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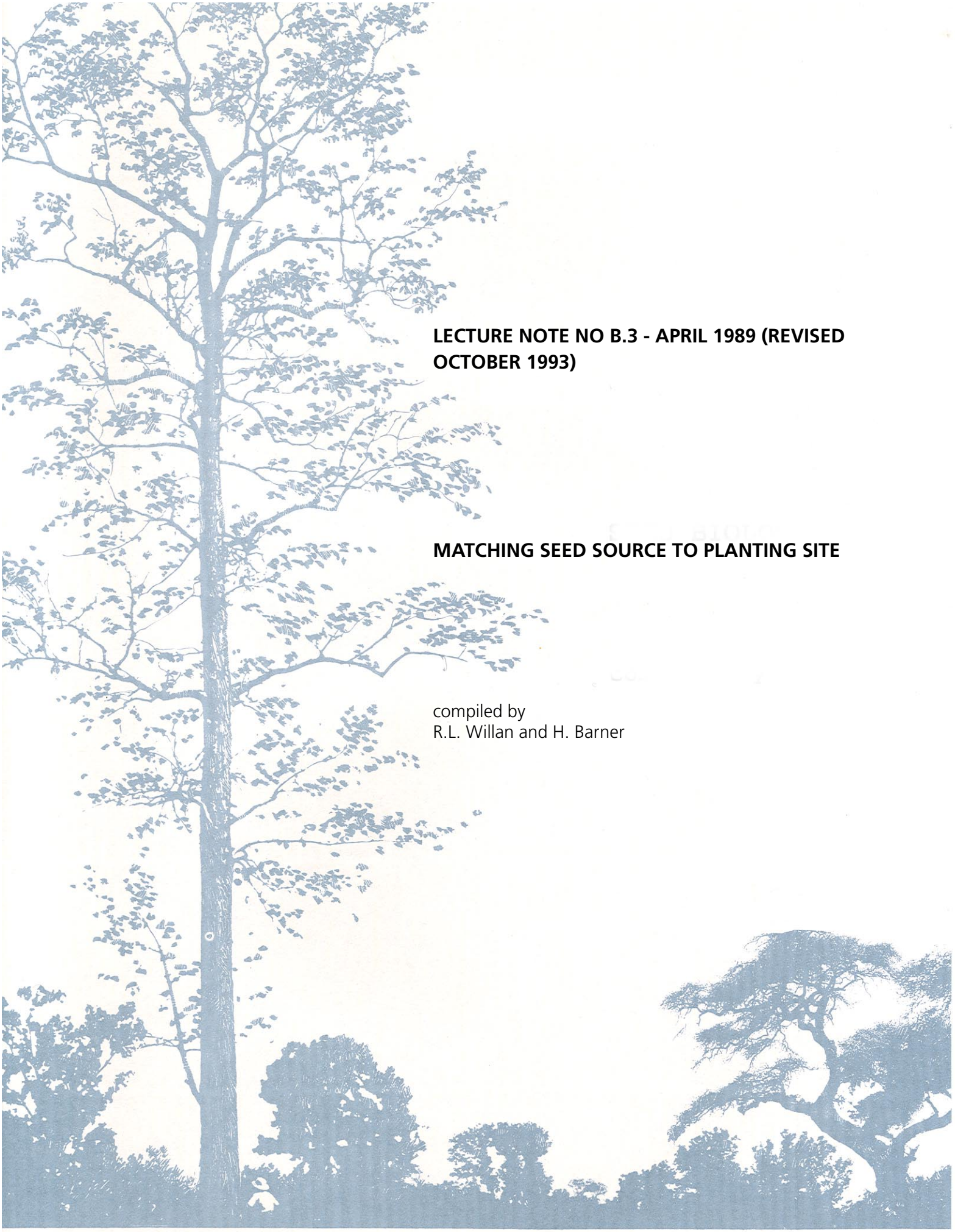

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MATCHING SEED SOURCE TO PLANTING SITE

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DANIDA FOREST SEED CENTRE

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1 INTRODUCTION

Matching seed source to planting site involves two comparisons:

(1) A species or seed source should be chosen that is capable of yielding the wanted product, which may be construction timber, fuel-wood, protection of a water-catchment area or any other "product" or purpose of tree planting.

(2) A species or seed source should be chosen that is likely to survive, grow and remain healthy on the planting site.

"Planting site" here includes all environmental conditions which will affect the health and growth of planted trees; local climate as well as local soil and local topography also local biotic factors such as pests, diseases and the beneficial or detrimental influence of man himself. To include (1) above, it may be expanded to include the local environment for harvesting, utilization and marketing. Much of the present lecture is concerned with matching the growth opportunities of a planting site to the growth conditions of a seed source, but the need to remember the purpose of planting is equally important. A light softwood will not make a good fuelwood, nor will a short-fibred hardwood produce long-fibred pulp, however well adapted they may be to the site or however large volumes of unsuitable products they may produce. In some cases, multi-purpose species (e.g. yielding both fuelwood and fodder) may have an important role. In others, separate needs may be met more efficiently by separate species. Examples of the useful differentiation between seed sources on grounds of end use characteristics are less common than between species but this reflects inadequate or unfinished research rather than lack of differences. It seems likely that, with increased knowledge, seed source differences in traits such as spiral grain, stem straightness, nutrient content of fodder etc, will be found to be statistically significant and economically important in many species.

Seed source (provenance) research, with a few notable exceptions, (teak, *Gmelina*, a few tropical pines and eucalypts), is still in its infancy in the tropics. It is, however, possible to derive some general guidelines to matching seed source to planting site, not only from experience on those few species but also from the considerably larger body of experience of matching species to planting site.

The matching operation involves the acquisition of knowledge about both the seed source and the planting site. The subject of seed sources, their classification, characteristics, selection, delineation and documentation, has been covered in the lecture note B-l "Classification and Selection of Seed Sources". Similar information is needed on the environmental characteristics of planting sites.

In the following, section 2 touches briefly on the needs and methods for describing seed sources and planting sites. Some of the methods are described in more detail in section 4.2 and the important subject of site survey is discussed in section 5.

Section 3 distinguishes the main categories of planting sites and seed sources to be considered. Section 4.1 discusses the problems of transfer of seed of a species within its own natural range, when a local seed source should usually be available as a standard of comparison, while section 4.2 discusses the problems of matching seed source to planting site when not only source but also species is exotic to the site. Section 6 discusses the special case of matching phenotypically or genetically superior seed sources to new planting sites.

2 ECOLOGICAL DESCRIPTION OF SEED SOURCES AND PLANTING SITES

For the purpose of matching, the more information that can be supplied about a seed source, the better. A suitable format is contained in the sections of Locality, Site and Stand in the Danida Forest Seed Centre's form for seed collection data, reproduced in Appendix 1. Where a country already has an operational system of defined and mapped seed zones and identified stands, it may well be possible to provide data in this format. Where a national seed-source system has not yet been initiated, it may be difficult to provide so much detail. In all cases, however, it is essential to provide data on the location of the seed source (province, district, county etc. plus latitude and longitude), altitude, an estimate of rainfall (mean annual and distribution pattern) and temperature, and any special or unusual features of soil, topography or vegetation. Numerous attempts have been made at classifying the different components of site at local, national, regional and global level. These include climate (homoclimes, climatic indices etc.), soil types, vegetation types and ecosystems. Some of these are discussed in Section 4.2.

The need for accurate and detailed description of ecological conditions applies no less to species than to provenance or seed source trials. There is little value in establishing trials to compare species X with species Y on the basis of seed of unknown origin; especially so, if both species have wide distribution over a range of environments. The comparison should be between clearly identified seed sources of each species. If the seed source of the best performers are known, further collections from the same seed source can be arranged, and the results will also provide guidance to the planning of subsequent provenance trials of the successful species.

Foresters or others in charge of tree planting schemes may have to rely on others for identification and description of seed sources; it is their own responsibility to know their own planting sites. The more that is known about the ecological characteristics of the planting site(s), the better the chances of matching it (them) with the most suitable seed sources. Site survey is an essential preliminary to any well-planned afforestation project and one of its objectives should be to provide a basis for selection of species and seed sources within species. Site survey is considered further in section 5 below.

3 MAIN CATEGORIES OF PLANTING SITES AND SEED SOURCES

For convenience, planting sites may be considered as:

(1) Within the natural range of the species to be planted.

(2) Outside the natural range of the species to be planted.

A primary breakdown of seed sources may be made into:

1) Sources identified as to location and, as far as possible, environmental conditions, but without any conscious selection for superiority. These include Seed Collection Zones and Identified Stands (Lecture Note B-1 "Classification and Selection of Seed Sources").

2) Sources selected for same degree of superiority, in addition to being identified to locality. These include Selected Stands, Seed Production Areas, Provenance Seed Stands and Seed Orchards. In the early stages of an afforestation programme, especially with introduced species, countries are likely to be most concerned with the first two categories, Seed Collection Zones and Identified Stands.

4. SEED SOURCES IDENTIFIED AS TO LOCATION

These include Seed Collection Zones and Identified Stands. Phenotypic quality should be representative of the area in question, i.e. there is no effort at selecting superior stands or plus trees within stands. On the other hand, the worst stands and trees should be avoided. A useful guide is to collect seed from "not worse than dominant and co-dominant trees of average quality... from normal stands" (FAO 1969). The phenotypic quality to be expected is thus "not poorer than the average for the area."

4.1 Planting sites within species' natural range

It can be assumed that, when natural forest has established itself on a site and regenerated over a number of generations, the local seed source will be better adapted to the local site conditions than any other. An important distinction must be made between (1) A local seed source which is indigenous and therefore, after generations of natural selection, well adapted to the site, (2) A local seed source of an introduced provenance, on which local selection pressures have been operating for only one or a few generations. These introduced sources are

likely to be considerably less well adapted to the sites on which they are growing. After a number of generations, an "introduced" species or provenance grades into a "naturalized" one, when it maybe as well adapted to local conditions as a truly indigenous one. Examples of species which have become naturalized outside their natural range are fairly common, e.g. *Tectona* in Indonesia, *Casuarina* on tropical coasts, ornamentals worldwide. Examples of naturalization of provenances far away from their own origin but within the natural range of the species are less common; oak introduced into Denmark from the Netherlands at the beginning of the nineteenth century has proved well adapted and shows promise of successful naturalization.

Introduction of non-local provenances from elsewhere within the natural range of the species is sometimes stimulated by their apparent superiority in some useful characteristic. In such cases not only is it necessary to demonstrate that the introduced provenance maintains its superiority (e.g. in stem straightness) on the new site but also that it is not significantly inferior to the local indigenous provenance in adaptation to the site (e.g. resistance to drought or disease, tolerance of poor drainage).

In most cases, however, local natural seed sources should be preferred for planting on sites within the natural range. A problem may arise if large quantities of seed are needed for a major planting project, but local seed sources are unable to supply it. This can happen where there has been massive deforestation and it is decided to reforest with the original species. In such a case the forester needs to know how far he can safely transfer seed from a natural but non-local source to his planting site.

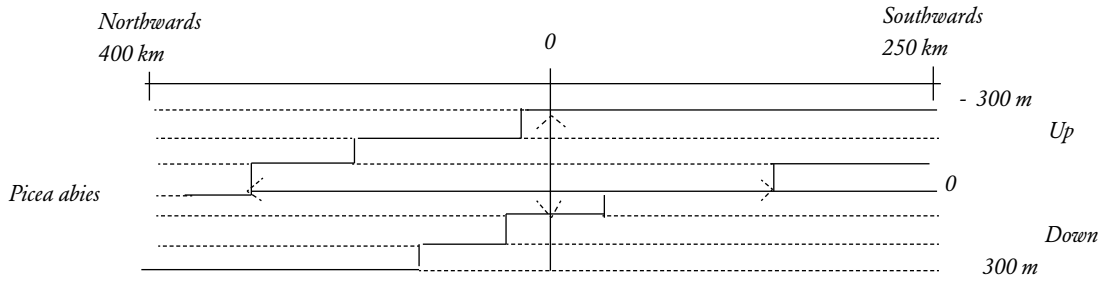
Any sensible system of seed source zonation should provide a useful guide to safe limits for seed transfer. Ideally this would be based on results of research on genetic differences between populations, but there are few cases in which genetic research has advanced to this stage.

Most seed zone systems, in default of demonstrated genetic variation, rely on observed ecological variation, often modified by the need for administrative convenience in organizing seed collection. An example is the preliminary delineation of provenance regions for *Pinus caribaea* and *Pinus oocarpa* within the Republic of Honduras (Robbins and Hughes 1983), which is summarized in Appendix 2 of Lecture Note B-1 "Classification and Selection of Seed Sources". The primary classification of provenance regions (or seed collection zones) was based on broad physiographic zones (mountain and valley systems), with special attention paid to discontinuities in species distribution. Within the primary physiographic zones, limits were prescribed for individual seed collections; these were a 300 m maximum range in altitude and a 50 km maximum range in horizontal extent.

In Norway, a system of seed zones has been introduced and the zones demarcated on maps. In that country it is recommended that seeds and plants be preferably used within the zone from which the material was collected. However, it was considered that seeds and plants could, if necessary, be moved within certain limits and still give satisfactory results.

The following diagram shows the guidelines for moving *Picea abies* (Norway spruce) seed from the place of collection (Fystro 1983). The area of permitted transfer is indicated by the solid line. Thus, at the same latitude, it is considered safe to move seed not more than 100 m lower and not more than 300 m higher in elevation. At the same altitude, moves of up to 300 km northwards and 150 km southwards are permissible. More distant transfers are allowed if altitude compensates for latitude, e. g. 250 km southwards provided there is also an increase of 100-300 m in altitude.

Guidelines for transfer of seed in Norway



In mountainous areas the occurrence of rapid changes in altitude over short horizontal distances, and their effects on genetic adaptation of the local populations, is likely to be a major consideration when matching seed source to planting site. Thus, if sufficient quantities of seed from a preferred seed source are not available, the user may sometimes find a better match, as his second best choice, in a seed source from the same altitude and aspect in an adjacent seed zone rather than in a source in the same zone but at 500 m lower altitude.

One example in which preliminary guidelines on safe transfer of seed have been based on genetic research is the study on Seed Transfer Guidelines for Western Larch (*Larix occidentalis*) in the Northern Rocky Mountains of USA (Rehfeldt 1982, 1983). The author defined an appropriate criterion for differentiating seed zones as the minimum geographic or elevational interval across which differences among populations could be detected at the 80% level of probability. Geographic seed zone contours[1] were mapped and the elevational interval was found to be about 1500 ft (460 m). It was recommended that seed from a single source should not be transferred more than one half the minimum geographic or elevational interval over which differentiation could be detected, e.g. no more than ± 750 ft (230 m) in altitude within the same geographic seed zone. It was recognised that changes in altitude could compensate for changes in geographic zone, for example it would be safe to transfer seed by no more than two geographic contours in a colder direction if maintaining the same elevation, but by no less than three and not more than seven geographic cap contours in a colder direction provided that the geographic shift was compensated by a drop in elevation of 1875 ft (575 m). The present guidelines were developed from a single study of very young trees and were regarded by the author as provisional, subject to modification as the study trees mature.

1) Four geographic contours on the maps are equivalent to one geographic interval over which differentiation can be detected.

Cases where a non-local seed source yields better-adapted crops than the lo-

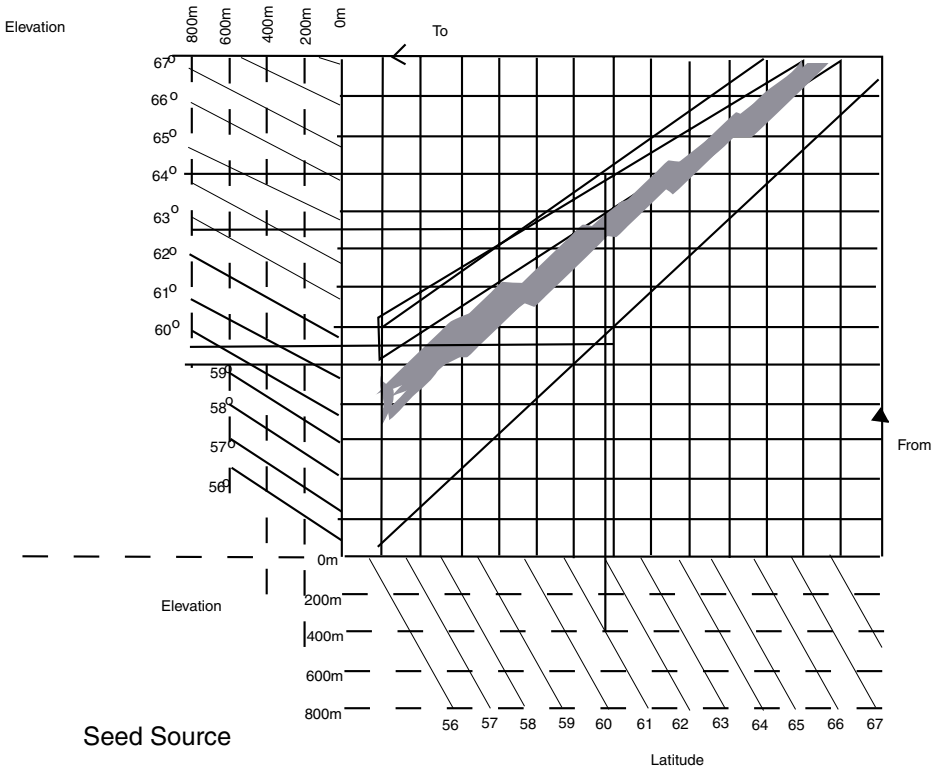
cal natural source can be considered extremely rare. However some non-local sources may prove to be nearly or quite as well adapted, and in addition may have certain more desirable end use characters. Sweden is one of the few countries where delimitation of seed zones and recommendations for seed transfer are based on results of provenance trials.

The results of the trials of *Picea abies* in northern Sweden are of particular interest since they indicated that best performance could be obtained by moving provenances rather than by using the local provenance. Rosvall and Ericsson (1981) summarized the findings:

> "Transfer effects of *Picea abies* in northern Sweden
>
> Seven provenance trials set up in 1958-60 in northern Sweden (61°- 67°N) with Norway spruce (*Picea abies*) provenances from different latitudes (57°-67°N) and altitudes (20-445 m a s) have been measured in 1979. Tree height, diameter, mortality and different kinds of damages were recorded. The aim of the study is a revision of the provenance transfer recommendation used in practice. This recommendation is based on the same provenance trials. The interaction between optimum transfer and the location of the experiments has been investigated by regression analysis. The origin of provenances and the location of the sites have been described by latitude and elevation. Tree height has been criterion for the choice of provenance. Risks connected with transfer of provenances have been discussed based on rate of mortality and damages.
>
> Maximum tree height is achieved by moving provenances northward 2-4 degrees of latitude. ..... The advantage of moving provenances latitudinally decreases with increasing site severity, and the optimal transfer will also be shorter. Severity is to most extent a function of the elevation of the site. In some of the experiments, the height growth between 1973-79 indicates a shorter optimum transfer than does the tree height in 1979. A schematic map of northern Sweden connecting sites, described by latitude and elevation with the same optimum transfer, is recommended to be used for site classification.
>
> The mortality and the damages indicate that the calculated optimum transfer should be reduced when applied to extraordinarily poor sites exposed to wind and drought on high elevation in the northernmost parts of Sweden. Weak development in combination with damages caused by snow blight (*Laphophasidium hyperboreum*) is a threat to young spruces. However it may be questioned, if these sites should be regenerated with spruce at all, as long as no better methods of regeneration with a more intensive soil preparation are used, compared to those applied when the experiments were planted. In practice it is recommended to reduce the northward transfer with 0.5 degrees of latitude to each altitudinal transfer of 200 m and not to exceed an altitudinal transfer of 400 m. This is supported by damages and mortality observed in the most severe sites.
>
> It is finally stressed that spruce regeneration should be directed to good sites.

Variation in site index and tree height within trials shows that the choice of site is more important than the choice of provenance."

The results of the above research have been incorporated in the prescriptions for movement of seed within northern Sweden issued by the State Board for Forestry, shown in the following diagram. The dark central band indicates the prefer planting zone, the outer solid lines demarcate the limits of less suitable but still acceptable sources. For example, the ideal planting site match for a seed source at 400 m elevation and 610 lat. is at 400 m and 63 3/4°; equally suitable would be 0 m and 64 3/4°; 200 m and 64 1/4°, 600 m and 63 1/4° or 800 m and 62 3/4°. The extreme acceptable range for planting would be from 400 m and 60 1/2° to 400 m and 65 1/4°, or equivalent combinations of elevation and latitude.



4.2 Planting sites outside species' natural range

The use of exotics for tree planting has increased enormously in the present century. Well known examples are North American conifers in Europe, *Pinus radiata* in the Mediterranean, New Zealand, Australia and Chile, eucalypts in South America and Africa. More recently, the tropical pines have assumed an important role for afforestation throughout the tropics, much of which lacks adequate resources of coniferous wood. At the present time there is intense interest in the testing and use of species for fuelwood and agroforestry in rural communities. If well chosen and managed, the exotics may be capable of producing larger quantities and/or more suitable end products than any indigenous species.

With the use of exotics, there can be no local natural seed source which can be assumed to be well adapted to the planting site and, if the species to be planted is indigenous in a distant country or a different continent, the problems of matching seed source to site are increased.

A special case arises if there is a local seed source of an exotic previously introduced. If this has already demonstrated good growth and health over several generations, it may be considered as "naturalized" or as a local "landrace" and as well adapted to the site as a local seed source of an indigenous species. More recent introductions, however, should be regarded with caution. Even if stands established from a given seed source, perhaps introduced only because seed was readily available, show promise of good adaptation, it does not follow that it is the most suitable of all. In the absence of comparisons of a range of seed sources on the same site, studies in matching seed source to site should continue to be pursued with vigour.

Climate

A major tool in matching seed source to planting site has been homoclime analysis, the comparison of climates at different locations in order to identify those with the closest similarity, even though they maybe geographically far distant. This has been used extensively in selection of species for introduction trials. The homoclime concept is a useful guide in the initial stage of selecting species and provenances but it is no substitute for testing. Classification and mapping of world climates on a small scale has been done, notably by Köppen (based on temperature and total and seasonal precipitation) and Thornthwaite (temperature, precipitation and potential evapotranspiration). Classification of bioclimatic, ecological or silvi-cultural zones on a national basis, together with lists of species recommended for each zone, has been made in a number of countries, e.g. Brazil, South Africa, Zimbabwe (Golfari et al. 1978, Poynton 1971, Barrett and Mullin 1968). Webb et al. 1984 classified tropical and subtropical climates (excluding the arid zone) into 21 zones, based on Mean Annual Rainfall and Mean Annual Temperature (or Altitude), and suggested species worth trial in each zone.

Development of computer programmes for homoclime analysis has facilitated its application to finer comparisons of seed source or provenance with planting site. In Australia the BIOCLIM (Bioclimatic Prediction System) and CLIMSIM (Climatic Similarity Programme) programmes have been developed to assist other countries to select the Australian species and seed sources likely to be best suited to the climatic environment of their planting sites. The data required for these programmes consist of (1) Monthly mean of daily maximum temperature for each month (2) Monthly mean of daily minimum temperature for each month (3) Precipitation for each month. From these 36 basic figures, 18 climatic indices are compiled for each location; these are tabulated in the attached Appendix 2. It is possible to define the range of native species, and from that to predict, from homoclime analysis, the regions in other continents where the species is likely to perform well. One study carried out on *Eucalyptus citriodora* (Booth 1985) indicated a satisfactory correlation between the degree of success of plantings in Africa and the degree of climatic similarity between the areas in Africa and the areas of natural distribution in Australia.

It is possible to reverse the procedure by first defining the climatic indices of the planting site, and then identifying locations elsewhere in the world with the same or very similar indices. This has the advantage that it can suggest not simply a species worth trial but also one or more seed sources within the range of that species. Also, a location identified may have seed sources of more than one species to offer. The same location in Australia, for example, might provide seed of *Acacia* and *Casuarina* species as well as *Eucalyptus*. With the current worldwide interest in species for fuelwood and agroforestry, there are additional species which may be of potential value but which are still little known.

Within Australia, climatic indices have been estimated, by interpolation techniques, for 2795 points on a half degree grid. It is possible to compare these indices with those at a given proposed planting site, for example in Africa, and grade the Australian locations in accordance with their climatic similarity to the African site. A convenient grading method is to use the letters of the alphabet, 'A' indicating locations most similar to the planting site and 'Z' those least similar. Zones of different degrees of similarity can then be plotted on the map. In an example of the method applied to Kaolack in Senegal, West Africa (Booth et al. 1987), a broad zone of fairly high similarity (grades A-C) was identified in northern Queensland and the northern parts of Western Australia and Northern Territory. For a more precise homoclime (grade A only), a much smaller total area, split between several discrete blocks, was shown to be appropriate. See Appendix 2.

In matching seed source to planting site, no amount of climatological or ecological matching will reveal a species' or seed source's capacity to adapt to changed conditions (Leuchars 1965). In this connection, the conditions in which an introduced seed source has performed well can be no less important in evaluating its potential than those in its natural occurrence and should be incorporated in its "climatic profile". In particular, a series of trials over a range of site conditions may already have indicated certain seed sources as being of wide adaptability. A good example is the performance of the Lake Albacutya provenance of *Eucalyptus camaldulensis* over a range of sites in a number of Mediterranean countries and of the Petford provenance over several site types within the moist tropical, summer rainfall, zone of Africa (Lacaze 1978). Results such as these indicate the enormous value of international trials in obtaining and disseminating results of wide application. Priority should be given to introducing seed sources of known broad adaptability if they exist.

Soil

Climatic matching has generally proved more helpful than soil matching. Although soil characteristics may be critical for some species, they are more difficult to assess, more difficult to interpret and more subject to small-scale variation, than climatic factors. For these reasons soil matching is often confined to the tolerance or intolerance of a species to particular soil types, for example that *Leucaena* is unsuited to highly acid soils. Webb et al. (1984) list a number of species tolerant of particular soil conditions. Little is yet known about the soil preferences of individual seed sources within species, although the Port Lincoln and Wiluna seed sources of *Eucalyptus camaldulensis* have shown particular toler-

ance to calcareous soils of high pH both in Australia and in trials in the Mediterranean (Jacobs 1981).

It is usually advisable to consider too many, rather than too few, species and seed sources for trial on a given planting site. Useful as it is, climatic matching cannot evaluate all the factors affecting the success of an intro-duced species or provenance. The effect of 250 mm less annual rainfall may be compensated by the presence of a water retentive loam soil in place of a free-draining sandy soil.

Vegetation

Vegetation can often be considered as an expression of all the environmental factors operating at a site. In some cases it provides a valuable guide to matching sites, especially where local climatic data is not available. For example conditions for an exotic are likely to be similar on a *Podocarpus/ Ocotea* montane forest site, whether it is in Kenya or Tanzania. Comparing vegetation from two different continents is much more difficult, since few if any species are common to both.

Vegetation type is a reliable means of distinguishing riverine sites from the drier savanna between. Climatically they are indistinguishable but the soil-moisture relations and thus the list of well-adapted species/seed sources for each are very different.

Where there are several species and many seed sources (provenances) to be considered and there is no clear evidence about their relative adaptability to a local planting site, there is no sensible alternative to a carefully planned experimental programme in advance of large scale tree planting. Af-forestation is expensive and failures over large areas are unacceptable. The methodology of provenance testing is described in Lecture Notes D-3 and D-6. Here it is sufficient to note that replicated trials of seed sources, using small plots, can provide a sound basis for subsequent afforestation at modest expense, provided care is taken that the sites used for the trials are a representative sample of the sites which occur through the planting area. If this is the case, results from the trials can be extrapolated with confidence to the whole area of the planting project and will lead to a sound choice of the best adapted seed sources. Site survey is an essential tool in the achievement of this objective.

5 SITE SURVEY

Surveys of particular areas for tree planting should, ideally, be made within the context of national land use planning. Guidelines to land evaluation at the national level are available (e.g. FAO 1976, FAO 1984). For present purposes it can be assumed that an area has been earmarked for a tree-planting project, say a compact block of 5,000 ha for production of sawlogs or the same total area of village woodlots distributed over a district of 80,000 ha. Site assessment is required, both to provide the data for selection of species and sources and to assess the variation in site quality over the area.

Assuming that there are no trees of appropriate species growing in the area, it will be necessary to establish replicated trials of potentially useful species and seed sources on sites representative of the major site types in the planting area. Survey to identify these types and estimate their relative extent in the area should ensure that the trials are sited to give the fullest and most relevant information for future planting. Even the best designed and managed trials in the world are of limited value if they are sited on a heavy clay soil, while the predominant soils of the project area are later found to be free-draining sands.

The existence of plantations of suitable species already growing in the area may reduce or eliminate the need for additional trials, but here too it is important to assess how representative the sites are on which the trees are growing. The original choice of site may have been dictated by incidental factors such as proximity to roads or villages. If evaluation of the area shows that important site types have not yet been planted, supplementary trials on those particular site types may be necessary.

When there is good information on the general environmental characteristics of an area and on the species appropriate for planting there, and a policy decision has been taken to start tree planting, there is still a need to evaluate the variability in site quality within the project area. A good example of the methods which are available is that of an afforestation project in Turkey (Gaddas 1976, Cooling 1977). A system of site evaluation or classification of planting suitability was developed (1) to assist the allocation of species to specific sites; (2) to facilitate the prediction of growth rates; and (3) to determine the type of reforestation appropriate to a given site (e.g. fully mechanized, partially mechanized, manual). The classification was inspired by various systems of land suitability classification used for agricultural land. Emphasis was given to the potential productivity of the site on the basis of various factors, notably climatic conditions, soil texture, rockiness, land form and slope, taking into account the feasibility of mechanized operations and also the hazard of erosion.

Sites were classified into four classes suitable for planting: P1, very good land; P2, good land; P3, medium land; and P4, poor land. Land unsuited for mechanized reforestation was designated NP, not plantable.

In the pilot plantation areas, which varied from a few hundred to over a thousand hectares in area, one pit was dug per 4 or 5 ha and profile descriptions were supplemented by surface observations and auger borings between pits. Vegetation was described at the same points. Soil laboratory analyses were carried out and the field work led to the preparation of 1/10,000 maps of (i) soil; (ii) vegetation; (iii) site (a combination of the vegetation and soil maps); and (iv) plantation suitability.

The table in Appendix 3 shows the planting suitability classes used for mechanized coniferous plantations in Turkey, as an example of the factors considered to affect site quality. In practice, a key was provided to define more precisely the terms used in classifying individual site factors, e.g. “slightly saline” was defined as 4-8 mmhos/cm, “very acid” as pH $<$ 5.5.

The intensity of soil survey depends both on the variability expected and the purpose of the survey. In Zambia, for example, an intensity of one soil pit every 36 ha was recommended for initial land evaluation, this was increased to one every 9 ha in areas already selected for an afforestation project (Sanders 1967). In areas where soil depth is the single most critical factor for tree growth, soil-pit survey may be supplemented by soil augering at a higher intensity.

Site assessment has most commonly been used for differentiating sites on the basis of quality. The higher suitability classes may be planted first (e.g, Pl and P2 in the Turkish example) and the lower suitability (P3) planted only if there is an inadequate area of Pl and P2. If all sites have to be planted, the forest manager will use the site assessment to predict higher yields from the higher planting suitability classes. In some projects, the species to be planted is adjusted to the suitability class. Thus, in the Black Sea region of Turkey, *Pseudotsuga menziesii* was recommended for non-calcareous areas with high rainfall, *Pinus radiata* for the most fertile sites in lower rainfall areas, *Pinus pinaster* for sites of moderate fertility, and *Pinus brutia* for calcareous sites (Cooling 1977).

In East Africa, *Cupressus lusitanica* has been found most suitable for cleared forest sites, *Pinus patula* for montane grassland sites. In many projects particular seed sources may be specified, which are known to be climatically well adapted to the area and to produce a desired end produce, e.g. the Lake Albacutya provenance of *Eucalyptus camaldulensis* or the Elburgon (Kenya) land race of *Cupressus lusitanica*. Until now, however, there seem to be very few reported cases where more than one seed source of the same species is used within a project area. As research reveals more about variation between seed sources, and techniques for site evaluation become more efficient, the precision of matching seed source to planting site should improve. It will then be possible to identify, not just species suited to the climate of the planting area, but separate seed sources suited to each of the major site types within the area, e.g. a seed source for the deeper soils of the valleys and a different one for the shallower soils and more exposed positions on the ridge tops.

6 SEED SOURCES PHENOTYPICALLY SELECTED OR GENETICALLY IMPROVED

The categories included here, according to the classification of seed sources described in lecture B-1 “Classification and Selection of Seed Sources”, are Selected Stands, Seed Production Areas, Provenance Seed Stands and Seed Orchards. The degree of improvement, expected or demonstrated, varies from Selected Stands (phenotypic selection at low intensity, no silvicultural treatment, no evidence of genetic improvement) to Tested Seed Orchards (initial phenotypic selection at high intensity, genetic superiority demon-strated by progeny trials, inferior genotypes removed).

The economic benefits of tree improvement are well documented (e.g. Hollowell and Porterfield 1986, Stier 1986, Willan 1988). Nowadays no forester or tree planter should be content to plant source-identified seed if he can obtain genetically improved seed of a well adapted provenance. In the past there has been very little improved seed available in the tropics, but its availability should increase rapidly as seed production areas and seed orchards mature. The real point at issue is the extent to which genetic improvement achieved in one area can be applied to another.The same care is needed in matching an improved seed source to a planting site as in matching a locality-identified seed source. Improved "exotic" seed sources need to demonstrate their local adaptability no less than unimproved, and "exotics" comprise ecological, not just national, foreigners.

There is no hard and fast rule to assist the choice between "best adapted" and "genetically most improved" seed sources. Each case must be judged on its merits. A few hypothetical examples may illustrate the sort of choices that have to be made:-

1. Country X has evidence that the source of *Eucalyptus camaldulensis* best adapted to its environment is a pronounced summer rainfall source such as Petford. No improved sources of seed are available of this provenance, but tested seed-orchard seed is available of a pronounced winter rainfall source such as *L. Albacutya*, which has demonstrated in winter rainfall conditions a substantial genetic improvement over the natural sources. This is a clear case where local adaptation is to be preferred to an improved source of an unsuitable provenance. In fact, selection and breeding for improved performance in winter rainfall conditions is likely to have made this seed orchard seed even less adapted to country X than the original proved winter rainfall source. Country X should continue with unimproved Petford until it can develop its own seed production areas and seed orchards of this provenance, or obtain seed of it from improved sources elsewhere which have been developed in environmental conditions identical or very similar to its own.

2. Country X has selected a provenance well adapted to certain sites. It has not yet developed its own improved seed sources but neighbouring country Y has available seed-orchard seed of the same provenance from orchards grown on sites virtually identical with the planting sites of country X. Country X need have no hesitation in using the seed orchard seed available from its neighbour. An actual example of something very similar is the use on montane sites in Tanzania and Uganda of seed from the Elburgon (Kenya) seed production area of *Cupressus lusitanica*.

3. Country X is about to start a series of *Pinus caribaea* seed source trials, but has learnt that genetically improved seed of one seed source, Mountain Pine Ridge, is available from Queensland, Australia. Should it forego the provenance trials and go ahead at once with a full-scale planting project using only improved Queensland seed? The correct procedure here is to continue with the provenance trials but to include the improved Queensland (and any other promising) land race with the seed sources from within the natural range.

Only if the Queensland source proves its adaptability under the conditions of country X, should it be adopted as a source for major planting schemes.

It must be admitted that often in the past, and sometimes still in the present, seed sources have had to be used not because they were locally best adapted nor because they were genetically improved, but because they were available. As genecological exploration, site assessment techniques and international cooperation improve, it should become easier to avoid the mistakes of the past. As tree planting with given species and seed sources in a country expands, a programme of tree improvement will need to be initiated (see Lecture Note A-2/A-3). Improved seed sources, e. g. seed production areas and seed orchards, will figure prominently in the programme. Although a proportion of genetically improved seed may need to come from similar sites abroad, at least in the early stages, it is a wise precaution to ensure that most of it, say at least two-thirds, comes from the appropriate silvicultural planting zone within the country itself. As a last resort, the best local source to match a particular site is the source which has already proved its superiority on the site, not a source growing well on an apparently similar site half way across the world. Even when sites are initially similar, differences in local climatic cycles and local management techniques may introduce different selection pressures. Ultimately any country with substantial tree planting programmes will aim to develop its own land races, well adapted to local conditions, and continually improved by selection and breeding of superior individual genotypes under local conditions. The bulk of all seed will be home-produced, although reproductive material of the very best genotypes will be exchanged at international level.

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Appendix 1

DANIDA No. _____

SEED COLLECTION DATA - DANIDA FOREST SEED CENTRE

Botanical Name :_____ Provisional No._____

Vernacular Name : _____ Provenance _____

LOCALITY

Country _____Prov./State _____Region/Adm. Unit _____
Latitude _____ Longitude _____Elevation _____
Map ref., Detailed Location _____
_____

SITE

Soil Type _____
_____pH_____
Slope _____Aspect _____Drainage _____

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/Mean
Rainfall													
Temperature													

Nearest Weather Station _____Lat. _____ Long. _____ Elev. _____

STAND

Density: open _____ patchy _____ dense ____ Establishment _____
Height _____ Diameter _____ Tree Quality _____ Age _____
Association _____
State of Stand _____
Remarks _____
_____

COLLECTION

Method _____ Date Collected _____
Number of tTrees Collected from_____ Spacing of Trees Collected from_____
Quantity of Seed/Cones _____ Condition of Seed/Cones _____
Possibility of Commercial Coll. _____
Remarks _____
_____

SEED HANDLING (FIELD)

Field Storage (Cones/Fruits) _____days. Extraction Method _____
Yield per Unit Volume _____ Field Storage (Seed) _____days.
Remarks _____

Description by: _____ Collector: _____
_____ _____

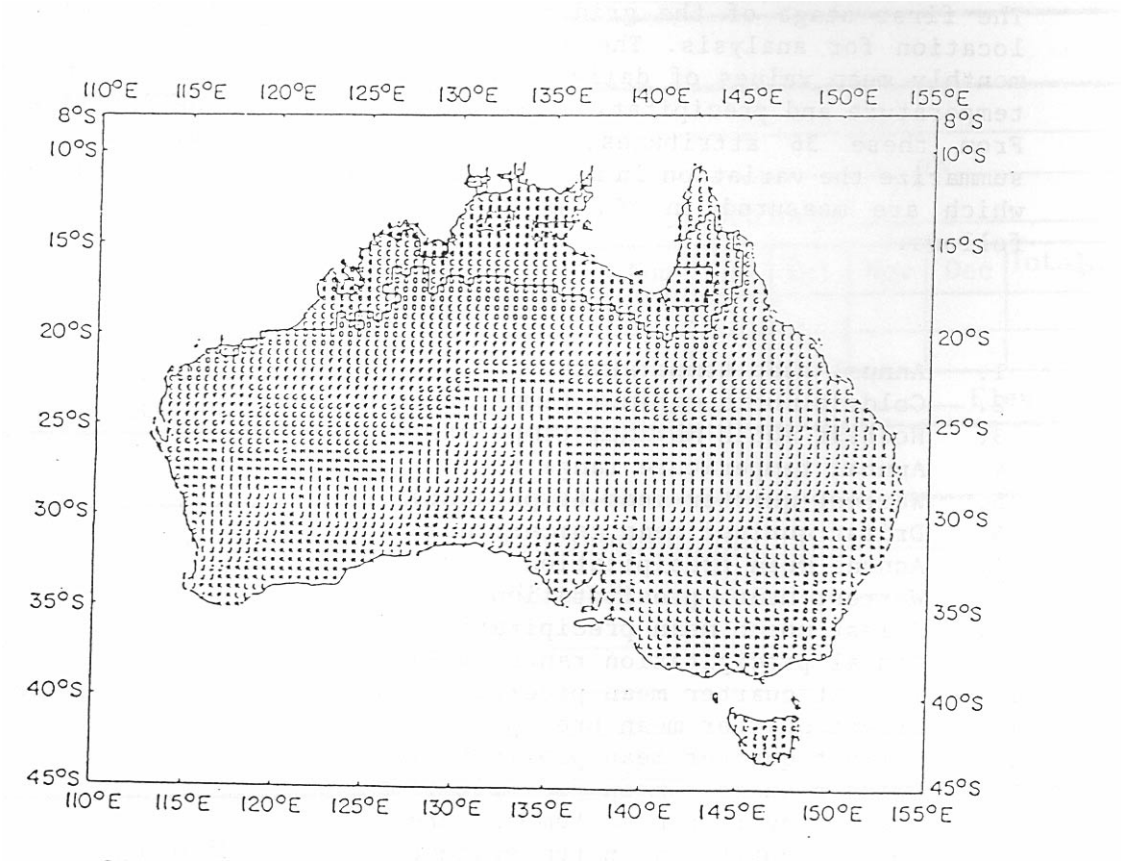
Extract from: "Grid matching; a new method for homoclime analysis" (Booth, Nix, Hutchinson and Busby 1987).

Climatic indices

The first stage of the grid matching procedure is to select a location for analysis. The location can be any site for which monthly mean values of daily maximum temperature, daily minimum termperature and precipitation are available or can be estimated. From these 36 attributes, 18 indices are calculated which summarize the variation in mean climatic conditions. The indices, which are measured in °C, mm or dimensioneless units, are as follows:

1. Annual mean temperature
2. Coldest month minimum temperature
3. Hottest month maximum temperature
4. Annual temperature range (3-2)
5. Wettest quarter mean temperature
6. Driest quarter mean temperature
7. Annual mean precipitation
8. Wettest month precipitation
9. Driest month mean precipitation
10. Annual precipitation range (8-9)
11. Wettest quarter mean precipitation
12. Driest quarter mean precipitation
13. Warmest quarter mean precipitation
14. Coldest quarter mean precipitation
15. Warmest quarter mean temperature
16. Coldest quarter mean temperature
17. Annual precipitation range/(annual mean precip(12)
18. Annual temperature range/annual mean temperature

The largest area demarcated in northern Australia indicates areas with moderate similarity in climatic indices to the 'target site' at Kaolack, Senegal (Classes A to C inclusive). The smaller and scattered areas demarcated are those with a high similarity in climatic indices (Class A only).



Climatic similarity between Kaolack, Senegal and locations in a half-degree grid across Australia. 'A' and 'Z' respectively indicate most and least similar locations

PLANTING SUITABILITY CLASSES FOR MECHANIZED CONIFEROUS PLANTATIONS IN TURKEY

Class Site factor	P1 Very good land	P2 Good land	P3 Medium land	P4 Poor land	NP Unplantable land
	MAXIMUM ACCEPTABLE FACTOR LEVEL, BY CLASSES				ELIMINATING LEVEL
1. Land-form	Rolling	hilly	hilly	steeply dissected	mountainous
2. Microtopography	slightly rough	slightly rough	rough	rough	very rough
3. Gradient	20%	30%	40%	60% in north 50% in south	over 60% in north over 50% in south
4. Erosion hazard	slight	slight	slight	moderate	high
5. Exposure	slight	moderate	moderate	severe	very severe
6. Stoniness	slightly stony	stony	stony	very stony on over 50% ground	extremely stony
7. Rockiness	rock free	fairly rocky	rocky	very rocky	extremely rocky
8. Water table	absent or at depth	at depth	at moderate depth	shallow	permanently at or near surface
9. Salinity	non-saline	non-saline	slightly saline	slightly saline	saline or very saline
	ACCEPTABLE RANGE IN FACTOR LEVEL, BY CLASSES				
10. Soil depth	91 cm +	61 cm +	31 cm	16 cm +	less than 15 cm unless on fissile parent material
11. Texture	P1-1 medium to heavy / P1-2 light to coarse	P2-1 medium to very heavy / P2-2 light to coarse	very coarse to very heavy	very coarse to very heavy	very coarse[1] to very gravelly
12. Drainage	well drained	imperfect to somewhat excessive	excessive to poor	excessive to poor	very excessive or very poor
13. pH	acid to slightly alkaline	very acid to alkaline	very acid to alkaline	very acid to very alkaline	excessively acid or excessively alkaline

1) Usually only if associated with other eliminating factors