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Establishing an integrated model for supporting agricultural land use planning: A case study in Tran De district, Soc Trang province

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ABSTRACT

Optimizing agricultural land use for sustainable development is one of the important challenges for agricultural management, especially in areas with changing socio-economic and environmental conditions. Optimization techniques have been researched for solving land use problems; however, there is not any appropriate optimization and spatial distribution method for agricultural land use. Therefore, the main objective of this study was to develop the ST-IALUP model between the open source application-LandOptimizer and ST-LUAM model to solve the multi-objective optimization and distribution for agricultural lands. The ST-IALUP model was built to target land use decisions in agricultural areas by the choice of planning scenarios. The case study for supporting agricultural land use planning in Tran De district pointed out that the ST-IALUP model not only assisted multi-objective optimization based on the factors of socio-economic, environmental and risk of LUT but also determined both land use allocation map and the new increasing area LUTs map for Tran De district to support planners in implementing solutions. The study results provided a reliable basis for supporting the decision-making process for planners in district-level agricultural land use planning in the Mekong Delta.

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1 INTRODUCTION

Solving the multi-objective optimization problem to find the best solution in all options is a difficult problem in the current land use planning (Haque and Asami, 2014; Kucukmehmetoglu and Geymen, 2016; Kumar *el al.*, 2017; Nguyen Hong Thao *el al.*, 2017). Recent optimality studies have used the optimal approach for each land unit with optimal objectives such as maximizing profits, labor, capital efficiency and land adaptation. (Nguyen Hieu Trung, 2006; Nguyen Hong Thao, 2007; Pham Thanh Vu *el al.*, 2016; Nguyen Quoc Duy *el al.*, 2017). Commercial software was used to perform the optimal problem and unresolved problem of proper agricultural land allocation. Recently, the results of research by Nguyen Hong Thao and Nguyen Hieu Trung, (2017) have developed the LandOptimizer application based on LpSolve open source code to solve the optimal problem of a target. Therefore, the main objective of this study is to develop multi-objective optimization function on LandOptimizer application integrated with the ST-LUAM model (Nguyen Hong Thao *el al.*, 2017) to build an integrated model in distribution for agricultural land area.

Tran De district, Soc Trang province is a brackish area where the agricultural land accounts for 87.8% of the total 37,798 ha natural area. Most of the district's cultivated area is acid sulfate soil and often faces drought and shortage of freshwater in dry season (Department of Agriculture and Rural Development Tran De District, 2017). This coastal district has diversity ecological system and is facing not only the changed of the natural conditions (soil and water) but also socio-economic development (Nguyen Hieu Trung and Van Pham Dang Tri, 2012; Pham Thanh Vu *el al.*, 2015). As a result, people tend to shift their agricultural production structure, especially intensive rice and intensive shrimp land (Nguyen Van Be *el al*., 2017).

Given the current situation, it is necessary to carry out a study to propose the optimal use of land for agricultural production to meet desires of local farmers to improve their income and to support work of agricultural land planning by local government.

2 METHODOLOGY

2.1 Data collection

Data maps of soil, depth of alum appearances, water salinity, and water salinity duration in 2015 were received from Department of Agriculture and Rural Development, Soc Trang province. The land use map in 2015 and salinity intrusion maps in 2010 and 2015 of the study area were analyzed from Department of Natural Resources and Environment, and Meteorological Center, Soc Trang province.

The field survey was conducted in four communes divided into two groups: local governmental staffs (five local officers who work in agriculture field of Tran De district) and 150 typical farmers. The sample size is described in Table 1. All of them were interviewed directly in the form designed to assess the actual and potential local agricultural land use type in the district in 2017. Individual interviews were done with advanced local farmers who had sufficient farming experiences (more than 10 years) in the study area. Each land use types (LUT) has 30 interview cards and the questionnaire is designed to collect data on the household characteristics related to profitability, total cost, profits, labor demand, environmental benefits and risk of LUTs. With environmental benefits, people evaluated that their LUT have a positive impact on improving the quality of the environment and risks of LUT were divided into four levels (high, medium, low and no risk) corresponding to the percentage of farmers self-assessing the level of risk in agriculture production. The following data was encoded and descriptive statistically analyzed using Microsoft Excel software as input data source of the ST-IALUP model.

Table 1: The sample size

NO	Location	Number of samples	
		Typical farmers	Local governmental staffs
1	Department of Agriculture and Rural Development Tran De district		1
2	Lich Hoi Thuong Town	40	1
3	Lich Hoi Thuong village	40	1
4	Trung Binh village	40	1
5	Lieu Tu village	30	1
	Total	150	5

2.2 Optimal agricultural land use method

LandOptimizer software has solved the problem of optimizing a target (Nguyen Hong Thao and Nguyen Hieu Trung, 2017), but in this study, the researcher groups would like to improve this software by developing new features and multi-objective optimization solutions such as maximizing profitability, labor, environment but minimizing risk of LUT in agricultural production.

2.2.1 Multi-Objective optimization function

Objective function for LandOptimizer is composed by the different objectives of maximizing profits, labor demand, environmental benefits and minimizing the risk of LUTs. These factors are normalized to [0, 1] to build the objective function. They are defined as in the equation (1).

$$w1\sum_{i=1}^{n}\sum_{j=1}^{m}\mathrm{P_{ij}LS_{ij}X_{ij}} + \mathrm{w2}\sum_{i=1}^{n}\sum_{j=1}^{m}\mathrm{EB_{j}X_{ij}} + \mathrm{w3}\sum_{i=1}^{n}\sum_{j=1}^{m}\mathrm{LD_{ij}X_{ij}} - \mathrm{w4}\sum_{i=1}^{n}\sum_{j=1}^{m}\mathrm{RI_{j}X_{ij}} \rightarrow Max \quad (1)$$

Where,

i=1..n, with n is the number of land mapping units (LMU) and j=1..m with m is number of land use types (LUT)

Xij: The area of LUTj in the LMUi need to find (unit: ha).

Pij: Profit of LUTj in LMUi (unit: million VND/ha).

LSij: Land suitability of LUTj in LMUi

EBj: Environmental benefits of LUTj. This factor is based on the percentage of farmers who answered that their LUT give environmental advantages such as CO2 reduction, non-toxic.

LDj: Labor demand of LUTj/ha/year.

RIj: Risk index of LUTj. It was calculated based on the proportion of households how evaluated that the their LUT having the high-risk level.

Wi: the weight of the objectives. The weighted value received from 0 to 1, which represents magnitude of the objectives in multi-objectives function. In LandOptimizer application, the weights are set to 1 mean the objectives have the same priority.

2.2.2 The constraints for optimization function

When performing optimization, the problem needs to be identified and clearly formulated the constraints. In this context, there are the constraints such as

$\sum_{j=1}^{m} X_{ij} \leq$ Area _LMU$_i$, i = 1..n (2)

$\sum_{i=1}^{n}\sum_{j=1}^{m} LD\_LUT_j X_{ij} \leq$ Total working days are available in the local area (3)

$\sum_{i=1}^{n} X_{ij} \leq$ Area_required$_{LUT_j}$, j = 1..m (area requirements of LUT$_j$) (4)

2.3 Allocation land use for agriculture

LandOptimizer developed by Nguyen Hong Thao and Nguyen Hieu Trung (2017) determines the optimal area of each LUT and then integrates with ST-LUAM model (Nguyen Hong Thao *el al.*, 2017) to arrange LUTs, which are shown in Figure 1.

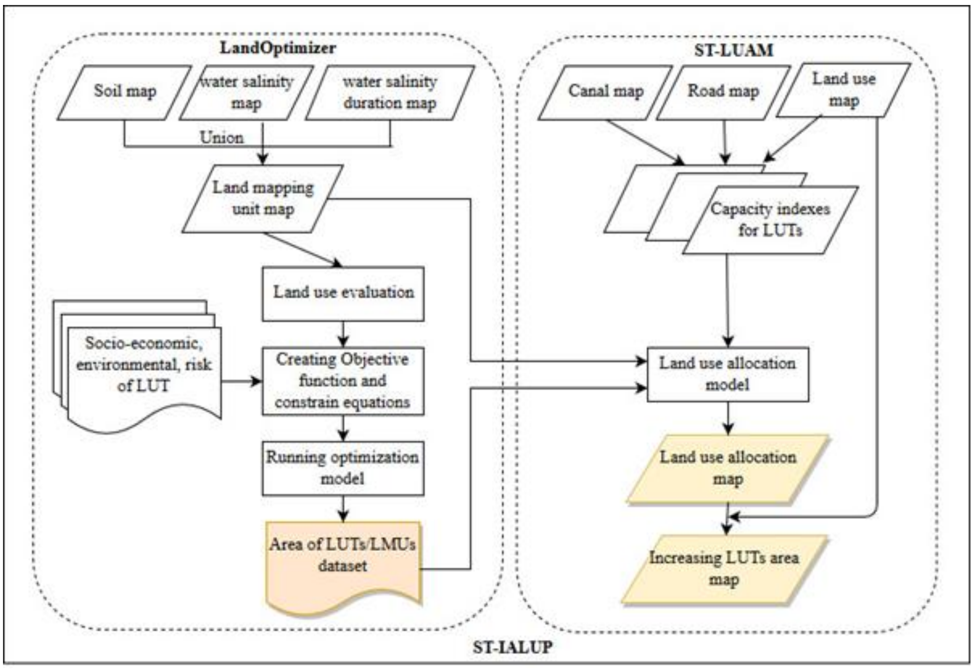


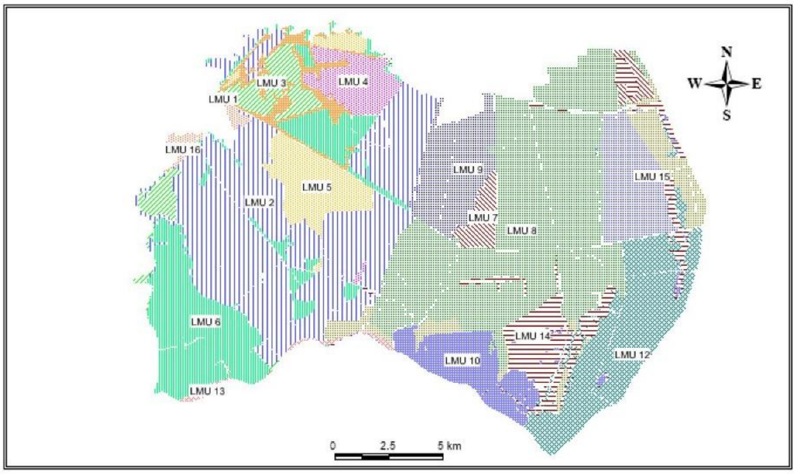
Figure 1: Process flow diagram of the integrated model ST-IALUP

3 RESULTS AND DISCUSSION

3.1 The data input for optimization

3.1.1 Land use evaluation

Land mapping unit (LMU) map was built by using Union method to analysis the maps such as soil, depth to the acid sulfate soil (ASS) occurred, water salinity, and water salinity duration maps of Tran De district, Soc Trang province. The LMU map of Tran De district was isolated into 16 LMU s (Figure 2). In which, all of units faced the constraint not only salinity water for at least five months per year with salinity from 2 (‰) to 12 (‰) but also having the acid sulfate soil. These characteristics were used for natural land evaluation of prospective LUTs.



LEGEND

LMU	Type and depth to ASS	Salinity(‰)	Months	LMU	Type and depth to ASS	Salinity(‰)	Months
LMU 1	Non-acidity (Gleysols)	2-6	5	LMU 9	Potential > 50cm (Fluvisols)	6-10	5
LMU 2	Non-acidity (Fluvisols)	2-6	5	LMU 10	Active >50cm (Anthrosols)	6-10	5
LMU 3	Active < 50cm (Fluvisols)	2-6	5	LMU 11	Non-acidity (Fluvisols)	10-12	8
LMU 4	Potential < 50cm (Fluvisols)	2-6	5	LMU 12	Active < 50cm (Fluvisols)	10-12	8
LMU 5	Potential > 50cm (Fluvisols)	2-6	5	LMU 13	Non-acidity (Fluvisols)	10-12	8
LMU 6	Active >50cm (Anthrosols)	2-6	5	LMU 14	Active >50cm (Anthrosols)	6-10	5
LMU 7	Non-acidity (Arenosols)	6-10	5	LMU 15	Non-acidity (Fluvisols)	6-10	5
LMU 8	Active in <50cm (Fluvisols)	6-10	5	LMU 16	Non-acidity (Fluvisols)	6-10	8

Figure 2: Land mapping units of Tran De district

Besides the traditional agricultural LUTs like Double rice and Crops, Rice Shrimp and Shrimp were prospective LUTs for local people and staffs (Department of Agriculture and Rural Development Tran De district, 2017). Therefore, five LUTs such as Double rice, Crops, Fruit, Rice Shrimp and Shrimp were selected for the assessment of land suitability according to FAO (1976). The suitability evaluation results of LUTs were presented in Table 2 and coded sequentially from LUT1 to LUT5 and entered into the LandOptimizer application.

Table 2: Land suitability of Tran De district

LMU	Land evaluation					Area (ha)
	LUT 1	LUT 2	LUT 3	LUT 4	LUT 5	
LMU 1	N	S3	S1	N	N	164.00
LMU 2	S1	S1	S3	N	N	6414.50
LMU 3	S2	S3	N	N	N	929.75
LMU 4	S1	S2	N	N	N	811.25
LMU 5	S1	S2	N	N	N	1218.25
LMU 6	S2	S3	N	N	N	3204.00
LMU 7	S3	S2	N	N	N	413.00
LMU 8	S2	S3	N	N	N	6615.25
LMU 9	S2	S2	N	N	N	1471.75
LMU 10	N	N	N	S1	S2	1199.50
LMU 11	N	N	S2	S1	S2	766.25
LMU 12	N	N	N	S2	S2	2505.75
LMU 13	N	N	N	S1	S1	140.50
LMU 14	S2	S2	N	S2	N	1614.50
LMU 15	S2	S2	S1	S2	N	1177.75
LMU 16	S3	S3	N	S2	S2	184.25

Note: LUT 1: Double rice; LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

3.1.2 Socio-economic and environmental factors

Table 3 shows the results of the statistical analysis describing the average values of each LUT such as total cost, economic benefits, labor demand, and environmental benefits from the interview household. These data were aggregated and averaged each LUT, and that were used as the input database for the LandOptimizer application to optimal agricultural LUT area.

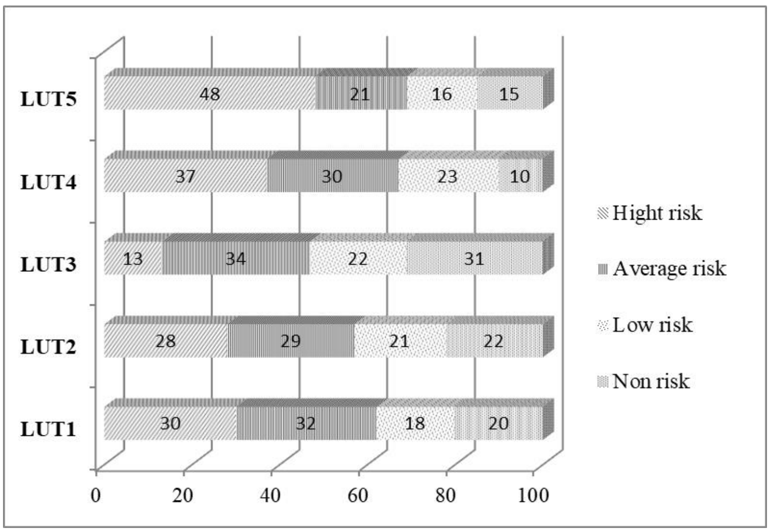
The profit factor was the main concern of local people and local staffs (Gouzaye and Epplin, 2016; Kennedy *el al*., 2016; Pham Thanh Vu *el al*., 2017) besides labor demand and environmental factors, because more than 90% of surveyed households thought that production capital or production cost of LUTs were not the major issues in local agricultural production. Farmers could buy seeds, pesticides and fertilizers that will be paid later at the end of seasons.

Table 3: Socio-economic and environmental factors of LUTs

LUT	**Total cost** (mil. VND)	**Profits - P** (mil. VND/ha)	**Labor demand - LD** (Day/year/ha)	**Environmental benefits – EB (%)**
LUT1	29.8	45.1	53	37.1
LUT2	41.1	98.2	285	17.6
LUT3	31	51	62	26.5
LUT4	132.5	112.6	165	30.5
LUT5	362	334	270	10.2

Note: LUT 1: Double rice; LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

LUT's risks (RI) are affected by production process, natural disasters or epidemics (Tran Ngoc Tung and Bui Van Trinh, 2014), which reduce the productivity of crops or livestock. Therefore, in this study, the risk factor was determined on the assessment level of local authorities and typical farmers. Figure 3 showed that 48% of households thought that LUT 5 has the highest risk level, followed by LUT 4, LUT 1, and LUT 2; LUT 3 was evaluated as the lowest risk. It was explained that LUT 5, LUT 4, LUT 2 and LUT 1 were affected by weather, water quality and seedling. Although LUT 5 has a high level of risk, local people still would like to shift this LUT because they need to increase their profitability per unit of cultivated area. This is shown by Nguyen Van Be *el al*., (2017) that farmers who wanted to improve their income sometimes they have to faced potentail high risks in their production.



Note: LUT 1: Double rice; LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

Figure 3: The assessment of the local government and experienced farmers about risk of LUTs

3.2 Objective function and constraint equations of the scenarios

Based on the previous studies of Kalvelagen (2002), Le Quang Tri *el al.* (2013), Nguyen Huu Kiet *el al.* (2014) and Pham Thanh Vu *el al.* (2015), Nguyen Hong Thao and Nguyen Hieu Trung (2017), five land use scenarios showed in Table 4 such as maximizing profit (SC 1), maximizing labors (SC 2) and the SC 3 was maximizing integrated objectives about profit, labor, environmental benefits and minimization of risk. Following Nguyen Hong Thao and

Nguyen Hieu Trung (2017), an integrated objective was implemented by multiple these factors to solve with single objective linear programing. Thus, in this study, the multi-objective scenarios (SC 4, SC 5) were taken into account to minimize risk of LUTs in agricultural land use planning.

Table 4: The land use scenarios for optimization

Scenario	Objective function	Max of Profit	Max of Labor	Max environmental benefits	Min of risk
SC 1	Single objective	x			
SC 2	Single objective		x		
SC 3	Single integrated objective	x	x	x	x
SC 4	Multi-objective	x		x	
SC 5	Multi-objective	x	x	x	x

These five scenarios were based on the same all constraint equations on area of LUTs which required total area of land mapping units and number of labors of the district. These equations are defined as the 2nd, 3rd and 4th equation in section 2.2.2, with the case in Tran De district, the distribution area of LUTs were defined as follows:

Total area for each LMU was taken from the total area in Table 2. Sixteen LMU, thus, 16 constraint equations were defined.

Required area of each LUT was based on the development requirement for agricultural production in 2017 from the sub Department of Agriculture and Rural Development Tran De district. In which, the area of the Double rice (LUT 1) is 22,700 ha; the area of Crops (LUT 2) is 505 ha; the area of Fruit (LUT 3) is 520 ha; and the area of aquaculture is 5,098 ha, among that, 700 ha for Rice-Shrimp (LUT 4) and 4,398 ha for intensive Shrimps (LUT 5).

Total labors supplied for implementing LUTs could be less than total labor of the district. This value was converted to 25,125,600 working days per year (Statistical Office Soc Trang province, 2016).

3.3 Optimization results for land use scenarios

All of the scenarios were solved by LandOptimizer application that provided optimal LUT areas per suitability LMUs with the same constraints. The optimization result shows the total profit of each scenario and was aggregated in Figure 4. In which, the lowest profit maximized for the SC 2 was 2,102 billion VND, and the scenarios SC 1 and SC 3 gave the highest profit with 2,113 billion VND. The profit of SC 5 (Multi-Objectives) was lower than that of the SC 1 about 1 billion but has considered all objectives including minimizing the risk of LUT.

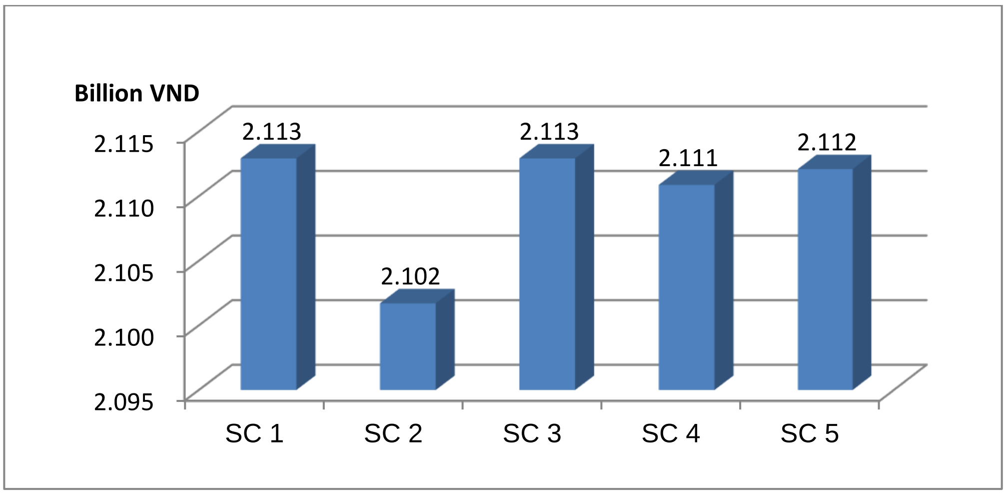


Figure 4: Total profit of the scenarios

Table 5 shows the optimized results of five scenarios proposed for each LUT. In the scenarios, the total area of each LUT was equal, but due to different objective functions and the choice of optimal LMUs were also different, that led to different profit among the scenarios. Regarding profit of LUT 1 in the first three scenarios, they were lower than that of the scenarios 4 and 5. Inversely, the profit of LUT 2 in scenarios 4 and 5 was higher than that of the other scenarios. This phenomenon was caused by the same level of suitability among the LUTs in a LMU (Table 2). LandOptimizer was choise to distribute area based on the objective function of the scenarios. This rule was explained the same total profit for LUT 3 and LUT 5 where the LMUs had the only option of suitability for these LUTs.

Table 5: Profit in detail of the scenarios

Scenarios	Profit of scenarios (Billion VND)				
	LUT 1	LUT 2	LUT 3	LUT 4	LUT 5
SC 1	852.68	49.59	26.89	70.33	1,113.43
SC 2	852.68	49.59	26.89	59.12	1,113.43
SC 3	852.68	49.59	26.89	70.33	1,113.43
SC 4	863.03	37.19	26.89	70.33	1,113.43
SC 5	862.00	39.45	26.89	70.33	1,113.43

Note: LUT 1: Double rice; LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

The total profit of five scenarios, the SC 5 was only lower than the SC 1 about 1 billion but it has considered all multi-objectives. Since this scenario provides the better solution than the others, so distribution area of land use patterns proposed in SC 5 needs to be considered by managers in land use planning process.

Considering the land distribution for the SC 5, Figure 5 shows optimized results in details of each LUT on each LMU. The LUT 1 areas were 22,700 ha, arranged on land mapping unit as LMU 2, LMU 3, LMU 4, LMU 5, LMU 6, LMU 8, LMU 9, and LMU 15. The area for LUT 2 was distributed in the units LMU 2 and LMU 7 with 505 ha. Total area of LUT3 was 527.25 ha, arranged in the 1st land mapping unit (LMU 1) and in the 15th unit (LMU15). Regarding on aquaculture areas, the results showed that the LUT 4 areas were proposed in LMU 11, LMU 14 with 700 ha while the areas of LUT5 were distributed at the LMU 10, LMU 11, LMU 12, LMU 13, and LMU 16 with 4,398 ha in total.

The detailed areas of the SC 5 are pointed out that each unit can be distributed for many LUTs. For example, LMU 2 was allocated for LUT 1 and LUT 2, in the same way; LMU 11 was divided into LUT 4 and LUT 5. This is still difficult for local government staff to determine the spatial position of the LUTs in land use planning

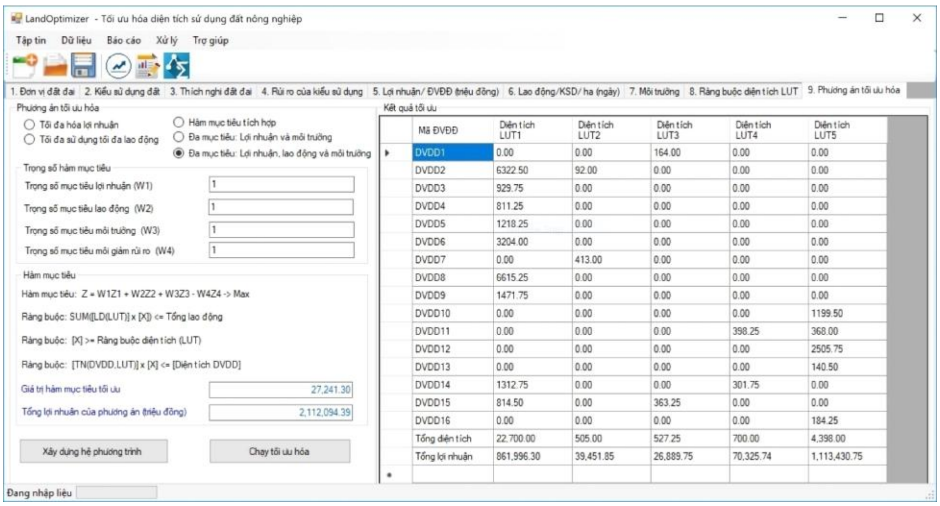
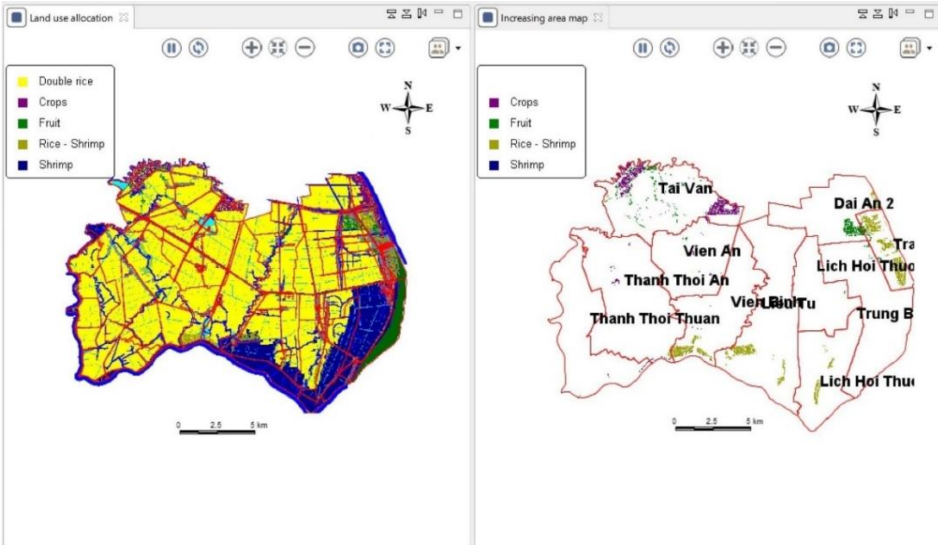


Figure 5: Optimization results for the SC 5 on interface of LandOpimizer

Note: LUT 1: Double rice; LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

3.4 Land use allocation map for the selected scenarios

As there were conflicts on distribution of many LUTs on each LMU, the areas optimized for the SC5 were put into the ST-LUAM for determining the spatial distribution of agricultural land use planning. The land use allocation map of the SC 5 was shown in Figure 6 (a) and (b) revealing the places where the increasing areas are, where the proposed LUTs can be implemented in comparing with real agricultural land use map in 2015 of Tran De district.



a) *b)*

Figure 6: Land use allocation map of the scenario SC5. a) Land use allocation map. b) Increasing area of the LUTs comparing with land use map in 2015

The increasing area of the LUTs compared with real agricultural land use map in 2015 of Tran De district (Figure 6b) was calculated the detail for the villages represented in Table 6. In this solution, the new added area was mainly converted from LUT1 to remaining LUTs. In which, LUT 2 was proposed to increase 324.5 ha mainly in Tai Van village (283.75 ha) and a small part of Thanh Thoi An, Vien An and Vien Binh villages. For LUT 3, the proposed area was expanded at Tai Van (107.5 ha) and Dai An 2 (90 ha) villages. The area of LUT 4 was proposed the most in Tran De Town with 256 ha, followed by Lieu Tu and Vien Binh villages about 259 ha, and the remaining area of LUT 4 was arranged other villages. Particularly for LUT 5, this LUT was desired most of farmers who want to convert, but due to limited area required of local government, the area of LUT 5 increased was not significantly; a small area is scattered in the Thanh Thoi An, Thanh Thoi Thuan and Vien Binh villages.

Table 6: Area of the LUTs needs to increase in the villages for scenarios SC5

Unit: ha

Village	LUT 2	LUT 3	LUT 4	LUT 5
Lieu Tu	0.00	0.00	124.75	0.00
Tai Van	283.75	107.5	0.00	0.00
Thanh Thoi An	15.50	0.00	10.75	4.00
Thanh Thoi Thuan	0.00	0.00	0.00	6.50
Vien An	17.50	1.75	0.00	0.00
Vien Binh	7.75	0.00	124.25	4.00
Dai An 2	0.00	90.00	25.50	0.00
Tran De Town	0.00	25.25	256.00	0.00
Lich Hoi Thuong	0.00	0.00	56.25	0.00
Lich Hoi Thuong Town	0.00	1.50	0.00	0.00
Trung Binh	0.00	5.75	0.00	0.00
Total area	324.50	231.75	597.50	14.50

Note: LUT 2: Crops; LUT 3: Fruit; LUT 4: Rice shrimp; and LUT 5: Shrimp

Land use allocation map was the results of the last phrase of the ST-IALUP model which the input data was received from the optimization phase. The innovation point in this study is the LandOptimizer, developed by the authors; user interface and the spatial distribution model for land use are integrated in a process. The differential land use between current land use map and allocation map are also provided by the new increasing map. This map will be useful for the planners who want to implement the optimization solution and allocation space detailed for each village on the ground.

4 CONCLUSION

Application of ST-IALUP model in Tran De district has positively supported in determining the optimization area of LUTs and the flexibility to test different optimal scenarios. In which, the multi-objective scenario is most appropriate solution since the factors of socio-economic, environmental and risk of LUT were solved. The land use allocation map and the new increasing map gave the advantages for planners to locate LUTs that need to increase or decrease cultivated area.

The ST-IALUP model provides two phases in which the first phase uses the optimization to define different land use scenarios with multi-objective analyzed, and the second phase used the optimal results by the computer model ST-LUAM to provide the land use allocation map.

In conclusion, the integrated model result does not only assist organizers an easily way to adjust the area optimization in defining the plans but also support them to allocate the new planned areas on the maps. Thus, this integrated model provides an easy-to-use analytical tool for building different scenarios for planners and supporting sustainable development solutions in land use planning process for district level.

REFERENCES

Department of Agriculture and Rural Development Tran De district, 2017. Report on agricultural production in Tran De district 2016-2017. (in Vietnamese)

FAO, Food and Agriculture Organization, 1976. A framework for land evaluation. FAO Soil Bulletin 32, FAO, Rome

Haque, A., and Asami, Y., 2014. Optimizing urban land use allocation for planners and real estate developers. Comput. Environmental Urban System. 46: 57-69.

Gouzaye, A., and Epplin, F.M., 2016. Land requirements, feedstock haul distance, and expected profit response to land use restrictions for switchgrass production. Energy Economic. 58: 59–66. Available from https://doi.org/10.1016/j.eneco.2016.06.019

Kalvelagen, E., 2002. Solving Multi-Objective Models With GAMS. GAMS Development Corp., Washington DC.

Kennedy, C.M., Hawthorne, P.L., Miteva, D.A., el al., 2016. Optimizing land use decision-making to sustain Brazilian agricultural profits, biodiversity and ecosystem services. Biological Conservation. 204: 221–230. https://doi.org/10.1016/j.biocon.2016.10.039

Kucukmehmetoglu, M., and Geymen, A., 2016. Optimization models for urban land readjustment practices in Turkey. Habitat International, 53: 517-533.

Kumar, A., Bikash Sah, Arvind, R.S., Yan Deng, Xiangning, H., Praveen, K., and Bansal, R.., 2017. A review of multi criteria decision making (MCDM) towards sustainable renewable energy development. Renewable and Sustainable Energy Reviews, 69: 596–609.

Le Quang Tri, Nguyen Pham Xuan Tai, and Pham Thanh Vu, 2013. Optimization for selection of sustainable agricultural land use types at district levels. Case study at the Tra On district, Vinh Long province. Can Tho University Journal of Science. 25: 173-182. (in Vietnamese).

Nguyen Hieu Trung, 2006. Comparing land use planning approaches in the Mekong Delta - Vietnam. PhD thesis Wageningen University, The Netherlands.

Nguyen Hieu Trung and Van Pham Dang Tri, 2012. Possible Impacts of Seawater Intrusion and Strategies for Water Management in Coastal Areas in the Vietnamese Mekong Delta in the Context of Climate Change in Coastal Disasters and Climate Change in Vietnam. Science Direct. 219–349.

Nguyen Hong Thao, 2007. Optimal agricultural land use in Co Do district, Can Tho city by GAMS- (Generalized Algebraic Modeling System) and GIS (Geographic Information System). Master thesis in Soil Science Can Tho University (in Vietnamese).

Nguyen Hong Thao and Nguyen Hieu Trung, 2017. Establish open-source application for optimization agricultural land-use area. Can Tho University Journal of Science. 52a: 62-72. https://doi.org/10.22144/ctu.jvn.2017.111. (in Vietnamese).

Nguyen Hong Thao, Nguyen Hieu Trung and Le Quang Tri, 2017. Establishing the model for supporting agricultural land use allocation - A case study in My Xuyen district, Soc Trang province. Can Tho University Journal of Science. Special issue environment and climate change (1): 166-177. https://doi.org/10.22144/ctu.jsi.2017.065 (in Vietnamese).

Nguyen Huu Kiet, Le Quang Tri, Bang Thanh Binh and Thieu Quang Thien, 2014. Combination between land evaluation and objective optimization mathematics model is as a basis for planning of the agricultural land in Co Do district, Can Tho city. Can Tho University Journal of Science. 30: 70-77 (in Vietnamese).

Nguyen Van Be, Van Pham Dang Tri, Tran Thi Le Hang and Tran Van Trien, 2017. Impacts of saline intrusion on agriculture and aquaculture in the Tran De district, Soc Trang province. Can Tho University Journal of Science. 50: 94-100. https://doi.org/10.22144/ctu.jvn.2017.071 (in Vietnamese).

Nguyen Quoc Duy, Le Quang Tri, Pham Thanh Vu and Ton That Loc, 2017. Optimization model of paddy rice land allocation in Long Ho district, Vinh Long province. Can Tho University Journal of Science. Special issue environment and climate change (1): 66-77. https://doi.org/10.22144/ctu.jsi.2017.054 (in Vietnamese).

Pham Thanh Vu, Nguyen Hieu Trung, Van Pham Dang Tri and Phan Hoang Vu, 2015. Agro-ecological dynamics in the coastal areas of the vietnamese Mekong Delta in the context of climate change (A case study in Bac Lieu province). Can Tho University Journal of Science. 01: 81–88. https://doi.org/10.22144/ctu.jen.2015.027.

Pham Thanh Vu, Le Quang Tri, Vuong Tuan Huy and Nguyen Thi An Khuong, 2016. Application of mathematical optimization method in agricultural land use - case study in Vi Thuy district, Hau Giang province. Can Tho University Journal of Science. 44b: 38-47. https://doi.org/10.22144/ctu.jvn.2016.463. (in Vietnamese).

Pham Thanh Vu, Le Quang Tri, Nguyen Hieu Trung, Vuong Tuan Huy and Ton That Loc, 2017. Enhancing land use efficiency for income optimization of farm households in Tra Hat hamlet of Chau Thoi commune, Vinh Loi district, Bac Lieu province. Can Tho University Journal of Science. 51b: 54-63. https://doi.org/10.22144/ctu.jvn.2017.079 (in Vietnamese).

Statistical Office Soc Trang province, 2016. Statistical year book Soc Trang.

Tran Ngoc Tung and Bui Van Trinh, 2014. Effects of meteorological and hydrological factors to shrimp farming in Soc Trang Province. Can Tho University Journal of Science. 35: 117-126 (inVietnamese).