Towards adaptive town environmental planning: the experience from Xiamen, China

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ABSTRACT In China, concern is growing with regard to environmental issues related to the growth of peri-urban towns. Rapid urbanization and the backlog in constructing needed environmental infrastructure have resulted in severe environmental issues for many peri-urban towns, affecting their sustainable development. In Xiamen, a coastal city, town-level environmental planning was proposed in 2003 as an important tool to control pollution and conserve ecosystems. But for environmental planning to work, it needs to be more adaptable to local circumstances and decision-making processes. This paper presents a framework for adaptive environmental management and discusses how it was implemented in Dongfu Town, one of the peri-urban towns around Xiamen. It describes the principles of adaptive peri-urban town environmental planning and how this process integrates information from multiple sources and different stakeholders. This experience shows how science can be integrated into the decision-making process, avoiding both the narrow-minded viewpoints of planners and the natural resource use conflicts among a variety of stakeholders. It also shows how the environmental planning process can propose results that are acceptable to local communities and decision makers, even when they suggest directions that were not in accordance with the public's initial priorities. Finally, it shows that sustainable development of targeted areas can be achieved through well-designed environmental planning.

KEYWORDS environmental planning / governance / natural resource management

I. INTRODUCTION

China has been undergoing rapid urbanization since the 1980s, and projections suggest that between 150 and 200 million rural dwellers will move to urban areas in the next ten years and that up to 60 per cent of China's population may live in urban areas by 2020. The most significant urbanization trend in China involves industrial development in what were traditionally agriculture-based towns close to urban centres or along roads out of such urban centres. These areas, so-called peri-urban towns, are typically characterized by strong rural–urban interactions.(1)

There are growing concerns about environmental problems in these peri-urban towns, as increasing numbers of factories are locating there without any sound planning. Many are moving from urban areas due to increasing operational costs and stricter environmental requirements there. However, the capacity of the environmental infrastructure in the

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peri-urban towns to which they move, for instance for sewage and solid waste management, is usually inadequate. This has meant serious environmental problems, including environmental deterioration and ecosystem damage.

To resolve these issues in Xiamen, a southeastern coastal city of China, since 2003 town-level environmental planning has been proposed by the Xiamen Environmental Protection Bureau as one of the important tools for controlling pollution and conserving ecosystems. Dongfu Town was the first location for demonstrating environmental planning in Xiamen.

It is argued here that environmental planning and management of the peri-urban interface cannot be based simply on the extrapolation of planning approaches and tools applied in rural and urban areas. Instead, an approach must be constructed that responds to the specific environmental, social, economic and institutional aspects of the peri-urban interface.[2] In this paper, the current problems of town-level environmental planning are considered, then adaptive environmental management is discussed, along with the principles and relevant process to make environmental planning adaptive. We then describe the application of adaptive environmental planning in Dongfu, along with some suggestions.

II. CHALLENGES FACING CURRENT ENVIRONMENTAL PLANNING

Environmental planning is necessary in designing the desired future and achieving ecological sustainability.[3] It can be defined as the appropriate arrangement of time and space for human activities within the environment in order to achieve the coordination needed in the development of the environment, the economy and society.[4] It includes all planning activities with the objective of preserving or enhancing environmental values or resources.[5]

In association with the Ministry of Construction of China, in May 2002 the State Environmental Protection Administration of China promulgated the "Guideline for Town-level Environmental Planning (Trial)". In this document, environmental planning was recognized as a fundamental part of town environmental protection and pollution control. Although some case studies of environmental planning have been reported, most are not for towns and, to date, there is still no report of demonstrated town-level environmental planning in China.

More importantly, there is a need to improve procedures and methodologies for integrating environmental planning into the decision-making process. The critical factor for environmental planning is its implementation. Only when the measures or specific engineering projects to control pollution and conserve ecosystems that are put forward by environmental planning have been successfully put into practice can environmental planning be effective. To date, the effectiveness of environmental planning is in doubt because the decision makers do not readily accept it.

There are various challenges faced by town-level environmental planning. First, there are no broadly applied methodologies that are widely accepted by environmental planners. Land suitability evaluation

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1. Tacoli, Cecilia (1998), "Rural–urban interactions: a guide to the literature", *Environment and Urbanization* Vol 10, No 1, April, pages 147–166; also Tacoli, Cecilia (2003), "The links between urban and rural development", *Environment and Urbanization* Vol 15, No 1, April, pages 3–12.

2. Allen, Adriana (2003), "Environmental planning and management of the peri-urban interface: perspectives on an emerging field", *Environment and Urbanization* Vol 15, No 1, April, pages 135–148.

3. Daniel, S E, D C Diakoulaki and C P Pappis (1997), "Operations research and environmental planning", *European Journal of Operational Research* Vol 10, No 2, pages 248–263.

4. Ortolano, L (1984), *Environmental Planning and Decision-making*, John Wiley Press, New Jersey; also Baldwin, J H (1985), *Environmental Planning and Management*, Westview Press, Boulder, Colorado.

5. Dougherty, T C and A W Hall (1995), "Environmental impact assessment of irrigation and

drainage projects", FAO Irrigation and Drainage Paper No 53, HR Wallingford, United Kingdom.

6. FAO (1993), "Guidelines for land use planning", *FAO Development Series* No 1, FAO, Rome, page 96.

7. Benjamin, M (2001), "Land use conflicts resolution in a fragile ecosystem using multi-criteria evaluation (MCE) and a GIS-based decision support system (DSS)", International Conference on Spatial Information for Sustainable Development, 2–5 October 2001, Nairobi, Kenya.

methodologies developed by the United Nations Food and Agriculture Organization[6] have been applied worldwide for land use planning. Other methods applied include the Decision Support System (DSS) and Geographic Information Systems (GIS), which have also been applied in land use planning.[7] These have been used successfully in planning the leading industries of targeted areas, but at the scale of towns it is difficult to collect the basic data these methods require. In addition, social and economic factors need to be taken into account.

Environmental planning, in its arrangement of human activities, attempts to find solutions to conflicts in natural resource use, to determine ecological function zones, to set environmental standards for factories, and to take countermeasures to protect the environment and conserve ecosystems. The achievement of these objectives will have a considerable effect on interested parties or stakeholders. All stakeholders should be involved during the process of environmental planning, so their interests and opinions can be considered openly and fairly. However, traditional planning is a closed process rather than an open one, providing another challenge for environmental planners.

Furthermore, conventional planning practices cannot manage the range and depth of information needed for environmental planning, including natural, social and economic information; quantitative and qualitative information; and information from different sources. Additional complications arise because it is difficult to integrate environmental planning results into decision-making processes; this is because environmental planning was introduced after the core of the planning system in China had been developed. There is no legal requirement for environmental planning at the town level or even at some higher levels. Without the authorization of environmental planning by the local People's Congress, the outcomes of environmental planning cannot be effectively implemented.

Finally, there are the scientific uncertainties, including those regarding the cause and effect of pollutants. In the open, dynamic environments in which humans live and operate, knowledge often has limits, and scientific certainty is difficult to attain. Uncertainty itself comes in many varieties, non-scientific as well as scientific. Some kinds of uncertainty can be addressed and reduced; others cannot.[8] There have been some mathematical methods to address and reduce the uncertainties that environmental planning faces,[9] but these are too complex to implement in environmental planning at the level of towns.

8. Tickner, J, C Raffensperger and N Myers (1998), *The Precautionary Principle in Action – A Handbook*, Science and Environmental Health Network, Windsor, North Dakota.

9. Costanza, R and L Cornwell, (1992), "The 4P approach to dealing with scientific uncertainty", *Environment* Vol 34, No 9, pages 12–20 and 42.

All these challenges mean that town-level environmental planning in China lacks the flexibility and adaptability it needs in order to be integrated into the decision-making process. As a result, its acceptability is often compromised and its effectiveness can be discredited.

III. THE ADAPTIVE MANAGEMENT APPROACH IN ENVIRONMENTAL PLANNING, AND ITS PRINCIPLES

a. Definition of adaptive management

The adaptive management approach has been attracting more attention recently. In the Millennium Ecosystem Assessment synthesis report, it was pointed out that:

> "A variety of frameworks and methods can be used to make better decisions in the face of uncertainties in data, prediction, context and scale. Active adaptive management can be a particularly valuable tool for reducing uncertainty about ecosystem management decisions. Commonly used decision-support methods include cost-benefit analysis, risk assessment, multi-criteria analysis, the precautionary principle and vulnerability analysis. Active adaptive management is a tool that can be particularly valuable given the high levels of uncertainty surrounding coupled socio-ecological systems."[10]

Adaptive management is a methodological innovation in resource management that began initially in the 1970s as an approach to managing the harvest of fisheries and forests, focusing on the use of systems models to underpin management decision-making.[11] Since then, various definitions of adaptive management have emerged and been applied in the management of ecosystems[12] and conservation areas.[13] As one kind of integrated natural resource management and/or complex ecosystem management, in the face of the complexity and uncertainties, environmental planning calls for an adaptive approach.

The basic concepts underlying adaptive management can be summarized as the implementation of policies as experiments.[14] Adaptive management tries to incorporate the views and knowledge of all interested parties in the management of complex environmental systems that are characterized by high levels of uncertainty about system processes and the potential ecological, social and economic impacts of different management options.[15]

As a generic approach, management that monitors the results of policies and/or management actions and integrates this new learning, adapting policy and management actions as necessary, characterizes adaptive management. As a specific approach, it involves the integration of multiple kinds of knowledge (scientific, local and indigenous) in the exploration of a management "problem", in management goal setting and in management planning.

Environmental planning is a fundamental step towards more quantitative and scientific environmental/ecosystem management. The process, methodologies and outcomes of environmental planning should be active to ensure adaptive environmental/ecosystem management.

b. The principles of adaptive town-level environmental planning

The following four critical principles of adaptive management can guide environmental planning:

- **The resource-oriented principle**. The conditions and characteristics of the resources in targeted areas are the foundation of planning and development.[16] The resource conditions regulate the environmental carrying capacity, a threshold that should not be exceeded by the degree of development intensity of one region if the integrity of existing ecosystems is to be preserved. Based on detailed surveys of local resources, compared with those of surrounding regions, a Strength–Weakness–Opportunity–Threat (SWOT) assessment can be made and objectives can be determined effectively.
- **The critical ecosystem conservation priority principle**. The critical

10. Millennium Ecosystem Assessment Board (2005), "Millennium ecosystem assessment synthesis report", accessed 2 April 2005 at http://www.MAweb.org

11. Holling, C S (1978), *Adaptive Environmental Assessment and Management*, John Wiley & Sons, Chichester; also Walters, C (1986), *Adaptive Management of Renewable Resources*, Macmillan, New York.

12. Lee, K H (1995), "Deliberately seeking sustainability in the Columbia River Basin", in L H Gunderson, C S Holling and S S Light (editors), *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, Columbia University Press, New York, pages 214–238; also Walkerden, G and A J Gilmour (1996), "Adaptive environmental assessment and management (AEAM) programme for the Tuggerah Lakes system and associated catchment", Final Report, Maquarie Research Ltd, Melbourne, Australia.

13. Mertsky, V J, D L Wegner and L E Stevens (2000), "Balancing endangered species and ecosystems: a case study of adaptive management in Grand Canyon", *Environmental Management* Vol 25, pages 579–586; also Salafsky, N, R Margoluis and K Redford (2001), *Adaptive Management: A Tool for Conservation Practitioners*, The Biodiversity Support Programme, World Wildlife Fund, Inc.

14. Johnson, B L (1999), "The role of adaptive management as an operational approach for resource management agencies", *Conservation Ecology* Vol 3, No 2, accessed at http://www.consecol.org/vol3/iss2/art8/

15. Jacobson, C (2003), "Introduction to adaptive management", accessed 15 August 2004 at http://student.lincoln. ac.nz/am-links/am-intro.html

ecosystem has the most important role in an area in protecting the environment, interacting intensely with human activities and, at the same time, being easily affected by human activities. Consequently, it is usually fragile. It is important to identify and conserve critical ecosystems in order to achieve sustainable development. For example, sea areas may be the critical ecosystem in coastal areas, so during environmental planning the marine ecosystem should be prioritized and land-based pollutant discharges should be controlled to ensure that they do not exceed the environmental carrying capacity.

- **The precautionary principle**. "*When an activity raises threats of harm to human health or the environment, precautionary measures should be taken, even if some cause-and-effect relationships are not fully established scientifically*."[17] The implementation of the precautionary principle is necessary when facing scientific uncertainty.[18]
- **The community-based principle**. Community-based, or public, participation has been widely accepted in resource management.[19] As noted by Mulcrone: "*It is important to define local needs and opportunities in partnership with local communities. A key element of the success of any management strategy is the contribution and guardianship by local communities*."[20]

The precautionary principle also requires developing more democratic and thorough decision-making criteria and methods so that the public or specific population groups that may be impacted can be involved in the decision-making process.[21] In high-income nations, public participation within environmental planning is a relatively new phenomenon that is being introduced to traditionally closed planning processes.[22]

IV. THE PROCESS OF TOWN ENVIRONMENTAL PLANNING

The steps proposed for town-level environmental planning, based on its need to be adaptable and flexible, were designed as follows:

Characterize the state or condition of the targeted area. A survey of the current situation is the first step to understanding the background of the targeted area. This should include profiles of its natural resources, ecology, environment, society and economy, and the identification of the main environmental issues. It is an intrinsic requirement of adaptive environmental planning that consultations with local communities be part of the survey, in part because these communities will not accept environmental planning unless it accords with their traditional knowledge.

Analyze related planning. As one part of a city, a peri-urban town is strongly influenced by that city's planning – mainly the urban master plan, subject planning and sector plans. The aim of this step is to avoid serious conflicts between the city's planning and development, and environmental planning in the peri-urban town. There is now an emerging expectation, at all levels, that planning should recognize the linkages between human-made and natural capital, and should integrate social, cultural, political, economic and environmental issues.[23] Environmental planning seeks a more integrated approach than other forms of

16. Fang, Qin-Hua, Luo-Ping Zhang, Wei-Qi Chen, Pei-Er Wang, Hua-Sheng Hong and Frances Bristow (2005), "Resources-oriented principle and sustainability: theory and application in China", International Conference on Energy, Environment and Disasters (INCEED, 2005), 24–30 July 2005, Charlotte, NC, USA.

17. Raffensperger, C and J A Tickner (editors) (1999), *Protecting Public Health and the Environment. Implementing the Precautionary Principle*, Island Press, Washington DC, USA, page 385.

18. deFur, P L and M Kaszuba (2002), "Implementing the precautionary principle", *The Science of the Total Environment* Vol 28, No 8, pages 155–165.

19. Alcala, A C (1998), "Community-based coastal resource management in the Philippines: a case study", *Ocean & Coastal Management* Vol 38, pages 179–186; also Luttinger, N (1997), "Community-based coral reef conservation in the Bay Islands of Honduras", *Ocean & Coastal Management* Vol 36, pages 11–22.

20. Mulcrone, A (1993), "Planning for coastal areas and inland waterways", in Proceedings of the Irish Planning Institute Annual Conference, 22–23 April 1993, Cork.

21. See reference 8.

22. Richardson, T and J Dusik (1998), "Parallel public participation: an answer to inertia in decision-making", *Environmental Impact Assessment Review* Vol 18, pages 201–216.

23. King, P, D Annandale and J Bailey (2003), "Integrated economic and environmental planning in Asia: a review of progress and proposals for policy reform", *Progress in Planning* Vol 59, pages 233–315.

planning, both with regard to coordinating human and natural systems and to resolving conflicts in resource utilization among various sectors, plans and programmes.

Ecological function zoning and environmental function zoning. Ecological function zoning aims to provide a scientific basis for environmental management, and to optimize human activities spatially within the limitations of natural resources and environmental carrying capacity. Inadequate attention to such zoning may bring more severe environmental problems – for instance, locating an industrial park that generates air pollution upwind of a residential area. First, the targeted area is divided into sub-divisions according to geographical characteristics and natural resources, and urban function is determined by relative planning whereby the location of villages and roads is considered. Then the ecological suitability of each sub-division is analyzed, mainly based on the natural conditions (social and economic conditions being used as references). The leading function can be determined by integrating consideration of ecological suitability and comments from the public, decision makers and experts. Some of the methods for ecological function zoning will be described in more detail in the next section.

Environmental function zoning determines the environmental quality standard to be complied with in different ecological function zones.

Predictions. The trends for society, the economy, ecosystems and the environment will be predicted according to the ecological function and related planning. The objective is to identify the area of primary concern for pollution control and ecosystem conservation and to provide the basis for the next step.

Propose environmental planning objectives and related countermeasures. According to the results from the zoning and predictions steps above, rational objectives at different stages, including those involving environmental factors, ecology, afforestation and population, can be put forward. Programmes and countermeasures to achieve those objectives will be presented, including water, air, solid waste, noise and natural ecology.

Implementation schemes and measures to guarantee management. This stage includes key engineering projects and their financial support, responsible sectors and other guarantee measures such as institutional arrangements.

Public participation and expert consultation. The ultimate aim of environmental planning is to achieve sustainable improvement of the environment and welfare of local communities. Environmental planning can reduce resource use conflicts between stakeholders, but it must involve the participation of all stakeholders in order to reduce suspicion and apprehension among them. The success of environmental planning largely depends on its acceptance by all stakeholders as an initiative that will eventually bring benefits to the community.

Public participation can be applied in two fields of environmental planning. One is for local knowledge collection, and includes the opinions from local people about environmental quality and trends, and the main ecological and environmental issues; the other is for ensuring that the interests of these people are addressed, taking into account the leading ecological function of the town or village they live in, with measures to improve or conserve the environment.

Public participation methods include gathering information, and consultation and dissemination. Thus, they include, but are not limited to, questionnaires, individual interviews, public meetings, public hearings, telephone hot lines, public activities, expert consulting, and information dissemination and discussion through posters and television, radio, newspapers and magazines. The choice of which methods are finally adopted should be decided according to the requirements; however, questionnaires, individual interviews and expert consultation are most commonly used during environmental planning.

The involvement of local communities should be introduced at all the different stages of environmental planning, including the initial survey, ecological function zoning, environmental function zoning, countermeasure proposals, and implementation. Participation is the most necessary, and also the most effective, way of making environmental planning adaptive. Expert consultation is included in the broad meaning of public participation. External experts can analyze issues objectively and suggest alternatives.

Among all steps described above, ecological function zoning is regarded as the foundation and key element of an environmental planning process, from this point of view, its process and methodology should be explained further.

A typical flow chart of ecological function zoning for peri-urban towns is designed to be adaptive and flexible; it is summarized in Figure 1, and many of the components shown here have been described above. To give more details on two of the stages:

- **Assessment factors selection**. Assessment factors may cover geographic, natural resource and socioeconomic factors. Geographic factors include geographic and ecological conditions such as climate, soil, landform, ecosystem and environmental characteristics. Those factors with heterogeneity will be selected as assessment factors, such as landform, ecosystem characteristics (including those resulting from human interventions) and environmental characteristics (water and air, upstream or downstream). Natural resource factors include their abundance and distribution (land, water, minerals and tourism).

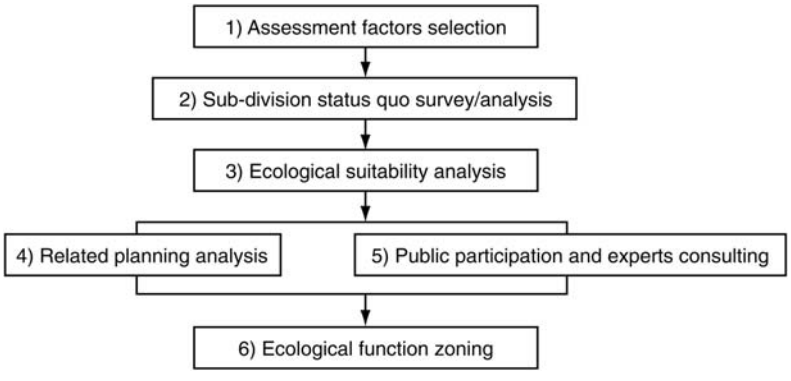

FIGURE 1
Technical flow chart of ecological function zoning

Those resources that are especially abundant or limited (resource features) should be identified in terms of the strength/weakness or opportunity/threat of the development. Socioeconomic factors should be considered for their capacity to promote or hinder the function. The main socioeconomic factors include population, transportation, current industries' development, level of education and infrastructure.

- **Ecological suitability analysis**. Ranking the factors selected by experts/planners according to earlier stages. The ranking ranges between 0 and 10, depending on where the factors lie in the range, from suitable (promote) to unsuitable (limit), for a specific function, such as a nature reserve, agriculture, manufacturing industry, commerce, administration, residential area or tourism. When all the rankings from the different assessors are brought together, then the leading and secondary functions can be determined. The Delphi survey technique[24] has proven an effective and popular tool to obtain the most reliable consensus from a group of experts. For ranking ecological suitability, a method similar to Delphi can also be applied during data collection and analysis. The development direction and its ecological structure will be determined through the steps above, with full investigation and scientific analysis. The results should integrate considerations of different dimensions, including environment, economy and society, and opinions from decision makers, local communities, experts and environmental planners. Alternatives need to be proposed in order to improve the adaptability of environmental planning.

24. Dalkey, N and O Helmer (1963), "An experimental application of the Delphi method to the use of experts", *Management Science* Vol 9, No 3, pages 458–467; also Okoli, C and S D Pawlowski (2004), "The Delphi method as a research tool: an example, design considerations and applications", *Information & Management* Vol 42, No 1, pages 15–29.

V. CASE STUDY IN XIAMEN – DONGFU TOWN ENVIRONMENTAL PLANNING

a. Background to Dongfu Town and its environmental planning

Dongfu Town is a coastal town[25] to the west of Xiamen City, and is administered by Haicang District (one of six districts within Xiamen City). Dongfu itself administers 13 villages within a land area of 85.1 square kilometres (Figure 2). The population in 2002 was 26,768; 89.2 per cent of local residents are engaged in agriculture and 76.3 per cent live along the main roads. Only 16.3 per cent of the local workforce are educated beyond high school.

25. In China, usually there are only "rural", "suburban" and "urban" settlements. A town close to the city centre, but that has not been built up, is neither rural nor urban and is usually termed a suburban town.

The Strength–Weakness–Opportunity–Threat (SWOT) analysis produced the following:

- **Tourism**. Dongfu is to the northwest of Maluan Bay, the land area around which the urban district of Xiamen City plans to develop marine tourism and a second area of residential, commercial and administrative activity. Aside from Maluan Bay, the potential tourism resources include some hot springs, Tianzhu Forest Park and Xiamen No 1 Farm, all of which will become potential new leisure areas if tourism is well developed.
- **Manufacturing industry**. Dongfu is in the north of Haicang District, the most important industrial district and also Xiamen's harbour and shipping base. It is to the west of Guankou Town, the principal

machinery industrial park of Xiamen and, because of its location, Dongfu is easily affected by developments in these locations. Town government officials have sought to develop a manufacturing industry in the past few years and several small industrial parks have been built and soon will be expanded. However, manufacturing industry in Dongfu will be limited by the environmental capacity of Maluan Bay. As a semi-enclosed sea area, the seawater exchange is limited because of a dam built in 1960. In addition, marine aquaculture has grown rapidly since the 1980s, and marine pollution has become increasingly severe. Not only does the fragile ecosystem need to be restored but the scale and direction of development must also be limited.

- **Agriculture**. Agriculture, including vegetables, fruit and flower cultivation as well as stock raising is the traditional base of the local economy. Agriculture in Dongfu is well developed because of the favourable weather, soil, landscape and skilled farmers, and also because of the demand for agricultural products from 2 million people living in Xiamen Island, the centre of Xiamen City. The factor affecting agricultural growth in Dongfu is the scarcity of fresh water. Seasonal streams are the main source of surface water in Dongfu, and the total artificial reservoir storage is 5.664 million cubic metres. Farmers have abandoned some farmland because of difficulties with irrigation. Only 500 out of a total of 566 hectares of farmland could effectively be irrigated by reservoirs in 2002.

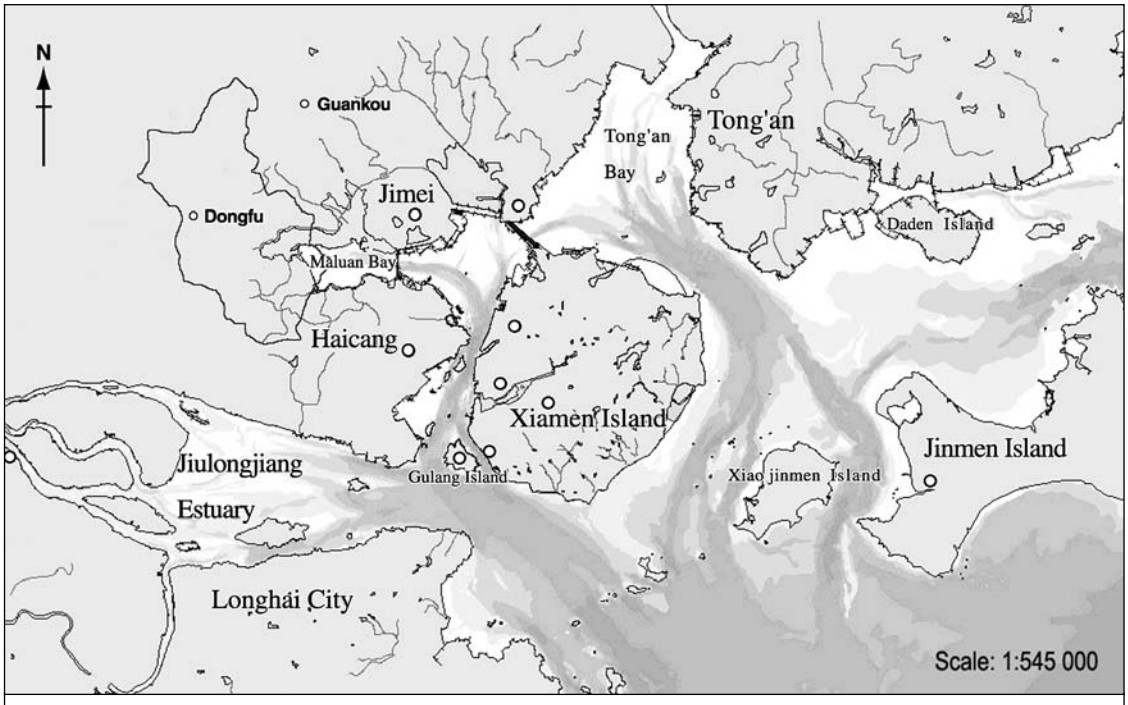

FIGURE 2
Location of Dongfu Town

Maluan Bay was identified as the critical ecosystem for Dongfu, to be reserved during the environmental planning process. Multiple problems have emerged for Dongfu, including how to optimize the use of natural resources, how to protect and restore the critical ecosystem (Maluan Bay) and how to determine the kind of development that is most sustainable. Environmental planning is a possible approach to finding solutions and determining a definite development direction.

A further complication for Dongfu is the solid waste landfill site for Xiamen, located in the northwest of Dongfu. Built in 1996, the treatment technology, especially for treating the filtrate, is not perfect. Local communities have strongly opposed the landfill site for a long time because of the foul smell and the pollution of underground water. While the landfill site is important because it is the only one for the city, it creates serious problems; environmental planning may find solutions to this conflict.

b. The environmental planning process in Dongfu Town

The main environmental issues were identified based on the initial survey:

1. Water resource scarcity.
2. Infrastructure lagging behind development, especially the construction of sewage pipelines, with untreated industrial and domestic liquid wastes being discharged directly into the environment.
3. Underground water (the drinking water for the local communities) has possibly been polluted.
4. Excessive and disorderly kaolin resource exploitation without regulation and planning, which is destroying agricultural land and the surrounding environment.
5. Risks to surface water and human health from the landfill site filtrate.
6. Transportation noise along the main roads.
7. Non-point source pollution discharged into Maluan Bay.

Some of the environmental issues (e.g. 1, 2, 4, 6 and 7) were identified by planners, while others were emphasized by the local communities (e.g. 3 and 5).

Related planning for Dongfu includes the 1996 Dongfu master plan, the 2002 industrial park plan and Tianzhu Forest Park master plan. The 1996 master plan divides the town into seven sections: the northern fruit area, the central comprehensive agriculture development area, the southern fruit area for leisure and sightseeing, the eastern aquaculture area (Maluan Bay) and three other sections. The main development industry in Dongfu was identified as agriculture. Planning for the industrial park and for Tianzhu Forest Park provided detailed design for two specific areas in Dongfu. From the related planning, we find that development surroundings have changed quite substantially since the 1996 town master plan was developed, and the development direction should be reconsidered. And second, the scale and design of the industrial park and Tianzhu Forest Park resulted mostly from human needs, without full consideration of natural resources and ecosystem carrying capacity; in this sense, the planning lacked a scientific base.

In order to adapt environmental management to the different requirements of each section of Dongfu, the whole town was divided into eight sub-divisions according to the heterogeneity and homogeneity of natural resources, and geographical characteristics (Figure 3).

The following were selected as assessment factors:

- landform;
- ecosystem characteristics (qualitatively described by the degree to which the ecosystem is natural or changed by human intervention);
- water and air environmental capacity (qualitatively described by its location);
- land area (square kilometres and percentage);
- mineral resource (type);
- landscape resource (natural and/or cultural);
- water resource;
- population density;
- transportation infrastructure;
- educational level (the percentage of those educated above junior high school level); and
- current main industrial development.

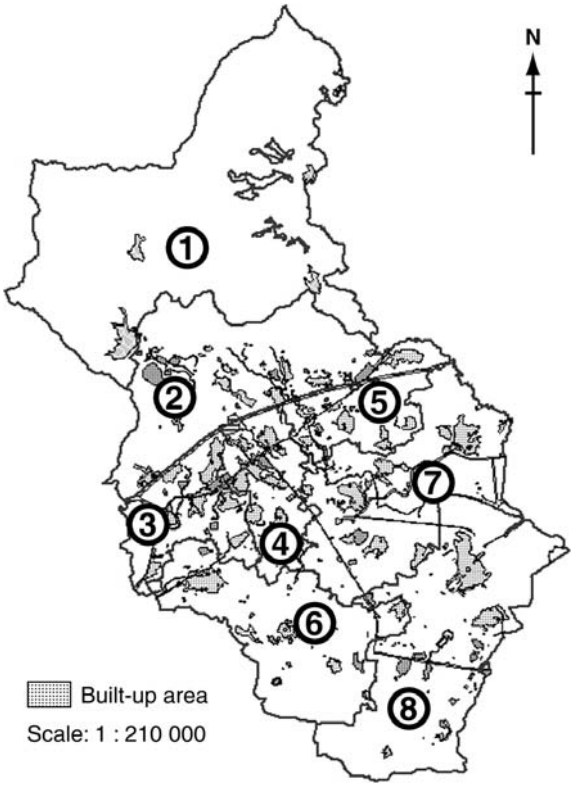

FIGURE 3
Sub-divisions of Dongfu Town

An initial survey by planners formed the basis for grading each sub-division. The order of ecological suitability for each sub-division is listed in Table 1.

The order of ecological function for each sub-division is a synthesis of the opinions of the planners. However, to determine the leading and secondary ecological functions of the sub-divisions, the opinions of experts and the public should be integrated into this.

Public participation through questionnaires was sought at the beginning of environmental planning, to obtain opinions regarding Dongfu's development direction (Table 2). The results indicate an urgent demand by local communities for manufacturing. Experts and local and upper-level governors were consulted through personal interviews or questionnaires, and their opinions on Dongfu's leading industry are summarized in Table 3.

Obviously it is not easy to reach a consensus among all stakeholders, and disputes may continue for a long time. But for environmental planning, as a spatial and temporal arrangement of local natural resources

TABLE 1
Grade order of each sub-division

	Average suitability grades					Function order*				
	Nature reserve	Tourist	Agricultural	Residential	Industrial	N	T	A	R	I
1	30.4	25.0				1	2			
2	19.0	18.9	22.2	21.2	20.2	4	5	1	2	3
3			21.8	21.3	19.8			1	2	3
4		21.9	21.3	24.4	20.9		2	3	1	4
5			21.4	20.3	24.7			2	3	1
6	20.7	24.8	22.3	21.6	19.9	4	1	2	3	5
7		22.7	22.7	21.2	20.2		1	1	3	4
8	19.1	24.3	20.6	20.1	20.9	5	1	3	4	2

* N = Nature reserve; T = Tourist; A = Agricultural; R = Residential; I = Industrial

TABLE 2
Part results of questionnaire on leading industry options

Questions	A	B	C	D	E
What is your attitude to the rapid development of manufacturing industry in Dongfu Town at present? A. Agree B. Indifferent C. Oppose	83	13	4		
What kind of industry is the most suitable for Dongfu Town in your opinion? A. Manufacturing industry B. Agriculture C. Tourism D. Commerce E. Other	64	4	19	9	4

TABLE 3
Different opinions on leading industry in Dongfu Town

Stakeholders	Opinion on leading industry	Main reasons
Local communities	Manufacturing industry	More job opportunities; to increase family income
Local officials	Manufacturing industry	To promote local economy during their tour of duty to show their achievements while in their post
City governors	Agriculture	To ensure supplies of agricultural products to the whole city
Consulted experts	Manufacturing industry	To drive economic growth rapidly; to accelerate urbanization
EP planners	Tourism	Market demands of residents of Xiamen Island as leisure destination; local natural resources

and local industries, the leading industry should be determined first. Two alternatives were selected in this case: one was manufacturing, because the desire of local communities and officials should be respected; and the other was tourism, because the environmental planners regarded it as the most likely way to achieve local sustainable development.

In order to improve the adaptability and acceptability of environmental planning, two alternatives, according to the two different leading functions, were put forward by the planners for broader discussion (Table 4).

Both alternatives would meet basic environmental standards, but the tourism alternative is more in line with the results of the suitability analysis (Table 1). Thus, the tourism alternative is more compatible with

TABLE 4
Ecological function of sub-divisions in Dongfu Town

Sub-division	Leading ecological function*	Secondary ecological function
1	Nature reserve	Ecological forest tourism
	Nature reserve	Ecological forest tourism
2	High-tech agriculture	Sightseeing tourism (flowers and fruits) and residential
	High-tech agriculture	Residential and sightseeing tourism (flowers and fruits)
3	High-tech agriculture	Residential
	Residential	High-tech agriculture
4	Administration and residential	Recreational tourism
	Administration and residential	Recreational tourism and manufacturing industry
5	Manufacturing industry	Agriculture
	Manufacturing industry	(None)
6	Tourism	Agriculture and manufacturing industry
	Manufacturing industry	Agriculture
7	Recreational tourism	Residential and agriculture (flowers and fruits planting)
	Residential	Recreational tourism
8	Recreational tourism	Residential and wetland conservation
	Manufacturing industry	Residential and wetland conservation

* The first row in each of the eight sub-divisions represents the ecological functions taking tourism as the leading industry; the second row represents those for the manufacturing industry.

the resource-oriented principle, and there are less subjective judgments. These ideas were put forward in the draft environmental planning report that was then sent for review. A month later, a meeting for technical examination and public review was held and, subsequently, some of the report's findings were understood and finally accepted by local communities' and government representatives. Finally, a leading ecological function zoning plan, integrating both preliminary alternatives, was put forward (Figure 4). It was planned based on the manufacturing industry, and tourism was emphasized.

After the leading and secondary functions of each sub-division had been determined, the environmental standards for surface water, air quality and noise in different sections were determined, and the total pollutant loading to ensure environmental objectives was calculated.

Pollution control countermeasures include:

- the existing domestic waste treatment plant should be shut down and a new site should be selected as soon as possible;
- factories should be located in the planned industrial parks, and those factories with high water consumption should be prohibited; and
- a sewage system, including collection and transportation, should be constructed.

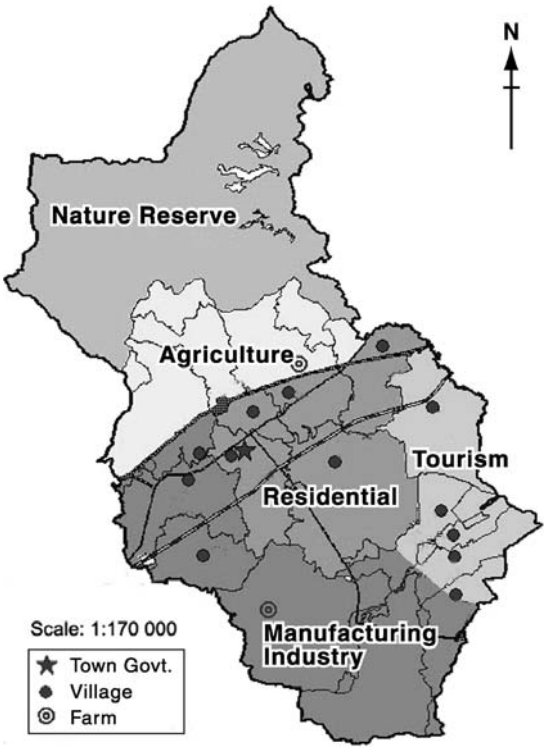

FIGURE 4
Integrated ecological function zoning

VI. CONCLUSIONS

- Environmental planning has been shown to be a necessary and effective approach to integrating science and the decision-making process, to optimize natural resource use and, subsequently, to achieve sustainable development in a peri-urban town in China.
- Environmental planning is a critical part of ecosystem management. Adaptive ecosystem management calls for adaptive environmental planning. The existing methodologies of town-level environmental planning should be improved further to increase its acceptability and adaptability for decision makers. The resources-oriented principle, the critical ecosystem conservation priority principle, the precautionary principle and the community-based principle can enable adaptive environmental planning.
- Ecological function zoning is the key step for environmental planning. The methods presented in this paper, of grading ecological suitability and of integrating the opinions of the public/communities, local decision makers and experts, have performed well in Xiamen.
- Adaptive environmental planning is a cyclical, learning-oriented approach to the management of complex environmental systems that are characterized by high levels of uncertainty about system processes and the potential ecological, social and economic impacts of different management options.[26] Environmental planning is the first step for adaptive management, with further monitoring needed for improvement in the future.[27]

26. See reference 15.

27. US EPA (2003), "Watershed analysis and management guide for states and communities", EPA 841-B-03-007, Office of Water (4503T), US EPA, Washington DC.