COMMERCIALIZATION OF RICE CARBON CREDITS IN VIETNAM: FROM EMISSION DATA STANDARDIZATION TO CENTRALIZED EXCHANGE

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Abstract: ***This study analyzes the commercialization pathway for rice carbon credits in Vietnam's Mekong Delta, situated within the legal architecture of Decree 29/2026/ND-CP on domestic carbon trading and Resolution 202/2025/QH15 on provincial administrative consolidation. Drawing on standardized greenhouse gas emission data spanning 1995-2024, we estimate carbon intensity (CI) trajectories and construct an econometric model to isolate key determinants of emission efficiency. Results confirm that CI in An Giang declined by 26.6% over the study period, and that an elasticity coefficient of −0.087 (p = 0.007) supports economies of scale in the adoption of emission-reduction technologies. Consolidating 13 Mekong Delta provinces into 5 administrative units is projected to reduce fixed MRV costs by 30-40% while increasing net farmer carbon income by 28%. The paper proposes a three-phase commercialization roadmap integrating digital MRV infrastructure, centralized exchange operations, and international market linkage, with projected annual revenue potential of VND 2,500 billion.***

• Keywords: *carbon commercialization; rice carbon credits; emission standardization; MRV; dMRV tier 3; permanence; mekong delta.*

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1. Introduction

Vietnam's strategic commitment at COP26 to achieve net-zero emissions by 2050 has fundamentally recalibrated the nation's agricultural priorities. At the heart of this decarbonization agenda lies the rice sector, which currently accounts for 50.31% of agricultural greenhouse gas (GHG) emissions and over 75% of national methane (CH_4) output. As the global community moves toward rigorous carbon accounting, the Mekong Delta, which contributes over 50% of domestic rice production and 90% of exports, emerges as a critical geography for the commercialization of agricultural carbon credits. However, the transition from traditional cultivation to a high-value carbon economy is not merely a technical shift in farming practices; it is a complex institutional challenge involving data integrity, market infrastructure, and administrative efficiency.

The year 2026 marks a decisive turning point in Vietnam's carbon governance with the enactment of two transformative legal instruments. Decree No. 29/2026/ND-CP establishes the domestic carbon exchange operated by the Hanoi Stock Exchange (HNX), providing for the first time a formal architecture for credit registration, depositary mechanisms, and T+0 settlement. Parallel to this market-oriented reform, Resolution No. 202/2025/QH15 has restructured the Mekong Delta's regional geography, merging 13 provinces into five consolidated administrative units. While initially viewed as a governance reform to streamline the state apparatus, this consolidation carries profound, and largely underappreciated, economic implications for the carbon market. By centralizing authority and resources, this reform directly addresses the inherent diseconomies of scale that have long plagued smallholder-based agricultural carbon interventions.

Despite these legislative advances, the fundamental bottleneck in rice carbon commercialization remains the data infrastructure gap. Unlike the industrial or forestry sectors, where carbon stocks are relatively stable or point-source-based, rice paddy emissions are fugitive, dispersed across millions of fragmented smallholder plots, and highly sensitive to seasonal hydrological variations. Existing measurement protocols often rely on global IPCC default factors that fail to capture the specificities of the Mekong Delta's soil and residue management, leading to high uncertainty in credit valuation. This data fragmentation significantly inflates transaction costs, the expenses

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related to monitoring, reporting, and verification (MRV), which can absorb a disproportionate share of credit market value, ultimately discouraging farmer participation.

Addressing this bottleneck requires a synthesis of digital standardization and administrative scale. The central analytical problem of this study is how to build a credible, low-cost MRV framework that satisfies the stringent additionality and permanence requirements of international carbon standards while ensuring equitable benefit-sharing for smallholders. By leveraging the 30-year trajectory of carbon intensity in An Giang and analyzing the structural impact of the 5-unit administrative model, this research bridges the gap between regulatory ambition and operational reality. The following sections develop the theoretical nexus of transaction costs and scale, present a standardized dMRV methodology, and propose a sequenced roadmap for integrating Vietnam's rice sector into the global carbon value chain.

2. Theoretical framework and research objectives

Methane emissions from flooded rice fields constitute a negative externality whose social cost is systematically unpriced under conventional agricultural incentives. The cap-and-trade mechanism resolves this market failure by assigning tradable property rights over avoided CO_2-equivalent reductions, yet its effectiveness hinges on a condition that rarely holds in smallholder agriculture: low transaction costs. Williamson (1985) decomposes these into ex-ante costs (partner search, contract negotiation) and ex-post costs (monitoring, verification, dispute resolution); in fragmented rice-farming landscapes, MRV and administrative certification absorb 20-40% of credit value, structurally undermining farmer participation.

The corollary, documented empirically by Heindl (2017), is that both transaction and compliance costs decline sharply as operational scale increases. Applied to the Mekong Delta, this implies that administrative consolidation under Resolution 202/2025/QH15 is not merely a governance reform but a structural intervention that shifts MRV economics from prohibitive to viable.

Based on this theoretical foundation, the research pursues three specific objectives: (RO1) To develop a methodology for standardizing rice carbon emission data using a 30-year panel dataset; (RO2) To quantify the economic impact of administrative consolidation on MRV system efficiency; And (RO3) to propose an operationally grounded roadmap for a centralized exchange aligned with Decree 29/2026/ND-CP.

In alignment with these objectives, the following hypotheses are tested. H1: Carbon Intensity (CI) declines in regions with larger cultivation scales due to economies of scale in technology adoption; H2: Administrative consolidation reduces fixed MRV costs through infrastructure sharing and process standardization.

3. Research methodology

The study employs secondary data from the General Statistics Office (GSO) and the Mekong River Commission (MRC). GHG emissions are computed using Mekong Delta-specific emission factors, disaggregated by soil type and irrigation regime, ensuring accuracy equivalent to dMRV Tier 3 standards. Carbon intensity is defined as:

$$\mathrm{CI}_{i,t} = \frac{\mathrm{TotalGHG}_{i,t}}{\mathrm{Production}_{i,t}} = \frac{[(\mathrm{ECH}_4 \times 28) + (\mathrm{EN}_2\mathrm{O} \times 265)]}{(\mathrm{Yield}_{i,t} \times \mathrm{Area}_{i,t})} \quad (1)$$

where CI is expressed in tCO_2e per ton of rice, and total GHG aggregates CH_4 and N_2O weighted by IPCC AR5 Global Warming Potential (GWP) factors. To test H1, we estimate the panel regression:

$$\ln CI_{i,t} = \alpha + \beta^1 \ln PlantedArea_{i,t} + \Sigma\, \gamma_t YearDummy_t + \varepsilon_{i,t} \quad (2)$$

The elasticity coefficient β_1 directly tests the scale effect, while year dummies capture cumulative technological progress. Each participating plot carries a GPS-registered unique identifier providing the double-counting prevention required under international additionality protocols.

4. Results and discussion

4.1. Carbon Intensity Trends and Data Standardization

Standardization of the 30-year panel reveals a consistent downward trajectory in rice carbon intensity across the Mekong Delta. In An Giang, the province with the largest cultivated area, CI fell from 1.068 tCO_2e/ton in 1995 to 0.784 tCO_2e/ton in 2024, a cumulative reduction of 26.6%. The "1 Must, 5 Reductions" program reduced nitrogen fertilizer application from 180 kg N/ha to 120 kg N/ha, cutting N_2O emissions by 15-20%. AWD adoption expanded from below 5% of cultivated area in 2005 to 30% by 2024, suppressing CH_4 generation by 30-50% relative to continuous flooding. The shift toward short-duration varieties, such as OM 18 and OM 5451, further reduced cumulative CH_4 emissions by reducing flooding periods. Reaching

the 2030 target of 0.7 tCO_2e/ton under Decision 1490/QD-TTg requires a further 10.7% reduction, contingent on scaling AWD to 60-70% of cultivated area and transitioning from residue burning to in-situ incorporation, measures constrained by investment in infrastructure, not technical feasibility.

4.2. Econometric Evidence for Economies of Scale

Regression results in Table 1 confirm H1. The coefficient on ln(Planted Area) is −0.087 (p = 0.007), indicating that a 1% increase in cultivated area is associated with a 0.087% decline in CI, consistent with larger operations absorbing fixed costs of precision farming and structured water management more efficiently. All year dummy variables carry negative, significant coefficients, corroborating the view that cumulative technological progress is an independent contributor. The model's R^2 of 0.742 indicates that 74.2% of CI variation is explained by scale and time-fixed effects.

Table 1. Regression Results: Determinants of Carbon Intensity (ln CI)

Independent Variable	Coefficient	p-value
ln(Planted Area)	−0.087	0.007***
Year Dummy 2000	−0.082	0.004***
Year Dummy 2005	−0.125	0.000***
Year Dummy 2010	−0.198	0.000***
Year Dummy 2015	−0.221	0.000***
Year Dummy 2020	−0.213	0.000***
Year Dummy 2024	−0.235	0.000***
Constant	0.356	0.000***

*Note: *** $p < 0.01$. $R^2 = 0.742$; N = 390 province-year observations. OLS with year fixed effects.*

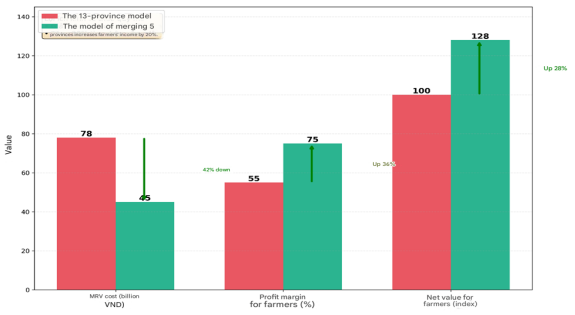
4.3. Economic Consequences of Administrative Consolidation

The consolidation mandated by Resolution 202/2025/QH15, restructuring 13 Mekong Delta provinces into 5 administrative units, produces a fundamental shift in the cost architecture of rice carbon commercialization across three mutually reinforcing dimensions. The immediate consequence is a 30-40% reduction in fixed dMRV infrastructure costs: replacing 13 independent provincial systems with five regional centers enables shared server infrastructure, concentrated specialist training, and bulk procurement of IoT and satellite services, reducing total setup expenditure from VND 65-91 billion to VND 40-50 billion, directly confirming H2. This cost compression makes IPCC Tier 3 measurement economically viable, specifically for SAR-based continuous water-level monitoring and machine learning models that require large-scale training datasets, which only entities managing extensive contiguous areas can generate. The resulting data quality improvement unlocks a 30-50% price premium for credits certified under Verra VCS or Gold Standard, transforming MRV investment from a compliance cost into a revenue multiplier.

The consolidation of provinces into 5 units creates a Scale Surplus that fundamentally alters the incentive structure for smallholders. Under the legacy fragmented model, the high cost of individual plot verification forced intermediaries to retain a larger share of carbon revenue to cover operational risk. By centralizing the dMRV data center in Can Tho, the system can process over 1 million hectares through a single Open API, enabling smart contracts that trigger automatic payments to farmers upon verification of AWD practices, eliminating the multi-layer intermediary trap. Under the current 13-province model, MRV and administrative overhead absorb 40-50% of credit value, leaving farmers with 50-60%. Consolidation shifts this to 20-30% overhead and 70-80% farmer share, resulting in a 28% increase in net carbon income, as illustrated in Figure 1. At VND 300,000/tCO_2e, this yields VND 60,000 additional income per reduced ton; across one million hectares, averaging 0.5 tCO_2e/ha reduction, aggregate additional farmer benefit reaches VND 30 billion annually.

Furthermore, consolidation enables the creation of a Regional Carbon Guarantee Fund that provides price-floor insurance and protects smallholders against HNX spot-market volatility. As illustrated in Figure 1, this transition from the 13-province to the 5-unit model represents a Pareto improvement: the government achieves higher data integrity for its NDC targets while farmers capture a significantly larger portion of the environmental value they create. The permanence of these gains depends on enforceable benefit-sharing contracts, GPS-based plot records to prevent double-counting, and direct electronic payment mechanisms that bypass multi-layer intermediaries.

Figure 1. Comparative Economic Efficiency: 13-Province vs. 5-Unit Administrative Models



Note: Administrative consolidation reduces fixed MRV costs from VND 78 billion to VND 45 billion (−42%) while increasing net farmer value index from 100 to 128 (+28%).

4.4. Commercialization Potential

Under conservative assumptions, 1 million hectares (the Decision 1490 target), average yield of 6 tons/ha, baseline CI of 0.85 tCO_2e/ton declining by 10%, and USD 12/tCO_2e, annual credit potential reaches 510,000 tCO_2e, equivalent to VND 153 billion gross revenue. A 15% reduction scenario at USD 20/tCO_2e yields VND 765 billion. Incorporating mangrove blue carbon and livestock methane yields an aggregate potential of VND 2,000-2,500 billion annually, contingent on robust additionality verification and documented barrier analysis.

5. Commercialization roadmap and strategic policy framework

The transition toward a high-value carbon economy in the Mekong Delta requires a phased approach synchronizing infrastructure development with institutional reform. Guided by Decree 29/2026/ND-CP and underpinned by the scale economies unlocked by Resolution 202/2025/QH15, the roadmap addresses both the technical bottleneck of data fragmentation and the economic barrier of prohibitive MRV transaction costs.

In Phase I, the immediate priority is the construction of a Mekong Delta Agricultural Carbon Digital Map, integrating SAR cloud-penetrating radar (Sentinel-1), high-resolution optical sensing (Sentinel-2), and IoT sensor networks to achieve dMRV Tier 3 accuracy. A ministerial circular must codify Mekong Delta-specific emission factors and mandate GPS-based plot identification as the only means of satisfying international additionality and permanence requirements. The dMRV data center in Can Tho must be built on an Open API architecture, enabling international verifiers to conduct real-time remote audits and dramatically reducing credit issuance timelines. As Figure 1 demonstrates, consolidating functions to five regional centers during this phase reduces fixed infrastructure costs by up to 40%, making sophisticated monitoring systems economically viable for the first time.

Phase II shifts focus to the Large Carbon Field model, aggregating cooperatives within the new provincial boundaries to activate the HNX compliance market. Transparent benefit-sharing, retaining 70-75% of credit value for farmers, enforced via smart-contract direct payments, is a non-negotiable condition for sustained smallholder participation. Green loans at 2-3% interest, secured against Verified Forward Carbon Credits as high-quality collateral, provide the financial bridge for AWD irrigation infrastructure (approximately VND 15-20 million per hectare). A Regional Carbon Guarantee Fund mitigates price volatility risk. Phase III then integrates the Mekong Delta into global voluntary and compliance markets under Paris Agreement Article 6.2, pursuing the ICVCM Core Carbon Principles label to access premium pricing of USD 15-25/tCO_2e. By integrating the HNX trading platform directly with the dMRV backend, Vietnam can achieve T+0 settlement for carbon transactions, providing farmers with immediate liquidity during harvest season. Table 2 summarizes the three phases and their measurable targets.

Table 2. Three-Phase Commercialization Roadmap for Mekong Delta Rice Carbon Credits

Phase	Key Objectives	Expected Outcomes
Phase I (2026-2028)	Construct Mekong Delta Agricultural Carbon Digital Map (SAR/Sentinel-1 + Sentinel-2 + IoT network); issue ministerial circular codifying Mekong Delta-specific emission factors and GPS-based plot identification; pilot 3-5 cooperatives (≥500 ha each); deploy centralized dMRV data center in Can Tho with Open API architecture for real-time remote audit by Verra / Gold Standard	dMRV Tier 3 accuracy (±10-15%); 50,000-100,000 verified credits issued; fixed MRV infrastructure costs reduced 30-40% (VND 91 bn → VND 45 bn); additionality and permanence documentation aligned with Verra VCS / Gold Standard; T+0 settlement enabled via HNX-dMRV backend integration
Phase II (2029-2030)	Scale 'Large Carbon Field' model to 100,000-200,000 ha within new provincial boundaries; activate HNX compliance market; enforce 70-75% farmer benefit-sharing formula via smart-contract direct payment; deploy 'Verified Forward Carbon Credits' as collateral for green loans at 2-3% p.a.; establish Regional Carbon Guarantee Fund (price-floor insurance)	500,000-1,000,000 credits/year; VND 150-300 billion gross revenue; >50% participating farmers receive direct carbon income; industrial emitters offset ≤30% of compliance quotas with rice credits; AWD adoption cost barrier addressed via VND 15-20 million/ha concessional finance
Phase III (Post-2030)	Register under Paris Agreement Articles 6.2/6.4; obtain ICVCM Core Carbon Principles (CCP) certification; integrate mangrove blue carbon, livestock methane, and biodiversity co-benefits into a composite Mekong Delta carbon asset	2-3 million credits/year; premium pricing USD 15-25/tCO_2e; aggregate annual revenue VND 2,000-2,500 billion; Mekong Delta established as Southeast Asia's leading agricultural carbon hub

Source: Authors' elaboration based on Decree 29/2026/ND-CP and Resolution 202/2025/QH15.

6. Policy recommendations

Three institutional priorities emerge from the analysis. MRV standardization is the most urgent: a ministerial circular should codify Tier 2/3 protocols with Mekong Delta-specific emission factors, mandate GPS-based plot identification to prevent double-counting, and designate a centralized dMRV data center in Can Tho with Open API access for third-party verifiers. Without this foundation, additionality claims and baseline comparisons cannot withstand international scrutiny.

The second priority is benefit-sharing transparency. The distribution formula, farmers and cooperatives retaining 70-75%, MRV and administration absorbing 10-15%, intermediaries 10-15%, and a community environmental fund 5%, must be encoded in legally

enforceable standard contracts with dispute resolution mechanisms and carbon price risk insurance. Smart-contract-based direct electronic payment mechanisms that bypass multi-layer intermediaries are both technically feasible and operationally essential to sustaining smallholder trust at the scale required by Phase II.

The third institutional priority involves a radical reimagining of agricultural finance through the lens of carbon assets. Currently, the upfront cost of laser land leveling and IoT piezometers, roughly VND 15-20 million per hectare, remains the primary barrier to AWD adoption. To bridge this gap, the government should authorize the use of Verified Forward Carbon Credits as high-quality collateral for green loans: the projected 2030 credits, verified against the dMRV Tier 3 baseline, would allow cooperatives to access concessional credit at 2-3% interest rates, unlocking capital before harvest-season cash flows materialize. A 30-50% investment subsidy for laser leveling equipment, piezometers, and IoT sensors, targeted at Phase I pilot cooperatives, would catalyze adoption at demonstration scale before national rollout. Moreover, the dMRV data center's Open API architecture enables international verifiers to perform real-time remote audits, drastically reducing both the time and cost of credit issuance. By integrating the HNX trading platform directly with the dMRV backend, Vietnam can achieve T+0 settlement for carbon transactions, providing farmers with immediate liquidity after verification. This policy package transforms carbon from a mere compliance metric into a powerful engine for rural capital accumulation and technological modernization, with two to three specialized MRV technicians per district constituting the minimum human capital investment for long-term operational sustainability.

Conclusion

This paper makes three substantive contributions. It develops and applies a standardized rice carbon-emission methodology to a 30-year Mekong Delta panel, documenting a 26.6% CI decline in An Giang and establishing a replicable measurement framework with Tier 2/3 precision. It demonstrates, empirically through the elasticity coefficient of −0.087 and analytically through MRV cost decomposition, that economies of scale are the decisive mechanism linking administrative consolidation to market viability and farmer income: the projected 30-40% reduction in fixed dMRV costs and 28% increase in net farmer carbon income are structural consequences of the cost architecture that Williamson and Heindl's frameworks jointly predict. And it proposes a three-phase roadmap sequenced to address infrastructure, compliance market development, and international integration in the order that institutional logic demands.

What distinguishes this study's contribution, however, is the identification of a structural complementarity that policy discourse has thus far underappreciated: the simultaneous enactment of Decree 29/2026/ND-CP and Resolution 202/2025/QH15 is not a coincidence of timing but a policy conjunction of rare design coherence. The carbon market framework creates the demand architecture, legal recognition of carbon property rights, exchange infrastructure, T+0 settlement, and international linkage pathways. The administrative consolidation reform creates the supply-side precondition, sufficient scale to make MRV economically viable, data systems credible, and benefit-sharing ratios attractive to smallholders. Neither reform alone generates a functional market; together, they constitute the institutional foundation that has eluded previous agricultural carbon initiatives in Southeast Asia. Realizing this potential is not a technical challenge. It is a question of sequencing, governance, and sustained political commitment to the roadmap this analysis maps out.

Study limitations include assumed rather than forecast carbon prices, remote-sensing errors under persistent cloud cover, and the absence of a behavioral model for smallholder adoption of AWD. Future research should address CBAM implications for Vietnamese rice exports, combined carbon-biodiversity credit valuation, and long-term soil carbon sequestration dynamics under alternate management regimes.

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