LAND USE CHANGES AND GIS-DATABASE DEVELOPMENT FOR STRATEGIC ENVIRONMENTAL ASSESSMENT IN HA LONG BAY, QUANG NINH PROVINCE, VIETNAM

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Abstract

Halong Bay is a UNESCO World Heritage Site, with a unique natural scenery of thousands of limestone islands. It is also an area of conflicting issues, which all matter in a sustainability context. Quang Ninh province, bordering the P.R. of China, is part of the strategic economic development triangle Hanoi-Haiphong-Quang Ninh. It is the heart of Vietnam’s coal industry. Also, Halong Bay is a prime tourism area. Finally, Halong Bay is also the scene where a major deep sea port at Cai Lan is proposed. Current planning is ad hoc and uncoordinated, with little environmental consideration. Halong Bay provides a fine example of (environmental) conflicts to be analyzed in a framework of competition for control of resources. Actual conflicts of interest, between ministries, institutions and interest groups, and between the central and local governments, will intensify in the future. The authors report on database development, based on the application of remote sensing and GIS techniques. The effort aims to support local and national authorities with a systematic and scientific basis for decision-making. This is exemplified through a Strategic Environmental Assessment of development planning. Also, the database provides a means to objectively present environmental conflicts. The database constitutes a major structural information source, with a high potential for expansion, both in thematic and spatial scope. The report presents database design, tools and methods applied, and data used. The database is composed of physical, socio-economic and biological/ecosystems components. Data are generated from remote sensing images (LANDSAT TM and aerial photography), existing maps, statistical data, and fieldwork. The database is complemented with Geographical Positioning System field photos. The physical component is finalized. Overlay of the “Master Plan of Ha Long City” on thematic data layers (e.g. land cover/use maps) enables a preliminary impact analysis. Statistical computations document significant potential environmental impact and land cover changes, in particular for the mangrove areas. The socio-economic and biological/ecosystems components are being added to allow full impact assessment. Modeling of interactions between human activities and the environment aims to generate impact scenarios of different development alternatives. The ultimate aim is to support improved planning.

Keywords: Remote Sensing, GIS, Strategic Environmental Assessment, Ha Long Bay, Vietnam

INTRODUCTION

Problem in Context

The clash between development and environment is evident in Ha Long Bay, the “Bay of the Descending Dragons”, an UNESCO World Heritage Site, with a unique natural scenery of thousands of limestone islands. Ha Long Bay provides a fine example of conflicts to be analyzed in a framework of competition for control of (natural)
CASE STUDY AREA

Introduction

Quang Ninh province, bordering the P.R. of China, is part of the Northern strategic economic development triangle Hanoi-Hai Phong-Quang Ninh (Figure 1). Quang Ninh is the heart of Vietnam’s coal industry, which employs about 71,000 workers. In 1997, coal output reached over 10 million tons, of which 3 million ton were exported from Ha Long City. However, the coal mining sector has a poor environmental record. Ha Long Bay is a priority area for tourism development; the number of visitors increased steadily in the 1990s and reached 400,000 tourists in 1997. Finally, planning focuses on the development of Cai Lan port, adjacent to Ha Long City. With the ad hoc development of different economic sectors, the environmental situation deteriorated, while major industrial developments are planned for Cai Lan Port, again with little environmental consideration. In response, a comprehensive

![Fig.1 Location of Quang Ninh province](image)

a. they are not integrated and non co-ordinated; as such, strategies proposed in one plan do not reflect priorities proposed in others;

b. they do not incorporate environmental issues; in particular, limited attention is paid to the medium and long term implications on environmental quality or the conservation of natural resources.

c. as a result of a) and b) they do not address fundamental trade off between: a) infrastructure, transportation, industrialisation, and tourism development; b) between development and the environment.

The change in the area is structural, involving shifts from historically dominant to newer types of economic activities. Important development trade offs need to be made and many are environmental in nature. Planning is the responsibility of many different agencies, depending on whether it is municipal, spatially oriented, or focused on the setting of socio-economic targets. The capacity of local and national institutions to make these trade offs through integrated planning and management is weak and insufficient.

The impact of the East Asian crisis on Vietnam is severe. Hai Phong and Quang Ninh experience significantly lower export demand and an investment collapse: the expected growth rates have fallen dramatically. The regional crisis appears to have changed the rules of the game. There is an urgent need to revisit existing development plans and to develop a framework for strategic growth. The current options may result in excess infrastructure capacity. Careful review and selective modification of the current development plans can generate a viable alternative to the status quo (World Bank, 1999).

Master Development Plan of Ha Long City (1994-2010)

The Master Plan for Socio-economic Development of Quang Ninh Province (1996-2010), highlights the following
development goals (Vo Van Kiet, 1997):

a. to build Quang Ninh into a province of high, steady and sustainable development..., achieving the main
targets in economic growth and social progress and preserving the ecological environment;
b. to transform Quang Ninh into an industrial, trade, service and tourist centre.

The Master Plan of Ha Long City (1994-2010) outlines the orientation of long term socio-economic and spatial
development (NIURP, 1994). The Master plan contains no comprehensive zoning plan and whatever spatial
planning was undertaken, it is too general and insufficient to ensure that development occurs with regard to the
environment. Little attention has been paid to factors that influence the development process (preplanning land
uses and constraints, external forces such as (foreign) investment and government policies). From an integrated
coastal zone management perspective, a number of disfunctional characteristics have been identified in the area.
These clearly stem from insufficient segregation of incompatible uses to minimize negative impacts (ADB, 1996):

a. The tourism zones containing the major hotels are adjacent to a coal and an oil port;
b. The marine transportation route runs directly through Ha Long Bay;
c. Urban development is degrading the scenic views of Ha Long Bay;
d. Coal mine overburden dumps are well within the view of the road and the near shore areas;
e. Marine morages of coal barges exist throughout Ha Long Bay;

Also, a number of coastal and marine environmental issues have been identified, that are of consequence to
current and future investment and development patterns (ADB, 1996):

a. Increased urbanization; without investments, environmental quality will further degrade;
b. Environmental effects of rapid tourism development, including unplanned physical development, conflicts
with other uses, pollution and ecological impacts;
c. Environmental effects of transportation; the most significant issue is the proposed Cai Lan Port;
d. Constraints on development of the new economy from coal mining and transportation;

As such, it is an immediate priority to include the environment into the planning of new projects and to co-ordinate
closely with efforts to incorporate environmental considerations into regional planning. As the current Master plan
does not consider the threats to natural resources, it is advocated that an Environmental Assessment (EA) of the
plan be conducted urgently. The recommendations of the EA report and of the environmental management plan
being developed should be used in the revision of the plan (Nippon Koei Ltd. and Metacean Ltd., 1997).

Strategic Environmental Assessment

Environmental Impact Assessment (EIA) is applied mainly at the project level. Strategic Environmental
Assessment (SEA) is a relatively new concept, aimed at the application of Environmental Assessment to higher
levels of decision making. Basically, SEA is a pro-active process, to insure the full integration of environmental
considerations into the earliest stages of policy, plan and programme (the 3P's) development, on a par with
economic and social considerations. There is a growing consensus on its need, as to realize the goals of
sustainability (EPA Australia, 1996; UNEP, 1996). Worldwide, SEA is a field of intensive research and practice

There is little experience with SEA in South East Asia and Vietnam in particular. In 1994, EIA was formally
introduced in Vietnam with the Law on Environmental Protection. Decree GD 175/CP states that EIA should be
conducted for specific projects but also for overall strategies for regional development, strategies and plans for
provinces and cities and strategies for urban and population development.

There is a high interest in SEA in Vietnam and capacity building "to carry out Environmental Assessment of
development activities of a higher degree of complexity and development of appropriate methods for regional
planning, industrial areas, master planning, and cumulative and Strategic EA" is recommended (Le Thac Can,
1997). The Ministry of Planning and Investment (MPI) is actively supporting attempts to incorporate
environmental considerations into higher levels of decision-making (DSEE, 1998).
Environmental Assessment and GIS: The Necessity of Database Establishment

Geographical Information Systems (GIS) can serve as a valuable tool for E(l)A and has a role to play in improving Environmental Assessment effectiveness. (Joao and Fonseca, 1996). Eedy stresses the advantages of the use of GIS in EIA; management of large data sets, data overlay and analysis of development and natural resources patterns, trend analysis, data sources for mathematical impact models, habitat and aesthetic analysis and public involvement (Eedy, 1995). Antunes et al., outline that attempts to utilise GIS in EIA demonstrated that GIS can have a wide application in all EIA stages, acting as an integrative framework for the whole process, from the generation, storage and display of the thematic information relative to the vulnerability/sensitivity of the affected resources to impact prediction and finally for their evaluation for decision support (Antunes et al, 1996). However, currently GIS is used in EIA practice mainly as a tool to manage baseline information and is frequently restricted to map production and report preparation. Joao concludes that the full power of GIS has not been fully explored, yet (Joao and Fonseca, 1996).

GIS can be useful in cross sectoral and regional development, for example in coastal zones, as a powerful tool to identify and analyse site and design alternatives. (World Bank, 1993 and 1995).

In an SEA framework, GIS can prove particularly useful for the evaluation of cumulative impacts. Smit and Spalding stress the potential of GIS for this type of analysis, arising from the ability to consider the spatial component and to allow the analysis of the temporal evolution (Smit and Spalding, 1995).

OBJECTIVES

The objectives of the project "Capacity Building for Environmental Management in Vietnam" fit into these priorities. Next to strengthening project level EIA, the project aims to conduct an SEA study. As such, the project supports Capacity Building in SEA in Vietnam (Nierynck, 1997).

A GIS database is established for the study area. As such, the SEA, which aims at investigating the cumulative impacts of the development of different economic sectors (coal mining, tourism, Cai Lan port), is structurally organised. Basically, the SEA addresses the development activities as outlined in the Master Plan of Ha Long City. The case study does not focus on scientific aspects of the establishment and operation of a GIS-database, but on the demonstration of how GIS (and Remote Sensing) techniques can be useful to support improved Environmental Assessment. The output also focuses at producing different development scenario’s for the authorities and objectifying present environmental conflicts.

MATERIALS AND METHODS

Database Design for Environmental Assessment

The database is established to support the environmental assessment of the impact of the Master Development Plan of Ha Long City (1994-2010). It partially provides opportunities to realize a strategic environment assessment of the Master Plan. To fulfill these targets, the database should contain major information on the current status of surface natural resources (land cover/land use), topography, infrastructure, population, coal mining industry, tourism and the development plan of Ha Long City.

As the application of GIS for environment assessment is rather new in Vietnam, the effort has both research and application characteristics.

The study area covers two geographical levels:

a. the "Core area", which includes Bai Chay-Cua Luc and Hong Gai;

b. the "Extended area", which covers Bai Chay-Cua Luc-Hong Gai-Cam Pha-Cua Ong.

The layout of the study area is visualized on Fig. 2. The background image is MOS-1 MESSR of 1996. On this figure, the extended study area is limited by the background image and the core study area is bordered by the green line. The database for the extended area is established on the basis of 1/50 000 topo maps and LANDSAT TM satellite image; the database for core study area is based 1/10 000 topo maps and aerial photographs.
The environment assessment of the Master Plan of Ha Long City requires the database to enable the:

a. determination of the past and current status of land cover/use and identification of patterns of change during the past 10 years (1988 – 1998);

b. assessment of the impact of infrastructure, industry and tourism development on the environment according to the Master Plan of Ha Long City for the period 1994 – 2010;

c. recommendations of modification of the Master Plan, which could reduce the impacts of development to the environment;

d. trial application of GIS for strategic environmental assessment.

Fig.2 Extended and core study area
(background image MOS-1 MESSR image of 1996, courtesy of NASDA).

To fulfill the objectives, the following information is collected & archived in the database (Table 1):

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographical base map</td>
</tr>
<tr>
<td>Administrative boundaries</td>
</tr>
<tr>
<td>Land cover/ use</td>
</tr>
<tr>
<td>Digital Elevation Model (DEM)</td>
</tr>
<tr>
<td>Population</td>
</tr>
<tr>
<td>Tourism facilities</td>
</tr>
<tr>
<td>Coal mining facilities</td>
</tr>
<tr>
<td>Ecology and habitats</td>
</tr>
</tbody>
</table>

Table 1: information collected and archived in the database

**Materials**

The current database has been established by drawing on the following information sources:

a. Topographical maps UTM 1/50 000 printed in 1997

b. Topographical maps GAUSS 1/10000 printed in 1998

c. LANDSAT TM image observed on February 17, 1998


e. Ground truth data collected in May and November 1998
Tools

Hardware: IBM PC Pentium II 300 MHz, 512 Mb RAM

Software: PCI EASI/PACE 6.2 & SPANS Explorer, MapInfo, WinASEAN 3.0

Other equipment:
- Handycam SONY CCD-TRV62
- GPS camera Konica LandMaster

Methodology

Land Use / Cover Mapping by LANDSAT TM Image

The LANDSAT TM image (February 17, 1998) utilised, is multi-spectral data with 7 spectral channels and 30 m ground resolution. As the purpose of the study is environment assessment, the following legend has been used for interpretation (Table 2):

<table>
<thead>
<tr>
<th>Code</th>
<th>Land use / cover category</th>
<th>Code</th>
<th>Land use / cover category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No data</td>
<td>13</td>
<td>Wet rice field</td>
</tr>
<tr>
<td>1</td>
<td>Dense forest</td>
<td>15</td>
<td>Rice field and secondary crop</td>
</tr>
<tr>
<td>2</td>
<td>Sparse forest</td>
<td>16</td>
<td>Bare land</td>
</tr>
<tr>
<td>3</td>
<td>Forest plantation</td>
<td>17</td>
<td>Dry bare land</td>
</tr>
<tr>
<td>4</td>
<td>Scrub land</td>
<td>19</td>
<td>Dry agricultural field</td>
</tr>
<tr>
<td>5</td>
<td>Grass land mixed with scrub</td>
<td>20</td>
<td>Built – up area</td>
</tr>
<tr>
<td>6</td>
<td>Grass land</td>
<td>24</td>
<td>Clear water</td>
</tr>
<tr>
<td>8</td>
<td>Settlement in rural area</td>
<td>26</td>
<td>Scrub on limestone</td>
</tr>
<tr>
<td>9</td>
<td>Urban settlement with dense tree coverage</td>
<td>28</td>
<td>Open-pit coal mining</td>
</tr>
<tr>
<td>10</td>
<td>Urban settlement with sparse tree coverage</td>
<td>30</td>
<td>Shrimp farm</td>
</tr>
<tr>
<td>11</td>
<td>Mangrove of sparse leave coverage</td>
<td>32</td>
<td>Turbid water</td>
</tr>
<tr>
<td>12</td>
<td>Mangrove of dense leave coverage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Legend used for satellite image interpretation

The legend contains many anthropogenic land cover/land use categories, that are difficult for digital classification. As such, digital image enhancement has been complemented with visual interpretation. The interpretation has been supported by ground truth checking through extensive field work. To achieve the best interpretation results, the authors have used different false color composites to enhance the different land cover/land use categories. The following channel combinations have been applied: combination 1: Red = 4, Green = 3, Blue = 2; combination 2: Red = 5, Green =4, Blue =3; combination 3: Red = 4, Green = 5, Blue = 7. The color combinations can be changed at any time during on-screen digitizing. Prior to the interpretation, the image was geometrically corrected and geo-referenced to UTM map projection. The accuracy of the geometric correction was within 2 pixels. The error is due to the hilly terrain characteristics of the study area. Better accuracy can be achieved by ortho-rectification with digital elevation model (DEM). A portion of Ha Long City is displayed on LANDSAT TM image with false color composite Red =4, Green =5, Blue =7 (Fig. 3).
Land Use / Cover Mapping by Series of Aerial Photographs

The series of aerial photographs have been interpreted visually using the following land cover/land use categories (Table 3):

<table>
<thead>
<tr>
<th>Code</th>
<th>Category</th>
<th>Code</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Settlement</td>
<td>7</td>
<td>Lake, reservoir</td>
</tr>
<tr>
<td>2</td>
<td>Rice field</td>
<td>8</td>
<td>Scrub</td>
</tr>
<tr>
<td>3</td>
<td>Mangrove</td>
<td>9</td>
<td>Pine trees</td>
</tr>
<tr>
<td>4</td>
<td>Tidal flat</td>
<td>10</td>
<td>Aqua-culture</td>
</tr>
<tr>
<td>5</td>
<td>Sparse forest</td>
<td>11</td>
<td>Bare hill</td>
</tr>
<tr>
<td>6</td>
<td>Dense forest</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Legend used for aerial photograph interpretation

The interpretation results were transferred to 1/10 000 topographical maps and projected to UTM to enable overlay on the 1/50 000 database. Fig. 5 shows Ha Long City as visualized by aerial photograph. The interpretation result is displayed on Fig. 6. For the 1969-1971 period, 57 photos have been interpreted; for the 1985 period, the number of interpreted photos totaled 50 and for 1993, 96 photos have been interpreted.
Figure 4: Interpretation result of LANDSAT TM image (February, 17, 1998)

Fig. 5 Ha Long City as seen by aerial photograph (1993)
Digitizing of Topographical Maps at 1/50 000 and 1/10 000 Scale

Topographical maps at 1/50 000 scale have been used for the establishment of the database for the extended study area. The maps published on 1997 are new versions of a previous edition. Most information, such as administrative boundaries, infrastructure, roads has been upgraded. However, some other information remains the same as in the original map, released in 1965. As such, discrepancies are identified between the information covered in the map and actual field observation. Nevertheless, the maps can still be used as geometric reference for thematic information. Seven sheets were digitized by on-screen digitizing technique. This technique offers the most accurate results. However, it requires a powerful computer configuration: IBM PC computers with 256 and 512 Mb of RAM have been used for this purpose. The name and the nomenclature of the 1/50 000 topographic sheets that were digitized are listed in Table 4.

<table>
<thead>
<tr>
<th>Map name</th>
<th>Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam Pha</td>
<td>6451-II</td>
</tr>
<tr>
<td>Ha Long</td>
<td>6450-IV</td>
</tr>
</tbody>
</table>
The same digitizing technique has been applied for topo-maps at 1/10 000 scale. These maps were compiled from aerial photography recorded in 1993. The name and the nomenclature of the 1/10 000 topographic sheets are listed in Table 5.

The digitized information, such as hydrographic features, human settlements, road and railway infrastructure, and many other information components have been organized into different layers so that further computation could be realized.

One of steps that consumes substantial time and effort is manual contour line digitizing, for both 1/50 000 and 1/10 000 scale maps. The digitized contour lines are used for digital elevation model (DEM) establishment. The DEM will be used for three dimensional perspective view generation, slope and aspect computation and drainage system generation.

To support image classification and thematic information collection, several field trips have been realized to the study area. Information on land cover and land use has been collected by using a video recorder and Konica LandMaster GPS camera. The GPS camera with a built-in GPS chip provides information such as date and time, geometrical co-ordinates and bearing captured on the film media together with image. This information combination represents an excellent tool for accurate data registration and enhances the efficiency of the in-house work.
Fig. 8: Impact of coal mining on human settlements and agricultural cultivation. The image was recorded by Konica LandMaster GPS camera.

PRELIMINARY ANALYSIS OF IMPACT OF MASTER DEVELOPMENT PLAN OF HA LONG CITY ON ENVIRONMENT

The Master Development Plan of Ha Long City (1994-2010) is one of the baseline documents for environmental assessment. The spatial map of development orientation has been digitized and overlaid on the established database to initiate preliminary assessment. Fig. 9 displays the spatial map of the Master Development Plan.

Prior to actual assessment of the Master Development Plan, a quantified inventory of land cover/land use categories has been carried out, based on the LANDSAT TM satellite image and topographical maps. The results...
of both inventories are outlined in Table 6. Subsequently, the results of both interventions have been compared.

Topographical maps in Vietnam reflect land cover/land use status of some date in the past. A change study can be performed to show trends and patterns of land cover/land use change in the study area. Mangrove and forest cover, for example, constitute one of the most important environmental indicators. According to the topographical maps, the mangrove area in the study area totals 81,851,965 m$^2$, of which 33,445,407 m$^2$ (about 40%) is located in Cua Luc estuary. From satellite image, the total mangrove area is calculated at 38,928,128 m$^2$. It means that only 47.6% of mangrove remains, when compared with topographical maps. In Cua Luc estuary, the mangrove cover interpreted from satellite image is 21,660,916 m$^2$ which is about 64.8% of the area indicated on the topographical maps. The most drastic change of mangrove, concerns the ones distributed along the coastline. While on the topographical maps coastal mangroves (excluding the mangrove in Cua Luc estuary) total about 48,410,492 m$^2$, the actual area of mangrove calculated from LANDSAT TM image is only 17,267,213 m$^2$. As such, only 35.7% coastal mangrove area remain.

According to the topographical maps, the forest area (excluding mangrove) is about 409,202,958 m$^2$. However, from satellite image 260,757,511 m$^2$ of forest only can be interpreted. It means that about 148,445,447 m$^2$ of forest has been cleared for different purpose.

<table>
<thead>
<tr>
<th>Code</th>
<th>Area [m$^2$]</th>
<th>Category</th>
<th>Code</th>
<th>Area [m$^2$]</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>554217</td>
<td>Dense forest</td>
<td>1</td>
<td>330521</td>
<td>Rocky beach</td>
</tr>
<tr>
<td>2</td>
<td>128295825</td>
<td>Sparse forest</td>
<td>2</td>
<td>62224729</td>
<td>Muddy tidal flat</td>
</tr>
<tr>
<td>3</td>
<td>66700933</td>
<td>Forest plantation</td>
<td>3</td>
<td>2546707</td>
<td>Sand beach</td>
</tr>
<tr>
<td>4</td>
<td>102483870</td>
<td>Scrub</td>
<td>4</td>
<td>28396839</td>
<td>Settlement</td>
</tr>
<tr>
<td>5</td>
<td>54689715</td>
<td>Scrub and grass</td>
<td>5</td>
<td>6621509</td>
<td>Seasonal flooding area</td>
</tr>
<tr>
<td>6</td>
<td>4067815</td>
<td>Grass land</td>
<td>6</td>
<td>236996497</td>
<td>Sea and water body</td>
</tr>
<tr>
<td>7</td>
<td>32223619</td>
<td>Village</td>
<td>7</td>
<td>689899</td>
<td>Salt field</td>
</tr>
<tr>
<td>8</td>
<td>37681966</td>
<td>Urban settlement with dense tree coverage</td>
<td>8</td>
<td>18603753</td>
<td>Scrub</td>
</tr>
<tr>
<td>9</td>
<td>31705963</td>
<td>Urban settlement with sparse tree coverage</td>
<td>9</td>
<td>936692</td>
<td>Industrial tree plantation</td>
</tr>
<tr>
<td>10</td>
<td>28074887</td>
<td>Mangrove with low coverage</td>
<td>10</td>
<td>88198715</td>
<td>Rice cultivation</td>
</tr>
<tr>
<td>11</td>
<td>10853241</td>
<td>Mangrove with dense coverage</td>
<td>11</td>
<td>81851965</td>
<td>Mangrove</td>
</tr>
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<td>12</td>
<td>29368092</td>
<td>Wet rice field after harvest</td>
<td>12</td>
<td>409202957</td>
<td>Forest</td>
</tr>
<tr>
<td>13</td>
<td>1412527</td>
<td>Rice field</td>
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<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>14</td>
<td>1418518.388</td>
<td>Bare land</td>
<td>14</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>15</td>
<td>104788.986</td>
<td>Dry bare land</td>
<td>15</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>16</td>
<td>1807407.691</td>
<td>Dry agricultural field</td>
<td>16</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>17</td>
<td>1340657.501</td>
<td>Built-up area</td>
<td>17</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>18</td>
<td>19896599.49</td>
<td>Low tidal flat</td>
<td>18</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>19</td>
<td>39566611.34</td>
<td>High tidal flat</td>
<td>19</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>20</td>
<td>284051845.8</td>
<td>Clear water</td>
<td>20</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>21</td>
<td>27524569.65</td>
<td>Sparse forest and scrub on limestone</td>
<td>21</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>22</td>
<td>8265159.953</td>
<td>Grass on limestone</td>
<td>22</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>23</td>
<td>48011291.96</td>
<td>Coal mining</td>
<td>23</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
<tr>
<td>24</td>
<td>1162806.006</td>
<td>Coal overburden</td>
<td>24</td>
<td>128919946</td>
<td>Bare land</td>
</tr>
</tbody>
</table>
Following the overlay of the spatial map of the Master Development Plan on thematic maps, the authors carried out a preliminary assessment of the impact of the Plan on the environment. The impact is defined in terms of direct and indirect impact. Direct impacts are limited to the physical boundaries of the development project; indirect impacts include a buffer zone. As an example, Table 7 lists the direct and combined direct and indirect impacts of industrial development for the different land use categories, as a result of the full the realization of the Master plan. A buffer zone of 200m is considered for each industrial facility. Many resources in this buffer zone will be destroyed or moved out. As displayed in table 7, about 13.8% of total area of mangrove and 7% of the human settlements in the study area will be directly impacted by industrial construction; however, in the end, 20.5% of the mangrove area and 13.5% of the human settlements area will be affected, resulting from the combined direct and indirect impacts by realization of the Master Development Plan.

<table>
<thead>
<tr>
<th>Code</th>
<th>Direct impact</th>
<th>Direct and indirect impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>246957.6514</td>
<td>Coal storage and transition</td>
</tr>
<tr>
<td>30</td>
<td>7549046.124</td>
<td>Aqua-culture</td>
</tr>
<tr>
<td>31</td>
<td>76769944.77</td>
<td>Bare agriculture land</td>
</tr>
</tbody>
</table>

Table 6: Quantified inventories of land cover/land use
CONCLUSION AND FUTURE PROSPECT

This paper reports interim results of database development for environmental assessment. The importance and effectiveness of the application of database and GIS for environmental assessment has been demonstrated. The advantages of the GIS and database for environmental assessment can be highlighted as follows:

a. Ability to store large multidisciplinary data sets;

b. Identification of complex interrelationships between environmental characteristics;

c. Evaluation of change over time;

d. Ability for systematical updating and usage for different projects;

e. Input data source for a variety of mathematical models.

f. Capability of storage and manipulation of three dimensional data.

The database has been utilized for preliminary assessment of the environmental impact of the Master Development Plan of Ha Long City. As a next step the following activities will be realized:

a. Interpretation of the recently acquired LANDSAT TM image of 1988 and establish land cover change map for a 10 year period (1988-1998);

b. Update the database with socioeconomic and biological/ecosystems data, e.g. population, health, tourism and other information necessary for environment study;

c. Usage of the database to generate secondary scientific products in terms of tabular data and maps, indicating the impact of Master Plan from different environmental points of view;

d. Modeling of interactions between human activities and the environment, and if possible to generate impact scenario’s of different development alternatives on the environment in Ha Long City and the surrounding area.

It is the ambition of the authors to extend the geographical scope of the database to Hai Phong province, which with Ha Noi and Quang Ninh constitutes the strategic economic development triangle in North Vietnam. This area will be experiencing economy growth in the future, as well as environment problems. Without appropriate technology, such as remote sensing, GIS and database, problems may not be controlled and managed in a proper manner. Application of GIS and well developed database will certainly bring useful results and support planners in Vietnam to chose appropriate development alternatives with respect to environment consideration.

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REFERENCE


