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THE INTER-NORDIC PROJECT OF FOREST TERRAIN AND MACHINES IN 1972—1975

YHTEISPOHJOISMAINEN METSÄNTUTKIMUS-PROJEKTI "MAASTO-KONE" 1972–1975

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PREFACE

During the years 1969—1972 an Inter-Nordic Terrain Classification Project was going on. It was one of five projects started on the initiative of the Nordic Council. The final report of this project, written by Rihko Haarlaa and Roger Assertåhl, was published in the series Research Notes of the Department of Logging and Utilization of Forest Products, University of Helsinki (No. 20/1972). It was pointed out in that report that many problems remained, and further studies were needed. Among other things, it was regarded useful to aim at a terrain classification system covering all the terrain operations included in the field of forestry, i.e., not only harvesting operations but also forest cultivation, forest drainage of peatlands, and forest road construction activities. Further studies therefore began in a project named »Terrain and machines».

Research work connected with this project has been carried out partly in Finland, partly in Sweden and partly in Norway. The final report of the project was written by Mr. T. Eriksson (Finland), G. Nilsson (Sweden) and G. Skråmo (Norway). Mr. T. Eriksson has acted as leader of the project. The members of the project council have been: Mr. Søren Honoré (Denmark), Prof. Kalle Putkisto (Finland), Mr. Gunnar Skråmo (Norway), and Mr. Einar Malmberg (Sweden).

The draft manuscript of this publication was ready in the autumn 1976. The delay in publishing the report was due to the alterations which were made on the basis of the comments received from all the Nordic countries on the original manuscript. The Society of Forestry in Finland has agreed to print the final report in its series »Acta Forestalia Fennica».

On behalf of the project council, I would like to express my thanks to all those mentioned above, as well as to all other persons who have contributed to the research program.

Helsinki, January 1977

KALLE PUTKISTO

1. INTRODUCTION

11. Background

111. General

The most central functions of forestry are the production, harvesting and transportation of timber. The various forms of forest ownership further widen its field of activity. For instance: if owned by a farmer, a forest is a part of the farm economy, if by forest industries, the timber supply is in a close connection with wood processing. Nowadays, recreational use is also included in the field of forestry. The most important parameter for forestry activities is always, however, the terrain (ground).

Other environmental parameters are watercourses (water), and climate (air). These are the three partial factors that determine the existance of the animal and vegetable kingdoms and their innumerable interrelationships, knowledge of which (vital conditions, structure and possibilities) has always formed and will form the basis of all human activities.

When investigating the quality and features of these partial factors, assistance may be acquired from many different branches of science, such as geology, hydrology, geography, botany, zoology, ecology, pedology and meteorology (Mitchell 1973). Thus they also have a more general significance.

So the concept of terrain consists of or is affected by many different parameters, e.g., ground and rock bed with their differences of level, watercourses, vegetation, climate (with local weather conditions). Many other factors must also be taken into account when describing terrain, especially, it the description is to be a starting point of one or some activities in that terrain.

Military operations and heavy transportation, for instance, have earlier demanded information about the traversability of the terrain according to the needs of traffic at that time (roads).

In the middle of the 18th century there began a phase of development that revolutionized both general attitudes and military tactics, and forced people to pay still more attention to the terrain and not only to the roads. This led to the mapping of the surface forms and topography of the terrain, and was the stimulus to the development of cartography. (Kaje 1968).

Because both military operations and other actions connected with the accessibility of the terrain have much in common with forestry, almost all maps provide some kind of basic information that can be utilized in forestry. Thus, we must consider maps to be important documents in collecting preliminary data of terrain, as well as in recording information collected personally in the terrain. Knowledge of the meaning of the symbols used (the description connected with a map), and acquaintance with the documents connected with the map make it possible for a person, who understands the interdependence of terrain factors, to draw fast and in many cases pertinent conclusions as to the nature of the terrain in question. This method costs little. Aerial photographs represent a valuable supplement to the maps, and even detailed information about the terrain is attainable from photo interpretation.

In practical working life, the terrain is best seen as a traffic base, and a part of the difficulties is considered to be the variety of relative altitudes, i.e. topography, both macro and micro. Because there is an effort to determine distinctive values by the mutual and internal dependences of different difficulty factors, it must be mentioned, as an example, that the variety of altitudes may be described by mathematical values (Kaje 1963).

112. International need of terrain description and classification in forestry

As long as timber was harvested by using muscular strength, and the amount needed was available from relatively easy terrain conditions, there was no practical need to investigate terrain, except with regard to wood production. When approaching the quantitative limits of wood, areas which are difficult to traverse have fallen into the sphere of cutting operations. The rationalization of different phases of forest work has, for its part, led to the mechanization of forestry work.

Developing machines suitable for terrain conditions has continued through experimentations for a long time. KAJE (1968) makes it clear that the terrain ought to be known first, and vehicles subsequently developed, either with the aim of mobility in the terrain in general, or for special conditions, because, for example, if only the motor power was increased, no speed higher than 10 km/h in the summer and 20 km/h on relatively even strips was reached by terrain machines. As a matter of fact, in this case a horse is a fully competitive means of transportation. Long experience has shown that vigorous technical developments only emphasize the necessity of the knowledge of the conditions where vehicles will be used.

Because we can equate the environment of forestry operations and the circumstances of using machines, the need for investigations of terrain factors has proved to be great, concerning both the development of forest machines and the economical use of the most difficult areas in forest terrain.

Because forest machines imported from beyond Europe have been succesfully used in Nordic countries, and because this kind of machines manufactured here can be marketed around the world, studies of terrain factors also have an international significance. This was the main theme of the meeting of the Section 32 of IUFRO in Montreal, Canada as early as in 1964.

Opinions concerning the aims of an international terrain classification were presented in this meeting and can be found in the documents of four different discussion groups (Proceedings ... 1964), the most important of which are summarized in the following:

Discussion group I, goal applied internationally:

- To make the comparison of working methods and study results easier with regard to timber cutting and transportation,
- to act as a base for the regional and national development of equipment and working methods,
- to give references for the proper treatment of forests, and for planning transport nets, applicable to both separate forest enterprises and whole forest areas, and
- to act as a base for estimating and comparing cutting and transport costs, such as in different parts of a forest enterprise or a country.

Discussion group II, goal applied internationally:

- A general system for measuring and describing those terrain conditions having a significant influence on any forest operation. This is the basic aim, and such a classification system would serve all the purposes of a terrain classification.

It would therefore appear that the aim of an international terrain classification was settled, but it proved impossible at this meeting to work out even a preliminary classification draft, so different were the opinions of different groups. In common, however, was an emphasis on objective measurements and descriptions, as well as general opinion concerning the central position of at least the following three factors in the classification:

- soil conditions (soil types, bearing capacity),
- ground surface conditions (roughness), and
- slope conditions (uphill or downhill gradient).

Vegetation factors, whilst having a great significance in all the phases of forest work, were only forwarded by Discussion group IV.

Thus the principal problem, the terrain classification itself, was delegated to a working group with representatives from four countries, its proposals to be presented to the following meeting of the Section in 1967.

So the XIV IUFRO Congress in Munich 1967 received the following proposal for consideration: »Proposal for international system of terrain classification by the Working Group on Terrain Classification: Gustav von Segebaden, Sweden (chairman), Ragnar Strømnes, Norway and Herb. I.

Winer, Canada, 1967». Because this system included all the significant factors for a global classification, except vegetation factors, the major headings are presented in the following:

Major Headings:

The following main factors are described.

A. General description of the whole
1. Geographical location
 — longitude and latitude degrees
 — height above sea level (metres)
 — whether above or below highest coast line
2. Climate characteristics
 — zone (arctic — tropical e.g.)
 — types (maritime or continental e.g.)
 — precipitation (form and quantity e.g.)
3. Geomorphological characteristics
 — the major land form

B. Detailed description of the component parts
1. Slope
 — gradient (%)
 — length (m)
 — aspect (N = NW)
2. Ground roughness
 — general occurrence of obstacles
 — types and size » »
3. Surface and subsurface with special reference to bearing capacity and thrust (»slipperiness»)
 — the structure and thickness of humus layer
 — the texture and thickness of mineral soil
 — the stoniness of the surface
 — drainage
 — bearing capacity
4. Susceptibility to erosion
5. Accessibility
 — distance to access road (km)
 — description of adjucent terrain

In this proposal most terrain factors are divided into measurable sub-units. The decimal system has been used (e.g., distances in metres, slope in percentages, and so forth). A separate classification of digging difficulty is connected with the classification. The proposal for the classification is in accord with the positions of the IUFRO meeting in Montreal and, internationally taken, it includes all the factors applying to terrain.

When examining the mutual relations of terrain classifications in different countries (Norway, Sweden, Finland, United Kingdom France, Italy, Japan and USSR), Rowan (1974) writes: ». . that each country will obviously have its own special requirements for information on terrain, but it is possible to discern a number of points of agreement, and that descriptive terrain classification system should be quite distinct from functional terrain classification systems.»

In the meeting of FAO/ECE/ILO in Geneva in February 1976, German and French classification models were presented by Löffler (1976) and Ragot (1976). Although the German classification includes many opinions of researchers from EEC countries concerning the basis of a terrain classification, the French classification is different in spite of being a member of the same economic union.

It seems to be obvious that in the present state of forest machine development, when the relationship between terrain and machines is continuously changing, functional classifications are preferred everywhere. Thus, international research will have to wait for an established basic classification which, based on common terrain factors, would improve the comparableness of study results.

The Nordic (Norway, Sweden, Finland and Denmark) similarity of biological, technical, economical and environmental problems of forestry has led to long-standing cooperation between these countries. Norway with its fjords was the first to pay systematic attention to the difficulty of terrain, and the first forest terrain classification in »Telemark-fylken» was carried out in 1954 (Samset 1956 a), and was continued in other Norwegian counties in 1954—1965. Terrain classification is a permanent part of the National Forest Survey of Norway, and the purpose is to determine accessability and fitness for forest operations and to analyse how forest conditions vary with operational conditions and accessibility.

A terrain classification model »Terrain classification for Swedish forestry» (Terrängtypschema . . . 1969) was produced by Skogsarbeten (»Logging Research Foundation» in Sweden). The Swedish system differs from the Norwegian one. It is intended for use in planning, operations control, machine appreciał and in work studies. The classes of the three basic factors ground conditions, ground roughness and slope have, furthermore, other definitions than in the Norwegian system.

On considering the international implications of this whole matter, »The Inter-Nordic Forest Terrain Classification Project» was started by the Nordic cooperative organ »NSR» in 1969, and published its report in 1972 (Haarlaa & Asserståhl 1972). This report is based on the Nordic studies on the accessibility of the terrain. The widening of the base of the study to include preparation of forest soil and forest road construction continued the work under the project title »Terrain — Machine». The present report is published as a result of that work.

113. Literature review

Several investigations connected with the problem of terrain classification have been published or given attention within the project »Terrain — Machine», and the results of these are found summarized in Appendix 11 (pp. 51—61).

German literature (Kieslinger 1953) presents terrain classifications from the years 1861—1946. In the most recent of these, an essential feature becomes observing the mutual relation between soil type (e.g., loose or hard soil) and tool (e.g., shovel), when digging. Experiments of that time on the use of an excavator instead of a hand tool are also presented.

Since the beginning of mechanization of forest transport of timber, most attention has been paid to incresed productivity. It has been discovered that the combined effect of terrain factors is much greater with mechanization in winter conditions than when employing muscular power, because the elasticity of muscular power is much greater than that of machine power.

The following list from international literature indicates the scope of both research and interest:

1. Nordic countries:
   Jakobson (1965) Sweden
   Mattsson-Mårn (1946) »
   Putkisto (1947, 1956, 1964) Finland
   Samset (1956 a, 1956 b, 1970, 1971, 1975) Norway
2. North America:
   Several publications, especially on hauling, for example:
   Bartholomeo et al. (1965)
3. Other publications:
   West-Germany:
   Knell (1967)
   India:
   Asthana and Thapliyal (1971)
   USSR:
   Muraskin and Gorysin (1971)
   and so forth.

The direct effect of terrain on forest transportation output has been dealt with in some articles included in IUFRO proceedings (Proceedings . . . 1964), and this subject is found also in the report of NSR, written by Haarlaa and Asserståhl (1972). The military aspect of the relation between the terrain and terrain classifications has been studied by Parry et al. (1968).

The following publications are also worth mentioning: Söderlund (1971), who considers it necessary to determine the output of forest machines on the basis of a terrain classification, and Samset (1970, 1971 and 1975), whose latest study (1975) has been of great help in the terminological definitions of this project.

12. Definitions of terms

121. General definitions

Three main principles of terrain classification can be distinguished:

— classification according to the size of the unit to which the system is applicable,
— classification according to the degree by which the design of the system and its application are influenced by activities in the terrain (degree of functional sensitivity), and
— classification based on the resolution of the system and the individual terrain factors.

The three divisional factors of size, functional sensitivity and resolution of the unit may be seen as three dimensions by which means a terrain classification system can be characterized. Yet it is difficult to place a given system unequivocally into a particular category. The three dimensions are not always mutually independent. Moreover, the system may enter one or more dimensions in different applications.

In the following, the most important terms used in this report are defined. In parenthesis are some synonymous terms which have been used in other publications in this field, e.g., in those mentioned in the list of literature.

Terrain. An area which is principally formed by nature, and has not been essentially changed by man's activities.

Forest terrain. An area which is mainly under forests and which is intended primarily for growing trees.

Terrain factor. A stable or slowly changing terrain characteristic, the nature and size of which influences the appearance of the environment (landscape factor), and/or to the amount and kind of the activities carried out in the terrain (influential factor).

— Macro factors: terrain units having more or less the same terrain conditions. Aerial photographs and topographical maps are useful tools in dividing the terrain into units.

— Micro factors: terrain details in sample plots. Registration, for the present, only in the field.

Vegetation factor. A changing factor in the terrain, mainly of micro form, formed of those characteristics by which plants and their roots bind the surface layer of the soil; the varied influence of ground vegetation and stumps as obstacles, and so forth. The exploitable forest is preferably described by the terms of forest mensuration, if needed.

Accessibility. A term which consists of the terrain, vegetation and distance factors. It is usually presented as a technical, operational and economic difficulty with regard to the conditions of using the right machine combination throughout the area of operations.

Terrain description. A description of the total image of the terrain of a certain area, which satisfies the general need for terrain information without objective measurements.

Terrain classification. Terrain information with the help of all the known factors and groups of factors, also making use of the grouping and/or division of micro factors into subclasses, which can be verified by objective measurements.

Terrain classification system. A system to the order of the mutual importance of terrain factors and their systematic internal division into subclasses.

Terrain type. Areas, which may be defined by means of same factors and with nearly the same distinctive values, are included in the same terrain type (e.g., rocky terrain, heath land, peatland).

Description of classification unit. An area, which can be clearly delimited in nature or on a map, the size and accuracy of description of which usually depends on each other so that the larger area, the lower the accuracy of description.

Grade of classification. Every terrain factor may be divided into certain parts of different sizes, which can be measured accurately.

— High grade of classification:
  All the influential factors with their objectively measurable parts are taken into account when defining the terrain type. Applies to sample plots and to detailed studies of small classification units, and a given factor is measured and recorded with a high degree of accuracy and precision.

— Low grade of classification:
  The opposite of the above; applies to the description of the terrain conditions of continents or large areas. In the extreme case it is only a question of terrain description.

122. Classifying terrain

Regional classification. The classification applies to a very large area (e.g., country or county, province).

Local classification. The classification in this case applies to an area smaller than that in the regional classification (e.g., economic area).

Forest unit classification. The classification applies to a relatively small area (e.g., forest stand, working site).

Sample plot classification. The smallest classification area.

Primary terrain classification (Descriptive terrain classification). Presents all the factors found in a classification unit, using the terminology defined above, by means of objective measurements and numerical values, relevant to the different factors within the special terrain classification system.

Secondary terrain classification (Functional, operational, technical, etc.). A terrain classification based on the factors of the primary classification, designed for a special purpose (e.g., timber transportation, silvicultural operation, road construction).

Descriptive terrain classification. Classification of terrain by means of objective terrain factors, the values or appearance of which are not influenced by activities in the terrain. The factors might have numerical values or be coded.

Functional terrain classification. Classification of terrain by means of objective and/or subjective terrain factors designed for a special purpose. The appearance or values of the terrain factors are influenced by a certain activity in the terrain. Similarly, the unit to be classified can also be influenced by a certain activity in the terrain.

13. Comments on the definitions

The term »terrain» has, in practice, not always been the same in different fields, e.g., agricultural, forest road building and military operations have had different interpretations. The definitions of terrain given by ISTVS (The Standardization Committee of the International Society of Terrain-Vehicle Systems) is the following (Glossary of . . . 1968): »Terrain: The total of all man-induced or natural non meteorological phenomena that influences the performance of vehicles». This definition has not been adopted by this project.

Samset (1975) gives the following definition: »Forest terrain is defined by the physical qualities of forest land, partly the main features of the terrain surface and partly details in the terrain surface itself. Conditions which alter according to the way in which a forest develops or is treated (brushwood, subvegetation, tree-dimensions, stumps, etc.) can be described by classification of forest conditions and are not included in terrain classification itself.»

Because terrain is usually thought to be an area away from roads and groups of buildings, and its classification system is considered to be the describing and measuring of all the terrain conditions having significant influence on any operation in the terrain, this project has also included vegetation factors in its classifications.

As Rowan (1974) shows, terrain classifications in different countries have usually been operative ones (i.e., secondary). Terrain problems have been studied jointly with short-distance transportation machines and equipment typical in each country. In Norway, the pioneer country of terrain classifications, some macro-factors have got functional designations even if the definitions of those factors are descriptive, e.g., cable slopes which are defined by angle and length of slope. To avoid any confusion on this point the designations are changed to nonfunctional terms. The micro-factors of the Norwegian terrain classification system are related to soil, moisture, terrain regularity, slope and vegetation types. Some functional factors are included, e.g., season of operation and skidding distance.

The Norwegian terrain classification system has been developed for the purpose of regional terrain classification. — According to the definitions above it is a secondary, descriptive system with some additional functional factors.

In Sweden (Terrängtypschema . . . 1969) the terrain is described by three factors: ground conditions, ground roughness, and slope. Each factor is sub-divided into five classes, without any operational implications. The Swedish system might, with the definitions above, be characterized as a secondary descriptive terrain classification system intended for use at the forest unit level. It has an intermediate grade of classification.

The Norwegian and Swedish systems may be considered to be preliminary terrain classifications based on a general need. The Swedish system has occasionally been applied in Finland.

With regard to the foregoing, the conclusion may be drawn that the basis of a complete international classification ought to be permanent and sound primary classification. Only in the secondary phase, in which the area to be classified is strictly limited, where the access has been taken into account, and where the machines, equipment, and methods are known, is it expedient to place values, the functional meaning of which is known, into the model of the primary classification for different terrain factors.

Normal summer conditions are the basis for classifications made for long-term planning. In this case, the classification grade is usually relatively low. It may be raised, by diminishing the area to be classified, e.g., the classification is aimed only at the net of strip roads instead of the whole logging area, or the time of actions is limited, e.g., harvesting is ordered to be carried out during the bare ground period in the autumn/summer.

Although any regular correlation need not exist, the size of a classification unit, the intensity of activities, and the classification grade of the terrain generally follow the rule: high classification grade = intensive operations, in which case, the size of a classification unit easily decreases to equal the minimum need of the classification grade, primarily for cost reasons. Diminishing of the accuracy of the classification to match the need in each case ought to be possible by changing the mutual relations of subfactors.

Applied internationally, it seems that only the detailed primary classification has some possibilities for the basis of a general and uniform terrain classification.

2. PURPOSE AND METHODS OF THE PROJECT

21. Purpose

The purpose of the project is to work out:

1. A proposal for a mutual primary terrain classification system which
— would be long-lasting due to its being based on permanent terrain factors, making it possible to analyse how forest conditions develop and vary with operational conditions,
— would have links with other fields of science because of efforts to make the Nordic results of forest research comparable, and
— would be applicable for classifying of sample plots and other areas of the same type (high grade of classification — high accuracy).

2. Secondary classification models, in addition to the primary classification, which would quantify the difficulties caused by terrain factors in each case as accurately as possible. Operations concerning the accessibility of the terrain, preparation of forest soil and forest road bulding are examples of this kind of classification.

These classification systems ought to be applicable in the following work phases:
— planning, in which the whole task, including terrain factors, is analyzed,
— defining traffic possibilities (obstacle and distance measurements), and
— division of operational units.

22. Methods

In its effort to design a primary terrain classification system the project has adopted the following starting points:

1. earlier literature in the field,
2. lists of terrain factors used in earlier terrain inventories, and
3. studies within the projet on:
— the mobility and capacity of terrain machines in the short-distance transportation of timber,
— the capacity of machines and the quality of the output in soil preparation for timber production, and
— the capacity of machines in forest road construction, and the quality of the output.

Considering forest economics, this classification base covers a great deal of the terrain operations which at the present are carried out in forestry by muscular strength or using various machines.

3. EARLIER TERRAIN CLASSIFICATIONS IN THE NORDIC COUNTRIES

31. Finland

311. History

The main features of the Finnish terrain as a whole are its levelness, and the extensive forests. As long as timber logging was entirely dependent on muscular power in winter conditions, the ground was considered only as soil, and was classified by its fertility.

In the forest economics classification of forest land, the principal objective was the combining of lands which were similar with respect to the amount and quality of timber production (LIHTONEN 1958). In Finland, it was stated as early as in 1909 that the areas growing trees could be described and classified according to the ground vegetation. This forest-type theory (CAJANDER 1925) has been the basis of all the silvicultural operations in Finland, and, for a long time, forest economics activities as well.

A classification of forest land with a broader foundation was developed with the mechanization of forestry, and the accessible forest land was classified according to the following criteria:

1. size of area
2. location of area in terms of business economics
3. utilization value of an area in producing of timber, if
   - proportions of the bedrock and loose regolith,
   - relative altitudes and topography, and
   - fertility of forest soil

   are taken into account. (LIHTONEN 1958)

When investigating the basis of forest work wages in the 1940's, terrain factors were perceived within forest engineering. VUORISTO's twin-basis pay-system based on the number of stems and their cubic contents consisted of three terrain classes, which were investigated separately for a strip and a permanent forest road (Metsätöiden . . . 1946). The classification of terrain difficulty by PUTKISTO (1947) included the following factors:

1. Ground vegetation (including slash)
2. Stoniness
3. Slope
4. Water content

In this classification, each factor is divided into five subclasses. If compared with corresponding Swedish classifications of that time, this classification is relatively elastic, because it defines only the factors of terrain difficulty and their grades, excluding their immediate effect on the work except for the part of ground vegetation. The Swedish classification of the same time was bound to the working methods used (MATTSSON-MÅRN 1946).

Because the affect of terrain is much the same for military and forestry operations, an example of a military terrain classification is considered (The terrain classification model of the Finnish National Defence 1963):

1. Terrain obstacles
   - slopes, > 45 %
   - rough rocks
   - stony soil
   - impassable peatland
2. Passable peatland
   - always passable
   - occasionally passable
   - naturally very dry peatlands
3. Passable mineral soils
   - fine
   - coarse

The terrain slope scale was:

— 0 — 5 % (even)
— 15 % (suitable for a farm tractor)
— 30 % (suitable for a four-wheel tractor)
— 45 % (suitable for a track vehicle)

This classification is based on the mobility of track and wheel vehicles in military use.

312. General review

Although many inventories have been made of the Finnish forests, and very accurate information exists of their area, fertility, and tree stands, no uniform national division to classes, in the sense adopted in this project, has been made in connection with these inventories, due to the lack of a generally accepted, simple classification and the relatively small significance of the terrain in winter conditions. Lots of studies have been made on the Finnish forest terrain and its areal distribution, based on either the forest terrain directly (KÄRKKÄINEN 1968 and 1970, HAARLAA 1971 a, 1971 b) or indirectly, such as studies on harvesting, machines and methods (e.g., HAARLAA 1970, 1971 c, 1972 a, 1973 a, SEPPÄLÄ 1974, TYNKKYNEN 1974, HANNELIUS 1975).

Because the methods of terrain research, as well as terrain inventories are in many ways connected with the classification itself, the methods of collecting terrain data and the future views are presented in the chapter 4 (p. 22).

313. Presentday situation

The lack of a detailed, generally accepted terrain classification system is particularly noticeable in the pricing of phases of forest work, in which the amount and quality of work mostly depend on terrain difficulty factors (work by unit basis or by contract).

Of the many examples of the classifications of different work phases, some typical ones are presented here:

1. Cutting and transportation by horse

— Cutting of timber and saw logs

I class Normal forest terrain
II class Terrain which clearly causes some inconvenience
III class Terrain which causes considerable inconvenience
IV class Terrain which causes very great inconvenience

— Transportation wages and charges of piled wood and saw logs

A worker has to be compensated for the effect of difficult terrain to the extent that it is estimated to hinder his work (Metsä- ja uittoalan . . . 1974).

2. Timber transportation from as strip by a farm tractor

— Terrain classification

I class Easy terrain
II class Fairly easy terrain
III class Fairly difficult terrain
IV class Very difficult terrain

The classification is made by using the following terrain factors:
— bearing capacity (rut formation),
— slope (uphill/downhill slope, %),
— terrain surface (difficulties in driving on strip roads), and
— winching terrain (factors impeding winching).
(Tavoiteansioon . . . 1975).

3. Mechanized forest soil preparation

a. Scarifying and harrowing
Factors of work difficulty:
— area,
— stoniness,
— density of scars, or driving distance by harrow,
— terrain slope,
— soil type and ground vegetation, and
— traffic connections.

b. Ploughing for cultivation
Factors of work difficulty:
— area,
— bearing capacity,
— stoniness,
— stumps and slash,
— slope of terrain, and
— ploughing distance or amount of furrows, m/ha.

The grade of difficulty is estimated by points, the sum of which gives the unit price.

All these classifications connected with practical working life are, for a great part, based on subjective estimations.

32. Norway

321. Basic considerations

All work operations for the purpose of forest production — in the broad sense of the term, e.g., wood, environment, protection, etc., are dependent on access to the forest areas. The accessability, again, is determined by the transport network and the terrain conditions in the area. Terrain classification describes the terrain so as to provide a basis f r judging the accessability of forest areas for any forest activity.

When constructing the classification system it is important to consider the purpose of the classification. If this is to analyse the accessability of a large area, the description has to be general. It should provide an overall appraisal of the accessability of the forest terrain for all kinds of activity. Detailed description of terrain features for particular operations is probably inappropriate in a survey of a large forest area. — When planning forest activities in certain areas, shortterm access analysis may prove useful. In addition to the descriptive classification, it is then of interest to carry out a functional classification of terrain, where equipment and methods to be used in the very near future may be considered — and even operational conditions which are not covered by the definitions of forest terrain may be included in the analysis.

The most ideal and accurate criteria and registration procedures are not always possible to practise because they are often work-consuming and expensive to carry out. There is a marked distinction between a commercial survey, with clear economical bounds concerning expenses available for data acquisition, and research work where it is often entirely necessary to perform the most accurate registrations in order to meet the intention of a particular investigation. — We also have to be aware of the evaluation of registration procedures, e.g., remote sensing, which may change the working routines considerably and even generate new criteria which are not possible to record with the present procedures.

Considering forestry on a world-wide basis, extensive inventories of forest resources have been produced, but no accessability analysis are available. Need for developing a system for surveying the accessability of forest resources is therefore pressing. — As the furtherance of forestry in the world depends partly on the degree of difficulty of operational conditions and partly on the possibilities of finding outlets for the timber, a need has been felt to make economic accessability basic to the system. Economic accessability is, however, a functional analysis based on the technical accessability and modified, among other things, by economic development, market conditions and development of processing industries. It means that the basic terrain classification system should be established to provide data for analysis of the technical accessability of forest terrain. This is, at the same time, in favour of a global validity of the system. As an example, the Norwegian terrain classification which is descriptive by its nature, could easily be adapted to the forest conditions in Greece (Samset 1967). If the terrain classification system is based on well defined terms and is mainly descriptive of nature, it should be quite easy to adapt to various terrain configurations.

Because terrain is more or less something permanent, the immediate thought is that terrain classification could tbe done once and for all. It has been stated, however, that there is a close relationship between terrain factors and forest conditions (Samset 1975). Therefore, terrain classification ought to be repeated together with conventional forest surveys, because it is useful to analyse changes of forest conditions within various terrain classes. For that purpose it is important that any terrain classification system makes it possible to refer changes in forest conditions from one survey to the next, back to the same objectively defined terrain classes.

What is essential when trying to analyse the relation between machines and environment, is first and foremost to establish a distinct and well defined terminology, in order to avoid confusions about words and terms. It is important to consider the purpose of the classification. Is it a regional classification (large areas), a local classification (e.g. a property) or a single unit classification (research)? Furthermore, it is important to separate between the general overview of terrain (macro-classification), the detailed terrain classification (micro-classification) and classification of operational difficulties in connection with research work. — Besides this, and referring to the above stated relation between forest conditions and operational conditions, it is imperative to improve planning techniques in order to take full use of recorded data.

322. Development

From experience with terrain classification in Norway, it is found that terrain factors in forestry should be restricted to those natural features which are distinguishable from traditional stand data factors. Accordingly, forest terrain is defined by the physical qualities of forest land, partly the main features of the terrain surface, partly in the terrain surface itself. Conditions which alter according to the way in which a forest develops or is treated, can be described by classification of forest conditions and are not included in the terrain classification itself (Samset 1975).

The Norwegian terrain classification system was introduced in 1954. It has been used mainly for regional classification carried out by the National Forest Survey, and there have been only minor changes in the definitions of terrain factors — only improvement based on experiences. This stability in the system makes it possible to refer changes in forest conditions from one survey to the next, back to the same objectively defined terrain classes.

There has been an effort to use the same terrain classification system for management planning, i.e., for local terrain classification. It has turned out, however, that this system is not applicable straight away for this purpose. This has resulted in development of several pure functional classification systems, by different associations (enterprises). For the purpose of management planning it is important with detailed location, and it is probably necessary to study combined effects of terrain factors — more than the distribution of each factor, and there are indications that still some natural features are missing in a system suitable for local classification (Skråmo 1975). In Norway, therefore, a need is felt for further investigations on terrain registrations laying stress on local classification and planning techniques.

On the basis of more than 20 years of experience with the Norwegian terrain classification system and handling of data, it has become ever more evident that within forestry there are various demands on a terrain classification system. For this reason it is found useful to summarize some technical terms related terrain classification. More detailed explanations are given by Samset (1975).

Regional terrain classification:

— Covers large forest areas, e.g., a national forest survey.
— Registrations on sample plots, usually without identification on maps.
— Results as relative distributions and relationships between factors.

Local terrain classification:

— Covers more limited areas, e.g., a forest property.
— Registrations within terrain units, usually on sample plots.
— Location on maps are important.

Detailed registrations of operational difficulties within a single forest stand are not regarded as terrain classification in this connection.

Macro-classification (terrain units):

— Divides the terrain into units having more or less the same terrain conditions.

Micro-classification (detailed classification):

— Detailed terrain classification, usually carried out on sample plots within terrain units.

Descriptive terrain classification:

— Describes the terrain by measurable characteristics, and is usually a long-term classification.

Functional terrain classification:

— Describes the degree of difficulty for specified operational methods. As the operational methods and the machines will alter over time this is usually a short-term classification. It should be based upon a descriptive classification.

The regional classifications carried out by the National Forest Survey of Norway, have been processed and published under the main headings of:

- Terrain and operational conditions (SAMSET 1956 a, 1956 b, 1970, 1975, JACHWITZ 1958, 1959, 1961, ARVESEN 1961, VIK 1962, and SKRÅMO 1966 a).
- Soil conditions (LÅG 1956 a, 1956 b, 1958, 1959, 1961 a, 1961 b, 1962, 1963 a, 1963 b, 1964, 1965, 1966, 1970).

Detailed descriptions of the fieldwork are given in the cited publications from the National Forest Survey (Taksering av Norges skoger utført av Landsskogstakseringen). These instructions are mainly in Norwegian, which may be a reason that some misleading comments on the system have occurred. The conclusion drawn by HAARLAA and ASSERSTÅHL (1972, p. 12) on the usefulness of the Norwegian terrain classification system is, according to SKRÅMO, not correct. Therefore, it is found expedient to refer how the system has developed. This has been treated more fully in the proceedings from the XVI IUFRO Congress, Oslo (SKRÅMO 1976).

3221. Norwegian terrain classification

Period of validity and year of changes are given for each factor. Only the initial year is given for the factors still valid.

1. Descriptive terrain classification

a. Macro-description

Cable slopes, steepness > 33 %, length > 300 m. 1955. (2 classes)

Cable plateaus. 1955. Located above cable slopes > 33 % steepness. (2 classes)

Other morphological characteristics, which may be derived from the micro-description, e.g.:

Winch terrain:

- Terrain steeper than 33 %, length of slope less than 300 m.
- Terrain steepness 20—30 %, terrain regularity class 2: stony and irregular.
- Terrain steepness less than 20 %, terrain regularity class 4: exposed cliffs and clefts.

Even if the factors have got designations which take into account the potential operational methods, the definitions of the factors are descriptive. To avoid any confusion, it is proposed to rename these factors (SAMSET 1975).

b. Micro-description

Soil conditions:

Depth of soil material. 1954. (4 classes)

Soil forming material. 1954. (4 classes)

Physical composition of soils. 1954. (5 classes)

Soil profile. 1957. (7 classes)

Depth of humus layer. 1957. (5 classes)

Proportion of stones. 1955. (5 classes)

Moisture conditions:

Ground water table and the amount of water available. 1964. (8 classes)

Lateral movement of water. 1964. (6 classes)

Terrain surface:

Regularity of terrain. 1954. (5 classes)

Terrain steepness. 1954. (5 classes)

Vegetation:

Vegetation types. 1954. (10 classes)

2. Functional terrain classification

Operational conditions:

Season operation. 1971. (3 classes)

Bearing capacity. 1971. Related to tractor locomotion. (5 classes)

Skidding distance. 1957.

Access:

Distance of extraction. 1971. (6 classes)

Former designations:

Horse and tractor extraction. 1954 only. (5 classes)

Distance of extraction. 1955—70. (5 classes)

Terrain factors used formerly:

Prevailing operational conditions. 1954—56. (3 classes)

Skidding conditions. 1957—65. (3 classes)

Logging economy. 1955 only. (3 classes)

Winch terrain. 1955—56. (3 classes)

The term terrain is not well-defined in all respects. Objection may be raised why vegetation types are listed among terrain factors. Vegetation types are, of course, a borderline case. They are, however, closely related to the bearing capacity of the ground, they are relatively stable over time — and, in this case, they are recorded anyhow by the National Forest Survey.

The present Inter-Nordic project shows a tendency to broaden the term terrain to include stand data also. This is, of course, due to the fact that terrain factors together with other operational difficulties are as parameters in the different investigations performed. From Norwegian point of view we greet with enthusiasm a common list of parameters deduced from the research work. This list, however, will be a list of operational difficulties which among other factors include terrain factors.

33. Sweden

331. Development

Terrain classification has long since been carried out in Sweden. Classification has focussed primarily on

— investigating the correlation between biotope conditions and forest increment, and
— achieving correct pricing of forest work (pricing of special wage rates).

Terrain classification varied according to the purpose of the classification and also between the different forest enterprises and research institutes.

But from the early 1960's, uniformity was introduced into the classification methods. Since 1961, the collection of ground data was carried out in conjunction with the National Forest Survey of Sweden. The factors and methods of collection used in the survey have provided a valuable basis for other, subsequent terrain classification systems.

With the rapid increase in the degree of mechanization in forestry which occurred during the 1960's, attempts were made to elicit more certain data on the environment in which people and machines were employed. Greater certainty in terrain data would facilitate the planning of logging work and reduce the number of interruptions to production. In the work on the development of terrain classification systems to this end, the objective has been to develop a form of terrain classification which is both general and capable of being practically employed and which is not tied to any given machine or logging method. The system would otherwise quickly become obsolete and the classification out of date owing to the rapid technical advances made in machine development, as well as to the wide variations in the appearance of terrain in different parts of the country.

During the 1960's, a variety of terrain classification systems were compiled along the lines of the above philosophy. The aim of these systems was to classify the trafficability of the terrain by means of the following main factors:

— ground bearing capacity,
— fixed obstacles, and
— slope.

The composition of the various systems for terrain classification was much the same. What mainly distinguished them from each other was the method of inventory and the classes used in the classification. Towards the end of the 1960's, the experience gained in the application of the various classification systems and the research findings with respect to machines in relation to terrain were brought together into a general terrain description system:

»Terrain classification for Swedish forestry» (Terrängtypschema .. 1969). This classification describes the terrain in terms of the three main factors mentioned above, namely:

— ground conditions,
— ground roughness, and
— slope.

Each factor is sub-divided into five classes, class 1 being the easiest and class 5 the most difficult in each case. Ground condition classes are supplemented by a soil type code.

This terrain classification system rapidly became used on a wide scale in Sweden. It is used by the majority of forest enterprises and research institutes. Between 1970 and 1972, terrain type factors were collected during the National Forest Survey in parallel with a number of other terrain and ground factors.

332. Terrain classification today

»Terrain classification for Swedish forestry» is used almost without exception by the forestry industry in Sweden for general terrain descriptions. The particulars are then utilized in such activities as:

— planning,
— operational follow-up,
— assessment of machines,
— time studies, and
— pricing of wage rates.

The general terrain classification is often supplemented by factors designed specially for certain purposes. For example, in the collection of data for short-term logging planning, a subjective ground bearing class is sometimes also recorded, the value of which is governed by the distribution of the bearing capacity within the entire planning area and by the specific capabilities of the machines with respect to mobility.

The topographical mapping carried out in conjunction with the National Forest Survey has made it possible to compile lists of the areal distribution of various terrain types. These particulars are used in such activities as market analysis and in assessments of specific machines or specific machine systems.

In practice, the factors of the terrain classification system are regarded as simple but adequate with respect to providing information on the trafficability of the terrain. However, the information about the terrain provided by the factors is insufficient for use in the planning of silvicultural activities. The classification system should be complemented, for instance, by a factor denoting the degree of difficulty in soil treatment (scarification).

The terrain classification factors have often been found to be inadequate for use in research aimed at solving various technical problems. In such cases, the classification system has been supplemented by new factors, which have been compiled with high resolution concurrent with the collection and specification of the factors for the terrain classification system.

4. ATTAINING THE TERRAIN INFORMATION NEEDED

41. Existing knowledge of terrain conditions

The description of the forms, topography and ground surface of the terrain by maps dates from early times and has been continuously developed. Specialized surveys have also produced maps of sub-surface features. However, in spite of the possibility of photographig the globe by satellites, there are still large areas without detailed maps. For areas where intensive operations have been carried on for extended periods, the only problem is, how detailed terrain and other necessary information may be got from the maps. A map is usually the starting point of a forestry operation, and planner's first task is to determine which of the following maps are available:

- general maps,
- topographical maps,
- soil maps,
- forestry maps,
- hydrological maps,
- climatological maps,
- geomorphic maps, and/or
- air photographs.

The maps most readily available in Finland are the general and topographic maps of scale 1: 20 000, as well as aerial photographs to the scale 1: 10 000 or 1: 4 000 (used for taxation purposes). In spite of generalizations, these maps give a detailed and accurate description of the terrain. Map interpretation must, of course, be mastered (Karttatulkintaopas 1971) and this presupposes knowledge of:

- the accuracy, scales and ways of drawing up maps,
- glacial and post-glacial evolution,
- the general regional terrain characteristics,
- the geomorphology,
- the order of soil layers,
- the meaning of the topographical compartments of the map with regard to the quality of ground base,
- the vegetation as an indicator of the type of ground base,
- the location of artificial forms, and of the hints they give of the quality of the base, and
- the references to the quality of an area, etc., based on place names.

The aim of interpretation, the judgment of the utilization of the terrain in different situations, may be reached only when the one who uses a map also has experience of the technical features of using different terrain types, and the map interpretation is made on the basis of more than one factor. For example: the micro and macro factors reveal the origin of a formation, and this, for its part, the structure and soil type. Both general and detailed investigations and interpreted images of the terrain from maps give the following important information to the planner of forestry operations:

- direction of the forms of terrain,
- waterways and their directions,
- relative altitudes,
- nearness of the bedrock,
- chains of ridges,
- soil types,
- tree stands, and
- artificial formations (e.g. highways). (VIRKKALA 1963)

42. On the methods of terrain difficulty inventories

When striving for an accurate estimation of the utilization of the terrain, a map is nothing more than a starting point, because it is only a miniature of the terrain and thus it is not possible to get detailed information of all the terrain factors in it. Usually the description of micro obstacles is lacking. Whilst terrain information ought to be interpreted as correctly as possible from a map, there ought to be methods for checking and completing them. Material connected with terrain difficulty has been collected from different parts of Finland since 1965 by the Department of Logging and Utilization of Forest Products of the University of Helsinki. A study has been made on the development of timber transport conditions in the Suur-Savo economic area (PUTKISTO 1971). The method used was the road-side inventory, the principle of which is presented on this page.

The method has involved placing of factors found into a classification system, which has been constantly improved as the work progressed. The following classification model has been used in these studies:

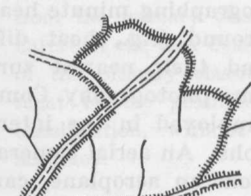
a. Macro forms of the terrain
— hilly terrain, abbreviations V1, V2, V3
— undulating terrain, » K1, K2, K3
— ridgelike terrain, » H1, H2, H3
— level morainic moor, » M
— level sandy moor, » Mh
— peatland, » S
— waterway, » A
— field, etc. » P

b. Micro factors of the terrain
— stoniness index, significant numbers 0—6
— height of individual stones, » » 0—3
— stumps, » » 0—3
— roughness, » » 0—2
— ground, » » 0—8
— density of trees, » » 0—3
— average diameter of tree stand, » » 0—6
— ground vegetation. » » 0 2

(KÄRKKÄINEN 1968)

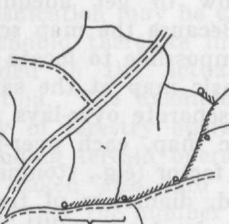
PRINCIPLES OF THE THREE TERRAIN INVENTORY METHODS

A. Road-side investory



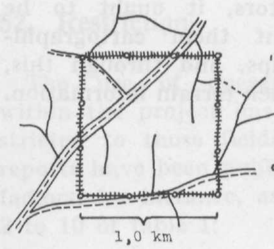
Expl.:
Highway
Country-side road
Single lane road
Ungraded wood road
Road-side classified by eye from car

B. Road-side line inventory



Expl.:
Road-side classified by eye during walking in terrain
A measured plot

C. Line-plot inventory



Expl.:
Line classified by eye during walking in terrain
A measured plot

The method was essentially simple; the sides of a road were considered to represent the terrain conditions in its surroundings, and thus classified from car windows. The classification was revised and amended by road-side inventories of sample plots by terrain descriptions from line surveys connected with general forest mensuration, and by aerial photographs. In this way it is possible, for instance, to make a map of accessibility for the whole Finland on the road map scale, 1: 200 000 (Esko 1976). Such maps would be necessary in planning and executing forestry operations, many of which require a higher than average classification grade.

The methods described above are examples of quick and cheap ways of getting terrain information that may be applied to very many practical situations.

Striving for scientific accuracy in collecting terrain information leads to systematic line surveys on the basis of a primary terrain classification, and this, for its part, is very slow and expensive.

43. Future views

Thus, a map is an important means of recording and presenting terrain information. Even in its presentday from, a map gives rather reliable basic knowledge, and with its help it is possible to verify the areas, information from which is lacking or seems to be so uncertain that a field inspection is needed. On the other hand, the combined effect of climate and other factors on the moisture conditions of the terrain cannot be ascertained from a map. Hydrological conditions are of such importance to all forest work carried out in the terrain, that these alone are reason enough for some kind of survey, during which it is possible to obtain other missing information.

The information provided by tables and graphs, which are often found as appendices to maps, often reveal the average amount and quality of many factors, and are therefore of great significance to general planning. A new period is beginning in the preparation and accuracy of maps, because satellites make it possible to photograph the ground surface from great altitudes with hitherto inconceivable accuracy and definition. This accuracy may be further increased by normal aerial photography at lower altitudes. The photos may be made clearer by using colour films, and the interpreting of them is still easier when using false-colour films, which reveal in the terrain and vegetation facts which remain hidden from human eye if normal colour film is used. Further, it is possible to use films which are sensitive to rays other than the visible spectrum in order to identify certain terrain conditions, for example, the photography of objects hidden by vegetation, such as by photographing minute heat differences on the ground (e.g., heat differences of stones and their nearest surroundings), using thermo photography. Computers can also be employed in the interpretation of photographs. An aerial camera, filming the terrain from an aeroplane, can feed what it »has seen» straight into a computer, which is programmed to process the data and produce the results in a form desired. (Esko 1976)

A problem is, how to get adequate factors onto maps. Because the map scale is often small, it is impossible to locate all the factors onto a basic map at the same time. It is better if separate over-lays are placed over the basic map, each over-lay describing a different factor (e.g., stoniness, quality of the ground, diameters of trees, etc.). In spite of the great possibilities of photographic techniques, most of these factors cannot be described immediately, but the information must be collected in the terrain. Once they are collected for the so-called stable factors, it ought to be possible to represent them cartographically on general maps, and through this, reach all who need such terrain information.

5. TERRAIN CLASSIFICATIONS AND THEIR APPLICATION

51. Scope of the classification

According to the criteria adopted within this project, the primary classification may be used:

- partly or wholely for all tasks connected with forestry, e.g., forest mensuration, forest politics, etc.,
- for fields outside of forestry, such as nature conservation, environmental description, etc.,
- for an extended period, because the emphasis of the classification is laid on stable terrain factors, such as the basic ground factors, and the slope, and
- as a basis for secondary classifications, in which the irrelevant terrain factors are left away from the primary classification, whilst if the nature of the task demands that all the factors of the primary classification are used, there must be the possibility of »broadening» the classification, without loosing the necessary accuracy.

Some applications are presented in more details in table 1 (p. 24).

A requirement of a primary classification is that parts of an operational terrain classification may be easily derived from it. It should therefore include all the factors needed in the actual operational classification. The examples in table 1 consist only of forestry operations. If the corresponding terrain operations in other fields are taken also into account, it becomes clear that the number of factors, as well as their division into different grades of influence, must be as great as possible.

52. Restrictions

The use of operational classifications within the project has naturally been restricted to those fields in which research reports have been published. The following factors, for instance, are required in points 2 to 10 of table 1:

A. STABLE TERRAIN FACTORS

Ground factors

- soil type,
- structure of ground surface,
- stoniness,
  rockiness,
- structure of humus (quality),
- thickness of humus (amount),
- grade of slope (steepness), and
- direction of slope (quarter or relationship to the direction of motion).

B. VARYING TERRAIN FACTORS

a. Vegetation factors

Under the ground surface

- living roots and root systems (density and size), and
- dead parts of plants (amount, size and age).

Above the ground surface

- Living:
  amount of trees, m³/ha,
  proportional shares of different sizes of trees (stout logs/pulpwood, %),
  shares of tree species (conifers/broadleaved trees, %),
  grouping of trees (advantage/disadvantage), and
  lower vegetation (sight/traffic obstacle).
- Dead:
  stumps (size, density and age),
  logging slash (amount and type), and
  lying trees (amount, size and age).

b. Seasonal factors

The amount and state of water influencing the characteristics of the terrain:

- moisture (influence on the »slipperiness» and bearing capacity of the surface),
- frost (penetration), and
- snow (amount and water content).

In addition to those mentioned above, the following factors ought to be taken into account in the points 11 to 14 of table 1:

1. Forest factors
   - fertility.
2. Climate factors
   - height above sea level,
   - latitude,

Table 1. Fields of application of the terrain classification system and examples of its application to forestry.

Field of application	Examples of application
1. Research and adjusting work	Studies on the bearing capacity of soil with cone penetrometer Studies of the possibilities of driving a farm factor in a certain area
2. Time studies	The relationship between the output with time of a certain terrain machine and the terrain difficulty
3. Machine estimation	Choice of machine
4. Market analysis	Potential market for a certain machine
5. Yearly planning of logging	Choice of logging method » » the season for logging
6. Monthly planning	Defining the order of objects
7. Planning of details	Marking of the main haul and strip roads Division into cutter's strips
8. Pricing of special wage rates	Pricing of cutting work » » hauling » » silvicultural actions » » forest road construction
9. Road planning	Determining road line
10. Supervision	Plan versus reality Supervising costs » production » the quality of work
11. Yearly planning of silviculture	Choice of seed, plants and cuttings for regeneration Choice of time for different actions Choice of methods
12. Long-term planning	Policy decisions Choice of methods for actions Division into action units Choice of year of action Long-term planning of labour power Relationship between terrain difficulty and forest conditions
13. Biological studies Biological supervision	Choice of tree species for artificial regeneration Plantation costs
14. Environmental actions	Describing »forest environments» Estimating changes in »forest environments»

— exposure, and
— humidity.
3. Historical factors
— previous operations,
— » methods, and
— » results.

The latter three groups of factors (1—3) are now examined from the viewpoint of the project.

1. Forest factors

Although soil fertility is very significant in the general description of forest terrain, and has indirect influence on almost all the phases of forest work, the definition of this factor rests on terminology borrowed from forest mensuration because its values cannot be reasonably measured in the terrain nor classified accordingly.

2. Climate factors are very important for those using the terrain. Although the geographical location of a place guarantees some kind of seasonal regularity for these factors, which are necessarily included in long-term planning and biological research, their effects must be omitted from this investigation, because they cannot be prejudged.

3. Historical factors are a good starting point for long-term plans and biological research, which effect the amount and quality of the output of work. Most of the factors in this group, the methodology of previous operations, for instance, cannot be interpreted in the way compatible with the project.

Thus, if the aim is a long-term terrain classification, it must be based on stable terrain factors.

Among the varying factors there are, however, very many that have a great significance on forest work carried out in the terrain. An essential part of the economic activities of today is controlling and comparing costs as the work progresses, and these factors must be fully taken into account. Accordingly, the amount of factors becomes very great; this is why the factors of other fields of science (e.g., geography) have been dealt with in the same way as climate, historical and fertility factors: they are not included in the primary classification. It must be made clear, however, that their influence on the ultimate result of activities cannot be totally ignored. Limiting the detailed factors has been very difficult, because the more accurate studies have been carried out in only few fields. With the increasing use of computers, the possibility of including all the factors having effect on forest work becomes possible. The simultaneous use of the factors of the primary classification is generally out of question, except perhaps in scientific working.

As mentioned earlier, the classification systems of different countries are dependent on the conditions, machines and methods used therein. If this continues, one of the most important objectives, the comparability of forestry operations carried out in different countries, cannot be reached. Without a common starting point, such as a primary forest terrain classification as presented in this research, such comparisons are nationally, and even locally, impossible with respect to terrain factors.

53. Requirements set on a terrain classification system

531. General requirements

See table 2, (p. 26).

532. Comments

Requirement 1. Possibility to measure the included variable in objective, quantitative amounts. A basic requirement for a terrain description system is that subjective estimations must not have any effect on the terrain description. Subjective influences are avoided by measuring the values of variables, and by objective location of sample plots.

The requirement must also be met in secondary systems if they are derived from a detailed system.

The requirement of objectivity also includes the uniform defining and applying of variables. The terrain description of one surveyor must not differ from that of an other in the same terrain area.

Requirement 2. Possibility to measure the value of the included variable in the terrain. The requirement excludes all the variables of the historical data type (except the year of final felling) or the variables that can be measured only on a map (except latitude). This causes a restriction on the applicability of the system.

Requirement 3. System must be stable in time. The requirement for stability with time signifies that high ambitions are set on the system. A terrain classification worked out today ought to be similar with the terrain classifications of tomorrow, and this, for its part, demands that, in principal, an invariable number of variables must be included in the primary system. According to the definitions, secondary systems do not *have to* but *can* apply to new machines and machine systems. Secondary functional systems for certain purposes may perhaps have a lifetime (applicability time) of not more than 5 years. It is preferable that no need of new applications happens during that time.

Requirement 4. Possibility to complete the system in detailed description of an area. The primary classification is so composed that the need to add new variables will not arise. Instead, the vari-

Table 2. General requirements on the following examples on terrain classification systems:

A. Primary terrain classification
B. Secondary descriptive classification
C. Secondary functional classification

X = Requirement must be met (X) = Requirement ought to be met

Requirement	A	B	C
1. Possibility to measure the included variable in objective, quantitative amounts	X	X	(X)
2. Possibility to measure the value of the included variable in the terrain	X	X	X
3. System must be stable in time	X	X	
4. Possibility to complete the system in detailed description of an area	X	X	X
5. Possibility to use the system without thorough special knowledge	(X)	X	X
6. The number of variables in the system must be minimized according to the field of application	X	X	X
7. Possibility to use the system as a whole or partly for all forest work	X	(X)	
8. Terrain variables that change within time or by different actions must be measured so that predicting of future values is possible	X	X	X
9. A measure for scattering in the value of the variable measured must be included in the system	X	(X)	(X)
10. The system must match existing terrain classifications	(X)	(X)	(X)
11. Comparisons between terrain classification systems must be possible	X	X	(X)

ables included in the system are measured and expressed more precisely. The details of the secondary classification can be increased by expressing the values in accordance with the primary system.

Requirement 5. Possibility to use the system without thorough special knowledge. Classification system must be so simple that it is possible to apply the terrain description without thorough special knowledge. In cases where special knowledge is necessary to make understand the terrain description, schooling and detailed instructions are needed for field work. However, a simpler system has to be based initially on the knowledge of the user of the day.

Requirement 6. The number of variables in the system must be minimized according to the field of application. A great number of the variables in a terrain classification system demand large labour and cost inputs. Difficulties in applying the results of data collection also arise. The demand for as few variables as possible is therefore natural.

In secondary systems, inclusion of many variables reflecting the same things in regard with the application field ought to be avoided. Furthermore, if there is a high correlation between certain variables in a detailed, general system, these variables may be included in order to make it possible to derive secondary systems and make them sensible, as well as in order to make the detailed system useful in research work.

Requirement 7. Possibility to use the system as a whole or partly for all forest work. The background of this requirement is the basic idea that the primary terrain classification system ought to include all the variables that are of interest in research and which are also applicable to the field of forestry. Also, the primary terrain classification ought to be able to yield variables for all the secondary systems to be applied in forestry.

Requirement 8. Terrain variables that change within time or by different actions must be measured so that predicting of future values is possible. For planning actions and choosing their methods, information concerning terrain conditions is needed, partly concerning the time of planning, and partly the time in the future. It is impossible, however, to measure the future values of variables in the terrain, and they cannot therefore be included in a primary system. Variables which make it possible to estimate future values, may be included.

Requirement 9. A measure for scattering in the value of the variable measured must be included in the system. In any classification system, a problem of scattering within the class arises. In the object, there may be found conditions, which essentially deviate from the type determined, and may have a significant effect on the eventual activities in the object. The scattering may be expressed, for instance, as existing extremes of values, or by standard deviation of the means of the variable.

Requirement 10. The system must match existing terrain classifications. There are many advantages in indicating and measuring the included variables in an applicable way. It must be possible to release the requirement in those cases in which it is not in accordance with the aims of the terrain description.

Requirement 11. Comparisons between terrain classification systems must be possible. The variables which are in common in the primary and secondary terrain classification systems, must be measured and expressed in the same way. With regard to the fields of application, as many variables as possible must be in common in these two types of systems.

The secondary systems which are developed for different aims, cannot be compared with each other in cases where the included variables differ. Instead, comparisons with the primary system may happen.

54. Requirement conflicts

Many of the requirements mentioned are contradictory. Some of the conflicts between requirements for a primary terrain classification system are presented in the following diagram:

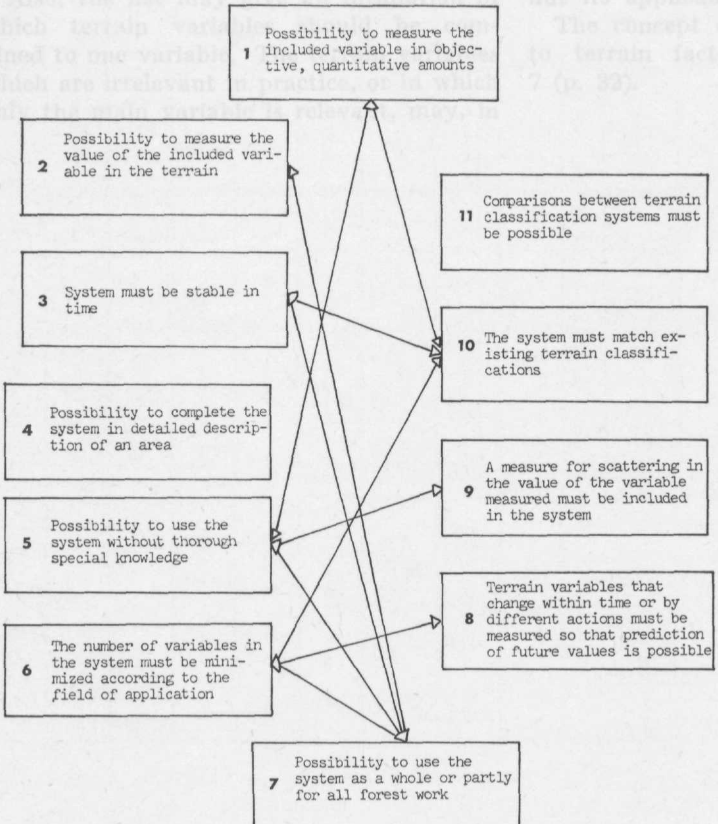


Figure 1. Contradictory requirements (<——>) set on a primary terrain classification system.

The figure reveals that the requirements concerning the simplicity of the primary system strive against the requirements for a high grade of explanation.

In formulating the detailed primary terrain classification system there has been an effort to meet with all the requirements presented. On the basis of the figure 1 (p. 27) it may be understood that deciding between conflicting requirements must happen.

6. VARIABLES RELEVANT TO FORESTRY (Variable catalogue)

61. Systematic general review

Table 3 (p. 30) includes a list of terrain variables which may be of interest in forestry. The list is considered to be a general review on the different terrain variables considered for a terrain classification system.

The separate variables have been divided partly on the basis of the fields of interest, accessibility, soil preparation and road construction, and partly on the aims of research and practice.

Interest in a terrain variable for a certain aim has been graded subjectively on the basis of different studies on the relation between the terrain and production and qualitative results, as well as detailed studies on the basic relationship between terrain and machines.

Also, the list may give an intimation of which terrain variables should be combined to one variable. The terrain variables which are irrelevant in practice, or in which only the main variable is relevant, may, in this case, act as the basis for estimating combinations.

62. Comments

Most of the factors included in the table 3 have been defined for scientific research use. As mentioned earlier, the operations of practical forestry must be based on a primary terrain classification. Many of the factors of table 3 (p. 30) are included in the list of the forest terrain factors of this classification. In the table there are some factors which have not been included in the primary classification. A conscious attempt has been made to decrease the number of factors, in consequence of which the grade of the classification is lowered, but its applicability has been improved.

The concept of this project with regard to terrain factors is discussed in chapter 7 (p. 32).

Table 3. Variables relevant to forestry, and grading of variables within fields of interest.

Declarations of marks:

P = Practice R = Research
3 = Very interesting
2 = Intermediate class
1 = Little interesting
— = Interest in the main variable
Blank = Not interesting

Dependence on time: Variables are:

A = Constant or changing in long-term
B = Changing in the term of about 5 years
C = Changing by sensons

Variable \ Field of interest	Grading: Total		Accessibility		Soil preparation		Road construction		Dependence on time
	P	R	P	R	P	R	P	R	
1. GROUND CONDITIONS									
11. *Soil type factors*									
111. Mineral soils									
Soil type to the depth of 1 dm	1	3	1	2	2	3			A
Soil type in the depth of 3 dm	3	3	3	3	3	3	3	3	A
Fine soil conditions	2	3		3	1	2	3	3	A
Stoniness	2	2	2	2	3	3	1	2	A
Boulder contents	3	3	3	3	3	3	3	3	A
Soil depth	2	2				2	2	3	A
Dry density		2		2		2		2	A
Porosity		2		2		2		2	A
Shearing resistance		2		2		2		2	A
Pressing resistance		2		2		2		2	A
E-module		2		2				2	A
Resistance to penetrating	1	3	1	3	1	3	1	3	A
Subject to frost	2	3	3	3	1	2	3	3	A
112. Organic soils									
Soil type	3	3	3	3	3	3	3	3	A
Stumps and roots	2	2	3	3	2	2	1	1	A
Share of organic soil	3	3	3	3	2	2	3	3	A
Total depth from bedrock	1	1					2	3	A
113. Outcrop of bedrock									
Proportion of outcrops of bedrock	2	3	2	2	2	2	3	3	A
12. *Soil factors*									
Humus form	1	2	1	2	1	3			A
Depth of humus — and litter layer	2	3	1	3	3	3			B
13. *Water conditions*									
Actual moisture of soil	3	3	3	3	3	3	3	3	C
Normal moisture of soil	3	3	3	3	3	3	2	3	A
Forest site type	3	3	3	3	3	3		1	A
Possibility of over-running surface water	1	2	1	2	1	2	2	3	A
14. *Conditions of strengthening surface layers*									
Roots of stumps	2	2	2	2	3	3			B
Slash	2	3	2(3*)	2	3	3			B
thickness	—	2	—	2	—	3			B
spreading	—	2	—	2	—	3			B
tree species	—	2	—	2	—	3			B
age	—	2	—	2	—	3			B
Strengthening effect of vegetation, resistance to shearing	2	2	2(3*)	2	2	3	1	1	B
Boulder contents (see 111)									

*) *for organic soils*

Field of interest / Variable	Grading								Dependence on time
	Total		Accessibility		Soil preparation		Road construction		
	P	R	P	R	P	R	P	R	
15. *Climate factors*									
Frost	3	3	3	3	1	3	3	3	C
depth	—	3	—	3			—	3	C
melting of surface	3	3	3	3	—	3	—	3	C
Snow	3	3	3	3	1	2	3	3	C
depth	2	3	2	3	1	1	—	3	C
hardness	2	2	1	3			—	3	C
snow type	—	2		2			—	2	C
density	—	2	—	2			—	2	C
Ice	2	3	3	3			3	3	C
thickness	—	2	—	3			—	3	C
consistency	—	2	—	3			—	3	C
Precipitation									
annual precipitation	3	3	3	3	3	3	3	3	A
Seasonableness of precipitation	3	3	3	3	3	3	3	3	A
2. GROUND ROUGHNESS									
Structure of surface	3	3	3	3	3	3	3	3	B
Outcropping stones and boulders	2	3	—	2	3	3	3	3	B
average height	—	3	—	3	—	3	—	3	B
spacing	—	3	—	3	—	3	—	3	B
Ground obstacles	—	2	—	2	—	2			B
average height	—	1	—	1	—	1			B
spacing	—	1	—	1	—	1			B
Stumps	2	2	1	1	2	3			B
Old windthrows	1	2	1	1	2	3			B
Ditches	2	3	2	3	2	3	2	2	B
3. SLOPE CONDITIONS									
Gradient	3	3	3	3	3	3	3	3	A
Length of slope	3	3	3	3	2	2	2	3	A
Form of slope	3	3	3	3	3	3	3	3	A
4. STAND FACTORS									
41. *Tree layer*									
density	3	3	3	3	2	2			B
diameter	3	3	3	3	2	2			B
tree species	2	2	2	2	2	1			B
group structure	3	3	3	3	3	3			B
42. *Bush layer*	3	3	3	3	3	3			B
density	—	3	—	3	—	3			B
diameter	—	3	—	3	—	3			B
tree species	—	3	—	3	—	3			B
group structure	—	3	—	3	—	3			B
43. *Development stage*	1	3		2	2	3			B

7. CONCLUDING REMARKS

71. Application problems

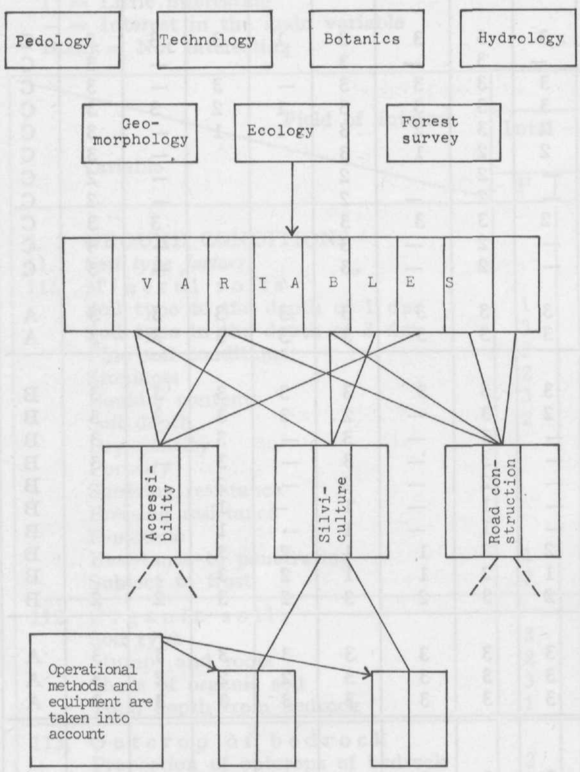


Figure 2. Schematical relations between different systems for terrain descriptions. Examples are given on some special branches of science.
The secondary terrain classifications for different aims may be descriptive and/or functional.

In the figure 2 (p. 32) some relations between different systems for terrain descriptions are presented schematically.

A primary terrain classification has been worked out within the project. This may be said to give a joint picture of the variables included in detailed partial systems.

The aim has been that the variables should be as general as possible for forestry purposes.

In many cases, the great number of details in the primary terrain classification may cause time consuming data collection work. The secondary classification is designed for a special purpose. This means that all the factors are not needed. All or some of the factors of a secondary system might be purposefully combined or coded in order to give a simplier form for data collection and registration.

The primary classification system ought to act as the basis for all secondary terrain classifications designed for practical use. Then the aim must be that as many variables as possible are in common for secondary classifications for different purposes.

When a terrain classification is necessary for solving a certain research problem, the researcher is initially directed at the primary terrain classification. The researcher may totally or partly accept the solution for a terrain description that this system offers. If the system is not applicable to the nature of the research problem, other terrain classification methods must be used. The primary terrain classification ought, however, to form the basis for choosing of variables and methods of measuring.

The nature of a research problem determines the choice of terrain variables and the method of data collection. After choosing the terrain variables relevant to the task, the degree of explanation needed for each variable (or group of variables) is defined. The following advice may be given in this:

- The variable is described according to the primary terrain classification, provided the requirement of the degree of explanation and work input for terrain description suit the nature of the research problem.
- The variable is described according to some system in a special branch of science if the explanatory value of the primary terrain classification is not high enough. For comparing with other researchers' results, the variable ought to be expressed according to the primary classification, too.
- The variable is described according to a secondary descriptive terrain classification provided this gives a degree of explanation high enough for solving of the research problem.

Terrain classifications ought to be defined with and derived from the primary terrain classification.

If the advice is followed, the values of variables that are collected in the field always relate to the primary terrain classification, either by completing information, or by defining the variable with and deriving it from this terrain classification system.

72. Grouping of factors for primary classification

The great number of factors, their partial equivalence and mutual dependence makes a simple grouping and definitions of actual factors of work more difficult.

A proposal for grouping and classifying different factors is presented in the following, however:

1. Basic conditions
   - 11. Soil factors
   - 12. Ground factors
   - 13. Water conditions
   - 14. Conditions strengthening the surface layers of the ground
2. Obstacles on ground surface
   - 21. Stones and undulations
3. Slope conditions of the ground
   - 31. Uphill slope
   - 32. Length of slope in uphill direction
   - 33. Type of slope
4. Climate factors
   - 41. Frost
   - 42. Snow
5. Vegetation factors
   - 51. Trees
   - 52. Bushes
   - 53. Field layer
6. Other factors

73. Applications and field recommendations

The terrain description according to the catalogue is aimed at sample plots of 100—2 500 m². Furthermore, the classification is intended to be used in research work.

Sample points for estimating values for single variables must be laid in a systematic square pattern in the sample plots. The sample point net is applied according to the size and figure of the sample surface. However, the sample points ought to cover and represent all the parts of the sample surface.

The number of sample points for a certain variable is given as a *recommendation.* Earlier studies within the project have been advisory for choosing the number of sample points.

In making the catalogue there has been an effort to avoid dividing of variables into classes as far as possible. In this way the catalogue becomes more applicable to different research purposes.

When measurements are carried out in many measuring points, the values of variables are given as means and standard deviations of measurings.

Recommendations apply to »normal Nordic forest terrain».

1. Basic conditions
11. Soil factors
111. Soil types

Soil types are classified using three-figure codes. The first number of the code refers to the dominant soil type at the depth of 30 cm. The main types are classified and coded in the following way:

CODE	MAIN SOIL TYPES
1	Sediment
2	Till
3	Rock
4	Humus soils

— Main types 1 and 2 (sediment and till).

The second number of the code of the soil type refers to the mechanical composition of the main type 1 or 2, which is classified as follows:

SEDIMENT	CODE	TILL, mainly comprising
Stony soil or rocky ground	1	Blocks or stony till
Gravel	2	Gravelly till
Coarse sand	3	Sandy till
Sand	4	Sandy — fine-sandy till
Coarse fine-sand	5	Sand — fine-sandy till
Fine fine-sand	6	Fine-sandy till
Silt	7	Silty till
Clay	8	Clayey till

The classification of sediments is based upon the Atterberg scale.

(The *field definition* of these *mineral soils* is found in the Appendix 1, p. 44).

The third number of the code refers to the vertical homogeneity of the soil type. If the topmost layer of 10 cm of the mineral soil is clearly coarser than the soil below it, this is marked in the following way:

CODE	VERTICAL COMPOSITION OF SOIL TYPES
0	Soil type homogeneous in vertical direction
1	Topmost layer coarser than lower layer
2	Topmost layer finer than lower layer

Examples of the codes of soil types: elutriated sandy — fine-sandy till is classified 241, 251 or 261 depending on what is the particle size of the soil type in the depth of 30 cm. The last figure of the code tells that the surface layer is coarser in its composition than the lower soil type. If the sample plot is covered by rock or the thickness of soil on the rock is less than 30 cm, the main type of the soil is considered to be rock (3). In this case the second figure of the code implies the mechanical composition of the soil on rock according to the codes presented above.

— Main type 3 (Rock)

The code 300 means naked cliff.

— Main type 4 (Humus soils)

When the main type is considered to be one of humus soils (4), the subordinate soil group type is marked according to the following classification:

CODE	SUBORDINATE GROUP OF HUMUS
410	Peat
420	Mud soils
430	Muddy clay soil
440	Clayey mud soils
450	Mud

The third figure is 0 in all the classes mentioned above.

112. Stoniness and block index

Stoniness and block index is defined as the penetration index of the soil. In every sample plot, borings are made with a soil auger to the depth, not deeper than 30 cm, to which it meets an obstacle. The depth of boring is measured in cm.

The depth of boring is measured from the upper limit of the humus layer. If a stone or block crops out of the humus layer, the boring depth is estimated to be 0 cm.

Sample points are located in a systematic square pattern so that they are well spread over the surface. It is expected that with 40 sample points the stoniness and block index may be estimated with an accuracy of 3 cm (standard deviation 9,5 cm, 95 % level of significance).

The index is given as its mean value in cm with its standard deviation.

113. Depth classes of soil types

The depth of a soil type is estimated on the basis of terrain conditions and classified as follows:

a. Mineral soils

CODE	AVERAGE DEPTH OF SOIL, m	
1	2,0+	Abundant
2	0,7—2,0	Rock bed visible to some extent
3	0,2—0,7	Rock bed generally visible
4	0,0—0,2	Rock bed extensively visible
5		Varying soil cover, steep breaks

In estimating the depth of loose soil, the depths of humus and mineral soils are summed. For a more accurate description of defining soil depth, see the appendix 2.

b. Humus soils

CODE	AVERAGE DEPTH OF SOIL TYPE, m	
1	2,0	Very abundant
2	0,7—2,0	Abundant
3	0,2—0,7	Normal
4	0,0 —0,2	Thin

The depth is measured to the mineral soil. (Appendix 2).

12. Ground factors

121. Humus types

Humus types are classified into four classes as follows:

CODE	HUMUS TYPE
1	Peat
2	Dry peat
3	Transition between dry peat and mould
4	Mould or rich soil

The humus type is classified to be peat, if the soil type is peat (410), and its depth is more than 30 cm. According to this classification, dry peat is humus soil with a thickness less than 30 cm. Mould is a composition of humus and mineral soils.

More accurate definitions of humus types are found in the appendix 3.

122. Thickness of humus and litter layer

The thickness of humus and litter layer (cm) is given as a mean value and standard deviation on the basis of measurements. The number of measurements is recommended to be at least 10. The upper limit of measuring is estimated from the level at which green parts of plants begin to be found. Usually the limit between mineral soil and dry peat and peat is clear. The limit of rich soil is also clear and in this case is defined as the depth which has been reached by treatments of the ground surface (ploughing, etc.). Determining the depth of mould is often difficult because there is usually a transition zone between mould and mineral soil. In this case the lower limit of the humus layer is estimated to be in the middle of the transition zone.

13. Water conditions

131. Normal moisture

The *moisture classes of the soil* are coded in the following way:

CODE	MOISTURE CLASS OF SOIL
1	Very dry
2	Dry
3	Fresh
4	Fresh-moist
5	Waterlogged
6	Very waterlogged

See appendix 4, in which the motions of free water and their significance are explained.

132. Prevailing moisture conditions

Prevailing moisture conditions are defined according to the water conditions of the ground in the following way:

CODE	PREVAILING MOISTURE CONDITIONS
1	Dry
2	Intermediate
3	Wet

Describing of the prevailing moisture class has been carried out in the following way:

1. Dry soil has been without rain for a long time
2. Intermediate
3. Wet means that the soil has received intermittent precipitation when the humidity of air is low, or on which rain has fallen for a longer time when the humidity of air is high.

133. Precipitation

Annual precipitation is given in mm.

14. Conditions strengthening surface layers

141. Stumps

Stumps are counted as the number of stumps/ha. The data is given as the number of stumps/ha, mean diameter and height and their standard deviations. The lowest limit of stumps included is given within parenthesis.

A stump is included if it withstands a kick without breaking. (More accurate information about measuring of stumps, appendix 5).

142. Logging slash

— *The share of slash cover* is given as a percentage of the area of a sample plot. The share of covering is estimated in four cases, as follows:

a. Share of covering for all slash
b. Share of covering for slash with thickness ≥ 10 cm
c. Share of covering for slash with thickness ≥ 25 cm
d. Share of covering for slash with thickness ≥ 40 cm

where $a \geq b \geq c \geq d$, and the limits of the classes are applicable after slight depressing with the foot.

— *Thickness of slash cover* (cm) is measured with a measuring stick in the places where slash has gathered. The heap is slightly depressed with the foot before measuring.
— *The tree species* content of the slash (%) is estimated with an accuracy of 10 %. All the slash is included in this estimation.
— *Age of slash* (years) is defined on the basis of the time between harvest and inventory.
— *Condition of logging slash* is classified as follows:
1. Brittle and slender branches and tops without bark and needles or leaves
2. Intermediate class
3. Dry and relatively slender branches and tops
4. Intermediate class
5. Fresh, poorly breaking branches with green needles or leaves
(A more accurate classification is given in appendix 6).

2. Obstacles on ground surface

21. Stones and undulations

Stones and undulations are classified according to both the relative relief and the average distance. An example of the secondary classification of obstacles is given in appendix 10. (Instructions for measuring stones, rises and depressions, appendix 7).

3. Slope conditions

31. Uphill slope (%)

is measured by a clinometer and its compass direction.

32. Length of slope in uphill direction

33. Slope types are classified as follows:

CODE	SLOPE TYPE
1	Even or sloping less than 2 %
2	Undulating or hilly
3	Evenly sloping
4	Terraced

4. Climate factors

41. Frost

— Depth of frozen soil

Depth from the ground surface to the lower edge is given in cm, and it is determined by R. Grandahl's method. In this method a protective tube is plunged into soil, and an inner tube with water in it (dyed with methylene blue) is set into it. The frozen liquid becomes light, and its thickness can ensily be read in the scale of the inner tube.

— Melting of frost surface

The depth of softening to the edge of frost is given in cm, and it is determined with a soil auger by at least five insertions in different places in the sample plot.

42. Snow

— Depth of snow

The depth is given as the mean of at least 10 measurings. The measuring points should represent the average snow conditions of the whole sample plot.

— Hardness of snow (structure)

The structure is coded and tested by digging out the layer profile of snow on a place that represents the sample plot in average. The effect of the structure of snow is measured and classified as may be seen in appendix 9.

5. Vegetation

51. Trees

The data is normally collected according to a forest survey method.

a. No. of stems/ha
b. Average height of stems, m
c. Share of covering, %
d. Distribution of stems
   1. Even distribution of stems
   2. Somewhat uneven distribution of stems
   3. Grouped distribution of stems

52. Bushes

— Ground vegetation
means low trees, woody bushes and low shrub, the height of which usually is more than 0,8 m.

53. Field layer

consists of seedlings, undergrowth, grass and herbaceous vegetation, the height of which is less than 0,8 m. The share of covering is given in %.

6. Other factors

— If there are other factors in the area to be classified, in addition to those mentioned, that have an effect on the time consumption during working (e.g., exceptionally high stumps, extra soft peatland, depression in the driving direction), they are taken into account in a suitable way, and marked in the remark column of the classification form.

74. Arguments for the grouping of factors mentioned, and for the classification of groups

There has been an effort to pay attention to the following facts in grouping of different terrain factors, and in classification of these groups:

a. Meeting the requirements set earlier on different classification systems (chapter 5).
b. Including the terrain factors that are considered to have effect on »any» work phase, when using the terrain as traffic or working environment (chapter 6).
c. Results of studies carried out within this project.
d. Other investigations carried out at the same time with this project by corresponding projects and institutes, with which there has been a direct contact.
e. Making use of the studies mentioned in the list of references.

— As may be noticed, not all the factors found in table 3 are included in this grouping. Even so, the number of factors and classes is so great that their simultaneous inclusion may be recommended only on small sample plots and with scientific aims. According to the criteria adopted in this project, the only way of using this classification succesfully in practice is to work out a classification form based on this grouping and classification for each different work phase (e.g., »Terrain classification for mechanized silviculture», appendix 8), in which only the significant terrain factors are considered, and their definition is guided by the columns of the form to match the classification.

Because a terrain factor may cause different troubles for different work phases, the separate effects of a terrain factor on, say, wages, must be left to the agreements on terms of work concerning either the State or the contracting parties. This has happened for some time in Finland. In order to make comparisons possible, the definitions of work difficulty factors ought to be based on a uniform classification, i.e. a primary terrain classification.

75. Remaining work

— Developing of a secondary terrain classifications system has not been included in this project.
— Developing a secondary system may be accomplished according to the following example:

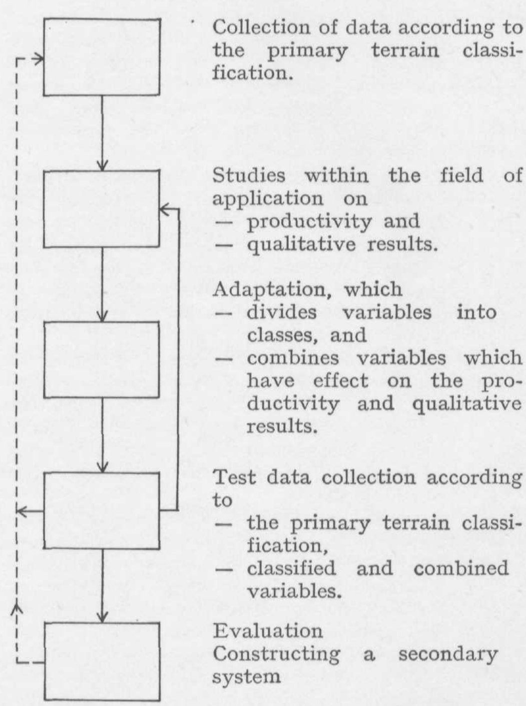


Figure 3. Flow diagram of secondary terrain lcassification construction.

All the time, the primary classification and the variable catalogue (table 3, p. 30) act as the basis for deriving and defining of variables in the secondary system.

In parallel with the development of a secondary scheme for practical application, the basic relation between the terrain and machines must be studied. Both the primary terrain classification system with further refinements and description systems from adjoining branches of science, may be utilized for this. The results of these studies may express the need for new variables and measuring methods, or demand more nuances to the class division in the secondary system. In this case the secondary system may be completed based on a certain variable or a new class, critical to a certain forestry activity.

SUMMARY

The change in military tactics during the latter part of the 19th century initiated the development of cartography. The mechanization of hauling, which took place in the field of forestry in the 1950's, further added to the need for a terrain classification. Different terrain classifications based on different terrain factors have been developed in many countries. In the meeting of IUFRO Section 32 held in Montreal in 1964, it was found that a general system was needed for measuring and describing those terrain conditions having a significant influence on forest operations.

The requirements for such a classification system are given in table 2 (p. 26). Because some of the requirements are contradictory, the classification must be a compromise. The most important factors from the forestry point of view are presented in table 3 (p. 30).

The terrain classification presented in this report consists of two stages, see figure 2 (p. 32). The first stage is a primary terrain classification, in which terrain factors are measured or described objectively. The second is a secondary descriptive classification. Only factors essential to the activity in question are taken into account. After this, in a secondary functional stage, the requirements of the employer of the system, e.g., working method, machines, etc., are also taken into account.

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YHTEISPOHJOISMAINEN METSÄNTUTKIMUSPROJEKTI »MAASTO-KONE» 1972—75

1800-luvun jälkipuoliskolla alkanut sotataktiikassa tapahtunut muutos aiheutti myös kartografian kehityksen. Metsäsektorilla puutavaran juonnon koneellistaminen 1950-luvulla lisäsi maastoluokituksen kehittämistarvetta. Eri maissa kehitettiin maastoluokituksia yleensä toiminnoittain perustuen eri maastotekijoihin. Vuonna 1964 IUFROn 32. Sectionin kokouksessa Montrealissa todettiin kuitenkin, että tarvitaan yleistä systeemiä niiden maastotekijöiden mittaamiseksi ja kuvaamiseksi, joilla on vaikutusta metsätalouden kannalta.

Tällaiselle luokitussysteemille asetettavat vaatimukset esitetään taulukossa 2 (s. 26). Koska osa vaatimuksista on vastakkaisia, luokitus joudutaan tekemään kompromissinä. Metsätalouden kannalta tärkeimmät maastotekijät esitetään taulukossa 3 (s. 30).

Raportissa esitetty maastoluokitus on kaksivaiheinen, ja sen periaate esitetään kuvassa 2 (s. 32). Ensimmäinen vaihe on primäärinen maastoluokitus, jolloin objektiivisesti mitataan tai kuvataan maastotekijöitä. Sekundäärisessä kuvaavassa luokituksessa on otettu mukaan vain ko. toiminnan edellyttämät muuttujat, mutta edelleen objektiivisina. Tämän jälkeen, sekundäärisessä toiminnallisessa vaiheessa mukaan tulevat käyttäjän vaatimukset, esim. työmenetelmä, koneet jne.

FIELD DEFINITIONS OF MINERAL SOILS

Code	Soil type	Rolling test (thread thickness)	Stroking test (with fingers)	Tearing test (with a glass staff)	Remarks	Particle size, mm
1.	*Sediment soils (assorted soils)*					
11.	Gravelly soil and stones	—	—	—	Defined visually. Gravelly soil comprises smooth round stones or boulders. Fields are formed by waves in a shoreline, e.g., the highest coast lines. No fine material between stones and blocks.	>20
12.	Gravel	Cannot be rolled	Doesn't hang together	Cannot be formed		20–2
13.	Coarse sand	»	»	Forms only weakly	Compare with type tests	2–0,6
14.	Medium sand	»	»	»	»	0,6 –0,2
15.	Coarse fine sand	»	Very loose. Scatters.	Very deep furrow. Insignificant consistency.	Compare with type tests. Mineral particles visible to the naked eye. Single grain structure.	0,2 –0,06
16.	Fine fine-sand	6–4 mm	Sprinkles very strongly. Coarse powder.	Very deep furrow. Weak consistency	Grains are hard to see with the naked eye. Forms lumps in dry condition. Very liable to solifluction.	0,06–0,02
17.	Silt	4–3 mm	Sprinkles very strongly. Mealy powder.	Very deep furrow. Rather good consistency.	Forms lumps in dry condition. Liable to solifluction and sticky in wet condition.	0,02–0,002
18.	Loamy soils	3 mm	Sprinkles strongly-very strongly	Deep and broad mat furrow	—	
19.	Stiff clayey soils	2–1 mm	Sprinkles weakly-doesn't sprinkle	Mat or gleaming furrow	—	
2.	*Moraine soils (unassorted soils)*					
21.	Bouldery soil and stony moraine	—	—	—	Defined visually. Stones and boulders of even size. Found in screes and taluses.	
22.	Gravelly moraine	—	—	—	Plenty of gravel grains, few smaller particles, except sand. Often abundant in stones.	
23.	Sandy moraine	Cannot be formed or rolled	—	—	Sand particles dominating. Usually moderately stony with boulders.	
24.	Sandy–fine sand moraine	Can be formed but not rolled	—	—	If a little of the sample is soaked with water, a lot of sand remains in hand. Rattles.	
25.	Sandy – fine sandy moraine	6–4 mm	—	—	When saturating, a moderate amount of sand remains in hand. Rattles weakly.	
26.	Fine sandy moraine	4–3 mm	Small amounts coarse powder	—	When saturating, an insignificant amount of sand remains in hand. Has a sticky, doughy feel. Small amounts of rough powder.	
27.	Silty moraine	3 mm	Sprinkles strongly	—	Sprinkles strongly. Becomes sticky and liable to solifluction when saturated.	
28.	Clayey moraines	2 mm	—	—	When rolled, existance of coarse grains can be felt. Usually poor in stones.	

(TROEDSSON and NYKVIST 1974, BJÖRKHEM et al. 1975)

APPENDIX 2

DEFINING SOIL DEPTH

The soil depth is determined in the following way: (with pits to the depth of the scoop of a shovel)

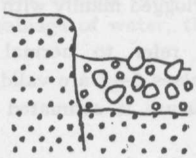
1. *Very deep.* Outcrops of bedrock cannot be found in the sample plot, or in its nearest surroundings. The average depth of soil > 2 m.

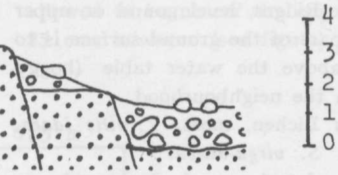
2. *Deep.* No outcroups of bedrock are found in the sample plot or within 50 m, when the topography is the same. No outcrops are met in pits. The average depth of soil 0,7–2 m.

3. *Rather shallow.* Detached, visible outcrops of bedrock are found 20–50 m from the sample plot. Rock is usually met in 1 of 5 pits. The average depth of soil is 0,2–0,7 m.

4. *Shallow.* Bedrock is met in at least 3 out of 5 pits. The number of outcrops is great. The soil may be deep in small crevices in the bedrock. The average depth of soil 0–0,2 m.

5. *Very varying soil cover.* An example of very varying soil cover. Outcrops of bedrock are found near the sample plot, as well as in it. The depth of soil cover varies greatly. The sample plot cannot be included in rather shallow (3) or shallow (4).





The depth of *organic soil* (the soil type coded 410 or 420) is classified with the same class lines as mentioned. The depth is estimated then as a mean value after at least 5 insertions by a soil auger in the sample plot. Insertions are made to mineral soil:

1. Very deep (> 2m)
2. Deep (0,7–2 m)
3. Rather shallow (0,2–0,7 m)
4. Shallow (0–0,2 m).

APPENDIX 3

HUMUS TYPES

Humus form. The humus form is classified into one of four classes:

1. Peat
2. Raw humus
3. Transition form between raw humus and mould
4. Mould and rich soil

1. Peat. In peat, the degree of humification is so low that the different plant remains may be identified. Plant remains originate from the plant community existing in that place when the peat was formed. Peat is not mixed with mineral soil. The depth of humus layer must be at least 30 cm. (Soil type coded 410, peat).

2. Raw humus. Raw humus usually lies as a carpet over mineral soil, and consists of humus with roots and mushroom hypha. Raw humus is not mixed with mineral soil. In the upper part of raw humus there are easily recognizeable plant remains. Under this, there follows a feltlike layer with plant remains, finer roots, mushroom hypha and structureless substance. The lower part of raw humus consists of structureless dark humus. The upper part of the undelying mineral soil is usually mixed with structureless humus, usually 0,5–2 cm. If the depth of raw humus cover exceeds 30 cm, the humus is classified to be peat.

3. Transition form raw humus — mould. Active raw humus, where the layer with humus mixed with mineral soil is > 2 cm, is included in this class. A thin feltlike layer with plant remains, finer roots, hypha and structureless substance must be found in the upper part of the humus layer.

4. Mould. In mould, all the humus is mixed with mineral soil. In mineral soils mixed with humus, the humus content decreases with depth, and mould conforms with the underlying layer (usually B-horizon in brown earth) without a sharp line. Mould lacks the feltlike layer that is found in raw humus. Mould is usually covered, for the most part, with a thin litter layer. Big earthworms are found in mould. If soil includes clay mould has an aggregate structure.

APPENDIX 4

MOISTURE CONDITIONS

Normal moisture of soil. The normal moisture of soil is classified on the basis of topography and some indicator plants according to the following classes:

1. Very dry soil (MT) is represented by terrain which lies either on ridges or consists of level ground on heavy alluvions of glacial rivers, or by eskers. It is rarely met with on moraine sites, but if so then on very coarse-textured soils. Water running off from surrounding ground should not occur, groundwater should not be found even when digging deep.

Indicator plants: *Cladonia ragifera, Stereocaulon, C. pyxidata, Vaccinium vitis idaea, Empetrum nigrum, Solidago virga-aurea, Arctostaphylos uva-ursi.*

2. Dry soil (T). Ridges, level gound or upper slopes. The main part of the ground surface is to lie at least 2 m aoove the water table (boggy depressions etc.) in the neighbourhood.

Indicator plants: Lichen, moss, *V. vitis idaea, Empetrum nigrum, S. virga-aurea.*

3. Fresh soil (F). Level ground, slopes or lower slopes without visible surface runoff. The level of groundwater must be at least 1—2 m below the surface.

Indicator plants: *Pleurozium, Hylocomium, Dicranum, Vaccinium myrtillus.*

4. Fresh to moist sites (FF). Level ground at the bottom of higher ground, the bottom part of slopes. After heavy rain, or during snow melt, water collects for short periods in small depressions. Sometimes the trees stand slightly raised, and this might indicate that the terrain has been moist. Groundwater level less than 1—1.5 m below the surface.

Indicator plants: *Ptilium, Polytrichum,* liverwort, *Hylocomium, V. myrtillum.*

5. Slightly waterlogged sites (NV). Occasional swampy areas with stagnant water or areas which often contain water for a number of days. Frequently hummocky.

Indicator plants: *Mnium, Sphagna, Polytrichum, Hylocomium, herbs, grass, Equisetum.*

6. Very much waterlogged (MV). Areas where water collects frequently or permanently.

Indicator plants: Peat moss, fen moss, brown moss, *Equisetum, Eriophorum,* Elkgrass sedge, *Dryopteris, Caltha palustris, Comarum pallustre, Rubus chamaemorus.*

During estimation, attention is paid to how the conditions outside the sample plot have influenced the soil in the sample plot. If the soil depth is < 2 m, the moisture of soil is classified on grade drier than the result obtained from the description. This rule is not observed if it is evident that the depth of soil doesn't have any effect on the moisture of the soil. (Terrängtypschema . . . 1969)

Surface and profile drainage. Surface and profile drainage are estimated in the sample plot. Factors are classified in accordance with the following division:

1. Access to moving water lacking
2. » » » » seldom exists
3. » » » » likely for short periods
4. » » » » likely for longer periods
5. Location on a slope
6. Very waterlogged with moving water
7. Very waterlogged mainly with standing water

Classes 1—5 refer to normal soil moisture classes 1—5. Classes 6—7 are valid only when the normal soil moisture is estimated to be 6 (very waterlogged).

In estimating this factor, attention is paid of effect the conditions outside the sample plot have had on the possibilities for surface and profile drainage in the sample plot.

The classification is made according to the following description:

1. Access to moving water lacking. Terrain in isolated higher areas, extensive level areas (level ground = slope < 5 %), which cannot be thought to receive any water from sides. Swampy areas belong to this class, too, as well as areas with a top or a ridge in the sample plot.

2. Access to moving water seldom exists. This class consists of terrain on level ground near slightly higher areas from which it is possible that the sample plot receives water during or after precipitation. The uppermost parts of slopes are included in this group. The whole sample plot must, in this case, be situated on the slope.

3. Acces to moving water likely for short periods. Terrain in slopes or on level ground which are receiving water are included in this group. In the case of 5—15 % slopes the sample plot must be situated within about 40—150 m from the top. When the slope is > 15 %, the sample plot must be situated within about 30—100 m from the top. Level ground within about 25 m from the foot of this kind of slope is also included in this class.

4. Access to moving water likely for longer periods. The sample plot may be situated on a slope as well as on level ground below shedding area greater than that mentioned in the former class, but still within about 25 m from the foot of the slope.

5. Location on a slope. Fresh-moist soils in the central or lower parts of a slope are included in this group, situated at least 250 m from the top, and with a slope of > 10 %, as well as fresh-moist soils situated immediately below slopes of at least 300 m, and with a slope of > 10 %. The area is not permitted to be more than 50 m into level ground from the foot of the slope. N. B. Slightly or very waterlogged soils must be classified into this group.

6. Very waterlogged soils with moving water. Outlets of swamps are included in this class. The moisture of soil must be very waterlogged.

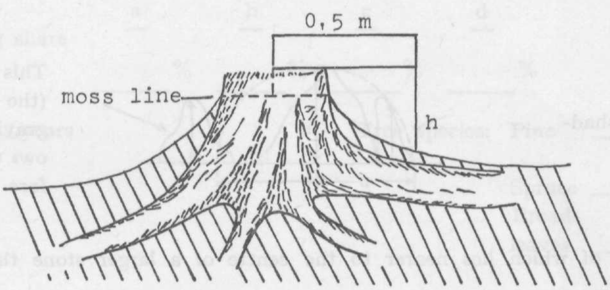
7. Very waterlogged soil mainly with standing water. If human actions have influenced surface and profile drainage of water, the reason for this is observed, e.g., a road or ditch cuts accross the slope aboveth e sample plot. (Instruktion . . . 1975)

APPENDIX 5

MEASURING OF STUMPS

Height of stumps. The mean value for the height of the stumps counted is expressed in cm for the stumps under bark.

The height of stumps is measured as a vertical distance from the top of a stump down to the ground surface at the distance of 0,5 m from the centre of a stump. The measuring point is not allowed to be nearer the edge of the stump than 25 cm, however (see figure).



In sloping ground the height of the stump is measured on both downhill and uphill slopes, and the mean value calculated.

Stump diameter. The mean value of the diameters of counted stumps is expressed in cm for stumps ≥ 12 cm under bark.

The stump diameter is measured on the cut surface of a stump by convenient diameter measure. The measurement of the diameter under bark is made with caliper.

APPENDIX 6

LOGGING SLASH CLASSIFICATION

The condition of logging slash is classified in one of the following classes:

1. Brittle slash
2. Intermediate class
3. Dry slash
4. Intermediate class
5. Fresh slash

1. Brittle slash. Branches are totally free of needles and bark. About 2 cm thick branches are broken without difficulty with slight bending.

2. Intermediate class

3. Dry slash. The branches of conifers must not have needles left on exposed limbs. About 2 cm thick branches of conifers and broad-leaved trees are broken with some difficulty with bending. With some difficulty it is possible to remove the bark that is left in thicker branches.

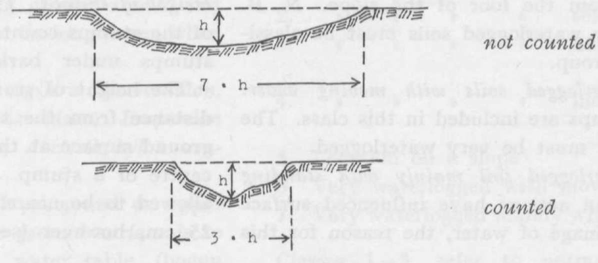
4. Intermediate class

5. Fresh slash. In this class the branches of conifers and broad-leaved trees must withstand much bending before breaking. Barking the thicker branches is difficult.

APPENDIX 7

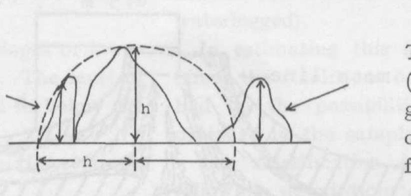
GROUND SURFACE CLASSIFICATION

Depressions should have clear edges and be well defined, and should be *at least 20 cm* deep by reference to the ground surface. Depressions with a mean diameter more than 6 times the depth are not taken into consideration unless the edges are very steep.



Groups of stones

This stone lies in the »shadow»; not counted

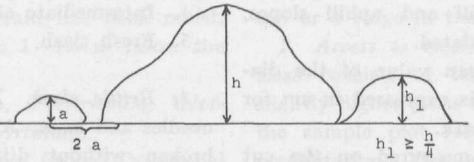


This stone has its centre (the imaginary centre of gravity) outside the »shadow» of the big stone, therefore it is counted

Rule 1

A stone the centre of which lies nearer to the centre of a larger stone than the height of the latter is not counted.

The centre of the small stone lies nearer to the circumference of the larger stone than twice the height of the smaller stone. Not counted



The height of the small stone is more than a quarter of that of the large stone. Counted

Rule 2

A stone which has its centre nearer to the periphery of another but larger stone than twice its height is not counted if its height is less than a quarter of the height of the larger stone. (Terrängtypschema... 1975)

APPENDIX 8

TERRAIN CLASSIFICATION FOR MECHANIZED SILVICULTURE

M = Mean value
D = Diameter
N = Number
C = Code

Operation no. _____ Sample plot no. _____ Date: 197 -

1. Basic conditions

Soil type C____

Stoniness index M____cm D____cm (N____)

Soil depth C____

Humus type C____

Thickness of humus layer M____cm D____cm (N____)

Soil moisture C____ Prevailing moisture C____

Stumps N/ha____ Diameter M____cm D____cm (Min.____cm)

Height M____cm D____cm

Logging slash: a b c d

Covering share ____% ____% ____% ____%

Age____years

Tree species: Pine ____%

Spruce ____%

Broad-leaves ____%

Effect on: Bearing capacity ____

Soil preparation ____

2. Ground roughness

Class of ground roughness C____

3. Slope conditions

Uphill gradient ____% Compass direction ____°

Length ____m Type of slope ____C

4. Vegetation

Share of covering: Field layer ____%

Bushes ____%

Trees ____%

5. Remarks ____

APPENDIX 9

DESCRIPTION OF SNOW CONDITIONS

Snow depth (decimeter). Measure on several points within that part of the area where work is in progress. The *mean* depth is given to the nearest dm (10 cm).

A snow profile is dug out on a representative point where work is in progress. Hardness is measured by means of a hand test[x]).

Hardness classes

1 The snow is throughout of hardness I according to the hand test

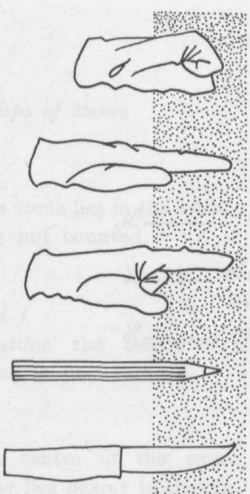
2 Maximum 1/3 of hardness II, maximum 1/20 of hardness III

3 1/3–2/3 of hardness II, maximum 1/10 of hardness III

4 More than 2/3 of hardness II, maximum 1/5 of hardness III

5 More than 2/3 of hardness II, more than 1/5 of hardness III

x) Degrees of hardness by the hand test. The following objects can be pushed into the snow »without major effort».



Grade I a gloved fist

Grade II a gloved hand, flat, fingers outstretched

Grade III a gloved index finger

Grade IV a sharpened pencil

Grade V a knife

APPENDIX 10

DEFINING STONES AND UNDULATIONS ON THE GROUND SURFACE

Average distance of obstacles (m) in the cases allowed in the obstacle height classes a, b, . . . , i.

Structure class of ground surface	Typical height class of obstacle	Allowed cases	Height class of obstacle, cm			
			20	40	60	80
			Average distance of obstacles, m			
1	H (20)	a)	1,6— 5,0			
		b)	5,0—16,0	>16,0	>16,0	>16,0
2	H (20—40)	a)	< 1,6	>16,0	>16,0	>16,0
		b)	1,6— 5,0	5,0—16,0	>16,0	>16,0
3	H (40—60)	a)	< 1,6	1,6— 5,0	16,0	>16,0
		b)	< 1,6	1,6— 5,0	5,0—16,0	>16,0
4	H (40—80)	a)	< 1,6	< 1,6	5,0—16,0	5,0—16,0
		b)	1,6— 5,0	1,6— 5,0	1,6— 5,0	5,0—16,0
5	H (40—80)	a)	< 1,6	< 1,6	1,6— 5,0	5,0—16,0
		.				
		.				
		.				
		i	< 1,6	< 1,6	< 1,6	< 1,6

CODE	STRUCTURAL CLASS
0	Surface fully free of stones
1	Very even ground surface
2	Intermediate class
3	Slightly rough ground surface
4	Intermediate class
5	Very rough ground surface

APPENDIX 11

RESULTS FROM PARTIAL STUDIES (ABSTRACTS)

1. Rihko Haarlaa: Puutavaran maastokuljetus traktorilla. Summary: Timber Skidding by Tractor. Kustannuslaskentatekninen tarkastelu — A study on Calculation of Costs. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 7, 1970. 59 p.

To analyze the background for the future terrain-machine studies, the fundamentals behind the timber transport costs in terrain were studied. The main emphasis was laid on the relationships causing changes in the unit costs in terrain transport of timber.

The cost calculation techniques useable for this purpose were reviewed first on the basis of literature. Three sheets for cost calculations were designed one for collecting the data, the second for calculating the time-unit-costs and the third for finding out the transport output and the cubic-unit-costs.

Based both on literature and empiric data examples on the variation of transport costs were given for four tractor types commonly used in this job. Especially the role of the time consumption in driving was stressed as a regulating factor. The use of cubic-unit-costs in decision-making was illustrated with two examples, too.

2. Rihko Haarlaa: Maaston ja kuorman vaikutus metsätraktoreiden ajonopeuteen. Summary: Effect of Terrain and Load on the Driving Speed of Logging Tractors. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 9, 1971. 76 p.

The effect of primary terrain factors and the size of load on the driving speed of logging tractors was studied in test conditions. The tests were arranged with four tractor types during the winter, the spring and the summer 1969. Parallel test lanes were driven several times by tractors with no, half or full load. The time consumption in driving was tallied according to the uniform parts of the terrain route.

The terrain conditions were classified on the basis of ground, ground roughness and slope factors. Ground factors were the thickness of the humus layer, the soil type and the moisture of soil. The amount of rocks, stumps and logging waste was measured describing the ground roughness. The gradient of the route was measured in driving direction. In winter the thickness and the quality of snow were taken up, too.

As results in the report the effect of different terrain factors, load size and tractor type were given. Mathematical models were developed for the variation in driving speed. In any case the effect of different affecting factors proved to be a joint and problematic one. Some guidelines for a secondary classification of terrain in timber transport was given, at the end of the report.

3. Unto Silvennoinen & Rihko Haarlaa: Metsätraktoreiden liikkuvuus lumessa. Summary: The Mobility of Logging Tractors on Snow. Silva Fenn. 5(2): 145–167, 1971.

When studying the effect of terrain and other environmental factors on the work of logging tractors some driving tests were arranged with ten different types or models in very difficult snow conditions of North-Finland in 1969. The effect of the thickness of the snow layer and its quality, the number of the snow layer and its quality, the number of passes made on the same route, the size of the load and the gradient in the driving, direction on the tractor's mobility was studied by using the driving speed as main variable.

Significant differences in the mobility of different tractors were observed. The higher number of passes made due to the packing phenomenon and the favourable changes in the snow quality — especially getting wet — the driving faster and bigger loads possible.

As a central, directly applicable result it was noted the very favourable effects of the long and bearing tracks and of the powerful frame-steering, as compared to the use of other structural components when operating on dry deep snow.

4. Rihko Haarlaa: Lisättyjen konekomponenttien vaikutus metsätraktoreiden maastokelpoisuuteen. Summary: Effect of Additional Machine Components on the Mobility of Forest Tractors. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 15, 1972. 31 p.

Four series of orienting tests were arranged with the aim of evaluating the effect of additional machine components on the mobility of forest tractors in 1970–71. The driving speed was used as the main criterion of the mobility. The observations were made and the values of all the terrain factors were measured at each homogeneous part of the test lane. Mathematical models were developed for explaining the variation in driving speed; the value of each terrain factor explaining the variance was examined.

It was found out in the tests that JUKKA grapple and PIKA 50 processor decreased significantly the mobility of VALMET 880 S skidder. On the other hand, LOGMA T-300 processor did not decrease the mobility of the basic machine (SMV Drivax). The same conclusion was reached in case of VOLVO ÖSA -feller-buncher as compared to BM VOLVO SM 868 forwarder. The effect of terrain factors on the driving speed was also indicated in the report.

The mobility of logging machines must not be decreased when increasing the level of mechanization, because all harvesting will be made by machines in the future. The mobility of all new equipment should be tested in advance in test track conditions, since conclusions based on earlier models often seem to be misleading.

5. Rihko Haarlaa: Kuormatraktorin ajomatka puutavaran metsäkuljetuksessa. Summary: Driving Distance of Forwarders in Forest Transportation of Timber. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 16, 1972. 34 p.

The goal of the study was to analyze the length of the driving distance of forwarders and the possible effect of terrain factors on it both theoretically and by using empiric data and, in addition, to develop a mathematical prediction model for estimating the driving distance on the basis of external variables. Data for the study was collected in 1970–71 during 217 working days from two tractors working on 17 logging operations. Automatic recorders were used in collecting data. As result of the study the empiric daily driving distances and the distances driven per turn, in addition to the load sizes, were given in the report. The factors affecting the driving distance were analyzed on the basis of correlation coefficients. The highest correlations were found between the amount of timber cut in one logging site or the number of loads calculated from it, and the variables indicating ground roughnessa nd gradients in the area. The theoretical model developed proved to have a very high prediction value in the empiric data. When determining the driving distance of present forwarders, no terrain variables are needed. The effect of terrain is mixed with the other affecting variables. At the end of the report some recommendations for practical logging operations in this respect were also given.

6. Rihko Haarlaa: The effect of terrain on the output in forest transportation of timber. Seloste: Maaston vaikutus puutavaran metsäkuljetustuotokseen. Acta For. Fenn. 128, 1973. (Also printed in Journal of Terramechanics Vol. 12, No. 2, Sept. 1975: 55–94).

The purpose of this report was to combine the results gained in the earlier studies of the project and to find out the final effect of terrain factors on the output in forest transportation of timber. The first part of the report includes a summary of conclusions from five earlier reports dealing with terrain transportation costs, effect of terrain, load, snow and additional machine components on the mobility of forest tractors and the distance a vehicle has to move in forest transportation of timber. In the second part of the study the effect of these separate factors on the transport output was analyzed on the basis of simulating the transportation of 3 000 loads by computer. It was concluded that no one of the separate terrain factors proved to have a dominating effect on any component of the forwarding output, but their effect exists always as a joint one. It was possible to identify many terrain factor combinations with a nonsignificant effect on the mobility and also on the forwarding output of forest tractors. The most significant factors affecting the output were the size of load and the distance driven during the cycle.

7. Rihko Haarlaa: Eräitä ennakkotietoja Suomen metsämaaston vaikeuden alueittaisesta vaihtelusta. Summary: A Preliminary Report on Areal Differences in Finnish Forest Terrain. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 11, 1971. 32 p.

To get a rough idea on the areal differences in Finnish forest terrain and to test the suitability of a so-called roadside inventory for terrain inventories, some 50 % of all roads in a part of the country were driven by car and the type of forest terrain on roadsides was observed according to its macro- and microtype in 1965–69.

It was found out that the macrotype of terrain can be sufficiently defined already on the basis of large-scale topographic maps. The microstructure of terrain cannot be defined from present maps or aerial photographs, however. The results of the inventory were given in the report in maps and tables. Because the roads are located in an easier terrain than on average, the percentages presented are not absolutely correct, they only indicate the relationships in question. The skewness of the results of the roadside inventory was left to a separate study.

8. Rihko Haarlaa: Eräillä suuralueilla maastovaikeuden inventointimenetelmillä saatuja tuloksia. Summary: Some Results of the Terrain Difficulty of Large Areas Gained by Using Different Inventory Methods. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 12, 1971. 53 p.

The goal of the study was to present a synthesis on the results gained at the Dept. of Logging and Utilization of Forest Products, University of Helsinki in the inventories concerning the difficulty of forest terrain in Finland in 1965–69. The main emphasis was laid on the differences in the results of the three different inventory methods, the so-called roadside inventory, the roadside line inventory and the line plot inventory.

As results it was proved that the roadside inventories do give skewed data on the areal terrain factors due to several reasons, and that those results must be corrected using, for example, some coefficients. Quantified results were given on the corrections needed in case of each measured variable. In addition, the intercorrelations among different terrain factors were analyzed, and estimates on their joint effect were presented. As proposals for future design of terrain inventories, the utilization of random inventory lines together with the development of corresponding mapping methods, were stressed. In any case, only the needed and permanently measurable entities should be included in the inventories and mappings.

9. Rihko Haarlaa: Maastotekijöiden vaikutuksesta metsämaan laikutukseen. Summary: On the Effect of Terrain to Scarifying of Forest Soil. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 23, 1973. 48 p.

As a pilot study on the effect of terrain on mechanical forest soil preparation some data on a skidder-scarifier was collected in 1972. The data comprised 60 operations during 39 working days and included 380 sample plots for defining the factors affecting the effective scarifying time.

The type of soil, the moisture of soil, and the stoniness index proved to be significant ground factors affecting the time consumption in scarifying. Also the effective time concumption increased, when the ground roughness became worse, when the gradients changed from the level, and when moving along a side-slope. On the other hand, the thickness of the humus layer, the sparing of stumps, the amount of logging waste or remaining trees did not have a significant effect on scarifying. It was also noticed that the work result became worse with increasing terrain difficulties and a greater time consumption.

When comparing the gained results with the earlier studies, they strengthened the predicted trends and supported the earlier findings on the mobility of forest tractors in terrain. A proposal for classifying the six primary terrain factors for future studies in this field and a nomographic chart for predicting the effective time consumption for contract rates were also presented.

10. Rihko Haarlaa: Maaston vaikutuksesta metsäteiden rakennukseen. Summary: On the Effect of Terrain on Forest Road Construction Silva Fenn. 7(4): 284—309, 1973.

The aim of the study was to define the effect of ground, ground roughness and slope factors on the clearing of the road area, on the design of the road base and on the levelling of it by making time-studies. The data was collected in 1973 from ten road construction operations, where either a bulldozer or excavator method was used. In collecting data the thickness of the humus layer, the soil type, the moisture content of the soil, and an index indicating the stoniness of the soil (depth index), soil strength (cone index), the ground roughness, the amount of stumps, the slope of the road line and the side-slope were tallied as terrain factors. The most important terrain factors affecting the road construction time, and thus the most necessary factors to be included in the terrain classification in this respect, were the stoniness of the soil (the depth index), the moisture content of the soil and the amount of stumps. The slope-% and a dummy variable formed from the ground roughness classes were also significant variables explaining the variation in the effective digging time in the excavator method. On the other hand the soil type proved to be an insignificant constituent in the terrain classification because of high intercorrelations with the other terrain factors.

11. Simo Hannelius: Metsäteiden rakennuskustannukset. Summary: The Costs of Forest Road Building. University of Helsinki, Department of Logging and Utilization of Forest Products. Research notes No. 30, 1975. 94 p.

The circumstances of forest road construction, classifications used in the planning of roads, the scope of work phases and the average cost level were the central objects of this study. The dependence between construction costs and terrain factors were also determined. Furthermore, the dependence of the construction costs on the terrain factors was compared in two different road standards.

The study material consisted of 42 forest roads and 20 permanent forest roads built by the National Board of Forestry in the early 1970's. The data was collected from planning documents and from the book-keeping of costs. The terrain classifications for road building are based on the standards of forest road construction of the National Board of Forestry. Due to the nature of the study material, attention was paid only to the macro forms of the terrain.

Slope variations along the line of the road make a poor geometry and create the need for much earth moving, which raises the construction costs. The better the road class in question, the greater is the increase in the construction costs caused by slope differences. The bearing capacity of the ground also has a significant effect on costs. Digging difficulty classes do not seem to essentially effect costs.

Slopes were measured as the steepest upward slope in the road line. A more accurate variable would be hilliness, which is determined in the following way:

$$M = \frac{\Sigma AH}{L}, \text{ where}$$

M = Hilliness, m/km
AH = Sum of the differences of the level of the bottom lines of the road, m
L = Length of the road, km.

12. Jussi Seppälä: Työvaikeustekijöiden vaikutus metsämaan auraukseen KLH-170-piennarauraa käyttäessä. Summary: Effect of Work Difficulty Factors on the Ploughing of Forest Land with a KLM-170 Reforestation Plough. Metsäteho tied. 337, 1975. 13 p.

The purpose of the work was to study for work difficulty classification the effect of the work difficulty factors on the ploughing of forest land with a KLM-170 reforestation plough.

According to the study, the outputs per productive hour which are dependent on different work difficulty factors were 0,35—1,24 ha/h when the plough was drawn by a forwarder and 0,21—0,96 ha/h when a skidder was used.

Interruptions are more frequent in ploughing than in the forest haulage of timber. Maintenance jobs and bogging down of the ploughing unit caused considerable interruptions. Productive working time was an average of 76,3 per cent of working time.

The type of soil, stoniness, stumpiness, size of the driving pattern and slope were work difficulty factors that influenced time consumption significantly. The thickness of the humus, logging residues and residual trees did not affect ploughing significantly. Soil type, stoniness and stumpiness increased the time consumption of the skidder more than that of the forwarder.

The most difficult soil type of the material increased the time consumption of the forwarder by 15,3 min/ha and of the skidder by 26,0 min/ha. It has been calculated that the furrow thus produced is 2 500 m/ha. On moving, from the easiest class of stoniness to the most difficult the time consumption of the forwarder increased by 8,3 min/ha and of skidder by as much as 25,0 min/ha. Stumpiness at its greatest increased the time consumption by 9,6 min/ha and 23,3 min/ha, respectively. If the time consumption in average soil type, stoniness and stumpiness conditions is denoted by 100, the corresponding forwarder value in the easiest conditions was 76 and in the most difficult 132. The comparable values for the skidder were 64 and 146.

The size of the driving pattern distinctly lengthened the time consumption compared with straight line driving, especially in driving patterns smaller than 3 ha. The driving patterns of under 0,5 ha in size caused the greatest additional consumption of time, 43 per cent of straight line driving time. The ploughing units responded fairly sensitively to the slope. The ploughing speed increases on downward slopes up to a certain gradient limit. Upward slopes, on the other hand, slows it down very sharply. The consumption on time increased by 50 per cent on 12—15 per cent gradients.

The furrow deficit, the length of the track in which no furrow was driven, was studied. The deficit was increased partly by the same work difficulty factors which slowed down the ploughing speed. The deficit was 9 per cent of the track in easy conditions. In difficult conditions it rose to 30 per cent.

13. Martti Tynkkynen: Työvaikeustekijöiden vaikutus lautasauraukseen. Summary: Effect of Work Difficulty Factors on Dish Ploughing. Metsäteho tied. 330, 1974. 12 p.

The purpose of the study was to establish the effect of work-difficulty factors on the expenditure of time, output and furrow when TTS-Disc-Trenchers are used in the preparation of forest soil.

The share of productive working time in the working-site time was approx. 85 per cent. Ploughing alone was about 96 per cent of the productive working time. Turning and movements within the working site accounted for approx. 4 per cent of productive time. Interruptions represented about 15 per cent of the working site time. The majority of the breaks were for service and repairs.

Work-difficulty factors affecting a machine unit are hilliness, stoniness, and the shape and size of the topographical compartment. On the other hand, stumpiness, thickness of dry peat, soil type and logging waste do not affect the expenditure of time. Both the steepness of hills and their requency in the area of the topographical compartment affected the expenditure of time. More numerous hills did not influence the time expenditure greatly, if the hills were gently sloping (gradient under 15 per cent and crossfall under 10 per cent), but they increased the time expenditure distinctly if the hills were steep (gradient over 15 per cent and crossfall over 10 per cent). If hills accounted for under 1/3 of the area the change from gently sloping to steep increased the expenditure of time by 3,1 min./ha on average. When hills covered a 1/3—2/3 of the area the expenditure of time on steep hills was an average of 9,7 min./ha greater than that on gently sloping hills. When over 2/3 of the area was hills the time used on steep hills was an average of 16,5 min./ha greater than that on gently sloping hills. This last increase in the expenditure of time lowered output by an average of 24 per cent in a topographical compartment of over 3,0 ha with few stones.

The effect of stoniness on the expenditure of time was great. For instance, when changing from stoniness class 1 to 2 (from terrain with few stones to stony terrain) the increase in the time expended, depending on the machine unit, was 3,4—26,6 min./ha. Correspondingly, a change from stoniness class 1 to class 3 (from terrain with few stones to one with a great many stones) increased the expenditure of time by 15—53,4 min./ha.

The shape and size of the topographical compartment also affected the expenditure of time essentially. Small compartments and compartments of irregular shape necessitated numerous extraordinary turns and keeping to the same track, with a resulting decrease in output. When the topographical compartment was over 3,0 ha (= shape and size class 1) its shape and size increased the driving time by 6 per cent compared with straight driving. When the compartment was 0,5—1,0 ha and free of narrow projections or was 1,1—3,0 ha (= class 2) the expenditure of time was 26 per cent greater than for straight driving alone. Driving in a compartment smaller than 0,5 ha or 0,5—1,0 ha with narrow projections (= class 3) required 60 per cent more time than straight driving.

In addition to the factors already mentioned, output was affected by the weight of the tractor, the size of the harrow and the additional weights used in the harrow. When a 5,000 m furrow is ploughed per hectare, output may be at best 1,34 ha/h and at worst 0,21 ha/h only. A heavy tractor always gave a greater output than a light one. Additional weights, on the other hand, reduced the output distinctly in difficult conditions when a light tractor was used. Additional weights did not affect output to any appreciable extent when a heavy tractor was used.

14. P-O. Andersson: Pilot time study on equipment for bare-root planting conducted at Mo and Domsjö Ab. Redog. Forskn. Stift. Skogsarb. Preliminary report, 18 November 1975. 5 p.

The objectives of the study were to determine the general level of productivity in planting with the relevant equipment and to investigate the variation in productivity owing to a variety of impeding factors.

Terrain classification was carried out with the main purpose of classifying the impeding factors of incidence of stones and rocks, quantity of slash and quality of soil scarification.

20 sample plots, each with an approximate area of 1500 m², were marked out in an area of artificial regeneration in which patch scarification had been carried out. The terrain inventory was conducted in the form of a systematic sample point cruise with 50 sample points per sample plot. The following were recorded at the points or at a given distance from the points:

1. The extent to which the thickness of the slash cover exceeded 10 cm or not.
2. The extent to which more or less than 1 m² of mineral soil was exposed by patch scalping.
3. The extent to which the possible depth of insertion of a soil auger exceeded 20 cm or not.

In addition to the sample point cruise, the following factors were determined:

4. Ground roughness
5. Soil type
6. Slope

Factors 4 and 5 were determined in accordance with »Revised terrain classification for mechanized silviculture« (Nilsson 1974).

In the case of factors 1 and 3, measuring methods were also employed. However, the classification of the measured values was confined to two classes.

After the cruise, time studies were conducted in the sample plots. — The results were as follows.

— As well as mean values of productivity, functions were obtained for the variation in productivity as a result of the incidence of stones and rocks.
— The total time consumption per plant was best expressed by the incidence of stones and rocks down to a depth of 20 cm.
— The time consumption for the work element »walking and reconnaissance» was best expressed by the frequency of sample points with a slash cover less than 10 cm.
— The time consumption for the work element »insertion of plant» was best expressed by the frequency of scalped patches with a mineral soil area in excess of 1 m².
— There was a good correlation between the incidence of stones and rocks down to a depth of 20 cm and the frequency of mineral soil patches greater than 1 m².
— The time taken to conduct a cruise of the impeding factors in a sample plot was between 20 and 30 minutes.
— The simplified terrain inventory afforded savings in time but is probably sufficient in a study such as this with the given objectives and limited scope.

15. Staffan Berg: Hyggesavfall och arbetsresultat vid markberedning. Summary: Slash and Working Results of Scarification. Redog. Forskn. Stift. Skogsarb. 6: 74—80, 1976. Seminar on scarification research, Umeå, 26—28 August, 1975.

The objective of the study was to elucidate the extent to which the thickness and degree of decomposition of the slash influence the scarification result of certain units of scarification equipment. The aim was that the study would provide a basis for assessing how the presence of slash could conceivably influence future machines for artificial regeneration.

Study period was September 1974, August 1975, and the equipment studied KS 860 and TTS 612 under varying loads, KS 861 and Bräcke unit.

222 sample plots of 3 x 5 m in six cutovers of different ages were studied. The plots were marked out in terrain conforming to ground conditions classes 2–3, ground roughness class 2 and slope class 1. An effort was made during the marking out of the plots to obtain as homogeneous terrain conditions as possible. In addition to 20 plots where there was a complete absence of slash, an effort was made to obtain plots with a 100 % slash cover. Where applicable, the terrain difficulty was determined in accordance with »Revised terrain classification for mechanized silviculture» (Nilsson 1974).

An increase in the depth of the slash cover adversely affected the scarification results of both the TTS 612 and the Bräcke unit. The degree of decomposition of the slash only had a significant influence in the case of the TTS 612, the operating results of which also varied considerably with the depth of the slash cover. The operating results were also affected to a great extent by the magnitude of the load due to a thicker slash cover. The terrain variables only had a limited effect on the operating results since as uniform terrain conditions as possible were included during the marking out of the sample plots. However, these did vary somewhat during the 1975 study and, consequently, the soil type — gravelly moraine together with an increase in the proportion of spruce had an adverse effect on the results.

There were difficulties in recording field data. — The degree of slash cover must be assessed using an objective measure. *The number of sample points in plot with slash* divided by total number of sample points (15) was used as the criterion of this study.

It is difficult to measure the depth of the slash and stones exactly owing to difficulty in locating the measuring point for the level of the ground and, in the case of slash, the springy property of the slash which means that errors of the estimated order of 5 cm may be made in the case of more extensive slash cover.

The performance of ground roughness classification requires a greater area than the area of 15 m² used here.

Time consumption was 10–30 min/sample plot.

The following factors are judged to have been assessed sufficiently accurately for the purposes of the study: slope, depth of stones and roots, soil type, depth of slash cover, degree of slash cover, stumps, humus thickness and form and, finally, the number of windthrows.

16. Björn Jahnke & Göran Nilsson: Mechanized scarification — operational study results. Redog. Forskn. Stift. Skogsarb. 7, 1975, 37 p.

The objective was to make a qualitative study of the operating results of some existing scarification units. A secondary objective of the study was to elicit suitable methods of terrain classification for use in technical research in the field of silviculture.

Sample plots, each with an area of 20 × 5 m (100 m²) were marked out in different scarification sites. Terrain factors in the sample plots were recorded in accordance with »Revised terrain description for mechanized silviculture» (Nilsson 1974). A scarification unit was then set to operate in the sample plot and the operating result determined.

Altogether seven different scarification units were studied in 151 sample plots. The studies were carried out between 1973 and 1974.

The studies showed that:

- 10–28 % of all planting sites had not been scalped,
- 28–52 % of all planting sites had no mineral soil,
- the mean values of the area of the scarified patch per planting site varied between 0,5 and 0,47 m²,
- the mean values for the area of mineral soil per planting site varied between 0,07 and 1,13 m²,
- only between 38 and 49 % of all planting sites met the following requirements:
  - open planting depth down to a depth of 10 cm
  - the planting point shall be in mineral soil
  - the planting point must not be at the lowest point of the mineral soil.

The following results refer to patch scarifiers and forest harrows.

In tests to establish the influence of the prevailing terrain conditions in the sample plots on the operating result, the following factors were found to have the greatest significance:

— ground roughness

— stone and rock ratio

— area of slash cover

— thickness of humus layer

— number of stumps.

Other terrain factors also had an effect on the operating result, though not as extensively, and included humus form, soil type and ground moisture content.

The time taken to cruise a sample plot was around 30 minutes.

Difficulty was experienced in classifying s l a s h. In the end, linear cruising was employed with 40 sample points along the four lines through the plot. The thickness of the slash was measured at each sample point after gentle compaction.

The *ratio of stones* was expressed as a mean value of recordings at 20 sample points. The confidence interval thereby was $\pm$ 4—5 cm (95 %).

The *humus thickness* was measured at between 5 and 10 sample points in the sample plot. The confidence of the mean value was thus $\pm$ 1,2 cm (95 %).

Ground roughness was classified in accordance with »Terrain classification for Swedish forestry» (Skogsarbeten 1969). This system of classification was found to be adequate for the purposes of the study.

17. Göran Nilsson: Summary of response to questionnaire survey on revised terrain classification for mechanized silviculture. Redog. Forskn. Stift. Skogsarb. 2 April 1975. 7 p.

During the springs of 1973 and 1974, a preliminary terrain classification system was drawn up for use in studies on silvicultural activities. Early in 1975, the 1974 terrain classification system was sent, together with a questionnaire, to about 40 research institutes and companies in the Nordic countries.

The objectives were to elicit viewpoints on a broad and descriptive terrain classification system in order to receive comments on the terrain factors selected and the methods used to measure them.

Only 17 of those circulated responded to the questionnaire.

The complexity of the problem and the intended (limiting) field of application of the system resulted in several of those contacted feeling that they were not competent to answer.

The vast majority of the opinions given on the terrain classification system were extremely favourable. However, the forest enterprises consulted pointed out that the high resolution of the system means that it cannot be implemented in practical situations by the user.

Two typical general comments were as follows:

»The terrain classification appears to have been well thought out. There is justification for nearly all of the terrain factors and these should be included. Some thorough and careful directives must be drawn up to provide a detailed description of how each item of data is to be collected. Most of the comments in the enclosed answers to the questionnaire deal in fact with the collection procedure.

A common system for terrain classification for silvicultural activities would probably be extremely valuable in many contexts. The work on the compilation of the classification is highly commendable and should be supported in every possible way.» (Researcher).

»The number of factors is large but is probably justifiable for research and investigative purposes where it is necessary to make a fundamental specification of causal relationships. But for practical applications, however, the number of terrain factors should not be great than currently the case in »Terrain classification for Swedish forestry» Report No. 9/69 (Skogsarbeten).» (Forest Enterprise).

The questionnaire asked whether a given factor should be included in the system, whether the method of collecting data on the factor was correct and whether it satisfied any requirements that may be made.

The opinion was that the factors contained in the catalogue of factors were justified. With respect to the finished system, the following wishes were expressed:

— more concise definitions of factors and class limits,

— clearer directives for marking out sample points, and

— a specification of the number of sample points required for sample plots of varying sizes.

Conclusions were as follows.

— The response to the questionnaire indicated a need for a standardized detailed terrain classification system of the type in question.

— The resolution of the catalogue of factors was of the correct order in the light of the demands emanating from the intended field of application (research).

– The definitions of individual factors should be explained more clearly.
– Directives should be given for the marking out of sample points and the number of sample points required per sample plot.

18. Ivar Samset: Skogterrenget i Norge. Summary: The Forest Terrain in Norway. Taksering av Norges skoger. Landsskogstakseringen 50 år: 159–203. Oslo.

The terrain conditions of the productive forest areas in Norway were analyzed on the basis of data collected in connection with the National Forest Survey during the period 1954–1965. The surveys were carried out by counties and employing systematic distribution sample plots. In estimating skidding distances, the results were brought up to date by means of a low-percentage survey during the period 1964–67. Survey squares of 1 km^2 were used, with sample plots along the sides of these squares, according to the layout of the State Forest Survey in Sweden.

The terrain classification system used was introduced in 1954, and has been in use since then primarily without amendments in areal terrain surveys in Norway. As regards the details of the Norwegian terrain classification system, see chapter 31.

The author describes, in broad outlines, the geological processes which have formed the topography with varying forms and degrees of terrain difficulty. A general review of relative relief, timber lines and existence of sediment soils is given. Due to low timber lines, the forest terrain in Norway is not as difficult as might be assumed on the basis of the fjord scenery. This may be noticed in the results of the registered terrain factors, too.

Connecting terrain registrations with the registration of stand data makes it possible to correlate forest conditions and the degree of the terrain difficulty. The material reveals, for instance, that a relatively large amount of exploitable timber is found in difficult terrain.

According to the descriptive classification of forest terrain in Norway, the productive forest soils have been divided into 9 terrain regions, which are listed in tables referring to groups of terrain factors. (See the table, p. 60).

These main terrain regions are indicated by a rough principal classification with variations within single regions, but with typical features showing differences between regions.

The material reveals that fellers and other machines which ought to run over the whole terrain surface, are useable only in about half of the productive forest area in Norway. This leads to the conclusion that the most natural way of gathering timber together, is to take it as tree-lengths or whole trees to central processing stations. Machines for soil preparation, e.g., for reforestation, ought to be constructed with high mobility for Norwegian conditions.

An example is given for using the terrain classification in estimating the road density. An analysis has also been made of the changes in the forest road lengths which have taken place as a result of forest road construction between the surveys in 1954–65 and 1964–67. The result was that while the length of truck roads was doubled, the average skidding distance was reduced by about 17 %. This is due to, among other things, replacing floating by truck transport in long-distance hauling. For reducing the skidding distances effectively, more emphasis must be laid on planning in order to be able to structure the road network so that it will bring an essential reduction in skidding distances.

The correlation between skidding distances and the road density was investigated in detail in Vestfold county.

19. Ivar Samset: Skogterrengets tilgjengelighet og terrengforholdenes innflytelse på skogtilstanden i Norge. Summary: The Accessibility of Forest Terrain and its Influence on Forestry Conditions in Norway. Medd. Norske Skogsforsøksv. 92 Bind XXXII, 1975. 92 p.

The aim of terrain classification in forestry is to analyse the accessability and the terrain conditions with respect to various forestry activities. A prerequisite to carry out these activities is access to the areas, and accessability again depends on the terrain conditions.

The present analysis comprises the National Forest Survey of 1970–73, and the results are compared with previous surveys from 1954–65 and 1964–67. These are typical regional terrain classifications. Based on more than 20 years experience with the Norwegian terrain classification system and practical use of the data, definitions of various terms related to terrain classification are given. Improvements for future use of the system are proposed.

Up to 1964 the survey was performed by counties, concentrated in one county at a time, and het results were published gradually as the surveys were completed. A change in sample plot lay out

The terrain-regions in Norway. The terrain-classes and their relative part of the productive forest area.

Terrain region	*Steeper than 1: 5*	*Steeper than 1: 2*	*Irregular terrain with large stones*	*Boulders, cliffs, bedrocks*	*Winch-terrain*	*Cable-terrain*	*Soil deeper than 70 cm*
1. *South-East Norway*	20–35 %	2– 3 %	25–35 %	5–10 %	20–30 %	0– 2 %	35–40 %
2. *The Southern coast region*	40–60 %	2– 8 %	30–50 %	5–20 %	10–40 %	0– 3 %	15–20 %
3. *The South-central mountain region*	40–55 %	8–14 %	30–50 %	10 %	20–30 %	15–25 %	45 %
4. *The North central mountain region*	40–50 %	4– 7 %	15 %	5 %	20 %	5 %	40–70 %
5. *The Hedmark region*	10–15 %	— %	10–20 %	— %	10–20 %	— %	80 %
6. *The Western mountain region*	65 %	10 %	20 %	10 %	35 %	20 %	35 %
7. *The North-West mountain region*	40–60 %	5– 8 %	30–45 %	5–20 %	15–25 %	3–10 %	10–45 %
8. *The Trondelag region*	30 %	12–14 %	15 %	5 %	20 %	2– 3 %	50 %
9. *The Salten region*	55 %	12 %	25 %	15 %	25 %	18 %	50 %

was introduced in 1956, from parallel lines to location on the sides of survey squares of 1 square km. In 1964 the survey by counties was changed to survey the forest counties as one entity at a fairly low percentage level in the course of 12 years. This design of the survey is the same as used by the National Forest Survey of Sweden.

The Norwegian terrain classification system has been applied with just minor changes since the introduction in 1954. The main content of the system is given in chapter 3.2.

If terrain classification was good enough, it could possibly be done once and for all. Comparisons of the three Norwegian surveys show, however, that there exist a close relationship between the degree of difficulty of terrain and the forest conditions. Terrain difficulties provide barriers to the use of some operational methods, and this again influences forest conditions. It is, therefore, desirable that terrain classification is repeated and combined with survey of forest conditions. Together with stability in the terrain classification system it is then possible to refer changes in forest conditions from one survey to the next — back to the same objectively defined terrain classes.

The present analysis provide the following conclusions:
Half of the forest area in Norway is flatter than 20 % and well suited for above-land machines. Realizing that modern equipment requires big investments of capital, as well as large scale operational concentrations, it would be useful to include in future surveys records on the shape and total size of the forest stands which the sample plots belong to.

According to the most recent survey, 50 % of total mature volume is in terrain steeper than 20 %, as compared to 44 % in the previous survey. Terrain steeper than 33 % contains 24 % of mature volume as against 14 % previously. This means that half of the productive forest area is in the most difficult terrain, i.e., the forest conditions have become relatively worse since the earlier survey. The steeper and more uneven the terrain, the bigger the relative proportion of mature volume. Therefore, the attention should now be focussed on the more difficult part of the terrain, while operational developments of recent years evidently have favoured the best terrain.

The considerable expansion of the forest road network during recent years has transformed some cable terrain to winch terrain. This is a favourable development since the longest cable slopes are rarely logged today. Although the cable need has been reduced, the area and the volume of mature forest in difficult terrain are increasing. The reason is that forest areas which have become mature, remain untouched because of the terrain difficulties. Calculations based on these facts show that in addition to the existing annual cut in Norway, a further 2 million cu.m a year could be logged in the most difficult winch- and cable-terrain if provisions are made for it. This terrain category represents approx. 25 % of the productive forest area.

The above-mentioned increase in mature forest in difficult terrain, together with research concerning productivity of winch and cable equipment, ergonomics and considerations regarding worker satisfaction indicate a need for expansion of forest roads in difficult terrain. The need for thinning provides an additional motive for expansion of the forest road network.

Analysing changes in extraction distance shows that hitherto mainly access roads have been extended, indicating that in the future it will be important to expand the collecting roads, and consequently to allow the transport network to improve the accessibility by means of reduced extraction distance. Calculations have been carried out to determine the need for road construction, using as a basis for modern operational methods an extraction distance of about 500 metres. The conclusion of these calculations (1973) was that it is necessary to double the length of the road network, and that it ought to be done mainly by development of the collecting roads.

The extraction distance in forests of a low site class has been very little influenced by the development of forest roads in recent years. If modern forestry is to be practised on such land, the analysis indicate that it is important to develop an adequate transport network even on land of low site classes.

20. Gunnar Skråmo: Effekten av en del vanskelighetsfaktorer på markberedningsresultatet ved bruk av TTS skogsharv. The Influence of Certain Impeding Factors on the Scarification Result from the Use of a TTS Forestry Harrow. Invited paper Nordic research seminar in Umeå. Redog. Forskn. Stift. Skogsarb. 6: 59–66, 1976.

Real variations of defined operational difficulties were registrated on clear cuts which then were scarified with a TTS forest harrow. The registrations are part of both work studies and studies of the scarification result. This part deals with an analysis of the influence of operational difficulties on the scarification result.

Registrations were performed on sample plots, 200 sq.m. for the difficulty factor and 10 sq.m. for the scarification factors. The difficulty factors are in the main in accordance with the instruction for terrain description within the Nordic project »Terrain-machine». In processing the data it is used analysis of variance and multiple regression.

It is evident directly from the data that parts of the test areas were too difficult to drive due to a combined effect of slope-uneveness, which amounted to 20,5 per cent and 1 200 obstacle per hectare respectively. These figures alone indicate that half of the productive forest area of Norway is inaccessible with this special equipment.

Based on analysis of variance, only the age and amount of logging waste have significant influence on the scarification result. The material shows directly a clear variation between different parts of the test area — with respect to the scarification result. At the same time, however, multiple regression shows that only small part of the variation is explained by the difficulty factors which were registrated. This gives reason to believe that there exist other sources of variation than those registrated here. I.e., may be that mutual spacing or grouping of the factors, influence the effect of the scarification equipment.

20: Gunnar Skaar: Virkningen av visse vanskelighetsfaktorer på markberedningsresultatet ved bruk av TTS skogsharv. The Influence of Certain Impeding Factors on the Scarification Result from the Use of a TTS Forestry Harrow. Invited paper Nordic research seminar in Umeå Sweden. Forskn. Stift. Skogsarb. 6 59–66, 1976.

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1978. The Inter-Nordic project of forest terrain and machines in 1972–1975. — ACTA FORESTALIA FENNICA 164. 61 p. Helsinki.

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