CHAPTER 2

ENVIRONMENTAL INDICATORS

Background

Although studies on forest recreation in Peninsular Malaysia have been undertaken, these mainly focus on the socio-economic aspects (Abdul Kadir, 1983, Wan Sabri et al., 1983; Khalid and Mohd Shawahid, 1983; Mohd Nasir, 1993, Wan Sabri, 1993), rather than on the biological aspects (Musa, 1983; Lai and Amat Ramsa, 1993). These inconsistencies are reflected by Abdul Kadir (1983), who has identified historical circumstances, location competition and social values as major socio-economic constraints in developing Gunong Jerai FRA, Kedah while simultaneously, lamenting on its lack of promotion. Similarly, Khalid and Mohd Shawahid (1983) on their basis of their investigation on the valuation of three recreational parks; Agricultural Park in Shah Alam, Mimaland in Gombak and Subang Ria Park in Subang, using "willingness-to--pay" and "travel-cost" methods have concluded that socio-economic factors, such as travel-cost, travel-time, parking and access can exert strong influences on recreational demand.

Meanwhile, Wan Sabri (1983, 1993) compared "willingness-to-pay", "travel-cost" and "site consumers' surplus" methods in an attempt to value five recreational areas; FRAs, urban parks, thematic parks, coastal and hill recreational resort sites and gathered that not only were there substantial economic values associated with outdoor recreation, but also that recreational demand would increase in the future, consistent with increasing population size and economic growth.

Applications of "travel-cost, willingness-to-pay and site consumers' surplus" methods of determining recreational demand have continued to remain popular with social scientists in valuating recreational areas (Khalid and Mohd Shahwahid, 1983; Wan Sabri et al., 1983; Mohd Nasir, 1993; Wan Sabri, 1993).

However, such studies are subject specific, focusing mainly on the socio-economic aspects of natural resource development. As such, they lack the scope and depth to meet the long-term requirements of sustainable development in terms of resource capacity, recreational opportunities, maintenance of vistas and managing visitors' impact (Chin, 1993). This concern holds true for FRAs, which are nature based, readily accessible and more specific in nature (Anon, 1994), while environment changes within them can be readily detected, if the right indicators are used.

To address this need, as an initial step this study examines the use of indicators to describe and evaluate the environment (resource) in relation to recreational impact. This will allow the manager not only to derive baseline information, but also permits him to interprete the results for purposes of sustainable uses of FRAs, consistent with the carrying capacity of their natural habitats. In the process, he can compare conditions, identify over-use and suggestions of remedial measures not only against further site deterioration, but also of their restoration. This utilisation of the environmental indicators will no doubt encourage progress towards decision making and managing present, as well as potential FRAs.

In the process of this study, two objectives are proposed. First is to introduce the definition of environmental indicator, present the state-of-the-art information on its early beginning and current applications. The purpose is to assess and document the status of the resource, particularly to establish baseline information of environmental conditions, with special reference to the Malaysian situation.

Methods to detect and interprete trends in environmental status, and early warning of significant long-term change in environmental condition, are also reviewed, since they are used to anticipate emerging environmental problems before they become widespread or irreversible.

Second is to discuss the choice of indicators with particular reference to those indicators selected for this study, interpretation of indicators' information about environmental effects and status, as it affects the public, FRA managers and decision makers.

Definition and Characteristics

The concept of developing environmental indicators, their measurements and monitoring for environmental integrity seemed to be the goals of many of the early researchers and monitoring programmes on issues such as water pollution (Karr et al., 1986; Regier, 1992; Schneider, 1992), air pollution (Munn et al., 1988; Ward, 1992), and environmental degradation (Brockman and Merriam, 1959; Cairns, 1986, Olsson and Reutergardh, 1986; Marshall et al., 1987; Gilbertson, 1988; Schneider, 1992).

As a result of such interest on environmental indicators, numerous researchers have attempted to define and characterise them (Spellerberg, 1991; Jorgensen and Gabanski, 1992; Peterson, 1992; Schneider, 1992; Ward, 1992). Spellerberg (1991) defined it as a device indicating the condition of the environment both physical or man-made, while Jorgensen and Gabanski (1992) recognised that indicators represent a broad category of measurements used to signal environmental changes, which could result from either human perturbations (e.g. toxic discharges) or represent natural variations (e.g. succession), which are important to society. Schneider (1992) recognised it as a consistent set of measures to gauge the well-being of the environment. He further acknowledged that environmental degradation is not confined only to local level, but could also include regional and national levels. On the other hand, Peterson (1992) recognised that environmental indicators represent a broad category of measurements, used to signal environment changes important to society. Similarly, Ward (1992) defined indicators as the key design of a system to measure and provide the information necessary to make management decision, regarding the environment desired status and behaviour.

Generally, environmental indicators are not simply the recording of unusual phenomena in nature, but the identification of signs that are well known and have important consequences for nature's state of health (Peterson, 1992). Nevertheless, the criteria used to define indicators will depend on the purpose of their uses and target audience (Jorgensen and Gabanski, 1992). Suite of indicators will be needed at various levels of biological organisation for various purposes to provide a more complete assessment of environmental conditions (Jorgensen and Gabanski, 1992).

In terms of their characteristics or measurements, Schneider (1992) recognized seven categories ranging from chemical to biological indicators. These include chemical constituents, genetic alterations, biomarkers, species occurrence/abundance, population size/variation; species composition/diversity; and ecosystem biomass/ productivity.

Nevertheless, the three major characteristics emerge from the definition of environmental indicator are: (1) they must readily be detectable; (2) they must provide early warning signals of environmental transformation; and (3) they must provide integrated measures of environmental sustainability.

State-of-the-Art Information

The aim of this section is to describe some basic aspects of indicators, which are relevant to the monitoring of environmental transformation. In the process, an assessment is made of their beginning and their current applications-their strength and shortfalls-and in ways, in which they can be enhanced for this study.

Early Days

Environmental indicators are not something new, they have long been used for practical purposes (Regier, 1992) and among the early indicators used were simple measures of water quality (colouration, oxygen contents), later from observations that foul smelling waters with their anoxic sediments containing an unusual abundance of blood red worm and early efforts to develop standards and measures of degradation were based on such indicator species (Leppakoski, 1975). Basically, the foul smelling, discoloured water sent strong signal that nature were over burdened (Peterson, 1992).

Similarly, Ryder and Edwards (1985) also reported that the disappearance of lake trout in the waters of the upper Great Lakes of the United States of America, which signal stress from toxic substances and nutrients loading. Local fish killed and gradual disappearance of local species was common place and this was the early genesis of standards and environmental indicators (Schneider, 1992).

Parallel efforts were also developed in the field of air pollution, such as air dispersion modelling and indices of ambient air quality for nearly 50 years (Munn et al., 1988). Establishment of atmospheric monitoring at Mauna Loa, Hawaii since the 1950s had allowed documentation of the rate of global atmospheric carbon dioxide increase (Smith and Palmer, 1992). In addition, documentations of acid rain in the United States of America was revealed in routine precipitation chemistry measurements, initiated in the late 1960s at Hubbard Brook Experimental Forest, New Hampshire (Smith and Palmer, 1992). Similar, documentation of air pollution by acid rain in Europe was also observed by Hutchinson and Scott (1988) during routine monitoring of precipitation in Scandinavia.

Within the terrestrial environment, early works included the detection of toxic effects and deformities in fresh water invertebrates (Cairns, 1986; Bengtsson and Miettinen, 1987), studies of impaired reproduction of aquatic species resulting from contaminant stress (Olsson and Reutergardh, 1986; Gilbertson, 1988), identification of indicator species, such as *Chlorophyta* and lake trout which by their presence or absence signifies healthy or unhealthy ecosystems (Ryder and Edwards, 1985; Marshall and Waring, 1986), and sensitivity analysis of ecosystem response to natural and experimentally included stress (Borman, 1985; Schneider, 1992).

Mellanby (1978) elucidated that non-vascular plants have long been used as general indicators of environmental quality and among them are lichens and mosses, by their presence or absence gives a picture which integrates the effects of long term exposure to air pollution, such as sulphur dioxide. Similarly, fungi particularly those like the tar spot fungus, which cause plant diseases, give results relating to air pollution in matter of weeks or, at most, months. Many higher plants react to short episodes where there are high levels of the pollutants in the air, and show their characteristic symptoms in at most a few days. In all, estimates of the harmful effects of the pollutants on vascular plants can be made.

Generally, indices that were used, essentially consist of several indicator sub-indices that "scale" results among indicators and an aggregation scheme for mathematically combining values for the sub-indices (Messer, 1992). They represent a powerful tool for presenting complex information in simplified form, especially to non-technical audiences (Messer, 1992). However, many of these methods are expensive as well as labour intensive, prompting investigators to develop indices in an attempt to shorten analyses of *in-situ* ecosystems (Schneider, 1992).

One of the most developed of these methodologies is the Index of Biotic (or environmental) Integrity (IBI) which was developed by James Karr with his colleagues to measure biological conditions in streams, based on data from the assemblage of fish species (Karr et al., 1986). The IBI methodology measures twelve different metrices of ecosystem structure (species richness and composition), trophic composition, and organism abundance and condition, developed mainly for fresh water streams (Karr et al., 1986). In addition, this methodology requires not only local knowledge of existing ecosystems, but also requires a pristine, unperturbed site for comparison with other sites (Schneider, 1992). This methodology has been adapted and adopted for use extensively in the United States of America, as part of its water quality standards and monitoring programmes (Schneider, 1992).

Another well known method of determining biotic (environmental) integrity was developed by Smit-Kroes (1989) from The Netherlands, based on environmental integrity criteria, such as maintenance of productivity, diversity of flora and fauna be preserved and the environmental ability to regulate itself, and resulting in an AMOEBA-like Chart. The circle is the centre representing pristine condition and distance from the centre representing number of species in the reference year. The current number of each species is indicated with reference to the circle and when plotted against the pristine condition will result in an AMOEBA-like figure, as expounded by Smit-Kroes (1989). Quantitative AMOEBA-like models were also developed with this method to assess the future of the various aquatic species in the North Sea by ten Brink (1989) and ten Brink et al. (1990).

In addition, many of the early indicators were based on readily detectable signs of local environmental degradation, in response to intense stress from concentrated human settlements and industrialisation (Rapport, 1992) and indicators or risk assessment, which were developed, were primarily for the protection of human health (Gentile and Slimak, 1992). As such, the effects of environmental degradation within the ecosystem is relegated into the background and often given scant attention during the early genesis. Thus, there is an urgent need to develop environmental indicators for conductivity and ecological risk assessment.

In Malaysia, the genesis of environmental indicator is one of recent development, initially focusing on *ad hoc* monitoring and related investigation, as a response to a growing number of complaints by the public (Abdul Samad and Hairi, 1990). Most of the complaints were directed against the uncontrolled emissions or discharge from highly polluting factories and related activities (Abdul Samad and Hairi, 1990) and naturally, they were mainly concerned with the protection of human health (Sham, 1990). The results of these *ad hoc* investigations formed the basis for the establishment of a permanent network of monitoring stations (Abdul Samad and Hairi, 1990). The government then reviewed the seriousness of the problem, and consequently comprehensive legislation in the management of the environment called the Environmental Quality Act, 1974 was enacted (Sham, 1990). The Act also provides for the Environmental Quality Council and the Department of the Environment (DOE), which administered the Act (Sham, 1990) and thus the genesis of environmental awareness in Malaysia.

Current Application

The majority of the indicators, which are currently being employed, are centred around the protection of human health, arising from the concentration of human activities and industralisation (Peterson, 1992). As such, the indicators that were developed reflect this situation (Peterson, 1992; Rapport, 1992). Indices such as sulphur dioxide, carbon dioxide, dust and suspended particulates have been used to measure urban air pollution in North America and Europe, caused mainly by incomplete combustion of fuel and industralised processes (Peterson, 1990).

Similarly, indices of water quality, such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total suspended solids, turbidity and pH were developed for the measurement of water pollution caused by industrial effluents, human waste and from land use activities including deforestation and mining (Peterson, 1992).

Indices for measuring traffic noise, industrial noise, construction noise and aircraft noise are also developed with the view of improving urban living conditions (Goh, 1990; Sham, 1990). These development of environmental indicators are not static and efforts to refine standards and to develop more sensitive indicators continued till present day (Rapport, 1992). However, the majority of the above indices are focused primarily for the protection of human health (Gentile and Slimak, 1992; Peterson, 1992; Rapport, 1992).

Given that the basic concern of environment transformation is the protection of human health risks either at individual, population or community levels (Messer, 1992; Rapport, 1992) and as such, the indicators which are developed and applied reflect this situation. However, equally important too is the recognition of the biological components and biological resources that makes up the environment (Zakri, 1993). As such, it may also be appropriate to expand environmental indicators to encompass habitat integrity, wildlife, insect, microbial population or the ecosystem.

Consequently, current development has included the applications of ecological indicators to assess pressure on the environment (Spellerberg, 1991). Magurran (1988) provides examples of ecological indices for terrestrial communities and O'Neil et al. (1988) for landscapes, while Peterson (1992) elucidated on other biological indicators such as phenology, age class and biotic stresses. Thus, when properly implemented, such indicators can be used to assess both ecological status and trends, thereby gaining broader understanding of ecological processes, in anticipation of emerging environmental problems, as well as addressing local and national monitoring, regulatory and policy needs (Peterson, 1992).

Ideally, ecological indicators should consist of a myriad of indicators, rather than an individual indicator to provide information on environmental transformation (Kerr and Dickie, 1984; Schneider, 1992). Frost et al. (1992) reported on a wide variety of indicators that have been suggested for use in evaluating the conditions of the ecosystem. These range from responses of individual organism to integrated behaviour of entire ecosystems.

Individual level measures are illustrated by behaviour responses (Little and Finger, 1990), while population level parameters focus on responses of sensitive species, whereas community scale parameters by species richness or diversity (Fausch et al., 1990). Similarly, ecosystem level parameters focus on measures of production, nutrient cycling or more complex assessments of system behaviour (Odum, 1985). Taken together this range of indicator parameters can be viewed as representing a systematic gradient of aggregation (Stolte and Mangis, 1992).

Frost et al. (1992) suggested that along this gradient, parameters vary in the extent to which they aggregate the behaviour of increased number of individuals that have a capacity to function independently of each other. Parameters emphasising individuals represent one extreme along this gradient with subsequent progression to population, community and ecosystem levels of aggregation. Thus there is interplay between natural variability and sensitivity across the gradient of aggregation, thereby allowing the detection of trends, while sensitivity to stress is maintained. Such co-relation provides the basis for the pragmatic choice of indicators (Peterson, 1992).

In terms of the forest system, scientists such as Waring (1983), Marshall and Waring (1986), Smith and Palmer (1992) have developed a variety of standard measurements that have been proven useful in tree health assessment, in relation to environmental conditions. These include diameter, height, annual increment, basal area, symptoms and signs. Current research efforts have proposed a large number of potentially new indices, such as leaf area, persistence, or chemistry (Waring, 1983); root area, persistence, or chemistry (Marshall and Waring, 1986); and soil or stream chemistry (Smith and Palmer, 1992).

In Malaysia, current applications of environmental indicators evolve around water, air and noise monitoring and monitoring of industrial effluent and air emission (Goh, 1990). Major indicators which are associated with water monitoring include Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonical nitrogen, suspended solids and pH levels (Sham, 1993), while for air monitoring, indicators such as carbon monoxide, sulphur dioxide and oxides of nitrogen have been used (Mohd Awang et al., 1990). Noise monitoring include monitoring traffic noise, industrial noise, aircraft noise for purposes of improving living conditions (Goh, 1990), while lead and copper appears to be the common heavy metals which are associated with industrial effluent (Sham, 1993). Again, they all focus on the protection of human health.

Sham (1993) reported that although the environment is still under control, a great deal of deterioration has occurred, particularly after the nation's independence, when land development became more aggressive. Such deterioration is currently evident in forestry, land erosion, water quality (both marine and fresh water), air quality, acid rain, noise and industralised waste.

As a result, the environmental protection activities have been expanded to include the assessment of the existing state of the environment as it relates more to human health and ecological well being, rather than just as a regulatory performance of pollution abatement programme (Abdul Samad and Hairi, 1990).

In terms of Malaysia's forest environment, tree parameters such as diameter, height, annual increment, basal area and volume are recorded and used as growth indicators for forest management and silvicultural programmes, rather as indicators of environmental conditions (Anon, 1992a). However, further analyses of these data can yield valuable information to assess ecosystem state and trends. Refinement of existing indices to include other variables affecting tree response to pollutants, such as available water capacity, diameter of trees and site factors will improve our understanding of the biology of the environment variables that are most important in evaluating pollution stress (Stolte and Mangis, 1992).

Choice of Indicators

Williams (1990) elucidated that the choice of environmental indicators for measurement is an absolute critical decision to be taken in any environmental programme. The easy answer is to measure everything, but of course in practice this will be prohibitively expensive, unwieldingly and mechanically impossible and a serious consideration will be the speed at which the results be obtained and the cost of equipment, manpower and skill necessary to sustain a sampling programme.

This view is also shared by Mohd Awang et al. (1990), who reported that it is normally impossible to study the entire biotic presence in a sampling area because of the constraints of time and of a wide variety of sampling methods required for different groups of organisms. Thus the choice of environmental indicators must be based on organisms that are most likely to provide information to the question being posed.

Furthermore, Abdul Samad and Hairi (1990) elucidated on the choice of suitable indicators species, basing on a number of criteria, such as: (1) species possess economic importance as a resource; (2) abundant data on their physiology and ecology; (3) wide distribution; (4) ease of sampling; (5) stable population: (6) limited genetic variation; (7) numerical abundance at sites; and (8) ready response to environmental transformation in a way that readily reflect their environmental levels.

Generally, the choice of indicators is not simply the recording of unusual phenomena in nature, but also the identification of signs that are well known and have important consequence for nature's state of health (Peterson, 1992), and in this case the use of indicators as a feedback mechanism in assessing the effects of recreation on FRAs, in Peninsular Malaysia. Acknowledging that no simple indicator is likely to prove efficient as an early warning symptom, which suggests a need for a spectrum of indicators of ecosystem dysfunction (Rapport, 1992). However, the need to act decisively often conflict with the slow and careful process of gathering scientifically credible information and the relationship between them need to be established (Greenwalt, 1992).

Guided by the past (Leppakoski, 1975; Mellanby, 1978; Ollsson and Reutergardh, 1986; Gilbertson, 1988) and current (Goh, 1990; Sham, 1990; Gentile and Slimak, 1992; Petterson, 1992; Rapport, 1992; Sham, 1993; Noor Azlin, 1999) applications of environmental indicators, the choice of indicators may encompass the short listing of major physical and biological resources, that may be sensitive to recreational pressure, monitor the spatial and temporal trends of identified recreational effects, determine the significance of their effects and in the process identify the sources of the recreational pressure causing the impact.

A series of physio-chemical and biological indicators may be in order, for use in measuring the recreational impact on the FRAs. As a result, broad based environmental indicators, such as soil, vegetation, surface and ground water quality not only to fulfill the expectations of the above criteria, but also that they are objective, cost effective and relevant in assessing the effects of recreation, based on test of related studies. Supported by the above criteria, they are subsequently chosen as environmental indicators for this study.

Although these environmental indicators have been investigated by numerous authors; soil (Lutz, 1945; Montgomery and Edminister, 1965; Stevens and Banks, 1973; Frissell, 1978; Weaver and Dale, 1978), vegetation (Heinselman, 1965; Settergren and Cole, 1970; Beardsley and Wagar, 1971; More, 1980), surface/ground water (Barton, 1969; Lai and Amat Ramsa, 1993), their investigations are site specific and singular in nature i.e. looking at one aspect separately at a time. Hence, there is a need to develop methodology to synthesize these environmental indicators in relation to forest recreation, and in the process develop systems to evaluate the recreational impact as a whole, based on a multi-disciplinary approach.

Additional advantages favouring their selection are their ease of identification, through which visual changes and data on them can be easily captured and analysed. As a result, a cursory examination of such environmental indicators may be in order to strengthen their selection.

Soil

Soil is the result of climate, topography and organisms interacting upon the parent material over a period of time (Gibbons and Downes, 1964). Therefore, parent rock provides much of the raw materials, the climate lubricates and determines the speed of manufacture, but the vegetation ultimately determines the nature of the products (Eyre, 1966).

Similarly, Gibbons and Downes (1964) acknowledged the multiple facets of soil; its texture which affects the soil capacity to absorb, store and yield water; structure which affects the permeability, storage capacity and rate of surface water loss; and depth which affects water quality, especially near the surface horizon. They further added that the relationship of soils to recreation capacity of the site often refers to the suitability the soil for construction (facilities), its permeability, trafficability, water storage capacity ,and its general fertility for growing plants.

Montgomery and Edminister (1965) reported that all soils can be used for recreational activities of some kind. He further added that on beach sites, coarse soils such as sands are desirable for their fast seepage, and absence of dust, while rock outcrop and shallow uniform soils have features which could be difficult or expensive to overcome when constructing roads, drains and foundations though they are generally well drained. The heavier soil of silt and clay are more susceptible to pudding, have several limitations for use as sites for camps, recreation buildings or other uses, such as horse riding and walking for pleasure. Loams of the medium textured soils are suitable for a variety of recreational activities where a grass cover is required, e.g. camping and picnicking, whereas sandy loam and loamy surface textured soils are the most desirable for intensive recreation.

However, studies on the impact of recreation on soil have been concentrated on campgrounds (Frissell and Duncan, 1965; Frissell, 1978), picnic areas (Lutz, 1945) and paths (Bayfield, 1971; Liddle and Grieg-Smith, 1975; Weaver and Dale, 1978). In the United States, studies have been conducted mostly in forested recreational areas (Lutz, 1945; Frissell and Duncan, 1965; Frissell, 1978; Weaver and Dale, 1978); in England the emphasis has been on chalk grasslands (Chappell et al., 1971) and sand dunes ecosystems (Liddle and Greig-Smith, 1975). Comparison and generalisation of the results are hampered by varying soil and vegetation types, climatic differences of study sites and by different methodologies used.

While soil compaction is generally associated with recreational pressure, less obvious is its relationship with other aspects of the environment, such as soil moisture, run-off, erosion, vegetation and the micro-habitats of soil organisms (Frissell, 1978).

These views are also shared by Meinecke (1978), who noted that compacted soil is impermeable to air, shed water, impede normal exchanges between soil and the atmosphere, influence the density and organic matter contents, thereby affecting the ground cover.

Litton (1972) focused attention on the fact that the colour of the topsoil (which may be reflective), is an important structural component of the landscape and its scenic appeal.

In Malaysia, soil investigations have been generally associated with agricultural crops, such as rice (Erh, 1977), rubber (Chan et al., 1977; Guha et al., 1977), oil palm (Guha et al., 1977; Turner and Gillbanks, 1982), cocoa (Wood, 1985), least of all for any investigation between soil and FRAs in Malaysia, and to apply the American or the British results to Malaysia may be misleading. The effects of climate and physiography, being the major influence on the nature of soil should be considered. Most outdoor recreation in forested areas in Peninsular Malaysia are generally located within the FRAs, comprising mainly of lowland *Dipterocarp* Forest (Anon, 1995a). These FRAs are generally water based (Anon, 1992c), usually comprises of riverine lateritic soil (Lai, 1983), which in turn influences the vegetation types and their growth rates (Eyre, 1966).

The major impact of recreation within the FRAs in Malaysia is concentrated during the non-rainy seasons, public and school holidays (Wan Sabri et al., 1983), so stresses to the soil, vegetation and water quality can be severe during these periods. On the other hand, the rainy season may have its advantages, since it reduces recreational activities thereby acting as rest periods for both vegetation and soil compaction from recreational activities. Consequently, the impact of recreation in Peninsular Malaysia is modified by these factors, and may differ from that experienced elsewhere, especially in the temperate countries.

By implication, texture, structure, depth, moisture content and pore space being the main characteristics of the soil, will be useful criteria in establishing relationship between soil and recreational impact. Furthermore, a knowledge of the soil type, e.g. as defined by Lutz (1945). Frissell (1978) and Weaver and Dale (1978) will simply enhance the understanding of soil characteristics in relation to recreation.

Vegetation

Landscape or scenery is a product of landform, land use, and vegetation (Anon, 1992b), while its aesthetic appeal often depends upon the nature of the vegetation, because of its colours, form and shapes (Brown et al., 1992). Diversity and uniqueness within and between species provide the vegetation variations (Margurran, 1988), which make the scenery aesthetically attractive (Magill and Nord, 1963). The uniqueness of giant *Scquoias* in California attracts many tourists every year to that part of the world (Wagar, 1969). Likewise, the mega-diversity of the rainforest within the FRA in Peninsular Malaysia is by itself a major attraction (Anon, 1994).

Heinselman (1965), Bayfield (1971), Douglass (1990), and Thomas et al. (1994) recognised that the attractiveness of a site can be enhanced further for recreation, if it is well vegetated or adjacent to a well vegetated area. Conversely, vegetation deterioration as a result of recreational pressure can be readily noticeable. This sensivity of vegetation to environmental changes and its ease of identification make it suitable as a choice of environmental indicator. This has stimulated considerable concern, which has been reflected in the relatively large volume of literature regarding vegetation and recreational activities; wilderness and parks (Heinselman, 1965), camp sites (Frissell and Duncan, 1965; Frissell, 1978, Cole 1989), forested recreational sites (Beardsley and Wagar, 1971; Little and Mohr 1979), nature trails (More, 1980), and ecology (Thomas et al., 1994).

Associated with forest recreation there are, commonly, trampling effects on the vegetation and soil, as well as disturbance effects on the forest fauna (Thomas et al., 1994). Trampling can make the soil an inhospitable environment for plants, and it can also mechanically damage the plants. The relationship is complex and depends upon the species involved (Frissell and Duncan, 1965; LaPage, 1967).

Frissell and Duncan (1965) reported that species loss in the initial stage of recreation is as high as 80%, but with vegetation recovery, the rate of decline tapers-off over time (LaPage, 1967). Likewise, species diversity also changes with increased recreational use from fragile to more resilient species, as a result of vegetative adaptation, as well as the dominance of more resilient species (LaPage, 1967). Similarly, the heights of plants are affected by trampling while flowering frequency decreases (Goldsmith et al., 1970). Although this is an adaptive mechanism of plant to become more resilient to trampling, reproduction rate will undoubtedly, decline (Frissell and Duncan, 1965). This will alter the age structure of the community and eventually without regeneration (Frissell and Duncan, 1965).

However, it should be noted that not all changes in vegetation induced by recreation are bad. The understorey plants receive more light and moisture at trial site and less tree root competition than do plants in a forest understorey, which in turn improve plant production (Dale and Weaver, 1974). Similarly, soil compaction also has positive effect on plant production, when it increases moisture retention (Liddle and Greig-Smith, 1975). They supported that plants grown in compacted soil maintained a greater percentage of live tissues under drought conditions than plants grown in uncompacted soil. Magill and Nord (1963) also found that compaction may improve growth rates of trees, when root-firmness of trees is greater, moisture rates increase and more nutrients became available, since competition for nutrients with micro-flora (which are more scarce) declines.

All of the above factors, which affect the resilience of vegetation use to recreation, will be considered in comparing studies and also in the course of this investigation.

Water Quality

As reported by Barton (1969), water is an essential component of most recreation areas. Directly, it is required for swimming, boating and fishing, while indirectly, it can be a significant component of scenic vistas.

These views are shared by Douglass (1990), who concurred that water is an essential ingredient for most forest recreational activities, such as existence requirements and is desirable for the recreation wants of the users. He added that the recreational use of water does not consume the resource, but goes hand in hand with other uses. Water plays a major role in forest recreation by providing either the primary purpose for the visit or by supplementing some other activity. People who travel into the forest to swim often combine that activity with picnicking for one or two meals. Campers prefer to have swimming, fishing or boating opportunities available to them in order not be too concerned about exact descriptions.

Similarly, Pigram (1983) have reported that water resource is the determining factor in the success of camp and picnic grounds, and hotels.

Activities such as domestic use, bathing and power boating will pollute the water resource, while shore-fishing compliment the pristine nature of the resource (Douglass, 1990).

In the evaluation of water resources for outdoor recreation, water properties such as water quality information (Barton, 1969; Lai and Amat Ramsa, 1993), odour (Douglass, 1990), colour (Douglass, 1990) and its chemistry (Barton, 1969; Douglass, 1990) are essential in enhancing the attractiveness of a recreational site (Lai and Amat Ramsa, 1993). Turbidity in streams is related to the sediment load (Barton, 1969; Lai and Amat Ramsa, 1993), while colour of water is caused by decomposition of organic matter (Douglass, 1990). The overall water chemical budget is affected by the type of recreational activities (Barton, 1969; Douglass, 1990).

Recreationist are often less aware of the impact they may have on water than they are of their impact on other components of the environment. Where compacted soil

(Lutz, 1945) and loss of vegetation (Beardsley and Wagar, 1971; Little and Mohr, 1979) are readily noticeable results of trampling, changes in water quality take place slowly and are not easily related to a specific cause (Douglass, 1990). Pollutants in water are transient, and may be attributed to many harmful uses of the water, which can occur simultaneously (Douglass, 1990). Furthermore it is difficult to distinguish between man-induced changes and natural eutrophication processes, which warrants further investigation relating to changes to water quality, brought by different types and intensities of recreational use.

It is very timely that an evaluation method on the choice of environmental indicators be undertaken in Malaysia, in view of the mounting pressure on the FRAs resulting from the nation's rapid development.