METRICATION IN NEW ZEALAND FORESTRY

A. G. D. WHYTE*

SYNOPSIS

The background to and implications of metrication for New Zealand forestry are briefly reviewed. Forest measurement in metric units is examined with particular emphasis being given to the hope that opportunities to rationalize measuring techniques will be seized. The article concludes with a plea to foresters to contribute ideas to national committees.

INTRODUCTION

This article is a review of progress made in the adoption of a metric system of weights and measures in New Zealand, as it relates to forest measurement, and an indication of some troublesome aspects. A considerable amount of information has already been published on metrication overseas, and so, in discussing implications for New Zealand, a certain amount of repetition is inevitable. The amount, however, has been kept deliberately low, in order to concentrate on some personal views of measuring forest variables in metric units. Readers interested in wider issues and in more detailed information should refer to Finlayson (1969), U.K. Forestry Commission (1969), B.S.I. (1969), and Department of Industries and Commerce (1968), among others.

SALIENT FEATURES OF METRICATION

The use of metric units is already permitted in New Zealand under the Weights and Measures Act, 1925. Pharmacists, for example, use them exclusively, but other commercial concerns rarely do; they have been used by scientists and secondary schools in this country for many years. The use of solely metric units by everyone was advocated partly because substantial advantages would eventually accrue, but mainly because Britain had decided to turn metric bv 1975, as had other of her ex-colonies such as Australia and South Africa. Thus, by that date only Canada and the U.S.A. among the important trading countries of the world are likely to have retained imperial measures.

The three main advantages of a metric system are:

(1) The decimal relationship of units and their systematic nomenclature;

(2) Coherence.

(3) Regulation by an international body.

*School of Forestry, University of Canterbury.

A table explaining the decimal notation is appended, and the implications of this in forestry are discussed later. As a measure of its likely impact, the introduction of a metric system has been estimated to save one full year of arithmetical drudgery in school mathematics curricula; no longer will pupils have to learn by rote the number of inches in a foot, feet in a yard, yards in a chain, chains in a mile; or ounces in a pound, pounds in a stone, stones in a hundredweight, hundredweights in a ton, and so on. There are disadvantages, of course, in losing some flexibility with multiples of twelve, but these are mainly superficial and can be largely redeemed with logical restructuring of measuring principles. Indeed, *there is more justification nowadays for an octal rather than* either a decimal or duodecimal base, but that is another matter.

Not all units will have a decimal framework: a circle will still be divided into 360 degrees and the mean solar day into 24 hours. Also, distances at sea will be measured in nautical miles and tenths, as the nautical mile is one minute of latitude, and speeds of tidal streams and currents in knots.

New Zealand, for all practical purposes, is converting to the metric system, but actually the one that is being adopted here, as in most other countries, is the International System of Units (S.I.), a modern version of the original scheme. It has the quality of coherence in that there are six basic units from which all others are derived. The six are:

Unit of length	—	metre (m)
Unit of mass	—	kilogram (kg)
Unit of time	—	second (s)
Unit of electric current	—	ampere (A)
Unit of thermodynamic temperature	—	degree Kelvin (°K)
Unit of luminous intensity	—	candela (cd)

The kilogram has a prototype in Paris; the others are defined in terms of properties of matter — for example, 1 metre = 1650763.73 vacuum wavelengths of the orange radiation from the isotope Kr^{86}. Derivations are made from unit combinations: *e.g.*, m^2 and m^3 for area and volume, respectively; kg/m^3 for density; kg m/s for momentum, and so on. Some of these derived units are given special names: thus, the unit of force is called the newton, where $1N = 1\ kg\ m/s^2$; and the unit of work, energy or heat is called the joule, where $1J = 1\ kg\ m^2/s^2$ or 1Nm. Preferred multiples of all these units are in steps of 10^3 or 10^{-3}, except for 10^1, 10^2, 10^{-1} and 10^{-2}.

An international authority, the General Conference of Weights and Measures, regulates the metric system and imposes international standards. No such organization manages the imperial system so that units of the same name can have different values in different countries; *e.g.*, the U.K. gallon and the U.S. gallon; the U.K. ton and the U.S. ton.

There is an organized hierarchy within New Zealand itself which is supervising conversion here. It is explained systematically below:

Minister of Industries and Commerce

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Metric Advisory Board (16 members)

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Sector Committees

1. Agriculture
2. Education
3. Fuel and power
4. Manufacturing and processing industries
5. Engineering and engineering servicing industries
6. Standardization
7. Building and construction
8. Transport and communication
9. Food and consumer goods and services
10. Recreation, health and sport
11. Science and technology
12. Central and local government.

Each sector committee has divisional committees which report to its chairman. For example, there are three divisional committees in the Education Sector Committee, one each for schools, technical institutes and universities. Each divisional committee spreads its representation further; *e.g.*, the Universities Divisional Committee contains representatives from various universities in New Zealand, each of which in turn provides a range of disciplines from different departments.

The Metric Advisory Board has a permanent headquarters in Wellington. It has a full-time administrative and clerical staff. There is also a group handling public relations.

Forestry is not represented at the sector level. There is, apparently, one divisional committee for forest industries and another for the Forest Service, the former reporting to the Manufacturing and Processing Industries Sector Committee, a body which must have markedly diverse interests.

Both sector and divisional committees review the impact of metrication in their field of interest, and decide how to cope. This probably involves planning for a permanent change, and not a temporary expedient, delegating individual or group responsibilities, and co-ordinating information both within and among committees. It is important for all sectors to seize now the opportunity to provide sets of units that will need as little revision as possible. Then committees, and the Metric Advisory Board itself, can present a clear statement of policies, and sound reasons for such policies, so that realistic timetables and guidelines for the changeover can be prepared.

There are implications in all aspects of forestry. Planning for metrication of measurements in forestry should deal primarily with conventions of measurements themselves, instruments for measurement, and maps.

MEASUREMENT

Commonly used units of length will be the metre, kilometre and millimetre. Kilometres (= *c.* 5/8th mile) could be used for long distances on maps, for lengths of road, trucking hauls, and so on. Metres (= *c.* 3¼ ft) could be used for short distances, and for tree and log lengths. Obviously, measurement of both trees and logs needs to be more refined than to the nearest metre. Depending on circumstances, needs and instrumentation, 0.1, 0.2 and 0.5 m are all possibilities; 0.25 m, although still a convenient sub-multiple, is less suitable because of the extra, unnecessary figure involved. In Britain, log lengths are to be handled in the arithmetically complex increments of 0.3 m, presumably the nearest metric equivalent to the dimensions already in use.

Diameters should be recorded in millimetres, despite the objections voiced by, for example, Finlayson (1969), U.K. Forestry Commission (1969) and Hanson (1970). Indeed, in some situations, where measurement is by travelling microscope or vernier girth bands, even millimetres may be too coarse a unit. Careful measurement with a diameter tape on plantation trees can provide estimates of equivalent diameter consistently to within 2 or at the most 3 mm, particularly if only mid-internodal sections of the stem are chosen as points of measurement. There is a practical advantage in aiming too high, in that a better standard of operator consistency is usually attained. There are statistical and computational reasons, too, beyond the scope of this paper, which commend the adoption of millimetres, provided that the subsequent handling of data is correct. The more rounding that can be left to automatic machines the better.

Bark thickness in Europe is assessed in mm, which fits in logically with diameters in the same units. The possibility of reduced emphasis on this particular measurement will be discussed later.

Under linear measure, the question of what to do about breast height arises. Continental Europe uses 1.3 m for breast height; Britain and Australia 4.25 ft, which is 1.30 m to the nearest mm, but in New Zealand (and South Africa, Canada and U.S.A.) it is 4.5 ft, which is 1.37 m. Britain and Australia could logically adopt 1.3 m, but New Zealand would be well advised not to adopt the inconvenient height of 1.37 m. The French use 1.5 m as breast height for diameters obtained by tape. Since New Zealand will probably have to deviate from the metric equivalent of 4.5 ft anyway, and as there is a precedent of sorts, whatever its dubious connotation, a breast height of 1.5 m is not without merit; every little extra distance above ground level reduces problems of butt swell and, in my experience of tree growth patterns, of the frequency of unrepresentative breast-height sampling points likely to be encountered.

The opportunity to discard the practice of taking two diameters above and below a branch whorl when breast height, or other point of measurement, falls on or near such unrepresentative points, should not be lost. The mid-point of the "internode" in which breast height, or other sampling point, occurs is an alternative that I have found eminently satisfactory: it is easily identified, consistently estimated, and a much less variable and so more workable standard from which to manipulate inventory data.

Measurement of land areas presents one major problem; a hectare, 10^4 m^2, is not a recommended S.I. unit. Nevertheless, there is good reason to use the hectare as the unit for areal productivity; it is about $2\frac{1}{2}$ acres. A m^2 is too small and the km^2 ($=10^6$ m^2) too large. But, for the sake of unambiguous identification of its size in relation to 1 m^2, it ought to be designated hm^2 rather than by the IUFRO mensurational symbol ha.

Measurement of sectional area is probably the most easily handled in m^2 or mm^2, whichever is more appropriate. Thus, a tree of 30 in. d.b.h. has a basal area of 0.4560 m^2 rather than 456037 mm^2, but a seedling with a root collar diameter of 3 mm has a corresponding sectional area of 7.07 mm^2 rather than 0.000007 m^2. Again, 200 sq. ft/ac can be expressed as 45.92 m^2/hm^2, and 50 m^2/hm^2 represents 217.7 sq. ft/ac.

Common sizes of quadrat can be expressed in m^2. There will be no real difference in sampling variability induced by a changeover from imperial to metric sizes of quadrat, as can be seen from Table 1.

TABLE 1: SUGGESTED METRIC QUADRAT SIZES

Imperial Plot Size (ac)	*Metric Equivalent (m^2)*	*Suggested Metric Plot Size (m^2)*
0.001	4.047	4
0.025	101.172	100
0.050	202.343	200
0.100	404.686	400
0.200	809.372	800
0.250	1 011.715	1 000
0.500	2 023.430	2 000
1.000	4 046.860	4 000

Thus, 400 m^2 can be a square plot of 20 × 20 m, or a circular plot of radius 11.3 m, or a hexagonal plot of half-diagonal 12.41 m. There is, of course, no real difference in redefining predominant mean height (Beekhuis, 1966) to be the mean of the heights of the tallest tree in each 0.01hm^2 in 1 hm^2.

Conversion to metric units should allow us once and for all to use true cubic measure for volume and to discard entirely all the other ill-defined units that have been the bugbear of timber measurements for many years. It is important that growers, processors, transporters of, and traders in wood get together to resolve this crucial item. Individual logs or trees should be measured and recorded to the nearest 0.001 m^3 (= 0.035 cu. ft) and totals rounded off to the most suitable figure; sometimes it may be the nearest m^3 (= 35.3 cu. ft), at others the nearest 0.1 m^3.

A volume of 10,000 cu. ft per acre is 700 m^3/hm^3. But should this volume be over or under bark in future? Foresters in

New Zealand and elsewhere have been quite content to talk about overbark basal area per unit area, overbark mean diameter, etc., of a stand, and yet couple it with a total stem volume per unit area in underbark dimensions. Errors in measuring bark are often considerable when instruments such as the Swedish bark gauge are used. For any one operator, there may be a consistent bias, but evidence, as yet unpublished, suggests that differences between operators is considerable. If there is a move towards inventories at a local level being based on direct measurements of volume rather than indirect measurements from regional tree or stand volume relationships (possible reasons for such a move are outlined by Whyte, 1970), particularly when optical dendrometers are used to measure out-of-reach diameters, then overbark volumes should be adopted. Volume per unit area, as a measure of productivity, is merely a standard from which to derive recoverable and utilizable outturns; as such, therefore, the measurement of bark is an unnecessary component. Two complicating factors exist, however: first, substantial genetic variation in total bark volume and its distribution along the bole is present in a species like *Pinus radiata,* and a similar amount of phenotypic variation can be induced by different sites and silvicultural treatments; secondly, possible methods of determining volume increment are reduced in number, in quality and in efficiency when overbark volume is the parameter adopted. Neither of these problems is an insurmountable obstacle, but not enough is yet known to decide whether underbark or overbark volume of standing trees is more logical.

It is important that the volumes of sawn timber be measured in m^3, but, as advocated by Hanson (1970), in trading there is merit in linear measure of one cross-section at a time, an easy dimension for anyone to appreciate. Such a practice already exists in New Zealand for some items of timber in small dimensions.

The basic S.I. unit of mass is the kilogram, which is about 2.2 lb. A megagram, Mg, which can be called a tonne (preferred S.I. spelling) is equal to 0.98 of a British imperial ton. Both these will be easily assimilated in forestry practice. Thus, fertilizer spread at a rate of 200 lb/ac becomes 224 kg/hm^2, and 1 m^3/Mg = 35.87 cu. ft/ton.

Serious consideration should be given to the use of weight-scaling wherever possible once conversion to metric units begins, to reduce the wastage of time and manpower in volume-scaling. A change in technique, however, is desirable: instead of trying to predetermine an average specific volume in m^3/Mg, it would be better to conduct sampling schemes of continuous calibration geared to the variability of the material being handled, and to the precision and accuracy required of the scaling.

All these measurements, and others such as kg/m^3 for density of wood, are merely scales with which foresters must become familiar. As Weston (1969) pointed out, it is absolutely essential to think in metric units. Initially, this practice may be hard, but it will pay better dividends than a continual process of mental conversion. Further benefits will accrue, if foresters write reports and articles with only metric units and, incidentally, if they use IUFRO mensurational symbols too.

INSTRUMENTS AND EQUIPMENT

As with techniques of measurement, the opportunity to rationalize instruments and machinery should also be taken. For example, diameter tapes used in New Zealand are often 33 ft long, of which only the first 9 or 10 ft are used for even very large, mature exotic trees. There is a need to have lengths and widths of tape suited to the size of trees being measured; a suitable range has been obtainable from Europe for several years. Scales on tapes should be graduated so that no interpolation or rounding is needed when taking measurements. Also, manufacturers should be encouraged to provide reliable spring-loaded rewinding mechanisms rather than the unwieldly manual variety.

The same sort of reasoning should be applied to linear tape measures and to height-measuring instruments. Indeed, this aspect of instrumentation demands a thorough review, before foresters commit themselves to another generation of relatively inefficient measuring devices.

It is important, however, that clearly defined specifications be drawn up as soon as possible, as any instruments bought in future, particularly expensive ones, should be entirely suitable for measuring in the required metric dimensions. Thus, plans should already exist to phase out old instruments and machinery and to spread the expense of converting to metric ones over as long a period as possible, as no monetary compensation is likely to be paid in New Zealand. It is advisable not to purchase any more equipment with imperial scales. Some instruments can be easily converted merely with a cheap modification of scales; others, such as tapes or calipers, need more costly treatment. A clinometer such as the Blume-Leiss, for example, can be adapted in several ways:

(1) It can be used without modification, using the linear or degree scales with a metric measuring tape and not a range-finder.

(2) It can be fitted with a range-finder staff converted to the required units.

(3) It can be fitted with a new set of direct-reading scales.

The Suunto clinometer needs merely a simple modification of its range-finder staff.

One measuring instrument over which foresters may be able to exercise little control is the surveyor's band. The Metric Advisory Board has announced (Stevenson, 1970) that, subject to changes in legislation, to procurement of new equipment and to the adoption of a unit of area, 1 January 1973 will mark the change to metric units for surveys.

Surveyors in New Zealand have not, at the time of writing, decided on what metric conventions to adopt. Bands of 100 m, however, with a leader tape of 20 m, graduated in units of 0.2 m, are already being exported by this country. One link = 0.201 m, so that, if a link is a suitable unit for an intensive survey, the metric equivalent is almost exactly 0.2 m, and one chain = 20.12 m.

The Ordnance Survey in Britain has already taken steps to promote a more convenient set of scales. That of 1/10,560 is being replaced with 1/10,000: contours on the latter scale will be marked in intervals of 5 or more metres. There can be, unfortunately, no chance of avoiding unwieldly conversion of bench marks.

These are some few instances of points to consider for possible changes to a metric set of units.

A PLEA TO FORESTERS

Metrication should provide the catalyst for simplifying and rationalizing measurement in forestry. Countries like Britain, New Zealand, Australia and South Africa are all in the process of changing. Present indications are that each is going its own way, seeking individual dispensations here and there within the framework of allowed S.I. units. It seems unfortunate that there is no co-operation apparent among them, nor any concerted effort to bring together various sectors of forest industry, with notoriously conflicting conventions of measurement, within any one country.

It is to be hoped that sufficient interest may be kindled within the forestry profession in New Zealand for individuals to examine critically inconsistencies of present measuring practices and to contribute remedies which can be incorporated with the change to metric units. A few anomalies have been instanced here and many more problems, for which inadequate data are available, exist. For a successful conversion, all of us should be communicating ideas to relevant committees at the national level so that nothing is overlooked in providing a useful set of measuring units for the future. Metrication in New Zealand is a voluntary process, and the spirit of it is that anyone who can contribute should do so before time runs out: otherwise, another set of arbitrary and irrational units might be adopted which would once again obscure the real objectives and principles of measuring. Under the present system, the opportunities to do so exist; we shall have only ourselves to blame if we fail to take advantage of these opportunities.

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APPENDIX

Multiples and Sub-multiples of S.I. Units

Multiplication Factor	*Prefix*	*Symbol*
10^{12}	tera-	T
10^{9}	giga-	G
10^{6}	mega-	M
10^{3}	kilo-	k
10^{2}	hecto-	h
10^{1}	deca-	da
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	fento-	f
10^{-18}	atto-	a

USEFUL CONVERSION FACTORS

Acre	0.404 686	hectare
Centimetre	0.393 701	inch
Chain	20.116 8	metres
Foot	0.304 8	metre
$Foot^2$	0.092 903 0	$metre^2$
$Foot^3$	0.028 316 8	$metre^3$
$Foot^2$/acre	0.229 568 0	$metre^2$/hectare
$Foot^3$/acre	0.069 972 2	$metre^3$/hectare
Gallon	4.546 09	litres (dm^3)
Hectare	2.471 05	acres
Hundredweight	0.050 802 3	tonne
Hundreweight/acre	125.535	kilograms/hectare
Inch	0.025 4	metre
Kilogram	2.204 62	pounds
Kilogram/hectare	0.892 2	pound/acre
Kilogram/$metre^3$	0.062 43	pound/$foot^3$
Kilometre	0.621 371	mile
Litre (dm^3)	0.219 969	gallon
	1.759 76	pints
Metre	1.093 61	yards
	3.280 84	feet
	39.370 08	inches
$Metre^2$	1.195 99	$yards^2$
	10.763 9	$feet^2$
$Metre^3$	1.307 95	$yards^3$
	35.314 7	$feet^3$
$Metre^2$/hectare	4.356 0	$feet^2$/acre
$Metre^3$/hectare	14.291 4	$feet^3$/acre
Mile	1.609 34	kilometres
Pint	0.568 261	litre
Pound	0.453 592 37	kilogram
Pound/acre	1.120 85	kilograms/hectare
Pound/$foot^3$	16.018 5	kilograms/$metre^3$
Ton (U.K.)	1.016 05	tonnes (Mg)
Tonne (Mg)	0.984 207	ton
Yard	0.914 4	metre
$Yard^2$	0.836 127	$metre^2$
$Yard^3$	0.764 555	$metre^3$