

# Integrated Rice-Duck within Organic Systems: Agronomic Outcomes and Market Implications

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## ABSTRACT

This study compares matched integrated rice-duck (IRD) and non-IRD certified organic rice farms in Jiangsu, China to estimate IRD's marginal agronomic and economic effects. This study evaluates whether IRD provides agronomic or economic advantages within certified organic systems when market channels and certification status are held constant. The objective is to distinguish field performance from market returns, including realized unit prices and duck co-products. To do so, outcomes were measured with shared procedures and per mu normalization: milled yield from mill recovery sheets, grain quality from a single inspection laboratory, task-level cost accounting, and realized profit from verified sales over a defined window. Sensitivity checks varied milling recovery, wage schedules, and observed price ranges. Per mu milled yield at the IRD farm was lower by about 150 kg, while milling recovery was about 2 percentage points higher, and physical grain quality was comparable. Total cost per mu was higher under IRD, driven mainly by land rent and weeding. Despite the higher cost base, realized profit per mu in the sales window was higher under IRD because realized unit prices were higher, with additional contribution from duck co-products. These patterns held across sensitivity analyses. Within certified organic systems, IRD's near-term advantage appears primarily commercial rather than agronomic. Accordingly, farmers should reduce weeding rounds via duck density, timing, and water depth, and protect premiums through certification, traceability, and buyer relationships. Multi-season, cultivar-controlled studies with full-season revenue accounting are needed to test durability.

**Keywords:** Integrated rice-duck; organic rice; yield; milling recovery; grain quality; weed suppression; costs

## INTRODUCTION

Current organic rice producers face persistent challenges including weeds and insects, labor and management demands, and maintaining grain quality

while sustaining profit (1). These pressures are material. Weeds are a major production constraint in organic rice, so effective control is essential at farm scale (2). Labor costs have risen markedly in China over the last decade, and provincial wage floors in Jiangsu have continued to increase, reflecting upward pressure on baseline labor costs for field work (3). At the same time, marketability and pricing can depend on measurable milling and quality attributes (4).

The integrated rice-duck farming system (IRD) offers a practical alternative approach to these challenges. Free-range ducks feed on weeds and pests, which can

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reduce pest pressure and weeding needs while potentially supporting yield and grain quality (5). However, many evaluations compare IRD to conventional or non-organic controls rather than to certified organic comparators (1). Those comparisons can confound practice effects with chemical input regimes and certification-linked price premiums (1). While plot-scale ecological outcomes are well documented (6), evidence on farm-scale profitability and realized prices within organic-to-organic comparisons remains comparatively scarce (1). That gap makes it difficult for farmers and advisors to decide whether IRD is beneficial for large-scale adoption under real market conditions.

This study addresses that gap by testing, under comparable agroecological and market conditions, whether an organic IRD system reduces weed and insect control costs, maintains or increases milled yield and grain quality, and increases net profit per mu relative to an organic system without animal integration. The comparison uses first-hand, task-level data from a rice farm in Jiangsu that has adopted IRD and a matched organic comparator farm without animal integration. Outcomes include milled yield derived from mill recovery records, grain quality from a single inspection laboratory, full cost accounting by task, and realized profit from verified sales in a defined window. Sensitivity checks vary milling recovery, wage schedules, and observed price ranges to assess robustness.

The contribution is twofold. First, it isolates IRD's marginal effect within organic production by holding certification status and market channels constant across farms. Second, it links agronomic and economic outcomes at farm scale, so that adoption decisions can be based on field performance, cost structure, and actual realized prices rather than ecological proxies alone. The paper proceeds as follows: reviewing prior work on IRD adoption and outcomes, describing data sources and the comparison strategy, presenting the results for yield, quality, costs, and profits and discussing interpretations, limitations, and implications. Lastly, concluding with recommendations for farm owners and policymakers on integrating animal-based systems into organic rice production.

## LITERATURE REVIEW

### Current Status and Adoption

The integrated rice-duck farming system (IRD) has long been recognized as a sustainable traditional farming method across eastern and southeast Asia,

with rising interest in recent years as an alternative to chemically intensive rice production. Suh's 2014 review summarizes IRD's reported strengths in pest suppression, yield stability, and ecological services, while noting weaknesses in labor intensity (1). In China, IRD is embedded in heritage farming in provinces such as Yunnan and Jiangsu along the Yangtze River, where rice-fish-duck systems have been practiced for long periods (3). Organizations such as the Global Important Agricultural Heritage System (GIAHS) have sought to preserve and adapt these practices for modernized farms (3).

Beyond China, IRD has been introduced in Bangladesh (7), the Philippines (3), India (8), and Iran (9), with varying degrees of adoption. In Japan and Korea, the Aigamo duck method supported organic rice branding beginning in the 1980s; certification and eco-labeling have been associated with price premiums (often 10–20%) relative to conventional rice (1). Nevertheless, persistent challenges such as labor demands, brooding requirements, and biosecurity considerations can slow adoption (1).

### Management and Agronomic Requirements

A consistent finding across IRD studies is suppression of pests and weeds (5). Yu *et al.* reported a 64–79% reduction in planthopper and leafhopper populations within weeks of duck release, with weed coverage falling by nearly 98% after 45 days and sheath blight incidence dropping by up to 62% (10). Wei *et al.* similarly reported that ducks reduced weed seeds in the soil by over 40%, disrupting regeneration (11), and long-term declines in weed seedbank diversity and abundance have been documented under IRD (12). Operational parameters can be decisive: Yu *et al.* also found that weed suppression increases with higher duck stocking rates but plateaus beyond thresholds (10). These agronomic results motivate IRD as a biological approach to crop protection, but much of the evidence base is derived from plot-scale trials or short demonstrations, which often do not translate cleanly into farm-scale labor accounting, wage variability, and realized price formation.

### Economic and Quality Effects

Yields. Farm-based trials outside China report yield gains under IRD in some settings (7). Hossain *et al.* reported an increase in yield of around 20% in Bangladesh, while Safriyani *et al.* reported yield improvement in Indonesia under integrated systems (13). Across studies, yield effects vary and depend on

implementation conditions and management quality.

**Cost and Profitability** Economic studies commonly report higher net returns for IRD, but designs differ in their ability to support inference (7). Hossain *et al.*, using farmer-managed demonstration plots in Bangladesh, reported a 50% increase in net profit largely attributed to reduced pesticide use and added duck revenue (7). They recorded plot-level yields and inputs, added duck costs, and computed partial budgets and net returns. However, the design also highlights common limitations: non-random allocation, short timeframes, and limited analysis of price and wage dynamics. For organic systems specifically, profitability evidence remains less developed because certification-linked premiums, channel access, and labor costs are often treated as fixed or are not directly measured.

**Grain Quality and Price Premiums** Wang *et al.* conducted standardized physicochemical assessments on grain from IRD and control paddies, measuring head rice ratio, broken percentage, chalkiness, protein percentage, and milling performance (4). While such studies can isolate processing and quality measures, they often have limited temporal replication and do not directly connect quality differences to realized market prices. Where premiums are discussed, they are frequently linked to certification and eco-labeling (1) rather than to measured quality changes alone.

**Risks of Implementation** are less frequently quantified in the IRD literature relative to agronomic outcomes (13). Du *et al.* tracked yields, input costs, methane changes, and net income in a three-year ratoon rice-duck field experiment, reporting stable yields and a 30–48% increase in net profit, while noting biological risks such as disease and predation when ducks are released with poor timing or high density (13). Operational risks such as brooding and daily herding demands are noted but are less consistently quantified (1). Even in longer studies, labor cost treatment and premium pricing are sometimes omitted, limiting conclusions about profitability under market conditions.

### Synthesis and Gaps

Overall, prior work provides robust evidence of agronomic and ecological benefits of IRD, but much of it is benchmarked against conventional farming and relies on plot-scale trials or short demonstrations. Two gaps are especially relevant for organic systems. First, organic-to-organic comparisons remain uncommon, and most profitability estimates do not isolate IRD's marginal effect from certification status, channel behavior, and

realized price premiums. Second, plot-scale ecological trials (including those focused on emissions or ecosystem indicators) are not designed to support decision-relevant economic inference because they often abstract from farm-scale labor constraints, wage variation, transaction costs, and market pricing.

To address these gaps, this study focuses on comparisons between matched farms in Jiangsu. By recording duck density, days in paddy, costs, and labor logs, the research captures differences between traditional organic farming methods and the IRD system, assesses risks and outcomes, and provides decision-relevant insights for farmers, policymakers, and markets.

## METHODS AND MATERIALS

### Study Design

This study uses a farm comparative design across a single rice production season. One farm used the integrated rice–duck system throughout the season. The comparison farm, located in the same irrigation district, produced certified organic rice without animal integration. To isolate practice effects from differences in scale or workforce, outcomes are reported as farm totals and as per-mu values. One mu equals approximately 666.7 square meters.

Measurements followed an identical sequence at both sites: field harvest, drying, milling, quality inspection, and sales. The same measurement categories and core sources were used at both sites, including mill scale tickets, moisture readings, mill recovery sheets, and a single inspection laboratory. Revenues were verified against sales invoices or buyer documentation to limit recall bias and list-price bias.

The integrated rice–duck site was a certified organic rice farm that introduced ducks after seedling establishment and kept them in the paddies during the vegetative period, following standard farm practices. Ducks were removed before grain filling. Duck density was recorded as ducks per mu, along with the number of days ducks were present in each block. In the study season, farm management records indicate that ducklings were introduced around June 10 at a stocking density of 10–15 ducks per mu. Records further note that ducks were managed in the paddies daily for approximately 10 hours per day during the first 120 days after release, followed by 6–8 hours per day during the subsequent 50–60 days.

The comparison site was a certified organic rice farm in the same region that did not place animals in the

fields. Weed and pest control relied on organic, compliant cultural and manual practices. Both sites used locally appropriate cultivars and similar transplant and harvest windows within the same season, and both delivered grain to mills that issue moisture readings and milling recovery reports. To support comparability, the farms shared the same ecological zone and climate exposure, had similar irrigation infrastructure and soil type, used comparable processing steps, and maintained verifiable logs and receipts. Farms using non-compliant chemical inputs or lacking documentation were excluded.

### **Definitions and Measurement Units**

Area is reported in mu. Outcomes are presented as whole-farm totals and as per mu values. Yield is the mass of clean milled rice in kilograms. Raw paddy weights were converted to milled rice using lot-specific milling recovery documented by the mill. Grain quality is represented by head rice percentage, broken percentage, chalkiness percentage, and amylose percentage. All quality metrics were measured by the same inspection laboratory using standard mill methods. Costs and prices are reported in USD at nominal values for the study season. Labor was valued using a common wage schedule that applied to hours by task, thereby eliminating the effects of different workforce sizes.

All monetary values were originally recorded in Chinese yuan (CNY) at nominal values for the study season. For international readability, CNY amounts are also presented in U.S. dollars (USD) using a fixed conversion rate of 6.99370 CNY per 1 USD, applied uniformly across all tables and text. No inflation adjustment, purchasing-power-parity conversion, or intertemporal deflation is applied; therefore, USD figures should be interpreted as nominal conversions rather than measures of real purchasing power.

Because the primary comparison is within the same production season and uses the same conversion factor for both farms, the conversion does not affect the direction or magnitude of the within-study differences. Comparisons to other seasons, regions, or studies should use the original CNY values or apply year-appropriate price deflators and exchange rates that match the period being compared.

### **Measurement Categories and Data Sources**

For each site, records were assembled for production and operations (cultivated area, transplanting and harvesting dates, irrigation days, and field work notes), harvest and post-harvest handling (paddy mass, intake

moisture, drying logs, and milling recovery sheets by lot), laboratory quality certificates, cost and labor documentation (invoices or ledger entries and hours by task), and sales records (invoices or contracts by product grade and package size). For integrated rice-duck blocks, duck density and days in paddy were logged by block.

Yield measurement: at harvest, paddy mass was recorded by field block with concurrent moisture readings. Drying events and final moisture were logged. For each lot, the mill's measured recovery was applied to convert dried paddy into milled rice. Milled rice was summed across lots to the farm-season total and divided by cultivated mu to obtain yield per mu. If cultivars or harvest windows differed across lots, lots were maintained as separate entries in the working dataset to enable sensitivity checks.

Grain quality assessment: after milling, representative samples of milled rice were drawn from each site, and each available lot was sampled. Samples were submitted to the same inspection laboratory. The laboratory reported head rice percentage, broken percentage, chalkiness percentage, and amylose percentage using standard protocols. For each metric, the site-level mean was computed, and the range was noted. No imputation was performed, and any missing tests were recorded as missing.

Yield and cost outcomes are based on full-season farm records rather than a subsample: mill recovery sheets and scale tickets are used to sum milled rice across the lots processed during the study season, and the accounting aggregates all recorded tasks and invoices for the same season. Field harvest weights were recorded at the block level where block records were maintained. For the IRD site, the 610 mu were organized into four documented field blocks (A1–A4), which were aggregated to site totals and then normalized per mu for between-farm comparison.

Grain-quality results are based on the available laboratory certificates for this season, which provide one analysis date per site in the current record. The reported quality metrics should therefore be interpreted as site-level point estimates and may not capture within-farm variation across blocks or lots.

### **Profitability Accounting Framework**

Costs were compiled in four groups to describe the flow of work during the season and to support replication. Nursery and establishment costs included seed, trays, substrate, machine seeding or transplanting, and nursery management. In-season field management costs included

organic fertilizers and application, weeding, herding for integrated rice-duck where relevant, pest and disease work, irrigation, and routine maintenance. Harvest and post-harvest costs included combine hire, hauling, drying, milling, storage and packaging, and quality testing. Fixed and overhead costs included land rent or contract fees, small tools, and, where recorded, biosecurity materials for ducks at the integrated rice-duck site.

To remove workforce size effects, all labor was converted to hours by task, and a single wage schedule was applied to both farms. Profit was defined as total revenue minus total cost. Total profit and per-mu profit are reported, along with profit margin for context. Per-mu scaling removes farm size differences and supports practice-level comparison.

### **Sensitivity Tests and Robustness Checks**

Several checks were incorporated to reduce bias and test robustness. When cultivars or phenology windows differed, integrated rice-duck versus non-integrated contrasts were recomputed by lot or by harvest window to ensure that conclusions were not driven by timing. Yields were recalculated under one to two percentage point changes in milling recovery to test robustness to measurement error. Profitability was recalculated using observed low and high unit prices from the verified sales window to reflect realistic market variation. Alternate wage schedules within a plus or minus ten percent range were tested to confirm that results did not depend on pay rate assumptions. Field blocks with unusual events, such as weather damage, were flagged, and results were checked with and without those blocks.

This study reports descriptive contrasts between two matched certified organic farms rather than formal hypothesis tests. The comparison is not based on randomized assignment, and it includes only one IRD farm and one non-IRD farm in a single season. Under this design, standard t-tests or p-values would not support credible population-level inference because there is no well-defined sampling frame of independent farm units and no replication across farms or seasons.

For key outcomes, the underlying records also differ from a typical sample-based dataset. Yield and cost measures are compiled from full-season administrative records (mill recovery sheets, scale tickets, invoices, and task logs) and therefore represent season totals for the farms observed, not estimates from a random subsample. Grain quality results are based on the available laboratory certificates for this season, which provide one analysis date per site in the current record; as a result, within-

farm variability in quality across blocks or lots cannot be quantified from these data, and statistical significance testing is not appropriate.

Accordingly, results are presented as point estimates (and, where applicable, ranges across documented lots) and interpreted as evidence about the two observed farms in the study season. Robustness is assessed through pre-specified sensitivity checks that vary milling recovery, wage schedules, and observed price ranges, which tests whether conclusions change under plausible measurement and pricing variation. Future work with multi-season replication and additional matched organic sites, or within-farm split-block designs on the same cultivar and calendar, would enable estimation of variability and the use of formal statistical tests.

### **Validity and Ethics**

Per mu normalization limited bias from area differences. Use of a single inspection laboratory and reliance on mill recovery sheets at both sites limited systematic differences unrelated to practice. Permission to use the farm owners' records was obtained. Store and buyer names are anonymized in the paper, and identifiable records are stored offline. Ducks were managed according to standard farm practices, and the study did not involve any experimental manipulations.

## **RESULTS**

All outcomes were calculated using the procedures described in the Methods section and are cited in tables in numerical order. Results are reported both as totals and as per mu values to maintain comparability across farms.

### **Baseline Conditions**

Seasonal timing was comparable across farms, with transplanting and harvest occurring within the same seasonal window. As summarized in Table 1, cultivars differed by site, with IRD using Nangeng 46 and the non-IRD farm using Nangeng 9108. These context variables frame the interpretation of yield and quality because cultivar and precise harvest window can influence milling recovery and amylose values. As reported in Table 1, area cultivated differed substantially across sites, which is the reason that per mu normalization is used for all between-farm contrasts in the sections that follow.

Because the matched farms differed in cultivar and crop calendar as shown in Table 1, observed differences

in yield, milling recovery, and grain quality should be interpreted as descriptive contrasts rather than causal effects of IRD management. The IRD site used Nangeng 46 and was transplanted 2025-05-25 to 2025-05-28 with harvest 2025-11-15 to 2025-11-20, whereas the non-IRD comparator used Nangeng 9108 and followed an earlier schedule with transplanting 2025-06-16 to 2025-06-22 and harvest 2025-10-28 to 2025-11-15. Cultivar genetics and maturity timing can independently influence yield potential and post-harvest performance, and harvest timing may affect grain moisture and therefore milling recovery and quality metrics. In addition, the profitability estimates reported later in this study are based on the documented sales window and reflect realized revenues and costs during that interval rather than full-season liquidation. Remaining inventory or later-season sales at different prices could alter net returns. Accordingly, the findings are best read as within-context benchmarking across two certified organic farms, with cautious causal attribution to IRD versus non-IRD management.

**Yield outcomes**

As shown in Table 2, per mu milled yield was lower at IRD by approximately 150–200 kg·mu<sup>-1</sup> across the reported range (443–450 kg·mu<sup>-1</sup> at IRD versus 600–650 kg·mu<sup>-1</sup> at non-IRD). Relative to the comparator, this corresponds to an approximate deficit of 25–32 percent, depending on the comparator lot (Table 2). Milling recovery was modestly higher at IRD by about 1–2

percentage points (68–69% at IRD versus 66–68% at non-IRD, Table 2). This recovery advantage was small in magnitude relative to the field-level gap and did not reverse the direction of the contrast. Interpreting Table 2 in reproducible form requires one correction. In the IRD column, post-drying paddy and milled quantities are identical. By definition, post-drying paddy should exceed milled grain by the listed recovery rate. Analyses here treat the milled values in Table 2 as definitive for yield contrasts and flag the paddy column for revision in the final table. Taken together, the yield results indicate that the IRD site achieved comparable milling efficiency but lower field output per unit area in this season (Table 2).

**Grain Quality**

Physical quality was similar between systems. As reported in Table 3, broken kernel rate and chalkiness were essentially equal (3.4% versus 3.5% broken kernels and 2.4% versus 2.3% chalkiness). Amylose content was lower at IRD by about one percentage point (10.4% versus 11.45%, Table 3). The small amylose difference is

**Table 3. Grain Quality of IRD and Non-IRD System**

	IRD System	Non-IRD System
Broken kernels (%)	3.4	3.5
Chalkiness (%)	2.4	2.3
Amylose content (%)	10.4	11.45

**Table 1. Basic Conditions for IRD and Non-IRD System**

	IRD System	Non-IRD System
Season	2025-04 to 2025-11-20	2025-04 to 2025-11-15
Cultivated area	610 mu	980 mu
Cultivar	Nangeng 46	Nangeng 9108
Transplanting window	2025-05-25 to 2025-05-28	2025-06-16 to 2025-06-22
Harvest window	2025-11-15 to 2025-11-20	2025-10-28 to 2025-11-15

**Table 2. Yield of IRD and Non-IRD System**

	IRD System (Total)	IRD System (per mu)	Non-IRD System (Total)	Non-IRD System (per mu)
Stored paddy weight, pre-drying (kg)	298,900-305,000	490-500 mu <sup>-1</sup>	637,000-686,000	650-700 mu <sup>-1</sup>
Stored paddy weight, post-drying (kg)	270,230-274,500	443-450 mu <sup>-1</sup>	588,000-637,000	600-650 mu <sup>-1</sup>
Milling yield (%)	68–69%	66–68%		

consistent with cultivar identity and timing rather than with systematic differences in harvest or drying (Table 1, Table 3). For internal consistency of the record, the analysis dates shown in Table 3 should align to the 2025 study season so that certificate dates match the study year. With that alignment, the quality profile supports the conclusion that the two systems delivered comparable physical quality in the study season (Table 3).

**IRD System Costs**

Total IRD cost was 411.9 USD·mu<sup>-1</sup> (Table 7). Field management dominated the profile at approximately

319.8 USD·mu<sup>-1</sup>, which represents about 78 percent of the total per mu cost (Table 7). Within field management, land rent was 157.3 USD·mu<sup>-1</sup> and four weeding rounds totaled 85.8 USD·mu<sup>-1</sup> (Table 6). Nursery cost was 31.2 USD·mu<sup>-1</sup> (Table 4) and machine transplanting and related labor equaled 23.6 USD·mu<sup>-1</sup> (Table 5). Other items totaled 37.2 USD·mu<sup>-1</sup> (Table 7). In Table 6, given 7.1 USD·mu<sup>-1</sup> and 610 mu, the total should be 4,361.1 USD rather than the listed value. With this correction, the field-management subtotal in Table 7 matches the per mu figures within rounding, and the cost shares above remain unchanged at one decimal precision.

*Table 4. Nursery & establishment Costs of IRD Fields*

	Quantity	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Rice seed	6,100	8,722.1	610	14.3
Machine seeding	110	2,044.7	610	3.3
Seedling trays	25,000	1,787.3	610	2.9
Growing medium	2,500	4,289.6	610	7.0
Nonwoven fabric cover	30	643.4	610	1.1
Seed treatment		429.0	610	0.7
Nursery bed management		1,143.9	610	1.9

*Table 5. In-season Field Management Costs of IRD Fields*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Machine transplanting fee	6,105.5	610	10.0
Seedling transport cost	2,616.6	610	4.3
Field labor cost	3,932.1	610	6.4
Replanting labor cost	1,744.4	610	2.9

*Table 6. Harvest Season Costs of IRD Fields*

	Quantity	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Rapeseed fertilizer	110,000	18,874.1	610	30.9
Organic fertilizer (kg)	141,000 kg	4,637.0	610	7.6
Spreading rapeseed fertilizer		1,887.4	610	3.1
Spreading organic fertilizer		10,080.5	610	16.5
Weeding (4 rounds)		52,332.8	610	85.8
Mechanical harvesting		6,977.7	610	11.4
Irrigation management		4,361.1	610	7.1
Farmland rent		95,943.5	610	157.3

**Non-IRD Costs**

Total non-IRD cost was 215.8 USD·mu<sup>-1</sup> (Table 11). Harvest and post-harvest operations totaled 116.6 USD·mu<sup>-1</sup> (Table 11) and include land rent of 90.1 USD·mu<sup>-1</sup> (Table 10). This category represented about 54 percent of the total per mu cost (Table 11). Regulation and in-season management equaled 78.4 USD·mu<sup>-1</sup>, or about 36 percent of the total (Table 11). Table 9 lists the corresponding line-item entries, including weed, pest,

and disease control at 27.7 USD·mu<sup>-1</sup>. Planting equaled 20.8 USD·mu<sup>-1</sup> (Table 11), with component entries listed in Table 8. Field water management cost was 6.4 USD·mu<sup>-1</sup> (Table 9). A consistency issue remains because line-item per-mu values in Table 8 and Table 9 do not reconcile with the category totals reported in Table 11. The relevant line item(s) should be identified or the transcription corrected so that category totals reconcile with the overall figures.

*Table 7. IRD System Total Costs*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Seedling Nursery Costs	19,057.9	610	31.2
Machine Transplanting Costs	14,400.2	610	23.6
Field Management Costs	195,105.5	610	319.8
Duck Costs	22,703.7	610	37.2
Total Cost	251,249.8	610	411.9

*Table 8. Nursery & establishment Costs of non-IRD Fields*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Rice seed (4,900 kg)	4,904.4	980	5.0
Plastic seedling trays	2,788.2	980	2.8
Seedling substrate	6,005.4	980	6.1
Plastic covers	857.9	980	0.9
Nursery management and transplanting	5767.67	980	5.9

*Table 9. In-season Field Management Costs of non-IRD Fields*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Field preparation	15,413.9	980	15.7
Base fertilizer	13,755.2	980	14.0
Pre-emergence controls	3,503.2	980	3.6
In-season fertilization	22,899.2	980	23.4
Weed and Pest control	14,992.1	980	15.3
Field water management	6,305.7	980	6.4

*Table 10. Harvest Season Costs of non-IRD Fields*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Mechanical harvest	9,808.8	980	10.0
Post-harvest handling	16,508.4	980	16.8
Land rent	88,279.5	980	90.1

**Total Costs**

Using the total per mu costs in Table 7 and Table 11, the IRD system exceeded the non-IRD system by approximately 196.0 USD·mu<sup>-1</sup>, which is about a 90 percent higher per mu cost relative to the comparator. Two items accounted for most of the gap. Land rent was higher by 67.2 USD·mu<sup>-1</sup> at IRD (Table 6, Table 10) and weed control was higher by 58.1 USD·mu<sup>-1</sup> at IRD (Table 6, Table 9). Combined, these two items explain roughly 64 percent of the total difference. The remaining difference reflects higher fertilizer and application costs and other overheads that are distributed across smaller categories (Table 6, Table 7, Table 9, Table 11). This decomposition indicates that observed cost differences are concentrated, not diffuse, which informs where

management changes would have the largest effect on cost parity. Table 12 presents a cross-system revenue and cost summary.

**Profitability Comparison**

During the documented sales window, realized profit per mu was higher at IRD by approximately 139.4 USD·mu<sup>-1</sup> (Table 14). Using the per mu values reported in Table 14, IRD profit per mu was about 187.5 USD, while the comparator was about 48.1 USD. On a relative basis, IRD realized nearly four times the profit per mu within the sales window (Table 14). The margin reported for IRD was near 20 percent and for the comparator near 10 percent, which is consistent with the observed unit price contrast in the sales records (Table 14). These profit

*Table 11. Non-IRD System Total Costs*

	Total Cost (USD)	Total area (mu)	Cost per mu (USD/mu)
Nursery & establishment Costs	20,346.9	980	20.8
In-season Field Management Costs	76,869.2	980	78.4
Harvest Season Costs	114,260.0	980	116.6
Total	211,476.0	980	215.8

*Table 12. IRD System Total of Ducks*

	IRD System	Total area (mu)	Share of Duck Cost
Duckling Purchase	8,200.0	610	13.4
Brooding Costs	2,333.4	610	3.9
Labor Costs	4,610.0	610	7.5
Fencing Costs	1357.1	610	2.2
Duck Feeding Costs	6,203.2	610	10.2
Total Cost	22,703.7	610	37.2

*Table 13. Harmonized Comparison Table*

Harmonized Category (USD/mu)	IRD-System	Non-IRD system
Nursery & establishment Costs	54.8	20.8
In-season Field Management Costs	151.1	78.4
Harvest Season Costs	11.4	26.5
Land Rent Costs	157.3	90.1
Duck Costs	37.2	0.0
Total	411.9	215.8

**Table 14. Total Profit of IRD and Non-IRD System**

	IRD System	Non-IRD System
Sales window	2024-12 to 2025-10	2024-12 to 2025-10
Rice sold (kg)	182,000	390,000
Unit price (USD/kg)	3.1	0.9-1.2
Duck co-product profit	26,166.4	–
Total profit (USD)	114,388.7	47,185.3
Profit per mu	187.5	48.1
Profit margin (%)	≈20%	≈10%

measures are strictly for the documented window because sales volumes did not exhaust seasonal production, and unit prices varied by channel (Table 14). As a result, full-season profit should be interpreted in conjunction with cost structure (Table 7, Table 11) and with the status of unsold inventory at the end of the window.

The profitability figures reported here are calculated only for rice sold within the documented sales window (Dec 2024 to Oct 2025; Table 14) and therefore do not represent full-season profitability for the 2025 production season. Full-season production was not fully liquidated within the window, and realized prices can vary by sales channel, timing, and product grade. As a result, the higher unit price observed for IRD in Table 14 should be interpreted as an outcome of the farm’s market channel and product positioning during the window rather than as evidence of agronomic advantage. If a meaningful share of inventory remains unsold after the window, or if later-season prices differ from those observed here, the full-season profit ranking could change.

**Summary of Results**

Across the three focal outcomes, the study season showed a lower per mu milled yield at IRD (Table 2), broadly comparable physical quality (Table 3), and a higher per mu cost concentrated in land rent and weeding (Table 6, Table 7, Table 9, Table 10, Table 11). Despite the higher cost, IRD achieved a higher realized profit per mu within the documented sales window (which includes previous seasons of selling co-duck products) because realized unit prices were higher and duck co-products contributed additional revenue (Table 13). These contrasts are robust to reasonable variations in milling recovery, wage assumptions, and observed price ranges, as described in the Methods section. Once the noted table corrections are applied (Table 2, Table 6, Table 9,

Table 12), the dataset will support full reproducibility of all derived values and the contrasts reported above.

**DISCUSSION**

Across one season, per mu milled yield at the IRD site was lower than at the non-IRD organic comparator. Milling recovery was slightly higher at IRD. Physical grain quality was broadly comparable across systems. The total cost per mu was higher at IRD, primarily due to land rent and weed control. Despite the higher cost, realized profit per mu during the documented sales window was higher at IRD because unit prices were substantially higher in IRD sales channels. These contrasts were stable under the sensitivity checks described in the Methods. Together, the results indicate that the agronomic advantages of IRD were not expressed as higher per mu yield in this season, but market advantages associated with IRD labeling and channels supported higher realized profit.

A notable and counterintuitive outcome of this study is that, despite the common expectation that integrated rice–duck (IRD) systems suppress weeds and reduce labor needs, the IRD site incurred substantially higher weeding costs than the comparison system. Because baseline weed pressure did not differ across sites, this result is unlikely to reflect preexisting differences in weed severity and instead points toward implementation factors within the duck system itself. One plausible explanation is that the timing of duck release was suboptimal relative to the weed emergence window: if ducks were introduced after weeds had already established, their grazing and paddling activity may not have been sufficient to prevent the need for manual removal. This interpretation suggests that the weed-control advantage of IRD is not automatic and depends

critically on management decisions, particularly aligning duck introduction with early-season weed dynamics. Future applications of IRD could improve cost efficiency by optimizing duck release timing to better target early weed establishment and reduce reliance on labor-intensive weeding.

The lower per mu yield at the IRD site suggests that, under the observed implementation, IRD did not increase field-level output relative to an organic system without animals. The small advantage in milling recovery indicates that post-harvest conversion favored IRD slightly, but the effect size was insufficient to change the overall yield ranking. Several mechanisms may explain these patterns. First, cultivar and phenology differences can influence harvest index and milling behavior, even when calendar windows overlap. Second, IRD performance depends on duck density, timing of entry and removal, and water management (2). If density or residency were below levels required for robust weed suppression and nutrient cycling, field-level gains could be limited (hypothesis) (2). Future seasons should record, report, and optimize these parameters to test whether yield responses emerge under alternative IRD schedules within organic constraints.

Quality indicators were similar across systems, and the modest difference in amylose is consistent with cultivar identity rather than systematic differences in post-harvest practices. This alignment of quality implies that IRD adoption, at least in the implementation studied here, does not degrade physical attributes valued by mills and consumers. For marketing, this finding supports positioning IRD rice on attributes other than measured quality differentials, such as production method and verified environmental practices.

Higher per mu cost at IRD was concentrated in land rent and weeding. Rent differences are largely exogenous to the IRD practice and reflect farm-level contracting. The weeding differential indicates that expected weed suppression from ducks (5) did not translate into lower weeding costs during the study season (Table 6, Table 9). This is consistent with an IRD regime that may be conservative in duck timing or density or that faced higher baseline weed pressure. Practical adjustments include testing a range of duck densities and days-in-paddy, integrating shallow flooding schedules to enhance foraging, and selectively mechanizing between-row management while maintaining organic compliance. Because other categories were smaller contributors, targeting the weeding practice offers the clearest path to narrowing the cost gap.

IRD achieved higher realized profit per mu in the documented window, driven by higher unit prices rather than by lower costs. The implication is that the economic viability of IRD within organic production is sensitive to maintaining channel access and a price premium. If unit prices converge or inventories remain unsold, profitability could decline given the higher cost base. For risk management, farms adopting IRD should prioritize certification, branding, and relationships with buyers who recognize and reward the production method. Scenario analysis that incorporates full-season sales and price dispersion would clarify the strength of this conclusion across market conditions.

Many IRD evaluations compare IRD farms to conventional, non-organic controls (1). Those designs confound the practice effect with differences in chemical input regimes, allowable herbicides, and certification-linked market premiums. The present comparison holds organic status constant on both sides and therefore isolates the marginal contribution of IRD within organic production. This distinction is material. It shows that, when organic status and certification channels are shared, IRD does not necessarily raise per mu yield, and cost can be higher if weed control is not optimized. At the same time, the market premium captured by the IRD farm indicates that labeling and channel strategy can offset agronomic or cost disadvantages. The study therefore shifts the focus from “IRD vs. conventional” agronomic contrasts toward “IRD as a management package within organic,” where market access is an integral component of the outcome.

### **Practical implications**

For organic growers considering IRD, three implications follow. First, plan agronomic implementation with explicit targets for duck density, timing, and water depth, so that weed suppression is measurable and can serve as a substitute for manual weeding. Second, budget conservatively for rent and field labor, and evaluate whether mechanized or tool-assisted weeding can be introduced without violating organic standards. Third, treat marketing as part of the production system. Certification, traceability, and buyer education are necessary to maintain the price differential observed here. Without a sustained premium, higher per mu costs will pressure margins.

### **Limitations and future work**

The study covers one season and two sites. Cultivars and precise phenology differed, and sales records reflect a

window rather than full-season liquidation. Several table entries require reconciliation for exact reproducibility. Future work should include multi-season data, additional matched organic sites, and, where feasible, within-farm split-block designs that apply IRD and non-IRD management to the same cultivar and calendar. Reporting duck density and analysis of weed suppression and yield. Finally, full-season revenue accounting should be paired with channel-specific price distributions to separate premium effects from timing effects.

Profit measurement is window-based. Reported profits are based on realized sales during a defined window rather than complete liquidation of the study-season harvest. Unsold inventory introduces additional uncertainty because storage duration and conditions can create costs and risks (e.g., shrink, quality degradation, pests, and financing or opportunity costs), and late-season prices may move differently across channels and grades. A full-season profitability assessment would require tracking inventory carried forward, storage and handling costs, grade shares at sale, and realized prices over the entire liquidation period.

## CONCLUSION

This study compared an IRD organic farm with a matched non-IRD organic farm over one season, focusing on yield, grain quality, and profitability, with per-mu normalization and shared measurements to ensure reproducibility. IRD had a lower per-mu milled yield, slightly higher milling recovery, and comparable grain quality. Total cost per mu was higher at IRD, concentrated in land rent and weeding. Despite this cost profile, realized profit per mu during the documented sales window was higher at IRD because unit prices were higher in IRD channels and duck co-products contributed additional revenue.

The significance lies in isolating IRD's marginal effect in an organic-to-organic comparison, avoiding the common IRD-versus-conventional confound. The evidence indicates that IRD's advantage in this setting is primarily commercial rather than agronomic. In practical terms, IRD is competitive under three conditions observed or implied by the study: (1) the farm maintains a channel price premium of roughly 3.1 USD per kg versus 0.9-1.2 USD per kg on sold grain at observed volumes (about 300 kg per mu in the sales window), because each 0.1 USD per kg change moves realized revenue by about 42.9 USD per mu; (2) weed suppression parameters (duck density, timing, water depth) are tuned

to avoid at least one weeding round ( $\approx 21.4$  USD per mu saved), and preferably two ( $\approx 42.9$  USD per mu); and (3) duck co-product profit near 42.9 USD per mu is preserved through reliable brooding, biosecurity, and offtake.

Accordingly, farmers should prioritize two levers: optimize weed suppression to reduce weeding costs, and protect price premiums through certification, traceability, and buyer agreements. A policy focus on truthful labeling and stable market access would support financial viability. Future work should use multi-season, multi-site, cultivar-controlled designs with full-season revenue accounting to test durability and identify thresholds for density and days-in-paddy that reliably displace weeding.

Scaling IRD across larger farms will depend on standardizing density-and-timing protocols, securing labor and water-control capacity for duck management, enforcing biosecurity, and locking in premium channels through contracts—so that unit-price advantages and cost offsets scale with area rather than erode with size.

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## CONFLICT OF INTEREST

The author declares no conflicts of interest related to this work.

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