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THE ROLE OF VEGETATION SCIENCE IN REGIONAL PLANNING AND ENVIRONMENTAL MONITORING IN THE YEAR 2000

A.N. Gillison

1. Introduction

Among the likely scenarios to confront the human race,year 2000 is the prospect of significant change in global climate and population density. We therefore need to plan ahead to meet the likely impact of shifts in resource distribution along changing environmental gradients. An appropriate strategy must include a rapidly improved understanding of resource pattern and process. As integrators of environmental change, plants offer a useful surrogate for such purposes. But despite advances in computer-based decision support models for resource management, vegetation science has not yet indicated which vegetation attributes are most relevant or how the data should be sampled.

Plant ecological research will provide useful insights for future strategies. But plant ecologists tend to be concerned more with naturally occurring vegetation than with vegetation which has been severely modified by human management. Much of the ecological literature is also concerned with limited aspects of vegetation performance such as biomass rather than with features that reflect a more sensitive response to change along environmental gradients. It is likely that to cope with the possible consequences of forecasted changes in global atmosphere, and to help interpret the links between plant process and environmental change, resource planning and management will seek new developments in vegetation science rather than rely on traditional ecological practice. I therefore use the term 'vegetation science' to emphasise the need for process-oriented, investigations of vegetation under both natural and man-modified conditions.

The aim of this paper is to examine:

(a) some assumptions and limitations of present-day applications in vegetation science especially in resource survey and analysis

(b) some likely consequences of environmental change on resource distribution, and

(c) a strategy for vegetation science to help identify these consequences and apply this knowledge in regional land management.

2. Some underlying assumptions in vegetation science in resource applications

Outside the purely experimental areas of plant industry which involve agronomic, pastoral and horticultural disciplines, resource applications in vegetation science have been concerned primarily with classifying naturally-occurring vegetation cover as a means of identifying indices of land use capability. In this respect FAO, UNESCO and IUCN have contributed useful methodology e.g. (1).

The 'land system' approach of Christian and Stewart (2) is one resource survey method that has been widely applied in Australia and elsewhere. The process of land resource survey usually involves preliminary analysis of available information about land history, land form, terrain pattern and land cover including vegetation. Field sampling intensity is then a product of perceived diversity of total landscape pattern and available logistic support. Both during and subsequent to field survey, the 'land system' method seeks to identify repetitive sequences of landscape units for which indices of land use capability are then estimated.

All or most of these applications assume there will be recogniseably distinct clases of land cover and that these will correspond with appropriate classes of potential land use. The capacity to interpret how vegetation, and hence land use capability vary with environmental change therefore depends on the nature and distribution of land cover classes. The outcome will be a product of observer experience; the level of subjectivity in pre-classifying vegetation cover and land form; the representativeness of sample sites, and an assumed stability in the environment.

3. Some limitations of vegetation science in 'traditional' resource applications.

3.1 Scale and purpose

Whereas scale and purpose in resource applications should determine the role of vegetation science, 'universal' methods tend to be applied regardless of these criteria. In Australia, CSIRO has been concerned for many years with methodological development in land use research. But because of the largely subjective methods used in the past to record and classify field data, we now find problems in evaluating the results of many resource surveys. These surveys have provided much useful first level information. But with increased pressure on the resource, we now find there are significant gaps in our knowledge base.

The reasons are partly historical, but there are more fundamental issues which restrict our ability to interpret and compare the results of resource surveys conducted at varying scales and for different purposes. These include both the variability of methods used to record field data and to classify vegetation along physical environmental gradients.

3.2 Vegetation classification methods.

Vegetation classification is central to almost any application involving estimates of the living resource. Classification methods are based either on visual estimates of structure or physiognomy or else on the spatial distribution of plant species (e.g. the Zurich-Montpellier school (3) - or both. In Australia the methods of Specht (4, 5) and Walker and Hopkins (6) employ broad structural categories based on growth form and either foliage projection cover or crown cover. These are classed according to broad formational groupings and are best used at that scale. They are unsuited to dynamic aplications and are difficult to link with classifications of rainforest (e.g. Webb et al 7) which require different descriptive attributes.

While floristic classifications can be very useful at local level, their facility for useful extrapolation decreases rapidly with geographic distance. The Linnaean binomial (genus + species name) was never intended to indicate environmental relationships. The fact that many do, is to a large degree, fortuitous. For example, a floristic study of vegetation change along an environmental gradient from mangrove to savanna, reveals little about the species *per se* that can be related directly to environmental variables. It is by attaching functional information about the behavior of individuals that floristic classifications can be enhanced for resource management.

Most vegetation classification methods in the western world were designed for descriptive purposes. With the exception of the life form classification of Carl Raunkiaer (8) few have been developed for dynamic classifications (see also Mueller-Dombois and Ellenberg (9)). One good reason for this is that the plant attributes which are required for greater environmental sensitivity are unsuited to simplistic descriptive classifications. The converse that simple, descriptive classifications are unsuited to dynamic investigations is equally true.

3.3 Remote sensing applications in vegetation science

Athough hardly 'traditional', remote sensing applications in vegetation science are well established. Rapid progress has been made in the numerical analysis of multispectral imagery from space-borne image sensing vehicles. Among the best known sources of satellite imagery are those from LANDSAT and, more recently, SPOT. In vegetation science the most promising developments seem to lie in image analysis of large areas under intensive cropping rather than those under woody plant cover.

Much has been published about the use of computer-based image analysis in helping to interpret vegetation change along environmental gradients. But despite these high-tech advances there are considerable difficulties in matching spectral data with visible, on-ground, changes in naturally occurring woody vegetation and other land cover at fine scale (e.g. > 1:25 000). In semi-arid Australia, enhanced image analysis using the CSIRO Micro-Brian system (Jupp et al. 1981 et. seq.) accounted for less than 40% of variance in intensively sampled vegetation using a wide range of plant functional and structural features (Gillison unpubl.). Considerable groundtruthing of spectral imagery remains before we can arrive at a useful minimum attribute set for land management at 1:50 000 and above. For the present, variability in climate, vegetation cover and land use patterns make difficult a ready application of space borne, remotely sensed imagery for vegetation science. For most management applications, especially in closed woody vegetation, the subjective, visual analysis of colour aerial photographs at mapping scales of 1:50 000 and larger appears to offer the most cost-effective solution for image interpretation.

4. Some likely consequences of forecast environmental change.

Atmospheric scientists have evidence to suggest that over the next 50 years significant global climate change is probable as a result of increasing levels of greenhouse gases in the atmosphere. These gases are composed mostly of carbon dioxide but include as well, methane, nitrous oxide, and chlorofluorocarbons (CFC's). Their presence in increasing concentrations, in the upper atmosphere has the net effect of depleting the ozone layer and thus increasing the amount of ultraviolet radiation at the earth's surface. Together, the four gases absorb and re-radiate infrared thus increasing global atmospheric temperature.

It has been suggested that with these atmospheric changes there will be a loss of coastal areas due to rising seas, destruction of plant and animal habitat and major changes in world agriculture. Depletion of the ozone layer has implications for both human health and agriculture (10).

There are no definitive models for global atmospheric change. But there is general concensus that there will be change and change is on the way. We only know of the increase in the four 'greenhouse' gases; the rest is informed speculation (11).

Current global trends indicate a net increase in global warming of 0.5 deg. C. This is consistent with most models but is also within the range of natural variation. Predicting how the changes in the energy budget of the atmosphere will translate into regionally specific climate changes is very complex. The following scenarios for Australia are to be discussed at 'Greenhouse 87' later this year (11):

The Changes

Temperature

A rise of 2 to 4 deg. C in the annual mean temperature is predicted with the greatest warming in the south and in winter, and least warming in the north. Some regional variations in this general picture might be expected due to changes in cloudiness, air-sea temperature differences, etc. Oceanic temperatures will tend to lag behind atmospheric temperatures by about 10-20 years.

Rainfall

Higher spring, summer and autumn rainfall by up to 50% in those regions deriving such rain from the southward penetration of tropical/ subtropical air during the Australian Monsoon season is expected. This change will be a maximum at the southern limits of the summer rainfall regime. Winters will be generally drier by 20% or more in those areas deriving such rain from the eastward passage of midlatitude high and low pressure systems and associated frontal storms with the possible exeption of Tasmania and southern Victoria.

Daily maximum rainfall will increase by the order of 20-30% with some change in the frequency distribution of the rainfall.

Sea level

For the sea level a general rise of 20 to 140 cm is expected which needs to be added to any local tendency due to subsidence, etc.

Tropical cyclones

The southern limit of tropical cyclones (determined by sea surface temperature > 27 deg. C;) is expected to shift some 200-400 km further south and the maximum intensity may increase by 30-60%. The frequency of occurrence of tropical cyclones may change.

Show line

The snow line would on average rise by about 100m per 1 deg. C warming, however, local variations related to changes in storm frequency may be as significant.

Wind speeds

Wind speeds could decrease by 20% north of 36 deg. S, but should increase south of 36 deg. C due to changing north-south temperature gradients.

Evapotranspiration

Evapotranspiration could decrease due to higher ambient CO_2 concentrations, but generally greater leaf area may partially compensate.

Present models provide for global averages; they do not as yet, allow us to predict what will happen at regional level. For policy makers there is no access to monitoring equipment or relevant computer models that allow us to integrate multiple system components.

Apart from the impact in cereal crops for which climatic domains are likely to shift, it is possible to speculate on changes in naturally-occurring vegetation. For areas in northern Australia, and possibly parts of Indo-Malaysia a 40% increase in mean annual precipitation is likely. The impact may be more visible in the drier, seasonal vegetation rather than in the less seasonal, warm moist areas. There are likely to be changes in the geographic distribution of so-called 'edge' communities as forest-savanna boundaries, especially in the more mesic components of vegetation such as monsoon forest and related seasonal vine thickets.

On the positive side, this may be acompanied by an increase in the proportion of plants that are capable of fixing atmospheric nitrogen. A possible increase in soil erosion and rises in ground water levels and soil salinity may be ameliorated by the better prospects of increased vegetation cover.

5. What can be done to develop useful indications of environmental change at regional level?

As indicated, there are great difficulties in projecting the effects of global averages for regional policy-making purposes. We have neither sufficient instrumentation or the appropriate atmospheric models to provide the solutions at this scale. One possible avenue may be to use vegetation as an 'integrator' of such changes but the level of sensitivity requires monitoring and field recording methods that are not to be found in the more traditional areas of vegetation science.

In recent years there has been increasing interest in what has become referred to as 'functional ecology'. Among other things, this is a research area which focusses especially on plant behavioural response to environmental change.

The traditional methods of vegetation recording referred to previously have limited application in this field. Rather, we need to develop a minimum attribute set of functional plant characteristics which can then be used in a uniform way across a wide variety of environmental gradients. A recently-developed plant functional attribute proforma (12) has been designed for such a purpose. It is based on the concept that a plant individual is a 3-component functional system; the photosynthetic envelope; the vascular support structure and the mode of reproduction and/or regeneration. Emphasis is placed on the nature and spatial and temporal distribution of the photosynthetic 'leaf' elements in the envelope. These may be true 'botanical' leaves or other plant organs such as stems with active photosynthetic tissue. For each individual it is thus possible to record, in a repeatable way, these components according to leaf size class, leaf inclination, leaf 'type' and the supporting life-form, together with simple categories of sexual reproduction and vegetative or asexual regeneration. These attributes have been selected according to theory-based concepts of their environmental relationships and from empirical data (13, 14).

The proforma has been field-tested in wide range of physical environments from sub-arctic and sub-antarctic to tropical regions and on a wide variety of substrates and conditions of land use. It is by no means the perfect answer to the recording of plant functional variables but it has provided useful correlative models for bioclimate and associated animal species and types of land use (15).

By analysing correlation patterns between certain of these plant functional attributes and biophysical variables it is possible to develop first-approximation regressions. These can then be used as basic input for models that can help predict likely changes either in bioclimate or in vegetation. For example, it has been possible to examine shifts in the proportional occurrence of attributes such as leaf size class under changing mean annual precipitation as this has implications for detecting change in vegetation at formation class level.

6. How might vegetation science contribute to the detection of environmental change?

In any ecosystem, plant performance and land use will be determined by the nature and distribution of environmental gradients. Provided these gradients can be detected in the first place, they should be amenable to stratification. A series of representative environmental units can then be located for which changes can be monitored. To this end a purposive method of locating belt transects or line intercepts along such gradients has been developed by CSIRO (16). These are known as 'Gradsects'.

In Australia we are currently examining the posibilities of locating a network of representative gradients with selected sample sites that can be referenced first by the existing plant functional attributes as well as certain site physical variables.

Given the correlations between plant functional attributes and other bioclimate and site physical factors we may then be able to detect certain trends in environmental change through varying plant functional attributes. With regular monitoring at say, five-yearly intervals, it may be possible to detect significant shifts in the physical environment brought about for example, by atmospheric change.

If detected, the levels of change can then be integrated with existing atmospheric models to help refine their application at regional level and thus assist policy makers.

7. The role of vegetation science in developing geographic information systems

The development of spatially-referenced (geocoded) data in computerised information systems has been accompanied by a decreased need for vegetation classification _per se_. Whereas the raw, elemental field data were once subjectively classified _a priori_, or else passed through some process of numerical classification, this practice is now less frequent. Advances in computer technology, especially in database and Geographic Information System (G.I.S.) software has meant that the elemental data can be retained. Databases can thus be interrogated directly for specific requirements and detailed thematic maps produced for very specific purposes. When related to digital terrain models, overlays of specific themes may be output, such as bioclimatic or plant growth indices (17, 18). Spatially referenced data have the added advantage that target variables can be manipulated by statistical means and thus extrapolated to areas for which there may be very limited data.

It is certain the development of national and regional G.I.S. will play a central role in future planning. There will be an increasing role in the use of vegetational data to and groundtruth G.I.S. models as well as image classifications derived from remotely-sensed, multispectral data.

8. Summary

There is much that can be added to fuel speculation about the likely impact of environmental change in the year 2000. Despite the uncertainties of atmospheric modelling, one thing appears to be highly probable and that is change is already upon us. To develop suitable strategies for the future we construct flexible plans to meet significant changes. Whether we are due for a decrease or an increase in global averages of climatic variables means little unless this can be translated to regional level. Trends in vegetational change along biophysical gradients appear to be more readily investigated and interpreted by the recording of attributes that are selected according to their functional significance rather than by traditional descriptive means. Provided it is possible to locate and identify spatially-referenced biophysical data according to regional and/or global gradients, vegetation science can perform a useful function in helping to refine geographic information systems. For the present; it is necessary to establish relevant methods of data recording and analysis for uniform application across widely varying biophysical conditions.

It is likely that vegetation may well provide the kind of biological integrator necessary to help refine the highly complex atmospheric models for which groundtruthing seems so elusive. In this respect, international cooperation can also assist by seeking to establish a minimum attribute set for uniform vegetation recording procedures. In this way a common information system can be devised and accessed by those who will find it useful for regional planning.

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