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Can organic rice certification curb the pressure of the agrarian transition in Cambodia? A farming system approach

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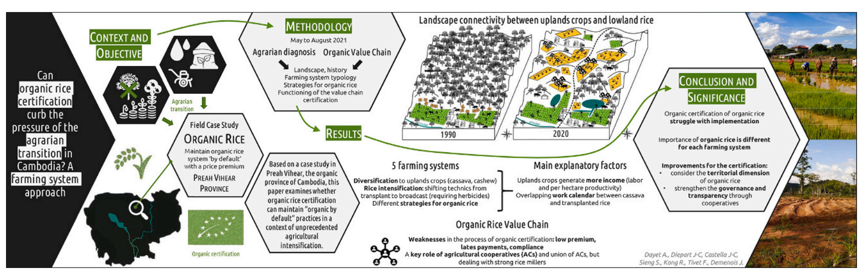
HIGHLIGHTS

- The role of organic rice was analyzed in five co-existing rice-based farming systems.
- Organic rice is threatened by intensified production in lowland areas.
- Other lock-in factors in upland areas jeopardize the cultivation of "organic by default" rice.
- Organic certification is complex, hence the progressive abandonment of organic rice.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Over the past two decades, the Mekong region has experienced significant transformation of its agricultural sector from subsistence farming to export crops driven by the expansion of agricultural land and of irrigation, plus intensification thanks to mechanization and the use of chemical inputs. In the context of agrarian transition, maintaining "organic by default" rice farming systems that do not rely on chemical inputs, is challenging.
OBJECTIVE: Based on a case study in Preah Vihear, the organic province of Cambodia, this paper examines whether organic rice certification can maintain "organic by default" practices in a context of unprecedented agricultural intensification.
METHODS: Using agrarian diagnosis, we investigated the impacts of an organic rice certification scheme on the future of organic rice-based farming systems. We built a functional typology of five farming systems that co-exist in the study area to understand the roles of organic rice in each system.
RESULTS AND CONCLUSIONS: From an economic perspective, organic rice is less profitable than recently introduced cash crops, e.g. cassava, cashews. The positive impact of certification of organic rice is threatened by

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lock-in factors, e.g. labor diversification in both farming and non-farming activities, cash flow management, the certification process, leading farmers to abandon organic rice for cash crops for export. We discuss the key role of agricultural cooperatives in the certification process of organic rice.

SIGNIFICANCE: The paper questions the capacity of a certification scheme to keep up with the process of intensification that undermines the profitability of the remaining "organic by default" rice systems. Beyond the significance of the results in the study area, one of the last strongholds of traditional rice systems in Cambodia, the paper illustrates the disappearance of "organic by default" rice systems in the whole country as well as in the Mekong region.

1. Introduction

The agricultural sector in the Mekong region has undergone significant transformation in the last 20 years from subsistence farming to commercial farming driven by export markets (Cramb, 2020; Thompson et al., 2019). These agrarian changes occurred through two main movements: the expansion of agricultural land into forested areas to produce commercial annual and perennial cash crops; and agricultural intensification based on mechanization, the use of chemical inputs and irrigation that are part of a multifaceted process known as "agrarian transition" (Ingalls et al., 2018). While this transition has provided high short-term returns, it has also exposed smallholder farmers to significant risks including market volatility and debt burdens (Green, 2022; Kong et al., 2021), exacerbated socio-economic disparities (Diepart and Thuon, 2022), and environmental degradation, including deforestation and soil erosion (Kong et al., 2019; Nut et al., 2021). As a result, the sustainability of current practices and smallholder farming is jeopardized.

Agroecology is often promoted as an alternative way to address these challenges. It emerged as a model of sustainable and resilient agriculture that offers more biodiverse, energy efficient, socially equitable, and food sovereignty-based production systems (Altieri et al., 2012; Gliessman, 2014). Transition pathways toward agroecology vary depending on the state of the agro-ecosystem to be transformed or maintained; but transitioning to agroecology always requires active investment in knowledge, time, and resources while risks increase during the transition (Tittonell, 2020). Agroecological transitions are fostered by enabling factors and threatened by lock-ins, i.e. situations, stakeholders, and narratives that prevent the development of alternative practices or promote the status quo (Meynard et al., 2013; Plumecocq et al., 2018; Vanloqueren and Baret, 2009). Understanding agroecological transitions thus requires examining multiple, non-linear, and open-ended trajectories (Lamine, 2011; Plumecocq et al., 2018). This article investigates these trajectories, with a particular focus on the preservation of "organic by default" rice practices in northern Cambodia. We use the term "organic by default" to describe the practices of farmers who never used chemical inputs to grow rice before any certification was introduced (Bolwig et al., 2009; Kleemann and Abdulai, 2013; Preißel and Reckling, 2010).

Preah Vihear province is often referred to as the organic province in Cambodia, due to its long-standing tradition of pesticide-free cultivation. Since the 2010s, there have been pioneering efforts to develop organic rice certification schemes (Cramb, 2020; Savoeurn and Brun, 2018) to maintain the "organic by default" rice practices. However, most studies in the Mekong region have focused on promoting organic practices rather than preserving them (Baird, 2024; Hérique and Faysse, 2021; Taotawin, 2011), arguing that the demand for organic rice on international markets is a strong incentive for farmers (Baird et al., 2022; Presilla, 2018; Sok et al., 2019). These studies also stress the difficulties involved in achieving organic certification (Hérique and Faysse, 2021; Presilla, 2018), misalignment with international organic standards (Baird, 2024; Hérique and Faysse, 2021) and marketing challenges such as inconsistent premium prices paid to farmers and/or side sales to conventional markets (Neang et al., 2017; Presilla, 2018; Sok et al., 2019). Other studies reveal the socially uneven outcome of organic certification as a rural development strategy that benefits some farmers but may exclude others (Beban, 2014; Presilla, 2018). In Cambodia, organic agriculture is relatively under researched, and understanding the intricacies of organic rice production and certification in Preah Vihear province offers the ideal opportunity to investigate those of agroecological transitions.

The objective of our study was to examine whether organic rice certification will enable the survival of "organic by default" practices in the context of rapid agrarian transition in the province of Preah Vihear (Cambodia). Agrarian diagnosis was used to understand farming system trajectories and characterize the interactions between organic rice, other crops and non-farm activities at both household and landscape levels in Rik Reay commune (Rovieng district). The farming systems approach not only informed our analysis of the organic certification process but also allowed us to explore enabling conditions toward broader adoption of agroecological practices at the landscape level.

In the following section, we describe the methodology we used for the study (Section 2). In Section 3 (Results), we first describe past transformations and the current diversity of farming systems, and analyze the ins and outs of the organic certification scheme implemented in Rik Reay. We then discuss (Section 4) the limited capacity of organic certification to lever an agroecological transition at the landscape level and for the different types of farming systems we identified. We explore how more horizontal multi-actor territorial governance could help address the limitations of an organic value-chain approach to enable agroecology to prosper.

2. Methodology

2.1. Study site

Rik Reay commune (Rovieng district, Preah Vihear province) is located in the northern uplands of Cambodia (Fig. 1). Administratively speaking, the commune consists of three villages (Bos, Doung and Pahal), but in practice, also includes a fourth large settlement area, Koh Loung, which we included in our surveys. In 2019, the commune accounted for an area of 9570 ha with a total of 2825 inhabitants in 613 households (NIS, 2020).

The study area has a tropical monsoon climate (Köppen Classification), with little annual variation in temperature (average 27 °C), with a rainy season from April to November, and a dry season from November to April (annual rainfall 1600 mm per year) (Shanmugasundaram et al., 2020). At present, only one cycle of rainfed lowland rice is possible, but the ongoing rehabilitation of an irrigated perimeter may enable two rice crops soon.

The topography is gentle (20–100 m above sea level), with local variations creating a gradient of coarse and fine elements along the toposequence. The soils of Rik Reay developed on volcanic rocks and sandstone and tend to be sandy, acidic, and poor in nutrients and organic matter (Gatignol, 2022). The lowland hydromorphic soils used for rice paddies, and while upland crops, e.g., cassava, cashew, pulses, are cultivated on the plinthite podzols (Crocker, 1962) of the slopes.

Fig. 1. Location of Rik Reay commune in Rovieng district, Preah Vihear province. *Data: GADM; State of Land in the Mekong Region; Aruna Technology, Phnom Penh.*

2.2. Agrarian diagnosis

We used the agrarian diagnosis approach *(*Cochet, 2015*)* to position "organic by default" rice in its spatial and temporal context and to identify the interactions between organic rice and other components of the agrarian system. This method has been used to describe agroecological transitions *(*Aubron et al., 2016*;* Cremilleux et al., 2023*;* Dumont et al., 2020*;* Levard et al., 2019*)*, and to study associated incentive mechanisms *(*Van Hecken et al., 2019*)*. Agrarian diagnosis offers a multi-dimensional framework to understand the different roles played by organic rice in a range of different farming systems. Further, agrarian diagnosis helps articulate farmers' choices and motivations in implementing organic rice practices along with all the other activities in which they are involved *(*Cochet, 2012*;* Dufumier, 1997*)*. An agrarian diagnosis typically includes three main steps: (1) Landscape analysis; (2) Historical analysis; (3) Technical-economic analysis.

- **Landscape Analysis**

Understanding how ecological processes shape agricultural production processes is a key step in capturing the diversity of agricultural practices *(*Cochet and Devienne, 2006*)*. The underlying hypothesis is that biophysical conditions partly define the range of existing farming practices in a given area.

- **Historical Analysis and Farming System Typology**

Agrarian diagnosis relies on a second hypothesis: the diversity of farming systems are the products of historical differentiation processes *(*Cochet, 2012*)*. Reconstructing agrarian history is a pivotal step toward understanding the current diversity of farming systems. Interviews are conducted to identify the dynamics of land use and land tenure systems and their environmental, technical, and socio-economic drivers *(*Cochet and Devienne, 2006*)*.

To simplify the diversity of farming practices, a farm typology that clusters individual farms into distinct archetypal groups that share similar characteristics is developed *(*Landais, 1998*;* Tittonell et al., 2020*)*. Landscape and historical analysis allow researchers to set the context for a functional typology of farming systems. This typology reflects the process of farm differentiation in time and space based on the origins of the farming systems (e.g. settlement period, composition of the household, etc.) and predictions for their future outlook in a changing environment *(*Cochet, 2015*)*. The typology is informed by researchers' understanding of both structural factors, such as land, workforce, and equipment, and functional factors, such as resource allocation, schedule organization, and nutrient flux. Social factors, such as farm history, are also considered. As the aim of this typology is to capture the diversity of farming systems in the region and present farming systems that differ in terms of available resources and production, the typology's construction is an iterative process. The typology cluster households according to their similarities or dissemblance around farm archetypes that emerge gradually as interviews progress. The process continues until no new information is identified, and the typology remains stable *(*Lacoste et al., 2018*)*. Because each type of farming system has different strategies and different agroecological trajectories *(*Teixeira et al., 2018*)*, this typology informs our reflections on agroecological transitions.

- **Technical-Economic Analysis**

The last step consists of a technical and economic assessment of each farming system, defined here as a combination of land, labor, and equipment, used for crop and livestock production, common to a group of farms *(*Reboul, 1976*)*. Farming systems are not real farms, but models *(*Landais, 1998*)*, in other words, archetypes used to understand the functioning and perspective of a type of farm in a given agrarian system *(*Cochet, 2015*)*. This analysis relies on an in-depth understanding of cropping and livestock practices, the flow of energy and materials between these activities, as well as the organization of labor at farm level. Based on the technical assessment of each activity, socio-economic indicators - such as labor and land productivity (value-added) of the cropping and livestock systems, and incomes at the farm level - can be calculated (**Appendix 1**).

2.3. Data collection

We conducted an agrarian diagnosis based on four months of immersive fieldwork, from May to August 2021 *(*Dayet, 2021*)*. For landscape analysis, we used satellite imagery, maps of soils, bedrock, and water flows, transect walks and direct field observations that allowed us to become familiar with the study area and to identify the main agroecological zones. For the historical and technical-economic analyses of the farming systems, we conducted individual interviews using a semi-structured and an open-ended questionnaire. To triangulate the information collected in our historical and technical-economic analyses, we interviewed several farmers clustered in the same archetypical farming system model *(*Ferraton and Touzard, 2009*)*. Farmers were selected using stratified random sampling according to the farming system diversity identified in the historical analysis step. Key factors for differentiating and categorizing farms were identified during the landscape and historical analysis stages. These factors include historical elements such as the timing of diversification toward upland crops (recent or past), the local population or migrants, structural factors such as the type of land (uplands or lowlands), workforce, and equipment (tractor or power tiller), and functional factors such as labor organization, which varies depending on the type of rice cropping systems. These differentiation factors were validated by a group of experts involved in local development projects. We conducted a total of 10 interviews with elderly people to characterize the agrarian history, and in addition to a total of 18 interviews with active farmers to analyze current cropping, livestock, and farming systems. We obtained additional knowledge on the history and characteristics of the farming households in this area from a study of rice cropping systems and households in Rik Reay (Filloux, 2020).

In addition, we interviewed two representatives of local agricultural cooperatives (ACs), held three focus group discussions, and conducted 49 individual surveys of different types of farmers involved in the organic certification. The interviewed farmers were distinct from those interviewed during the agrarian diagnosis phase. We designed semi-structured questionnaires to focus on the certification process, interactions between different stakeholders, as well as on the farmers' decision-making process, and the advantages and constraints they face concerning organic certification. Finally, in June 2023, we completed our comprehensive analysis of the history of the organic value chain in Preah Vihear province with an interview with an independent consultant who served as an advisor for the SCCRP project (Support to the Commercialization of Cambodian Rice Project) that supported organic rice farming in Preah Vihear province from 2012 to 2016.

3. Results

3.1. Setting the scene: where does organic rice stand in the landscape and history of the commune of Rik Reay?

Before 1975, the landscape of Rik Reay commune mainly consisted of forests, rainfed rice and pulses were grown in the uplands under shifting cultivation, with permanent vegetable production in the vicinity of the villages and paddy rice grown in lowland areas (Filloux, 2020). Rice seedlings were transplanted, which is still the case today although this system tends to be less widespread. The amount of agricultural land owned by each farmer already varied considerably before 1975: some households were already landless, while others owned several hectares. Finally, livestock (cows, buffaloes) contributed more to the wealth of the farmers than the land they owned. Cattle were considered as living capital and used as draft animals for agricultural work.

Under the Khmer Rouge (KR) regime (1975–1979), agriculture, labor and lands were collective. The KR regime implemented a radical communist experiment based on the construction of a nation-state aimed at an egalitarian rural society. The regime used forced displacement of the population from the cities to the countryside to farm the land. All means of production were nationalized, the population was used as forced labor, and the previous land tenure system was abolished. Numerous hydraulic projects were undertaken to increase agricultural productivity, which was also the case in Rik Reay with the excavation of two artificial reservoirs, O'Kambor and O'Sakkarach. However, the construction of these reservoirs was never completed, and they were consequently not operational. In 1982, three years after the end of the Khmer Rouge period, the land was redistributed based on family land ownership before the KR regime, thus reproducing preexisting inequalities. From 1980 to 2000, the landscape resembled that of the 1970s: rice cultivation in the lowlands, shifting cultivation in the uplands, and extensive animal husbandry for plowing the rice paddies. The upland land was owned by farmers but left uncultivated.

In the wake of the 2001 land law, the liberalization of land transactions and the opening of new agricultural markets incentivized land-poor households to migrate to the uplands to grow new crops such as soybean, corn, cassava, rubber or cashew. As of 2008, 26% of the population had been involved in migration within Cambodia, and 51% of the migrants moved from the central lowland areas to the forested provinces like Preah Vihear province, where land was still available (Diepart, 2015). In Rik Reay commune, migrants came from Kampong Thom and Kampong Cham provinces to clear forests and grow cassava,

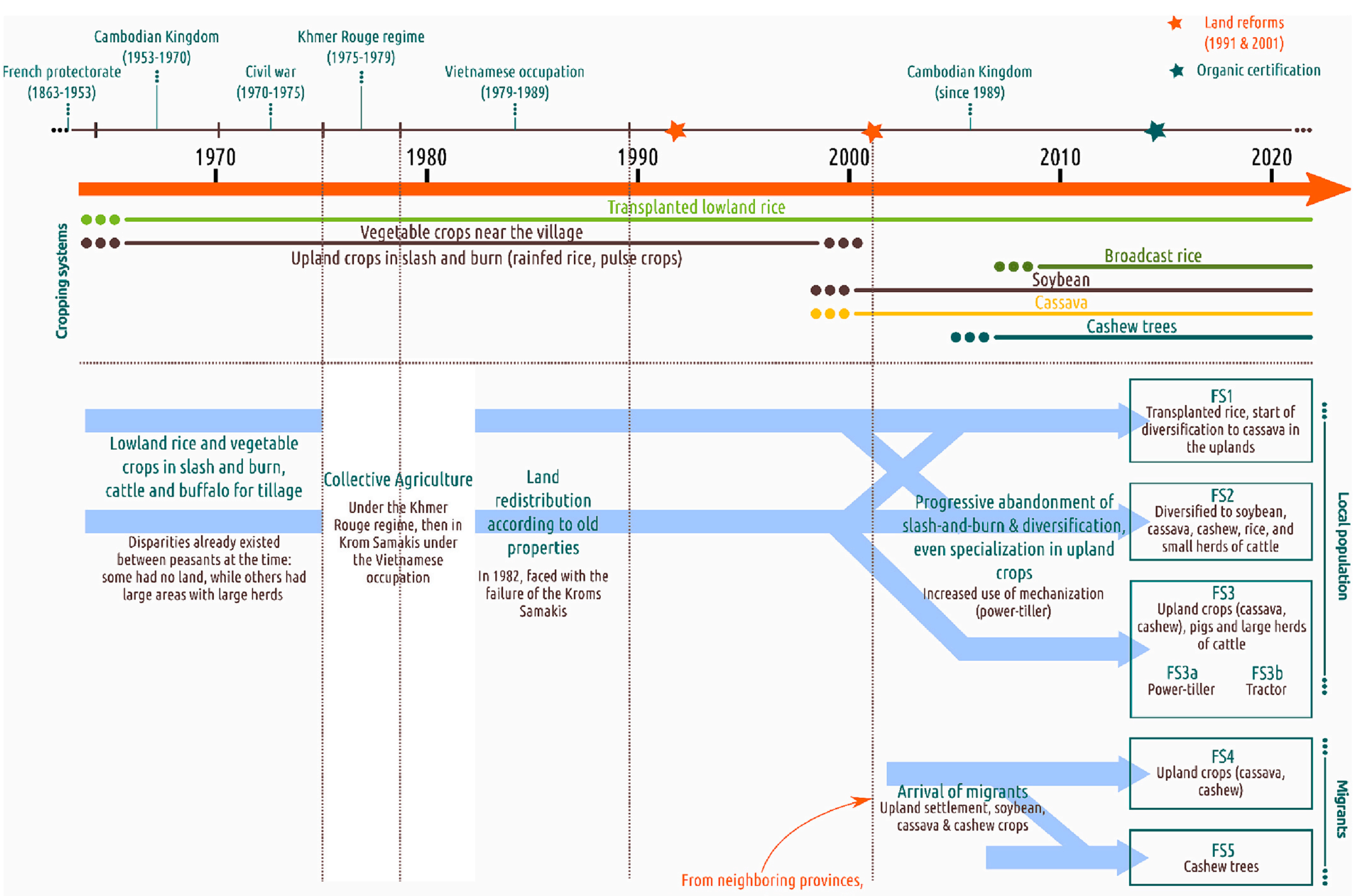

Fig. 2. Evolution of cropping and farming systems (FS) from the 1960s to 2021, with the main historical factors explaining the changes. These factors were used to develop a functional typology comprising the five production systems representative of Rik Reay Commune (Table 1).

soybean, and cashew. Around 2010, the native population started to mimic these pioneer migrants thus contributing to the expansion of agricultural land into forested areas. As a result, the entire landscape of the commune was transformed. From 2000 to 2020, 95% of the forest cover disappeared (Diepart and Kong, 2022) and commercial upland crops became central in nearly all farming systems. Fig. 2 summarizes these transformations and shows the evolution of cropping and farming systems from the 1960s to 2021. In 2021, agricultural activities in Rik Reay commune were spatially organized according to topography (Fig. 3). Rice was cultivated in the lowlands and cassava and cashew were grown in the uplands.

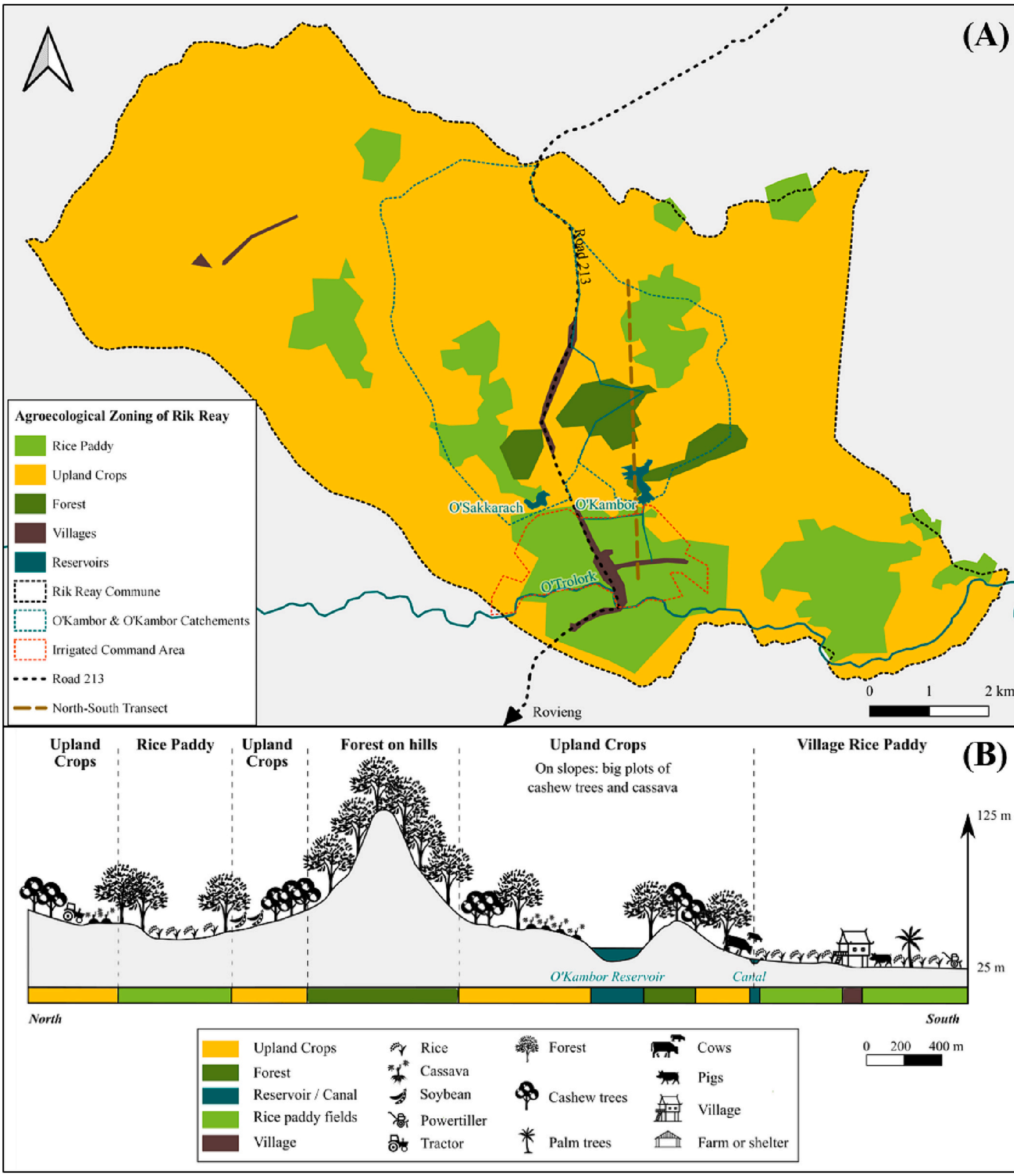

Fig. 3. (A) Agroecological zoning of Rik Reay commune and (B) north-south transect in 2021. Rice is cultivated in the lowlands, mainly around the villages in the south, while cashew, cassava, and soybean crops are grown in the upland areas. Forests are limited to the steepest slopes or mountain/hill tops and are fragmented.

3.2. Farming systems dynamics under the influence of upland diversification and intensified rice cropping

3.2.1. A move toward upland crops

In Rik Reay commune, we identified five farming systems along a gradient of diversification toward upland crops (cashew, cassava) (Fig. 3, Table 1). The first type of farming system (FS1) was mainly based on cultivation of organic rice, while the last type (FS5) described farms that pioneered upland crop diversification; the main difference between all the types being the types of crops cultivated. FS1, FS2 and FS3 were the farming systems used by the original inhabitants, FS4 and FS5 the farming systems of the newcomers (migrants). FS1 farmers grew transplanted rice on between 1 and 3 ha, and cassava on 0.5 to 1.5 ha (Table 1). FS2 farms were more diversified, with cashew and soybean crops, and livestock played a major role in differing them from FS1 farms. Livestock represented a source of income that allowed them to invest in upland crops. FS3a and FS3b, the pioneers in upland crops, owned more land and had bigger herds. The main difference between FS3a and FS3b was in the degree of mechanization: farmers in the FS3a group owned a power tiller, while those in FS3b only owned a tractor. FS4 and FS5 concentrated on upland farming: cashews and cassava were their main crops and accounted for up to 30 ha, while they only grew rice on a small area (Table 1).

Growing upland crops allowed farmers to diversify at three levels: land use, labor management, and income. First, growing cashew or cassava in the uplands was a way to diversify their land use, while rice was grown in the lowlands. Farmers gained access to upland areas after clearing the forest. Until the 2000s, deforestation and access to land was relatively simple, relying primarily on the amount of family labor available on each farm. After the year 2000, with the influx of migrants and the implementation of land laws, the process became monetized through market transactions. Second, diversification of labor occurred over the course of the year (**Appendix 2**). Rice was grown in the rainy season while the technical operations required by upland crops were undertaken in the dry season. Rice was transplanted at the beginning of the rainy season and harvested at the end of the rainy season. Except at harvest, cashew plantations required little labor. Cassava could be harvested over a period of several months in the dry season and consequently enabled considerable flexibility in terms of the labor calendar. In addition to other benefits of diversification (land use, labor management), the third reason to diversify was and still is economic. Our economic analysis demonstrated the comparative productivity of different cropping systems, highlighting the financial incentive behind diversification. It showed that organic rice was less productive per hectare (return on land) and man/day (return on labor) compared with the upland crops (Fig. 4). This can be explained by low yields, i.e., only one rice crop possible per year, and high labor requirements (for transplanting and manual harvesting). In addition, upland crops benefited from higher and rising prices. For example, in 20 years, the price of cashew nuts had almost quadrupled (*from US$440 in 2002 to US $1974 per ton in 2022. These prices apply to Vietnam as no data are currently available for Cambodia (*FAOSTAT, 2024*))*.

Table 1
Structure of the different farming systems in Rik Reay Commune – FS: farming system; CS: cropping system; LS: livestock system.

			FARMING SYSTEMS (FS)					
			FS1	FS2	FS3a	FS3b	FS4	FS5
			FS mainly based on transplanted rice, currently start of diversification to cassava in the uplands	FS diversified to soybean, cassava, cashew trees, rice, and small cattle herds	FS diversified across lowland (rice) and upland areas (cassava, cashew trees), pigs, and large cattle herds.		FS based on upland crops (cassava, cashew trees)	FS based on cashew trees
					FS3a farmers own a power tiller	FS3b farmers own a tractor		
Land	Location of land	Lowlands	yes	yes	yes	yes	yes	yes
		Uplands	yes	yes	yes	yes	yes	yes
	Total agricultural area (ha)		2.5	6.5	13	17	30	17
Labor	Number of family laborers		2	3	3	3	3	2
	Use of wage laborers		no	no	yes	yes	yes	yes
Equipment	Equipment (P – power tiller/ T – tractor)		P	P	P	P & T	P & T	P
Cropping systems (area in ha)	CS1	Transplanted organic rice	2	2	1	0	0	0
	CS2	Broadcast rice	0.5	1	3	4	2	2
	CS3	Soybean	0	0.5	0	0	0	0
	CS4	Cassava – power tiller – dry	0	1.5	0	0	0	0
	CS5	Cassava – tractor services – dry	0	0	3	0	0	0
	CS6	Cassava – tractor – fresh	0	0	0	5	18	0
	CS7	Cashew trees <6 years old – limited use of chemical inputs	0	1.5	6	8	0	0
	CS8	Cashew trees >6 years old – high use of chemical inputs	0	0	0	0	10	15
Livestock systems	LS1	Cattle herd – 10 animals	no	yes	no	no	no	no
	LS2	Cattle herd – 50 animals	no	no	yes	yes	no	no
	LS3/LS4/ LS5	Pigs	no	no	yes	yes	no	no

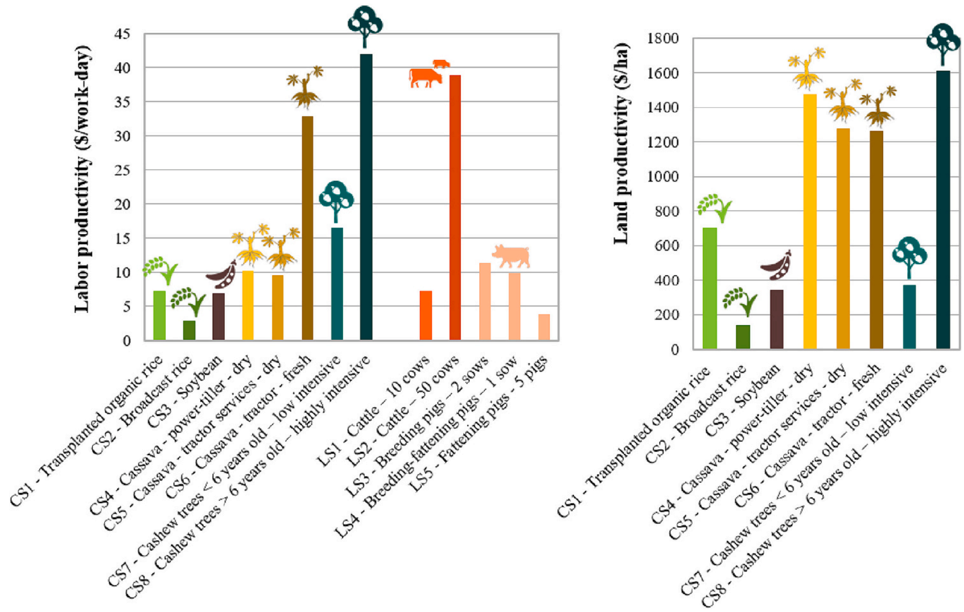

Fig. 4. Labor productivity (per working day) and land productivity (per hectare) of the different cropping (CS) and livestock systems (LS) at Rik Reay. A working day is calculated at 8 h/day. Detailed calculations are provided in Appendix 1.

3.2.2. Shift from transplanted to broadcast rice

Farming systems with a high degree of diversification in upland crops (FS3, FS4, FS5) had already shifted from transplanted to broadcast rice. FS1 and FS2 had also started to follow this trend. The main reason for this change was overlapping labor calendars. Rice was cultivated in the rainy season, while cassava and cashew mainly required labor in the dry season. However, tilling, planting and weeding cassava competed with transplanting rice in May–June. Farmers preferred to broadcast rice seeds instead of transplanting seedlings because it frees-up labor time. What is more, erratic rainfall early in the rainy season often prevented timely rice transplantation and led many farmers to change to broadcast rice. In the transplanted rice system, relatively mature seedlings (approximately 15 cm in height) were transplanted from a nursery to plowed and waterlogged paddy. This system was advantageous for rice as it reduced competition with weeds, thereby reducing the need for manual weeding and eliminating the use of herbicides. By contrast, broadcast rice increased competition with weeds and consequently farmers needed to use chemical herbicides for weed control. The shift to broadcast rice thus increased reliance on herbicides. With the exception of the herbicides used for broadcast rice, there is almost no use of chemical fertilizers or pesticides in the area. We therefore used the terms of transplanted and broadcast rice as equivalent to organic and non-organic rice respectively.

Farming systems (FS1 and FS2) that continued to transplant rice seedlings were the least diversified and own the least farmland (respectively 2.5 ha and 6.5 ha). These farming systems have not been able to expand into upland areas and were limited to growing organic rice. In our study, given their limited lowland area, a farming system (FS1) based on organic transplanted rice still appeared to provide the best return on land compared to broadcast rice (Figs. 4 and 5). Rice was only grown in small areas, as transplanting and harvesting by hand was labor intensive. What is more, FS1 produced a limited income per family member due to the limited paddy area per family (Fig. 5). Farmers consequently had to diversify into non-farm activities, i.e. by selling their labor on a daily basis, or by migrating. FS2 farmers were able to diversify to upland crops because they had the capital available for such investments thanks to the income they obtained from their livestock. However, they only owned small areas of upland, and transplanted rice remained the main activity for farmers in this group (FS2). In diversified (FS3) and even in specialized (FS4 and FS5) farming systems, rice had

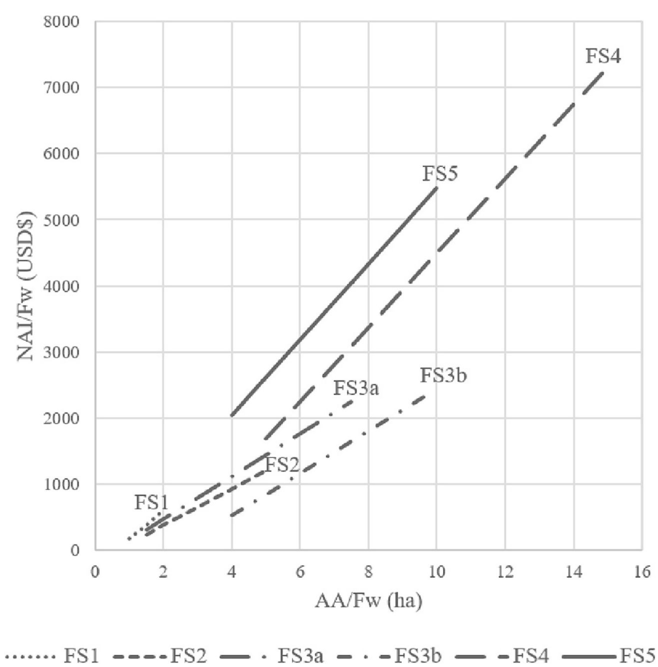

Fig. 5. Reconstructed Net Agricultural Income (NAI) per family worker (NAI/Fw) as a function of observed range of farmland (AA: Agricultural Area) per family worker (AA/Fw) for the 6 farming systems (FS).

become a secondary crop, and farmers preferred broadcast to transplanted rice.

Diversification into upland crops was thus only an option for farmers who had both capital and available labor. These farmers could therefore invest in new commercial crops and had access to land in the uplands. Cassava and cashew required considerable capital investment up front to pay for high input use, tractor rental, and daily-wage workers. In fact, the ongoing current evolution of farming systems across the landscape was characterized by an increasing socio-economic differentiation between households.

Not all the farmers have changed from organic rice to non-organic rice, but the number of farmers who change was likely to increase with the rehabilitation of irrigation schemes. Indeed, since 2023, the O'Kambor and O'Sakkarach reservoirs whose construction began under the Khmer Rouge regime, have been rehabilitated. At present, only one crop of rainfed lowland rice is still possible using *Phka Rumduol*¸ a photosensitive rice variety. Nonetheless, the rehabilitation of irrigated perimeters paves the way for two rice crops per year if farmers change to short duration varieties that are generally associated with seed broadcasting and chemical weed control.

3.3. A certification scheme to maintain the remaining "organic by default" rice

3.3.1. The organic rice value chain in Rik Reay commune

From 2013 to 2015, organic certification of rice in Preah Vihear province was supported by a development project "Support for the Commercialization of Cambodian Rice Project" (SCCRP) coordinated by SNEC (the Supreme National Economic Council) in partnership with COrAA (the Cambodian Organic Agriculture Association). In 2014, the Rik Reay commune cooperative joined the certification scheme that grouped farmers in five communes in the Rovieng district. To facilitate marketing of organic rice, contract farming was adopted by eight agricultural cooperatives in Preah Vihear province and the rice miller AMRU. In 2015, the Preah Vihear cooperatives established "Preah Vihear Meanchey Union of Agricultural Cooperatives" (PMUAC), the first Union of Cooperatives in Cambodia, to reinforce the certification scheme and to mutualize the resource handled by the project. In 2017, PMUAC comprised 26 agricultural cooperatives and handled 10,000 tons of organic rice sold to AMRU *(*Savoeurn and Brun, 2018*)*. In 2021, the Rik Reay cooperative had 418 members and purchased a volume of 800 tons of organic rice; in 2020 and 2022, it has respectively 418 members and 376 members for 650 and 740 tons of organic rice purchased. The cooperative was managed by a farmers' committee with headquarters in the Rovieng district center. The preferred varieties were aromatic jasmine rice varieties (*Phka Rumduol*), for which the rice miller had secured export markets.

The specifications for organic certification were simple. First, no chemical inputs were allowed. Farmers had to separate paddy fields by digging ditches to prevent run-off and to create a 50 m buffer zone between conventional and organic plots. Finally, the rice could not be produced on a plot created after the recent clearing of forest. Compliance with the specifications was monitored by the Preah Vihear Meanchey Union of Agricultural Cooperatives (PMUAC) that manages an Internal Control System (ICS), and by an External Control System conducted by an expert from Ecocert, an organic certification organization. According to our interview with the SCCRP expert, the ICS played a crucial role in certification. The PMUAC team demonstrated professionalism having developed strong human resource capacities for ICS supervision and management, and for training new farmers and ICS inspectors. Ecocert certification was group certification, meaning that checks were made of randomly selected farmers. During the inspection, an Ecocert expert visited the farmers' rice fields accompanied by members of the cooperative's committees. However, not all farmers' plots were necessarily inspected because they were located a long distance from each other. The certification system was paid for by the rice miller AMRU.

3.3.2. Weaknesses in the process of organic certification

We identified several weaknesses in the organic certification process. First, the existing process did not limit farmers to only selling transplanted rice: broadcast rice was also accepted despite the risks of contamination by agrochemical residues. As the process is group certification, only some farmers were actually subject to individual inspections, farmers may thus be able to circumvent inspection and sell rice that does not meet organic specifications, at the same price as that of organic rice.

Second, for farmers, the premium price commanded by organic rice was too low compared to the profit they could make from upland crops. Indeed, while labor productivity of organic rice was higher than for broadcast (non-organic) rice (US$7.5/man-day vs. US$2.5/man-day respectively), it was still much lower than the price obtained for upland crops like cassava or cashew (US$10- US$33/man-day and US$16-US $42/man-day respectively, Fig. 4). Productivity per ha was also lower for rice (organic rice: US$700/ha, broadcast rice: US$141/ha, cassava: US$1265–1745/ha, cashew: US$374–1616/ha). As upland cash crops provided the majority of the farmers' income, they often underestimated the value of organic rice production due to the limited labor available. This profitability gap has been reinforced by the fact that farmers have never received the highest premium: for *Phka Rumduol*, the price of organic rice ranged between US$325 and US$400/t, depending on the quality of the rice, while the price paid for non-organic rice was US $300/t. Premium prices depended on the quality of the rice produced by the farmers. However, according to the farmers, rice millers often reduced the quality of rice at the farmgate to increase their own margin. The quality of the rice was not declared when the farmers delivered the raw product to the cooperative, only when the farmers collected what is owed them by the cooperative. Several farmers believed they did not fully benefit from organic certification because their rice was undervalued by representatives of the cooperative.

A third issue concerned delayed payments to the farmers by the cooperative that could take several weeks. Farmers often went into debt to buy supplies, and they had to pay back the money they owe rapidly. In contrast, when they sold their rice to an intermediate trader, payment was made on the spot. This direct payment was a real advantage for farmers who were under pressure to reimburse the money they borrow from microfinance institutions or private moneylenders.

What is more, the cooperatives only dealt with one or two rice millers who imposed their conditions. Rice millers set the volumes and varieties to be produced according to their own needs. Consequently, they were not obliged to buy all the rice the cooperatives had for sale, and in some years, they simply reduced their quotas. This occurred in 2020 during the Covid-19 pandemic. Due to the constraints facing exports of rice to EU markets, the rice millers reduced the volumes of rice they purchased and switched their buying preference from aromatic to common varieties. With no buyer, the rice could not be valued or certified as "organic" to enable the farmers to receive the associated premium. To avoid just this problem, agricultural contracts were supposed to be negotiated between the PMUAC and the rice farmers and signed in advance, but in some cases, these rules were not respected.

In another scenario, rice millers exerted their influence on the cooperatives. Part of the price premium, which was calculated based on the tonnage of rice sold, went to the PMUAC and to the Agricultural Cooperatives, while the remainder went to the farmers. Rice millers has been lobbying for a reduction in the share of the premium allocated to the PMUAC whereas there has been no increase in the share of the premium allocated to the farmers. The cooperatives had little bargaining power with the millers and has consequently been obliged to accept the deals proposed. However, in reality, the financial contributions to PMUAC were used to pay the salaries of the permanent staff responsible for the ICS. The millers underestimated the crucial role of the ICS and the huge effort required to carry out the necessary inspections, thus jeopardizing this step and the entire certification process as a result.

4. Discussion

4.1. Certification of organic rice is not enough to curb the pressure of the agrarian transition on farmers

Our results show that the factors that enable the production and certification of organic rice are threatened by technical, economic, geographical, and historical lock-in factors. All the farmers in our study region are gradually diversifying into upland crops, such as cassava and cashew trees. The agricultural commodity-driven deforestation observed in Rik Reay illustrates the dynamics of the crop boom at play across the Mekong region (Castella et al., 2023; Ingalls et al., 2018) and in Cambodia (Beban and Gironde, 2023; Kem, 2017; Kong et al., 2019; Mahanty and Milne, 2016). This reflects policymakers' and market actors' desire to encourage commodity crops that are valued by export markets. Boom crops are notorious for their negative environmental impacts, i.e., deforestation, soil erosion, and water pollution, which after a few years, lead to decreased yield (Montgomery et al., 2017; Touch et al., 2016). These cropping systems also have serious socio-economic consequences as they expose farmers to market volatility and increase their economic vulnerability and indebtedness (Beban and Gironde, 2023; Kong et al., 2021; Mahanty and Milne, 2016).

The move toward diversification into upland crops also works against organic rice. The higher price commanded by organic rice certification is not sufficient to incentivize farmers, who instead are switching from organic transplanted to broadcast rice, and broadcasting requires the use of chemical inputs, which is not compatible with organic certification. Thus, farmers are trapped in a pincer movement of agricultural intensification in the lowlands, and diversification in the uplands. Both are difficult to curb through organic rice production because of their environmental or socioeconomic outcomes. Extension of irrigation in Rik Reay commune is likely to amplify the challenge. In this context, organic rice certification alone is not enough to encourage alternative agroecological practices.

Our findings concerning the challenges facing organic certification in Preah Vihear are consistent with those of other studies of organic rice production in Cambodia and neighboring countries. For example, Hérique and Faysse (2021) pointed out the weaknesses of inspections and internal control systems in the organic certification process, and the mismatch between actual (lower) and expected (higher) premium prices received by farmers. Conversely, in her case studies, Beban (2014) reported that an Internal Control System was more effective than external inspections, in line with our results. Neang et al. (2017) and Thavat (2011) also showed that farmers in other provinces of Cambodia suffer from late payments from cooperatives and that the price premium was not high enough to maintain production of organic rice. These authors also revealed that land suitable for organic rice was shrinking due to chemical contaminants transported in irrigation water.

Finally, Taotawin (2011) described the difficulties farmers face in expanding organic farming due to the increasing opportunity costs of their labor linked to the more advantageous production of other crops and non-agricultural activities. Based on farmers' perceptions, Khoy (2017) and Beban (2014) identified labor intensity and market instability as key constraints to the production of organic rice. Baird et al. (2022) reported that in Laos, organic rice certification did help maintain transplanted rice but raised concerns about its sustainability due to declining labor availability.

4.2. The future of organic rice in the different types of farming systems

In Rik Reay, we identified five distinct farming systems, each with differing interests and strategies for organic rice production. While the technical or social diversity of the farms should be taken into consideration to support the farmers more effectively (Aubron et al., 2021), we can already propose hypotheses concerning the future of organic rice in each system. For now, the first two farming systems, FS1 and FS2, continue to transplant organic rice. These farms are small and have not yet started to significantly diversify. FS1 farmers will likely have limited ability to access uplands and may abandon organic rice and farming altogether and diversify into non-farming activities. Households with more family members are more likely to transition to off-farm activities and take advantage of new job opportunities and migration (Filloux, 2020). Farmers in the FS2 group have already diversified their activities. They may have the most interest in continuing to cultivate organic rice due to its economic value, despite facing constraints similar to those faced by FS1. However, in contrast to FS1, FS2 households are likely to have enough resources to remain in the village and continue farming while intensifying their organic rice production. FS3 farms no longer produce organic rice. FS4 and FS5 farms are the most capital-intensive and rely heavily on chemical inputs. Farmers in these systems have never produced organic rice but rather focus on cash crops. FS4 and FS5 are the driving forces behind the dynamics of crop booms in the region that drive the agrarian transition.

Finally, the rationale for farm differentiation is based on the availability of land in the uplands as long as there is forest to clear. Due to the increasing difficulty in opening new agricultural plots in the remaining forest in upland areas, expansion of cropland into forest is expected to decrease in the future. In its place, a trend toward intensification and economic differentiation within each type of farming system can be expected, driven by market logic (Le Coq and Trebuil, 2005). This process will be reinforced by the introduction of irrigation, which may enable intensification of rice production with two rice crops per year. While access to irrigation allows farmers to reduce their vulnerability to climatic hazards, two rice crops per year is generally associated with intensification with a change to broadcast rice and increased use of inputs (Diepart and Kong, 2022).

4.3. Collective action and territorial governance of agricultural cooperatives

Our study identified weaknesses in the process of certification of organic rice. To improve the impact of certification schemes, we argue that attention needs to be paid to more horizontal and multi-actor territorial governance.

Indeed, organic rice production in lowland areas is influenced by agricultural practices in the upper parts of the watershed. Through upstream-downstream interactions, lowland rice cultivation is impacted by soil erosion and surface run-off from upstream plots in which conventional practices are used. Residues of agrochemicals sprayed on upland fields are transferred to rice fields in the lowlands. Furthermore, irrigation systems in the lowlands connect plots and facilitate the transfer of chemical residues from conventional to organic plots. Thus, organic certification needs to include a territorial component that promotes agroecological practices, such as crop diversification, integrated pest management, use of organic fertilizer, in the uplands with the aim of maintaining organic rice systems in the lowlands.

The certification process itself raises several questions, especially related to group certification, in which only randomly selected farmers are checked by the third-party organization, Ecocert. As a result, there is a risk that some farmers manage to avoid the inspection and sell non-organic rice under the certification scheme. To solve this problem, an alternative approach to organic certification could be inspired by the Participatory Guarantee System (PGS) (Bellon et al., 2011; Wezel et al., 2018). PGS relies on the active participation of stakeholders, including both farmers and consumers, meaning products can be certified at less cost as expensive, third-party certification is no longer required. This system has primarily been for local markets rather than for export markets, and, in our case study, this could be a problem as organic rice is destined for European and North American markets. However, some authors suggest that PGS could also promote sustainable products in export markets (Jacobi et al., 2023). Still, PGS requires collective action, trust and strong coordination among actors.

Finally, improving the certification process requires strengthening the management of the agricultural cooperatives and their relationships with farmers and rice millers through collective action. Unlike other organic rice initiatives that have tended to increase the dependence of members of agricultural cooperatives on development agencies (Beban, 2014), the Rik Reay cooperative was always in the driver's seat throughout the project at the origin of the certification scheme. Over time, the cooperative has gained influence and gradually taken over the functions originally fulfilled by the project. While the rice millers still have considerable power over the cooperatives that supply their raw materials, the cooperatives also have more bargaining power because they formed a Union. For example, some rice millers tried to cut the ties between some cooperatives and the PMUAC, but the cooperatives rejected the proposal, arguing that this would not benefit them. One of our interviewees emphasized the role of the Union, which provides strong social cohesion, a key point for the success of the certification scheme, and of its resilience over time.

Although the PMUAC appears to be robust, efforts are needed to build stronger relationships with other actors at the community level. Non-economic institutions can be key players in securing the future of organic rice. For example, Farmer Water User Communities (FWUCs) are central to irrigation water management. The FWUCs could solve some of the problems of connectivity between uplands and lowlands through run-off, and irrigation during the dry season, as mentioned above. They could promote the use of cover crops or pulse crops combined with a single organic rice crop instead of the conventional double rice crop enabled by the use of chemical inputs. The local Community Forestry (CF) is another community-based organization that brings together people from the whole commune to protect local forest resources. Such collective action could help local farmers to discuss and shape a vision of a more sustainable landscape that includes organic rice systems. Community Forestry could also play a role in reforesting riparian areas to limit silting up and pollution of the river network. Finally, interviews with local resource persons underlined the importance of collective action to strengthen the coordination of all stakeholders in the territory by developing a participatory local development plan within the commune.

4.4. Limits of the study and future outlook

The agrarian diagnosis methodology has some limitations that require attention. First, the tool primarily focuses on technical and economic aspects related to decision-making and socio-economic differentiation, rather than investigating actor networks and the power dynamics that may be involved in organic rice certification. To address these limitations, we completed our diagnosis with interviews with resource persons about organic rice certification. Still, more interviews are needed with a variety of stakeholders throughout the organic rice value-chain, including certification auditors, the union of cooperatives, and rice millers to explore the potential for improved governance of the organic rice value chain. Second, agrarian diagnosis leans on the expertise and judgment of researchers, and this could introduce bias and subjectivity in the analysis, however long-term fieldwork and participatory observation were conducted by multiple researchers, thereby mitigating potential individual bias.

By highlighting the specific issues faced by each farming system, this research supports a critical examination of their possible future evolution. However, it is important to approach this typology with caution, as it provides a snapshot of the farms' situation at a given moment. Finally, we describe the trajectories of farming systems in a context where some resources were still accessible to all, including land that was accessible through the appropriation of forested areas. It would be useful to investigate the evolution of farms in a context where resources are finite once there won't be any forest left. Such a study would reveal how market pressures and market-based differentiation play a significant role in shaping these trajectories. For instance, smaller farms with limited access to land in the uplands may find it difficult to diversify their farming activities, and, instead, may resort to diversifying their non-farming activities. Further research could shed light on how such dynamics impact the smallholder farming systems in the long term and their capacity to sustain organic rice production.

5. Conclusion

This paper examines whether organic rice certification can maintain "organic by default" practices in a context of rapid agrarian transition in the province of Preah Vihear, one of the last organic strongholds in Cambodia. Using a farming systems approach, we explored the interactions between organic rice and non-organic rice and other crops and non-farm activities at both household and landscape levels.

Our results show that organic rice production and certification are threatened by lock-in factors including low premium prices for organic rice, labor diversification across different farming and non-farming activities, cash flow management, and the process of certification itself, leading farmers to shift to cash crops for export. This move to diversification toward upland crops works against organic rice certification. Specifically, organic rice is less competitive than recently introduced cash crops such as cassava and cashews. The premium price for organic rice is not sufficient to incentivize farmers, who are instead switching from cultivating organic transplanted rice to broadcast rice. However, broadcasting requires the use of chemical inputs, which is not compatible with organic certification. We identified five types of farming systems with varying strategies regarding organic rice: shifting away from organic rice to pursue non-farming activities (FS1), potentially maintaining organic rice (FS2), ceasing organic rice but still having the potential to invest in complementary agroecological practices for rice and upland crops (FS3), or relying on upland crops and having no interest in organic rice (FS4 and FS5). To promote organic rice production through certification, a landscape-based approach should be considered, integrating farmers' knowledge and involving them in strengthening incentive mechanisms. We have shown the importance of collective action, particularly through agricultural cooperatives, in the implementation of organic rice certification in Preah Vihear province. However, the relationship between farmers, agricultural cooperatives, the union of cooperatives, and the rice millers requires more in-depth study and further strengthening.

Finally, this paper provides insights into one incentive mechanism, organic certification, among others. Further study of incentive mechanisms and how they articulate in creating an enabling environment for sustainable rice systems may help inform strategic rice policies in Cambodia and beyond.

CRediT authorship contribution statement

Alexia Dayet: Writing – review & editing, Writing – original draft, Visualization, Data curation, Investigation, Formal analysis, Conceptualization. **Jean-Christophe Diepart:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Jean-Christophe Castella:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Sreymom Sieng:** Writing – review & editing, Investigation. **Rada Kong:** Writing – review & editing. **Florent Tivet:** Writing – review & editing, Funding acquisition. **Julien Demenois:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data availability

Data will be made available on request.

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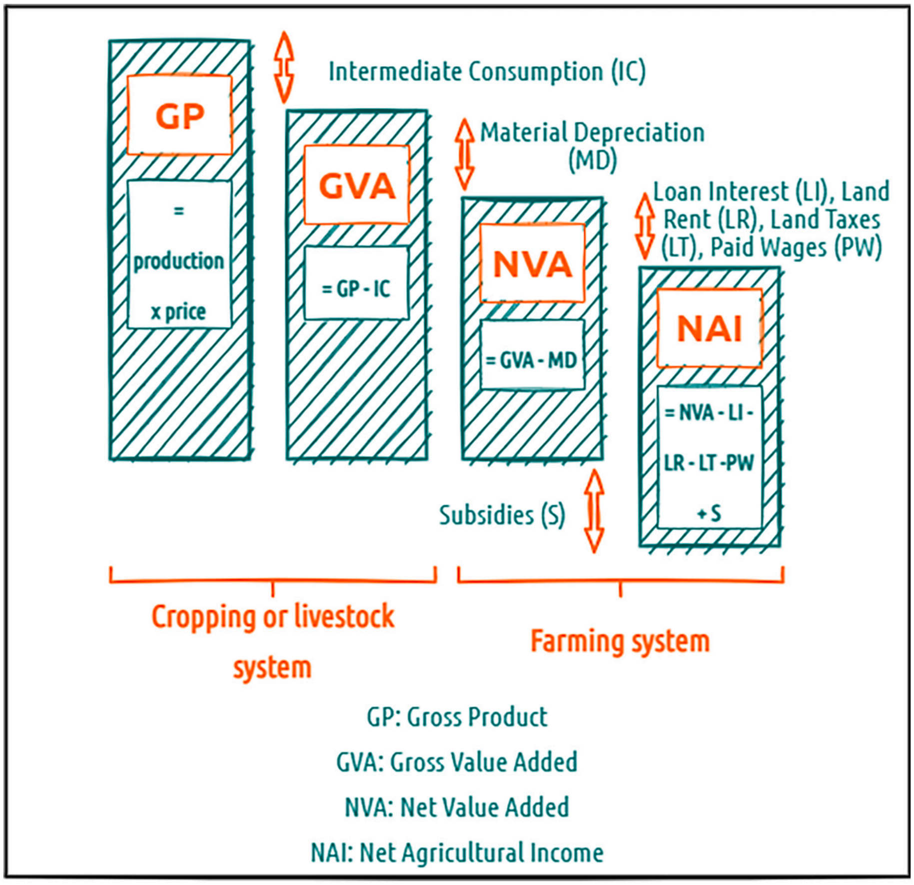
Appendix 1. Detail of economic calculation of the net agricultural income per family worker (adapted from (Cochet, 2015) and (Moreau et al., 2012))



Economic assessments are based on the following basic principles:

At the cropping or livestock systems level:

(1) Annual **Gross Product (GP)** = Production * Market Price.
For a cropping system: GP = average yield/ha * area * average price.
Gross product considers agricultural products sold as well as agricultural products consumed by the farmer's family. All products are valued at the local market price or, in the case of products for household consumption, at the equivalent purchase price.

(2) **Gross Value Added (GVA)** = GP − (annual Intermediate Consumption (IC)).
Intermediate consumption is the cost of inputs, goods and services that are fully consumed during the production cycle, such as seed, fertilizer or plowing services.

Labor productivity is the GVA/man-day of labor required for the crop or livestock system (we consider one man-day to be 8 h). Land productivity is the GVA/ha of the crop or livestock.

At the farming system level:

(3) **Net Value Added (NVA)** = GVA − (annual Material Depreciation (MD))
Annual MD corresponds to the annual consumption of multi-year equipment. It can be proportional (e.g., livestock stalls in a building) - or not - to an area (e.g. tractor, pump, plow).

(4) **Net Agricultural Income (NAI)** = NVA − (Loan Interest (LI)) − (Land Rent (LR)) − (Land Taxes (LT)) − (Paid Wages for employees (PW)) + Subsidies (S).

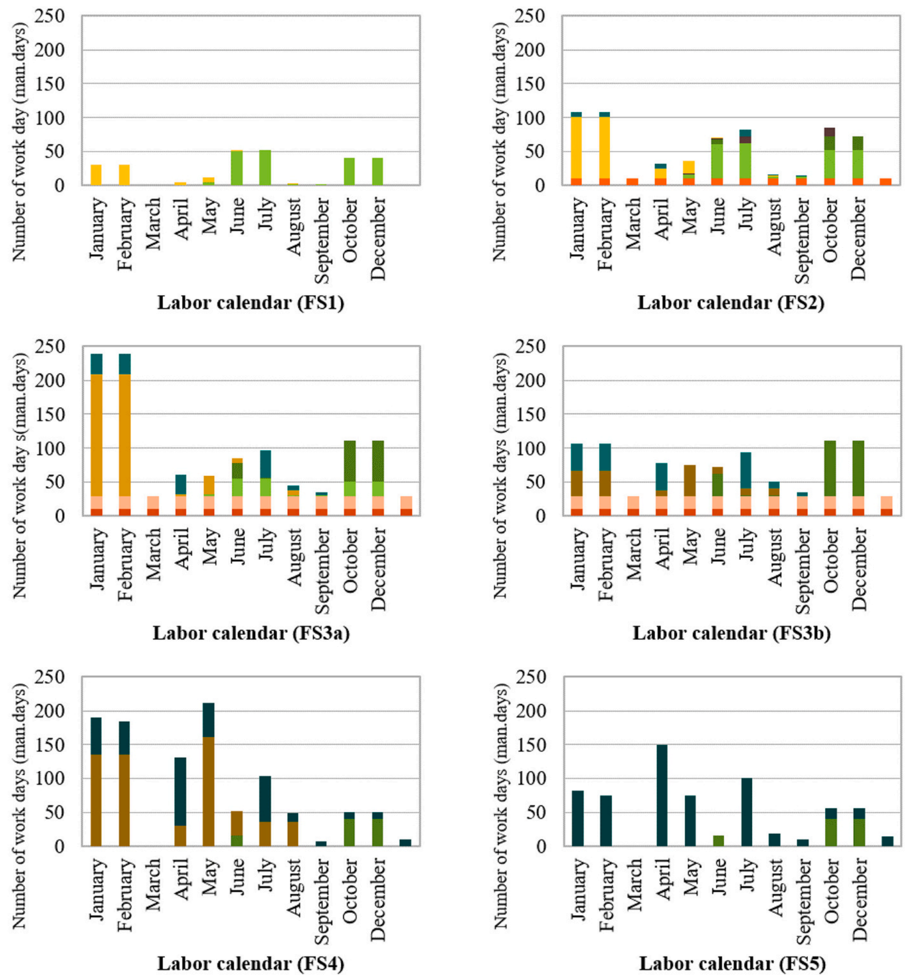
For each farming system, net agricultural income per family worker can be expressed as:

$$NAI/Fw = GP/ha - IC/ha - pMD/ha - LR/ha - pLI/ha - LT/ha - pPW/ha - SC/ha + S/ha) \times AA/Fw - npMDnpLInpPW/Fw$$

where Fw is the number of family laborers; AA, the Agricultural Area (surface of Farmland); AA/Fw, agricultural area per family laborer.

For detailed calculations of all these indicators, please refer to (Dayet, 2021).

Appendix 2. Working calendar of the farming systems



		Name of crop	Description
Cropping systems (CS)	CS1	Transplanted organic rice	Transplanted rice, sold under organic certification to the cooperative
	CS2	Broadcast rice	Broadcast rice, sold to a middle-man
	CS3	Soybean	Soybean
	CS4	Cassava - power-tiller – dry	Cassava, cropping practices carried out with a power tiller, sold cut and dried and in pods
	CS5	Cassava - tractor services – dry	Cassava, cropping practices carried out with a rental tractor, sold cut and dried and in pods
	CS6	Cassava - tractor – fresh	Cassava, cropping practices made by tractor, sold fresh
	CS7	Cashew trees < 6 years old – low intensive	Cashew tree, less than 6 years old, low input and low output (low yields)
	CS8	Cashew trees > 6 years old – high intensive	Cashew tree, older than 6 years, intensive in inputs and very productive (high yields)
Livestock systems (LS)	LS1	Cattle – 10 cows	Small herd of about ten cattle
	LS2	Cattle – 50 cows	Large herd of 50 cattle
	LS3/LS4/LS5	Pigs	Breeding pigs (SE3), breeding-fattening pigs (SE4) & fattening pigs (SE5)

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