Snow Cover Properties and Winter Climate in North Sweden

Bengt AGER
The Royal College of Forestry, Stockholm, Sweden

Abstract

Between 70 and 80% of the land area of North Sweden is forested. Snow cover data from forest areas have been recorded partly during local field tests both on snow stabilization and on vehicle mobility, and partly in an annual logging survey in 1946/47~1955/56. Snow studies carried out by Rodhe (1965, unpublished) have also been a major source of information.

Frequency distributions of grain size and density for different snow types are presented as well as the typical snow type distribution during the course of the winter. The hardness of the snow is also discussed. Temperature, precipitation and snow depth figures are given for the region where the snow observations were collected.

I. Introduction

Forest industry plays a very important role in the economy of Sweden, especially in the northern and central part of the country. In these areas the bulk of the wood is harvested and extracted (logged) on snow-covered ground. The snow cover has significantly influenced the construction of machines as well as the techniques of logging, roadbuilding etc. Several investigations in this field have been carried out by forest research organizations, mainly during the fifties and partly in co-operation with the Swedish Army. During the field tests, snow cover observations were generally made as well, mainly in accordance with the recommendations of the International Association of Hydrology (1954). Although the snow cover observations have to be considered as by-products of these field tests, there was sufficient information available to be worth publishing. This was done in a summary of the Swedish studies on snow stabilization (Ager 1965, in Swedish with an English summary).

The present paper consists partly of an extended presentation of these results and, in order to facilitate international comparisons of snow cover characteristics, partly of climatic data from the regions where the snow cover information was collected.

II. Snow Cover Properties

Field observations. The field studies on snow stabilization, vehicle performance in snow etc., were carried out in the winters of 1954/55~59/60, and 1962/63, mainly during December to March in two areas in North Sweden—the Lycksele and the Arvidsjaur areas (*cf.* Fig. 1). During the tests the following snow cover data were collected.

—ram hardness,

—hardness according to the "hand test" (de Quervain, 1950),

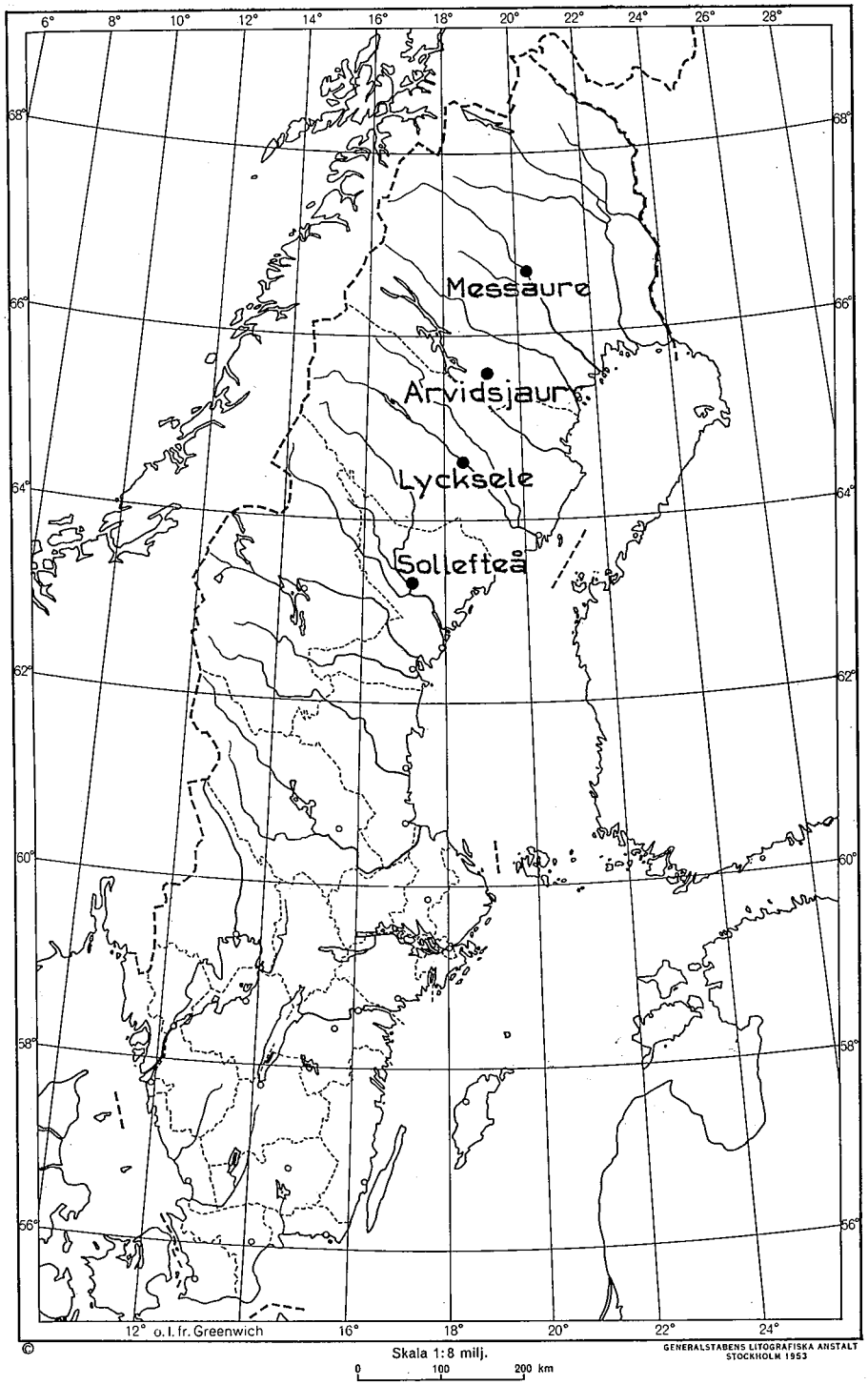

Fig. 1. Location of field test areas in Sweden

Table 1. Description of snow cover information collected in the Lycksele, Arvidsjaur and Messaure areas

Number of "profiles" observed

	Lycksele					Arvidsjaur					Messaure					
	Dec	Jan	Feb	Mar	Apr	Dec	Jan	Feb	Mar	Apr	Dec	Jan	Feb	Mar	May	Apr
1954/55	1	1	1	1	2											
55/56	1	1	3	1	5											
56/57																
57/58	1	13	11	14	1			1	1							
58/59							5	30	22	6		17	2	45	57	
59/60	1	10	5	4										53	62	10
60/61													22	78	70	33
61/62													37	75	58	30
62/63								2	2							
Sum	4	25	20	20	8		5	33	25	6		17	61	251	247	73

—snow (crystal) type according to the International Association of Hydrology (1954),
—grain size,
—density on 5, 15, 25 etc. cm depth in the snow pack.

In the winters of 1958/59~1961/62 Rodhe (1965, unpublished) collected the same snow cover data in the Messaure area (Fig. 1) in order to study the grazing conditions for the reindeer.

Since the investigations mentioned above represent the main source of information, a more detailed presentation is shown in Table 1.

The Arvidsjaur and Lycksele observations were carried out by one or two observers each year, different persons from one year to another. All the Messaure observations were carried out by one observer. All the observers were instructed by the same instructor.

In the winter of 1958/59 the author undertook a minor study of the local variations of the snow cover. On the 410 km route Sollefteå-Lycksele-Arvidsjaur (Fig. 1) snow type, grain size and hardness according to the hand test were observed every 10 km on three occasions (January, February, April) during the winter.

On field trips to logging operations the author also occasionally observed snow type and hand test hardness in several parts of northern and central Sweden during the years 1954~60.

Additional information on the snow cover was received from a survey carried out by the forest employers' associations. The main objective of this survey was to record production of cutters, horses and tractors in logging operations. Snow depth, dryness (2 classes) and hardness (3 classes, *cf.* page 1034 were recorded simultaneously. Observations were carried out on every working day in 60–80 logging operations each winter, from 1946/47 to 1955/56, generally different operations each year. The period of observation on a single operation was between one and four months (Ager, 1964).

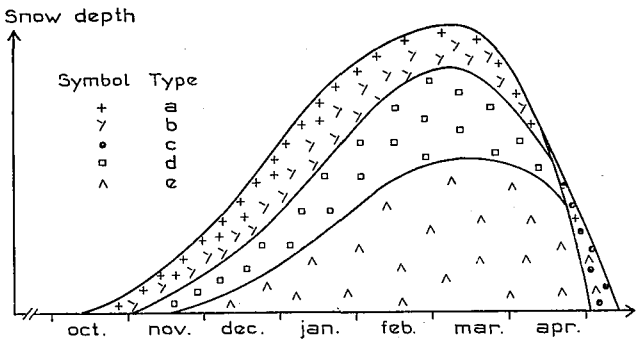

Fig. 2. Typical snow type distribution (from Ager, 1965)

The following presentation of the characteristics of the snow cover in the inner parts of northern Sweden is valid only for *sheltered* areas (if nothing else is mentioned), *i.e.* the forested areas. About 70~80% of the land area (except mountains) of northern and central Sweden is forested.

Snow type. The typical snow (crystal) type distribution in the snow cover is shown in Fig. 2.

As is well known, the proportion of type "d" is greater and that of type "e" (depth hoar) smaller if the winter is mild, and the reverse is true if the winter is cold. As to the proportion of depth hoar in February, the lowest values observed were 25~30% of the total snow depth, and the highest values 75~80%.

Grain size. It was generally estimated by eye on a sample of grains placed on a plate ruled in millimetres. For snow types "c", "d" and "e", the greatest extension of the individual grains was observed, as is recommended by the International Association of Hydrology. However, this measure was considered to be irrelevant as far as types "a" and "b" were concerned, with respect to the purpose of the investigations. This type of snow is generally crushed into small particles by the action of a vehicle track, or by equipment for snow stabilization. Eriksson (1954) suggested the use of the diameter of the largest sphere that could be described in the snow particle. This measure was found more suitable than the greatest extension, and was therefore used for types "a" and "b".

According to the grain size classification described above, nearly all snow of types "a" and "b" was classified as "very fine", *i.e.* less than 0.5 mm. The size of snow particles for shape "d" generally ranged from 0.5 to 2 mm. For snow classified as depth hoar, the grain size was usually between 0.5 and 4 mm. On a few occasions depth hoar crystals larger than 4 mm were found.

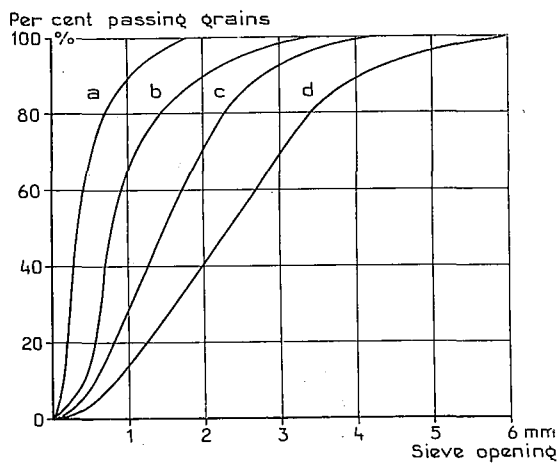

Fig. 3. Typical grain size distribution for different snow types (from Ager, 1965)

During the winter of 1959/60, the snow was also occasionally graded by means of sieve analysis. In 1960/61 the author carried out similar observations in Ottawa, Canada. On the basis of these very limited observations, the author has tried to establish typical grading curves for different types of snow, these can be seen in Fig. 3.

Density. The density was measured at 5, 15, 25 cm etc. depth of the snow cover by means of an aluminium tube 20 cm long and 5.6 cm in diameter, which was inserted horizontally into the snow profile. Figure 4 shows density distributions of different snow types for the period December to March.

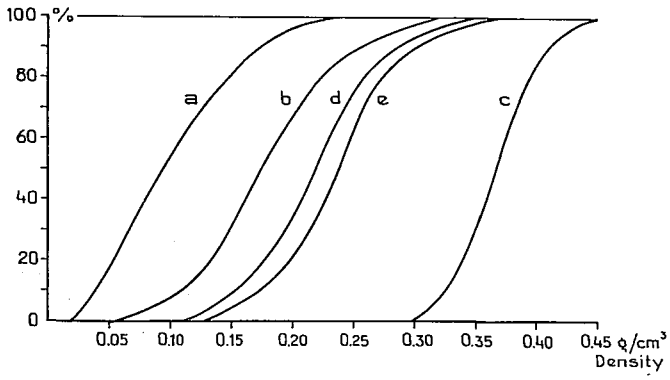

Fig. 4. Relative frequencies of densities for different snow types, Dec-March (from Ager, 1965)

Hardness. The "hand test" described by de Quervain (1950) has been found to be a very useful method of classifying the hardness of snow for several practical purposes.

de Quervain suggested the following classification: (The corresponding ram hardness range in each hand test class is also shown (de Quervain, 1950)).

It should be possible to force the following subjects into the snow:

	Class	*Subject*	*Range of ram hardness* (kg)
I	Very soft	The gloved hand (Movement sidewards is possible)	0~ 3
II	Soft	The flat, gloved hand	3~ 15
III	Medium hard	The streched finger	15~ 50
IV	Hard	A sharpened pencil	50~150
V	Very hard	A knife	>150

The classification I–V has been used by the author. Of course, the notation "it should be possible" is not very precise. In our application of the test method we have added the instruction "without strong effort", which is also used when the observers are instructed in the home country of the method (Th. Zingg, personal communication, 1957). However, it should be possible to standardize the method more by recommending a certain pressure (kilos) against the snow, at least for the classes II–V.

According to this test, hardness class I, "very soft", was most commonly encountered in our field tests. During the period December to the middle of March, it was also

typical to have hardness class II ("soft") in a quarter to half the snow profile. Greater hardness does not usually appear until the end of March or the beginning of April, when the thaw begins.

In the survey of logging operations mentioned above, snow hardness was classified into the following three classes:

1) loose (soft)
2) snow crust not carrying a person
3) snow crust carrying a person

The aim of this classification was to describe the snow hardness in terms of the degree of difficulty for the wood cutters to walk between the trees and along the felled trees. The boundary between the last two classes is generally quite clear. From the author's experience it would require a 10 cm layer with hand test hardness class III resting on a layer with at least hardness class II in order to support a walking person. The boundary between the first and the second class is more subjective and diffuse. If there was a crust layer or a hard layer in the snow which did not carry the cutters but was hard enough to make walking difficult, the second snow hardness class was chosen.

There were generally different observers for each year and for each logging operation, but the observers were usually trained by the same instructor.

In this area of northern Sweden the following relative frequencies were found during the winters of 1946/47~55/56 from about 150 logging operations and a total of about 14 000 observed working days (from Ager, 1964):

	Relative frequencies				
	Dec	Jan	Feb	Mar	Apr
Loose snow	90	82	87	62	61
With crust not carrying a person	5	12	8	28	26
With crust carrying a person		1	1	6	8
Others	5	5	4	4	5
Sum	100	100	100	100	100

These figures support the conclusion that the snow cover generally consists of "very soft" and "soft" snow in the forested areas of northern Sweden (*cf.* also Hamberg, A., 1907, and Hamberg, H. E., 1912).

III. Winter Climate

The amount of snowfall and the temperature have been considered to be the most important factors influencing the properties of the deposited snow. In sheltered areas we can exclude the wind as a major contributary factor.

Amount of snowfall. The larger the amount of snowfall, the more compact will be the deposited snow, resulting in higher densities, greater hardness and slower metamorphism.

The average amount of monthly precipitation, measured in millimetres of water, generally falls within the following ranges (Ager, 1964).

	Nov	Dec	Jan	Feb	Mar	Apr
Mean monthly precipitation, (mm)	30~50	35~50	30~40	25~30	20~30	25~35

Rainfall is very rare during these months.

The amount of snowfall is also reflected in the snow depth. In Fig. 5 the range of average snow depth for different locations in the region in question is shown. As an indication of the snow depth variation between different years, the standard deviation is also given (Ager, 1964).

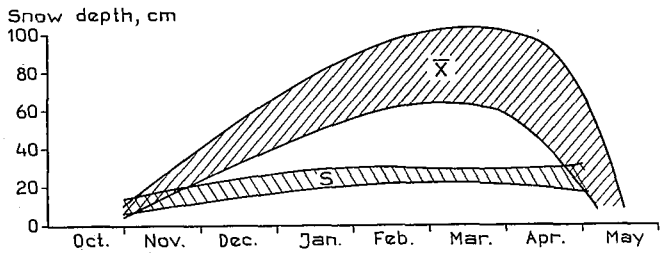

Fig. 5. Approximate local range of snow depth averages ($\bar{X}$) and standard deviations (S) on different dates (period 1931/32~58/59)

Temperature. The frequency and intensity of thaws and the length of cold spells are temperatures factors which have been considered good indicators of snow properties. The local variations within the region are shown in Table 2.

Table 2. Local variations of temperature in the region where the snow studies were carried out

	Nov	Dec	Jan	Feb	Mar	Apr
*Mean monthly temperature (°C)	−5° to −10°	−8° to −12°	−10° to −14°	−9° to −14°	−5° to −9°	−1° to −3°
**Average No. days with max. temp. >0°C	9~13	7~9	4~5	4~5	11~14	24~27
Average No. days with min. temp. >0°C	1~ 2	0.5~1	0.2~0.4	0.2~0.3	0.8~1.5	2~4
Average No. days with max. temp. <−10°C			20~ 40 (Nov–Apr)			
Average No. days with min. temp. <−10°C			70~110 (Nov–Apr)			

* from Atlas of Sweden.
** from Ager (1964).

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* In Swedish with English summary.

† In Swedish.