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ORIGINAL PAPER

Integrated land-use planning for sustainable agriculture and natural resources management in the Vietnamese Mekong delta

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Abstract The greatest concern confronting resources managers for years in the Vietnamese Mekong delta was mismanagement of land use and natural resources. This paper considers the integrated land-use planning approach developed by Food and Agriculture Organization (FAO) and United Nations Environmental Program (UNEP) to assess the suitability of agricultural production systems and examine socioeconomic factors affecting household (HH) land-use decision making and natural resources management in agricultural landscapes. Various data were spatially and socioeconomically gathered through HH survey and qualitative methods. The findings indicated that a large proportion of the area under existing production systems didn't match its land requirement and the resources management was partially effective due to socioeconomic driving forces. Land-use options and management measures were thus made upon the land suitability and socioeconomic analyses to secure the rural livelihoods in respect to restoration of degraded native ecosystems. This could only be realized if having institutional instruments and an improved awareness of farmers on land mapping units (LMU) through agricultural extension and credit assess services.

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Introduction

Rapid population growth has accompanied specific problems of increasing demands for food and other agricultural products, degradation of land quality, soil erosion and extensive deforestation (Fressco et al. 1992). The imposition of private land owners and the state appropriation of lands also results in unsustainable utilization of common pool resources (CPR; Adger and Luttrell 2000). This can be extrapolated to the third world where majority of degradation problems are associated with inappropriate agricultural management practices and mis-match of land quality with land use (Beinroth et al. 1994). In Asia-Pacific 24% of land is degraded because of improper cultivation (WRI 1994). It is triggering the economic loss and contributing to depletion of natural resources and loss in biodiversity (Arimoro et al. 2002). In South and Southeast Asia, the annual economic loss from such degradation ranges from 1 to 7% of agricultural gross domestic product (Scherr 1999).

Vietnam, a home of 10% of global species (Greentop.net 2002), its habitats are rapidly shrunk due to deforestation, socioeconomic and institutional driving forces. Considering the rural sector where over 76% with a density rate of 1,031 persons per sq.km of arable land because of annually unchecked population growth (1.6%), high poverty rate (35.6%) and insatiable demands for more natural resources (World Bank 2002), more than half of the total country land were degraded in terms of *fertility and productivity (*VEPA 2001). The natural forests were sharply dropped from 43% in 1943 to 33.2% in 1999 (Nghia 2003).

Identified as an eco-region of which 30% of area is hilly and the rests are coastal mangroves and mixed seasonally flooded grasslands with melaleuca forest, the study area is not only significant for biodiversity conservation but also for eco-tourism with historical places (MAB Vietnam 2005). Out of 155 vertebrate species, 6 animal, 6 bird and 5 reptile species are found in the Vietnam red-list 1992, Collar 1994 (Buckton and Cu et al. 2000), and IUCN red-list (IUCN 1996). Emphasized by WWF's Global 200 on its outstanding ecological features for biodiversity conservation in the terrestrial priority landscapes of LMF2 (Baltzer et al. 2001), however under pressing basic needs and problematic subsidies of local authorities to encourage farmers in converting native wetland ecosystems into shrimp farms, paddy fields along with other anthropogenic activities such as urban expansion, and development of cement-work, the area had been suffered by problems of deforestation, degradation of land resources, and loss of biodiversity and habitats of globally endangered species e.g. red-head crane.

Restoration of ecological values and formulation of long-term land-use options had therefore been a major concern. This can't only be achieved unless direct economic or indirect incentives related to environmental and social services resulting from the reforestation programs are provided to the local communities (Sayer et al. 2004). Today's key agenda for every developing nation has called for jurisdiction of more integrated planning approach of resources (UNCED 1993), i.e. primarily (not exclusively) for increased agricultural output to meet the production goals of farmers (Fressco 1994) or profitability as well as the goals of the rest of the community e.g. welfare of future generation, poverty alleviation and environmental preservation (Izac and Sanchez 1999).

This study aims to evaluate the suitability of agricultural production systems, analyze socioeconomic determinants of the rural economy, and examine management regimes of natural resources using Geographic Information Systems (GIS), a decision support system involving the integration and processing of spatially referenced data (Cowen 1988).

The study area

Located between latitudes 10°08′05″–10°32′05″ N and longitudes 104°31′06″–104° 48′04″ E (Fig. 1), the study area covers 90,632.27 ha consisting nine administrative villages and one township. The climate is monsoon tropical semi-equatorial with annual mean temperature of 27.5 °C. Two distinct seasons and the annual rainfall average of 1,442 mm were observed. The wet season (May to November) constituted 80% of the total rainfall and caused soil erosion in some upland areas while the dry season (December to April) was characterized by fresh-water scarcity for farming. The land form is mostly plateaus. Flood annually occurred during the rainy season with the average inundation level of one meter during two to four months.

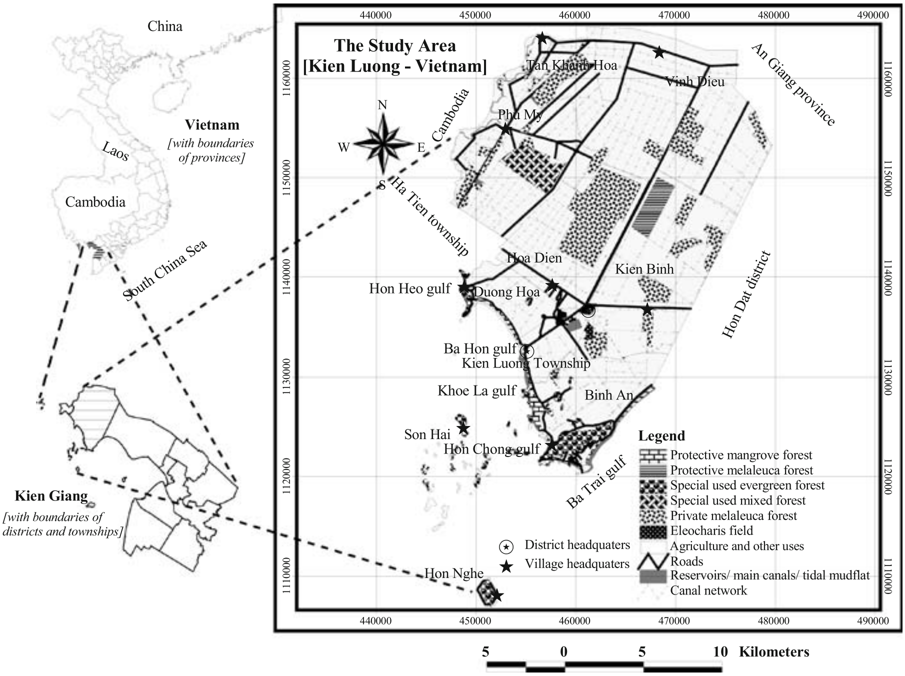

Fig. 1 Map showing location of the study area and major land uses

The reasons to select the study area were that it was diverse landscapes and owned the world's major ecosystems: seasonally flooded grasslands, limestone, mangrove and evergreen forests, and rich in biodiversity (Baltzer et al. 2001). Although lesser populated (99 inhabitants/km^2) than that of the national average (253 inhabitants/km^2), the area had been facing with risks of overall ecological integrity. In the upland where special used evergreen forest[1] occupied, people practiced rainfed rice and agro-forestry production systems. They cut down trees for wood and exploited the forestland for constructing roads and houses while in along the coastal area they transformed mangrove protective forest[2] into shrimp ponds with limited ecological restoration. Transportation in mangrove was a big problem due to its remote location from resided areas (MAB Vietnam 2005).

In the lowland[3] where 80% of land was acid sulfate soil (ASS), irrigated rice and extensive salt-water shrimp culture were the dominant land-use types (LUT) with approx 47 and 17.23% in turn. A quick expansion of shrimp farming destroying fresh-water ecosystems which were known as the rest remaining ecological niche of red-head cranes, an important endanger species of IUCN red list. The number of this species was declined from 384 individuals in 2001 to 295 individuals in 2006 (Triet 2006) because of fragmented habitats and insufficient *Eleocharis dulcis* roots. 50% of the area was affected by saline water while about 40% had irrigation facility where a second crop of irrigated rice could be grown.

More than 47% of HH living in the lowland were migrants from adjacent regions. They didn't have permanent jobs and lived on deforestation and forest products (MAB Vietnam 2005). Inappropriate agricultural practices had triggered natural resources to be degraded seriously. 20.3% of the area covered by natural grasslands and melaleuca in 1992 had been converted to the lowland agriculture in 2003. Likewise, the forestlands had sharply dropped down from 28% in 2000 to 17% in 2005. The average HH size was five persons, and more than 70% had low educational levels, namely primary and secondary school levels. Half of the population engaged in agriculture while students (19.5%) and 30.8% responsible for fishing, small-scale service, wage labor, and housework.

Methodology

Figure 2 shows the planning process integrating both biophysical and socioeconomic factors. Land suitability classification for major LUT was first assessed based on expert knowledge. The suitability areas were then grouped into two biophysically homogeneous zones in respect to the land-use negotiation step conditional to

[1] Co-managed by the provincial Govt. and HH through a contract under 327 program, a national reforestation program of 5 million ha of land in upland areas degraded by fire, shifting agriculture and war (Gilmour 1999).

[2] Defined for a main purpose of long-term protection and any land-use conversion must be permitted (Decision 51/2005/QD-UBND).

[3] Rice or rice-based upland crops; extensive salt-water shrimp farming; and commercial and protective *malaleuca* forest plantation.

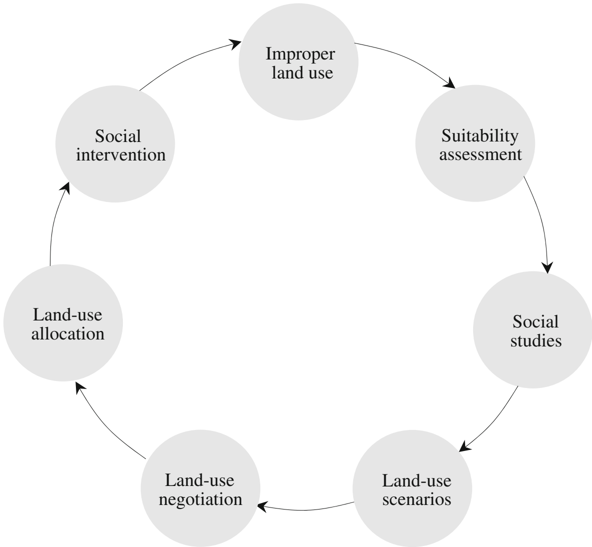

Fig. 2 An overview of the integrated planning process

stakeholder preferences. Formulating land-use scenarios subsidiary to a number of criteria was set up for the final suitability map. Documenting socioeconomic structure and examining natural resources management were further undertaken for policy implications.

Land suitability classification

To put the best land-use options into the practice, it was necessary to underlie a biophysical land suitability[4] classification for key existing LUT: irrigated rice, rainfed rice, pineapple, and melaleuca so as to examine LMU in accordance to its suitability levels. Suitability levels were expressed in qualitative terms, namely highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and unsuitable (N) (FAO 1976). The spatial dataset used for this assessment included:

- District soil map 2005 (1:25,000)
- Land-use map 2005 (1:25,000)
- Climatic data (2002–2004)
- Topographic map 2005 (1:5,000)

Soil information of diagnostic parameters related to land characteristics of 14 soil groups derived from the soil-map legends were sampled based upon pre-determined localities and analyzed for soil reaction (extracted by 1N KCl 1:25), organic matter (method of Walkley-Black), available phosphorus (method of Oniani), available nitrogen (extracted by 2M KCl 1:10), cation exchange capacity (extracted by 30 ml 0.1 M $BaCl_2$ 2.5 gram soil), base saturation (exchangeable bases divided by CEC), and electrical conductivity (extracted by H_2O 1:5). The results were encoded as the

[4] The technical and biophysical fitness of land unit for a specific kind of use (Bydekerke et al. 1998).

attributes to the respective soil mapping units in the GIS coverage. The land-use requirements for each LUT were obtained through a number of literatures (LDD 1992; Phuc 2001; Sys et al. 1993). The limitation method introduced by Sys et al. (1991) was followed. By this method, rating land characteristics for those classes was given according to its limitation, i.e. the more severe limitation; the lower rating scores.

The weight assigned for each land characteristic and land quality was based on the significant influence on the crop growth using the pair-wise comparison method developed by Saaty (1980) to determine the relative importance of each factor. The standard scales for making comparisons are: 1 (equally preferred), 3 (moderately preferred), 5 (strongly preferred), 7 (very strongly preferred), and 9 (extremely strongly preferred). Values 2, 4, 6, or 8 may also be assigned and represent preferences halfway between the integers on either side. The derived consistency ratio (C.R) of 0.1 or below is considered acceptable. The higher weight value was assigned to more significant, the lower score to less significant factor for the existence of the crops.

Arc/Info was used to process thematic layers using Boolean functions and to perform computations using the linear combination formula introduced by Bonham-Cater (1994). The final suitability maps comprised 4 suitable classes: S1, S2, S3, and N. S1 category refers to the land having no limitations to sustained application of a given use. S2 category refers to the land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land. S3 has increased limitations compared to S2 and N category has so severe limitations that they are simply not suitable for the specified use evaluated against.

Socioeconomic analysis

Land-use options derived from the assessment for each land mapping unit were biophysically suitable, it must nevertheless be appraised according to financial and economic viability, social acceptability and potential impacts on environment (FAO and UNEP 1999). Both qualitative and quantitative analyses were both implemented secondary and primary data. Primary data were collected using a structured questionnaire to sampled HH and other qualitative methods.

To appropriately draw the sample that could be best extrapolative to the whole area, a two-stage sampling technique was employed. The study area was firstly stratified into three zones: lowland, upland, and coastal areas based on the topographic features and farming characteristics. Then, a sample of 151 samples was proportionately estimated, in which 35 HH were of the upland, 33 of the coastal area. The lowland was more complex in production systems than that of the others so that 83 samples were respectively drawn.

Parametric and non-parametric analyses were applied to satisfy the paper scope. We hoped to produce results subjective to economic indicators of existing production systems, and determinants of HH earnings and forest condition that could meet the goals of effective land use and natural resources management. A xcorrelation matrix was firstly constructed to evaluate the association between variables. The multiple regression technique was subsequently deployed to predict determinants of HH earnings. The entry into the regression equations was set at $\alpha < 0.05$.

Examining forest management condition was also made based on the hypothesis that the forests under clearly defined boundaries, user rights and enforced rules would better conditions than that of the ones being limited in such assumptions for the sake of pertinent recommendations for excessive and perturbing anthropogenic activities using indices of priority index[5], participation index[6], and satisfaction index[7].

Land-use scenario analysis and negotiation

S1 and S2 lands were grouped into a so-called suitable zone and S3 and N into a marginal zone in respect to maximized production of the suitable zone while optimization of the other one for long-term food security and environmental safeguard.

We set up criteria for land-use scenario analysis based on (1) suitability classes in which S1 and S2 selected because they had minor land-quality limitations to a given LUT and adjustable return, (2) irrigation availability, (3) salinity intrusion, and (4) economic efficiency in terms of benefit–cost ratio (BCR).

For land-use negotiation, diagnostic factors including (1) economic viability, (2) social viability, (3) environmental viability. To collect this information, a group of 20 stakeholders consisting of heads of villages, farmer unions, and old-hand respondents of both genders was invited for the rapid rural appraisal workshops in each suitability zone. The Analytical Hierarchy Process (AHP) providing an indication of the significance of each feature in terms of perception, with 4 being highly significant and 0 having no significance at all was used for the analysis.

Land-use allocation

Land-use alternatives for each LUT were made based on the negotiating results and overlying the current land-use map with land suitability maps using Boolean function to explicitly exclude or include LMU wherever necessary.

Results and discussion

Land suitability

The area percentage under S1 class of both cases of irrigated and rainfed rice was very low, from 0.83 to 9.69% on the basic of land quality, whereas 44.18 and 39.13% for pineapple and melaleuca (Table 1). Land under S2 class was shared for

[5] Priority levels with no priority (0), fifth (0.2), forth (0.4), third (0.6), second (0.8), first (1.0).

[6] Participation levels with no participation (0), occasionally (1), sometimes (2), quite often (3), always (4).

[7] Satisfaction levels with dissatisfied (-1), satisfied (+1), neutral (0).

Table 1 Land suitability classes of major land uses

	Suitability class (%)			
	S1	S2	S3	N
Irrigated rice	0.83	45.84	49.75	3.57
Rainfed rice	9.69	65.80	20.94	3.57
Melaleuca	39.13	44.57	15.16	1.14
Pineapple	44.18	39.83	14.85	1.14

all LUT. It varied from 39.83 to 65.80%. In S3 category, irrigated rice was found as much as 45.84% while the other LUT differentiated from 14.85 to 20.94%. The proportion of land unsuitable for irrigated and rainfed rice was similar (3.57%), comparative to pineapple and melaleuca (1.57%).

Matching land-use requirements with land qualities illustrated that in all cases limiting land qualities were imposing individual LUT at all suitability levels, either excessive or scared. The major constraints derived from diagnostic factors for LUT were nutrient availability and nutrient retention. Exceptionally soil toxicities were observed for melaleuca.

When examining mis-match of land uses with land considering S1 and S2, a large proportion (27.83%) of existing irrigated rice areas was improperly allocated. 12.82% under melaleuca plantation was not suitable as well. Upland crops and rainfed rice under existing areas were altogether suitable for cultivation.

Economic indicators

Melaleuca was found to be highest BCR (3.61). The estimation was computed for one production cycle of seven years at a prevailing discount rate of 10%. The second was pineapple (3.32) whilst irrigated rice and extensive salt-water shrimp were 1.30 and 1.13 in turn. The integrated fish-mangrove system had a lowest ratio (1.20; Table 2). The BCR of rainfed rice was 1.30 (SAPD 2003). Melaleuca gave a highest economic efficiency because it was the regenerated forest; thus the beginning investment costs were substantially low, estimated only 750 USD per ha for one production cycle of seven years. This figure was comparative to the cost of annual rice production of two crops. Be and Khiem (2003) argued that the consuming

Table 2 Economic indicators of major LUT

Indicators	Salt-water shrimp	Irrigated rice	Mangrove-fish	Melaleuca	Pineapple	Rainfed rice
Total cost	15,045.52	5,261.40	61,282.05	1,730.55	5,917.32	4,146.00
Gross return	16,975.84	6,836.09	73,696.40	6,248.16	19,425.00	5,400.00
Per ha net return	1,930.32	2,051.38	12,414.35	4,517.61	13,507.68	1,254.00
Cost of production	126.22	0.39	57.76	0.73	0.52	0.48
BCR	1.13	1.30	1.20	3.61	3.32	1.30
Net return to input	0.13	0.39	0.79	0.43	0.70	0.23

Note: unit (1,000 VND/ha/year); Vietnamese currency (1 USD= 15,960 VND) market for melaleuca in terms of providing materials for small-scale buildings was still promising during the next 20 years. However, the melaleuca area had promptly been declined in recent years due to the long planting cycle and limited demands since its poles used for the constructing industry being replaced with the cement ones.

In spite of lacking adaptability to adverse soil condition, irrigated rice, a short-term crop of export importance, was dominant and in the trend of being expanded for both reasons of adequate marketing channels and short-term financial return. The BCR was observed to be relatively high for pineapple; however it was less cultivated due to locally limited consuming markets. In fact, there was no beverage factory surrounding the area. The produce was presently sold out to Cambodian markets nearby by middlemen. Extensive salt-water shrimp culture was likely to be a super-profit system for the first two years 2003–2004. However, its profitability was enormously dropped down afterwards from 6.97 in 2003 to 0.13 in 2006 because of exposed environmental problems.

Agricultural extension and credit source

Providing credit for farmers to improve and diversify the farmlands was one of the most critical factors to raise production. 55.56% in the lowland got loan whereas a few percentages in the coastal (11.11%) and (25.93%) in the upland areas were observed. People borrowed money from different sources e.g. agricultural bank (70.37%), private lenders (18.52%), and other sources (11.11%) for different purposes including aquaculture (33.33%), crop cultivation (37.04%), livestock raising (24.07%), and other (5.56%). The large farmers (>6 ha) borrowed money easier than the medium (5–6 ha) (31.48%) and small ones (1–4 ha; 12.96%) did because they had solid collateral. The large farmers were likely to borrow money for shrimp farming (40%) and rice production (50%) while the medium was for livestock raising (41.18%) and shrimp farming (29.41%); and small ones 57.14% for raising livestock and the rest of percentage equally shared for aquaculture and cropping.

Determinants of HH earnings

The correlation matrices indicated 14 variables in the upland to be significantly associated: HH size, land holding size, economically active population, education attainment, gender, male population in agriculture, female population in agriculture, agricultural extension, agricultural production costs, effect of forest policy, income from agricultural production, income from off-farm activities, number of income sources, and migration. 10 variables were found correlated in the coastal area: HH size, land holding size, economically active population, education attainment, gender, male population in agriculture, female population in agriculture, effect of forest policy, income from off-farm activities, and number of income sources; and similarly in the lowland: HH size, land holding size, economically active population, education attainment, male population in agriculture, female population in agriculture, agricultural extension, shrimp farming production costs, number of income sources, and migration.

The estimates of sequential search technique showed that in most cases determinants were significant relationship with HH earnings (Table 3).

In the upland the fitted model included four significant variables determining HH earning (*P* value < 0.05, *F* statistics 722.46, *df* 34). The *R*-squared of this model explained 99% of validity in HH earning. The standard error (SE), which showed the standard deviation (SD) of the residuals, was 4,897.36. The Durbin–Watson (DW) statistic of 2.56, which was greater than 2, indicated no significant autocorrelation in the residuals or no significant correlation due to sequence of variable input in the analysis.

In the coastal area, six variables significantly included in the HH earning model were land holding size, incomes from off-farm activities, number of income sources, number of HH family members, land holding size, and economically active population ($p<0.05$, *F* statistics 58.86, df 32). The model explained 93% of validity of HH gross earning. The S.E. was 11,250.27. In this case, there was also non-

Table 3 Multiple regression analysis of HH earnings

Parameter	Coefficient	SE	*t* statistic	*P* value
Upland				
Intercept	2716.412	1,729.52	1.57	0.127
Income from off-farm activities	1.68	0.25	6.77	0.000
Agricultural production costs	1.08	0.27	3.93	0.000
Income from agricultural production	0.92	0.38	2.46	0.020
Educational attainment	7,430.34	4,091.23	1.82	0.079
R^2=0.99 R^2 (adjusted for *df*)=0.98				
Standard error of estimate (SE)=4,897.36				
Durbin–Watson (DW) statistic=2.56				
Coastal area				
Intercept	−5,130.99	9,896.69	−0.52	0.609
Land holding size	−3,334.71	1,184.62	−2.82	0.009
Income from off-farm activities	1.28	0.15	8.55	0.000
Number of family members	−3,623.85	1,579.09	−2.30	0.030
Male population in agriculture	309.19	133.08	2.32	0.028
Number of income sources	9,361.36	2,803.34	3.34	0.003
Economically active population	194.34	108.48	1.79	0.085
R^2=0.93 R^2 (adjusted for *df*)=0.92				
Standard error of estimate (SE)=11,250.27				
Durbin–Watson (DW) statistic=1.81				
Lowland				
Intercept	−36,674.98	9,241.53	−3.97	0.000
Agricultural extension	70,798.53	13,769.68	5.14	0.000
Agricultural/aquaculture production costs	0.19	0.05	4.13	0.000
Educational attainment	45,487.64	13,355.82	3.41	0.001
Number of income sources	6,539.93	3,935.51	1.66	0.101
Economically active population	357.12	146.04	2.45	0.017
R^2=0.80 R^2 (adjusted for *df*)=0.79				
Standard error of estimate (SE)=23,130.83				
Durbin–Watson (DW) statistic=2.23				

Note: weighted education index (1: undergraduate; 0.75: high school; 0.5: secondary; 0.25: primary; and 0=illiterate); agricultural extension (no. of visits per year).

autocorrelation to be observed with DW (1.81), near 2. Number of family members and land holding size observed was negatively impacting on the HH earning, which implied that smaller land-holding size and larger HH size would not be contributing to an increased HH earning.

Variables predicted for lowland HH earning were agricultural extension, HH education level, number of economically active population, investment costs of agriculture and aquaculture, and number of income sources ($p<0.05$, F statistics 60.73, df 82). The model explained 80% of validity of HH earning. The SE and DW were 23,130.83 and 2.23 in turn, which wasn't auto-correlated too. Agricultural extension was among four important determinants in predicting HH earning. Raising farmer's awareness of farming technique was necessarily required to meet the objectives of sustainable agriculture.

Forest resources benefits and management

The highest priority index in forest benefit fell in the firewood category (0.92) while timbers (0.43). For those living along the coastal area or in the upland, benefits from humidity and non-timber products were 0.49 and 0.3 in turn (Table 4). Other benefits such as medicine, wildlife sanctuary, etc were lower than 0.2. Considering HH use of forest wood, the most priority was of energy (0.90). Timber extraction for the aim of constructing materials of small-scale buildings was ranked second (0.83). Agricultural materials, furniture, etc were almost equal (0.72).

The forest management was partially effective as a result of a number of conflicts between stakeholders. 52.58% proclaimed that driving forces of such conflicts were driven by improper arrangement of forest policies, unsatisfied benefits (30.93%), and social aspects (16.49%) (Table 5). Managing the protective mangrove forest was rather effective (41.38%) than the special used evergreen forest (64.71%) and the

Table 4 Priority in forest resources use and benefits

Items	Special used evergreen forest n=32	Protective mangrove forest n=33	Protective melaleuca forest n=31	Total $n=96$
Priority in forest benefit				
Firewood	0.84	0.98	0.94	0.92
Timber product	0.64	–	0.62	0.43
Medicine	0.21	–	–	0.07
Aquatic product	–	0.47	0.44	0.30
Honey	–	–	0.47	0.17
Wildlife sanctuary	0.39	0.21	–	0.20
Humidity	0.71	0.42	0.33	0.49
Natural hazard defense	–	0.21	–	0.07
Priority in forest wood use				
Energy	0.81	0.88	0.98	0.90
Fencing materials	0.49	0.81	0.53	0.72
Construction materials	0.85	0.61	0.84	0.83
Furniture	0.82	0.77	0.74	0.73
Agricultural materials	0.61	0.87	0.80	0.72

Table 5 Conflicts, satisfaction and participation in forest management

Items	Special used forest $n=32$	Protective mangrove forest $n=33$	Protective melaleuca forest $n=31$	Total $n=96$
Conflict				
Forest policy	64.71	41.38	50.00	52.58
Forest benefit	26.47	44.83	23.53	30.93
Social aspect	8.82	13.79	26.47	16.49
Satisfaction				
Afforestation activities	−0.03	0.79	0.48	0.41
Product extraction	−0.35	0.10	0.00	−0.12
Participation				
Past afforestation program	0.84	0.94	0.31	0.71
Nursery activities	0.03	0.00	0.10	0.40
Forest care	1.09	1.79	0.74	1.22

melaleuca protective forest (50%) because under the co-management regime, the HH had consistent rights to exploit and responsibilities to care for the forests. The HH property rights were well-defined and defended, which provided a strong power for HH to exclude outsiders and to eliminate open access. However, 44.83% of HH faced a conflict of forest benefits while smaller percentages were found for special used (26.47%) and melaleuca protective (23.53%) forests because before the Decision 51/2005/QD-UBND launched in late 2005, HH were not provided residential land inside the forest as a consequence of unabling HH to monitor illegal logging. The participation index of forest care was thus 1.79, greater than that of the special used (1.09) and melaleuca protective (0.74) forests.

Although remaining some limitations of forest extraction (0.10), the arrangement of protective mangrove forest had likely contributed to sustainable use of CPR (satisfaction index 0.79) because, under economic incentives, HH had more opportunities to improve their livelihoods via timber, non-timber products and residential land for resettlement. The allocation of residential land within the forest enhanced HH to monitor forest more effectively so that the transaction cost of monitoring illegal logging is minimized. Non-timer benefits e.g. aquatic products from shrimp and fish farming generated high economic return although it had not commonly been practiced; therefore, HH livelihoods did not heavily rely on timber.

The co-management of special used forest in the upland was ineffective because the current forest policy had provided less economic incentives for those caring for the forest leading to occasional participation declining as a deprivation to be pronounced. In practice, HH had a contract to re-plant Cay Sao (*Hopea odorata Roxb*) and would receive a subsidy of only 150,000 VND for the first 3 years of re-planting period. Afterwards, they did not receive any more for the forest management. In fact, the current investment policy was completely contradicted to the growth rate of the trees. So, only 30% of replanting special used forest was under good condition. Suggested that subsidies must be provided for at least five years long when the trees could not be affected by external environment.

The arrangement of melaleuca protective forest was unsustainable because the property rights and boundaries were not defined and defended due to rent-seeking behavior[8] between local bureaucrats, political party and better-off contractors had converted an enormous of natural forestland (5,327 ha) into irrigated rice and shrimp ponds (MARD 2005). The rapid expansion of shrimp farming could be derived from two main possibilities: the high market value of shrimp and rice understated the low market value of melaleuca and the weak enforcement of the rules from forestry staff. A related conflict to the forest management was between agricultural, brackish aquaculture and forest HH in terms of benefit. In dry season aquaculture HH took saline water into the shrimp farms, making salt-affected for those cultivating rice and caring melaleuca nearby while in the rainy season water with toxicities by ASS drained out from inland had caused seawater to be polluted for those practicing the mangrove-based aquaculture systems along the coastal area. In some cases, forest fire also occurred for forest HH when rice HH burnt their field for the next crop production.

Land-use negotiation

36.03% of the area considered as suitable area for all LUT could be put under intensive cultivation for the subjective to local community's food security while about 50% should be considered marginally suitable for upland crops and melaleuca production because the land was moderate limitation and salt-affected. Pineapple and melaleuca seemed more biologically suitable for this area than rice (16.20%). Even so, land-use decision making of specific LUT on specific land mapping unit must be based on stakeholders. Of three aspects of the sustainable development term introduced United Nations (1992), the economic one was given a highest weight (9) (Table 6) while the environmental and social branches were equal (5).

In the suitable zone, irrigated rice-based upland crops had highest weighted score (66), mono-irrigated rice (47), and melaleuca (37). Few HH practiced the integrated irrigated rice-based upland crops with very little comprehensive about it. The reasons this system reached a highest score was because of economic reasons in which food security and raised income aspects were major thrusts triggering farmer's decision. The people could aware of ecological importance from melaleuca forests but the lowest score (37) was found due to limited marketing channels and a long production cycle.

In the marginal zone, rainfed rice had a greater scope of suitability (71). However, rainfed rice based salt-water shrimp system was referable (57) as it had a highest score (37.5) in the economic branch and also supported the increasing trend of shrimp farming while minimizing environmental impact. This result was comparative to that of previous studies conducted in a similar environmental condition, namely the net income of rainfed-rice based salt-water shrimp system higher than that of extensive salt-water shrimp mono-culture (Duong et al. 1998).

Upland crops i.e. pineapple biophysically had a largest suitable proportion of land and its economic indicators were promising. Encouragements for expanding this

[8] Use of resource through lobbying for the increased net benefits of a special interest group (Tietenberg 2004)

Table 6 Rating and weighting and weighted scores

Diagnostic factors	Suitable zone						Marginal zone			
	Weight	LUT1	LUT2	LUT3	LUT4	LUT5	Weight	LUT6	LUT7	LUT8
Economic (Cum Wt=9)										
Investment costs	9	2	1	4	3	3	9	2	3	4
Gross return	8	1	1	2	4	4	8	2	3	4
BCR	7	3	2	2	4	3	7	4	2	3
Financial return	8	1	3	2	4	4	8	1	3	4
Farm holding size	6	1	2	2	2	3	6	1	2	3
Productivity risk	7	3	1	4	3	3	7	1	2	3
Market risk	8	1	1	4	3	4	8	1	2	4
Weighted score		10.0	7.4	28.9	34.7	37.5		6.3	20.6	44.2
Social (Cum Wt=5)										
Food security	9	0	0	2	3	0	9	0	4	3
Accessibility to credit	8	1	1	3	2	2	8	2	3	3
Technology required	7	2	1	4	2	2	7	2	4	3
Cultivating custom	6	1	1	4	2	2	6	2	4	3
Labor requirement	6	2	4	3	2	3	6	3	3	2
Weighted score		1.7	4.4	24.1	8.3	10.5		4.4	26.3	13.3
Environmental (Cum Wt=5)		26.3	0	17.5	8.8	8.8		26.3	0	8.8
Environmental impact	6	4	1	3	2	2	6	4	1	2
Weighted score		26.3	0	17.5	8.8	8.8		26.3	0	8.8
Total weighted score		38.0	11.8	70.5	51.8	56.8		37.0	46.9	66.3

Note: LUT1 & LUT6: melaleuca *forest*; LUT2: extensive salt-water shrimp farming; LUT3: rainfed rice; LUT4: upland crops (pineapple); LUT7: irrigated rice; LUT8: irrigated rice-based upland crops

model were probable if met the goal of government's supports in marketing. Provision was not made to recommend the salt-water shrimp monoculture because it was high productivity risks and long-term caused land and water resources to be degraded. For melaleuca, suggested that at areas where severe limitations for crop growth should be covered with melaleuca to protect the environment and optimize land-use efficiency.

Land-use allocation

The land-use scenarios (Fig. 3) showed out of 46.75% area under current irrigated rice 31.11% could be intensively promoted for maximized production of irrigated rice-based upland crops with the required management levels. Besides an improved nutrient availability, better-off irrigation and drainage systems was required to prevent a large cultivating area from annual flooding and salinity intrusion. 12 out of 24% of the area under extensive salt-water shrimp culture was favorable for practicing the integrated farming systems according to the production scheme that in the dry season when saline water remained, prawns were raised whereas in the rainy season when saline water was drained out and the soils flushed free of salinity by rainwater, rainfed rice was cultivated. Noted that soils in this zone were acid sulfate soils so that it was necessary to be kept wet at all times to prevent a decrease of soil pH from soil oxidation during the dry season.

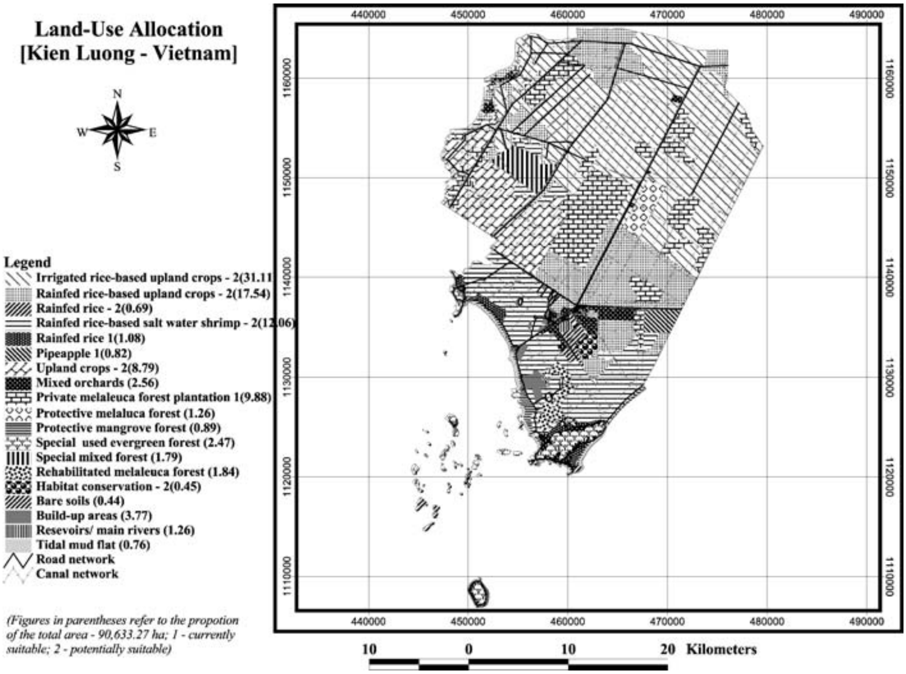

Fig. 3 Map showing land-use scenarios

As mono-cultivation of upland crops such as pineapple had a greater suitability scope for expanding, raised beds, mulching technique, irrigation and drainage improvement were suggested management decisions besides basic factors of production including fertilizers, particularly available phosphorus and high yielding varieties. Provision was made to encourage private commercial melaleuca forest plantations at areas identified unsuitable for cultivating economic crops.

0.45% of the area naturally suitable and worth for conserving the eco-niche of red-head cranes could be put under a CPR management[9] (Agrawal 2001). Since a large proportion of CPR of seasonally flooded wetlands had been privatarized for other land uses due to rent-seeking, the benefits only focused upon a small group of bureaucrats in terms of shrimp farming whereas for those who were the poor farmers unable to invest. As the privatization of wetlands was enhancing the inequity of income distribution (Adger and Luttrell 2000), it could be comparative to the case of natural resources in the study area where a few of bureaucrats received a huge benefit from shrimp culture while generating negative externalities to the environment resulting agricultural losses and ecological degradation. Those costs were imposing on poor rice farmers who could not invest in shrimp farming.

[9] Jointly owned and managed by a group of co-owners within a community (Tietenberg 2004).

Conclusion

Lack of knowledge of land use against its inherent quality and understanding of socioeconomic constraints were the two major factors responsible for unsustainable agriculture and grave challenges for natural resources. These disparities could be overcome once both biophysical and socioeconomic solutions were due time addressed. The land suitability classification showed that none of the highly suitable areas classified for irrigated rice or very humble and not exceed 50% of the area in turn found highly suitable for rainfed rice melaleuca and upland crops. This indicates that land quality in the study area is pretty poor as a result of either overexploitation of soils or cultivation in the marginal lands. Low soil reaction, restricted available phosphorus and excessive CEC were noted constraints for individual LUT.

Mono-production systems were less productive probably due to low capacity of soils as its economic indicators manifested the BCR and were reaffirmed by stakeholders. Comparing land use with land, 31.11% could be put under extensive production of irrigated rice-based upland crops while 39.08% considered for the optimized land-use alternatives. Together with the unchanged melaleuca forest area (9.88%), other degraded ones (1.84%) unsuitable for cropping should be rehabilitated for the sake of ecological services. Encouragement was made for cultivating pineapple and other upland crops (8.79%) with conditional marketing channels. Besides, incentive stewardships of CPR management to preserve 0.45% of the eco-niche of red-head cranes because once it is gone it can’t be replaced.

The suitability of production systems and natural resources management was much associated with both land quality and land user’s socioeconomic requirements in each landscape. Therefore, interventions to archive the objective of sustainable agriculture and natural resources management must also be formulated based on suggested land-use options on better LMU and socioeconomic requirements, basically involved in determinants of HH earnings including income from agricultural/ aquaculture production practices and education attainment. This could only be attained if employing institutional concerns, better-off rural credit services, and an improved HH awareness of farming techniques through agricultural extension.

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