

METHODOLOGY FOR THE ASSESSMENT OF VULNERABILITY OF SOUTH PACIFIC ISLAND COUNTRIES TO SEA-LEVEL RISE AND CLIMATE CHANGE

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Abstract

A methodology for the assessment of vulnerability to sea-level rise and climate change in the South Pacific was developed using the island countries of Fiji and Western Samoa. The present methodology is flexible; it does not depend so much on data referring to natural and social conditions, and can introduce indigenous characteristics of the countries. The traditional social characteristics include subsistence economy, close ties of people to land through customary land tenure, extended family structures, etc. The approach adopted here recognizes the coastal zone as a set of coastal systems. Each coastal system is made up of sub-systems, which consist of coastal sub-system elements. The concepts of vulnerability and resilience were employed for assessing the possible impacts of sea-level rise and climate change on each system. A semi-quantitative scoring method was developed to judge the vulnerability and the resilience of each system. This methodology was adopted in the studies for Fiji and Western Samoa (SPREP *et al.*, 1993a,b, 1994a,b). The results of the assessment for Nacula, Fiji, are presented as an example of the case studies, showing the effectiveness of the methodology in reflecting the particular attributes of the South Pacific in vulnerability assessment.

KEYWORDS: *sea-level rise, climate change, vulnerability assessment, methodology, South Pacific*

1. Introduction

Sea-level rise and climate change induced by global warming are anticipated to have various impacts on natural resources and human activities in the coastal zone. As a first step to establish appropriate measures to alleviate the impacts, the vulnerability of the coastal zone to

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sea-level rise and climate change has been studied so far by scientists in various fields, in which the Inter-governmental Panel on Climate Change (IPCC) has played a central role. IPCC published the "Common Methodology for Assessing Vulnerability to Sea-Level Rise" (Common Methodology) as a guideline for the assessment. Since the Common Methodology was first published in September 1991, 46 nations and regions have done a vulnerability assessment. These studies demonstrated the important role of the Common Methodology. However, because a wide range of detailed data is required to perform the vulnerability assessment based on the Common Methodology, it is difficult for developing countries to fully follow the Methodology. In addition, there is a criticism that the results obtained do not give a relevant basis to develop and evaluate the response options in such situations.

The authors have studied the vulnerability to sea-level rise and climate change of the island countries in the South Pacific, such as the Kingdom of Tonga, Fiji, and Western Samoa (e.g. Mimura *et al.*, 1993, Aalbersberg *et al.*, 1993a,b, Nunn *et al.*, 1992). In these studies, a methodology was developed, which was based on a semi-quantitative evaluation of the coastal vulnerability and resilience. This methodology also takes into account the indigenous natural, social, and cultural characteristics. This paper introduces the outline of this methodology, and the results of a case study for Fiji (SPREP *et al.*, 1993b, 1994b), which was carried out using the methodology.

2. Characteristics of the IPCC Common Methodology

It may be useful to review the IPCC Common Methodology to understand the background of the development of the new methodology. The Common Methodology was developed by the IPCC Coastal Zone Management Subgroup (1991, 1992) in order to promote the vulnerability assessment (VA) in each country. According to the Common Methodology, the vulnerability of a country to sea-level rise involves the susceptibility of coastal systems, both natural and social, to change and technological and financial ability to adopt appropriate measures. Then, the objective of the VA is to understand not only the magnitude of physical impacts of sea-level rise and climate change but also the technological and financial ability of each country. Aiming to assess both categories of the vulnerability, the Common Methodology consists of seven steps that start with choosing case study region and establishing the scenario for sea-level rise and climate change (Fig.1). As the indices for the vulnerability, the following items are taken:

- socio-economic value at loss: land, property, and population in inundated areas
- socio-economic value at risk: land, population, and property in flooded areas
- socio-economic value at change: land use pattern, additional financial expenditures
- loss of ecosystem: total area of inundated wetlands, areas of important ecosystems
- loss of cultural and historical heritage: number of historical spots

The VA case studies have been done so far in 46 countries and regions mostly using the Common Methodology. However, there are few countries and regions that could assess all the above indices. Various problems were pointed out from the experiences of the case studies (e.g. Waterman *et al.*, 1993):

1. There are few countries that can readily prepare the data sets required by the Common Methodology. It is difficult for some countries to prepare even the most basic data such as topographic maps at 1m contour intervals.
2. The Common Methodology uses monetary value as the measure to evaluate land losses. Since most of the island countries in the South Pacific depend largely on subsistence

economy, and have indigenous land tenure systems managed by traditional communities, it is impossible for these countries to assess the impact through solely the monetary value indices.

3. The Common Methodology assesses only the vulnerability to the impacts of sea-level rise and climate change. It is necessary to assess resilience of coastal systems such as coral reefs and mangroves in each country, since such understandings of the resilience of coastal systems are most likely to lead to optimal response options.

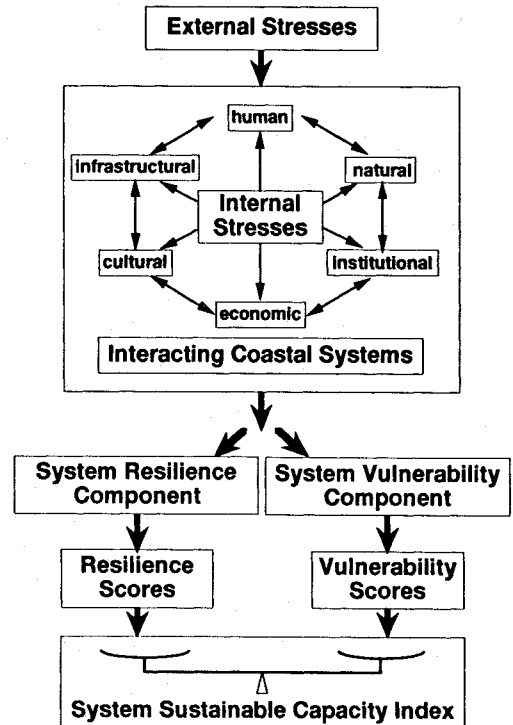
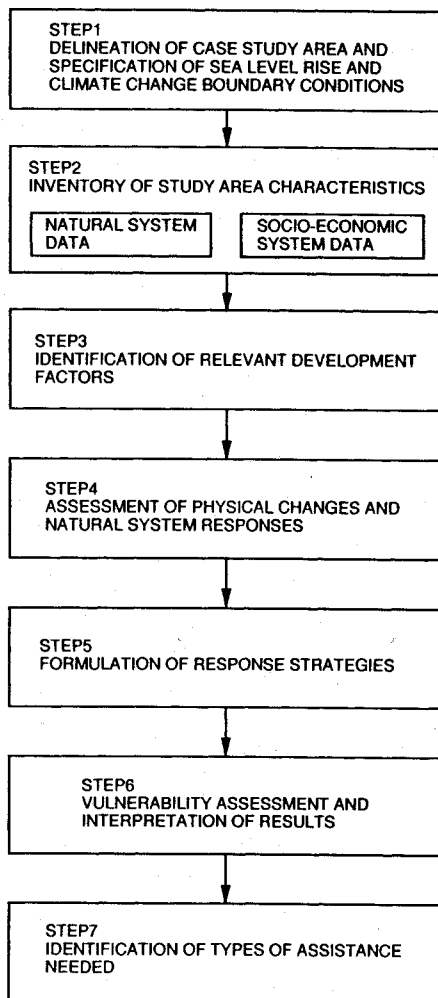


Figure 1. Stepwise structure of the Common Methodology

Figure 2. Framework of Assessment Methodology

3. New approach to Vulnerability Assessment

3.1 Objectives

The most significant problem which the authors faced at the first stage of the VA studies for the islands in the South Pacific was the lack of data, such as precise topographic maps at 1 m contour intervals, data referring to tide and waves, records of historical storm surges, and land-use patterns. This forced us to develop a new approach to the VA which uses the combined knowledge of local experts' experiences and available data to evaluate the vulnerability. This approach also pays attention to the indigenous characteristics of local areas such as subsistence economy and predominant decision-making role of the traditional communities.

The objectives of this new approach can be summarized as:

1. The VA can be done without supporting information such as precise topographic maps and socio-economic data.
2. The VA should be done mainly by in-country experts, policy-makers, and coastal managers.
3. The VA can evaluate not only the impacts of sea-level rise and climate change but also those of other external and internal stresses such as cyclones, population pressure, and overexploitation of resources.
4. The VA can consider regional and indigenous characteristics of the South Pacific island countries.
5. Even if some data are not available, the objectivity of the assessment can be retained to some extent.

3.2 Framework of the assessment methodology

In order to develop a relevant methodology of VA, it is necessary to understand the structure of the coastal systems, and the ways in which stresses influence the systems. The stresses can be both external and internal, and, of course, the external stresses include future sea-level rise and climate change.

Kay *et al.* (1993) suggested a framework of the evaluation of coastal vulnerability and resilience. Following this approach, the coastal zone is viewed as a set of six systems that belong to two categories (Fig.2); hard and soft systems. The "hard" systems include all tangible elements of coastal zones; natural environment, inhabitants, and man-made infrastructure. The "soft" systems encompass less tangible components of coastal zones; institutional, socio-cultural, and economic systems. These systems not only receive impacts from external and internal stresses but also interact with each other.

Each coastal system is made up of a number of sub-systems, which in turn consist of sub-system elements. For example, the system "Nature" consists of the "Physical" and "Biological" sub-systems, and the elements of the "Physical" sub-system are coastal morphology, lowlands, coral reef, mangrove, etc. For the systems of "Infrastructure", "Institutional", and "Cultural", the sub-systems are taken on the basis of the spatial scale; the communal (settlement), and national sub-systems. The "Economic" system is divided into the "Cash" and "Subsistence" economy sub-systems, since this study focuses on the island countries in the South Pacific. The systems and sub-systems are listed in the tables given as an Appendix.

The potential numbers of sub-system elements are enormous, but a relatively small number can be chosen on the basis of the relative importance of the elements to the case study

site. Therefore, the items of sub-system elements should be selected by experts with full understanding of the characteristics of the target site.

3.3 Scoring of vulnerability and resilience

The concept of vulnerability and resilience were employed to assess the weakness and strength of each system for the external and/or internal stresses. Vulnerability is interpreted as the potential for attributes of a system to respond adversely to the occurrence of hazardous events. The vulnerability defined here can be seen as susceptibility of the system, in other words. Resilience is interpreted as the potential for attributes of a system to absorb the impacts of hazardous events on it without significant or adverse response. If a range of scores, say from -3 to $+3$, is assigned to the degrees of the vulnerability and resilience, it would be a scale of the weakness and strength of the system. Moreover, the net impact to the coastal zone imposed by the external and internal stresses can be expressed by the difference of the scores between the resiliences and vulnerabilities of coastal systems. In this study, difference of scores is called the Sustainable Capacity Index (SCI), which is regarded as a measure of a system's overall ability to cope with external and internal stresses.

A method was developed to evaluate the vulnerability and the resilience of each sub-system by assigning scores in a semi-quantitative way. The scores for the degrees of the vulnerability of each system run from 0 to -3 , with -3 being the most vulnerable, while resilience scores run from 0 to $+3$, with $+3$ being the most resilient.

The assignments of scores are listed in the Appendix. These scores are determined on the basis of the results of the past VA, scientific knowledge, and expert judgment. Since the scores were established particularly for the islands of the South Pacific, it may be required to develop another set of scores for the different regions and countries, although the framework itself can be transferred.

The scoring procedure is repeated for the present and future conditions, to consider the effects of the changes in external and internal stresses (including sea-level rise and climate change). In this study, two sets of the future conditions are used. First, it is assumed that there would be no management interventions to reduce vulnerability, or enhance resilience. This is termed No Management scenario. Second, it is assumed that a coastal management response would be employed to optimally reduce vulnerability and enhance resilience. Such a management response is considered to optimize the reduction of vulnerability and the enhancement of resilience, and is called Optimal Management Response (OMR) scenario. The scorings were done for both scenarios as well as for the present condition for the purpose of comparison.

The present methodology was applied to the case studies for Fiji and Western Samoa (SPREP *et al.*, 1993a,b, 1994a,b). Though case studies for many local areas were carried out in both countries, only a typical one, i.e. Nacula in Fiji, will be presented owing to the limitation of space.

4. Case study for Nacula, Yasawa Islands, Fiji

4.1 Outline of Fiji and Nacula

Fiji is located about 2,300 km north from New Zealand and is the biggest archipelagic country consisting of about 320 islands in the South Pacific (Fig.3). Total area is 188,300 km² and its main islands are Viti Levu Island (10,388 km²) and Vanua Levu Island (5,536 km²).

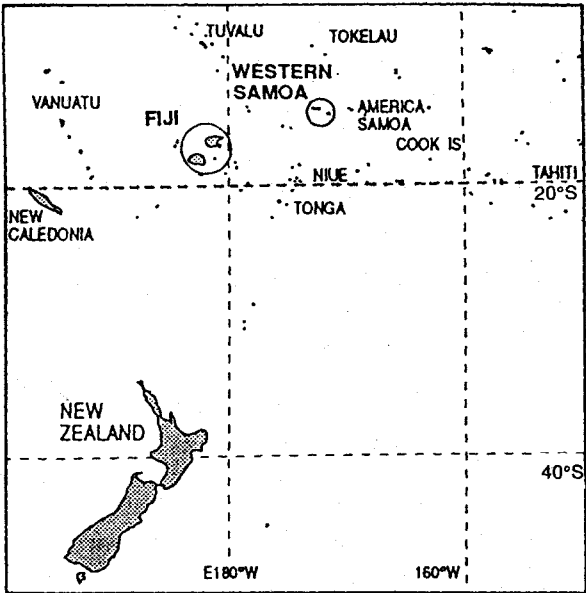


Figure 3. Location Map of Fiji

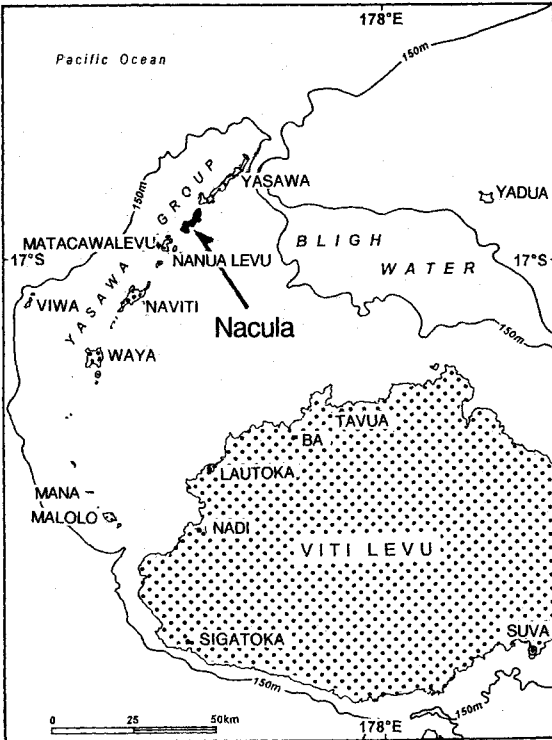


Figure 4. Location Map of Yasawa Group and Nacula

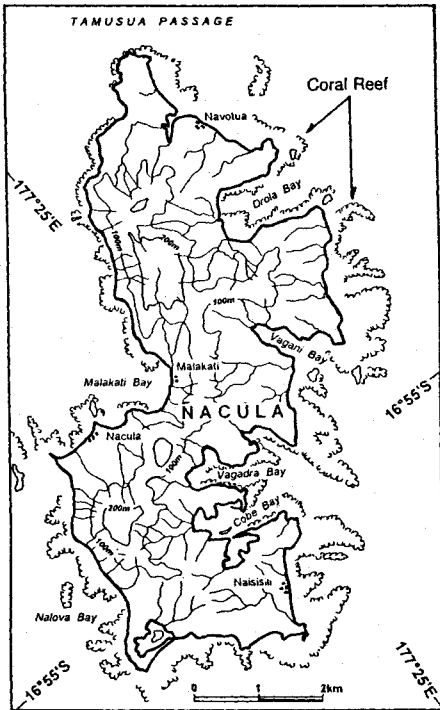


Figure 5. The Island of Nacula

Frequent cyclones cause disasters by flood, erosion, and storm surge etc. About 90% of its population of 740,000 are in the coastal zone. About 46% of them are original inhabitants of Fiji, and about 44% of them are Indian immigrants in the colonial days. About 20% of its population are concentrated in the capital, Suva. About 70% of Fiji's indigenous inhabitants are in villages. Villages have regional communities of "vanua," consisting of kinship groups of "mataqali." The chief is called as "turaga." Fiji depends on subsistence economy as other islands in the South Pacific do, and maintains traditional life style related to land. The idea of this community is "benefit of the community has priority over that of individuals," and the community makes much use of ceremonies to show its regional unity.

Nacula Island is located in the central part of the Yasawa group (Fig.4). This comprises mainly hilly volcanic islands with many small bays. Flat sandy areas of elevation less than 2 m and of varying dimensions border these bays. The four villages on the island occupy these sandy coastal plains (Fig.5). Annual precipitation is close to the lowest in Fiji (1500 mm). In the period from May to December there are few rainfall events, especially during El Niño years. This leads to water shortages that affect water availability for human use and agriculture.

Tropical cyclones and droughts have a major impact on the island. The Yasawa group is on a common tropical cyclone track and these islands are the first land fall so often bear the full fury of the storms. Direct hits come every 10-20 year with sideswiping tropical cyclones occurring more numerous in between.

The villages are large by the standards of rural Fiji, each containing about 300 residents. Additional members of the villages live and work on Viti Levu but may have a house in the village. The present village sites have moved from the hills as tribal warfare ceased in the last century and more recently (in at least one case) in response to increasing populations.

People are fairly isolated from "modern" life on Nacula. Most have a radio. Other contact is by a radiotelephone system that operates occasionally. Trips to the mainland by open punt or fishing boat take 4-6 hours and are usually undertaken only for commercial and/or traditional reasons. Life in the island consists mainly of subsistence activities, especially fishing, agriculture, and mat-making, together with traditional ceremonial activities.

A team of experts was sent to assess the vulnerability and resilience of Nacula mainly based on interviews and expert judgement. The criteria listed in Appendix were used for the judgement.

4.2 Assessment for Nacula, Yasawa Islands

(1) Natural System: Physical Sub-system

Nacula is surrounded by a fringing reef which in places extends more than 1 km from the shoreline. This reef has been adversely affected by recent sedimentation in places but overall appears healthy. Most of the villages on Nacula are located on coastal plains which are among the lowest parts of the island relative to sea level, yet still higher than some. Naisisili, for example, moved to its present site within the last two decades and now occupies a large area some 1.5 m above mean sea level separated from the sea by a well-vegetated beach ridge, some 20 m wide, which rises about 2.5-3.0 m above mean sea level in places.

Many people are aware of the effects of sea-level rise. People of Nacula village reported that their shoreline had receded some 10 m in the last 30-40 years, pointing out that large trees used to grow where boats are currently anchored. Naisisili villages report the inland reach of a very gently sloping inlet had increased some 50 m in the last two decades.

Most of the higher parts of Nacula are covered by grassland or, where there is insufficient

soil, consist of bare rock. Trees are usually confined to valley bottoms, where there are thicker soils and a concentration of fresh water. Most of the coastal lowlands are covered with coconut palms and people's food gardens tend to be on slightly higher ground.

Should the present high frequency of tropical cyclones persist in the future, then the Yasawa group including Nacula are likely to experience continued high levels of soil loss at such times. Since most storm surges approach the island from the northwest, gardening on southeast-facing slopes, which are sheltered from the worst effects of such events, could be encouraged. Resettlement on the leeward (southeast-facing) side of Nacula may also become an option to be encouraged.

Certain parts of Nacula are vulnerable to sea-level rise, notably the lower-lying coastal plains, but on the whole the island is comparatively resilient. If there is no management, then many coastal plains may become badly eroded and unusable for settlement or agriculture.

Optimal management strategies for reducing the effects of future sea-level rise on the physical elements of Nacula include raising the level of coastal plains and coastal defenses. This process has been done already by the far-sighted management of Turtle Island Resort on nearby Nanuya Levu Island using large boulders. The resort management is also notable for having engaged in considerable reafforestation of the island it occupies and has generally behaved in an environmentally responsible manner.

(2) Natural System: Biological Sub-system

In undeveloped areas, coastal trees such as *dilo* (*Calophyllum inophyllum*) and *tavola* (*Terminalia catappa*) and shrubs such as *vevedu* (*Scaevola toccada*) line the edge of the beach front. The mangrove ecosystem is found in a few areas. Offshore from the island are extensive patch reef systems. There is a fringing reef in some places. Many reefs are extremely healthy owing to minimal fresh water or sediment inputs from the land. Marine resources form a major source of food and income.

The present biological vulnerability is -1 , a reflection of the limited range of land biota (Table 1). The reef biota is of course much more complex, and the resilience is $+2$. Most plants are tolerant of the dry, salty conditions in this area.

In the future, increased intrusion of salt water will affect the coastal land biota, and rising sea levels and temperature may affect the reefs. Increased intensity and frequency of cyclones will affect both. This raises the vulnerability score to -2 . There is little that can be done at a local level to offset these problems. However, afforestation, better soil management, and restrictions on burning could improve the biological resources of the hilly areas so that the optimal management score is -1 . The resilience under both regimes is $+1$.

(3) Human System

The population density on Nacula is low with a total permanent resident population of about 1000 people. About half of the population is not permanently resident owing to employment or study. Improved living conditions and health care have led to significant increases in the rural Fijian population. This has also occurred on Nacula. The main reason for the relocation of Naisisili village was the lack of space at the old village site. Other villages are expanding onto land at the edge of the village that would otherwise be used for agriculture. There is still much land available as long as this coastal land is not inundated.

The human population vulnerability is -1 and resilience is $+2$. With optimal management the vulnerability would remain -1 but with none it could rise to -2 . Resilience could fall to $+1$ with no management but rise to $+3$ with optimal management.

Table 1. Nacula present day and future coastal system vulnerability and resilience components and sustainable capacity indices

Coastal systems	Coastal sub-systems	Vulnerability component	Resilience component	Sustainable capacity index	Future					
					Vulnerability component		Resilience component		Sustainable capacity index	
					Present day					
		present management regime	present management regime	present management regime	No management	Optimal management	No management	Optimal management	No management	Optimal management
Natural	physical	-1	+2	+1	-3	-1	+1	+2	-2	+1
	biological	-1	+2	+1	-2	-1	+1	+1	-1	0
Cultural	communal	-2	+3	+1	-1	0	+2	+3	+1	+3
	national	-1	+1	0	-1	-1	+1	+1	0	0
Institutional	village	0	+3	+3	0	0	+3	+3	+3	+3
	national	-2	+2	0	-3	0	+1	+2	-2	+2
Infrastructural	individual	-1	+2	+1	-2	-1	+1	+3	-1	+2
	communal	-1	+2	+1	-2	0	+1	+2	-1	+2
	national	0	+2	+2	-1	0	+1	+3	0	+3
Economic	subsistence	-2	+1	-1	-2	0	+1	+3	-1	+3
	cash	-1	+2	+1	-2	0	+1	+2	-1	+2
Human	populations	-1	+2	+1	-2	-1	+1	+3	-1	+2
Average Sustainable Capacity Index		-1.1	2.0	0.9	-1.8	-0.4	1.3	2.3	-0.5	1.9

(4) Infrastructural System

As would be expected in a rural area, infrastructural elements are few beyond individual houses. Each village contains two large churches (one Catholic, one Methodist). These are usually located at the landward side of the village. A primary school and medical post are located near Nacula village. Both are situated inland at the edge of the hills on higher ground. The only other infrastructure is the piped water supply system that serves the villages.

All individual and communal structures are currently located near the coast on sandy substructures at elevations of not more than 2 m. Thus, a significant rise in sea level and/or storm surges could cause these structures to be abandoned or moved. Some protection is offered by the fact that houses are set back somewhat from the sea front, which is planted to some measure with trees whose roots will slow down the rate of erosion. In most villages an elevated sand bank occurs at the sea front. Rocks are available to build seawalls in front of villages to slow down the rate of erosion but the effort to build an effective one would be substantial. Whether this effort would be warranted is not clear. Vulnerabilities and resiliences for these infrastructure elements are given in Table 1.

(5) Institutional System

The organization is well established at a traditional level that has been validated by the legal system. Resource management occurs through discussion at the village level with the final decision being that of the chief. Such a system has low vulnerability (0) and high resilience (+3). It is unlikely that this will change in the future given the strength of the traditional system in the outer islands (the periphery) of Fiji.

At the national level, the situation is somewhat different. Although especially for a developing country, the national government is well run and understands the importance of rural development, the realities of working on outer islands with few resources limit the effectiveness

of government efforts.

As this area of Fiji tends to be under-represented in government, less pressure is put on government to develop it. An additional factor is that at present throughout Fiji the management of the coastal zone is fragmented among several government departments. The score would be -2 for vulnerability and $+2$ for resilience. With optimal management the vulnerability could go to 0 and resilience to $+2$. With no management vulnerability could be -3 and resilience $+1$.

(6) Economic System

The monetary economy has only recently become important for Fijians living in the Yasawa islands. Food, housing, and clothing needs were traditionally obtained from the immediate environment or by ceremonial interchange. The need to pay educational expenses and a desire for western goods has changed this. Marine life such as fish and lobsters abounds around the Yasawa islands and these can be sold, generally in Lautoka in Viti Levu Island. People will typically engage in such activity if they have a specific urgent need for money.

In the last decade or so, tourism has become important in the Yasawa chain. Tourists are drawn by the white beaches, colorful water and reefs, and friendliness of the people. This enterprise started as cruise ships touring the island chain. Villages benefited mainly by landing fees and being paid for entertaining guests and selling handicrafts.

Another major source of funds for these islanders is mainland employment, either directly or via remittances from relatives. Another major economic activity that occupies much of the islanders' time is agriculture. Some coconut trees are grown for copra, but its low price has lessened the return from this activity. The vast majority of agricultural activity is at the subsistence level. Although this does not generate income, the cost of replacing these mainly carbohydrate items in the diet could be thousands of dollars per year in an average household. Most protein in the diet is provided by reef fish.

Agriculture, especially on the low-lying area might benefit initially as the water table rises, but would definitely deteriorate once salt-water intrusion occurred. If enough water was made available by the drilling scheme (which should in theory be possible), irrigation could solve the problems of droughts (this has been successful on Turtle Island). Tree planting and refraining from burning could help make the hill areas more productive. The availability of fish and other sea resources are unlikely to be affected in the foreseeable future. Tourism, however, is more problematical.

The study area has limited cash economic activity and is therefore given a vulnerability of -1 . Subsistence is more important and rates a -2 . The chance of changing to different economic activities is limited but more so in the commercial sense than the subsistence one. Resiliences are therefore given as $+2$ and $+1$, respectively. Effective management practices in terms of agriculture and coastal management for hotels could greatly improve the ability of these economic activities to survive sea-level rise and these are reflected in the scores given in Table 1, especially the differences in the sustainable capacity index for the no management and optimal management options.

(7) Cultural System

The four villages on Nacula are populated by indigenous Fijians. The traditional system is very strong. This system emphasizes communal activity under the direction of the chief. In such a system there is strong cohesion within the village in which decisions are reached by extensive discussion of problems facing the village until a consensus is achieved.

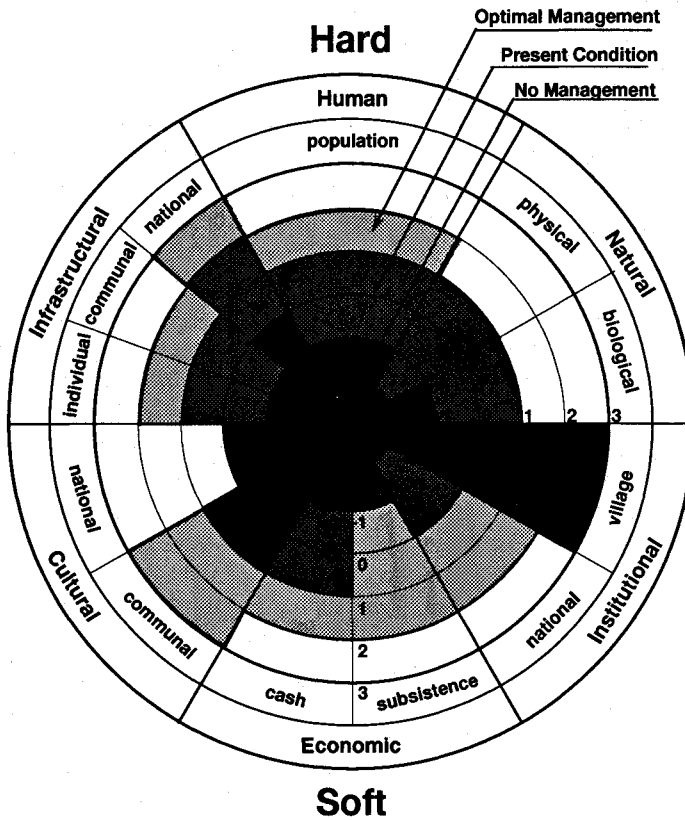


Figure 6. The Scores of SCI of Nacula Case Study

The strong community-oriented Fijian culture is ideal for dealing with outside threats. Since this system is so important, its vulnerability is rated as -2 and resilience at $+3$. This is unlikely to change significantly in the future, in fact unity is likely to increase in countering increased problems. These villages have had to relocate in the past and have done so successfully.

Even with no management it is expected that vulnerability and resilience would change only slightly to -1 and $+2$ respectively, whereas with optimal management they would remain at 0 and $+3$. In terms of national cultural importance, the status of Nacula as an outlier means that there is little national importance to this area. Vulnerability is -1 and resilience is $+1$. These values would not change significantly regardless of the management approach.

(8) Overall results

The scores of vulnerability and resilience obtained through the above analysis are shown in Fig.6 for the present, and the future scenarios of no management and optimal management response. The coastal systems of Nacula have relatively high adaptability to sea-level rise and climate change. Though the no management option increases vulnerability, various response options can be taken by enhancing the traditional systems of the community. These options can even increase the score of SCI for the future.

4.3 Consideration on response options

It is unlikely that the magnitude of sea-level rise predicted by the IPCC for the year 2050 will have any serious effects on the important aspects of life on Nacula island. Some areas may suffer salt-water intrusion, but there is sufficient land available that such land could merely be abandoned. Certainly some decisions such as not building on the lowest-lying land or near the sea would make sense. Planting the shoreline areas of villages with vines and trees that might build up the coastal embankment and help prevent erosion would also be wise.

With the likely acceleration of sea-level rise beyond 2050, the land occupied by the villages on Nacula at some point will become inundated. Both village and agriculture would need to move to higher ground. The time when this happens could be postponed by building shoreline-protection structures but this would only be a stop-gap measure, especially given the permeability of the sandy soils. For some villages, suitable land in the hills is already available. For others, flat sites would probably have to be created. The availability of water to support domestic use and agriculture on the hills would have to have been developed at this point. Practices that help retain water and soil fertility would certainly need to be followed. With sustainable agriculture being practiced and a continued supply of marine resources, life as is currently practiced on Nacula should be able to continue.

It is not clear, however, what the carrying capacity of this island would be, especially under a scenario of inundation of coastal land. Populations are likely to continue to rise in villages. The trend of greater migration to urban centres is likely to accelerate to offset this increase.

The example of the development of Turtle Island Resort on Nanuya Levu Island provides testimony that with appropriate machinery, planning, and expertise, the quite stark environment of a small Yasawa island can be greatly enhanced. This is reassuring evidence that the potential is available for the people of the Yasawa islands to respond effectively to the threat of sea-level rise and associated external stresses.

5. Conclusion

A new approach to Vulnerability Assessment, considering indigenous natural and social / cultural characteristics, was developed for the South Pacific island countries. Based on this methodology, semi-quantitative assessments for regional and indigenous characteristics were performed through case studies of Fiji and Western Samoa. By showing SCI of each system in the form of radar chart, the present vulnerable systems and the degree of effects under various management conditions could be understood.

By using this methodology, it is possible for decision makers without detailed data to understand vulnerability, resilience, and effectiveness of appropriate measures. Therefore, it is considered as a useful assessment methodology as a first step to examine practical measures. Future tasks would be to reflect relevance within each system on scoring, and to examine the importance of each system.

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Appendix Judgment criteria for scoring of subsystems (1)

System	Subsystem	Subsystem element	Score	Judgment
Natural	Physical	Vulnerability refers to coastal morphology and coastal lowlands.	-3	Most of the hinterland is 1.5 m or less (considered to be the most vulnerable height range to sea level rise of around 0.5 m and associated increase in maximum-wave amplitude) above mean sea level, and the majority of the coast is made of erodible materials and is poorly protected against erosion.
			-2	Around 50% of the hinterland is 1.5 m or less above mean sea level. No more than approximately 50% of the coast is made of erodible materials and is poorly protected against erosion, the remainder being made of more resistant material and/or better protected either by artificial structures and/or appropriate vegetation from marine erosion.
			-1	At least 25% of the hinterland is 1.5 m above mean sea level. Only a few parts of the coast are made from erodible materials and poorly protected from erosion, the remainder being more resistant and/or better protected as for -2.
			0	There is no significant part of the hinterland below 1.5 m above mean sea level and the shoreline is not made of easily erodible material and is not highly vulnerable to marine erosion.
		Resilience refers to coastal morphology and to the physical effect which fringing reefs and mangrove forests, for instance, have in reducing external stresses from the ocean on the shoreline.	3	The shoreline is well protected from erosion, both internally and externally. External protection along the entire stretch of coast is afforded by a healthy fringing coral reef and/or by mangroves which are not being actively cleared.
			2	Overall the shoreline is moderately well protected internally. External protection from offshore reefs and mangroves is present but is either discontinuous and/or in a state of moderate stress as the result of physical damage and human over exploitation for instance.
			1	The shoreline itself is only slightly protected throughout or well protected in places yet with conspicuous parts of it poorly protected. External protection from offshore reefs and/or mangroves is slight. Reefs may be either discontinuous and/or under stress, mangroves may be sparse and likewise under stress.
			0	The shoreline has no internal protection from marine erosion, and reefs and mangroves are absent or severely debilitated.

Appendix Judgment criteria for scoring of subsystems (2)

System	Subsystem	Subsystem element	Score	Judgment
Natural	Biological	Vulnerability refers to species diversity, biomass and valued species along the shoreline and the areas immediately adjacent to it	-3	The biota of the site are extremely diverse (there is a comparatively large number of species, and/or extremely productive in biomass terms, and/or highly valued species occur here. Plants used in daily faunal (including human) subsistence living may occur in abundance.
			-2	There is moderate species diversity, moderate production of biomass, and there is a moderate number of valued species occurring here. Some plants needed for daily faunal (including human) subsistence living may be found.
			-1	Species diversity are low, as is production of biomass and the numbers of valued species in the area. Only a few plants needed occasionally for faunal (including human) subsistence may be found.
			0	There are only a few species (3-5) growing on the study site, which are not productive in terms of biomass. There are no species of any notable value growing.
		Resilience refers to the tolerance of plants in the study area to external stresses such as erosion, storm surge damage, wind damage, ground water salinization and human impacts.	3	The tolerance of all species within the study site is very high. There is little that could disturb the ecosystem, perhaps because it is well protected from physical damage, such as wave attack and/or because it is diverse and well developed.
			2	The tolerance of most species is high. There may be minor weaknesses in the ecosystem which could be exploited by certain types of external stress and/or the ecosystem may not be adequately protected from the sea and/or it may be slightly under stress because of existing disturbances.
			1	The tolerance of most species is moderate. The ecosystem has been subject to change recently but has not been completely transformed and is demonstrating some internal resilience. The ecosystem may be subject to severe destabilization if external stresses continue to affect it.
			0	There is little tolerance of plants in the area to stress. Evidence of imminent ecosystem collapse may be manifest.

Appendix Judgment criteria for scoring of subsystems (3)

System	Subsystem	Subsystem element	Score	Judgment
Human	Population	Vulnerability refers to the number of people in the area compared to the perceived average densities of the nation as a whole.	-3	The area has a very large population, perhaps crowded together (a much higher population density than for the country as a whole) and growing. It implies that at present humans are the principal source of stress on the physical fabric of the area. It implies that there is an imbalance between human demands on the area and its short-term capacity to meet those demands.
			-2	The area has a large population and there are some signs of stress within it as the result of its size. It implies that humans are an important source of stress to the area's physical fabric.
			-1	The area has some people living in it but they are not crowded together and do not pose a significant threat to its natural elements. The relationship between people and the environment within the area is clearly sustainable.
			0	The area has very few (or no) people living in it. There is little perceptible effect of human habitation on the environment.
		Resilience is a measurement of the numbers of people living in the area who are protected from and well able to withstand stresses, both internal and external.	3	(Almost) all of the people living in the area are adequately protected from stress associated with each other, as the result of overcrowding, for instance. They are also well protected from external stresses such as those originating from the ocean and from inland areas.
			2	At least 60% of the people living in the area are adequately protected from both internal and external stresses as elaborated for +3.
			1	Less than 30% of the people living in the area are adequately protected from both internal and external stresses. There may be some overcrowding, localized problems of effluent disposal, some pollution, inadequate sea defenses locally or suchlike.
			0	(Almost) all the people in the area are unprotected from the principal sources of either internal or external stresses.

Appendix Judgment criteria for scoring of subsystems (4)

System	Subsystem	Subsystem element	Score	Judgment
Infrastructural	Individual	Vulnerability refers to the concentration of individually (rather than communally or nationally) owned and managed infrastructure, such as houses, kitchens, shops and workshops. The degree of concentration is measured relative to the rest of the nation.	-3	Individually owned and managed infrastructure is highly concentrated in more than 50% of the study area. There may be an industrial or residential subdivision in (part of) the area or a parade of shops to which people from other areas depend on for regular needs. Most of the area is urban or suburban; it may be close to the sea and/or only slightly above mean sea level.
			-2	Individual infrastructure exists within the area but is interspersed with other elements such as communal infrastructure and/or agricultural land. The area is not urban but may be a rural settlement with a few shops and other commercial infrastructure; it may be near the sea and /or less than 3 m above mean sea level.
			-1	There are some houses and other individually-owned infrastructure within the area, but these occupy a smaller area (<30%) than other elements such as communal infrastructure and/or agricultural land. Most individual infrastructure is well above 3 m above mean sea level.
			0	There are few houses in the area but there is no other individually-owned infrastructure and other elements such as communal infrastructure and/or agricultural land occupy around 90% of the area. Most individual infrastructure is well above 3 m above mean sea level.
		Resilience refers to the degree of protection from various sources of stress possessed by individual infrastructural elements.	3	Most of the individually-owned infrastructure is well protected from stress. Most (>90%) of the buildings will be made of strong, durable materials and located in least vulnerable locations, and/or will be easily relocated/built.
			2	More than 60% of the individual infrastructure is well protected by virtue of its construction and/or its location.
			1	Less than 40% of the individual infrastructure is well protected by virtue of its construction and/or its location.
			0	There are only a few or none (<5%) elements of individual infrastructure which have any protection against external stresses.

Appendix Judgment criteria for scoring of subsystems (5)

System	Subsystem	Subsystem element	Score	Judgment
Infrastructural	Communal	Vulnerability refers to the concentration of communally-owned infrastructure in the area such as churches, meeting houses, cooperative society buildings, and certain seawalls and jetties. It may also include communally-developed water supply and waste disposal systems, and any electricity generators which operate for the community's benefit.	-3	There is an unusually high concentration of communal infrastructure in the area compared to the national average. This may be because the area is a well-developed and comparatively prosperous settlement. Communal shoreline infrastructure may be concentrated here because the community also depends on large-boat access (hence has built jetties/wharves) or because seawalls have also been communally built.
			-2	There is a concentration of communal infrastructure but that this is close to the national norm. This might be what is expected of a typical rural settlement with perhaps some communally constructed seawalls and jetties.
			-1	There is a comparatively low amount of communal infrastructure in the area, less than the national norm. This may be because the settlement is not prosperous or well-developed and because the resources are not available communally to improve infrastructure.
			0	There is an insignificant amount of communal infrastructure in the area.
		Resilience refers to both to the degree of protection afforded communal infrastructure and to the ease with which it could be shifted, rebuilt or relocated to a more protected site if necessary.	3	All communal infrastructure is well protected from external stresses, and should it become necessary, there are many sites to which it could be relocated. It also implies that the physical shift involved in relocation of particular communal infrastructure would be comparatively easy.
			2	Much communal infrastructure is well protected from stress. There are a few places to which it could be shifted if necessary. The process of relocation would be problematic but not beyond the means of the community.
			1	Only some of the communal infrastructure in the area is protected from stress, the rest is not. There is an inadequate number of places to which such infrastructure could be shifted and/or the infrastructure would be extremely difficult to relocate/rebuilt.
			0	None or a very small proportion of the communal infrastructure is protected from stress. There is nowhere suitable for any of this infrastructure to shift and/or it would be impossible to replace this infrastructure.

Appendix Judgment criteria for scoring of subsystems (6)

System	Subsystem	Subsystem element	Score	Judgment
Infrastructure	National	Vulnerability refers to the concentration of national infrastructure such as roads, railways, national port facilities, shoreline protection structures constructed with national funds, and utilities such as water supply, waste disposal and electricity generation.	-3	There is a significant concentration of national infrastructure in the area, perhaps a major port facility or airport serving a number of dispersed settlements or a major storage or processing center for an industry of national importance.
			-2	There is some national infrastructure of importance in the area, perhaps reflecting its importance to a number of other settlements.
			-1	There is no national infrastructure in the area of significance outside the area. Yet the area is still well endowed with communications (such as road, rail and rivers) which are maintained by national authorities.
			0	There is no national infrastructure of significance within the area. There may be a few roads and other elements but these may not be well maintained.
		Resilience focuses on the degree to which national infrastructure is protected from stress within the area. In the case of coastal roads, for example, it is a measure of the adequacy of its protection from marine erosion. It is also a measure of the ease of relocation of national infrastructure and the availability of alternative, better-protected sites (whether another route exists for the coastal road, for example).	3	Most (>80%) of the national infrastructure in the area is adequately protected. It may also mean that, were it necessary to move that infrastructure, there are many alternative sites in better-protected locations, and that the process of relocation would be comparatively straightforward.
			2	Some of the national infrastructure is adequately protected but that some (<40%) is not. It may also mean that, although there are ample sites available where these elements of national infrastructure could be relocated, the process of relocation would be largely problematic.
			1	A little (<30%) of the national infrastructure in the area is adequately protected, the rest is not. There are some sites available for relocation but these are insufficient to accommodate all elements of national infrastructure in the area.
			0	Only a small amount (<5%), if any, of the national infrastructure, is protected from stress. There are no suitable places for relocation.

Appendix Judgment criteria for scoring of subsystems (7)

System	Subsystem	Subsystem element	Score	Judgment
Institutional	Settlement	Vulnerability refers to the degree to which the people living in or dependent on the area are organized. It refers to whether or not settlements are established as cities, towns or villages with all the functional implications of such categories. It also refers to land tenure, particularly whether land is communally-owned or whether it is leased; this is a measure of the attachment of the people living in an area to the land they work and thus the responsibility they feel for it.	-3	No formal settlements are established in the area, and people are not organized in a community although they may have cultural and/or familial links. Land may be alienated.
			-2	Settlements (at any level) are established but their operation is problematical. Perhaps people are strongly divided, unable to cooperate. Perhaps the organization is if an insufficient degree to assure the settlement functions satisfactorily.
			-1	Settlements are established and are operating reasonably well despite conspicuous problems.
			0	Settlements are established and are operating efficiently.
		Resilience refers to the flexibility of the organization of settlements, particularly with reference to their response to external stresses. For instance, is the community sufficiently well organized to fund and/or build seawalls? Is the land tenure system flexible in the face of receding coasts, or could some sections of the community become landless?	3	The settlement is operated in a flexible manner. External stresses are coped with efficiently and communally.
			2	There is some flexibility in the management of the settlement but conspicuous aspects of this (such as land tenure) are highly inflexible.
			1	There is little flexibility in settlement management, perhaps because things have been done in a certain way for so long that this is regarded as the only way.
			0	There is extreme rigidity in settlement management and operations. Its attitude to external stresses is potentially calamitous.

Appendix Judgment criteria for scoring of subsystems (8)

System	Subsystem	Subsystem element	Score	Judgment
Institutional	National	Vulnerability refers to the degree to which national initiatives affect the area. Such initiatives include the establishment and operation of a national land-use plan, a nature reserve or marine park, conservation of particular endangered biota and suchlike. They also include projects organized under the auspices of the principal religious bodies in a country.	-3	No national initiatives affect the area to a significant degree.
			-2	The effect of national initiatives on the area is noticeable but these are not well established and are not accorded the value which national authorities might desire for them.
			-1	National initiatives do affect the area and are moderately well managed although some major deficiencies remain.
			0	Well-managed national initiatives affect the area and largely control daily existence within it.
		Resilience refers specifically to flexibility of national initiatives in a particular area. They measure the degree to which stresses can be accommodated within such initiatives.	3	There is a high degree of flexibility. National management strategies may even have been designed with the view to accommodating specific stresses. Well-briefed persons may be involved in such initiatives locally.
			2	There is moderate flexibility of national initiatives within the area but there are conspicuous shortcomings, perhaps the lack of trained persons locally, which may adversely affect the accommodation of stress.
			1	There is only a little flexibility in national initiatives in the area. Many aspects appear inflexible. Trained persons may be absent.
			0	There is no flexibility in national initiatives, and they are unlikely to prove sustainable in the face of stresses. No-one is available locally to adapt these initiatives to changing conditions.

Appendix Judgment criteria for scoring of subsystems (9)

System	Subsystem	Subsystem element	Score	Judgment
Economic	Cash	Vulnerability refers to the importance of the cash economy to the area.	-3	There is considerable cash-generating economic activity. The area may be industrial and/or commercial or, if it is rural, may have a large income from forestry, cash cropping, fisheries and/or tourism.
			-2	There is some cash-generating economic activity, certainly enough to satisfy the needs of the people in the area but perhaps insufficient to improve their collective situation significantly.
			-1	There is a little cash-generating economic activity but this is neither assured nor does it continue regularly. It could be seasonal, it could be carried out just when funds are needed for a particular purpose.
			0	There is no significant cash-generating economic activity in the area.
		Resilience refers to the flexibility of the cash economy in the area. It measures the degree to which present levels of cash income could be maintained were the principal sources of that income adversely affected by stress. In other words, it measures whether there are alternative source of cash income for people in the particular area.	3	The present cash economy is founded on a diverse base and is not dependent on a single type of activity. Were certain elements of the economy to cease to be viable, there are many other options for cash generation in the area.
			2	A lesser diversity of cash-generating enterprises and a moderate possibility of successful conversion to other types of activity should any of the present ones fail.
			1	The present cash-generating activities are few and other potential cash-generating activities are possibly viable.
			0	The present cash economy has an unhealthily-narrow base yet, there are no alternatives for cash generation available in the area.

Appendix Judgment criteria for scoring of subsystems (10)

System	Subsystem	Subsystem element	Score	Judgment
Economic	Subsistence	Vulnerability refers to the dependence of the people in the area on a subsistence livelihood and the vulnerability of that livelihood to the effects of future sea level rise. It measures the degree to which people feed and clothe themselves rather than depending on their own cash-generating activities for such purposes and the vulnerability of the supply of raw materials to sea level rise.	-3	People are wholly dependent on their own resources and that there is little cash exchange in the community. Crops are grown largely for home consumption, fish and other animals are caught and killed for the same purpose. Most crops are grown in places less than 3 m above sea level and are not generally tolerant of saline conditions. Most sea food is from the reef or lagoon rather than the open sea. Most land animals are grazed and/or kept in places which are less than 3 m above mean sea level.
			-2	Although people depend heavily on a subsistence lifestyle, they do occasionally earn cash which they need for certain purposes. Cash might be earned by fishing, selling surplus crops or by handicraft manufacture. Of the subsistence crops grown, some are grown in places which are less than 3 m above mean sea level but other are not. Some crops may be well adapted to saline groundwater conditions.
			-1	Although people do grow/catch some food for their own consumption, most of them depend on cash earned to supply their daily needs.
			0	The people of the area are not in any way dependent on a subsistence lifestyle.
		Resilience refers to the flexibility of the existing subsistence economy, the degree to which its elements could be replaced by others if it came under stress. Of particular note is the diversity of the major elements (staples, vegetables, protein) of the subsistence economy. The less diverse, the more inflexible is a particular system.	3	The subsistence economy is diverse, and were one or two elements of that economy prove more difficult to cultivate and/or obtain in the future, this shortcoming would be easily remedied by a greater reliance on other elements. It may also mean that there is potential for new elements to be added to the existing subsistence base: new crops which could grow well, new initiatives for correcting dietary inadequacies, for example. There are sites where subsistence crops could be grown and animals grazed which are higher than those at which they are grown/grazed at present.
			2	The subsistence economy is diverse yet there are few alternatives to a few of its constituent elements. There may be some higher sites where subsistence crops could be grown and animals grazed.
			1	The subsistence economy is not very diverse but there are some elements which could be added to supplement or replace existing elements. There are few alternative sites on higher ground available for growing subsistence crops or grazing.
			0	A very limited subsistence economy with few (or no) alternatives possible for particular elements. Most of the crops are grown and animals grazed within 3 m of sea level and there are effectively no alternative sites for these activities.

Appendix Judgment criteria for scoring of subsystems (11)

System	Subsystem	Subsystem element	Score	Judgment
Cultural	Communal	Vulnerability refers to the degree to which the community shares a common culture or cultures and the degree to which this affects their everyday life. It also measures the importance of the site in a cultural sense to the people living there; high values may be because it is a long-established settlement low values because the people are transient and feel no particular affinity to the site.	-3	Cultural ties within the community and to the site are very strong.
			-2	Cultural ties within the community are strong but perhaps showing signs of minor disruption. The people feel a strong bond with the site but it is perhaps not their most valued site.
			-1	Cultural ties within the community are diverse and not particularly strong. No particular tie is felt with the site although people may still talk of it as part of their land.
			0	There is no significant cultural consensus within the community. No bond with the site is apparent.
		Resilience refers to the ability of the culture to withstand change, the ability of the communities bonded by a shared culture to withstand disruption to their traditional site.	3	The culture(s) is very strong, and is likely to remain so whatever happens to the community and the site they are now occupying.
			2	The culture is not able to cope entirely satisfactory with external stresses and perhaps a few people are breaking away from the community and its traditional site.
			1	The culture is becoming diffused and is threatened by various stresses. perhaps a large number of the community have rejected (the majority of) its traditional ways and abandoned its traditional site.
			0	The culture(s) is under stress and/or only superficial compared to the way it once was, The community is dispersed, no longer operating as a cultural entity. Perhaps the proximity of a nearby urban center and/or rural depopulation have contributed to this situation.

Appendix Judgment criteria for scoring of subsystems (12)

System	Subsystem	Subsystem element	Score	Judgment
Cultural	National	Vulnerability refers to the importance of the site, its people and their collective behavior in the national context. If the site is of great archaeological or historical significance, if its people are custodians of a special tradition, then high values will be scored.	-3	There is immense importance attached to the site and/or its occupants at a national level.
			-2	The site and/or its people have some importance at a national level but there are several comparable sites within the area.
			-1	The site and/or its people have little importance at the national level. There is nothing here that is not found in a large number of other places.
			0	There is nothing of national interest in the site and/or its occupants.
		Resilience refers to the likely degree of preservation of the national heritage at the site in the face of stress. Implicitly it refers to the support given to the preservation by national government and associated agencies.	3	There is optimal support from national bodies for the preservation of the site. Were it to come under undue stress, it is clear that steps would be taken to preserve the site.
			2	There is some support from national bodies, but this support is inadequate to completely guarantee the site's preservation in the face of stress.
			1	There are serious deficiencies in the support for the preservation of this site by national government.
			0	National government no longer supports the preservation of this culturally-significant site.