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ECONOMICS, ECOLOGY AND THE ENVIRONMENT

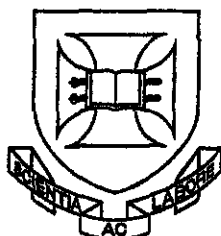
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**Integrated Regional Environmental Studies:
The Role of Environmental Economics**

by

Clem Tisdell

December 1996



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**Integrated Regional Environmental Studies:
The Role of Environmental
Economics***

Clem Tisdell¹

December 1996

* A paper prepared for inclusion in a book in honour of Percy Harris entitled 'Integrated Regional Environmental Studies: The Role of Environmental Economics

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INTEGRATED REGIONAL ENVIRONMENTAL STUDIES: THE ROLE OF ENVIRONMENTAL ECONOMICS

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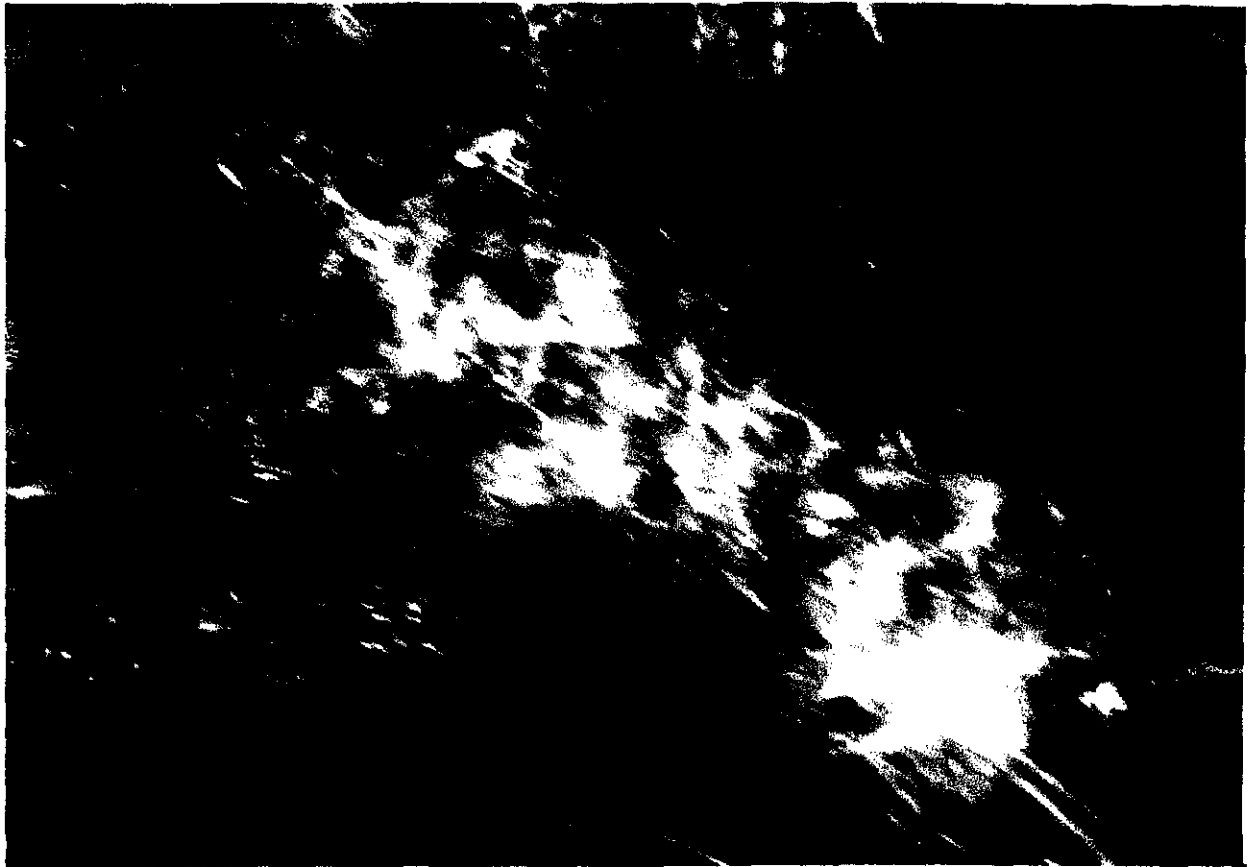
1. INTRODUCTION

The purpose of this contribution¹ is to show how environmental economics can be applied to help solve environmental problems in a regional context. This seems appropriate because Percy Harris has made many outstanding contributions to regional economics. In particular, it illustrates how environmental economics can contribute to an integrated adaptive environmental assessment and management (AEAM) program designed to bring about an environmental improvement taking *eutrophication* in the Tuggerah Lakes north of Sydney in New South Wales as an example.

*Eutrophication*² of water bodies has become an increasingly common phenomenon as human populations have increased and as land-uses have changed (Castensson, 1986). It involves increased concentration of nutrients, particularly nitrates and phosphorous, in water bodies and this stimulates aquatic plant and weed growth. Consequently, the composition of fish populations in the aquatic areas concerned may change so that fish stocks are less valuable (the proportion of bottom feeders and trash fish may increase), offensive odours may be generated by decaying aquatic vegetation to the annoyance of nearby residents and to recreationists, the use of an affected area for recreational purposes, such as swimming or fishing or boating, may be impeded or prevented, and when the water is freshwater and used for human or animal consumption, health risks can emerge as in the case of blue-green algae. While growth of *macrophytes* (large plants, see photograph 1,) rather than algae appears to be the main problem in the Tuggerah Lakes, which contain brackish water, as Herath (1996, pp.189-190) points out:

"Algal blooms have become an important water quality problem in Australia. They have occurred more frequently in recent years causing concern among water users, water managers and the public generally. There are considerable costs to the

community associated with algal blooms. These costs occur in the form of lost recreation and drinking water supplies, loss of income from commercial activities such as provision of accommodation, transport, food in caravan and tourist parks and serious health effects. Direct costs during the 1991 bloom along the Darling River were more than \$1.3 million."



Photograph 1: An example of dense aquatic weed growth in the Tuggerah Lakes.

Problems of algal bloom are not however confined to Australia's inland waters. Coastal areas have also been affected, such as reservoirs for urban water supplies e.g. in 1995 supplies of water from the Pine Rivers Dam in the Brisbane water supply system were suspended due to the presence of blue-green algae, and this has also occurred in Sydney area as well.

Tuggerah Lakes are brackish lakes located within the boundaries of Wyong Shire Council as is their catchment area. This shire is experiencing very rapid population growth which is expected to continue as Wyong is increasingly used as a dormitory area for Sydney and for retirement purposes. Furthermore, with changed technology, more people can work from this area using new electronic equipment. Serious weed problems exist in the lake system but could worsen as population densities in this shire increase. With this in mind, the Wyong Shire Council requested Macquarie Research Ltd. to investigate the situation and report to it on possible solutions. The research team decided to use an integrated adaptive environmental assessment and management approach (Holling, 1978). This is an interactive approach in which the main researchers interact with members of the community concerned to learn about the nature of the problem; the environmental interrelationships as community members perceive these and also the aspirations of local people. Parties to this process can be expected to adapt their perceptions and models as they interact. The approach is a side-by-side approach involving active community participation (Tisdell, 1995).

Adaptive assessment and management contrasts with the traditional or orthodox approaches to problem solving commonly used in economics, reviewed by Nijkamp (1987), such as deductive or axiomatic methods and the application of econometric models based on little interaction with the community. AEEM has much in common with other methods such as Rapid Rural Appraisal and Participatory Rural Appraisal (Chambers, 1980, 1982; McCracken et al., 1988; Pido et al; 1996) but is more sustained than the former with structured results often forming part of the outcome. It was the method preferred by Macquarie Research Ltd. in giving advice to the Wyong Shire Council. It recognizes the bounded rationality of researchers (Tisdell, 1996) and the importance of community involvement in problem-solving. The latter can be important in terms of information provision and ensuring the social acceptability of 'solutions' once determined (Berkes, 1989).

Let us consider some additional background on the environmental economics and data problems at the regional level, then consider how environmental economics can be integrated into regional environmental studies and contribute to the formulation of strategies and policies for regional environmental management, before discussing the Tuggerah Lakes and its

catchment as a regional case study and raising some general policy issues about eutrophication and nutrient enrichment of water bodies.

2. ADDITIONAL BACKGROUND

Nature of Environmental Economics

Environmental economics is a relatively new specialisation in economics which has developed since the early 1970s but which has its roots in the earlier subjects of welfare economics and development economics. It is concerned with the relationships between economic systems and the natural environment, economic methods of managing this relationship as well as the economics of altering natural and degraded environments taking into account the wants of people. So environmental economics is concerned about what people want from their environment(s) as well as how they can satisfy those wants economically or efficiently.

While the focus of economics may seem very man-centred (anthropogenic), it is less so than may appear at first sight. For example, if humans value the existence of other living things or the preservation of natural environments for their own sake, this can be factored into the economic optimisation problem.

Environmental Economics and Multidisciplinary Co-operation

In order to be valuable as a management tool in practical situations, environmental economics must be combined with data and inputs from other disciplines such as engineering, biology, ecology and so on. For example, although an economist may be able to predict how industries are likely to develop in a region, he/she may not be able to identify the environmental wastes likely to be generated and their ecological impact on aquatic environments such as Tuggerah Lakes. This is where engineering, natural sciences and local knowledge assist.

Data Problems

Economists and natural scientists often have to cope with limited knowledge when undertaking a specific environmental study such as the one conducted in the Wyong Shire of weed growth in the Tuggerah Lakes. One way to help fill the knowledge-gap is to engage people in the region in an interactive process of knowledge generation such as that involved in the Adaptive

Environmental Assessment and Management (AEAM) Program adopted by the Wyong Shire Council and applied by Macquarie Research Ltd.. The strength of this method is that it takes advantage of local experience and expertise, makes for readier identification of locally perceived issues and problems and because it is participatory, can be expected to result in politically more acceptable solutions than a top-down approach to environmental management. This is not to say that interactive processes for generating knowledge are completely unstructured; most are semi-structured but flexible. Environmental economics can be of assistance in design of the initial structure of an enquiry and the subsequent modification of this structure so as to increase the relevance of the information obtained to the socio-economic component of a regional environmental study. It can also ensure that results are useful for environmental management or policy purposes.

3. ENVIRONMENTAL ECONOMICS IN INTEGRATED REGIONAL ENVIRONMENTAL STUDIES

Holism and Links Between Socio-economic Systems and the Environment

In the past many social scientists, especially economists, have studied socio-economic systems as closed systems independent of the natural environment. This meant, for example, that circular flow diagrams representing economic interdependence between the sectors and actors in modern-day economics did not contain an environmental component. This created the impression that economic activity could sustain itself independently of natural environments. Fortunately, the spaceship analogy of the economy, as first popularised by Kenneth Boulding (1966) is now more widely accepted and economic circular flow diagrams are sprouting an extra loop which firmly links socio-economic systems with natural environments, making it clear that the performance and sustainability of economic systems as well as human welfare or standards of living cannot be divorced from the state of natural environments. This means that human welfare, the performance of economic systems the occurrence of human activities and the state of the environment must be considered as a whole (*Cf.* Braat and van Lierop, 1987). This can be illustrated by Figure 1.

In Figure 1, the socio-economic system is represented in the top oval. It involves human activities, including economic activities of individuals, households, business firms and institutions. The bottom oval represents the natural environmental system(s). Emissions from the socio-economic system (wastes, pollutants, by-products) are received by the natural resource system which provides a 'sink' for these. Depending however on the quantity and

nature of these emissions, the natural resource system may be impaired so reducing its value for sustaining economic activity and satisfying human wants.

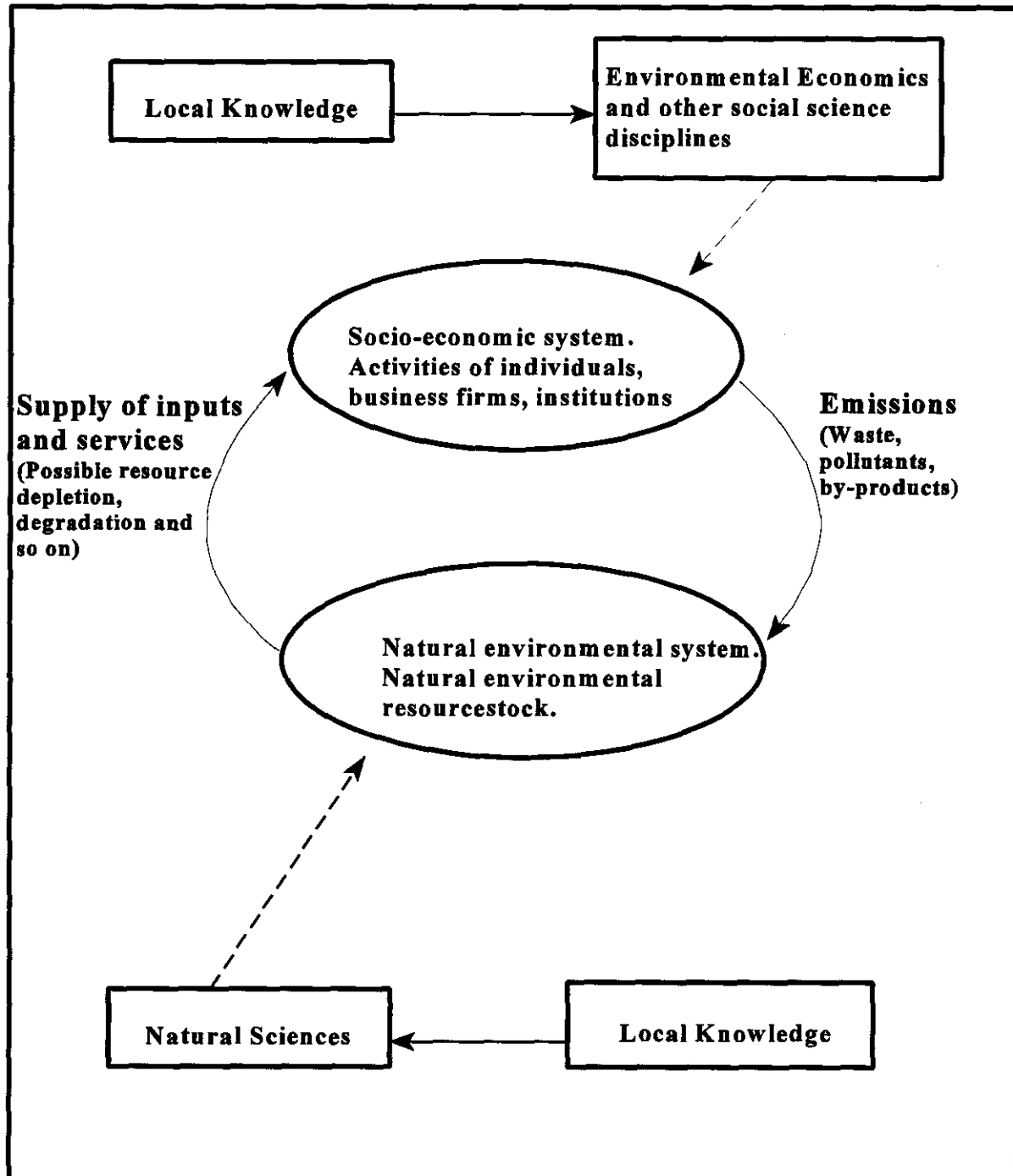


Figure 1 The natural environmental system and the socio-economic system are interlinked

In addition, the activities of humans often make direct use of natural resources. Natural resources may be used to provide recreational services e.g. amateur fishing opportunities in Tuggerah Lakes, boating and swimming opportunities and so forth or be used as inputs into economic production e.g. fish for the professional fishery, water for power station use in the case of Tuggerah Lakes. Such activities can sometimes deplete or degrade the natural resource-base making it more difficult to sustain future human welfare. Given these interactions between the socio-economic system and the environmental system, environmental studies and the study of sustainable economic development require the simultaneous study of both systems and their consideration as a whole. In this regard, it is likely that environmental economics and other social science disciplines would be able to make the greatest contribution to study of the upper sphere, whereas natural sciences might be expected to make the major contribution in relation to the lower sphere, with all naturally having to be taken into account in devising environmental management strategies.

Regional Modification

Figure 1 may be modified to depict the situation for a region. A region is usually only a partially self-contained entity from an economic and environmental point of view. It often involves economic imports, inputs or contributions from outside the region (this is true of Wyong Shire) as well as in many cases environmental imports (wastes or emissions) from outside the region. Some of the possible environmental and economic interdependencies between regions are illustrated in Figure 2. The strength of these interconnections will vary with the case in hand. In the Tuggerah Lakes case, there are strong socio-economic connections with other regions e.g. Sydney, but the environmental impact of other regional environments on the Lakes would appear to be small and the direct environmental spillover from the condition of the Lakes to other regions may also be small.

4. THE CONTRIBUTION OF ECONOMICS TO THE FORMULATION OF REGIONAL ENVIRONMENTAL STRATEGIES AND POLICIES

There are several ways in which economics can contribute to the formulation of regional environmental strategies. Together with other disciplines, it can establish trends in economic, demographic and other socio-economic variables for a region. This is a necessary backdrop

for predicting likely demands to be made on the local environment. Secondly, it may assist in establishing community objectives and the valuation placed on environmental conservation. Thirdly, it can recommend economic policies and instruments to help manage changes to achieve the objectives desired by the community. However cut-and-dried responses to these matters are not always possible and the needed depth of analysis can vary with the particular task in hand. Initially, for example only a broad overview of the community's environmental objectives or of environmental issues of greatest concern to the community may be needed. Figure 3 indicates some ways in which economics may make a useful contribution to decision-making about the management of regional environments.

5. THE TUGGERAH LAKES INTERACTIVE STUDY

Accelerated eutrophication of the Tuggerah Lakes due to human activities has become severe. Effects include dense aquatic weed growth, algal blooms, sedimentation reducing the depth of water in several places and decaying plant matter, including ooze and slime along foreshores of the Lakes. Impacts include the following

- (1) The Lakes have become unsuitable for swimming in many parts (see photograph 2).
- (2) Offensive smells make some areas along the foreshores of these lakes less attractive for picnicking and reduce the amenity-value of nearby residences.
- (3) Boat traffic is impeded or prevented by sedimentation and weed growth in some parts of these lakes (see photograph 3).
- (4) Some wharves have become unuseable (see photograph 4) due to silting and/or have had to be extended.
- (5) Stocks of fish for commercial and recreational fishing appear to have fallen and less valuable fish have increased as a relative proportion of fish stocks. Furthermore, line fishing has become impossible in many areas due to the growth of aquatic weeds. In addition, use of nets for commercial fishing is not practical in some weedy areas.

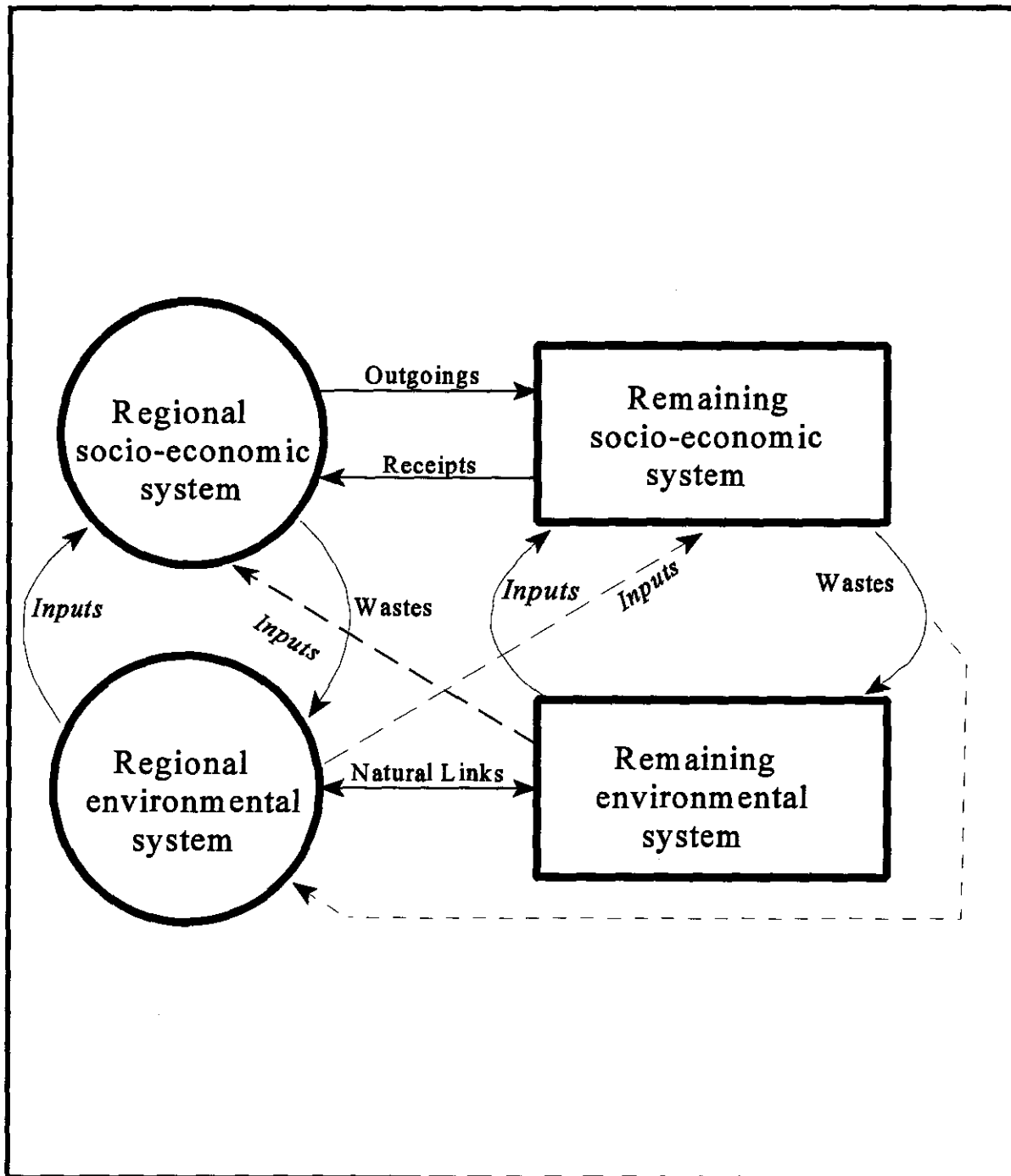


Figure 2 Although there may be some separation between socio-economic systems and environmental systems in different regions, a variety or myriad of links are possible as illustrated above. The strength of interconnections will vary depending upon the case being investigated.

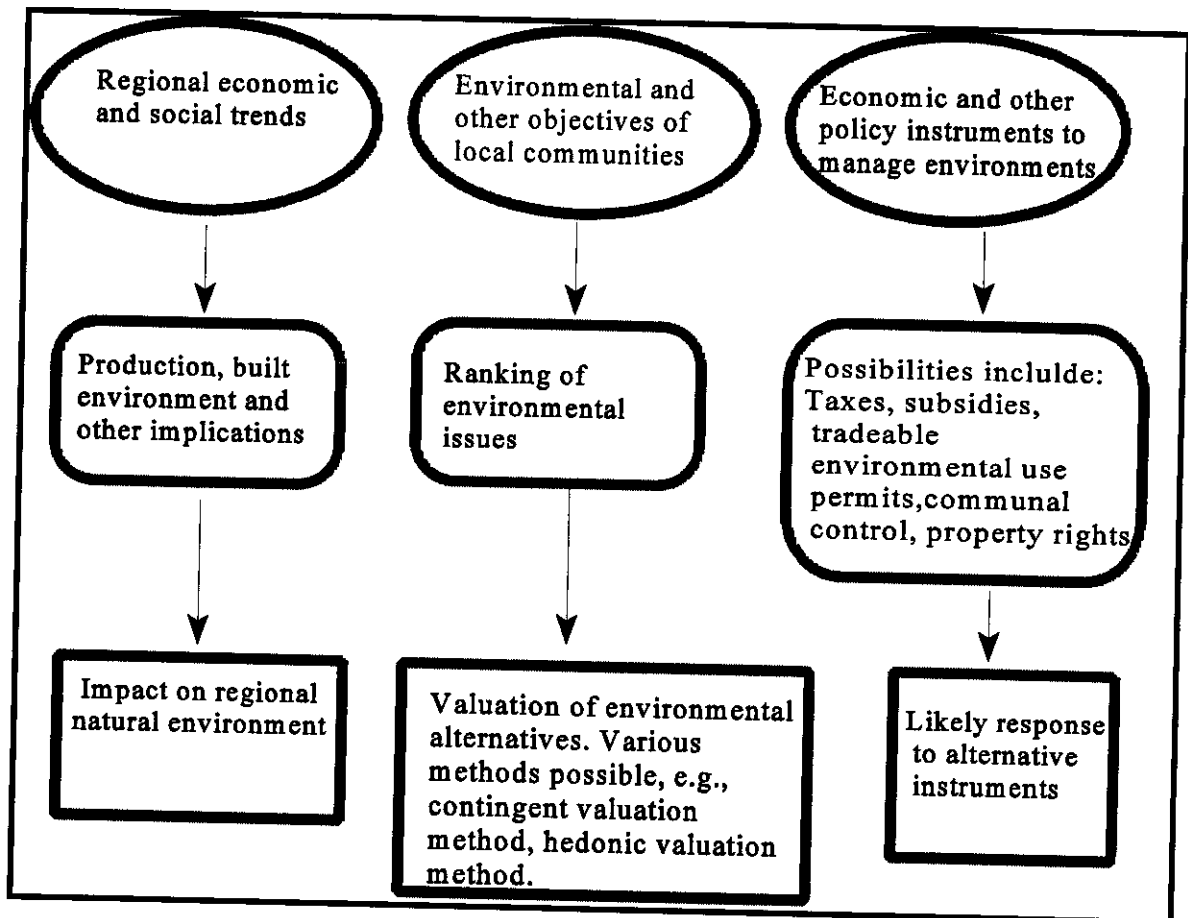


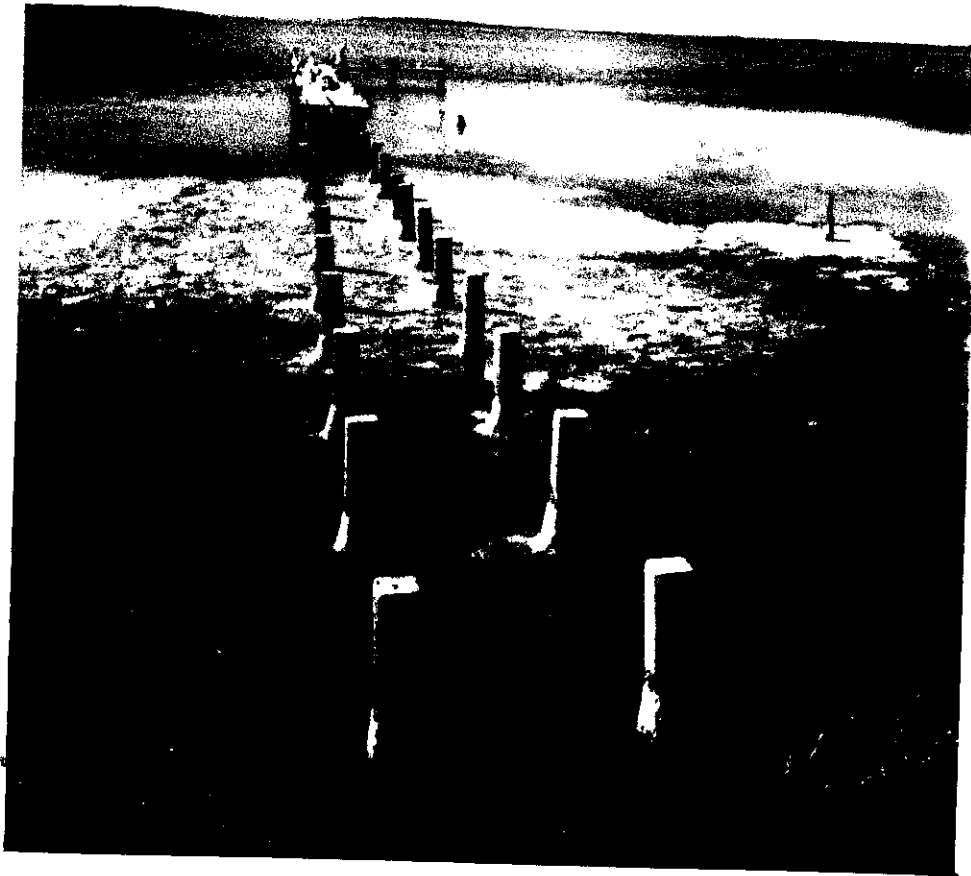
Figure 3 Some cases of regional environmental management where environmental economics can assist.



Photograph 2. Beach area on Tuggerah Lakes rendered unsuitable for swimming and fishing by eutrophication.



Photograph 3. Weed growth impedes boat traffic. It is now difficult to reach some parts of Tuggerah Lakes even in a flat punt.



Photograph 4. Wharf abandoned on Tuggerah Lakes due to eutrophication.

In order to ameliorate these problems, Wyong Shire Council has adopted a number of strategies: weeds and organic matter have been mechanically removed by the Council (see photograph 5) at considerable cost from the lakes and foreshores at points near important recreational areas e.g. in an inlet near a caravan park. Public wharves have been extended and channels for boat traffic dredged. Settling ponds have been constructed at the end of a few small watercourses (with irregular flows) prior to their entry to the lakes and suitable aquatic plants have been established in the settling ponds or creek outlets (see photograph 6) to help reduce the nutrients carried into the lakes and reduce turbulence. Except for the last strategy, which is most likely not on an adequate scale to have a major impact on nutrients entering the lakes, most of the strategies are reactive. Furthermore, the mechanical removal of aquatic weeds does not have a lasting effect. Aquatic weeds soon re-establish themselves.

Given the importance of the Lakes to local residents, to tourists and recreationists and for commercial fishing, Wyong Shire Council decided to search for longer term solutions and in 1995 requested Macquarie Research Ltd. to conduct an environmental assessment and make recommendations for improved environmental management of the lakes. An adaptive assessment approach was adopted.

Initially the process of assessment involved a number of modules; some concentrating on the physical issues, some on ecological aspects and one dealing with the socio-economic dimensions of eutrophication of the Lakes. In this stage there were interactive meetings between researchers and selected groups having local knowledge; reports on each of the modules followed. Subsequently, a meeting was convened between Council representatives, the researchers and "international experts" to formulate integrated management strategies, and a public conference was held to discuss the main findings as set out in these reports. Afterwards the research consultants and Council officers were expected to draw up feasible environmental management strategies.

The next stage envisaged was to discuss preferred feasible strategies with local communities to obtain further feedback, modify these as needed and hopefully obtain community agreement on (or acceptance of) a suitable approach.



Photograph 5. Ooze and organic matter in Tuggerah Lakes mechanically removed and placed in the black heap on the side of Tuggerah Lakes. It is unsightly and smelly and not effective in preventing continuing weed growth.

Photograph 6. Wyong Shire Council is in the process of revegetating the entrance of this watercourse to Tuggerah Lakes. Typha species have been planted in the watercourse itself and small barriers have been constructed along its outlet.



Photograph 7. The entrance of Tuggerah Lakes to the Pacific Ocean near Toukley, N.S.W. This is a shallow and relatively narrow entrance. One option is to extend it to increase the flushing of the lakes.

In connection with the socio-economic module, a workshop using the adaptive environmental assessment and management process identified important socio-economic issues relating to Tuggerah Lakes and its catchment. A list of alternative community attitudes towards and objectives for the environment of the lakes were identified. The degree of community support for the alternatives was to be assessed at a later stage. Two important uses of Wyong's aquatic environment were given considerable attention: its utilisation by tourists, especially day-trippers, and its use for fishing, both recreational and commercial. Components of income of the public sector (the State Government and the Council mostly), some of which are environmentally related, were identified and a breakdown of Council's expenditure, mainly on environmentally-related items, was completed.

Environmental costs and benefits involving variations in flooding in the Lakes and their catchment, urban developments, rehabilitation of the Lakes by beach cleaning, ooze removal and by dredging were considered. Increased flushing of the lakes by major expansion of the existing entrance to the sea or provision of a second entrance were discussed. Key concerns were identified. Matters given particular attention were the likely impacts of greater flushing of the lakes on land values, the possibility of a marina development, the impact of changed environmental quality on tourism earnings, the implications of patterns of urban growth (the speed and spread of urban growth) on environmental quality, congestion and tourists diversion costs associated with this growth and with any environmental deterioration in the lakes.

6. AN ANALYSIS OF EUTROPHICATION IN TUGGERAH LAKES AND SOLUTIONS TO IT: THE SOCIO-ECONOMICS IN CONTEXT

Discussion involved in the above-mentioned assessment procedures revealed that basically two possibilities exist for reducing eutrophication in Tuggerah Lakes:

- (1) Take measures that reduce the quantities of nutrients and sediments entering the lakes and
- (2) take action to ensure that there is more rapid exchange between waters in these brackish lakes and those of the Pacific Ocean.

These two strategies could also be used in combination.

Two alternatives for increasing the rate of flushing of these lakes are (a) to deepen and extend the present small channel by which the waters of these lakes enter the sea near Toukley (see photograph 7) and (b) to construct an additional channel to the sea north of Toukley in the vicinity of Marmong Point. Both could of course be done. For each of these possible constructions, there is a range of possible options with varying costs and possible environmental impacts. For example, if a second opening is envisaged would a flood gate to exclude high tides be a part of the construction? Let us consider each of the main strategies in turn.

Consider input of plant-nutrients to the lakes. It would be useful to know the following:

- (1) How does aquatic plant growth in the Lakes respond to nutrient inflows? Production functions (at least primitive ones) would be useful. Inflows of nitrates and phosphorous are believed to be major stimulants of aquatic plant growth but more should be known about this relationship. However the matter is complicated because one is not interested purely in the response of a single plant species. The composition of the species in the aquatic weed population is liable to change as the mixture and total availability of plant nutrients alters. What is likely to be the impact on the weed population of reduction in all inflows of nutrients? Is the weed population more sensitive to variations in some nutrients rather than others?
- (2) What are the sources of the inflows of nutrients to the Lakes? What quantities of nutrients come from the various sources and how can these quantities be controlled?

In relation to the last matter, it is believed that the main sources of inflows of plant-nutrients into the Tuggerah Lakes are as follows:

- (1) Fertilization of lawns surrounding domestic dwellings.

- (2) Turf farms.
- (3) Soil disturbance and/or vegetation removal particularly for urban developments such as housing estates.
- (4) In the past, human sewage from septic tanks.
- (5) Golf courses.

Pollution from these sources is not of a single-point type but is multiple-point or diffused. This makes monitoring of actual releases from individual properties difficult. Problems of measurement and the costs involved make it impractical for the Council to introduce pollution emission charges on landholders scaled to the level of their emission of plant-nutrients.

So far Wyong Council's main approach to dealing with the problem has been to require developers of housing estates to adopt measures to reduce soil erosion during construction and to provide for vegetated watercourses with settling ponds. While this is positive, it is probably insufficient to stem the nutrient inflows to the lakes substantially, especially since rapid population increase and urbanisation is occurring in the Shire.

If it is not possible to economically measure emissions of nutrients from properties, an emission tax is not economically worthwhile. The alternative of placing taxes on inputs known to be a prime source of nutrient entry into the Lakes, such as artificial fertilizers, is also not an option available to Wyong Shire Council. It is unlikely to have legal powers to impose such taxes. It does, however, have other policy instruments available to it. These include:

- (1) Higher rates for land uses which are a significant source of nutrient inputs to the Lakes, e.g. turf farms. Or again, other things equal, high density housing with less lawn would be preferred to estates with medium density and rates structure could be adjusted accordingly.

- (2) Zoning and permits for land use can be used to limit types of land use. Nevertheless care needs to be taken that these do not become too restrictive of enterprise.
- (3) Regulations restricting vegetation removal and requiring provision of settling ponds and so on could be strengthened.
- (4) Education can play a role. Household holders can be encouraged to develop gardens without lawns or gardens requiring use of little fertilizer.

As for strategies to increase the rates of flushing of the Lakes, these involve considerable investment by the Wyong Council. They would necessitate some increase in rates to pay for the capital works involved. For political reasons, the Council would need to assess the willingness of ratepayers to pay for such works.

A further political problem is also foreseen: Increasing the connection of the Lakes to the sea will increase tidal influences in the Lakes. This may result in some lakeside properties being flooded during high tides, especially during above normal high tides. Higher tides in the Lakes could also impede the release of floodwaters from the catchment of the Lakes. A trade-off problem exists. This problem could be mitigated if a second entrance to the Lakes is constructed by fitting it with locks to block out high tides, but this will add substantially to costs.

The solution to the above man-induced case of eutrophication is not an easy one given the political dimension involved and the fact that a Paretian improvement (one in which all parties gain compared to the *status quo*) does not seem possible. Furthermore, a considerable amount of scientific uncertainty exists about the environmental consequences of strategies which might be adopted to deal with the problem. In addition off-the-shelf policies from standard environmental economics, such as those on pollution emissions, are impractical because most of the pollution involved is of a non-point nature.

This problem is not specific to the Tuggerah Lakes. It is present in other brackish waters in Australia e.g. in Lake Macquarie and parts of Queensland. It is also a serious problem in many freshwater bodies (Herath, 1996).

7. CONCLUDING COMMENTS

Completing an integrated regional environmental study is a major task because of inadequate data for specific cases. The application of conventional methods to environmental assessment is usually not practical because of the considerable costs and long time-scale likely to be involved. At least in the shorter term and when early defensive environmental action is needed, adaptive environmental assessment processes are likely to be practical and useful. Environmental economics can assist in the design of such processes and in their adaptation as feedback is obtained from respondents. Several ways have been indicated in which this is possible. Furthermore, it is clear that an integrated regional environmental study without a significant input on the economic and social sides is likely to be of little or no value. However, at the same time, major information inputs are needed from engineering, natural sciences and the local community.

While adaptive environmental assessment is a useful approach, it is not a solution to all environmental problems. It provides some knowledge but not perfect knowledge. Furthermore, it is a useful technique for making local and regional communities aware of the nature of their environmental problems and possible solutions to these. Given political mechanisms of governance in democracies, this can improve policy formation and acceptance of policies. However, long-term progress requires sustained scientific research such as that carried out by permanent research institutions, e.g. the CSIRO and the universities. Sharing of existing knowledge and community participation can only take us so far. We must not forget this in our quest for knowledge through communalism, that is through community and 'expert' participation in problem solving. Collective participation provides a means to share our existing knowledge more effectively and disseminate it, rather than a means to increase our stock of knowledge. Long-term progress depends on the accumulation of knowledge even though dissemination and improved use of existing knowledge is not unimportant.

Notes

1. This is a revised and extended version of a paper presented at a conference on "Strategic Environmental Management: Managing Cumulative Environmental Impacts at the Systems Level" held August, 1995 at Toukley, N.S.W. and organised by the Wyong Shire Council. I wish to thank Mr. Brian Bell, Environmental Systems Manager, the Wyong Shire Council for inviting me to participate in the conference and to assist in the assessment of the environmental problems of Tuggerah Lakes. Thanks are also due to Professor Alistair Gilmour, Environmental Studies, Macquarie University for providing specific background material relating to the assessment of the environment of Tuggerah Lakes.
2. Castensson (1986, p.342) describes eutrophication in the following way
 "Eutrophication is the process by which lakes age. The lake is gradually choked with vegetation and filled with sediment. This process normally takes many thousands of years. But men's activities have rapidly speeded up the process. Man has drastically shortened the life-span of lakes by addition of plant nutrients originating from human activities. The lakes are becoming more fertile. The lakes will rapidly change character. This process is usually called man-induced or man-made eutrophication".

Man-induced eutrophication has become common in enclosed and slow flowing waters. It affects lakes, some coastal waters, ponds and slow flowing rivers and streams. It induces algal blooms, growth of aquatic plants, reduces oxygen levels in water, can cause unpleasant odours and produce offensive tastes in drinking water. It reduces the beneficial effects of water for human use. Urban water supplies, fishing and recreation are adversely affected. Algal blooms may make water consumption toxic for human and animal consumption and clog industrial and municipal water filters. Shores of lakes sometimes develop algal slimes and/or foul smelling plant matter may accumulate on their foreshores.

References

- Berkes, F. (1989) *Common Property Resources: Ecology and Community-based Sustainable Development*, Belhaven, London
- Boulding, K.E. (1966) "The Economics of the Coming Spaceship Earth". Pp.3-14 in H. Jarrett (Ed.) *Environmental Quality in a Growing Economy*, Johns Hopkins Press, Baltimore, MD.
- Braat, L.C. and van Lierop, W.F.J. (1987) "Environment, Policy and Modeling". Pp.7-19 in L.C. Braat and W.F.J. van Lierop, *Economic-Ecological Modeling*, Elsevier, Amsterdam.
- Castensson, R.G. (1986) "Impact Assessment of Eutrophication on Urban Water supply: Methods and Analysis". Pp.341-350 in H.A. Becker and A.L. Porter (Eds.) *Impact Assessment Today*, Vol.1, Uitgeverij Jan Van Arkel, Utrecht.
- Chambers, R. (1980) *Rapid Rural Appraisal: Rationale and Repertoire*. Discussion Paper 155. Institute of Development Studies, Brighton, U.K..
- Chambers, R. (1992) *Rural Appraisal: Rapid, Relaxed and Participatory*. Discussion Paper 311. Institute of Development Studies, Brighton, U.K.
- Herath, G. (1996) "A Review of the Costs of Removing Phosphorous to Control Algal Blooms in Waterways" *Australian Journal of Environmental Management* Vol.3, No.3, pp.189-261.
- Holling, C.S. (1978) *Adaptive Environmental Assessment and Management*, John Wiley, Chichester.
- McCracken, J., Pretty, J. and Conway, G. (1988) *An Introduction to Rapid Rural Appraisal for Agricultural Development*. Sustainable Agriculture Program, International Institute for Environment and Development, London.

- Nijkamp, P. (1987) "Economic Modeling: Shortcomings and Projections". Pp.20-35 in L.C. Braat and W.F.J. van Lierop, *Economic - Ecological Modeling* Elsevier, Amsterdam.
- Pido, M.D., Pomeroy, R.S., Carlos, M.V. and Garces, L.R. (1996). *A Handbook for Rapid Appraisal of Fisheries Management Systems*, International Centre for Living Aquatic Resources Management, Manila.
- Tisdell, C.A. (1996) *Bounded Rationality and Economic Evolution*, Edward Elgar, Aldershot, UK.
- Tisdell, C.A. (1995). "Issues in Biodiversity Conservation including the Role of Local Communities", *Environmental Conservation*, Vol. 22, No. 3, pp. 216-228.

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