

Cost-Benefit Studies use scarce resources too: some lessons from a study of forested wetlands in the Moreton region

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Abstract:

Although proposed developments which may adversely affect environmental assets are increasingly subjected to scrutiny through the application of an environmental assessment technique such as cost-benefit analysis, little consideration has been given to the question of the optimal allocation of resources to the actual cost-benefit study itself. It is argued here that significant resource savings may be made if the allocation of resources to cost-benefit analyses is commensurate with the importance of the decisions being informed by the analyses. Using a study of the *Melaleuca quinquenervia* dominated forested wetlands of the Moreton Region, it is demonstrated that the decisions about their future use may be accompanied by significant resource savings as a result of the development of rules of thumb linking the characteristics of wetland vegetation with the functions which wetlands perform.

Keywords

Cost-benefit, environmental assessment, wetlands, vegetation characteristics, ecological functions, rule of thumb.

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Introduction

Although there is a large body of economic literature dealing with optimal use of environmental assets, there has been much less discussion of principles which might guide the optimal allocation of resources to the process of environmental decision making itself. This paper looks at the allocation of resources to environmental decision making in the context of decisions about the future of wetlands. It is concerned primarily with an examination of decisions which involve a proposed change in the use of an environmental asset or assets when there is a governmental requirement that the decision making process be aided by a report which details the environmental impact of the proposal. Such a report may take the form of an environmental study, an environmental impact assessment or a cost-benefit study.

In discussing some simple principles which might assist in the determination of the optimum allocation of resources to the process of environmental decision making, this paper uses the example of a study on forested freshwater wetlands in the Moreton Region of Eastern Australia. These forests are dominated by the tree *Melaleuca quinquenervia* (commonly called 'paperbark', 'tea tree' or 'paperbarked tea tree').

Wetlands perform a number of ecological functions which may have considerable value. These functions include floodflow alteration, nutrient cycling, and provision of wildlife habitat (see, for example, Maltby 1987). The Moreton Region study shows that the ecological functions performed by each of the individual wetlands in this group are closely related to the characteristics of their vegetation.

Later in the paper it is demonstrated that an understanding of this relationship between ecological functions and vegetation could be used to reduce the commitment of resources to the determination of the costs of loss of wetland functions which might accompany conversion of wetlands for alternative uses. Depending on the circumstances under which a proposal to alter wetland use may be made, such a reduction in resource requirements may have the following consequences:

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- 1) In cases where existing regulatory controls mandate a comprehensive environmental study, rather than undertaking an exhaustive study of an individual wetland which is the subject of a development proposal, the link between ecological functions and vegetation may allow a much less resource intensive appraisal, thus freeing scarce resources for other worthwhile ends, including increased environmental amenity;
 - 2) Regulatory controls may be altered so as to obviate the need for a comprehensive environmental study in cases where vegetation indicates that the wetland in question performs few, if any, ecological functions;
 - 3) In instances where changes to wetland use are permitted without the requirement of a report on the environmental impact of these changes – as is often the case in developing countries where the cost of such an investigation is considered to be prohibitive – this link may be used as the basis for an affordable low cost method of assessment which would allow better informed decisions to be made.

In relation to the benefits of adoption of resource-saving assessment methods in developing countries, it is interesting to note that Williams (1990 pl4) argues that while the “developing world can rarely afford the luxury of ...non-financial benefits in the face of constant pressure to increase food production, ...paradoxically it is the increased pace and volume of investigations on wetland functions that is showing that sometimes greater financial rewards result in developing countries and in distressed regions of developed countries from leaving wetlands intact, or at least managing them carefully, than would result from converting them to dry land.” It seems that significant benefits may accrue from the use of resource-saving assessment methods which enable a fuller appreciation of the financial and non-financial benefits of ecological functions performed by wetlands in developing countries.

The paper proceeds in the following way: in the next section there is some broad discussion of the principles which might assist in allocating resources efficiently to environmental decision making; this is followed by a discussion of the findings of the study of *M.quinquenervia* wetlands in the Moreton Region; the next section

discusses ways in which the findings of the study could be used to reduce the cost of making decisions about development proposals which would impact upon these wetlands; and, finally, some conclusions are drawn.

ALLOCATION OF RESOURCES TO ENVIRONMENTAL DECISION MAKING

It is a fundamental tenet of economics that allocation of resources to a particular activity involves an opportunity cost – the cost of foregoing the next best alternative use of those resources. The notion of opportunity cost is used widely in the context of environmental decision making. For example, many such decisions involve consideration of the loss of an opportunity to reap financial rewards which would occur if commercial use of an environmental asset is prohibited. In spite of this common use of the notion of opportunity cost in making decisions about the use of environmental assets, the authors are unaware of any widespread application of the concept to the decision making process itself. That is, the process of making decisions about the best use for environmental assets involves the use of scarce resources which have an opportunity cost; and it would be expected, all other factors remaining constant, that a rational use of these resources would see a direct relationship between the amount of resources applied and the importance of the decision being made. As Baumol & Quandt have put it: “[t]he more refined the decision making process the more expensive it is likely to be, and therefore, especially where a decision is not of crucial importance, no more than an approximate solution may be justified” (Baumol 1964).

The importance of the decision being made may be measured in various ways. For heuristic purposes, it is defined here as a function of the probability of, and the cost of, variance of the decision actually made from the optimal decision, where the optimal decision is the decision which best meets the welfare criteria which have been set. To the extent that the importance of the decision being made varies directly with the values of the resources about which decisions are being made, it may also be the case that a rational use of resources in the environmental decision making process would involve a greater application of resources to decisions about choices involving large actual or imputed dollar values. Thus, all other factors remaining constant, we might expect that more resources would be

applied to the question of whether a river should be dammed for a hydroelectric project than whether a tree should be removed to allow electricity to be reticulated to a new consumer. Although such a tendency might be observed, it is not apparent that this outcome results from a conscious decision making process.

Assessing the costs and benefits of the commitment of resources to an environmental cost-benefit analysis involves the same optimisation principle as is employed in the environmental cost-benefit analysis itself. More efficient use of resources in making environmental decisions frees up resources which can be used to achieve other ends – including greater environmental amenity.

The idea that economic decision making involves an application of resources to the decision making process which varies directly with the importance of the decision being made is not new. In 1964, Baumol and Quandt described the formal (marginal) condition for application of resources to decision making as requiring “...that the marginal cost of additional information getting or more refined calculation be equal to its marginal (expected) gross yield.” (Baumol 1964) Rational consumers are thus likely to commit more resources, particularly search time, to researching the question of which model of new motor vehicle to purchase than to the question of which model of toaster to buy. Similarly, firms typically commit more resources to the search for a new manager than for a new clerk. Furthermore, the breadth and depth of services available to assist in making a decision to purchase a good or service having a high value or a high degree of uncertainty of outcome is typically higher than for goods and services having low values or relatively certain outcomes. (Witness the resources available to the potential purchaser of a new motor vehicle or a high class restaurant meal as compare to those available to purchasers of a new toaster or a snack from a street vendor). When it comes to environmental assessment, however, it is not uncommon to find that some decisions of great significance are taken with the assistance of little research while others having lesser importance are subject to a costly environmental assessment process. As an example of the latter, in her study of the allocation of resources to investigation of contaminated groundwater,

Forsyth notes that there is concern in North America that current investigations may involve a super optimal allocation of resources. (See Forsyth 1997).

RULES OF THUMB

In making economic decisions which are routine and which involve little cost of departure from the optimum decision, low cost rules of thumb are often used. Far from being evidence of sloppy work, Baumol & Quandt describe the use of rules of thumb as "...among the more efficient pieces of equipment of optimal decision making." (Baumol 1964). (Thus a decision as to the size of a structural member in the roof or floor of a new house may be determined by rule of thumb while the size of structural members in a substantial road bridge may be determined from first principles.) The rule of thumb results, of course, from previous research – often of a practical nature – which establishes for an indefinite period, the nature of the rule to be applied. Some rules of thumb are formalised and may appear in manuals outlining procedures to be followed in undertaking certain activities while others remain within an informal oral tradition.

These formal and informal approaches to rules of thumb can be found in many areas of environmental management. For example, in the field of fisheries management formal rules of thumb involving specification of fish size, season, location and equipment are often used to attain a desired environmental outcome. On the other hand a rich oral tradition of rules of thumb designed to assist in the achievement of multiple objectives, including sustainability, exists in farming and grazing communities. In relation to the ongoing monitoring of the condition of wetlands a number of methodologies for low cost rapid appraisals have been developed. (See, for example, Spencer 1998.) However, when it comes to formal environmental studies of development proposals there are few examples of the use of resource-saving rule of thumb or short cut methods.

The review of the study of Moreton Region *M.quinquenervia* wetlands presented below shows that a rule of thumb to predict the likely presence of ecological wetland functions can be obtained by using characteristics of wetland vegetation as an indicator of these functions.

MELALEUCA QUINQUENERVIA FORESTED WETLANDS

M.quinquenervia occurs in its natural habitat primarily along the east coast of Australia, between 25-35 degrees south, but also north to New Guinea and New Caledonia (Blake 1968). In the Moreton Region of South-East Queensland, the species forms forests in low lying areas which are seasonally flooded. The canopy of these wetlands consists frequently of pure *M.quinquenervia*, but other species such as *Eucalyptus spp.* L'Herit. ("eucalypts") also occur in some situations. Forested wetlands dominated by *M.quinquenervia* are recognised in Queensland to be among the most threatened of the state's natural ecosystems (Young and Cotterell 1993). Rapid urban and agricultural expansion in this region has decimated these wetlands over the last fifteen years (Davie 1991). At the same time, the literature on the ecology and diversity of *M.quinquenervia* forests is scarce. Most of it is comes from Florida, United States, where *M.quinquenervia* has become a serious weed (Morton 1965; Austin 1976). Consequently, most of these studies focus on the population dynamics of the species.

Most of the literature on *M.quinquenervia* in its native range is represented by large scale vegetation surveys (Dowling and McDonald 1976; Elsol and Dowling 1978; Elsol and Sattler 1979), although Greenway (1994) also reports on the litter accession and accumulation in one *M.quinquenervia* wetland within the Moreton Region, concluding that they are important nutrient sinks. The vegetation surveys indicate some variation in the species composition and structure of the canopy vegetation of *M.quinquenervia* dominated wetlands, but the extraordinary diversity in the ground cover vegetation and stem dimensions of these forests has so far gone unreported. The diversity in these vegetation parts (hereafter called "segments") suggests differences in environmental conditions, and hence differences in ecological functions performed by these wetlands. An overview is presented below of a study by Zoete (1997) which examined this relationship between vegetation characteristics and ecological functions performed. The ecological aspects of this study will also be reported on in forthcoming publications. (Zoete, forthcoming) The objective was to derive a set of indicators which can be used to predict the likely performance of ecological functions by wetlands.

WETLAND FUNCTIONS

Thirty *M.quinquenervia* dominated wetland sites were selected such that the sample included all major vegetation characteristics encountered during an earlier reconnaissance. Wetland functions assessed for each site included groundwater recharge and discharge, floodflow alteration, sediment stabilisation, sediment and toxicant retention, nutrient removal and transformation, production export, wildlife breeding, wildlife migration, wildlife wintering, and provision of aquatic diversity. Definitions of these functions are given in Table 1. Functions were evaluated according to the Wetland Evaluation Technique (WET) (Adamus et al. 1987). Although this technique was designed for the contiguous states of the United States, the similarity of the environmental conditions of the Moreton Region compared to those of the southern United States (where, as mentioned above, *M.quinquenervia* also happens to be an important exotic weed) suggests that WET would also be applicable to the Moreton Region.

Ground water recharge: "For purposes of this method, recharge assessment areas or wetlands are considered to be those where: (a) recharge to underlying materials or ground water (deep or shallow) exceeds ground water discharge to the wet depression on a net annual basis, and / or (b) the rate of recharge typically exceeds the rate of recharge from terrestrial environments".
Ground water discharge: "For purposes of this method, ground water discharge areas are those where the rate of discharge from ground water (deep or shallow) into the wetland exceeds the rate of recharge to underlying ground water from the wetland on a net annual basis.
Floodflow alteration: "For the purposes of WET, floodflow alteration occurs in those areas where surface water is stored or its velocity is attenuated to a greater degree than typically occurs in terrestrial environments. No judgement is made as to the value of such flow alteration, in fact, there may be situations in which reduction of flow velocity causes increased flooding due to flow synchronisation".
Sediment stabilisation: "For purposes of this method, HIGH sediment stabilisation areas are those which are more effective for binding soil and dissipating erosive forces than are typical upland environments".
Sediment / toxicant retention: "For purposes of this method, HIGH sediment / toxicant retention areas are those which physically (or chemically in the case of toxicants) trap and retain on a net annual basis the inorganic sediments and / or chemical substances generally toxic to aquatic life".
Nutrient removal/transformation: "For purposes of this method, HIGH nutrient removal / transformation areas are those which retain or transform (remove) nitrogen into its gaseous form, on either a net annual basis or during the growing season, and which are generally more effective at doing so than typical upland environments".
Production export: "For purposes of this method, HIGH production export is the flushing of relatively large amounts of organic plant material (specifically, net annual primary production) from the assessment area into downslope waters. No judgement is made as to the value of such export; indeed, there may be instances where such export represents a nutrient loss to the exporting system or where such exported material causes water quality problems downslope".
Wildlife diversity / abundance for breeding: "For purposes of this method, HIGH rating for a wetland means that during the breeding season the wetland normally supports a notably great on - site diversity and / or abundance of wetland - dependent birds. This definition does not take into account the contribution of the assessment area to off - site (regional) faunal richness or the uniqueness / rarity of the species".
Wildlife diversity / abundance for migration and wintering: "For purposes of this method, a HIGH rating for a wetland means that during migration or winter, the wetland normally supports a notably great on - site diversity and / or abundance of wetland - dependent birds".
Aquatic diversity / abundance: "For purposes of this method, a HIGH rating for an area means that, at least seasonally, the assessment area supports a notably great on - site diversity of fish or invertebrates (i.e. most trophic groups of secondary consumers with complex food webs). Other aquatic animals (e.g. waterfowl) are covered under other functions".

Table 1: Definitions of Functions Evaluated by WET (Adamus *et al.* 1987).

Following WET, the functions were evaluated in terms of "effectiveness" of wetlands and "opportunity" within wetlands. Whereas an effectiveness evaluation assesses the capability of a wetland to perform a function due to its physical, chemical, and biological attributes, opportunity evaluation assesses the chance or opportunity that a wetland has to perform a function. Only the floodflow alteration, sediment and toxicant retention and nutrient removal and transformation functions are evaluated in terms of "opportunity" by WET. The application of WET is manifested in a low, moderate, or high probability rating that wetlands are "effective" in performing a function and similar ratings for the "opportunity" they have to perform a function. For details of the methodology the reader is referred to Adamus *et al.* (1987). As an innovation of the WET method, in the present study

the probability that a function was actually performed by a wetland was calculated by retaining the lowest probability rating of either the "effectiveness" or the "opportunity" evaluations for each function. If, for example, the effectiveness of a wetland in altering floodflow was likely to be high (because it was located in a wide basin) but it had a low opportunity of actually doing so (because a formalised concrete channel bypassed the wetland), then the actual probability that the function is being performed is low.

Functions with the greatest number of high probability ratings were floodflow alteration, sediment and toxicant retention, nutrient removal and transformation, and wildlife wintering, indicating that most of the sites did perform these functions. On the other hand, the provision of aquatic diversity and wildlife migration functions are unlikely to be occurring in any sites, according to the WET evaluation.

Although there are good reasons why WET is also likely to be applicable in the Moreton Region, an expert opinion survey was held to check the results from WET with the opinions of local experts. For this purpose the Delphi iterative questionnaire method was chosen as an expert opinion assessment technique. For an overview of the methods of a Delphi survey see Linstone and Turoff (1975).

An expert panel for this research was created by sourcing appropriate expertise from a number of agencies, such as universities, government departments, and local authorities. A total of 15 experts participated. Round one questionnaires requested the panel members to rate each of the thirty study sites for effectiveness and opportunity in terms of all functions evaluated by WET. Information required to rate the sites was provided in an Appendix to the questionnaire. The results of the first round were provided with the questionnaires for the second round. The purpose was to provide those participants not entirely certain with their answers to the first round with the opportunity to review their answers with reference to the results of their peers. Since the results from the second round did not vary significantly from those obtained in the first round, the process was terminated after the second round.

The WET ratings were largely confirmed by the Delphi survey of the team of local wetland experts, except for the wildlife functions and the sediment stabilisation function. These functions were, therefore, discarded from further analysis.

VEGETATION AND ENVIRONMENTAL VARIABLES

The vegetation of each site was divided into four structural "segments" in order to determine the differential relationships between each segment and the presence or absence of wetland functions. The segments included the canopy layer, the shrub layer, the ground layer, and stems. The three layers were characterised by the foliage projective cover (FPC) of each species present, while the stem segment was characterised by the number and the diameters (at breast height) of stems of each species. Basal areas (horizontal area occupied by stems at breast height) were calculated from the diameters. The nomenclature followed was that of Stanley and Ross (1983, 1986, 1989). Pattern analysis (principally ordination and classification) was employed to determine the main patterns of variation within the vegetation, resulting in a number of vegetation groups with internally shared vegetation characteristics. Pattern analysis was also used to relate the vegetation variation to environmental variables. Environmental variables assessed included landform patterns and elements, texture, height of the watertable, soil conductivity (indicating salinity) and pH, carbon content of the soil, and the likely incidence of fire. Data were analysed using the PATN (Belbin 1993) computer program package.

Least variation between sites was encountered within the canopy layer. Most of this variation consisted of different proportions of *M. quinquenervia* FPC, among the sites dominated by that species. Of the three layers, the canopy was least related to environmental variables, though there is a clear affinity between *Casuarina glauca* Sieber ex Sprengel ("swamp she-oak") and saline soils, while sites with rainforest species appeared to have optimal moisture regimes and a low incidence of fire. Sites containing *Eucalyptus spp.* tended to have drier conditions which were more prone to fire.

Similar but stronger relationships between the vegetation and environmental variables were also found in the assessment of stems. It was found, in addition, that short and thick stemmed forest with low basal areas tended to occur on drier sites, while tall and thick stemmed forest with high basal areas occurred in slightly moister sites, often in association with rainforest species. Thin stemmed forest was prevalent in the more flooded sites and often consisted of pure *M.quinquenervia*. Severely stunted *M.quinquenervia* occurred on very sandy soils with a very low soil moisture retaining capacity.

On all sites the shrub layer was generally very sparse or absent, probably as a result of periodic waterlogging, fire, and periodic drought conditions. Where present, *C.glauca* and *Baccharis halimifolia* L. ("groundsel bush") dominated shrublayers occurred in saline environments, rainforest elements occurred in relatively wet conditions with dense overstoreys and a low fire incidence, while shrublayers dominated by species such as *M.quinquenervia*, *Lophostemon suaveolens* (Solander ex Gaertn.) Peter G.Wilson & Waterhouse ("swamp mahogany"), *Eucalyptus robusta* Smith ("swamp messmate"), or *Acacia aulacocarpa* Cunn. ex Bent. ("hickory wattle") occurred in the drier, non-saline sites, with only a moderate incidence of fire.

The highest species turnover occurred in the ground layer, resulting in several vegetation groups dominated by different species and assemblages. The relationships with environmental variables were therefore very clear. In low moisture environments, particularly in sandy environments, the vegetation is primarily determined by the ability of vegetation to cope with the dry conditions during the dry season and fires, which results in the predominance of grass species in the ground layer. In moderate to wet environments, the vegetation is determined by the ability of vegetation to cope with flooding during the wet season, by shading or other suppression from the overstorey, and by soil salinity levels. Freshwater sites tended to be dominated by ferns. An excess of waterlogging or shading in combination with high salinity levels resulted in a sparse ground layer. In the sites investigated, soil salinity levels alone were not likely to result in a sparse ground layer.

SYNTHESIS

The results of non-parametric analysis of variance on the WET probability ratings received by each site in each vegetation group suggest that the characteristics of vegetation groups based on phytosociological relationships can be used to indicate the status of a number of wetland functions which typify a site.

The ground layer and the stems were the most diagnostic vegetation segments, suggesting that these segments are most useful for the provision of functional indicators. Vegetation classification groups from the wettest sites generally had the highest mean ratings for most functions. In the ground layer, such groups were characterised by a dense layer of ferns or by an absence of vegetation. In the stem segment, they are characterised by large basal areas, whether in the form of few tall and thick trees or numerous thin stems. The presence of rainforest species in the canopy and the absence of *Eucalyptus spp* is another characteristic of relatively wet conditions. Vegetation groups from drier sites had higher ratings for groundwater recharge and floodflow alteration. Such sites are characterised by a predominance of grasses in the ground layer, and by the presence of *Eucalyptus spp*. Sandy sites, characterised by heath species in the ground layer and by low basal areas, are likely to perform the fewest functions of all sites, while rainforest sites are most likely to perform most. Sites with saline conditions, characterised by the presence of *C.glauca*, are likely to perform the sediment and toxicant retention and the nutrient removal and transformation functions.

The findings of the Moreton Region study show that within this region the vegetation of individual wetlands can be used as an indicator of the extent to which they perform various functions. It is important to understand that it is the likely existence of these functions which can be determined not the value of these functions. The likelihood that certain functions are performed is a necessary but not sufficient condition for the valuation of the benefits that performance of these functions confers. In order to determine the benefits conferred by these functions it is also necessary to determine the economic value of these functions. Nonetheless, if vegetation characteristics can be used to determine the likelihood that certain ecological functions are occurring, then significant resource savings in

the determination of the benefits which these functions confer may be possible. The potential resource savings which would flow from practical use of the link between vegetation and performance of function would be similar in nature to those which might result from the use of any rule of thumb.

MAKING DECISIONS ABOUT WETLANDS

From an economic perspective, a decision as to whether a particular wetland should remain in its present form or should be subject to alternative use will depend, all other factors remaining constant, on the costs and benefits of changing to that alternative use. The benefits will include any direct financial returns plus imputed returns associated with the alternative use. They will also include the value of any costs which are generated by the wetland in its current state but which would no longer be experienced if a change in use were to occur (for example, the costs of mosquito borne diseases or of mosquito control). The costs associated with a change in use will include those generated by the alternative use (including any incurred in the process of making the change) plus the cost involved in the loss of functions performed by the wetland in its current state. Such functions will include those discussed in the section above as well as those associated with visual aesthetics, amenity, existence value and so on.

While a rule of thumb involving the relationship between vegetation and wetland functions may be used to inform the process of undertaking a full cost-benefit analysis, it may also be used as a screening-level procedure to determine whether and to what extent it is necessary to undertake further investigation of the benefits which would be foregone as a result of a proposal to change the use of a wetland. For example, a site with a heathy ground layer and a canopy containing *Eucalyptus spp* (ie a relatively dry site on sandplain) is one in which few if any ecological wetland functions are likely to be performed. Conversion of the site would thus result in little or no loss of benefits derived from these ecological functions. If benefits from other functions performed by the site are also low then a development proposal in which the benefits accruing from the new use to which the site is put are in excess of the costs generated by that use then development may proceed without further environmental assessment costs being incurred. At

the other extreme, a wetland site with little ground cover or ground cover dominated by ferns, and with a high basal area of *M. quinquenervia* or *M. quinquenervia* and rainforest species (ie a relatively wet site on clay substrates) is one in which many wetland ecological functions are likely to be being performed. Conversion of the site would thus result in loss of these functions which, if significant value attaches to them, would mean that a significant loss of benefits would occur. If the development proposed for the site produces benefits which are not greatly in excess of its costs then a decision not to allow the alternative use may be able to be made without commitment of additional resources to a more comprehensive analysis of environmental impacts.

This study of Moreton Region wetlands shows that a process involving simple inspection of the vegetation of a wetland site may allow a low cost rule of thumb to be applied to determine the likelihood that wetland functions are being performed thus reducing the overall cost of assessment of the costs and benefits associated with conversion of the site to an alternative use.

CONCLUSION

The optimal allocation of resources to the process of determining the costs and benefits of a potential change to the use of an environmental asset involves the same economic principles as does the cost-benefit analysis itself. If significant resource savings can be made by the application of the principles of cost-benefit analysis to the allocation of resources devoted to carrying out the study of the potential change then these resources are freed for other uses which may include increased environmental amenity. Although environmentalists may be concerned that any such resource savings may not be allocated to environmental improvement – and may even be devoted to environmentally damaging uses – it is clear that environmental agencies (and others) with limited budgets could more efficiently use their funds if they were allocated to decision making activities in such a way as to reflect cost-benefit principles. If, as the result of the use of rules of thumb, such a reallocation involved a smaller allocation of resources to some decision making this should be seen for what it is – a more efficient use of scarce resources – rather than an exercise in cutting corners or engaging in sloppy work.

In the context of developing countries where income constraints may dictate that full cost benefit analyses are preserved for only a small number of important decisions about the use of environmental assets, development of, and greater use of, rules of thumb may allow for better decisions to be made about the use of environmental assets which do not qualify for a full cost benefit analysis.

There is an important proviso to the above observations; namely, that the application of rules of thumb to the allocation of resources to individual development proposals may ignore cumulative impacts in which the whole represents more than the sum of its parts. This problem is not confined to decisions involving rules of thumb and may indeed occur, although it is less likely, in the case of full cost-benefit analyses. Perhaps the cumulative impacts of a series of individual developments could, in some cases, also be assessed using appropriate rules of thumb?

This paper has used the study of the wetlands of the Moreton Region to show that the economic efficiency of the process of making decisions about the future use of these wetlands can potentially be raised by judicious use of rules of thumb which relate vegetation to wetland function. Although the Moreton Region study was concerned only with a limited range of ecological functions there is no reason why a number of rules of thumb could not be developed to assess the presence and importance of other functions. Such rules of thumb may also be adapted for use in the determination of whether it is appropriate to undertake restoration of wetlands which have been converted to alternative uses in the past. (See Parks 1995) Furthermore, this study raises the question of whether there is the potential for the application of rules of thumb to the determination of costs and benefits associated with development proposals affecting a wide range of environmental assets.

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<p>Ground water recharge: "For purposes of this method, recharge assessment areas or wetlands are considered to be those where: (a) recharge to underlying materials or ground water (deep or shallow) exceeds ground water discharge to the wet depression on a net annual basis, and / or (b) the rate of recharge typically exceeds the rate of recharge from terrestrial environments".</p>
<p>Ground water discharge: "For purposes of this method, ground water discharge areas are those where the rate of discharge from ground water (deep or shallow) into the wetland exceeds the rate of recharge to underlying ground water from the wetland on a net annual basis.</p>
<p>Floodflow alteration: "For the purposes of WET, floodflow alteration occurs in those areas where surface water is stored or its velocity is attenuated to a greater degree than typically occurs in terrestrial environments. No judgement is made as to the value of such flow alteration, in fact, there may be situations in which reduction of flow velocity causes increased flooding due to flow synchronisation".</p>
<p>Sediment stabilisation: "For purposes of this method, HIGH sediment stabilisation areas are those which are more effective for binding soil and dissipating erosive forces than are typical upland environments".</p>
<p>Sediment / toxicant retention: "For purposes of this method, HIGH sediment / toxicant retention areas are those which physically (or chemically in the case of toxicants) trap and retain on a net annual basis the inorganic sediments and / or chemical substances generally toxic to aquatic life".</p>
<p>Nutrient removal/transformation: "For purposes of this method, HIGH nutrient removal / transformation areas are those which retain or transform (remove) nitrogen into its gaseous form, on either a net annual basis or during the growing season, and which are generally more effective at doing so than typical upland environments".</p>
<p>Production export: "For purposes of this method, HIGH production export is the flushing of relatively large amounts of organic plant material (specifically, net annual primary production) from the assessment area into downslope waters. No judgement is made as to the value of such export; indeed, there may be instances where such export represents a nutrient loss to the exporting system or where such exported material causes water quality problems downslope".</p>
<p>Wildlife diversity / abundance for breeding: "For purposes of this method, HIGH rating for a wetland means that during the breeding season the wetland normally supports a notably great on - site diversity and / or abundance of wetland - dependent birds. This definition does not take into account the contribution of the assessment area to off - site (regional) faunal richness or the uniqueness / rarity of the species".</p>
<p>Wildlife diversity / abundance for migration and wintering: "For purposes of this method, a HIGH rating for a wetland means that during migration or winter, the wetland normally supports a notably great on - site diversity and / or abundance of wetland - dependent birds".</p>
<p>Aquatic diversity / abundance: "For purposes of this method, a HIGH rating for an area means that, at least seasonally, the assessment area supports a notably great on - site diversity of fish or invertebrates (i.e. most trophic groups of secondary consumers with complex food webs). Other aquatic animals (e.g. waterfowl) are covered under other functions".</p>

Table 1: Definitions of Functions Evaluated by WET (Adamus *et al.* 1987).