

WHICH IRRIGATION DEVELOPMENT PATHWAYS CAN SUPPORT SUSTAINABLE FARMING? A CAMBODIAN CASE STUDY

QUELLES STRATÉGIES DE DÉVELOPPEMENT DE L'IRRIGATION PEUVENT SOUTENIR UNE AGRICULTURE DURABLE ? UNE ÉTUDE DE CAS MENÉE AU CAMBODGE

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ABSTRACT

The development of irrigation is widely regarded as a key lever for agriculture and rural development, while also being a cornerstone of Green Revolution trajectories that are now associated with economic concerns (below-expected profitability, indebtedness), social concerns (inequities & health issues) and environmental concerns (soil and water quality degradation, loss of biodiversity). Rice farming has long been a core component of irrigated agriculture development policies in Southeast Asia since the 1960s. In Cambodia, water-based intensification and related practices (double or triple cropping seasons, High Yielding Varieties, use of synthetic inputs, mechanization) have emerged relatively recently (circa the late 1990s). This article draws on an empirical case study from an irrigated rice-growing scheme in Battambang province, north-west Cambodia, that has gone through several stages of rehabilitation since the 2010s, and where numerous initiatives promoting sustainable agriculture and collective water management are taking place. We examined how irrigation development in a formerly rainfed area has shaped agricultural trajectories and influenced the prospects for adopting more sustainable farming practices.

The results show that the simultaneous development of irrigation infrastructure and the related structuring of value chains has reinforced a Green Revolution model of agriculture. The shift from rain-fed subsistence farming to high-input/high-output irrigated systems has substantially increased productivity, while also generating growing concerns about sustainability of farmers' livelihoods. Recent initiatives promoting sustainable rice growing and collective water management, designed to address key constraints faced by farmers, were initially well received, but have not yet triggered a significant reorientation of agricultural trajectories. We argue that irrigation development requires a paradigm shift from infrastructure-led approaches toward resilience, sustainability and agroecology-oriented approaches, to avoid locking agriculture into unsustainable and destructive pathways.

Keywords: environmental concerns; loss of biodiversity; sustainable agriculture; water-based intensification; agroecology-oriented approaches.

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RESUME

Le développement de l'irrigation est généralement reconnu comme un principal moyen pour l'agriculture et le développement rural, tout en constituant un thème essentiel des trajectoires de la Révolution verte, désormais associées à des préoccupations économiques (rentabilité inférieure aux attentes, endettement), sociales (inégalités et problèmes de santé) et environnementales (dégradation de la qualité des sols et de l'eau, perte de biodiversité). Depuis les années 1960, la riziculture constitue un élément clé des politiques de développement de l'agriculture irriguée en Asie du sud-est. Au Cambodge, l'intensification basée sur l'eau et les pratiques qui y sont liées (double ou triple saisons de culture, variétés à haut rendement, utilisation d'intrants synthétiques, mécanisation) sont apparues relativement récemment (vers la fin des années 1990). Cet article s'appuie sur une étude de cas empirique menée sur un projet de riziculture irriguée dans la province de Battambang, au nord-ouest du Cambodge, qui a connu plusieurs phases de réhabilitation depuis les années 2010 et a fait l'objet de nombreuses initiatives visant à promouvoir l'agriculture durable et la gestion collective de l'eau. Nous avons examiné la manière dont le développement de l'irrigation dans une zone auparavant pluviale a façonné les trajectoires agricoles et influencé les perspectives d'adoption de pratiques agricoles plus durables.

Les résultats montrent que le développement simultané des infrastructures d'irrigation et la structuration des chaînes de valeur ont renforcé le modèle agricole issu de la «Révolution verte». Le passage d'une agriculture de subsistance pluviale à des systèmes irrigués à forts intrants et à haut rendement a considérablement accru la productivité, tout en suscitant des inquiétudes croissantes quant à la durabilité des moyens de subsistance des agriculteurs. Des initiatives récentes visant à promouvoir une riziculture durable et une gestion collective de l'eau, conçues pour remédier aux principales contraintes auxquelles sont confrontés les agriculteurs, ont d'abord été bien accueillies, mais n'ont pas encore donné lieu à l'réorientation significative des trajectoires agricoles. Nous constatons que le développement de l'irrigation nécessite un changement de paradigme, passant d'approches axées sur les infrastructures à des approches orientées vers la résistance, la durabilité et l'agroécologie, afin d'éviter d'enfermer l'agriculture dans des voies non durables et destructrices.

Mots-clés : Préoccupations environnementales; Perte de biodiversité; Agriculture durable; Intensification basée sur l'irrigation; Approches axées sur l'agroécologie.

INTRODUCTION

World agriculture is increasingly confronted with multiple structural challenges, reviving longstanding debates on the need to rethink agricultural development. Central to these discussions is the legacy of the Green Revolution (GR), still hotly debated. While the significant productivity gains enabled beneficiary farmers to increase their profits (Thi Ut & Kajisa, 2006), they also led to a general decline in crop prices which particularly hurt farmers who did not benefit from these gains (Evenson & Gollin, 2003), and the many who faced rising production costs associated with High-Yielding Varieties (HYV) and inputs use (John & Babu, 2021; Pingali & Rosegrant, 1994). Additionally, **the emerging practices, as monocropping and increased use of synthetic inputs**, brought adverse environmental effects, such as water and soil pollution, loss of biodiversity, disruption of ecosystems balance, promoting the overpopulation of certain pest species, soil degradation, and the loss of many traditional crop varieties, reducing food diversity (Cantrell & Hettel, 2004; John & Babu, 2021; Patel, 2013; Pingali & Rosegrant, 1994). Additionally, GR technologies and practices are often embedded in development trajectories that generate “lock-ins” and constrained transitions toward sustainability (Gaillard et al., 2025; Orjuela-Ramirez et al., 2025).

Various alternatives are being explored, including renewed investment in a second Green Revolution designed to reach a broader range of farmers and informed by contemporary knowledge, experience, and innovative practices. (Cantrell & Hettel, 2004; Conway et al., 1997; Evenson & Gollin, 2003; Otsuka & Larson, 2013; Pingali & Rosegrant, 1994; Ra & Chong, 2025). Other perspectives highlight agricultural models that place greater emphasis on sustainability, including agroecology (Gliessman et al., 2019; Wezel et al., 2020) **regenerative agriculture** or **organic agriculture**. Irrigation is inevitably at the heart of these discussions about the future of agriculture, as it was a key pillar of the initial GR and is now

regarded as a main enabler of both a second GR (Otsuka & Larson, 2013; Ra & Chong, 2025) and transitions toward more sustainable farming systems (Leauthaud & Leenhardt, 2025; Taguta et al., 2022). Moreover, irrigation is a key component of strategies aiming at meeting growing food demand, facing the consequences of climate change, and ensuring poverty alleviation and food security for smallholders farmers (Bwambale et al., 2022; Giordano et al., 2012, 2023).

The initial GR was rooted in irrigated regions, and achieved its biggest gains by combining irrigation, HYVs, and chemical inputs, particularly in the dry season (Evenson & Gollin, 2003; Giordano et al., 2023; Pingali, 2012; Thi Ut & Kajisa, 2006). Access to water is often considered one of the main constraints to the expansion of GR in new areas (Cassman & Grassini, 2013; Otsuka & Larson, 2013; Pingali, 2012), and the adoption of HYV and productivity benefits were more limited in marginal rainfed regions (Duong & Thanh, 2019; Gollin et al., 2018). But irrigation is not solely linked to this model, it is also crucial to support traditional farming systems (De Bont et al., 2019), and agroecological practices are found in irrigated area (Ameur et al., 2020). Irrigation and agroecology are, however, rarely conceptualized together: the first remains associated with productivity-oriented agriculture, while the latter is generally framed as an alternative model (Leauthaud et al., 2025). Building on a Cambodian case study, we examine how irrigation development in a formerly rainfed area has shaped agricultural trajectories and influenced the prospects for more sustainable farming pathways.

Rice farming has been a core component of irrigated agriculture development policies in Southeast Asia since the second half of the 21st century. In Cambodia, water-based intensification and related green-revolution practices (double or triple cropping seasons, HYV, use of synthetic inputs, mechanization) have emerged relatively recently (circa the late 1990s). In this vein, the Cambodian government introduced the “Promotion of Paddy Production and Rice Export” policy In 2010, with the aim of transforming the country into a major exporter of high-quality milled rice through a transition from subsistence-oriented to commercial rice farming (Royal Government of Cambodia, 2010). The expected benefits included economic growth, rural poverty reduction, and improved livelihoods for farmers. (Royal Government of Cambodia, 2010). Fifteen years later, the annual production of rice increased by more than 50% at national scale, and 3 different types of milled rice are exported to various countries (jasmine, fragrant and white rice, source: Ministry of Agriculture, Forestry and Fishery, 2024), with some varieties having won several international quality awards. Simultaneously, rural Cambodia is reported to show strong affinities with ecological agriculture, where organic and natural farming is viewed as a means of enhancing local control over standardization and food commodification (Feuer, 2011).

The aim of this study is to understand how agricultural development policies and initiatives have shaped farming households' trajectories, practices, and current conditions. We draw on an empirical case study of an irrigated rice-growing scheme in Battambang Province, northwestern Cambodia, which has undergone several phases of rehabilitation since the 2010s and has been the focus of numerous initiatives promoting sustainable agriculture and collective water management. We hypothesize that (1) the combined development of irrigation infrastructure and value chains has reinforced a Green Revolution-type agricultural model, and (2) recent sustainability-oriented initiatives have been able to alter or reverse this trajectory.

CONTEXT AND METHODOLOGY

Kanghot irrigated scheme

The Kanghot rice-growing irrigated scheme (>45 000ha) was built in Battambang province, northwest Cambodia, during the khmer rouge era. In the 2010s, Chinese state-capital first investments in irrigation infrastructures allowed double cropping. Farmers started to use short-cycle cultivars, like Sen Kra Ob (SKO), a fragrant variety promoted by the government in irrigated areas as part of the national export policy. This rehabilitation focused only on infrastructure construction despite a lack of schemes operation & maintenance (O&M) capacity at national scale (Sithirith, 2017). The intensification of rice production resulted in households' integration into commodity markets, leading to higher surplus output, rising inputs use, mechanized services use, production costs, faster capital circulation, and related indebtedness (Diepart & Thuon, 2022; Green, 2022; Green & Yi, 2024). Despite millions invested over

15 years, access to water remained until recently a challenge, due to infrastructure designs poorly adapted to hydrological variability, recurring conflicts, and the limited effectiveness of water user groups (Diepart & Thuon, 2022; Green, 2022; Green & Yi, 2024), making farmers still vulnerable to climate hazards (Doch et al., 2015).

A second wave of rehabilitation is underway through the WAT4CAM project¹⁰ (Water Resources Management and Agro-ecological Transition for Cambodia project, 2020–2026), including infrastructure implementation along with institutional support activities related to water management & monitoring, and agroecological transition. In a nutshell, the main proposals made to households through these activities are (non-exhaustive):

- The establishment of the Farmer Water User Community (FWUC, operated by farmers) to ensure water management and the O&M of the irrigated area
- The dissemination of a set of alternative practices including cover crops, the use of specific machinery (no-till rice planters, laser land levelers) and alternate wetting and drying (AWD)
- Sustainable Rice Platform¹¹ (SRP) standard, allowing a better-quality rice and a better remuneration of production
- Non-rice farming activities: off-season crops farming, vegetable farming, rice-fish farming

Methodology

This research relied on information drawn from publicly available official documents and statistics, from documentation about the numerous activities previously conducted in the area within the framework of WAT4CAM or other initiatives, and on ethnographic fieldwork and in-depth interviews at national, provincial and local scale. All these activities took place between March and August 2025. At local scale, field survey was conducted in “Main Canal 2” area (MC2), the sub-area of Kanghot irrigated scheme covered by the project. Farmers and other stakeholders were interviewed in the three communes included in the MC2 study area: Reang Kessei, Kampong Pring (Sangkae district), and Thipakdei (Koas Krolor district). Most of the interviews were conducted one-on-one, and we purposely limited group discussions to a maximum of 3 people. Interviews were transcribed and analyzed with the help of NVivo software and the statistics were generated using the RStudio software.

RESULTS

Development of irrigation and farm trajectories

Before the end of the first scheme rehabilitation between 2010 and 2015, irrigation was marginal in the area and most farmers were growing one rain-fed cycle of medium or late-duration rice varieties. They already started the intensification process at that time with the adoption of power tiller, complete transition to rice broadcasting, use of herbicides and fertilizers. But the most significant changes occurred when irrigation became widely available in the area, allowing a transition to short-cycle non-photoperiodic varieties and double annual rice cropping (SKO variety at first). Yield per cycle and annual yield per hectare have increased significantly over this period (now ranging from 4 to 6 tons/cycle/ha), enabling rice farming to generate substantial gross revenue for farmers. These gains were made possible by the extension of the annual growing period, the high-yield potential of the new varieties, and their responsiveness to inputs. Thus, input use surged when the two-cycle system was introduced, and

¹⁰, forming part of a new generation of irrigation initiatives combining infrastructure with institutional measures to improve water access and agricultural development with an emphasis on sustainability. The program is funded by AFD¹⁰ (loan: €55 million) and EU (grant: €11.5 million) and seeks to rehabilitate, develop, and modernize irrigation schemes and preks¹⁰ to enhance water supply reliability over 15,000–20,000 ha, with a target of restoring 7–13 schemes (or hydraulic units) and 20–40 preks.

¹¹ <https://sustainableice.org/>

has continued to rise ever since for most farmers, including seeds broadcasting density (increased from 100 to 200-250 kg of seed per hectare today), chemical fertilizers (increased from 50 kg/ha/year to 200-400 kg/ha/cycle), herbicides, insecticides, fungicides, and other pesticides. In parallel, agricultural mechanization expanded rapidly through service provision by entrepreneurial farming households, including pumps, tractors, and combine harvesters, contributing to a decline in family labor requirements, often reaching less than 10 man.day/ha/cycle. It allowed households to maintain or increase the diversification of household activities.

Despite improvements in water management over time, the extension of the growing season, weaknesses in water control, and climate-related uncertainties have posed significant risks to farmers in recent years, materializing in the form of droughts and floods affecting yields and destroying crops during their first attempts to grow two or more rice crops a year.

« During the 2-3 first years in the beginning it was not easy because there was little rain and not much water coming in the canal, also the FWUC did not manage well the water distribution so there was many problems at that time. » (Man, Rice farming household, Wat Kandal)

« In the first two years when I started to do two rice cycles there was some water shortage [...]. In that year I could only achieve 2-3 t/ha/cycle. » (Man, Rice farming household, Damnak Dangkao village)

Caught between water-related risks, rising production costs and indebtedness, farmers facing deteriorating economic conditions often had to sell their land to overcome these shocks. In some cases, land was subsequently rented back to previous owners, while in others, households became landless and shifted into local wage labor or migrated to Phnom Penh or Thailand to find wage opportunities.

Commercial rice farming today: risks and benefits

At the moment of the survey, although some inconsistencies in water management persist across the area, most farmers reported an improvement of water access, and a decrease of water-related risks, a minor constraint presently. But new types of risks have emerged over time, notably increasing pests and disease pressures, affecting yield and/or production costs due to greater reliance on fertilizers and pesticides, as well as substantial fluctuations in paddy, inputs and service price.

“During the first cycle, the rice was damaged by the brown planthopper, and I only harvested 3 tons per hectare. During the next cycle, I obtained 5 tons per hectare, but the price of rice had become very low.” (Man, Rice-farming household, Wat Kandal)

« The high costs of production are the main constraint as we need to spend a lot of money for inputs and gasoline, and to hire the service providers. On a good year we can get 500\$/ha/cycle, and 250 \$/ha/cycle or less for a bad year. » (Man, Rice farming household, Koun Prum village)

This range, reported by several households, is consistent with the statistics presented in Table 1, illustrating the economic conditions of rice production over the past few years and reflecting the important risks. It appears that paddy prices were considered high in 2024 (> 1,000 riel/kg or > \$250/t for all varieties, even those which are usually cheap) and low in 2025 (< 800 riel/kg or < 200 \$/t for some varieties)¹².

¹² According to official figures, prices are said to have fallen by more than 30% over this period., prices haven't really picked up since then - June 2026

Table 1. Gross output, production costs, and gross value added

		Cycle 1 - 2024		Cycle 2 - 2024		Cycle 1 - 2025 estimation based reported information
		mean	sd	mean	sd	
Gross product (\$/ha/cycle)	Yield (t)	4,6	0,8	4,6	0,7	5
	Price (\$/t)	264	22	290	20	188
	Gross product	1214	103	1349	247	938
Production costs (\$/ha/cycle)	Soil preparation	78	14	76	7	100
	Sowing	1	5	10	2	
	Purchased seeds*	100	20	111	106	100
	Land renting*	125	/	125	/	125
	Fertilizers	235	48	236	48	250
	Pesticides	111	46	107	44	100
	Irrigation	29	21	50	9	40
	Additionnal labor	52	14	37	20	40
	Harvest	103	17	98	13	100
	Total (land ownership + own seeds)	612	99	613	85	630
	Total (land renting + buying seeds)*	838	94	850	129	855
Gross added value (\$/ha/cycle)	Total (land ownership + own seeds)	537	238	677	499	308
	Total (land renting + buying seeds)*	364	242	269	299	82,5

We excluded depreciation, interest, and other expenses related to agricultural activity which would allow to estimate the income, since it was too difficult to estimate it accurately. Average values from a sample of 110 farmers for the year 2024, and estimated based on 34 farmers interviews for the year. 2025, both drawn from a diversity of villages in the Kanghot MC2 zone. *Not all farmers purchase seeds or rent land, so we have made two separate calculations.

Production costs now range from \$600 to \$800 per hectare per crop cycle, which many of the farmers surveyed considered high. Gross Added Value (or final income excluding depreciation, interests, and other expenses related to agricultural operations) is exceeding production costs of a portion of the yield corresponding to 1.5–2.5 t/ha in 2024, and dropped to 0.4–1.6 t/ha in 2025. This last figure indicates a high risk of unprofitability if yields were to slightly decline as it happened for many households during last years. The results also highlight the additional burden that land rental and purchase of seeds is for farmers (most of them were still saving their own seeds as a main source of seeds). Many households will maintain or even strengthen their diversification strategies, locally or through migration, to increase their livelihood and mitigate hazards related to rice farming. Some will engage into risky activities as renting land or growing 3rd annual cycle in an effort to maximize profits from rice farming or make up for previous cycles with poor economic results.

« Sometimes we cannot get good yields. Last year we could only harvest 2t/ha [per cycle] because of Brown Plant Hopper. Sometimes we lose profits as we spend already 250\$ just for the fertilizer. Five years ago, we used to rent another 2ha to do rice farming but it was not profitable. I rented in during three years but I could only get 2t per ha [per cycle]. If I work as a laborer, I can earn 10\$/day which is better than doing rice farming on some years.” (Woman, Rice farming household, Koun prum village)

Promoting sustainable rice farming in an irrigated scheme

Simultaneously to the above-mentioned trajectory, initiatives promoting more sustainable rice farming have met with some success, generating interest among numerous farmers who saw it as a potential solution to the challenges outlined above. However, significant obstacles have emerged at many levels, hindering households' engagement with the proposals.

« I learned about the cover crops from WAT4CAM project, I was interested when they promoted it. [...] I saw some improvements on soil quality, it was more loose than before, and there were more earthworms in the rice field. I want to continue, but sometimes there is floods so I cannot broadcast, and sometimes we lack water. In this area, there are no problems with cows and worms [contrarily to other areas]. » (Man, Rice farming household, Reang Kessei village)

Items in red and bold are those that are not emphasized—or are emphasized only to a limited extent—by farmers, but are highlighted by other types of stakeholders operating in the area. This table is not intended to be exhaustive given the complexity and wide range of initiatives and stakeholders involved in the area, types of commitments and perceptions among farmers.

Many proposals seek to directly address the challenges outlined above, and the dynamics that have emerged highlight certain stakeholders' interest in moving away from the high-input/high-output rice farming model. **However, this has not yet translated into major change.** Many farmers continue to increase inputs use year after year in order to optimize yield and deal with increasing risks of pests and diseases. Many have abandoned the SKO variety and contract farming, as premium proposed can hardly compensate the huge fluctuations in rice prices and yield losses caused by this variety's susceptibility to disease. Many have abandoned the practices promoted under the WAT4CAM project due to unsatisfying results, remaining constraints, lack of support, low profitability of rice farming or labor competition with non-farm activities. AWD practice is still largely unknown and abstract to many farmers. Despite frequently disappointing results, interest in a third annual rice crop is very common, even if it precludes many alternative practices and poses a risk to water distribution.

« If there is more water in the future I would grow a third rice crop, and hire land to do vegetable farming (upland). » (Man, Rice farming household, Koun Prum village)

The growth of the SRP standard program, the widespread adoption of "DIY" land leveling, the smooth operation of the FWUC, and a growing interest in irrigated diversification on small, backfilled plots near the home, are promising but may not yet have met the enabling conditions to become a game changer.

Error! Reference source not found. summarizes farmers' engagement with the main proposals aiming to improving rice farming sustainability.

DISCUSSION AND CONCLUSION

The development of irrigation, and the structuration of the value chain simultaneously, have enhanced a Green Revolution (GR) type agricultural model in Kanghot irrigated rice-growing scheme. The transition from rain-fed subsistence farming to irrigated commercial high-input/high-output farming has led to a sharp increase in productivity but also to the emergence of threats to economic, social, and environmental sustainability. Although recent initiatives promoting sustainable rice farming and water management have made interesting proposals to address those issues, meeting some success among farmers. But it has not yet led to a significant change in direction regarding farming dynamics.

Table 2. Summary of the proposals made as part of the WAT4CAM project and how households engaged with it.

Proposal	Context	Households' expectations	Households' constraints	Households' engagement in Kanghot area
Sen Kra Ob (Fragrant rice variety)	Promoted as part of "Quality rice export policy"	- Good yields and prices	- Lower yields and sensitivity to pests and diseases	Dominant variety during several years, now often replaced by shorter non-fragrant varieties more resistant to pests and disease
SRP quality standard	Promoted by stakeholders in Cambodia's rice value chain	- Good prices - Helps produce higher-quality rice	- Low premium - Quality standard difficult to follow - High certification costs for cooperatives - A lot of requirements to follow	Growing volumes of rice purchased. Many failed attempts have fueled farmers' mistrust in recent years.
Cover crops	Promoted as part of WAT4CAM agricultural support component	- Increase soil fertility - Reduced need for inputs	- Germination problems - Pests - Competition with third rice crop, livestock, non-agricultural activities (land, water, labor) - Need for more technical support - Production costs	Widespread trial, some have abandoned the practice, some have continued in relation with WAT4CAM initiatives and the local cooperative.
Farming diversification (other crops, raising systems...)		- Diversification of household income - Decreasing of inputs use for rice	- Lack of outputs - Competition with a third rice cycle for water and land	Investments with the project's assistance, on elevated agricultural plots close to houses
Improved mechanization (land leveling, no-till planter)		- Agronomic benefits - Mitigation of water related risks - Seeds use reduction - Improved input efficiency	- Costs	Most farmers now use land leveling. They have adapted the method. Some farmers still use no-till planters through service providing.
Alternate Wetting and Drying (AWD)	Promoted as part of greenhouse gas reduction/mitigation policies	- Access to subsidies - Improved rice health - Reduces water consumption	- General lack of knowledge about the practice - Requires a high degree of coordination and good access to water	- Trials conducted in specific, limited areas within the scheme
Farmer Water User Community	Promoted as part of WAT4CAM water management component	- Allow sufficient and fair water management - Ensure Operation&Maintenance	/	- Fully operational and well-known among farmers

When viewed from a broader perspective, the modalities of irrigation development in Kanghot are in line with the prioritization of new construction and rehabilitation, preferentially large schemes despite it is known to be difficult to manage and maintain, alongside chronic underfunding of Operations and Maintenance (Deligne, 2013; Sao, 2025; Sithirith, 2017). In our case, as elsewhere, it resulted at first in a poor access to water despite substantial investments, as evidenced by the severe water shortages and floods experienced by households for several years after the completion of the first rehabilitation project, focusing on infrastructures (Sao, 2025). Access to water appears to have improved significantly thanks to the infrastructure and collective water management components of the WAT4CAM project, showing encouraging results for this type of approach. But as virtually no resources have been allocated to the provincial and national agencies responsible for taking over the Kanghot scheme along with the FWUC once the project will be completed, the “build–neglect–rebuild” cycle is likely underway, and the expanding of dysfunctional infrastructure goes on, rather than addressing its root causes (Sao, 2025). This pattern places a substantial burden of uncertainty on farmers, drawing them into highly risk-prone production systems while appearing unable to sustain irrigation capacities, water management and infrastructure maintenance over the long term. Key recommendations from those authors include strengthening FWUCs, often described as helpless and lacking in resources in Cambodia (de Silva et al., 2014), prioritizing O&M funding over new construction, and enhancing infrastructure quality and data management.

As De Silva et al.(2014) already emphasized 10 years ago, the systematic continuation of large-scale rehabilitation investments also creates tensions between export-oriented agricultural intensification and rural poverty reduction. This tension can be observed in Kanghot, where SKO variety, promoted as part of the national export policy, has been gradually replaced in favor of varieties that better suit farmers' needs, and which are largely exported to Vietnam for processing. Thus, the initial aims of this policy were only partially achieved. First, a large share of the surplus allowed by irrigation is exported as paddy to neighboring countries (about 75% of total exported paddy in 2025, source: MAFF, 2024), limiting the added-value potential for all Cambodian value-chain actors, from farmer to rice miller. Then, rural poverty was maybe reduced on average, but rice farming has become very risky due to uncertainty regarding access to water, rising production costs, paddy prices and yields fluctuations, and it fuels a phenomenon of social differentiation linked to debt (Diepart & Thuon, 2022). Also

Simultaneously, agricultural and agronomic support is **neglected in terms of resource allocation**, underfunded during successive waves of rehabilitation, while Cambodia is characterized by limited opportunities for knowledge diffusion and co-production due to extension agents' minimal presence in the field and infrequent interactions with farmers (Tran et al., 2025). It is reasonable to assume that a major shift such as the transition from rain-fed subsistence farming to commercial, multi-cycle, irrigated farming, involving intensive use of inputs and mechanization, would struggle to succeed without a strong enhancement of agricultural support and local value chain, and maybe face the wasteful outcome of overproduction which ultimately drives prices downward. Kanghot case study reveals that alternatives to GR attracted farmers' interest and showed promising results. Several factors may account for the difficulty in maintaining their engagement over time, including the dilution of resources allocated to support across a large area, resulting in uneven technical support and cooperative activities across Kanghot scheme.

Our results underscore the strong and enduring bonds between modern irrigation development modalities and the GR model. We suggest that an unbalanced, infrastructure-heavy approach tends to “script” agricultural practices in ways that hinder transitions toward more sustainable farming models. Thus, for agroecology and irrigation to be compatible rather than mutually exclusive, they must be thought together to meaningfully create a favorable environment by allocating substantial resources and institutional support to O&M, collective water management, agricultural services and extension, and development of value-chain and markets. This calls for a rethinking of irrigation, its development rationale, modalities, and the resources currently devoted to it, in order to support agroecological futures and sustainable food production. It entails a paradigm shift that moves beyond viewing irrigation solely as a technical means of increasing productivity (Leauthaud & Leenhardt, 2025), a paradigm shift toward sustainable water management that ensures resilience while maintaining agricultural productivity and environmental integrity (Talbi et al., 2024).

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