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ABSTRACT

The Mekong Delta faces significant challenges in supplying Vietnam and its export market countries with agricultural commodities, while ensuring livelihoods and providing living space to its growing population in the context of climate change and the country's agrarian transition. Anthropogenic factors, such as the construction of dykes to control river flooding, river sand mining, the further development of triple-cropping rice production, and infrastructure development, together with climate change impacts on sediment and water availability, are all combining to threaten agricultural production. One of the key challenges in sustainable development is the need to identify plausible future states of agricultural-based socio-ecological systems which draw upon differing strategies of land management, and to characterise the impacts of these systems on both the landscape and employment. It was hypothesised from the literature and rapid rural appraisals that each land system can only provide a certain number of jobs, which was further demonstrated using binomial regressions. We show that the odds of being employed are lower for intensive agricultural systems (OR=0.78 for triple rice; 0.91 for intensive aquaculture) than for diversified systems (OR=1.16 for rice-aquaculture; OR=1.63 for mixed fruit trees). Drawing from workshops with local and national stakeholders, we then used Earth observation and national census data in a spatial land use systems dynamic framework to simulate two alternative Mekong Delta futures based upon the climate pathway RCP 4.5 in combination with two existing policies (i) Resolution No. 124 (Specialisation) which promotes triple crop rice and aquaculture intensification and (ii) Resolution No. 639 (Diversification), which states that there should be a development of sustainable rice aquaculture and crop diversification. Based on the quantitative objectives of each policy, we estimated likely changes of services provided by land use systems if either policy were to dominate. The estimated impacts of each future scenario on the provision of employment ultimately indicate that policies with a diversification development paradigm will provide more employment (+0.9%) than policies with a specialisation paradigm (−46%), and that current policies have potentially conflicting consequences. Decisions driving towards intensive farming risk triggering rural unemployment and outmigration, potentially exacerbating urban poverty in major cities such as Can Tho and Ho Chi Minh City. On the other hand, decisions aiming at increasing diversified agricultural systems can help secure more job opportunities. Our results indicate that spatial planning policies should rely on a broad-based assessment of land system services that include employment and environmental impacts to ensure a just transition towards resilient and environmentally sustainable rural territories.

Abbreviations: RCP, Representative Concentration Pathway; OR, Odds Ratio; NDVI, Normalised Difference Vegetation Index; GLM, Generalised Linear Model.

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1. Introduction

Major economic and demographic shifts are driving human societies towards increased food demand food demand with a projected rise of 59–98% by 2050 under the Shared Socio-economic Pathway "Middle of the Road" (SSP2) (Valin et al., 2014; Tilman et al., 2011). This increased demand leads to greater land use competition as they provide services such as food, housing, transportation, energy, employment, and water (Deichmann et al., 2019). Significant concerns over demand for land use services cannot be met without causing irreparable damage to the environment (Giller et al., 2021). Current approaches in land management for developing countries are often targeted to maximise economic factors via extractive models of land use, which exacerbate environmental degradation.

Managing agricultural social-ecological systems requires greater understanding of existing linkages between land, governance and people (Kremen and Merenlender, 2018; Hutton et al., 2021). Land use management, for example, through intensification or extensification of farming systems, can lead to substantial changes in terms of employment. High intensity or extractive models of land use may contribute to a substantial reduction in both quantity and quality of livelihood opportunities for local communities, which often underpins increased migration and unskilled labour (Berchoux et al., 2019; Garnett et al., 2013). As a consequence, policymakers need to balance trade-offs between high intensity production and sustainability (Hutton et al., 2021), hence shaping land management strategies through regulatory, voluntary, financial tools and spatial planning (Kremen and Merenlender, 2018).

The Vietnamese Mekong Delta, covering an extensive area of approximately 41,000 km^2, is home to a significant portion of the country's population. As of the 2019 census, Vietnam's total population was estimated at 96.2 million, with 17.3 million residing in the Mekong Delta, of which 12.9 million live in rural areas, underscoring the predominantly agrarian nature of the region's livelihoods (General Statistics Office, 2020). However, despite its economic significance, the Mekong Delta experiences the highest out-migration and negative net migration rate in Vietnam. In terms of employment, the Statistical Yearbook reports that the Mekong Delta's unemployment rate was estimated to be 4.1% in 2021, which is higher than the national average of 3.2%. Furthermore, the 2021 report indicates a significant increase in unemployment from 2.8% in 2020.

This highly complex and dynamic delta that has undergone rapid changes over the past decades as Vietnam developed economically (Smajgl et al., 2015). This development has been closely tied to the expansion of agriculture, primarily rice production, which has been the driving force behind many technological, economic, and environmental changes. However, this reliance on rice monoculture has also caused social unrest and created environmental problems, challenging the local social-ecological system's ability to adapt to changing circumstances (Chapman and Darby, 2016). Moreover, the Vietnamese Mekong Delta is projected to undergo significant environmental changes, primarily with respect to salinity intrusion (Eslami et al., 2021a), reduced sediment fluxes (Bussi et al., 2021; Vasilopoulos et al., 2021), more frequent climate extremes (floods, droughts) and decreases of precipitation, thus leading to declining groundwater recharge (Shrestha et al., 2016). Simultaneously, demographic changes (Szabo et al., 2016) and economic orientations (industrial and infrastructure development, export-oriented commercial agriculture) pose additional challenges to land use systems by increased demand on some land services.

To address these challenges, the Socialist Republic of Vietnam has passed Resolution 120 on Sustainable and Climate-Resilient Development in the Mekong Delta and the Resolution's 2019 Action Programme (Socialist Republic of Vietnam, 2017, 2019). Both resolutions are designed to move from a focus on food security towards high quality food production using a combination of high-tech, large-scale, and organic agriculture by developing: industry associated with agricultural production, water resource protection through increased production efficiency, markets and value chains, delta infrastructure for better regional connectivity as well as with neighbouring countries, and improved vocational training with the aim to prevent out-migration. Regarding aquaculture, the aim is to transform fisheries into a highly competitive, large-scale commodity production sector and to construct large fishing centres associated with major fishing grounds, concentrated material production zones, industrial parks and consumption markets. These measures, which oscillate between intensification and environmental protection, are designed to implement the Mekong Delta Plan - a strategic spatial plan the general principles of which were first set out in 2013 (Hutton et al., 2021) and formalised in 2022 with the Mekong Delta Master Plan. Apart from aforementioned general orientations, plan implementation is supported by a number of sectoral policies. Of these, decisions 124/939 (Socialist Republic of Vietnam, 2012a, 2012b) and 639/816 (Socialist Republic of Vietnam, 2014, 2018) are central policies governing land use. However, according to local stakeholders, the objectives of decision 124 are conflicting with decision 639 and with the 2017 Vietnamese Law on Planning. This law clearly stipulates that planning and development should "minimise the negative impacts due to the economy, society and environment on community livelihoods" while promoting "the development of the disadvantaged and slowly-developing areas and sustainable livelihoods for people therein" (Socialist Republic of Vietnam, 2017a; Hutton et al., 2021).

While the impacts of land use system changes on the Vietnamese Mekong Delta's environment and society are evident, there is a lack of understanding of how these processes impact livelihoods on the ground. A better understanding of how policies influence land use systems and livelihoods is necessary. To address these knowledge gaps, it is important to characterise the associations between land use systems and employment, and to model the impact of spatial planning policies on future land use systems. In this paper, we combined Earth observation and national census data in a spatially explicit and dynamic land use system change model to explore the effects of the two main Vietnamese land use planning policies on employment and land use systems.

2. General approach

We followed a four-steps approach (Fig. 1): (1) characterise associations between employment and land use systems; (2) identify current trends of land use systems change; (3) model projections of land use systems under the combined effects of current policies and environmental change (4) predict employment for each policy scenario based on projected land use systems. Our working hypothesis is that local-scale variations in employment are at least partly explained by changes in land use systems at a higher level, such as the municipality, and thus by land use planning policies. Overall, the findings of this paper show that current policies have conflicting objectives with each aiming to produce differing future land use systems in the Mekong Delta. In particular, scenarios that favour food production will lead to an increase in the area of land use systems that support fewer jobs, while scenarios that promote agricultural diversification will ensure greater employment opportunities.

3. Methods

3.1. Conceptualising the links between land use systems and employment

Fieldwork on the Mekong River Delta was conducted between April and May 2018 to understand components of rural livelihoods and land use systems, from a household perspective, across a range of diverse socio-ecological contexts. This fieldwork enabled us to characterise agricultural land use systems and to identify the main associations between land use, household livelihood strategies, and employment in each land use system. We used Rapid Rural Appraisal as the principal field method to collect data and to highlight the perceptions and opinions of representative stakeholders and local residents (see

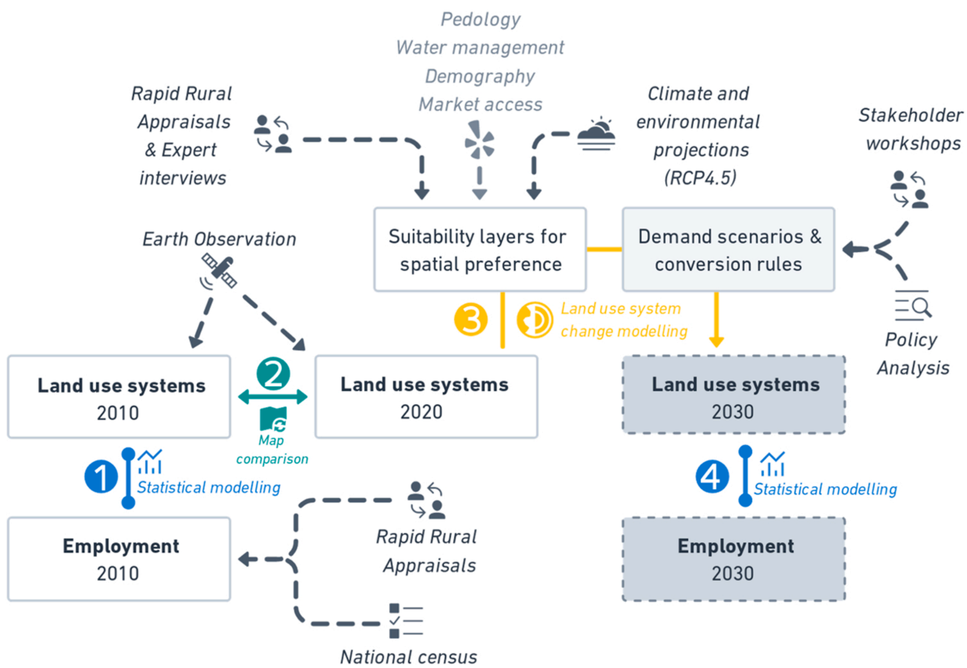

Fig. 1. Approach used to analyse land use systems and their associations with employment. Four steps were followed in the paper: (1) a territorial assessment characterising patterns of land use systems and employment; (2) an assessment of current trends in land use system changes; (3) a projection of trajectories of land use systems under global environmental change (RCP4.5, deltaic subsidence and salinity intrusion), exploring different policy options as a response (specialisation vs. diversification); and (4) predict employment for each policy scenarios based on projected land use systems.

Supplementary Material S1, S2). This method enables local people to share their knowledge, and to discuss and analyse their situation using their own terms (Mukherjee, 2005).

In total, ten villages were selected using a stratified sampling design of the main types of land use systems present in the community. Two villages for each main land use system (triple rice cropping, double rice cropping, aquaculture, orchards) were sampled to provide input from a variety of cases, based on the social-ecological characteristics of the community and on the main livelihood strategies conducted by households (Fig. 2). Rapid Rural Appraisals were conducted with 10–15 participants per community covering a range of livelihood strategies, socio-economic, and gender backgrounds. Different appraisal activities with communities were used to cross-check acquired data and to cover all aspects of land use systems and livelihoods. First, a participatory workshop was held as a focus group, where general information about the village, the land use systems and their evolution was discussed. Differences within the community regarding livelihood assets and employment strategies were investigated. Once different livelihood categories were identified by participants, they quantified the proportion of households falling into each category.

3.2. Characterising land use systems

Land use systems reflect a multi-functionality of landscapes, by taking into account land use, land management, and water management through irrigation infrastructures and practices (Malek et al., 2018). At the time of conducting the study, there was no delta-wide land use system map that included non-rice agricultural systems available for both 2010 and 2020. Some studies had created maps of a portion of the Delta (Truong et al., 2022), some for the whole delta but only for years 2010 and 2014 (Nguyen et al., 2015), while others only categorised rice agricultural systems (Vu et al., 2022). As a consequence, we generated our own land use systems maps by using supervised classification to ensure comparability between 2010 and 2020.

We used MODIS (Moderate Resolution Imaging Spectroradiometer) data to derive NDVI (Normalised Difference Vegetation Index) from a total of 46 MOD09Q1 cloud-free images at 8-days interval for each year, with a resolution of 250 m. We used maximum likelihood classification on NDVI time series (Fig. 3) to derive 9 land use systems classes representing the main agricultural systems identified during rapid rural appraisals (tripe rice, double rice, rice-aquaculture, cash crops, fruit trees, aquaculture, forest-aquaculture, forest, urban), as specified in Tran et al. (2015). We used the Natural Resources and Environment land planning maps collected from the local governments during fieldwork to train the model (stratified training sample, R^2 =.85). Finally, we characterised the links between agricultural land use systems, livelihoods and main types of employment thanks to the qualitative data collected during the rapid rural appraisals (Supplementary Material).

3.3. Associations between land use systems and employment

Logistic regression was used to investigate the effects of land use systems on the probability of being employed in a specific sector. Eight response variables (extracted from the 2010 Census on Population and Housing in Vietnam) were considered, derived as the number of people salaried or self-employed in one of the following sectors to total active population: (i) agriculture; (ii) forestry; (iii) aquaculture; (iv) industry; (v) construction; (vi) commercial; (vii) transportation; and (viii) inactive. The proportions of the response variables of interest varied continuously over a bounded range of [0,1]. Thus, an ordinary least squares regression model would be a model misspecification as it requires a response range over all real numbers. In this regard, a generalised linear model (GLM) with a logit link is a correct model specification as the logit function transforms the bounded proportion range from [0,1] to all real numbers as required. As contextual factors, such as socio-political and market contexts, strongly impact employment opportunities, outcomes and the ability of households to implement coping strategies (Berchoux et al., 2020), we used the proportion of ethnic minorities and travel duration as confounders to control for such factors.

$$\mathrm{logit}\,(\pi_i) = \log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1\, EthnicMinorities_i + \beta_2\, TDMarket_i + \sum_j \beta_j \frac{AreaLS_{ij}}{TotalArea_i}$$

where π_i refers to the probability of working in one of the sector listed above in the community i and $\sum_j \beta_j \frac{AreaLS_{ij}}{TotalArea_i}$ refers to the share of land use system j in the community i.

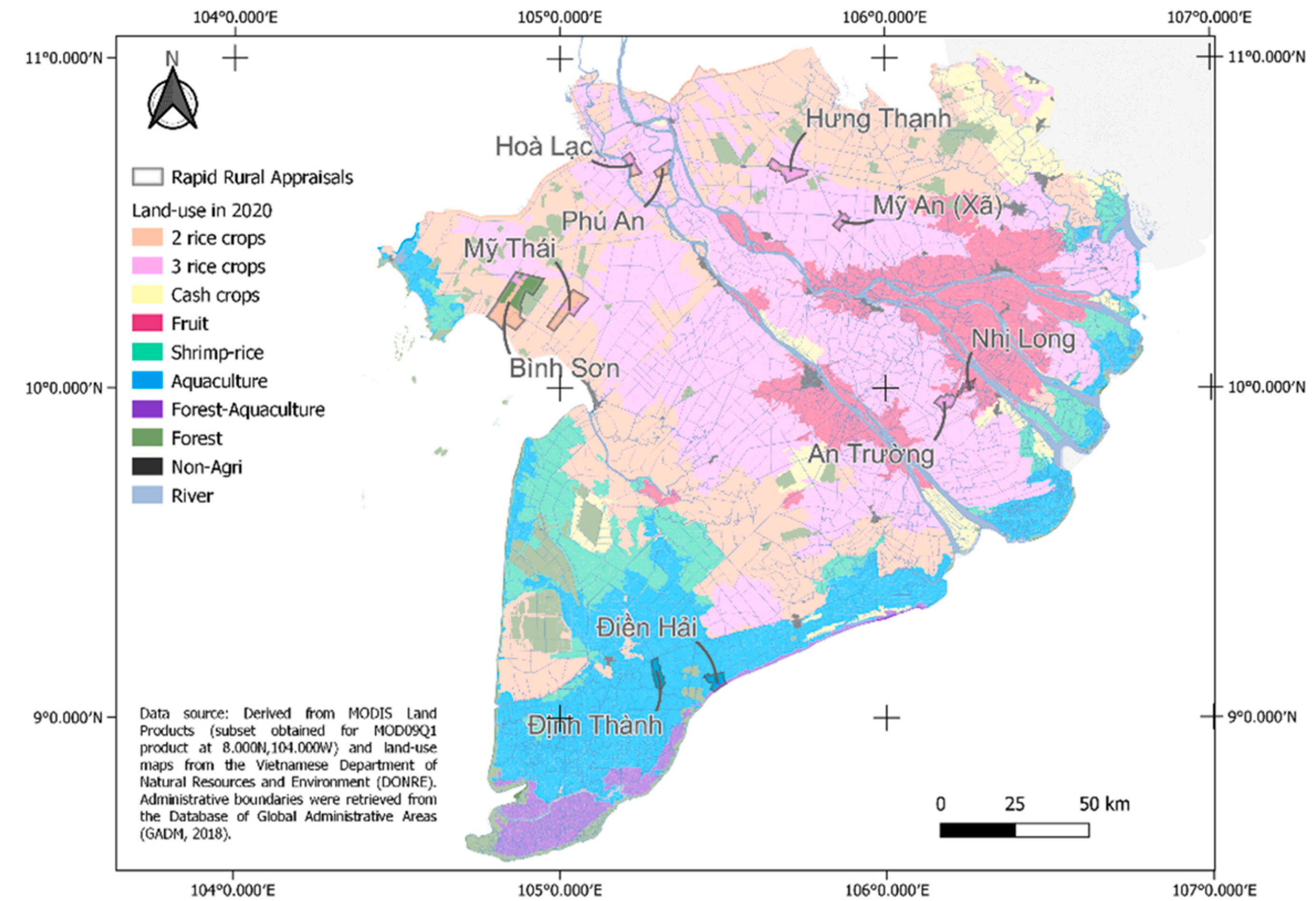

Fig. 2. Vietnamese Mekong Delta land use systems maps in 2020. Authors' land use systems map derived from 2020 MODIS data and location of the ten communities where Rapid Rural Appraisals were conducted.

3.4. Projections of land use system change

Plausible land use systems for 2030 were developed using CLU-Mondo, a model that simulates land use system change as a function of exogenously derived demands for commodities and services while accounting for local suitability and competition between land use systems (Van Asselen and Verburg, 2012). While other approaches to predict future land use like Cellular Automata (Rahaman et al., 2022) use past dynamics to derive future dynamics, CLUMondo can simulate future projections based on different scenario parameters that can be informed by current policies (Supplementary Material S3). The 2020 land use system map of the Vietnamese Mekong Delta was used as a baseline. For each year, a suitability map was created using logistic regression between the distribution of each land use system and a set of explanatory factors (Diep et al., 2022) (Supplementary Material S3). A total of 21 biophysical and socioeconomic explanatory variables were used. Explanatory variables included static factors that were assumed to not change over the ten years modelling span, such as soil properties, water logging, population density (we accounted for population change through demand, which drove the model), and access to markets. We also added dynamic factors that updated yearly to represent climate change under RCP4.5, including climate variables from CMIP6 models (Fick and Hijmans, 2017) and salinity projections (Eslami et al., 2021b).

Land use systems in 2030 were simulated under two different scenarios (Table 1), which were based on sets of demands for commodities and services from existing policy decisions (built-up, agricultural products, aquatic products). Policy-based scenarios were designed according to the main land use orientations of the development plans for the Mekong Delta: a scenario "Specialisation", based on the pair of decisions No.124 and No. 939 (Socialist Republic of Vietnam, 2012a, 2012b), which promote triple crop rice and aquaculture intensification; and (ii) a scenario "Diversification" for the pair of decisions No. 639 and No. 816 (Socialist Republic of Vietnam, 2014, 2018), which state that there should be a development of sustainable rice aquaculture and crop diversification (Supplementary Material S2).

For all scenarios, stakeholder input was key in setting model parameters during workshops, which were based on an analysis of policy decisions affecting the development orientations of the Mekong Delta (Hutton et al., 2021). Each scenario was modelled using different provisions of services (ability of each land use system to provide a service), demands for services (policy objectives) and spatial constraints. The latter represents transitions from one land use system to another, which were strictly prohibited or only allowed by predefined changes. For example, conversions from single-season rice to intensive aquaculture and later to triple rice were facilitated in the "Specialisation" scenario based on decision No. 124 to reflect the policy orientations found in the decision: "convert some one-rice crop in water-logged areas into fish or shrimp areas" and "to increase the area of triple rice and to do intensive farming". On the contrary, transitions to single rice were encouraged in the Decision No. 639 scenario, based on the policy statement "to increase the area of rice-aquaculture in both fresh and brackish water, rotationally lush flood into fields", while aquaculture and orchards were favoured compared to intensive freshwater rice area.

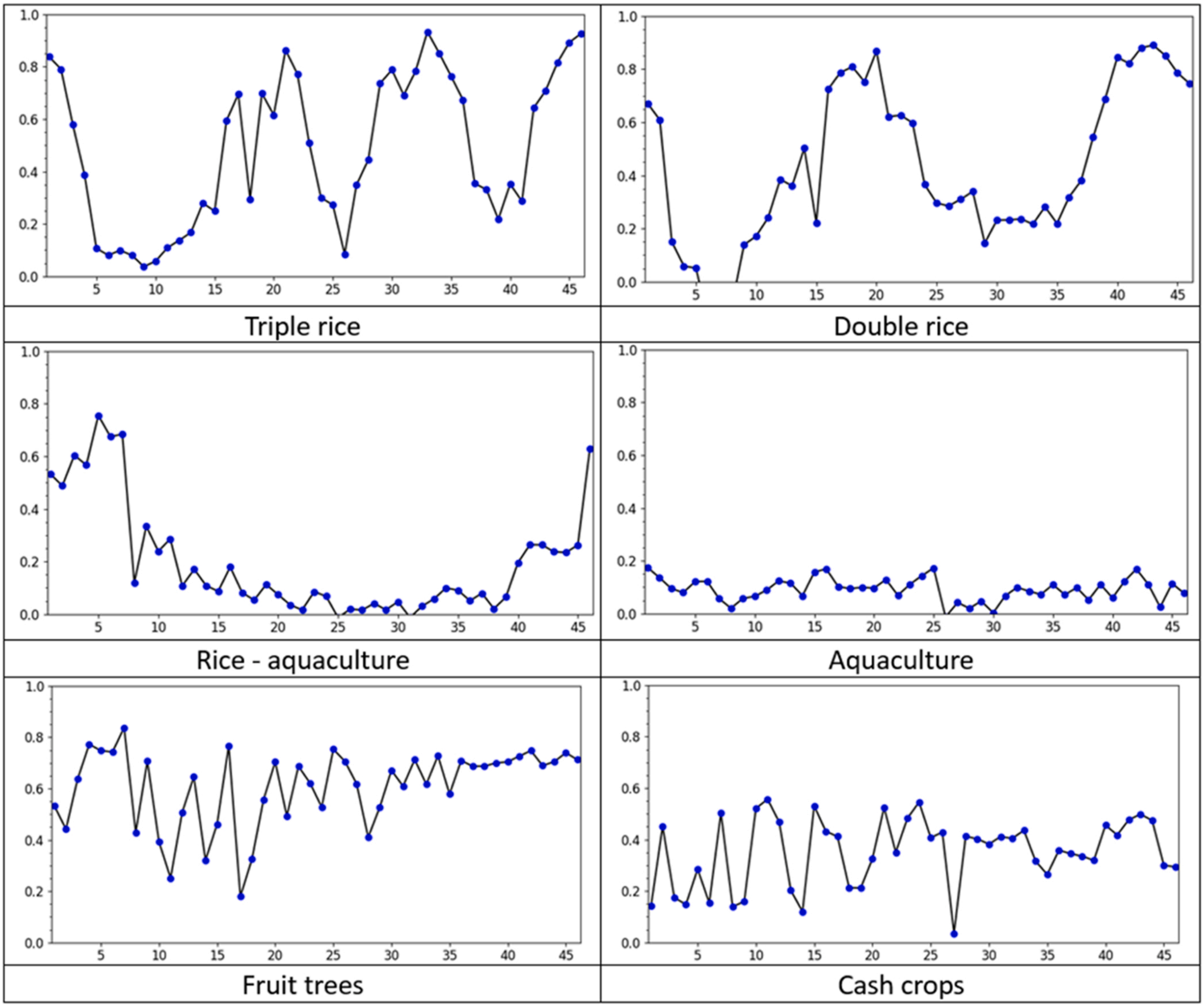

Fig. 3. Example of NDVI time series for the 6 most represented land use systems in the Vietnamese Mekong Delta. Derived from 46 MOD09Q1 cloud-free images at 8-days interval for each year.

4. Results

4.1. Employment opportunities in complex land use systems

Odds ratios (OR) were used to quantify the relationships between the response variable (employment or labour type) and the explanatory variables (land use systems), controlling for travel time to the closest district capital and the effects of ethnic minorities. An odds ratio above one indicates that, as the explanatory variable increases, the odds of being employed in a specific sector or labour type also increases.

Concerning the effects of land use systems on main employment sectors (Table 2), agricultural land use systems (triple rice, double rice, cash crops, fruits) had a significant ($p \leq 0.001$) positive effect on the odds of engaging in agricultural employment, while other land use systems (forest, aquaculture, mixed rice-aquaculture, urban) had a significant negative effect. Fruits/orchards had the greatest positive effect on providing agricultural employment (OR = 2.01, 95% CI = [1.92, 2.11]), cash crops had the lowest, and double rice had a greater effect (OR = 1.85, 95% CI = [1.77, 1.94]) compared to triple rice. Moreover, ethnic minority inclusion increased the odds of engaging in an agricultural job (OR = 1.57, 95% CI = [1.55, 1.59]).

Aquaculture, rice-aquaculture, and forest land use systems had a statistically significant positive effect on the odds of engaging in fishery-related employment, while agricultural and urban land use systems had a negative effect. Aquaculture had the greatest positive effect on providing fishery-related employment (OR = 7.12, 95% CI = [6.71, 7.57]), followed by mixed land use systems: rice-aquaculture and forest-aquaculture. Moreover, ethnic minority inclusion reduced the odds of engaging in a fishery-related job (OR = 0.48, 95% CI = [0.47, 0.49]).

For non-farming employment, land use systems with a greater share of urban areas increased the odds of engaging in commercial activities, construction activities, industrial activities and transport activities.

Four fitted models were used to analyse the effects of land use systems on labour types (Table 3). Agricultural and urban land use systems had a statistically significant positive effect on the odds of being salaried, urban land use systems having the greatest effect (OR = 5.75, 95% CI = [5.42, 6.10]), followed by cash crops, double rice, triple rice and fruits. On the contrary, the share of forest (OR = 0.68, 95% CI = [0.63, 0.73]), rice-aquaculture and aquaculture decreased the odds of being salaried compared to being self-employed. Finally, ethnic minority inclusion increased the odds of being salaried compared to self-employment (OR = 1.32, 95% CI = [1.30, 1.34]). In terms of

Table 1
Summary of main storyline elements of the two scenarios. Scenario "specialisation" is based on the pair of decisions No.124 and No. 939, which promote triple crop rice and aquaculture intensification. Scenario "diversification" is based on the pair of decisions No. 639 and No. 816, which state that there should be a development of sustainable rice aquaculture and crop diversification.

	Specialisation	Diversification
Population and livelihoods		
Population in 2030	9% increase (SSP2)	9% increase (SSP2)
Demand for livelihoods	N.A.	N.A.
Demand for built-up	Matching annual population growth rate	Undershoot annual population growth rate
Spatial pattern	Urban sprawl allowed, urban land has priority over all other uses	Compact and denser urban areas promoted
Agriculture and aquaculture		
Demand for products	Agriculture 4.5% yearly increase; aquaculture 3% yearly increase *(No.124)*; maintain rice export volume of 6–7 million tons *(No.939)*	Agriculture 3% yearly increase; aquaculture 7% increase *(No.639)*
Structure of overall value	Agriculture 55%; aquaculture 43.5% *(No.939)*	Agriculture 51.9%; aquaculture 40% *(No.639)*
Yields	Increase average value of land production by 50% to reach 110M₫/ha *(No.124)*	Agriculture 180M₫/ha; aquaculture 400M₫/ha *(No.639)*
Land-use planning	Convert one-rice crop to aquaculture (No.939); increase the area of triple rice and promote large-scale farming *(No.124)*	Reduce freshwater and ineffective rice systems, increase aquaculture and orchards *(No.816)*; increase rice-aquaculture area *(No.639)*
Climate change and salinity		
Climate change scenario	RCP4.5	RCP4.5
Salinity projection scenario	Subsidence B2; riverbed level incision of 0.05 m/yr	Subsidence B2; riverbed level incision of 0.05 m/yr
Water management	Develop hard infrastructure for water management with high dykes and sluice gates *(No.124)*	Increase of lush flood in fields; encourage small dykes system with agricultural rotation *(No.816)*

employment, a greater share of forest (OR = 1.97, 95% CI = [1.79, 2.17]), fruits, urban, cash crops or rice-aquaculture increased the odds of being active compared to inactive. On the contrary, a greater share of triple rice (OR = 1.28, 95% CI = [1.20, 1.38]), double rice or aquaculture increased the odds of being inactive compared to being active. Similarly, ethnic minority inclusion also increased the odds of being inactive compared to being active (OR = 1.09, 95% CI = [1.07, 1.12]).

As shown in the model summary (Fig. 4), triple rice, double rice and intensive aquaculture systems increase the likelihood of being unemployed. In these land use systems, the main source of employment is agriculture or aquaculture. As most of the work is mechanised, only petty tasks provide employment to landless households. Although there is a peak in labour demand during harvest, farmers tend to hire large organised groups of labourers from other provinces, which drives landless locals into migration to the industrial zones, especially in triple rice cropping systems. In the double rice cropping system, flooded fields provide fishing for home consumption (for better-off households) or to generate income by selling fish on the road side (for landless households), enabling the poorest households the opportunity to generate a livelihood.

One model was fitted to analyse the effects of the type of employment on the odds of falling under the poverty line for people within the legal working ages of 15–64 (Table 4). It was apparent that ethnic minority inclusion had the greatest positive effect on the odds of being poor (OR = 3.16, 95% CI = [2.98, 3.35]). Being unemployed (OR = 1.35, 95% CI = [1.16, 1.57]), being employed in the fishery sector, or in agriculture increased the odds of falling into poverty. On the contrary, engaging in non-farming activities decreased the odds of being poor (OR = 0.64, 95% CI = [0.59, 0.69]).

4.2. *Current trends of land use systems*

In 2010, double rice was the land use system with the largest coverage in the Vietnamese Mekong Delta (35%), followed by triple rice (19%), fruits (14%), aquaculture (12%), forest-aquaculture (9%), rice-aquaculture (6%), cash crops (4%) and urban (1%). By 2020, triple rice became the land use system with the largest coverage (32%), followed by double rice (24%), aquaculture (15%), fruits (10%), forest-aquaculture (7%), rice-aquaculture (6%), cash crops (5%) and urban (1%). The biggest changes that occurred between 2010 and 2020 were

Table 2
Results of the logistic models for the three main employment sectors. The dependent variable represents the odds of engaging in certain employment for people who are within the legal working age. The explanatory variables represent the share of area of land use systems found in the Vietnamese Mekong Delta. Statistical modelling based on the 2010 Census on Population and Housing in Vietnam and Authors' land use systems map derived from 2010 MODIS data.

	AGRICULTURAL					FISHERY					INDUSTRY				
	Odds	LB	UB	pval		Odds	LB	UB	pval		Odds	LB	UB	pval	
(Intercept)	**0.52**	0.50	0.55	0.00	***	**0.33**	0.31	0.35	0.00	***	**0.07**	0.06	0.08	0.00	***
Ethnic minorities	**1.57**	1.55	1.59	0.00	***	**0.48**	0.47	0.49	0.00	***	**0.72**	0.70	0.73	0.00	***
Travel duration	**1.00**	1.00	1.00	0.00	***	**1.00**	1.00	1.00	0.00	***	**0.99**	0.99	0.99	0.00	***
Triple rice	**1.70**	1.62	1.78	0.00	***	**0.02**	0.02	0.02	0.00	***	**2.95**	2.66	3.26	0.00	***
Double rice	**1.85**	1.77	1.94	0.00	***	**0.12**	0.11	0.12	0.00	***	**2.45**	2.22	2.71	0.00	***
Cash crops	**1.43**	1.35	1.50	0.00	***	**0.11**	0.10	0.12	0.00	***	**8.44**	7.60	9.37	0.00	***
Fruits	**2.01**	1.92	2.11	0.00	***	**0.04**	0.03	0.04	0.00	***	**3.09**	2.79	3.42	0.00	***
Forest	**0.57**	0.54	0.61	0.00	***	**3.72**	3.45	4.01	0.00	***	**0.91**	0.80	1.04	0.17	
Aquaculture	**0.11**	0.11	0.12	0.00	***	**7.12**	6.71	7.57	0.00	***	**1.65**	1.48	1.83	0.00	***
Rice shrimp	**0.32**	0.30	0.33	0.00	***	**5.07**	4.77	5.37	0.00	***	**1.87**	1.69	2.08	0.00	***
Urban	**0.50**	0.47	0.52	0.00	***	**0.02**	0.02	0.03	0.00	***	**14.57**	13.13	16.19	0.00	***
AIC	433939					216026					239561				

Table 3
Results of the logistic models for labour types. The dependent variable represents the odds of engaging in certain labour types for people who are within the legal working age. The explanatory variables represent the share of area of land use systems found in the Vietnamese Mekong Delta. Statistical modelling based on the 2010 Census on Population and Housing in Vietnam and Authors' land use systems map derived from 2010 MODIS data.

	ACTIVE					SELF-EMPLOYED					SALARIED				
	Odds	LB	UB	pval		Odds	LB	UB	pval		Odds	LB	UB	pval	
(Intercept)	**9.60**	8.93	10.32	0.00	***	**1.85**	1.76	1.94	0.00	***	**0.35**	0.33	0.37	0.00	***
Ethnic minorities	**0.92**	0.90	0.94	0.00	***	**0.75**	0.74	0.76	0.00	***	**1.32**	1.30	1.34	0.00	***
Travel duration	**1.00**	1.00	1.00	0.00	***	**1.00**	1.00	1.00	0.00	***	**1.00**	1.00	1.00	0.00	***
Triple rice	**0.78**	0.73	0.84	0.00	***	**0.70**	0.67	0.74	0.00	***	**1.34**	1.27	1.41	0.00	***
Double rice	**0.88**	0.82	0.94	0.00	***	**0.65**	0.62	0.68	0.00	***	**1.54**	1.46	1.63	0.00	***
Cash crops	**1.17**	1.08	1.26	0.00	***	**0.44**	0.42	0.47	0.00	***	**2.70**	2.55	2.86	0.00	***
Fruits	**1.63**	1.52	1.76	0.00	***	**0.94**	0.89	0.98	0.01	**	**1.29**	1.22	1.36	0.00	***
Forest	**1.97**	1.79	2.17	0.00	***	**1.76**	1.65	1.88	0.00	***	**0.68**	0.63	0.73	0.00	***
Aquaculture	**0.91**	0.85	0.98	0.02	*	**1.16**	1.11	1.22	0.00	***	**0.78**	0.74	0.82	0.00	***
Rice shrimp	**1.16**	1.07	1.25	0.00	***	**1.33**	1.26	1.40	0.00	***	**0.75**	0.71	0.80	0.00	***
Urban	**1.32**	1.22	1.43	0.00	***	**0.22**	0.21	0.23	0.00	***	**5.75**	5.42	6.10	0.00	***
AIC	78800					196516					165204				

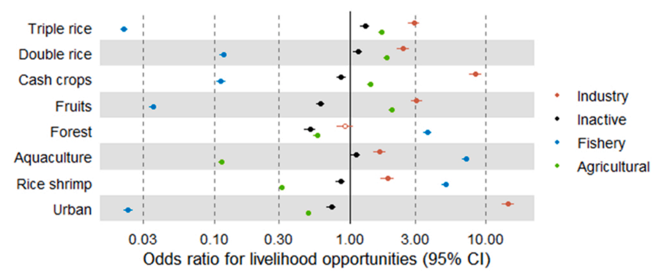

Fig. 4. Effect of land use systems on the likelihood of engaging in the four main types of rural employment. The dependent variables represent the odds of working in a certain sector for people who are within legal working age. The explanatory variables represent the share of area of land use systems found in the Vietnamese Mekong Delta. Statistical modelling based on the 2010 Census on Population and Housing in Vietnam and Authors' land use systems map derived from 2010 MODIS data. Non-significant entries are drawn as hollow points.

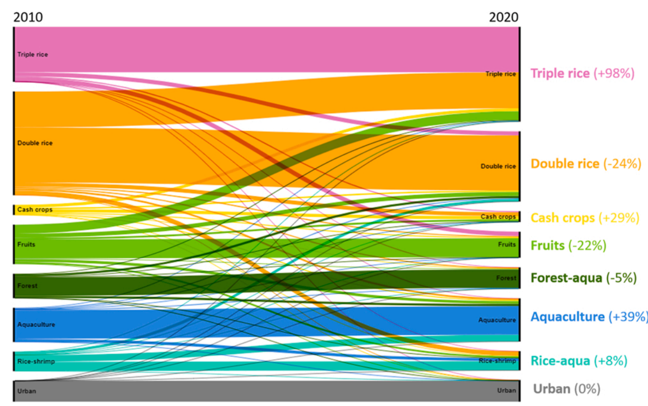

Fig. 5. Land use systems transitions in the Vietnamese Mekong Delta between 2010 and 2020. Sankey diagram showing land use system change between 2010 and 2020, as estimated from Earth observation. Transition matrices were derived from MODIS data.

the conversion of 34% of the 2010 double rice area and 23% of the 2010 fruits area into triple rice area (Fig. 5), which is in line with national statistics and estimations (Hui et al., 2022; Van Kien et al., 2020). The increase in aquaculture area was mostly due to the conversion of 35% of the 2010 rice-aquaculture area to aquaculture, while the increase in cash crops was mostly due to the conversion of 4% of the 2010 double rice area. Overall, we found that 58% of the Mekong area did not face land system change between 2010 and 2020. In particular, the two most specialised land use systems had little conversion of their areas to other land use system (84% of persistence for aquaculture and 83% of persistence for triple rice), while only half of the area of the others land use systems persisted: 53% for double rice, 48% for fruit trees and for rice-aquaculture.

Based on the model "Active" previously depicted, we predicted employment opportunities in 2020 based on land use systems distribution and controlling for population change (+0.9% annual increase). We found that land use systems transitions observed between 2010 and 2020 have led to a 3.2% decrease in employment.

4.3. *Projected changes of land use systems and their impacts on employment*

The largest expansions of triple rice areas were observed under the specialisation scenario in the West (Trans-Bassac depression), North-West (Long Xuyen-Ha Tien quadrangle), and in the North East (Plain of Reeds) following the intensification of double rice cropping systems into triple rice, while such a transition remained moderated in the diversification scenario (Fig. 5). As a consequence, double rice systems only covered 9% of the total area under the specialisation scenario,

Table 4
Results of the logistic model for poverty. The dependent variable represents the odds of falling under the national poverty line. The explanatory variables represent main employment types. Statistical modelling based on the 2010 Census on Population and Housing in Vietnam.

	POVERTY				
	Odds	LB	UB	pval	
(Intercept)	0.00	0.00	0.00	0.00	***
Ethnic minorities	3.16	2.98	3.35	0.00	***
Agricultural employment	1.17	1.08	1.27	0.00	***
Fishery employment	1.26	1.17	1.36	0.00	***
Non-agricultural employment	0.64	0.59	0.69	0.00	***
Inactive	1.35	1.16	1.57	0.00	***
AIC	10274				

Table 5
Spatial extent of the Vietnamese Mekong Delta land use systems in 2030 under different scenarios and evolution of associated land use system services. Analysis for 2010 and 2020 based on Earth observation, while projections for 2030 were simulated using CLUMondo, modelling global environmental change (RCP4.5) under different policy options (specialisation: policy scenario based on resolution No124; diversification: policy scenario based on resolution No639). The overall impact on employment was estimated based on logistic regressions developed using the 2010 Census on Population and Housing in Vietnam.

	2010	**2020**	**2030** (% of total area)			
	(% of total area)		SPE		DIV	
Share of land systems						
Triple rice	19.0	35.0	37.0	*	19.6	*
Double rice	35.0	24.0	9.1	*	25.1	
Cash crops	3.6	5.0	0.0	*	0.1	*
Fruits	13.8	24.9	27.0	*	26.0	*
Forest-aquaculture	9.0	6.7	5.5	*	6.6	
Aquaculture	11.9	16.1	20.6	*	19.0	*
Rice-aquaculture	6.0	6.0	0.0	*	2.7	*
Urban	0.8	0.8	0.8	*	0.8	*
Evolution of land system services between 2020 and 2030 (in %)						
		Livelihoods	-46.0		+ 0.9	
		Built-up	+ 2.9		-8.2	
		Agricultural products	-1.0		-6.8	
		Aquaculture products	-13.6		-6.5	

compared to 25% under the diversification scenario. Symmetrically, triple rice systems covered 37% (scenario specialisation) and 20% (scenario diversification) of the total area (Table 5). More rice-aquaculture systems were preserved in the diversification policy scenario: 3% more compared to the specialisation scenario. In the two scenarios, the area of intensive aquaculture increased around the South-West (Cà Mau peninsula), ranging between 18% (diversification scenario) and 27% (specialisation scenario) of the total area. Of the two scenarios, cash crops were the land use system that decreased the most, disappearing completely in the specialisation scenario while only a very small area remained under the diversification scenario, located on the South-East (coastal flat) near Trà Vinh. The reduction in cash crop land use systems in the freshwater alluvial area near Cần Thơ is mostly due to conversion to orchards and rice land use systems. There was also a substantial increase in urban systems (+14%) in the Cà Mau peninsula under the specialisation scenario at the expense of rice-aquaculture and fruits. (Fig. 6).

The overall change in employment opportunities between 2020 and 2030 (Table 5) is higher (+0.9%) under the diversification scenario than under the specialisation scenario (−46.0%). However, an increase in employment opportunities under the diversification scenario comes at the expense of agricultural gross product (diversification −6.8%; specialisation −1.0%). Interestingly, despite an increase of intensive aquaculture under the specialisation scenario, overall relative change of aquaculture gross product is the lowest in such a scenario (specialisation −13.6%; diversification −6.5%). Finally, as urban sprawl was constrained in the diversification scenarios, the relative change in built-up area is significantly lower in this scenario (−8.2%) while it grew under the specialisation scenario (+2.9%).

5. Discussion

5.1. Land use systems and employment opportunities

Understanding the links between land use systems and the services they provide under increasing pressure exerted by global environmental change is a central part in spatial planning and sustainable management of resources, as it underpins a balance of options for land use (Kremen and Merenlender, 2018). However, current approaches to spatial planning are often targeted on maximising economic value via extractive models of land use, thus exacerbating environmental degradation. While the latest evidence emphasises the importance of explicitly including livelihood provision in agri-food system planning (Davis et al., 2022), no earlier studies have quantitatively explored the associations between land use systems and employment opportunities.

Our findings show that mode of production has a significant effect on employment provision. Intensive farming land use systems (rice monoculture, aquaculture) support less employment than more diversified systems, thus supporting earlier findings, which demonstrated that transitions from shifting cultivation to intensive cropping has a negative impact on employment opportunities (Dressler et al., 2017; Tran, 2019).

The results of our study demonstrate that diversified farming systems (forest-aquaculture, orchards, rice-aquaculture), as promoted under decision 639, support more employment, yet they do not require a large agricultural labour force in comparison with decision 124. As agricultural land use systems are more diversified (e.g. smaller fields), they provide more alternative employment opportunities for landless households than decision 639, such as employment in processing companies and small businesses (packaging, upcycling of agri-processing waste) (Brunerová et al., 2020). Finally, we showed that access to urban areas decreases the likelihood of unemployment, thanks to the provision of off-farm employment (industry, construction, transport) (de Bruin et al., 2021).

5.2. Sustainability of the Mekong Delta under global environmental change and current policies

Despite the commitment to sustainable agriculture in post-2013 policies, Decisions 124 and 939 (2012) aim at intensifying production through the transition from one-rice crop into water-logged areas with intensive aquaculture and by increasing rice production through triple rice cropping. This strategic planning is expected to lead to a growth of production of 4.2% with the following farm-related GDP outputs: agriculture (55%), aquaculture (43.5%) and forestry (1.5%). The results from our model show that achieving this target under RCP4.5 will lead to exacerbating current observed trends, with an increase in intensive aquaculture and triple rice cropping systems at the expense of rice-aquaculture, forest-aquaculture and double rice cropping systems. This land planning strategy is vulnerable to global environmental change, as the three main land use systems (triple rice cropping, intensive aquaculture, orchards) will face (i) hot temperatures during the rainy season, leading to heat stress (rice and shrimp farming); (ii) prolonged rain during the wet season, leading to floods (rice and orchards); and (iii) salinity intrusion (orchards). Moreover, such systems lead to increased conflicts of natural resource management regarding water allocation but also cross-field contamination and pollution (Tran et al., 2021). Finally, while the policy narrative emphasises the need to prevent out-migration, our findings show that pushing for intensive farming decreases employment opportunities by 46%, especially for low-skilled labourers.

Decisions 639 and 816 (Socialist Republic of Vietnam, 2014, 2018)

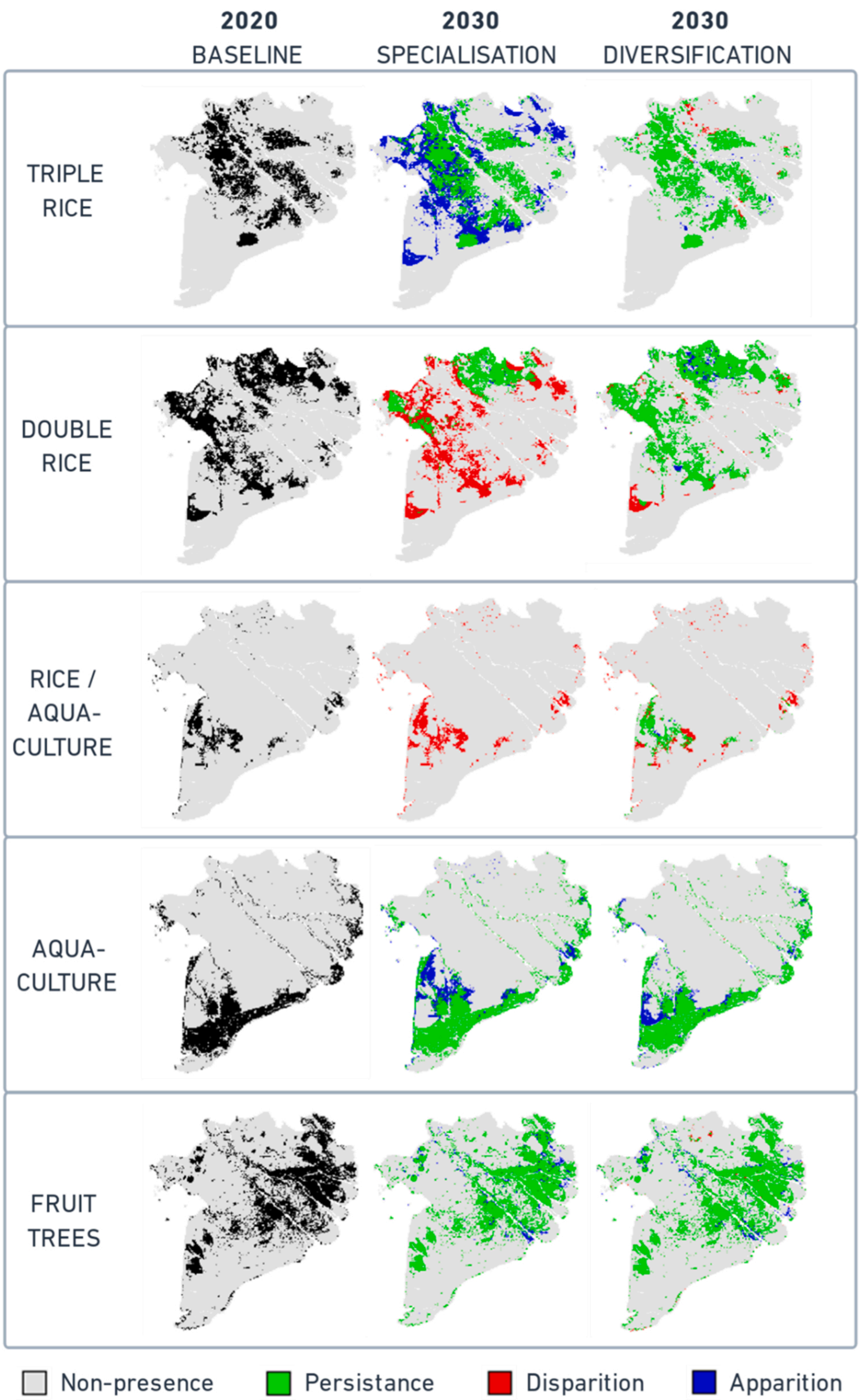

Fig. 6. Future land use systems of the Vietnamese Mekong Delta in 2030. Simulations were driven by global environmental change (RCP4.5) under two different policy scenarios: (i) specialisation of land services; and (ii) diversification of land services.

have objectives that align better with Resolution 120 and its Action Programme, but also with national-level climate change policies such as the 2021 National Strategy on Green Growth and the 2017 Sustainable Development Goals National Action Plan. They take climate change into account (transition of rice land to aquaculture due to sea-level-rise) and aim at decreasing the area of ineffective and freshwater land use systems (especially rice area), while increasing more diversified systems (rice-aquaculture, forest-aquaculture and orchards). In parallel, they aim to develop programs that create opportunities for agricultural labourers while accompanying livelihood transition. The findings from our model suggest that these two strategic decisions lead to a more balanced approach in land services in 2030 compared to the implementation of Decisions 124 and 939. Although favouring rice-aquaculture and double rice cropping systems to triple rice cropping systems negatively affects agricultural production, it is greatly improved compared to the other scenario, while livelihood opportunities remain stable. The greater diversity of land use systems reduces vulnerability to global environmental change that prevents yield loss by reducing sediment starvation associated with triple rice cropping (Chapman and Darby, 2016).

In practice, however, considerable obstacles remain as tensions continue to exist in the policy landscape between intensification and sustainability, which threatens to derail the sustainability goals in favour of a GDP-centred growth model (Hutton et al., 2021). Although provincial governments were successfully brought on board during the formulation of the 2013 Mekong Delta Plan (Seijger et al., 2017; Vo et al., 2019), a lack of political will and financial resources are proving to be obstacles for strategic spatial planning and the realisation of sustainability goals (Malekpour et al., 2017; Demazière, 2018; Gustafsson et al., 2019) that would put the Mekong delta onto a path towards a climate resilient future.

5.3. Implications for sustainable and inclusive strategic spatial planning

In this study, we translated land use planning policies into a land use change modelling framework. In analysing global change effects on local scale land management, we went beyond applying global demand projections only. We developed two scenarios representing the main Vietnamese planning policies under climate change and salinity intrusion (RCP4.5). One caveat to this study is that policy scenarios were modelled as mutually exclusive (specialisation vs. diversification). In reality, both scenarios might coexist spatially and across scales, depending on implementing agencies and place-based strategic decisions by local governments. Moreover, our prediction of employment based solely on land use system do not capture the complexity of livelihood strategies that households put in place in rural areas. Nonetheless, the patterns that we found allow us to advocate for the inclusion of employment as a service of land use systems in planning policies. Putting employment at the core of land use planning facilitates a more balanced future, situated in the middle of the two current strategies in terms of agriculture and aquaculture gross product, while ensuring an increase in livelihood opportunities.

Our modelling approach has a caveat that assumes the association between land use systems and employment remains constant over time. Furthermore, to develop a full picture of rural employment, additional studies are needed, which include gender-sensitive modelling approaches (Markussen et al., 2018). Nevertheless, the above findings suggest several courses of action for public policies and schemes to sustain rural livelihoods and reduce rural out-migration; hence, reducing urban and rural poverty. We show the necessity of moving from a profit-driven model of land use systems, as seen in current agricultural policies around the world (Garrone et al., 2019), towards a more holistic approach incorporating livelihood and biodiversity goals in rural policy design. Characterising the extent to which livelihoods can be supported by land use systems contributes to the wider framework of ecosystem services that helps design more socially and environmentally viable strategies for the future.

6. Conclusion

This study determined associations between land use systems and employment opportunities and to model future land use systems in the Vietnamese Mekong Delta under global environmental change and current policies. Our findings bring a new perspective on land use system science and livelihood studies by demonstrating that more intensive farming systems provide less employment opportunities than more diversified systems at a territorial level. We showed that current development policies potentially have conflicting aims and that current policy goals under RCP4.5 may lead to a drastic increase in intensive aquaculture and triple rice cropping systems at the expense of more diversified systems. We argue that inclusion of employment opportunities as a policy target leads to more diversified systems that provide more employment without compromising overall agriculture and aquaculture gross product.

This paper provides an approach for researchers and policy-makers to consider employment in land use planning policy design, and thus to target specific land use systems to maximise their environmental and social services rather than solely focusing on their economic value per unit. Future interventions should address rural development holistically rather than focus on agricultural development, or at least ensure that current planning policies do not have a detrimental effect on rural employment. As such, they should support transitions to off-farm livelihoods in well-connected communities, while steering to more diversified land use systems that could offer on-farm livelihoods to landless households.

Declaration of Competing Interest

All authors declare that they have no conflicts of interest.

Data Availability

Data will be made available on request.

Acknowledgment

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2023.106752.

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