DYNAMIC MAP REPRESENTATION OF VEGETATION SUCCESSION - A PRELIMINARY THOUGHT

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Abstract

The geographical distribution of vegetation has always been valuable information to bio-geographers, botanists, environmentalists and even to people working on hill fire and landslides prevention. Some require very detailed information on even species of individual stand while others are satisfied with generalized data upon a class or community. It means that the representation of vegetation data at different levels of abstraction, i.e. at different scales, is required to satisfy the requirements of different applications. Such a multi-scale representation is achieved by a process called 'generalization'. And it would be very desirable to have sound methodology to automate the generalization process so that smaller scale representation of vegetation data can be derived from larger scale representation efficiently. This avoids the problem of revising vegetation databases different scale frequently. However, at the present stage, such methodologies are lacking. This project aims to make some contribution to such methodologies.

A review of literature reveals that, current research is concentrated to the algorithmic development. Various operations needed for such a generalization process have been identified and algorithms developed. For example, pieces of small areas can be aggregated easily by algorithms. This solves the problem of "how to aggregate". However, two serious problems arising are "what should be aggregated" and "when to aggregate". In other words, some rules must be available so that automated generalization can be achieved. Indeed, this study aims at developing such rules for the automated generalization of vegetation maps in Hong Kong. The theoretical basis for rules formalization for such a purpose will be the bio-geographical principles. In other words, biological characteristics, spatial distribution of vegetation and the principles of plant succession will be used for formalizing rules so that realistic and comprehensive methodology can be developed to automate the process of multi-scale representation of vegetation data.

The successful completion of this project will make the automated multi-scale representation of vegetation databases possible, thus to increase the efficiency of vegetation data management. The economic benefit is obvious through the improvement of such efficiency.

Introduction

In the areas of environmental protection, landscape architect and botany science, plant information and its geographical distribution are one of the many important determinants to drawing accurate and sound conclusions. Plant information embraces a wide variety of data of species, composition, productivity, morphology, physiology, histology and so on. Geographical distribution refers to the spatial extent where a plant community, colony or even a particular plant species population occurs in time. Nonetheless, information like plant life cycle and succession owing to both predicted and abrupt environmental changes are often very dynamic and difficult to collect and manage if with high spatial and temporal accuracy. Besides, vegetation data are often piecemeal and of varying formats. Some are sketches based on field observations with higher positional precision and greater details, whereas some may be interpreted from aerial photographs or satellite imagery with wider coverage but less details and spatial accuracy. In order to support different applications based on vegetation distribution, a systematic management of vegetation data that enables dynamic classification is desirable. In the discipline of digital cartography, this means the representation of vegetation data at different levels of abstraction, i.e. at different scales, to satisfy the requirements of various applications. Map based information is useful as it provides not only data of individual plants or plant groups, but also reveals broad vegetation patterns and relationships with neighboring species and the environment. The multi-scale map representation is achieved by a process called 'generalization'. Despite the various generalization algorithms so far developed, the problems of how to generalize and when to generalize are not easily solved if without an in-depth knowledge of the feature characteristics and behavior to be generalized. The objectives of this paper are therefore to discuss a framework in which vegetation data could be organized systematically, to formulate rules for the creation of a vegetation database and for generalizing vegetation maps at varying scales of presentation.

Vegetation Classification

Each recognizable plant is designated as a 'species' whereas the grouping of closely related species constitutes a 'genus' such as Melaleuca leucadendron, Acacia confusa. This then is grouped into higher hierarchy of 'family', 'order', 'class' and 'phyla'. The term vegetation refers to the mosaic of plant communities in the landscape. World categorization of vegetation normally falls into physiognomic-structural system, floristic system and ecological system. Yet, there is no standardized way for vegetation classification and disputes often exist in the different classification systems. Generally, the first two methods are more commonly applied. The physiognomic-structural system refers to the appearance and physical characteristic of plant communities. Its structure involves the spatial distribution with regard to size, density and coverage, form of growth etc. On the other hand, the floristic system refers to the degree of dominance, abundance and fidelity of the constituent species and genera of the plant community. The grouping of plants that provide recognizable units of vegetation is regarded as an 'association'.

In the physiognomic classification, vegetation is differentiated only in a more general manner and simplified to basic types such as grassland, shrub land and forest. That is, it is classified according to their life form or growth form and appearance of the plants of an area viewed collectively. It is based on the visual impression created by the plants, not as individual kinds but en masse. This approach has been broadly used in traditional mapping and various surveys that normally involve small-scale representation of extensive coverage. Details on the composition of vegetation are limited. Some important information such as species diversity and rarity cannot be interpreted. The floristic classification, on the other hand is based more on the main species composition (dominance or association) of plant communities. Mapping floristic composition of varying scales would require detailed information of plant species groupings from the smaller units as 'societies and clans' to 'association', and there to 'formation' and 'biochore'. Normally, owing to the difficulty in data collection, this system does not lend itself commonly to vegetation mapping.

For whatever physiognomic or floristic classification, small-scale vegetation mapping is the most common practice. Such information is not only largely generalized, but also assumed that the plant community displayed has reached a climax state in accordance with the prevailing environmental conditions. The dynamic floristic system has been rarely incorporated or ever considered in the mapping database. It is worth noting that every plant community is having a specific ecological status, occupying a specific position in a hierarchy of plant communities as related to the climatic climax community in terms of ecological succession. It therefore means that every association of every formation has its own hierarchy of related plant communities. Such relationship, however, cannot be interpreted from and is seldom explicitly described in a small-scale generalized vegetation map. A more comprehensive and flexible approach to vegetation mapping is necessary to clearly show the readers the ecological status of plant species with its prevailing environment, and also with its neighboring plants.

Generalization in Vegetation Mapping

Mapping from one scale or database to another involves a cartographic process called generalization. Vegetation databases are normally referred to as thematic databases. The data sets are stored in terms of area feature. Research into the generalization of area features is not as active as that into line features. Only a few bodies of literature are available. One of the interesting works at early stage is done by Monmonior (1983). He has developed some techniques to produce the effect of elimination, aggregation and so on. McMaster and Monmonior (1989) have also produced a conceptual framework, into which various generalization operations have been put. A procedure for the generalization of area-patch has been developed by Muller (1991). A very comprehensive study of computational methods (algorithms) has been carried out by Schylberg (1993). In his study, some algorithms have been developed for operation like elimination, aggregation and boundary simplification. More recently, some more mathematically elegant algorithms have been developed by Su and Li, (1995), Su et al. (1997a, 1997b). In their studies, mathematical morphology has been used as a basis and many algorithms have been developed for various generation operators such as area-patch generalization, elimination and aggregation. Yet, these past studies emphasize on the geometric and visualization aspects only. There is no single set of comprehensive rules to guide the use of these algorithms. The simple rules that have been used are based merely on graphic features and requirements. For example, an area with a size smaller than 25 x 25 m^2 will be eliminated; the gap between two area features smaller than 5 pixels will be bridged. In order that the generalization operators are used more intelligently, more comprehensive rules of including the intrinsic semantics of thematic features are needed.

In the case of vegetation mapping, to reveal the dynamic nature of vegetation, it calls for a comprehensive database at varying scales of details. At the bottom database are the species and association of floristic classification for the larger scale mapping. This progresses to the top with physiognomic classification of broad plant communities. If intelligent rules of plant growth, life form and change etc. are incorporated into such process, this could perhaps implicitly reveal the dynamic stages of plant succession and ecology. In this regard, the bio-geographical principles, including both the inherent biological characteristics and spatial distribution of vegetation, is the vital source for rules to govern the generalization operators in vegetation mapping. The former concerns a logical classification of vegetation into larger units of communities. For example, the Pinus species belong to coniferous woods and grasses more than 1 metre high are classified as tall grassland. Geographically, vegetation displays a logical spatial relationship as related to 'plant succession'. Tall trees, low trees, shrubs, grass, lichens, bare soil should appear as a catenary sequence in natural conditions. Any deviation from this sequence may indicate an intended (like human construction) or unintended (e.g. natural fire) interruption. For example, adjacent to a woodland or trees should not be bare soil (except in localized places with human interference like a road, a BBQ site in country park). So in performing any amalgamation of vegetation patches, the smaller ones should not be omitted or dissolved if they represent a transitional stage of the succession sequence. Sometimes, it is these information that provide clues to habitats of certain fauna.

Case Study of The Hong Kong Vegetation
- Data Sources

The Hong Kong Special Administrative Region of China is taken as a case study of the dynamic vegetation mapping. Forests, shrub land, grasslands and coastal vegetation of varying characteristics were spatially distributed on the islands and peninsula. The species richness and diversity of flora on this 1096km^2 territory were comparatively high, as nearly 3000 plant species, including over 2000 species native species, had been found (Hong Kong Herbarium, 1993). The climax stage of the vegetation belonged to the zone of Guangdong southeast shore terrain as covered with a semi-evergreen monsoon rainforest. In the study of Chang et al (1989), it was believed that Hong Kong could develop a sub-tropical forest as located in between a bio-geographical zone of the tropics and sub-tropics. Although now this climax primary vegetation has almost been destroyed, some of the climax forests are still found. Today, the territory is predominantly covered by grassland and shrub land of over 50% of the area (Ashworth, et al 1993). Main vegetation are described as dry middle grass and warm scrub-grassland. Only about 4.6% of the area is covered with plantation woodland. Natural forest and mixed-natural forest were patchily found, occupying approximately 8% to 9% of the territory. This percentage has already included the forests in ravines at higher altitude. Agricultural land of around 4.2% has mostly been abandoned. At the estuarines and sheltered muddy bays are mangroves, covering 0.3% of the land with over 115 ha of Mai Po marsh included. Lastly, coastal zones especially rocky shores are coated with several salt tolerated trees, shrub species and herbs but the size is small.

Having briefly described the vegetation cover of Hong Kong, let's have an overview of the possible data sources for vegetation mapping at varying scales. The management of all 23 country parks and mangrove areas in Hong Kong has been the responsibility of Agricultural, Fisheries and Conservation Department (AFCD). It has kept planting records of afforestation species, number and location for each year. Records of the most recent 5 to 10 years are available at some of the 25 Country Park Management Centres. However, these records are kept for the sake of young forest management and would cease once the forests mature. Besides, the planted species are marked only very sparingly on paper maps and the Department does not have a systematic or automated means to manage these data. It is possible that some plantation woodland had been replaced by a semi-natural forest or destroyed by frequent hill fires. Concerning mangrove mapping, a more comprehensive study of its flora and fauna in 43 mangrove stands has been reported in a multi-media CD-ROM. This includes maps showing location, species distribution, a list of species, dominated community etc. On the other hand, there has been numerous scientific researches, papers and publications for the different parts of vegetation in Hong Kong. Studies for the recent 10 years are especially informative for the present-day plant distribution, such as the study of Mai Po Marsh Nature Reserve (Duke & Khan 1999), trees on roadsides and parks (Jim 1994 & 2000), restoration of borrow areas, eroded and degraded lands (Jim 1993, Chong 1999, Lau & Fung 1999), compensatory plantation woodland at Tung Chung and mangrove at Tai O (Chan & Chau 1998), natural succession and related factors (Chan &Thrower 1986 & Zhuang & Yau 1999), special features of Tai Po Kau forest (Nicholson 1996), study of natural woodland and fung shui woods (Chu & Xing 1997, Zhuang, Xing & Corlett 1997), flora in Lamma Island (Wong 1999), and so on. In many cases, these studies could provide detailed plant data of species type and number in specific areas for large scale mapping but they lack a continuous coverage for the whole territory.

To compensate for this, the territorial-wide vegetation mapping conducted by World Wide Fund for Nature Hong Kong in 1993 may provide clues for the missing gaps arising from the data collected by the AFCD and the numerous scientific studies. The major data sources are from manual interpretation of about 400 vertical aerial photographs taken from an aircraft flying at an altitude of 10,000 feet, supplemented by a geometrically corrected false colour composite image at 1:50,000 scale and selected areas of field checks. Therefore, only broad physiognomic classification for small scale mapping can be achieved. In all, 34 land cover categories were mapped using Genamap, including 11 broad vegetation/land-use categories, 5 urban categories, bare soil, hillside grave sites and abandoned hillside terraces. This information is summarized into the database at 1:20,000 and 1:50,000 scales. To produce a simplified classification, the 36 land cover categories were simply aggregated, so that too small areas of vegetation were amalgamated with larger surrounding areas (Ashworth & et al. 1993). In this aggregation process, only visualization was considered. That is, small areas were amalgamated without considering the gradation or succession nature of vegetation and the process was carried out manually because sound automated methodology was not available then and is still not available.

Prototyping The Mapping Process

For fully automated generalization, it is necessary to start from the most detailed information at the largest scale possible. In this regard, sketches or plans of plant species from the various stations of AFCD and all other studies are converted into digital format first. Most planted areas are represented as polygons except a few rare plants or small fung shui groves as points. At the same time, these plant data are classified according to their floristic composition of belonging to dominated species or associated species, formation and biochore. From such database, it is expected that generalization is to be performed according to both the classification rules and visualization-dependent geometric operations. However, there are two major problems. First, it is almost impossible to collect data for the whole territory for the same time frame. The plant data captured for the 70 areas ranges from 1979 to 2000. Therefore, only data of the recent 5 to at most 10 years are considered, assuming that changes in the growth form or life form are insignificant. Second, the collected data are largely restricted to planted woods that do not form a continuous coverage (Figure 1). To resolve the problem of incompleteness, the principle of plant succession is assumed. That is, the missing gaps are interpreted from its neighboring plant types and properties. For example, forest / woods, shrub land, grassland, lichens and bare surface would form a catenary and ecological sequence. Hence, adjacent to a planted or natural woodland should not be bare soil, except in localized places with human interference like a road, a BBQ site.

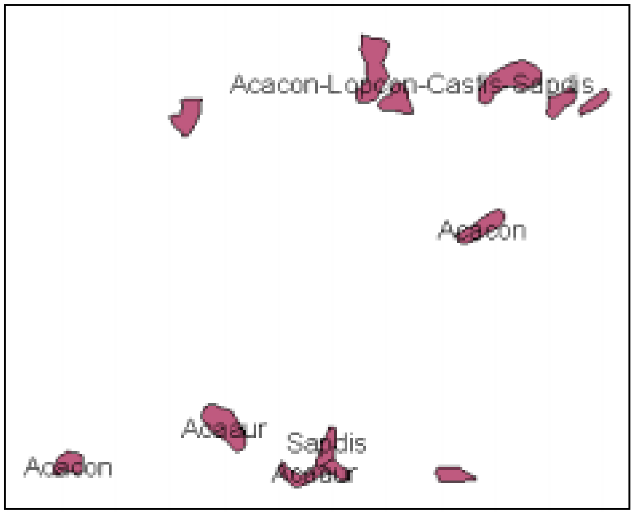

Figure 1 Plantations of Pat Sin Leng, N.T., Hong Kong

These same bio-geographical principles will also be applied when generalizing data from the larger to smaller scales for presentation. This involves two aspects: the biological characteristics and the geographical (spatial) distribution of vegetation. The former concerns with a logical classification of vegetation into larger units of communities as mentioned in the floristic classification. In such process, the proportion of dominated species to commonly associated species will also be considered. Figure 2 shows selected examples of vegetation classification in Hong Kong according to Chang and et al (1989). Plant species of trees, shrubs, grass and so on may be identified from their association with other species and constitute a formation, and there group to a subtype and a general biochore type. Such a guide would help determining the classification criteria in attribute transformation during aggregation or amalgamation (McMaster & Shea 1992).

Geographically, vegetation displays what has been mentioned a logical spatial relationship of ‘plant succession’. So instead of eliminating the smaller polygons of vegetation patches which represent a significant transition between vegetation types, these might have to be either exaggerated, displaced into larger adjacent patches or collapsed into points upon scale reduction. In Figure 3a, there are mixed patches covered with tall shrub/grass (TS/G), low shrub/grass (LS/G), and pure patches of grassland (G) and bare surface (B). With scale reduction, it is generalized to a higher level classification of just shrub land, grassland and bare surface. It is noted that the narrow gaps of low shrubs/grass (LS/G) between tall shrub/grass (TS/G) and bare surface (B) in Figure 3b have to be widened, so that a natural sequence of vegetation types can be preserved. The automation of such process would warrant a rule-based analysis of each vegetation patch with its neighboring types or even species to see if there is any possible association or conflict. The decision is especially significant in case of any polygon dissolve, elimination, amalgamation or collapse into points arising from existing generalization operators.

Type Group	Type	Sub-type	Formation Group	Formation	Assoication
Conferious Forest	Temperate Conferious Forest	Temperate Evergreen Conferious Forest	Temperate Evergreen Coniferous Forest	Pinus massoniana	Pinus massoniana
				Pinus elliotii	Pinus elliotii
				Keteleeria fortunei	Keteleeria fortunei
			Temperate Evergreen Mixed Coniferous and Broad-leaved Forest	Pinus massoniana + Liquidambar formosana	Pinus massoniana + Liquidambar formosana
				Pinus massioniana + Castanopsis fissa	Pinus massioniana + Castanopsis fissa
				Pinus massoniana + Schefflera octophylla +	Pinus massoniana + Schefflera octophylla +

				Sterculia lanceolata	Sterculia lanceolata
Shrubland		South Subtropical Shrub Land	South Subtropical Evergreen Shrub Land	Gordonia axillaris	Gordonia axillaris + Eurya muricata
					Gordonia axillaris + Acronychia pedunculata
					Gordonia axillaris + Pentaphylax curyoides
					Gordonia axillaris + Schima superba
Grassland		South Subtropical Grassland	South Sub-Tropical Gramineae Grassland	Miscanthus sinensis	Miscanthus sinensis
				Miscanthus floridulus	Miscanthus floridulus
				Neyraudia reynaudiana	Neyraudia reynaudiana
				Phragmites communis	Phragmites communis
				Arundinella nepalensis	Arundinella nepalensis

Figure 2 The classification of selected vegetation in Hong Kong. (dominant species is denoted by +)

Source: Chang, H.T, & et al (1989) The Vegetation of Hong Kong. Supplement to Acta Scientiarium Naturalium Universitatis Sunyatseni, 8(2).

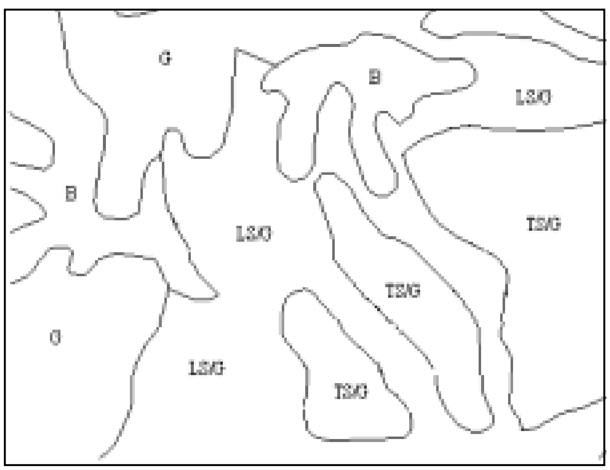

Figure 3a Vegetation patches before generalization

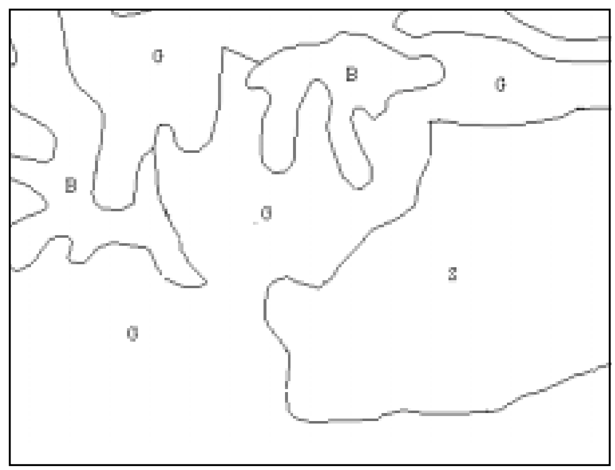

Figure 3b Vegetation patches after generalization

Conclusion

This paper has touched on general ideas of making rules for automated vegetation mapping. In order to apply the bio-geographical principles effectively, a comprehensive database of vegetation types is required, so that there can be enough information concerning their physiognomic, floristic and ecological characteristics for varying levels of classification. Nevertheless, vegetation data are among one of the most difficult land data to collect in view of their vast coverage and dynamic characteristics. Hence, the testing of suggested generalization algorithms will only be limited to a few sites with reliable and consistent plant data. It is hoped that with improving data collection techniques of for instance higher resolution satellite imagery and aerial photographs, as well as better interpretation methods, more vegetation data would become available. Besides, a systematic management of field collected data by site officers and interested parties, especially with the use of geo-information data capture techniques, will certainly play a very important role in contributing to the availability of this vast but necessary database.

References

Ashworth, J.M. & et al (1993) Hong Kong Flora and Fauna: Computing Conservation. Hong Kong: World Wide Fund for Nature.

Chan, Y.C. & Thrower, L.B. (1986) Succession taking place under Pinus massoniana. In Hodgkiss, J. (eds) Memoirs of Hong Kong Natural History Society. 17:59-66.

Chan, F. & Chau, K.C. (1999) A study of local plantations of Hong Kong. In Lam, K.C., Chen, Y.C. & Ng, S.L. (eds) Towards 21st century of China: environment, resources and sustainable development. Hong Kong: Chinese University Press, pp. 289-308. (In Chinese).

Chang, H.T, & et al (1989) The Vegetation of Hong Kong. Supplement to Acta Scientiarium Naturalium Universitatis Sunyatseni, 8(2) (in Chinese)

Chong, S.L. (1999) Restoration of degraded lands in Hong Kong. In Wong, M.H., Wong, J.W.C. & Bakers, A.J.M. (eds) Remediation and management of degraded lands. Boca Raton, Fla.: Lewis Publishers, pp. 185-193.

Chu, W.H. & Xing, F.W. (1997) A checklist of vascular plants found in fung shui woods in Hong Kong. In Memoirs of the Hong Kong Natural Histroy Society. 21:151-171.

Duke, N.C. & Khan, M.A. (1999) Structure and composition of the seaward mangrove forest at the Mai Po Marshes Nature Reserve, Hong Kong. In Lee, S.Y. (eds) Proceedings of the International Workshop on the Mangrove Ecosystem of Deep Bay and the Mai Po Marshes, Hong Kong. Hong Kong: Hong Kong University Press, pp. 104-115.

Hong Kong Herbarium (1993) Check List of Hong Kong Plants, 6th ed., Agricultural and Fisheries Department, Hong Kong: Government Printer.

Jim, C.Y. (1993) Ecological Rehabilitation of disturbed lands in humid tropics. In Parham, W.E. (eds) Improving degraded lands: promising experiences from South China. Honolulu: Bishop Museum Press, pp. 217-229.

Jim, C.Y. (1994) Urban tree survey: roadside trees managed by the Urban Council. Hong Kong: Urban Council.

Jim, C.Y. (2000) Trees in major urban parks in Hong Kong. Hong Kong: Green H.K. Campaign: Leisure and Cultural Services Dept.

Kent, M. & Coker, P. (1997) Vegetation Description and Analysis, A Practical Approach. John Wiley & Sons.

Lau, S.P. & Fung, C.H. (1999) Reforestation in the countryside of Hong Kong. In Wong, M.H., Wong, J.W.C. & Bakers, A.J.M. (eds) Remediation and management of degraded lands. Boca Raton, Fla.: Lewis Publishers, pp. 195-200.

McMaster, R. and Monmonior, M. (1989) A conceptual framework for quantitative and qualitative raster-mode generalization. Proceedings, GIS/LIS'89, 390-403.

McMaster, R.B. & Shea, K.S. (1992) Generalization in digital cartography. Association of American Geographers.

Monmonior, M. (1983) Raster-mode area generalization of land use and land cover maps. Cartographica, 20(4): 64-91.

Muller, J.C. (1991) Building knowledge tanks for rule-based generalization, ITC Journal, No.3, pp. 138-143.

Nicholson, B. (1996) Tai Po Kau Nature Reserve, New Territories, Hong Kong: A restoration history. In Asian Journal of Environmental Management. 4(2): 103-119.
Schylberg, L. (1993) Computational methods for generalization of cartographic data in a raster environment, Doctoral thesis, Royal Institute of Technology, Department of Geodesy and Photogrammetry, Stockholm, Sweden.

Su, B., Li, Zhilin, Lodwick, G. and Muller, J.-C. (1997b) Algebraic models for the aggregation of area features based on morphological operators. International Journal of Geographical Information Science, 11(3): 233-246.

Su, B., Li, Zhilin, and Lodwick, G. (1997a) Morphological transformation for the elimination of area features in digital map generalization. Cartography, 26(2): 23-30.

Su, B. and Li, Zhilin (1995) Knowledge-based systems for map design and production: A review and some considerations. Cartography, 24(1): 33-42.

Wong, Y.W. (1999) Ecology and biodiversity of a degraded landscape: Lamma Island, Hong Kong. PhD theis, University of H.K.

Zhuang, X.Y. & Yau, M.L. (1999) The role of plantations in restoring degraded lands in Hong Kong. In Wong, M.H., Wong, J.W.C. & Bakers, A.J.M. (eds) Remediation and management of degraded lands. Boca Raton, Fla.: Lewis Publishers, pp. 201-228.

Zhuang, X.Y., Xing, F.W. & Corlett, R.T. (1997) The tree flora of Hong Kong: distribution and conservation status. In Memoirs of Hong Kong Natural History Society. 21:69-125.

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