Technical Letter

Using Remote Sensing Data for Coastal TT-Hue Province, Vietnam

- providing information for Integrated Coastal Zone Management -

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Abstract

The demand for and uses of Remote Sensing (RS) in a vulnerable coastal province, such as Thua Thien Hue (TT-Hue) province, in Central Vietnam is increasing. This Technical Letter focuses on the applications of RS for policy- and decision-making. The TT-Hue RS end-uses are embedded in a national setting within an Integrated Coastal Zone Management (ICZM) frame. Increased knowledge on natural and socio-economic, coastal processes is required for ICZM in TT-Hue province. RS and GIS are integrating and supporting tools 'pur sang', providing overviews on topography and land-uses, through temporal and spatial analyses. International exchange of tools facilitates ICZM programming. Vietnam and the Netherlands are cooperating in the field of ICZM since more than a decade. The Coastal Cooperative Program (CCP) increases the exchange between Vietnam and The Netherlands in the fields of physical, bio-chemical and societal processes. The CCP-Remote Sensing applications for TT-Hue province has greatly contributed to thematic mapping and has strongly increased the knowledge base of provincial coastal dynamic processes: flooding, erosion and changes in land-use and aquaculture. The Vietnamese national and provincial authorities and the local stakeholders increasingly appreciate the significance of RS applications for: hazard assessments, physical planning through zoning of functional uses, and sustainable exploitation of the TT-Hue coastal resources.

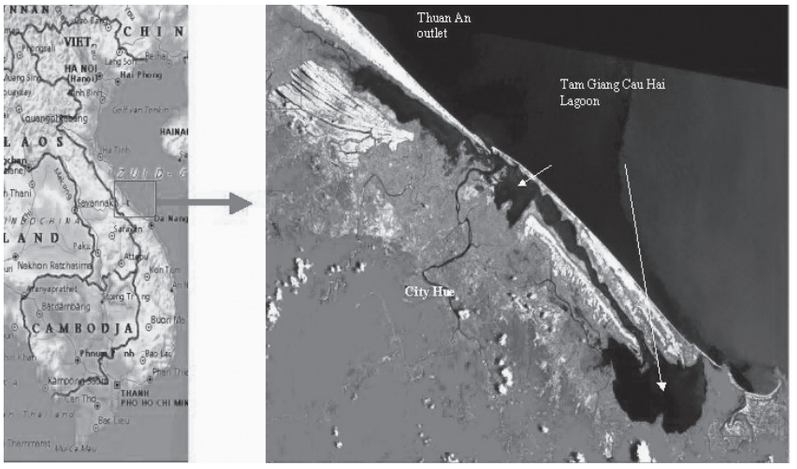


Figure 1: The coastal zone of Thua Thien Hue Province, in the centre of Vietnam, with the capital City of Hue includes the Tam Giang/Cau Hai Lagoon, the mountains, the rose coastal plain, the white sandy beach-barrier systems, the suspended sediment plumes (Landsat - Image, September 1, 1999. Source: Landsat.org, Center for Global Change and Earth Observations, Michigan State University (http://landsat.org); processed by the Remote Sensing Centre of Haiphong Institute of Oceanology, Haiphong, Vietnam).

1. Introduction

1.1 Remote Sensing related to ICZM

Integrated Coastal Zone Management (ICZM): This holistic management concept is acknowledged as an important adaptive mechanism by several international organisations such as UNCED- AGENDA 21, World Bank, Asian Development Bank (WCC'93) and the EU (EU, 2002). ICZM addresses present-day coastal problems as well as long term challenges such as impact of climate change, and is focused on the execution of sustainable, resilient, non-regret coastal solutions. Structured data collection and analyses are essential in the different phases of ICZM Planning and Implementation. Remote Sensing (RS) and Geographic Information Systems (GIS) are integrating ICZM tools, due to the fact that these tools encompass a specific (coastal) area, covering all the uses like human settlements, agriculture, aquaculture, fisheries, industry and nature in one image. Moreover sequential analyses of various remote sensing images may provide a quantified overview of changes of these uses and their impacts. These techniques contribute to the integration of spatial and temporal data dealing with natural and socio-economic coastal processes, so relevant for ICZM.

The UN-Intergovernmental Panel on Climate Change (IPCC) recommend ICZM as one of the main Adaptive Response options, the Vietnam Vulnerability Assessment *(VVA, 1996)* concluded that ICZM is the main Adaptive Response option for Vietnam.

ICZM process in Vietnam: With more than 3200 km long coastline and 50 million coastal inhabitants, Vietnam is a critical vulnerable coastal country (GVA, 1992). The Vietnamese coastal population and its economy are strongly growing. The present coastal vulnerability is large and will be increasing due to socio-economic pressure and envisaged impacts of climate change. These impacts are related to accelerated sea level rise and associated enlarged frequency and intensity of flooding and coastal erosion, changes in river discharges, increasing salt water intrusion through the river mouths and lagoon systems. Several million Vietnamese coastal inhabitants and the coastal rice productivity will significantly be affected by these impacts in case no adaptive measures are taken (GVA, 1992).

This Technical Letter is based on the results of two coastal Vietnam - Netherlands programs:

1) The Vietnam-Netherlands ICZM (VN-ICZM) project 2000-2004, which is simulta-

neously executed at Vietnam national and provincial levels (see: http://www.nea.gov.vn/projects/Halan/English/VNICZM_HomePage.html). This project is supported by the Royal Netherlands Embassy in Hanoi and the Dutch Consultancy Consortium: NeDeCo. A continuation of this project is presently being assessed.

2) The Coastal Cooperative Program (CCP): 2002-2004, supports the VN-ICZM project in specific coastal and water related fields, particularly in TT-Hue province. It aims to provide the TT-Hue provincial policy and decision-makers and local stakeholders with applied RS knowledge to assist solving their pressing policy concerns (CCP, 2002; 2003). The CCP is envisaged to continue by means of a Memorandum of Understanding (2004 - 2009) signed by the Vietnam Deputy Minister of Natural Resources and Environment (MONRE) and Netherlands Vice Minister of Transport, Public Works and Water Management (Min.V&W), spring 2004.

Most of the authors of this Technical Note are members of the CCP-Remote Sensing Task Group, which is coordinated by Mr. H.C. Thang (Vietnam Coordinator of CCP & Director of ICZM Division/Vietnam Environmental Protection Agency = VEPA/MONRE).

The problem setting in the TT-Hue Province and its relation to Remote Sensing:

TT-Hue Province and particular the large, valuable Tam Giang – Cau Hai Lagoon (Figure 1) are susceptible to coastal and river related hazards, such as flooding, coastal erosion, and to changes in land-use, urban and rural pollution and over-exploitation of the natural, coastal (fishery) resources. Two tidal outlets, Thuan An (mostly 6 m deep) and Tu Hien (mostly 1 m deep), connect the Lagoon with the Golf of Tonkin and determine largely the functioning of the lagoon, so relevant for human settling, safety, fishing, agriculture, shipping, water discharge and natural sediment transport to the sea.

Within the CCP frame, the TT-Hue Province and the coastal Districts policymakers have indicated their two main concerns dealing with present use and future sustainable development of the coastal resources, namely:

"What are the risks of flooding and pollution for the population", and

"How to assess the risks related to the Lagoon carrying capacity".

These concerns formed the base for the provincial CCP-RS data collection and analysis supported by the CCP Monitoring Program.

The CCP-RS efforts aim to effectively apply and disseminate the existing Vietnam national RS capabilities to the TT-Hue provincial level. The CCP-RS- TT-Hue results (CCP, 2002; 2003) were widely debated during several CCP Workshops in Hue and two intensive, two-weeks RS Training Courses (Hue, Nov. 2003 and Hanoi, Oct. 2004). These two courses were organised with the generous assistance of ITC (International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands) and supported by the Netherlands Organization for International Cooperation in Higher Education (Nuffic, The Hague). All these capacity building efforts will gradually increase the RS capabilities in TT-Hue province.

The RS analyses and applications further support the CCP-Monitoring Program on Shoreline Dynamics, Biodiversity and Environmental Quality. These combined data are input for GIS River Basin Modelling and 3-D Modelling of the Lagoon and Marine part of the Coastal Zone. These modelling efforts in its turn assist in the answering of the two main questions posed by the TT-Hue Province and coastal District leaders. All efforts will contribute to the creation of an ICZM-Zoning Plan for TT-Hue's coastal resources and assist in the execution of concrete ICZM coastal measures promoting sustainable development of the coastal zone.

2. TT-Hue Province: the CCP - Remote Sensing Products

At the request of the Provincial Peoples Committee of TT-Hue Province, the following seven Remote Sensing products were made available by the CCP-RS Task-Group. These products were

discussed during CCP Workshops organised in 2002 and 2003 (CCP, 2002; 2003) and during the CCP-ITC Training Courses in Hue-City, November 2003 and in Hanoi, November 2004 (ITC, 2004).

2.1 An inventory of RS images for TT-Hue was the start of the CCP-RS activities. For the first time, meta-information on satellite images of TT-Hue province was compiled and put into a database. More than 30 RS images of TT-Hue province are present within the cooperative CCP-Vietnam RS Institutes. A format for a meta-database is prepared for the TT-Hue RS images, derived thematic maps and information on sequential analysed images of the TT-Hue province (Figure 2).

This format is used in order to publish the information of meta-database on the Internet through the website of VN-ICZM project (www.nea.gov.vn/projects/Halan/English/VNICZM_HomePage/RSMeta-database), which will be linked to www.netcoast.nl (the website of the CZM-Centre, The Hague). In addition, standard available image data from Internet sources (free of charge) such as the Global Land Cover Facility (GLCF: http://glcf.umiacs.umd.edu) were introduced.

2.2 Nine thematic maps at a scale of 1/100,000 were made available for a 100 km long coastal zone of TT-Hue. These maps are produced by the RS-Centre of MONRE (RSC-MONRE, 2000), using 1965 topographic maps and analysing 1990 and 2000 SPOT, LandSat ETM, RadarSat imagery, as a part of a larger project covering more than 850 km of the coast of Vietnam. This set of thematic maps encompasses: i) General Geographic (Figure 3), ii) Land-use, iii) Urbani-sation and Infrastructure 1965-1990 -2000, iv) Wetlands, v) Mangrove map, vi) Coastal Erosion, vii) Flooding, viii) Ecology, ix) Environmental sensitivity. This set of nine maps provides a basic level of information for a large part of the TT-Hue's coastal zone.

Moveover, these RS derived thematic maps provide useful, preliminary elements to the essential steps in the ICZM process, e.g. delineating the coastal zone and its impacting areas, and the coastal administrative zones and the functional uses.

2.3 Land-use changes in hinterland: re- and deforestation, human settlement, agriculture expansion and dam construction impact the coastal zone. These upstream human interventions including impacts of soil erosion, cause downstream changes in water availability, in flooding regimes, in sedimentation patterns and increase of salt content of surface water and of coastal erosion. Sequential image analyses combined with ground thruthing (1966 – 2000, Center of Data Information and Mapping - CEDIM/FIPI) originally at a national scale using US-Picture Map'66, Landsat MSS'79, Landsat TM'89, SPOT'96 and Nat. Forest Map (2000) were applied for TT-Hue Province (CCP, 2002; 2003). These analyses revealed large changes (Figure 4). Forest cover decreased strongly (halved) during the first period (1966-1979: from over 300,000 to 150,000 ha). This is mostly due to herbicide spraying between 1962 and 1975. While the reduction thereafter by making open land for agriculture and human settlement was more gradually. The effects of subsequent reforestation are noticeable in slowing down the decrease of forest cover and even significantly increasing the forest cover during the last decade. The human settlement area in the province has increased gradually and has doubled in 35 years (from 8,600 to over 17,000 ha). The agriculture area is almost constant, at a level of 90,000 ha, during the last two decades.

Changes in forest cover influence the rate of soil erosion in the mountains and the sediment transport by the rivers to the coastal zone, effecting the long-term functioning and sediment-filling of the Tam Giang – Cau Hai Lagoon system. CCP made some rough preliminary estimates on the rate of soil erosion in the mountains of TT-Hue by applying the USLEquation in a GIS setting. This led to an estimated rate of soil loss of several tens of millions tons of sediment annually from the mountains of TT-Hue province towards the Tam Giang Lagoon (CCP, 2002;

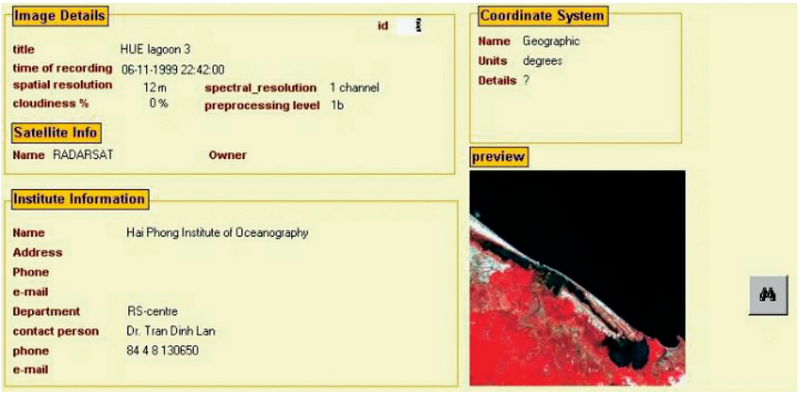


Figure 2: Template of the RS-Meta-Database

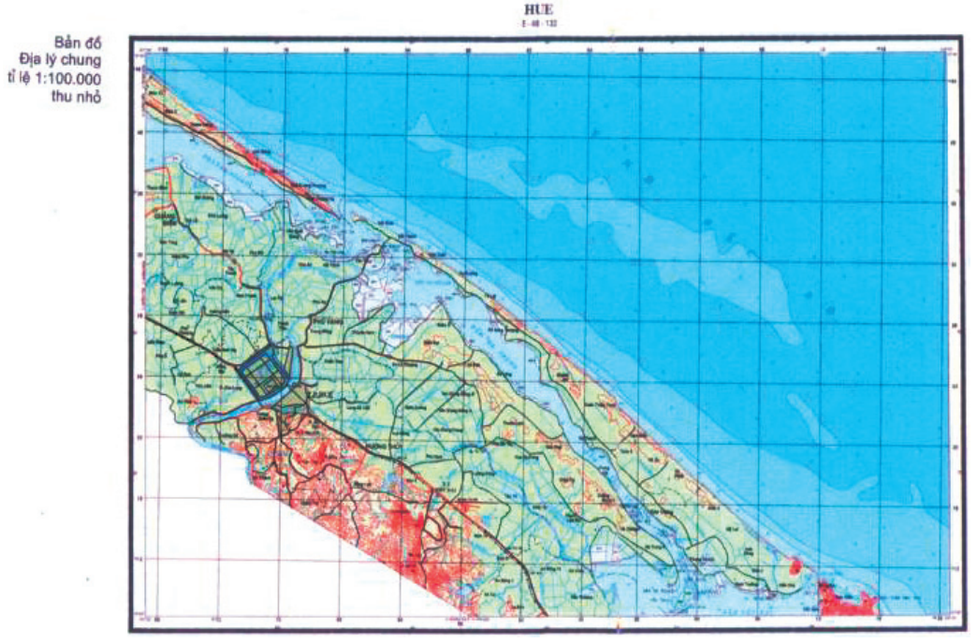


Figure 3: General geographic map, one of the nine thematic maps (Remote Sensing-Centre MONRE, Hanoi; see for more information http://www.monre.gov.vn)

2003). The rate of sediment filling of the Lagoon is yet unsure due to incomplete knowledge on sediment balances. A major cause of uncertainty is the unknown quantity of sediment transported from the Lagoon to the sea, mainly during floods.

2.4 Aquaculture in the Tam Giang-Cau Hai Lagoon: is exponentially increasing, from the community Huong Phong in the north to Sai and Dien Hai in the south, during the last decennium (Table 1). RS can be instrumental to analyse the numbers and surface area of aquaculture ponds (Figure 5). The strong increase in the aquaculture area is specially observed in the northern part of the Tam Giang Lagoon. The shrimp productions according to the Department of Fisheries of TT-Hue Province increased also strongly, particularly during the lasts years.

Not only the aquaculture on the borders of the Tam Giang Lagoon increased, also the net-fisheries covering in a systematic way a large part of the Lagoon as can also be seen from the Quick-

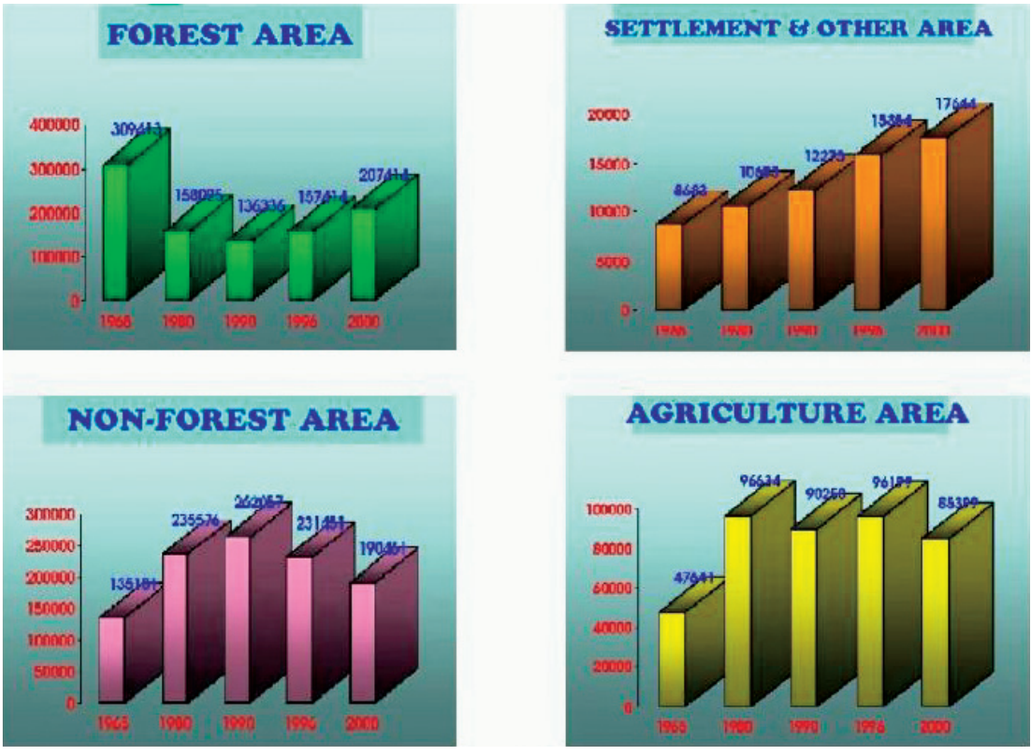


Figure 4: Land use changes in TT-Hue in hectares for the years: 1966, 1979, 1989, 1996, 2000 (CEDIM/FIPI)

Looks of very high resolution IKONOS-images (www.spaceimaging.com: see Quick Look Hue, Cau Hai, September 5, 2003).

Observations and analyses are the base to solve the question whether these exponential increases in fishery activities are still within the borders of sustainable exploitation. Answering this question posed by the Provincial policy-makers is one of the CCP challenges. As recent experiences in Thailand reveal, there is great potential danger in damaging the basic, coastal resources through non-sustainable development of aquaculture.

The value of these Remote Sensed data, properly entrusted, is apparent; it increases the monitoring knowledge for policy preparation and contributes to well-balanced decision making in the TT-Hue province.

2.5 Shoreline changes of the 170 km long TT-Hue Province shore influence the living conditions of coastal inhabitants. The TT-Hue shore exists mainly of sandy sediments and at several places severe erosion takes place (Figure 6). Some rocky mountains outcrop in the south. The 120 km long, sandy beach barrier naturally protects the Tam Giang Lagoon and the low-lying coastal zone from flooding.

The shoreline is the boundary line between land and sea. More detailed definitions are taking into account a two-dimensional reference- surface: mean sea level and sometimes including the third-dimension – the coastal profile (Min.V&W,

Table 1: Exponential increase of Aquaculture Area in Tam Giang – Cau Hai Lagoon, TT-Hue

Year of RS observation	Aquaculture ponds in hectares
1989	100
1997	265
2001	1310
2002	2900

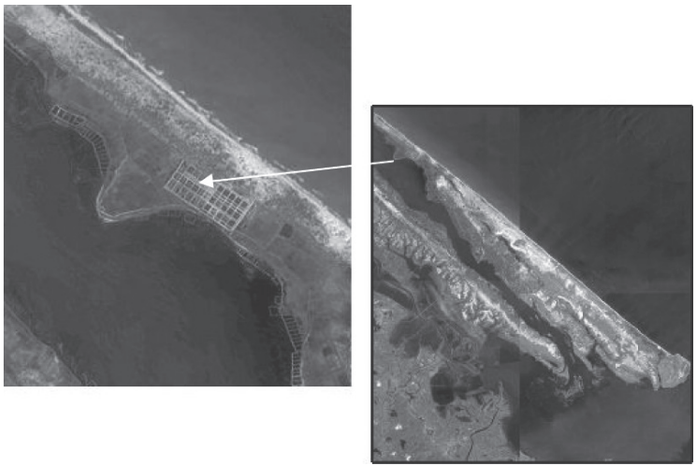


Figure 5: IKONOS-Quick Look displays the presence of aquaculture ponds on the border of southern part of the Tam Giang - Cau Hai Lagoon system; right the overview, left the zoom-in picture (IKONOS – Image, September 5, 2003. Source: Ikonos data © Space Imaging. Distributed by RADARSAT International under licence from Space Imaging; downloaded from internet: www.spaceimaging.com.; analysed by the Remote Sensing Centre of Haiphong Institute of Oceanology, Haiphong, Vietnam).

1990), all related to a national triangulation system. The RS reflection of a shoreline is well captured by the visible and near-infrared bands of Landsat TM as well as by the contrast-rich delineation in a Radarsat Image (showing textural differences).

The important question in comparing remotely sensed shorelines in time is: "What do these observed differences represent?"

The answer is hidden in the state of the sea (level) during the pass-over of the Satellite sensor. In the absence of a Vietnam beach-landmark system, the Haiphong Institute of Oceanology formulated geometric corrections for the actual shoreline based on information of lunar, astronomic tide, meteorological wind surge/set-up at the moment of the pass-over, and on the steepness of beach profiles of coastal stretches surveyed (CCP, 2003).

Several sets of RS images were compared:

1) A long term period of 8 years between Landsat-TM 8/1/1992 and 6/11/2000 images (Figure 7(a)), both taken during the north east monsoon, wet season and
2) Seasonal periods covering two dry season images: 3/4/1997-ADEOS/AVNR, 1/9/1999- Landsat/ETM and two monsoon Landsat/ETM images: 6/11/2000, 25/11/2001- Figure 7(b).

The most dynamic coastal areas are located around the two outlets near Thuan An and Tu Hien. Remarkable is the pattern of alternating strong erosion and accretion: up to tens of meters of change is recorded in a short period of less than one year. Considering a longer period (1992-2000) the amplitude of these oscillations are smoothed out and averaged retreat and accretion of 10 – 30 m/8 years are observed. Seasonal changes are strongly influencing erosion and accretion patterns around the outlets. After a strong tropical depression (November 1999), the eroded sediments are largely brought back to the coast by tidal and onshore-currents during the dry season. The morphological dynamics of the outlets are characterised by dominant northern sediment transport, more or less closing off the outlets during the dry season. So now and then the outlets are opened by violent interruptions of high river discharges during typhoons/floods and by large waves. The coastal area between the two outlets, a 70 km stretch, and the coastal zone further north of Thuan An outlet are more or less stable: 'only' several meters of coastal shifts of the coastline are observed in 8 years. Ground truth data surveyed in the frame of CCP-Monitoring Program (coastal profiling) confirmed the RS observed coastal changes. This RS

based information assists in the ICZM prioritisation of adaptive coastal solutions.

2.6 Flooding assessment of the 2nd November, 1999 - tropical depression illustrates that the TT-Hue Province is very vulnerable for flooding from the sea by storm surges subsequently followed by flooding from the rivers (particular the Perfume River) through extreme high rainfall around Hue City. The typhoon, hitting the coast of TT-Hue Province caused severe flooding of the coastal zone, several tens of human casualties (among many fishermen) and millions of Dollars damage. During November 2 and 3, 1999, the typhoon induced precipitation amounted to more than 850 mm/24 hours observed by the Meteorological Station of Hue - City. RS can be instrumental to assess: i) the areas most sensitive for flooding, ii) the economic & ecological damages and iii) risk reducing solutions through proper zoning of the different functional uses (human settlements, agriculture, fisheries, nature conservation, tourism and shipping), and taking into account, iv) long-term impacts of Climate Change, such as accelerated sea level rise, changes in storm frequencies and intensities and river discharges.

A composite image (Figure 8) combines a Landsat of 01/09/1999 (Non-flooded) and a Radarsat image of 06/11/1999. The flooded area is indicated by purple colour, 4 days after the peak rainfall of November 2, 1999. The total flooded area was large and covered about three times the area of the Tam Giang lagoon during non-flooded situation. The hue of the purple colour is an indication of flooding depth: deep purple represent a water depth of about 4 – 5 m above ground level. The maximum flooded area, directly following the cyclone-outfall, must have been even much larger. The propagation velocity of the river waters, an important model characteristic, from the top of the highest mountains of TT-Hue, located in the South, to the lagoon amounts to about 10 hours. Further GIS-analysis of RadarSat images of November 10 and 15, 1999 showed that the extent of Tam Giang flooding is gradually decreasing (Table 2).

Sequential analysis of Radarsat images combined with a Digital Elevation Map (DEM) provided relevant spatial information on flood duration, flood depth for flood-sensitivity and damage assessments, and for coupling hourly water heights observed to water quantities (= river discharges m^3/sec) by means of STREAM (Villegas, 2004). STREAM is a GIS modelled Water Balance – Spatial and Temporal Management Tool applied in various river basins of the world including the river basins of the TT-Hue province (CCP, 2002; 2003). The computer-generated water quantities through STREAM during the November 1999 flood correspond rather well with the observed water quantities derived from RS and DEM analyses. STREAM results allow furthermore analyses of future situations related to flooding and water availability under scenarios of climate change and future water demand for drinking water, irrigation, industry and nature under population pressure scenarios (see analogue: Ganges-Brahmaputra-Meghna STREAM, 2000)

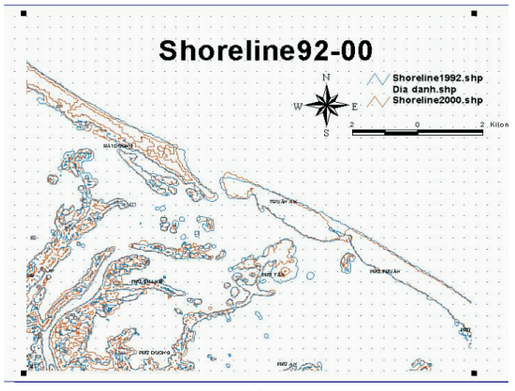
2.7 End-uses: Combining RS data with modelling, for planning purposes: is achieved by GIS coupling of the analytical results of RS (Water regimes and Land use changes) and STREAM to the 2/3 D WL Delft-Hydraulics Lagoon and Marine Modelling of coastal zone of TT-Hue. Analysis of remote sensing data for the TT-Hue province has shown that useful information can be derived from RS-GIS based on thematic mapping – Geography and Administrative boundaries and urban and rural settlements (Figure 9 (a)) and sequential RS analyses, from land-use changes to its effects on the state of the coastal zone.

In the TT-Hue-case, information on the area of rice culture and aquaculture (Figure 9(b)) were converted into loads of pollutants into the drainage basin (Nguyen 2004; Nga 2003). For this, information on water distribution and discharge of rivers into the coastal zone were derived from the STREAM model (Figure 9(c)). Based on the verified data, the hydrodynamics and water quality of the lagoon and the coastal

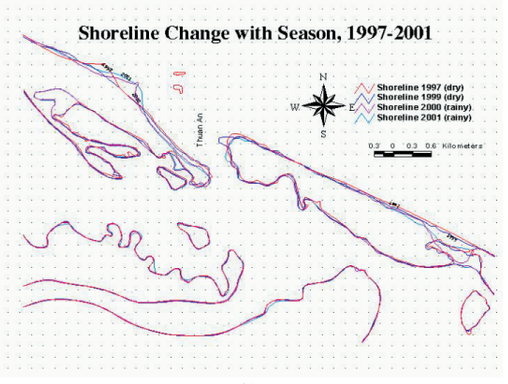
Figure 6: Eroding dune of Thuan An outlet looking from the sea into the Lagoon

Table 2: Flooded areas

Date 1999 RS images	Water surface In hectares
01/09: no-flood	22,600
06/11: flooded	63,150
10/11:: flooded	56,050
15/11: flooded	41,700



(a)



(b)

Figure 7(a): Shoreline changes at Thuan An outlet during 1992 – 2000;
(b) Seasonal shoreline changes at Thuan An: 1997 and 2001

zone are calculated with the help of the 2/3 D hydrodynamic and water quality model, (Delft 3D, Delft | Hydraulics: www.wldelft.nl ; Figure 9(c)). As a next step the calculated concentrations of pollutants were compared with Vietnamese water quality standards resulting in a calculation of areas where standards were violated. In this way the link between land use and ensuing impacts on the water system in the coastal zone became clear and future scenarios could be assessed (Nguyen, 2004).

An initial attempt determining the status of the carrying capacity of the coastal water system was made combining the impacts of strategies and scenarios. An integrated approach was created that allowed the effects of zoning of land use and other strategies, and climate change scenarios. These effects were related to risks, expressed by means of the following five status indicators: safety and flooding, effects of irrigation, fishing, and aquaculture (Figure 9(d)) and swimming water quality. The combination of field observations, RS analyses and modelling makes prognosis possible. Impact analyses of future land use and climate change - scenarios on the state of the coastal system are now within the reach at a provincial decision making level, for TT-Hue.

3. Concluding Remarks

RS and GIS: RS and GIS are growing tools for preliminary estimations of effects of natural and socio-economic developments in the TT-Hue Province. Sequential trends may, with care and

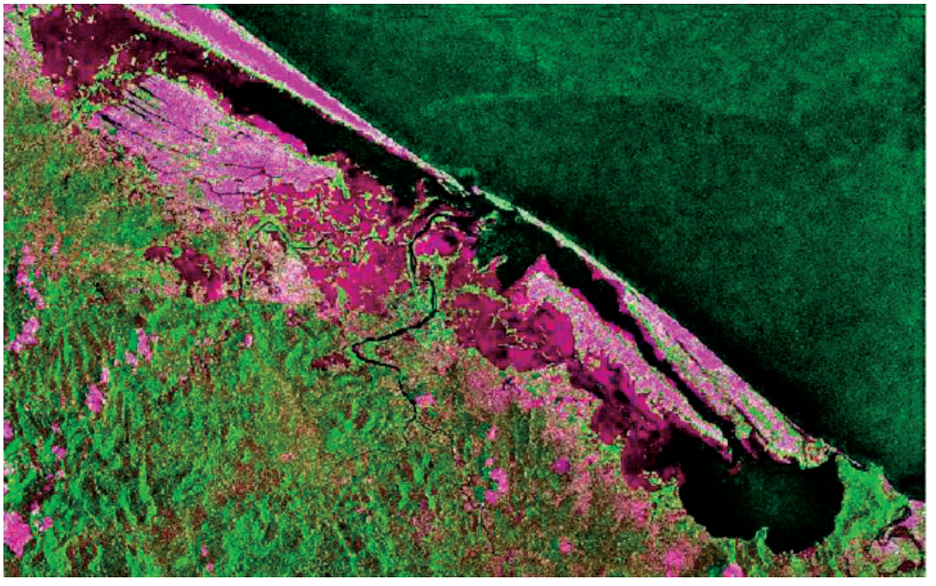
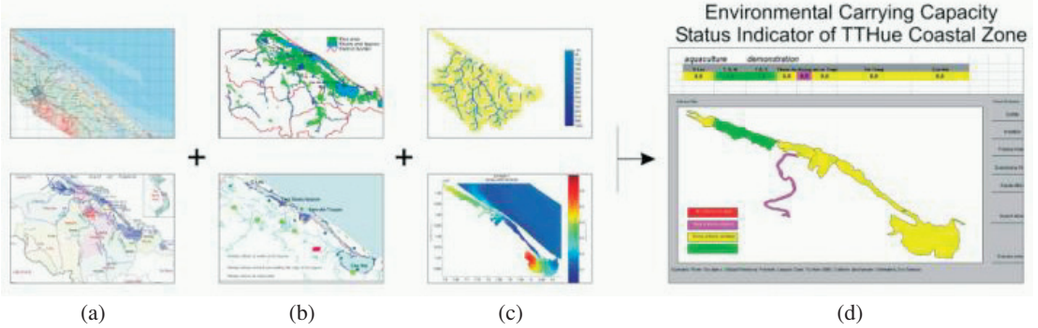


Figure 8: Composite image: LandSat of 01/09/1999 (Non-flooded) and a RadarSat image of 06/11/1999 (Flooded area = indicated by purple colour, 4 days after the maximum rainfall) (Sources: Landsat.org, Center for Global Change and Earth Observations, Michigan State University (http://landsat.org); Radarsat: RADARSAT data © Canadian Space Agency/Agence spatiale canadienne (year of acquisition: 2000); distributed under licence from RADARSAT International; received and processed by the Remote Sensing Centre of Haiphong Institute of Oceanology, Haiphong, Vietnam).



(a) (b) (c) (d)

Figure 9(a): Geographic Base Map & Coastal Districts and Rural Settlements, (b): Land-uses: Rice& Aquaculture, (c): Modelling: STREAM – river drainage and discharges & 2/3 D WL|Delft Hydraulic Lagoon + Marine water quantity and quality, (d): One of the carrying capacity state indicators, for: Aquaculture use

based on ground truth data, be extrapolated into the future.

Availability of RS data & expertise: Experiences from the TT-Hue case illustrate that a lot of data and expertise is already available in Vietnam for improving analysis of the dynamics of the coastal zone. These RS data and technology are largely available at the national level. The CCP has enhanced the link between the national and provincial level to transfer RS expertise, technology and data. This transfer to and capacity building at the provincial level was aided by the Vietnam national RS community and supported by CCP and ITC/Nuffic during 2003/4.

The end-users of Remote Sensing information in the TT-Hue province: The policy-makers of the Province and the coastal Districts, indicated their interest in closely monitoring the use of space and the provincial natural assets related to fisheries, agriculture, forestation and

human settlements. The results of RS and GIS analyses in the fields of coastal dynamics (sensitivity for erosion and flooding), the increase in aquaculture and fisheries, the changes of forestry in the mountains and agricultural land-use illustrated the power of RS. Combining the analytical results of RS, GIS and field monitoring with river basin-, lagoon- and marine modelling showed how the effects of future developments in the coastal zone and hinter-land-mountains, and the impacts of climate change can be estimated in a coherent way. Hence creating an "analytical toolbox" to assist the prognostication of the envisaged impacts of climate change and effects of policy options (related to changes in land-uses) on the development of the coastal zone ahead of implementation.

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