AN INTERACTIVE APPROACH TO SUPPORT NATURAL RESOURCES USE POLICY: A CASE STUDY IN THE VIETNAMESE MEKONG DELTA'S COASTAL AREAS

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ABSTRACT

The Vietnamese Mekong Delta is under great threats of climate change and sea level rise. In order to sustain the development of the area, an appropriate decision support approach should be developed, in which the natural resources and socio-economic dynamics are interactively considered. Such the approach should be able to: (i) support the participation of different relevant stakeholders in the society; (ii) support multi-scales and multi-disciplinary analysis; (iii) consider both spatial and temporal dimensions; and, (iv) help raise capacity of relevant stakeholders. In this paper, we present an example of the application of an interactive approach in the case study of Bac Lieu, a coastal province of the Vietnamese Mekong Delta, with the main focus on visualization to call for attention and sufficient contribution from local farmers, local and provincial governmental staffs, and national and international scientists. A decision support system was developed to help local and provincial government project changes under impacts of different climate change scenarios and institutional arrangements. In this approach, GIS plays an important role in visualization of the derived information to support decision-making.

Keywords: Natural resources policy, visualization, decision making, Vietnamese Mekong Delta.

1. INTRODUCTION

Even thought salinity-control infrastructure systems were built to prevent salinity intrusion for agriculture development in the coastal areas of the Vietnamese Mekong Delta (VMD), the area still faced risks as consequences of unexpected changes of natural resources and of unpredictable impacts of the developed constructions. The area was dealing with the conflicts between freshwater and brackish-water dependent land use systems (e.g. rice *vs.* shrimp) and between economic development and mangrove forest conservation (shrimp *vs.* forest) at both inside and outside of the salinity-controlled area (Ha et al. 2013; Trung 2006; Sakamoto et al. 2009). The situation would become worse under the threats of sea level rise (SLR) in the future (Nhan et al. 2011). With the less-favorable natural conditions, livelihood of local people in the coastal areas would be more vulnerable. This study in the coastal area of the VMD explores possibility for the area to adapt to SLR through land use planning in the case study of the Bac Lieu province. Based on detailed inventories of soils, hydrology and land use, yields and financial returns of different options will be compared. Promising land use systems with new technical level (e.g. new plants varieties and improved farming techniques), socio-economic settings (e.g. labor and levels of poverty) and environmental impacts (e.g. soil and water quality and quantity) were taken into account. This case study demonstrates how to involve stakeholders into a process of developing a master plan for climate change (CC) adaptation.

2. METHODOLOGY

2.1 Land Use Planning and Analysis System (LUPAS)

The LUPAS approach was developed under the Systems Research Network for Eco-regional Land Use Planning in Tropical Asia (SysNet) project (1996-2000) (van Ittersum et al.

2004). LUPAS addresses the questions "*what would be possible?*" or "*what would have to be changed?*"; therefore, it can be used for scenario analysis of complex problems such as proposing of land use strategy under CC and socio-economic change impacts. LUPAS has been applied for land use optimization in different parts of the VMD in tangible contexts and showed its capacity to overcome the limitations of a traditional top-down land use planning approach, in which achievements and impacts (of each land use system) were not sufficiently quantified and socio-economic conditions and technology development were not considered in details (Trung 2006, Hoanh et al. 2012). With its capacity of quantitative scenario analysis, LUPAS is suitable for analyzing land use systems under different socio-economic and CC scenarios.

LUPAS consists of three main parts: (i) Biophysical land evaluation, (ii) Socio-economic analysis; and, (iii) Interactive multiple goal linear programming. Based on the LUPAS framework, a model was developed by Trung (2006). For this study, the model was adapted. In addition, the GAMS modeling language (Rosenthal 2014) was used to perform Interactive Multiple Goal Linear Programming (IMGLP). The model includes the following modules:

In the *Biophysical land evaluation* module, biophysical land characteristics (e.g. soil and water) maps and administrative map are overlaid to delineate land mapping unit (LMU). This GIS's application helps incorporate socio-economic data collected from administrative units for the further evaluation stage. Soil and water characteristics, salinity intrusion, land uses, infrastructure data of the study area were obtained through remote sensing, soil survey and hydraulic modeling. The Biophysical land evaluation component is essential in determining resource availability (land area, labor, and capital) and identifying promising land use types (LUT) and possible technical levels applied in each LMU. The assessment of resource availability/constraint such as labor, capital, land or water were done by means of land use evaluation methodology (FAO, 1993), expert knowledge and literature review. The promising LUTs and possible technical levels were those either representing major production activities or having great potential on each LMU. The promising LUTs and possible technical levels were determined by qualitative land evaluation, statistical analysis of experimental and survey data, literature review or expert consultation. Yield of the LUTs in each LMU, one of the outputs of LUT, was estimated based on the suitability of the particular LUTs for each LMU at corresponding technical levels. The main tools and techniques used for yield estimation were crop yield simulation or statistical models, expert judgment, and farm surveys (Hoanh et al., 2000; Rötter et al., 1998). In this study farm surveys and expert judgment were applied.

The *Socio-economic analysis* component is based on the data obtained by Participation Rural Appraisal (PRA) techniques and key informant panel (KIP). This analysis helps formulate the objectives/goals of development. The development objectives were based on policy views representing stakeholders' perceptions on what goals the development should focus on. Production targets were defined based on the provincial socio-economic development plan. For each technical level at each LMU, the corresponding inputs used were estimated. Inputs were total input cost and labor per area unit.

In the *Interactive multiple goal linear programming* (IMGLP) component, the development's objectives were translated into objective functions. The constraints were based on the resources available such as limited labor resource and capital limitation. The goal restrictions were formed based on the development targets such as the minimum rice production for food security. Scenarios were built to explore the future land use when the biophysical conditions, socio-economic settings or development goals change. The results of different land use scenarios were analyzed to show *trade-offs* between costs and benefits of attaining different goals. In this study the scenarios would be the biophysical conditions under CC scenarios and the new technical levels including new plants varieties. The results were presented in graphical or tabular forms, and mapped by the geographic information system (GIS).

3. RESULTS AND DISCUSSION

3.1 *Biophysical land evaluation*

Figure 1 presents the results of biophysical land evaluation of Bac Lieu at the current condition (a), SLR of +17 cm (projected for the 2030s) in dry year (b), SLR of +17 cm in wet year (c), and SLR of +17 cm in the average year (d). The soil and water characteristics of the land were derived from soil survey and hydrological modeling. The combination of soil, water and district boundary formed 14 LMUs.

Nine promising LUTs were selected for land suitability evaluation. They were triple rice, double rice, shrimp-rice, shrimp, rice-vegetable, vegetable, forest-shrimp, shrimp-fish, and salt-fish farming systems. The obtained results show that there would be small changes in LMUs I and II where fresh water would still be protected by the current salinity control system (sluices and dykes). These two LMUs were suitable for all rice and vegetable LUTs. LMU VII, which is currently suitable for double rice, would be suitable for shrimp-rice due to the expansion of brackish water to the area (LMUs IV and VI). Shrimp-fish would also be an option in the future for LMUs III, IV, VIII, IX, X, XI, XII, XIII. These LMUs would be stable in near future.

3.2 *Socio-economic analysis*

The PRA's were implemented in 3 sub agro-ecological zones: freshwater, brackish water, and saline water. Through PRA, farmers' perceptions on the factors effecting on their land use were defined. Farmers in the study area considered increasing income as the greatest priority. Farmers also considered water (both quantity and quality) and bio-diversification to be the most important environmental factors as they had great influences on crops yield. They also highly concerned about market for agriculture and aquaculture products. The production price fluctuation strongly effect on their income.

Through KIP's at each LMU, farming inputs and outputs were estimated. This was important input data for the land use optimization analysis. In general, the analysis indicated that shrimp and rice production were main agricultural commodities. Compared to rice-related LUTs in the freshwater LMUs, shrimp-related LUTs in the brackish/saline LMUs were characterized as lower technical efficiency. Under projected scenarios of CC, a rice-upland crop (freshwater LMUs) and extensive shrimp (brackish/saline LMUs) would be potential LUT's. Improved shrimp value chains and create more off-farm job opportunities were amongst the greatest priorities to improve farmers' income.

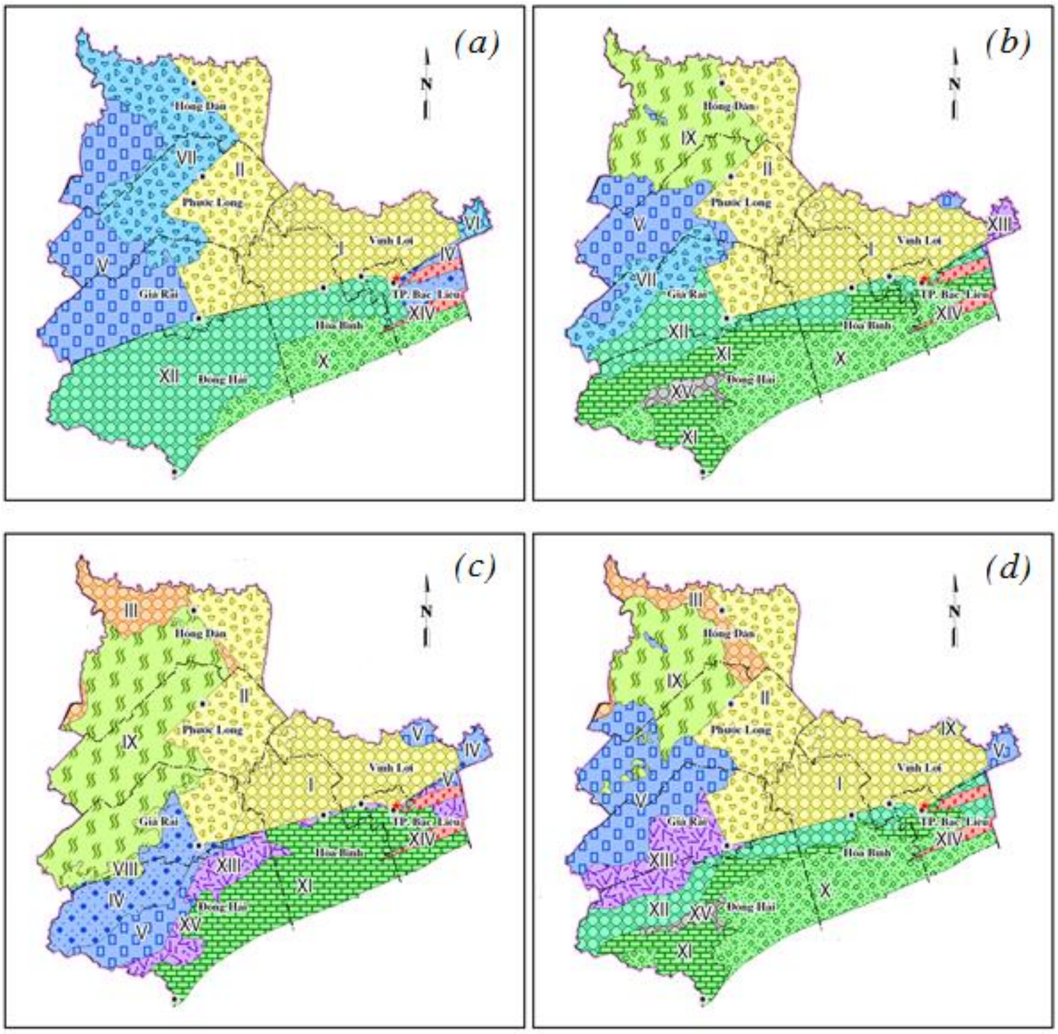

Figure 1 Biophysical land evaluation in Bac Lieu at the current condition (a), SLR +17 cm (projected for the 2030s) in dry year (b), SLR +17 cm in wet year (c), and SLR +17 cm in the average year (d).

3.3. Interactive multiple goal linear programming

An IMGLP model was developed in the GAMS modeling language (Figure 2). The model allowed interactively optimization scenarios. Figure 3 shows the comparison of regional income in different scenarios: (a) Normal year with and without improved cropping technology; (b) drought year, flood year and normal year; and, (c) drought year with SLR scenarios and new river lock; (d) flood year with SLR scenarios and new river lock. A1 is scenario with operation of river lock alone and A2 is scenario combining river lock and operational changes of existing sluice gates. The results imply that: (i) capital and farming technique limitations were main constraints to the provincial income; (ii) the current imposed production targets reduced land use effectiveness and would be infeasible under the impacts of CC and SLR; (iii) optimizing use of the available resources would reduce negative impacts of CC and SLR; and, (iv) new construction such as river lock could improve biophysical condition of the province. However, this hard measure was less economically effective than soft measures such as improving farming techniques and increasing capital investment or designing a better operation of exiting sluices and dyke systems.

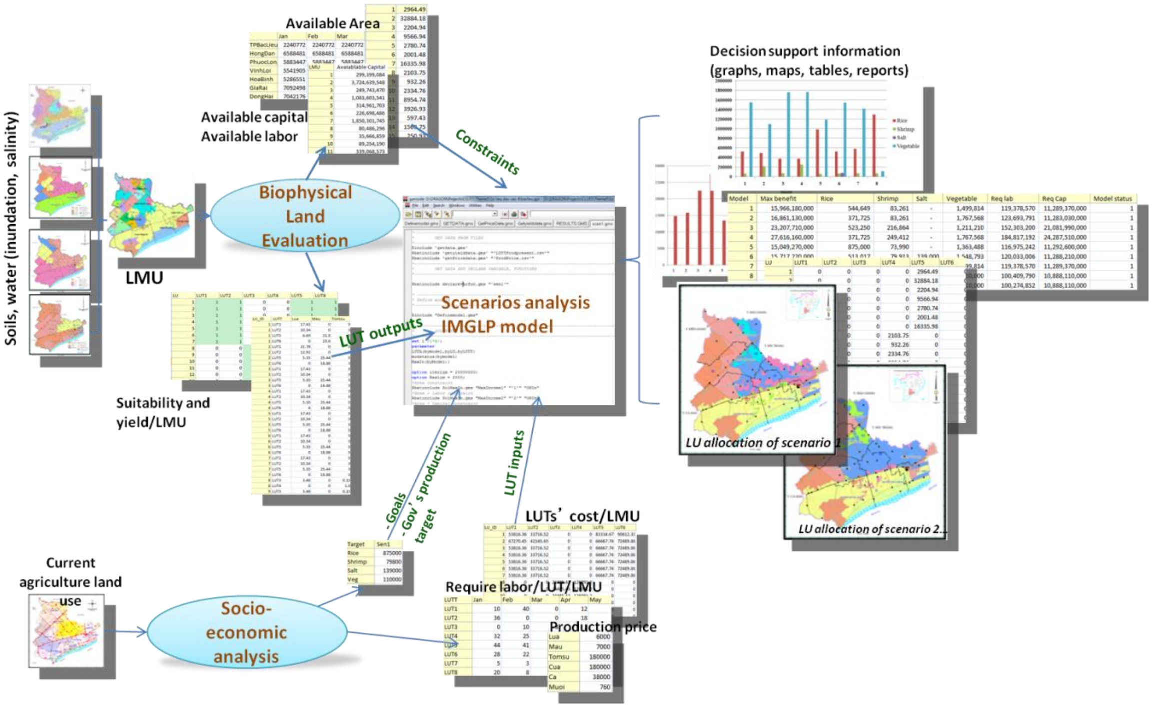

Figure 2 Land use planning and system analysis for CC adaptation strategy development.

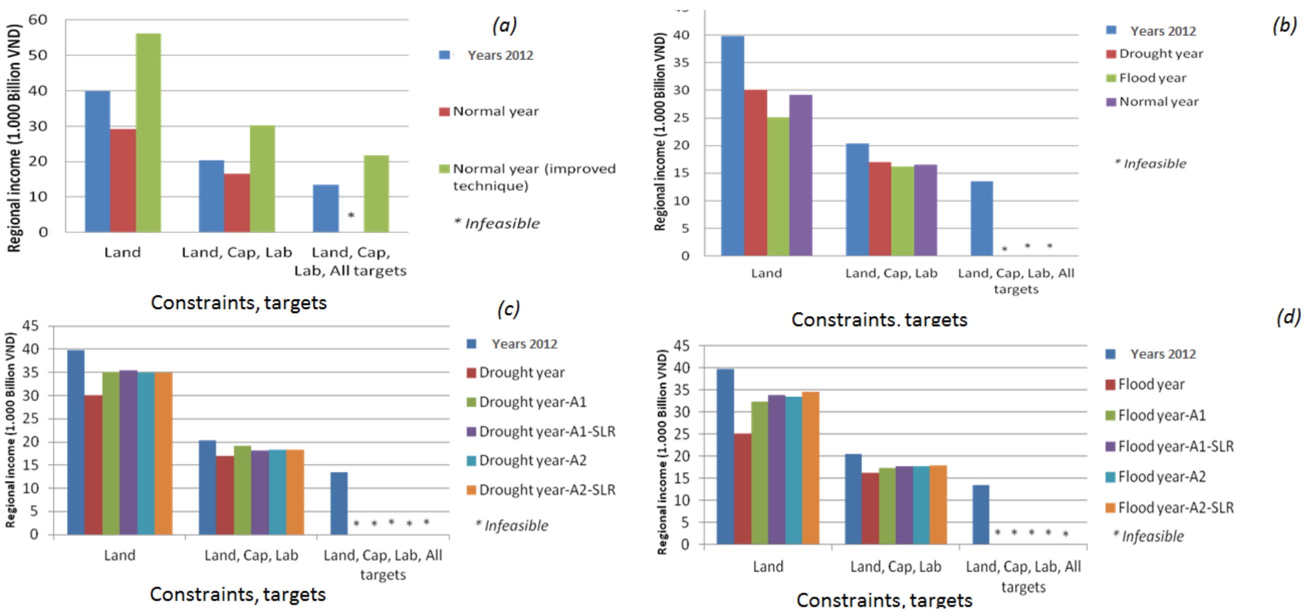

Figure 2 Comparing regional income of different scenarios: a. Normal year without and with improved cropping technology; (b) drought year, flood year and normal year; (c) drought year with SLR scenarios and new river lock; (d) flood year with SLR scenarios and new river lock

4. CONCLUSION

To adapt to the recent and near future biophysical and socio-economic changes in the VMD, a decision support system was developed. The system allows defining promising land use options with detailed quantitative information. The system was interactively implemented with high level of stakeholder involvement. The comparison of scenarios' results suggests suitable adaptation strategies for the study area.

For Bac Lieu province case study, in the medium term (up to 2030s), the most effective adaptation measures were (i) improvement of farming technology; (ii) providing farmers with higher financial supports; (iii) optimize use of the available resources (both biophysical and socio economic resources) based on the proposed land use options by the model; and, (iv) improving of the exiting sluice gate system's operational scheme.

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