owners carry out no logging whatsoever or have an annual cut smaller than 1.0 m^3 per hectare.

to the structure of the sample data, with the result that the value of the explanatory variable can easily become too high.

The explanatory value obtained from use of the MCA method was 23 %. Thus, the MCA method also failed to force up the value of the explanatory variable. It is interesting to note, though, that the interaction effects in the sample are apparently quite weak in consequence of the explanatory values of both methods being of approximately the same magnitude.

Weighting was performed according to the total volume of the holding, i.e. it is of a relevance nature. The explanation is that it is reasonable to allocate a greater weight to holdings with a high stocking level than those with low stocking levels, since a more "rational" policy is to be expected of these holdings. The volume of the forest probably implies that the forest is more important to the owner during planning from the viewpoints of both source of income and employment. In respect of holdings with a lower volume, it may well be fortuitous factors which influence the decisions of the owner concerning whether or not to carry out felling.

The results of the weighting will be of considerable interest provided that the variance reduction amounts to 49 %. The predictor for the first split is the same as that employed in the unweighted case, namely, quality class. This predictor will occur once again. Other predictors occurring are the forest land area and the age of the owner.

Thus, the weighting of the material demonstrates that the predictors included have a *greater* explanatory value than was first evident. It may also be established that to some extent, *different* factors on holdings with high and low stocking levels, respectively, influence the annual cut of the owners. It should be mentioned that the weighting implies a problem for as long as no methods exist for testing the significance of the results (cf. Section 2.4). A fortuitous variable was therefore used as one of the predictors. However, this predictor was not used for any of the splits performed.

If a variable has *skewed distribution,* then the total variance will be great. This may result in the variance reduction obtained being small. In this case, the distribution of the criterion variable is manifestly skewed. To elicit the possible effects of this on the variance reduction obtained, the square root of the average annual cut per hectare was therefore used as the criterion variable.

This resulted in the variance reduction obtained increasing to 28 %. The structure of the AID tree is markedly similar to that of the tree obtained when the square root is not used. This would also suggest that a number of important correlations exist in the sample data studied, in spite of the fact that the variance reduction for the uncorrected material may seem to be low.

Commentary

The results show, therefore, that the state of the forest explains some of the differences existing between the annual cuts per hectare of the different woodlot owners. This is quite natural. In time, it is impossible to extract a cut that is greater than the increment. However, temporary deviations may exist between "that which goes into the stores and that which is removed". Nonetheless, the policy of some woodlot owners may be to increase the volume of the forest; of others to reduce it; while others may attempt to keep the volume at a constant level.

A probable reason for these differences is that for different owners, the holdings are of varying importance as regards a source of income and employment. This is expressed indirectly in the predictors in that forest estates are distinguishable from farm holdings, and owners resident on the holdings from non-residents. The interesting aspect of the results is that this classification is *not* obtained.

A study of the entire sample data also establishes that the annual cut per hectare from forest estates is lower than that of farm holdings. The annual cut per hectare of the forest estates amounts to 2.4 m^3 ($S = 3.2$). In respect of the farm holdings, the annual cut per hectare increases according to a fairly linear course from 2.1 m^3 for holdings with 1—5 ha of arable land (S= =2.5), to 4.8 m^3 for holdings with more than 100 ha of arable land (S=2.5). The only exception is that of holdings with 51—100 ha of arable land, whose annual cut per hectare is approximately the same as that of holdings with 31—50 ha of arable land (approx. 4 m^3).[7]

Thus, there are variations between the groups. The deviation, or to express it another way, the differences between the owners in these groups, is of *such a magnitude,* however, that better predictors can be found if a maximum reduction in the total variance is desired. A controlled AID run in which the first split is between farm holdings and forest estates and between forest owners who are resident and non-resident on the holdings, respectively, will consequently produce a lower reduction in the variance.

A considerable part of the variance in the annual cuts of different owners may be explained by predictors not included in this analysis. One predictor which springs readily to mind here is the price of wood. As was discussed in the introduction to this section, the price of wood did not have any appreciable influence on the number of owners who carried out felling in the 1968/69—1972/73 seasons. (The same applies to the volume of the cut.) Other explanations of the varying annual cuts of the owners can therefore be found in the human factors. These refer to personal aspects of the owners. Fortuitous factors may also play a part. This probably applies primarily to holdings where a detailed plan from year to year of the forestry work is not required.

4.2 **Logging intensity**

The logging intensity for the entire sample (N=2203) is 74 %. In "Logging calculations, 1969", Janz establishes that the actual average annual cut in northern Sweden for the 1965/66—1969/70 logging seasons is roughly 70 % of that of alternative C. The corresponding figure for southern Sweden is approx. 65 %. (The calculation of the potential annual cuts is based on alternative C.) Thus, it is apparent that the calculated potential cuts are considerably higher than the actual cuts of private woodlot owners in the 1965/66—1969/70 seasons (Janz's findings) and also in the 1968/69—1972/73 seasons (this analysis).

The AID tree

The structure of the AID tree obtained when the criterion variable used is logging intensity (Fig. 4) is simple compared with the tree obtained when the actual annual cut was the criterion variable (Fig. 3). This is to be expected since a calculation of the potential cut based on the state of the forest implies a reduction in the value of the explanatory variable, the state of the forest, provided that the owner takes the state of the forest into account when deciding whether or not to carry out felling.[8] The results obtained earlier established that this was the case.

Subgroup 1

The first split in figure 4 is made for the predictor concerning whether or not the owner has received *further education.* The logging intensity in the case of owners who have participated in association meetings and/or in short forestry courses amounts to 86 % (S=90), as against 61 % (S=84) for owners not having received any further education.[9] Of course this split may be

[7] The results with respect to farm holdings with 50 or more ha of arable land are less certain owing to the relatively limited number of such holdings.

[8] An alternative explanation is that there is a marked increase in the total variance in respect of the constructed criterion variable, logging intensity, compared with the actual average annual cut. This may limit the possibilities of reducing the total variance. However, a comparison of the distribution of the two criterion variables does not support this reasoning.

[9] For the sake of comparison, it may be mentioned that the difference between the highest and lowest values of the fortuitous variable is about 15 %.

interpreted as an expression of the importance of association meetings and shorter courses to the volume of the owner's cut. It is more likely, however, that this split should be seen as indicative of the fact that forest owners with special personal qualities (reflected, for instance, by the fact that the owners attend association meetings) harvest an annual cut that varies from that of other owners. What is interesting in this context is that the most likely predictors for a split after that of further education are the existence of a forestry plan and membership of an association forestry district. Owners who have drawn up a forestry plan have a logging intensity of 90 % (S = 83) as compared with 67 % (S = 89) in the case of owners with no definite forestry plan. There is a marked difference between members of an association forestry district (95 %; S = 92) and other association members (72 %; S = 77) and other owners (65 %; S = 95).

Subgroup 3

In the case of owners who have not received any further education, a split is made according to the quality class of the forest land. The logging intensity increases considerably from about 25 % (S = 70) at quality classes lower than 2.0 m^3/ha, and 62 % (S = 88) at quality classes of between 2.1 and 2.8 m^3/ha, up to about 69 % (S = 88) at quality classes between 2.9 and 6.8 m^3/ha. There is a tendency for the logging intensity to be even higher at higher quality classes.

But to what can the appearance of this correlation be attributed? After all, the calculation of the potential annual cut took the quality class of the forest land into account. One reason may be that these calculations are based entirely on the state of the forest. However, several factors determine the "potential" cut; for example, the profitability of harvesting. Accordingly, in the inland areas of northern Norrland (quality class $\leqslant$2.8 m^3/ha), harvesting may be unprofitable owing to long transport distances. Another explanation is that in the calculations concerning the 1969 season (Janz, 1970), unrealistically high cuts were attributed to forest land with a low site quality class.

It should be noted in this context that holdings in the inland county of Jämtland in the province of Norrland have a lower intensity (61 %; S = 94) than holdings in Norrbotten and Västerbotten, which are in the same province but which include both inland and coastal regions (73 %; S = 91), which also applies to the rest of Sweden (78 %; S = 85).

Subgroup 4

The predictor after that of quality class most suitable for a further splitting of subgroup 3 is the age of the owner. This predictor is also used for a splitting of subgroup 4. The lower logging intensity existing in the case of older owners may be attributed to several reasons. When receiving an old-age pension, an older owner is less financially dependent on the forest. Furthermore, a younger owner generally has a greater need of available cash than does an older owner, owing to such factors as family commitments and mortgages, etc. In addition, older owners may have a quite different concept to that of younger owners as regards forest that is suitable for harvesting.

Excluding the variables describing the state of the forest

The structure of the AID tree received when the variables describing the state of the forest are excluded from the predictors (cf. Section 3.2) is not unlike that shown in figure 4. In this case, however, the group of owners with no further education which was previously split according to quality class is now split according to a predictor for the year of birth of the owner: owners born in or before 1905 (47 %; S = 66) or after 1905 (68 %; S = 91), respectively. A new variable is then introduced by splitting the older owners according to whether or

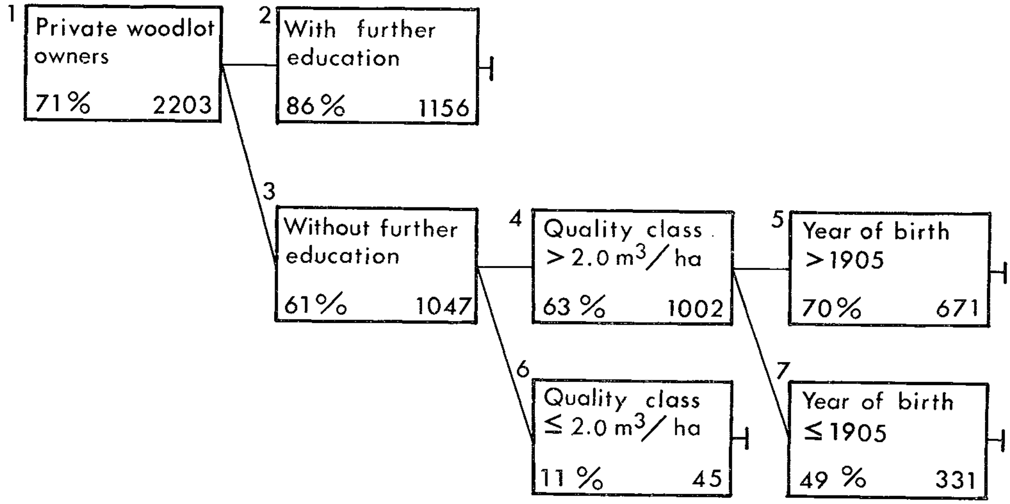


Figure 4. The AID when the logging intensity is the criterion variable.

not they are members of a forestry combine area, i.e. non-member of a combine area (24 %; S = 38) or member of a combine area, respectively, or resident in a district in which it was not possible to form a forestry combine area (55 %; S = 72). As is apparent, this variable may be interpreted as an expression of the importance of personal properties of the owner, on the one hand, and of the geographical situation of the holding, on the other.

Variance reduction

On dichotomization, only about 3 % of the total variance in the sample occurs between the subgroups described above. There is a reason why the variance reduction should now be lower than when the criterion variable used was the average annual cut. The predictors for the state of the forest from an explanatory point of view actually proved to be the most interesting in the previous results. Their explanatory potential is now reduced owing to the fact that the criterion variable, logging intensity, was constructed on the basis of these predictors.

Commentary

The variance reduction in this case is so low that it may safely be assumed that the predictors included in the analysis are of little assistance in explaining the varying logging intensity of the forest owners. Thus, the really interesting aspects of the results are to be found in splits that were *not* made.

4.3 Advantages and disadvantages of the AID method

In addition to the advantages described in section 2.1, it should be emphasized that the AID method is also pedagogic. Even persons with no formal training in statistics find it relatively easy to understand an AID tree. In contrast, methods based on regression analysis require a firm grasp of the theory of statistics.

Another advantage is that the method is easy to work with in respect of the processing of sample data. Once the predictors have been defined, it is fairly simple to employ different criterion variables for an analysis, and even to change the number of predictors. However, if the creation of new predictors from the old ones is desired, this will require special processing (more recent programs now permit such changes to be made in conjunction with the analysis itself). The program is relatively inexpensive to run. The analyses carried out in this study cost between SKr 50 and 150.

A reason which detracts from the stability of the AID method is that it would be purely coincidental if the same tree were obtained from a repeated run of this study. This is because it *might* be fortuity that decides the predictor for a split. It is therefore essential that a study be made to determine which predictor would give the next best split. In this way, it is possible to assess the results that would have been obtained in the absence of a given predictor.

Another drawback of the AID method is that the split made is that which will provide the maximum reduction in the total variance at each step. This is *suboptimization*. It is namely conceivable that a slightly less advantageous, earlier split may result in more favourable splits occurring at subsequent steps. However, the newer version of the AID program makes it possible to take the three next splits into account when a split is to be made. At present, though, there is no solution to how the problem of significance should be dealt with in this case. Another drawback of the newer version of the program is that it is currently expensive to run.

A test run was made using the more recent version in order to elicit what effect the new version could have on the results obtained. However, in consideration of the high cost of the run, an optimization of the next step only was permitted. Furthermore, only a part of the sample was studied. The results thus obtained provided no indication that there would have been any appreciable differences in the results of the original sample if the new version had been used in an analysis of the entire sample data.

5 Final comments

An annually recurring tax or charge on a part of the volume that is ready for harvesting causes an increase in the annual cut. If a private woodlot owner carries out felling, he will escape payment of the annually recurring charge. This implies that, other things being equal, the supply of wood on the market will increase. In 1973, the national survey on forest policy in Sweden put forward a proposal based on this reasoning. The system whereby this tax would be levied would be linked to a system whereby subsidies would be granted for regeneration measures (SOU 1973: 14).

This proposal received a good deal of criticism. The problem is not to increase the total annual cut as suggested by the survey but to regulate it to a level that is commensurate with sustained yield forestry. The proposal also implies that the annual cut will not only increase in the case of owners with a lower annual cut, but also in the case of owners who are already extracting a large volume. As demonstrated in the results of this analysis, there is a large variation among the owners both in respect of the annual cut per hectare and in respect of the logging intensity.

Another way in which the annual cut can be influenced is through legislation and control. For the private woodlot owner, this implies restrictions on his policy decisions. Through the formulation and content of legislation, it is possible to influence both the logging cost and the stumpage value. However, it is awkward for legislation to prescribe the size of the cut by a given owner in a given year. On the other hand, as demonstrated by current legislation, it is possible to apply certain restrictions on the annual cut in order to safeguard recreational interests, for instance. The effect of this is more likely to be a reduction in the annual cut.

Another means that can be employed is the dissemination of information. The advantage of information is that it can be adapted to the requirements of different target groups. It is even possible to limit dissemination of information to certain groups. However, a precondition for this is that the groups be well defined.

But the results of this study suggest the opposite to be true. Seen as individual groups, farm owners and forest estate owners, owners resident on holdings or non-resident, men and women, young and old, and private persons and Estates reflect no significant differences in the annual cut per hectare nor in logging intensity. However, variations *within* each group are wide.

As far as the wood buyers are concerned, there is nothing in the results to suggest the existence of any large, well-defined group with an annual cut that is "too low", and to whom they can turn in order to obtain more wood. Such owners do exist but they are to be found in all categories of woodlot owners. The study referred to earlier on private woodlot owners operating independently (Lönnstedt, 1974 a and b) suggested that one way in which the buyers could obtain more wood would be to link purchases to the provision of services.

The conclusion to be drawn from these results by those authorities on whom a regulation of the annual cut is incumbent is that the state of the forest is an important factor affecting the logging policy of *all* categories of private woodlot owners. This is apparently especially true in northern Sweden. However, there is a wide variation. An important explanation for the variation in the volume of the annual cut is probably attributable to personal and fortuitous factors, particularly as regards holdings with a small area of forest land. This would suggest that regulation of the annual cuts of private woodlot owners should be by means which are generally applicable.

However, it is evident that the results cannot be regarded as generally applicable from a statistical point of view, even if there is nothing to indicate that the results are not true with respect to a large group of private woodlot owners. A study on the influence of personal and fortuitous factors on logging decisions would be of interest to future research. Such a study would require a limited and in-depth analysis of the human factors. A comprehensive field survey is not capable of capturing all of the factors influencing the logging policy of private woodlot owners.

6 Sammanfattning

Syftet med detta projekt är att analysera ett multivativt och icke-experimentellt material för att studera vilka faktorer som inverkar på de enskilda skogsägarnas avverkningar. Detta är av intresse mot bakgrund av att den totala avverkningsvolymen i Sverige kommit i höjd med och t.o.m. överstigit tillväxten. De enskilda skogsägarna, som äger ungefär hälften av skogsmarksarealen, kommer därigenom att få en starkare ställning på virkesmarknaden. Detta medför att virkesköparna kommer att få öka sina insatser för att finna säljare. Från myndigheternas synpunkt innebär den nya situationen ökat intresse av att påverka utbudet och efterfrågan av virke så att kravet om ett uthålligt skogsbruk även framgent kan uppfyllas.

Den *analysmetod* som använts går under namnet "Automatic Interaction Detector" (AID). Denna metod kan, för en given population, användas för att förklara variationen i en kriterievariabel (undersökningsvariabel) med hjälp av en uppsättning prediktorer (förklarande variabler). I korthet fungerar AID-metoden på så sätt att den ursprungliga populationen delas in i två delpopulationer efter en av prediktorerna. Delningen görs så att vissa klasser, som definieras av prediktorn ifråga, kommer att tillhöra den ena populationen och de resterande klasserna den andra populationen. Kriteriet för en delning är att variationen mellan grupperna bör vara så stor som möjligt. De två delpopulationerna, som på ovan beskrivna sätt erhållits, undersöks i sin tur med avseende på tänkbara delningsalternativ och uppdelas enligt samma princip som ovan. Denna delning fortgår tills vissa av programanvändaren angivna krav inte längre kan uppfyllas.

Det *datamaterial* som analyserats består av 2203 enskilda skogsägare med minst 5,1 ha skog spridda över hela Sverige. I förhållande till det ursprungliga urvalet (3632 enheter) innebär detta en väsentlig reduktion. Orsakerna är bortfall, förändrade förutsättningar för undersökningsenheterna under studieperioden samt ofullständiga svar. Resultatet kan således inte i statistisk mening generaliseras utan är i första hand att hänföra till de brukningsenheter som studerats.

Två *kriterievariabler* förekommer i undersökningen: a) avverkningsvolym per ha och år samt b) avverkningsintensitet. *Prediktorer* är brukningsenhetens belägenhet, arealen åker och skog, skogstillståndet och djurhållningen samt ägarkategorier (fysisk person eller dödsbo), boendeort och antal bosatta, brukarens kön, ålder, sysselsättning, utbildning och organisationstillhörighet.

Resultatet visar att materialet inte låter sig uppdelas i enkelt lokaliserbara grupper för de två kriterievariablerna. Lantbrukare och skogsgårdsägare, bofasta och utbor, män och kvinnor, unga och gamla, enskilda och dödsbon har, betraktade som grupper, inga större skillnader i avverkningsvolymen per ha och år eller i avverkningsintensiteten. *Inom* grupperna är dock variationerna stora. Resultatet visar däremot att skogstillståndet är en viktig faktor för *alla* enskilda skogsägarekategoriers avverkningsbeslut.

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