Land Classification for Plantation Forestry

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SUMMARY

The purposes of land classification as a basis for deciding land use strategies, and the main approaches to it are discussed, including Land Capability and Land Unit classifications. The problems associated with evaluating the various options for the allocation of land are then described, especially in the context of conflicts between agriculture, forestry, conservation, etc. The various classifications used within forestry are discussed, including those based on site productivity, vegetation, soil, climate and multifactor classifications. In conclusion, some thoughts are given on how conflicts over land use many be reduced and the additional types of assessments which may be required in the future.

INTRODUCTION

Among the many purposes of classifying land are (1) those of providing a basis for rational decisions on its use and (2) having decided the use, of determining more precisely what sort of treatments are needed to manage it effectively on a sustained basis.

Evaluation involves carrying out, bringing together and interpreting basic surveys of such variables as soil, vegetation, climate and other factors in terms that are readily understandable to the user and releveant to the physical, economic and social context of the area concerned (Dent, 1978). Classifications depend upon a good data base. When the use of the land is being considered the information must also be relevant to the requirements of possible alternatives (e.g. forestry, agriculture, conservation and water gathering) as a means of solving land-use conflicts and arriving at an optimum combination of uses. Such evaluations are usually preceded by a recognition of the need for change.

Levels of classification

There are many levels of planning and hence of land evaluation and classification. For example, some global planning is done by international bodies such as FAO. Broad national planning is

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carried out for developing policies which enable regions to be identified for more detailed study. Much of this type of classification is done using existing maps, aerial photographs and/or satellite imagery. Lower levels lead to the identification of land for potential projects, and a detailed study of the site itself is needed to indicate the fitness of a given type of land for a defined use, either in its present condition or after improvement. This precedes the implementation of the plan, when even more detailed classifications may be needed for management. Classifications are therefore hierarchical, dividing areas into smaller and smaller relatively homogeneous units (Botero, 1981).

For each level, information is required in different degrees of detail. Contributions are needed from the natural sciences, technology of land use and economics, and often from sociology as well. Land classifications for most purposes are often eventually expressed in economic, or socio-economic terms (e.g. an estimate of employment provided) rather than physical ones for comparing land capability. However, they are based on physical criteria because physical boundaries are less susceptible to change (Dent, 1978). Thus, at a national, or regional level many classifications for forestry are based on climate but at the management level many other factors are needed by the users, often including climate, soil, vegetation and topography.

In spite of attempts at standardisation (e.g. FAO, 1976) there is no common recipe for carrying out land resource surveys and classifications since no system could cope with all environmental and socio-economic conditions. Scace (1981) reviews 46 systems of land use classification which "fall far short of the number known to be in use".

Types of classification

Classifications fall broadly into two groups: single factor classification of, for example, soil or climate, and multifactor methods.

Classifications based on single factors (which may be indicative of complexes), have the advantage of being simple to understand and cheap to carry out. They can also be combined quite readily as overlays on maps. If well designed they often work prefectly well: there is no point in complexity for its own sake.

However, the earth operates as a series of interrelated systems within which all components are linked. Integrated multifactor methods may, many feel, more adequately describe biological systems, and help explain how they operate. More objective classifications are often possible by such means and they are seen by many as being the direction for site classifications in the future (e.g. Bevege, 1981; Barnes *et al*, 1982). This does not mean that information-gathering systems about single attributes should be abandoned. They are as necessary for some integrated systems as single factor ones. The skill comes in delineating manageable units.

Land Capability Classifications

A distinction is often made between land *capability* and land *suitability* classifications. Capability refers to broad systems such as arable farming or grazing and is often defined rather vaguely in terms of the limitations which prevent some activities being considered, whereas suitability classifications are for specific crops or systems, such as eucalyptus production or herring fishing. They tend to concentrate upon the more positive features associated with that use (McRae and Burnham, 1981). Neither capability nor suitability classifications reveal any socio-economic information such as farm size or type of land tenure (Scace, 1981).

Capability classifications for agriculture, forestry and wildlife divide the land into a number of ranked categories according to the degree of its physical limitations for that purpose. A large number, including the British Land Use Capability Classification for agriculture (Bibby and Mackney, 1969) are based on the United States Department of Agriculture classifications of the 1930s. Commonly, seven or eight classes of land are recognised, Class I being the best, and a number of sub-classes represent major kinds of limitations on the land. In Britain these may include wetness; various soil limitations such as shallowness or low fertility; steep gradients which make mechanisation difficult; liability to erosion, and climatic limitations.

Canada has probably gone further than most countries in developing capability classifications for specific purposes. About one million square miles accessible from settled regions, have been assessed according to their capability for five resource sectors: forestry (McCormack, 1979); agriculture (CLI, 1965); recreation (CLI, 1969); wildlife, specifically ungulates and water fowl (Perret, 1970) and freshwater bodies have been evaluated for sports and fish (CLI, 1970). The Canada Land Inventory also has a socio-economic Land Classification and an Agroclimatic Classification for delineating climatic zones significant for crop production. The forestry classification is similar in structure to many of the agricultural classifications though details differ. Site index, or yield class, is used for the main classes because it is relatively easy to obtain productivity information of forest crops compared with agricultural systems.

Parametric Classifications

The division of land into a small number of categories in Land Capability Classifications is unavoidably artificial. An alternative approach is to use various soil and site properties (parameters) that are believed to influence yield, combined in a mathematical formula, the so-called parametric approach. Formulae may be additive, multiplicative or more complex and have been discussed by McRae and Burnham (1981). An ideal combination of soil and site properties gains the maximum score with progressively lower scores for poorer land.

Numerous additive systems were devised in Germany during the 1920's and some were (and still are) incorporated into legislation as a basis for land taxation. A multiplicative system is used in California for the same purpose. Helliwell (1967) has devised a multiplicative system for assessing the amenity value of trees based on seven variables. For each variable a unit on a scale of 1 to 4 is applied. The seven figures so derived are multiplied together to give a notional amenity value and this can, in turn, be multiplied by a constant to give a monetary value. The system has been widely used for assessing the contribution made by individual trees to amenity (Helliwell, 1978).

Parametric systems appear objective but their apparent objectivity and precision are illusory. Even the most elaborate systems assume relationships between crop behaviour and soil, site and other parameters that are still very imperfectly understood. That some systems seem to give reasonable results is "a triumph of the ingenuity of the workers who have developed them" (McRae and Burnham, 1981). However, in that some do give apparently reasonable results, theoretical imperfections can occasionally be overlooked. The additive British windthrow hazard classification for forestry (Booth, 1980) is one.

Land Unit Classifications

Capability and Parametric classifications both tend to have restricted objectives in keeping with an organisation's interests or statutory obligations. They have the disadvantage of being independent and relatively non-interactive, and so not particularly useful at some of the higher levels of planning where a framework is required for identifying all actual and potential land uses.

Land Units (or Land Classes) are being increasingly used for such classifications. They are areas of land with similar attributes of landform, soil, climate, hydrology and vegetation in which different uses may be appropriate. Land units can be mapped at a great variety of scales (with appropriate field checking) from satellite images, air photographs and maps and are widely used for providing the framework for investigations in developing countries (LRDC, 1980).

A system based on Land Classes is being used for examining alternative land use strategies in Britain, and was divided by the Institute of Terrestrial Ecology (Smith, 1982). Initially a survey area is divided into one kilometre grid squares and attributes in them are measured from Ordnance Survey, geological and other maps. Each square is allocated to a land class, and the classes are then used as strata for sampling ecological, land use, and land capability characteristics. The mean values of the sampled characteristics are used as a basis for economic or other calculations to produce alternative strategies. The agricultural capability is assessed in terms of the outputs of meat, milk etc., and the forestry capability in terms of yield of timber from each land class. Alternative strategies for agriculture and forestry development are formulated in terms of minimum acceptable levels for meat, timber, etc; the areas in which the present land use is preferred; constraints on the use of certain types of land and the output which is most desired. The land use pattern which gives the maximum amount of the most desired output is calculated using linear programming. These patterns are the alternative strategies.

The Institute of Terrestrial Ecology's Land Class system is proving to be very reliable for identifying rural areas where a change in land use may be appropriate.

Evaluating Options on Land Use

Eventually decisions have to be made about how specific areas of land should be used. In a few cases these present no problems. For example, steep slopes above villages in areas liable to avalanches should have a forest cover, however suitable they may be for other purposes.

In more complex situations land can, in theory, be allocated by the application of an appropriate system of land unit or capability assessment and this is done in many developing areas with low populations. However, where land use has evolved over long periods allocation is more complicated, influenced not only by environmental but also technological, economic, social and political factors. For example disagreement frequently occurs over the transfer of land from agriculture to forestry in Britain (Williams and Harding, 1982). Present policies are vague and, in so far as they exist, often conflict. In the context of conservation, the Ministry of Agriculture spends millions of pounds tempting farmers to drain and plough the countryside, fertilise, remove hedges and use pesticides while the Department of the Environment offers incentives to resist these temptations. Present decisions for allocating land on the market in upland Britain ultimately depend upon consultation and judgement of experienced officials concerned with agriculture, forestry, planning, etc.

It is unfortunate that during a period when the idea of achieving better integration of forestry and agriculture is receiving so much attention that, except on large privately-owned estates, trees are not considered by farmers as an alternative crop in Britain or Ireland. This has arisen because of divisive educational systems, difficulties in obtaining annual returns from trees and, in Britain, the fact that tenant farmers are often constrained from planting.

One possible method of allocation between forestry and agriculture has been developed by Maxwell *et al* (1979). They have described a modelling approach for square blocks of 10 ha (though any other size could be used) in the context of the hills and uplands of Scotland. The basic variables for economic analysis are altitude, soil type, vegetation, existing access and fencing. In order to reduce the number of solutions they applied constraints in allocating agricultural land: (1) it must consist of economically viable units which (2) must be contiguous and (3) agriculture must use land considered unplantable by forestry. The model attempts to minimise fencing and roading by aggregation of blocks selected for agriculture. It examines land allocations based on a range of possible stocking rates. The choice of discount rate is, as always, a problem and considerably influences results. In Britain, the test discount rate can often be as low as three per cent (which in real terms is considered high in relation to private industry). This tends to favour forestry, whereas rates of 5-7 per cent or more favour agriculture (CAS, 1980). Interestingly, and quite contrary to normal experience of foresters, while the more intensive agricultural systems tend to take the best land, the less intensive ones (which use more land), leave the better ground for forestry.

Having decided upon the best allocation by such means, nothing can be achieved unless the money is available for implementation. Investment in forestry is relatively expensive and there has been a noticeable shortage of both government and private money for it in the last few years.

While it is relatively easy to carry out cost/benefit analysis to optimise the use of land for *commercial* activities it is still difficult, if not impossible to link particular benefits with market values for many other uses. These especially include the benefits associated with landscape, nature conservation, jobs provision and other effects for which preferences tend to be established by political or group decisions rather than individual choice (Grayson, 1974). It is, at least, possible to estimate the economic "benefits" which are forgone by not managing areas commercially, or managing them in something less than the optimum way. This has recently been done for various silvicultural systems, in relation to conservation, by Pryor and Lorrain Smith (1982). In some cases serious conflicts arise and necessitate public enquiries and result in extensive "civil disobedience" by protesters.

Classifications for Forestry

Having produced a basis for deciding that land should be used for forestry (and possibly other purposes simultaneously), it is then necessary to carry out various *suitability* classifications. These help in deciding treatments such as species selection, the need for drainage and nutrition and, when converted into economic terms, enable the most desirable options to be selected.

Site productivity classifications (Yield class)

The single most useful classification of land for forestry is its productive potential in terms of the volume of usable timber on a unit area. It is particularly useful where there is existing forest and is expressed either in terms of productivity over a given time or as average annual productivity. Site productivity estimates normally rely on easily measured stand variables (height and age or some other index or growth). In much of the world "site index" is used, (the height a crop achieves at a predetermined age), or as mean annuall increment either at a fixed age or at the age when MAI culminates. The latter is the basis of the "yield class" system used in British forestry (Edwards and Christie, 1981). Such systems are most appropriate to pure, even-aged stands.

There are problems with these, as with other methods of classification. Different species, or even provenances, give different yields on the same site and it appears to be quite common for second rotations to be higher yielding than first. When attributes of unplanted ground have to be evaluated for making decisions, initially about establishment operations and species selection (and productivity) and later about factors such as fertilising, windthrow risk and harvesting, other features must be used as well. Especially within climatically narrow districts, they are made on the basis of features with an integrated character, such as soil and ground vegetatioin.

Ground vegetation

Classifications based on the composition of ground vegetation are common in Europe and in other areas where there is enough natural or semi-natural vegetation (Jahn, 1982). Various indicator plants or plant communities are used to give a guide to productive potential. In Britain and Ireland a system has been widely used as an aid to the selection of species since the time of Anderson's (1950) classical work on the subject.

There is, of course, no causal relationship between, for example, the suitability of a species to a site or rate of tree growth and the composition of the vegetation, but both are to a large extent determined by the same basic variables such as temperature, light, water supply, soil aeration, fertility, etc., none of which can easily be measured in practice. The main problem is that vegetation is often highly complex and difficult to sample objectively.

One of the best known classifications is that of Cajander (1909) in Finland. He classified natural and thinned crops of Scots pine and Norway spruce as well as treeless sites, based on the dominant plant species. He was able to predict site productivity with reasonable certainty and the need for drainage is based on his classification today. Similar systems are used elsewhere in areas of very uniform climate, parent material and land surface. In such circumstances ground vegetation can be a very sensitive indicator of the remaining site variability (Killan, 1981), especially if it has not been too much modified by man's activities.

However in Britain the main classification is based on soil and a consequence is that most foresters are relatively ignorant about the native flora and practical ecology. Such knowledge is especially important in the context of conservation and management of semi-natural woodlands. The lack of it has led to a justified impression among many (e.g. Peterken, 1981) that continental European foresters are more sensitive and sympathetic to the ecosystems they manage than the British.

Soil

Soil classifications are commonly used to indicate the potential of forest sites (Hägglund, 1981) since soils usually express nutrient status, water holding capacity and reflect many aspects of climate and waterlogging or drainage.

Soil is the major attribute for classifying sites for silvicultural purposes in the United Kingdom, with vegetation sometimes being used as a secondary indicator of fertility (e.g. Dickson and Savill, 1974), or drainage status. Soil has appeared more relevant than vegetation for four main reasons:

(1) Many factors affecting productivity and treatment are

direct soil properties or environmental characteristics which influence soil formation (McRae and Burnham, 1981).

(2) A large number of sites have been so extensively modified by agricultural practices and burning, that vegetation is not always a reliable indicator of conditions. This may be particularly true in areas dominated by heather and bracken.

(3) In establishing tree crops, many sites are so modified microclimatically and in terms of drainage, cultivation and nutrition that the pre-existing semi-natural vegetation is profoundly changed, often invaded by luxuriant weeds.

(4) Within a few years of planting the exotic species commonly used, there is virtually no ground vegetation left. Most is shaded out and killed.

Unless nutrient conditions are particularly difficult, as on many peats, soil physical properties are more important than chemical ones for forestry classifications. The British classification, devised by Pyatt (1970) and revised in 1982, forms the basis for the delineation of types of ground for each of which a distinct form of silviculture may be appropriate. From it specifications can be given which aid the selection of species and indicate the need for cultivation, drainage and nutrition. When the exposure of the site has been estimated, it allows the assessment of windthrow hazard (Booth, 1980). Based on the classification, a number of silvicultural guides have been produced for the nine regions of upland Britain (Busby, 1974) within each of which there is a narrow range of lithologic types, a characteristic range of terrain types, soils, climate and growth rates (Toleman and Pyatt, 1974). The classification does not take account of some potentially limiting factors such as the gradient of slopes, ground roughness and occurrence of boulders which are of relevance to harvesting, other uses of machinery and for setting wage rates. For this a separate Terrain Classification (Rowan, 1977) based on similar Scandinavian classifications (Berg, 1981) has been prepared.

Soil classifications such as Pyatt's (1970) place emphasis on the soil properties which influence yield and which, though they may be modified by cultural operations, impose relatively permanent limitations on the use of the soils. These include the status of the natural drainage, available depth for rooting, the presence of compact or cemented layers, the texture and general level of acidity or alkalinity and the occurrence of peat.

Climate

In broad classifications (global, national or general) climate can be one of the best indicators of forest productivity. A knowledge of climatic differences can also be valuable on more local scales, in situations where exotic species are to be introduced. Many climatic classifications have been produced and of those which have focussed specifically on Britain and Ireland most have been reviewed by Gregory (1976). Among the more relevant for forestry and other forms of vegetation growth are those of Tansley (1939), Fairbairn (1968) and that of Gregory (1976) himself who produced a pattern of 15 regional climates based on length of growing season, rainfall magnitude and rainfall seasonality.

Local variations in climate associated with topography are also very important in, for example, recognising frost hollows, sites prone to windthrow and today, sites liable to atmospheric pollution. Climate and, to a lesser extent, soil combine to give progressively more adverse conditions for growth with increasing altitude to the extent that the difference in climate of, for example, Ben Nevis or Snowdon and their adjacent lowlands are at least comparable in range with the more familiar contrasts between the climates of western Ireland and East Anglia, or Cornwall and Caithness (Taylor, 1976). Such differences are recognised in setting economic upper planting limits and we are familiar with classifications of relative "exposure" based on flag tatter (Lines and Howell, 1963) to estimate these limits.

Multifactor classifications

Multiple factor methods of ecological site classification have been used in Germany, other parts of Europe and Canada for over 30 years. They have been very fully discussed in a recent book, edited by G. Jahn (1982). They are based on interrelationships between climate, physiography, soils and vegetation. At the lowest, "site unit" level, appropriate for mapping at 1:10,000, sites have similar silvicultural potential, are prone to similar risks and have similar levels of productivity. They are, in effect, extentions at a lower and more ecological level of the Land Unit Classifications already discussed. These classifications are the basis for silvicultural and most other forms of planning associated with forestry. Proponents of them state that they are faster to use than single factor methods and overlays.

They are usually based on the work of soil scientists or plant sociologists and "are often overcharged with specific academic objectives and do not meet the utilitarian requirements of foresters" (Kreutzer, 1969). They appear to be much more appropriate for use in semi-natural forests than where bare land, or highly modified land, is being planted with exotics (Jahn, 1982).

DISCUSSION AND CONCLUSIONS

Classifications for determining the value of land for various uses are now reasonably well developed. They differ considerably in the extent to which they consider detail as this depends upon the availability of survey information. In developed countries, with good Ordnance Survey maps and records of geology, soils and climate, besides detailed socio-economic information, sophisticated methods are increasingly being used. At the other extreme, satellite images may be all that is available at the start.

Problems begin to arise in deciding how specific areas should be used and these difficulties are particularly serious in places where land use is fairly intensive and has evolved over long periods. Conflict often arises.

Among the possibilities for resolving some of this conflict are the development of more objective methods for allocation land between agrigulture, forestry, conservation and other uses, of the type being developed by Maxwell, *et al,* (1979). An end to our divisive systems of agricultural and forestry education would also do much to aid understanding and promote integration. Both foresters and farmers are concerned with growing crops. I have never understood why growing trees should be considered so completely different from growing grass, potatoes or cattle that it requires totally separate courses in most universities and colleges. Most of the principles are the same, only the details differ. Also, on rather less certain ground, it might often help if foresters were to become more concerned and involved in planning and decision making at higher levels of land evaluation. They are normally far more interested in the technical and managerial aspects of the work in their own enterprise. This is a failing also noted in American forestry by Stine and Byrne (1982).

At the forest level, classifications vary considerably according, in part, to the intensity and objects of management. Classifications appropriate to one situation are not always in another. For example, S. Hagner (1980), a Swedish silviculturalist stated: "I am suspicious of classifications based on the composition of ground-layer vegetation, for such classifications contain sizeable sources of error. Classifications on the basis of . . . . factors such as soil mineral characterists or water table demand extensive sampling. I very much doubt that such indicators could be of real practical use".

Classifications which may be needed in the future include the possible identification of sites which need nutrient management. We are moving from the days of correcting gross deficiencies to a period when more subtle information for maintenance of site fertility is required (Ballard, 1980). Ireland, at least, seems also to be moving from imposing standard ground preparation treatments on all sorts of land. If tunnel ploughing and mole drainage, for example, are going to be more widely used it will be necessary to ensure they are used on appropriate sites. We are all too well aware of the dangers of thinning in this part of the world. If the trend towards no-thinning and wider spacing continues, and if we also hope to grow reasonably valuable sawlogs, I am becoming convinced that we shall have to prune trees in the safer areas. We must try to identify these sites better by improving upon existing windthrow hazard classifications. Finally, I have been very impressed in some of the older forests of northern England and southern Scotland at the extent of natural regeneration of Sitka spruce and other species. I believe it could become a normal means of replacing crops on some sites but we need to identify the situations in which it occurs. Most of these comments clearly involve areas of research as much as classification.

REFERENCES

ANDERSON, M. L. 1950. *The selection of tree species.* Oliver and Boyd, London, pp. 151.

BALLARD, R. 1980. Pp. 159-200 in *Forest Plantations — The shape of the future,* Proceedings of Wyerhaeuser Science Symposium No. 1.

BARNES, B. V., PREGITZER, K. S., SPIES, T. A. and SPOONER, V. H. 1982. Ecological forest site classification. *Journal of Forestry* 80, (8), 493-498.

BERG, S. 1981. Terrain classification for forestry in the Nordic countries; pp. 152-166 in *Proceedings of the workshop on land evaluation in forestry* (ed. P. Laban). ILRI publication No. 28, Wageningen, Netherlands.

BEVEGE, D. I. 1981. The management of forest soils and nutrition; pp.253-261 in *Proceedings of Australian Forest Nutrition Workshop,* Canberra, A.C.T., Australia.

BIBBY, J. S. and MACKNEY, D. 1969. Land use capability classification. *Soil Survey Technical Monograph* No. 1, Rothampsted, UK.

BOOTH, T. C. 1980. Windthrow hazard classification. Pp 19-21 in *Forestry Commission Leaflet* No. 77, H.M.S.O., London.

BOTERO, L. 1981. FAO's experience in land classification for forestry with particular reference to developing countries; pp. 110-132 in *Proceedings of the workshop on land evaluation in forestry;* (ed. P. Laban). ILRI publication No. 28, Wageningen, Netherlands.

BUSBY, R. J. N. 1974. Forest site yield guide to upland Britain. *Forestry Commission Forest Record* No. 97, H.M.S.O., London, pp. 13.

CAJANDER, A. K. 1909. Über Waldtypen. *Acta For. Fenn.* 175pp, Helsinki.

CAS 1980. Strategy for the UK forest industry. *Centre for Agricultural strategy* Report No. 6, University of Reading.

CLI 1969. Land capability classification for outdoor recreation. *The Canada Land Inventory Report* No. 6. Department of Regional Economic Expansion, Canada. 114 pp.

CLI 1970. Soil capability classification for agriculture. *The Canada Land Inventory Report* No. 2, Dept. of Forestry, Canada. 16 pp.

CLI 1970. Objective, scope and organisation. *The Canada Land Inventory Report* No. 1, Department of Regional Economic Expansion, Canada. 61 pp.

DENT, F. J. 1978. Data requirements for land-use planning with emphasis on requirements for land evaluation studies. SIDA/FAO Seminar on Forest Resources Appraisal in Forestry and Land-Use Planning. New Delhi-Dehra Dun, 27 November - 16 December, 1978; pp. 57.

DICKSON, D. A. and SAVILL, P. S. 1974. Early growth of *Picea sitchensis* on deep ologotrophic peat in Northern Ireland. *Forestry* 47, 57-88.

EDWARDS, P. N. and CHRISTIE, J. M. 1981. Yield models for forest management. *Forestry Commission Booklet* No. 48, Edinburgh, UK; pp 32 and numerous loose-leaf tables.

FAIRBAIRN, W. A. 1968. Climatic zonation in the British Isles. *Forestry* 41, 115-130.

FAO 1976. A framework for land evaluation. *FAO Soils Bulletin* No. 32, 72 pp.

GRAYSON, A. J. 1974. Assessing the contribution of non-market benefits. 10th Commonwealth Forestry Conference, 16 pp. Forestry Commission, London.

GREGORY, S. 1976. Regional climates; pp. 330-342 in *The climate of the British Isles* (eds. T. J. Chandler and S. Gregory). Longman Group Ltd., London.

HÄGGLUND, B. 1981. Evaluation of forest site productivity. *Forestry Abstracts* (Review Article) 42, 515-27.

HAGNER, S. 1980. Pp 49-68 in *Forest Plantations — The shape of the future.* Proceedings of Weyerhaeuser Science Symposium No. 1.

HELLIWELL, D. R. 1967. The amenity value of trees and woodlands. *Scottish Forestry* 21, 109-112.

——— 1978. Preparation of value indices for non-market benefits based on characteristics of the forest environment. Paper FQL/25-3, Eight World Forestry Congress, Jakarta, Indonesia; pp.7.

JAHN, G. (ed). 1982. *Handbook of vegetation science.* Dr. W. Junk Puplishers, The Hague, etc. pp. 405.

KILLAN, W. 1981. Site classification systems used in forestry. Pp. 134-151 in *Proceedings of the workshop on land evaluation in forestry.* (ed. P. Laban). ILRI publication No. 28, Wageningen, Netherlands.

KREUTZER, K. 1979. How do physical classifications contrast with site type classifications. Pp. 39-56 in *Ecology of Even-Aged Plantations;* eds, E. D. Ford, D. C. Malcolm and J. Atterson, Institute of Terrestrial Ecology, Cambridge, UK.

LINES, R. and HOWELL, R. S. 1963. The use of flags to estimate the relative exposure of trial plantations. *Forestry Commission Forest Record.* No 51, H.M.S.O., London, pp. 31.

LRDS. 1980. *Land evaluation and rural development.* Central Office of Information, H.M.S.O., London, pp. 24.

MAXWELL, T.J., SIBBALD, A. R. and EADIE, J. 1979. Integration of forestry and agriculture — a model. Pp. 161-188 in *Agricultural systems.* Applied Science Publishers, UK.

McCORMACK, R. J. 1970. Land capability classification for forestry. *The Canada Land Inventory Report* No. 4. Department of Regional Economic Expansion, Canada. 72 pp.

McRAE, S. G. and BURNHAM, C. P. 1981. *Land evaluation.* Clarendon Press, Oxford; pp. 239.

PERRET, N. G. 1970. Land capability classification for wildlife. *The Canada Land Inventory Report* No. 7. Department of Regional Economic Expansion, Canada. 30 pp.

PETERKEN, G. F. 1981. *Woodland conservation and management.* Chapman and Hall, London; pp. 328.

PRYOR, S. N. and LORRAIN SMITH, R. 1982. An economic analysis of silvicultural options for broadleaved woodland. *Commonwealth Forestry Institute Occasional Paper* No. 19, Oxford, UK. 2 vols. pp. 120 and 116.

PYATT, D. G. 1970. Soil groups of upland forests. *Forestry Commission Forest Record* No. 71, pp. 51.

——— 1982. Soil classification. *Research Information Note 68/82/SSN, pp.4, Forestry Commission, UK.*

ROWAN, A. A. 1977. Terrain Classification. *Forestry Commission Forest Record;* No. 114, H.M.S.O., London, pp. 23.

SCACE, R. C. 1981. Land classifications: an overview, *Working Paper 14,* Lands Directorate, Environment, Canada.

SMITH, R. S. 1982. *The use of land classification in resourse assessment and rural planning.* Institute of Terrestrial Ecology, Cambridge, pp.43.

STINE, S. E. and BYRNE, J. G. 1982. Land-use planning: opportunity for resourse professionals. *Journal of Forestry* 80 (9), 581-582.

TANSLEY, A. G. 1939. *The British Isles and their vegetation.* Cambridge University Press.

TAYLOR, J. A. 1976. Upland climates. Pp. 264-287 in *The climate of the British Isles* (eds T. J. Chandler and S. Gregory), Longman Group Ltd., London.

TOLEMAN, R. D. L. and PYATT, D. G. 1974. Site classification as an aid to silviculture in the Forestry Commission of Great Britain. *Paper for 10th Commonwealth Forestry Conference,* UK, 1974. 20 pp.

WILLIAMS, H. J. and HARDING, D. 1982. Towards a land use strategy for the uplands of Wales. *Quarterly Journal of Forestry* 76, 7-23.