



Research Brief

UNLOCKING LOCAL VARIETY DIVERSITY : DISENTANGLING YIELD VARIABILITY IN AGROECOLOGICAL RICE SYSTEMS

EXECUTIVE SUMMARY

Rice yield variability in Preah Vihear, Cambodia, was studied through on-farm trials testing nine varieties under different ecosystems and management systems. Climate factors like frequency of high temperature ($>33^{\circ}\text{C}$), and humidity were major drivers of yield variability. Local varieties showed broad adaptability, while improved ones performed best in irrigated systems. Five varieties performed better under green manure (GM) management. However, the limited fit of improved varieties to agroecological (GM) systems highlights the need to use local varietal diversity to breed resilient, high-yielding varieties.

In the context of agroecological transition, understanding how commonly cultivated rice varieties (G) respond to different management practices (M) and rice-growing ecosystems (E) is critical for optimizing yields while ensuring stable farmer incomes, thereby supporting a more sustainable agricultural shift. Yet in Preah Vihear, knowledge remains limited on how widely grown Cambodian rice varieties perform under contrasting conditions, particularly when faced with variations in topography, soil characteristics, and agroecological management practices. This gap makes it difficult to guide farmers toward strategies that balance productivity with resilience.

RESEARCH OBJECTIVES

The study aims to:

- Analyze genotype $\times$ ecosystem $\times$ management (G $\times$ E $\times$ M) interactions for nine cultivated Cambodian rice varieties, with the goal of understanding how these factors jointly contribute to variability in rice grain yield.
- Evaluate the adaptability and performance of the studied varieties under agroecological practices, providing insights into which ones are best suited to specific environments and management practices (i.e. agroecological-based rice cropping systems).
- Identify the underlying causes of G $\times$ E $\times$ M interactions influencing rice grain yield, thereby clarifying the environmental and biological drivers that shape grain yield across diverse production systems.

CONTEXT

Rice production in Rovieng District exhibits important yield variability that constrains food security and economic development in this rural area of northern Cambodia. Understanding the multifactorial drivers of this variability is essential for developing targeted interventions to stabilize and improve rice productivity in the region.

The response of rice variety varies across ecosystems (Figure 1) and from year to year. Some varieties thrive in certain environments, while others are disadvantaged, leading to yield variability, among other things. This variability, known as genotype $\times$ environment $\times$ management interaction (G $\times$ E $\times$ M), complicates the identification and recommendation of suitable varieties for farmers.

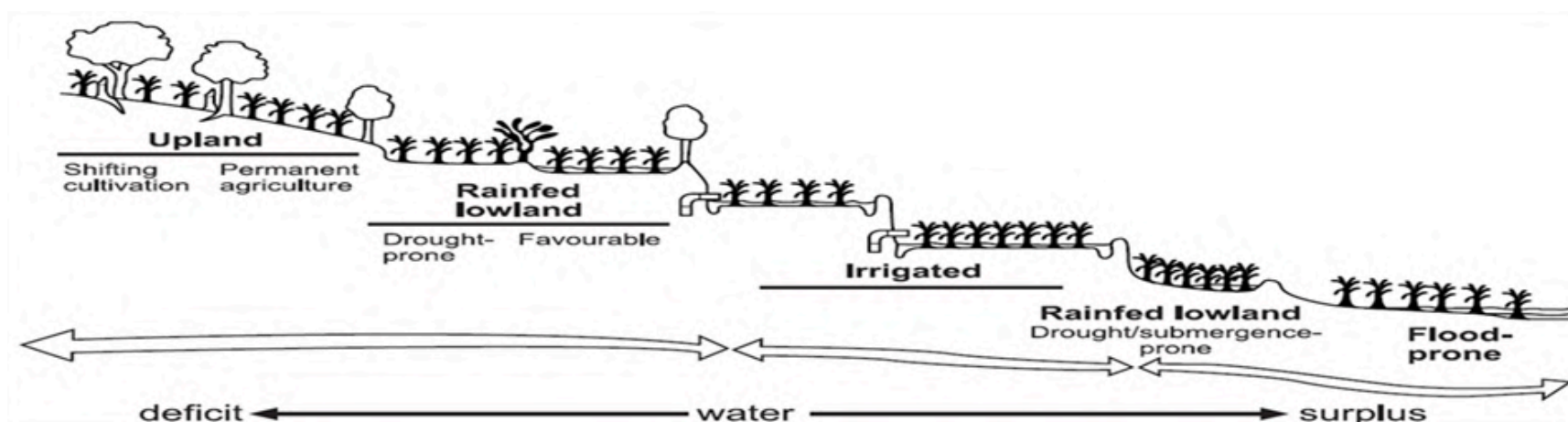
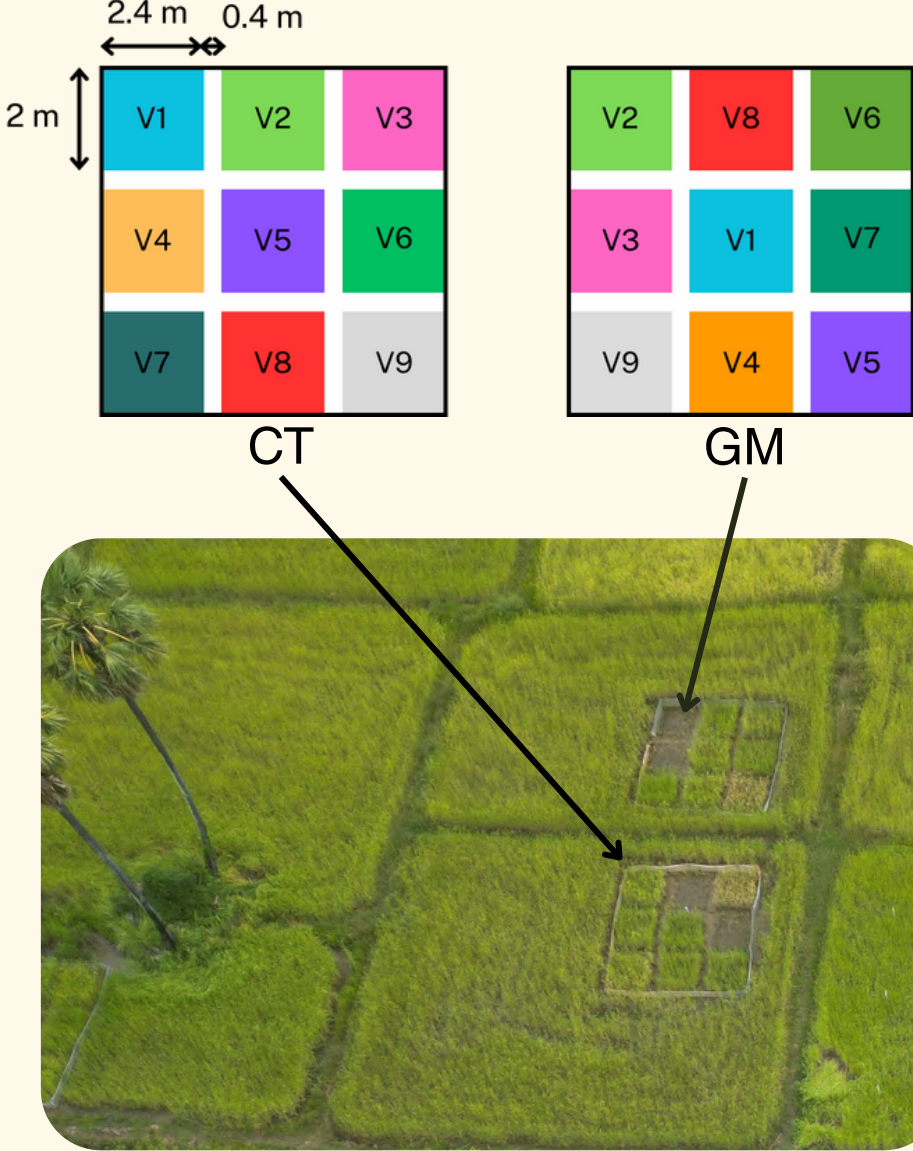


Figure 1: Cultivation of rice on a continuum from flooded to situations where rainfed is the only water supply

Experimental design to study G x E x M interactions

Genotype	Cycle duration	Number of days to maturity	Mean yield across the trials (t.ha-1)	Max yield across the trials (t.ha-1)
Champeï Sar 70	Short	115	1.31	2.92
Kraches	Long	162	2.07	4.81
Neang Om	Long	158	2.18	5.07
Neang Ork	Long	158	1.98	4.42
Neang Sar	Medium	143	1.92	5.11
Phkar Rumdoul	Long	155	1.9	4.93
Prich	Long	154	2.01	4.79
Red Phkar Rumdoul	Long	161	2.02	4.9
Sen Kro Oub 01	Short	118	1.68	3.78



- On-farm trials : co-designed by researchers and farmers
- Over 3 years : 2022 - 2023 - 2024
- 9 varieties
- 3 ecosystems : Upstream, Lowland, Irrigated
- 2 treatments : Conventional Tillage (CT) vs Green Manure (GM)
- 21 replicates (=plot)

METHODOLOGY

Field experiments were carried out from 2022 to 2024 in Rovieng District, Preah Vihear Province, Cambodia, across three rice-growing ecosystems: irrigated, lowland rainfed, and upstream rainfed. Nine rice varieties were evaluated, including seven local varieties obtained from farmers and two improved varieties. Designed as on-farm trials, the experiments were co-developed with farmers to align research goals with local needs.

Two soil management practices were compared. Conventional tillage (CT) reflected local practice, with bare fields in the dry season and tillage before planting. Green manure (GM) introduced cover crops during the dry season (Figure 2), either as long-cycle or short-cycle systems, using six species chosen for their suitability to local conditions and proven agronomic performances.

Data analysis combined individual ANOVAs for each environment and a joint ANOVA to capture genotype × environment interactions. To explain variability in grain yield, complementary data were collected for each variety within treatment plots throughout the three-year trial period. These explanatory variables included climatic indicators, water levels in experimental plots, and biomass production from green manure.

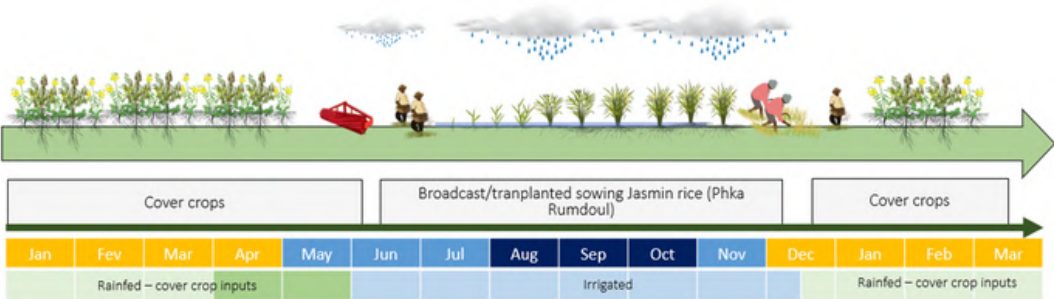


Figure 2: Inclusion of cover crop during the dry season as an agroecological practice

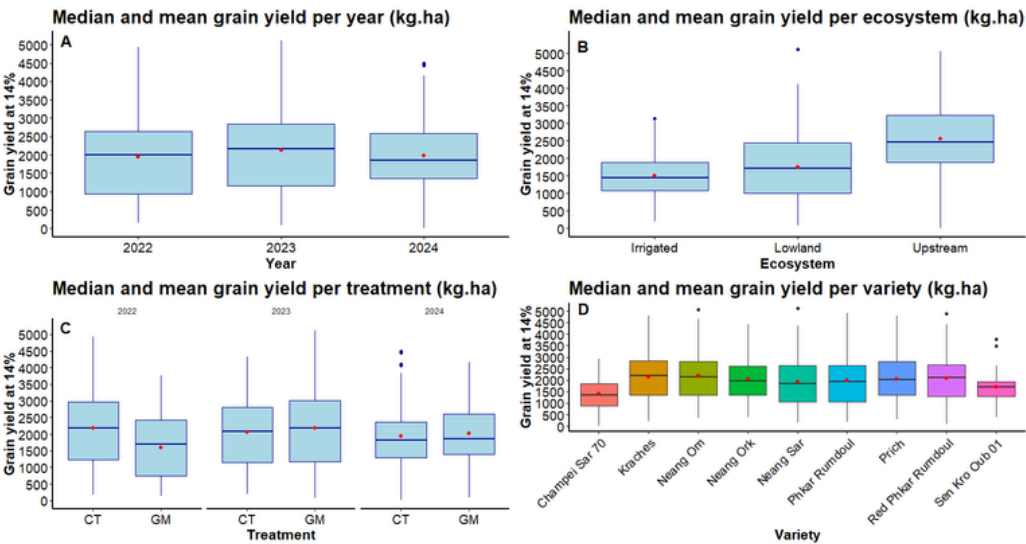


Figure 3: Grain yield at 14% moisture in kg.ha⁻¹ per (A) ecosystem, (B) year, (C) treatment, and (D) genotype

MAIN RESULTS

SETTING THE STAGE

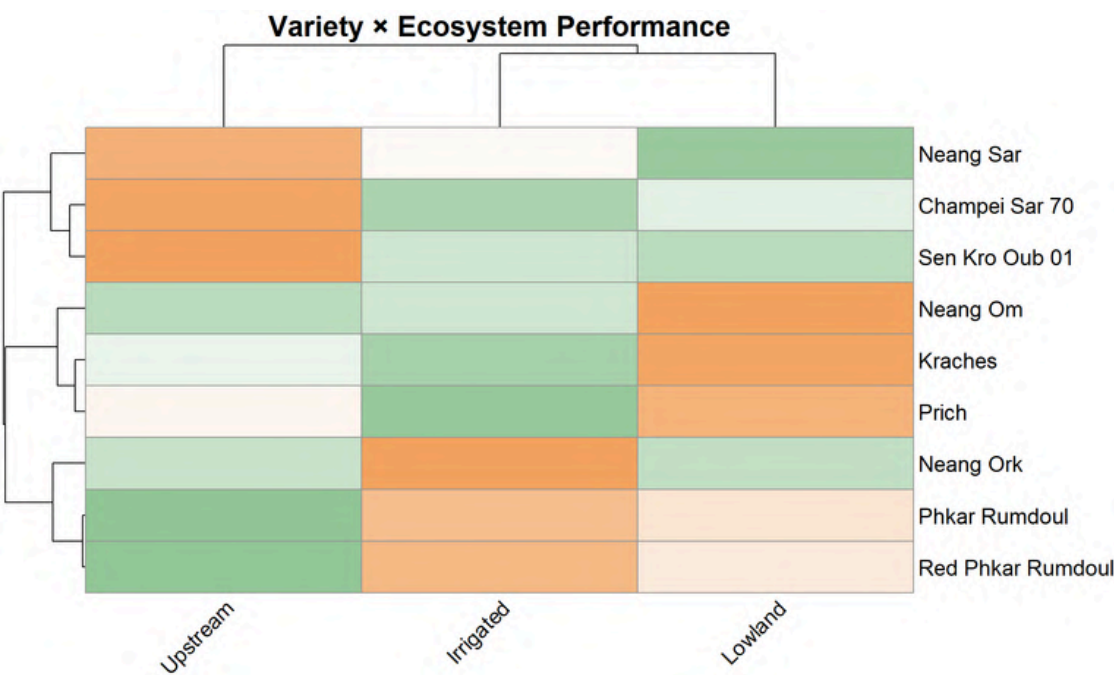
Grain yield remained steady across the three-year study, showing stability despite annual variability (Figure 3). Ecosystem differences were most important: irrigated systems consistently underperformed, averaging just 1.51 t.ha⁻¹. This was mostly due to longer cultivation period. To account for this significant difference, we standardized grain yield (subtracting the mean of the data and then dividing by the standard deviation) for the remaining analysis.

Management practices had little effect. Conventional tillage (CT) and green manure (GM) treatments delivered nearly identical results. However, GM performance progressively improved relative to CT over the experimental period (Figure 3).

Varieties performances revealed clearer contrasts (Figure 3). Yields ranged from 1.3 t.ha⁻¹ for Champei Sar 70 to 2.2 t.ha⁻¹ for Neang Om. Other varieties produced intermediate yields with relatively minor differences, suggesting that strategic variety choice is still important for farmers.

ECOSYTEM ADAPTATION

Varietal performance shows strong specialization. Neang Sar thrives in lowlands but performs poorly upstream, while Phkar Rumdoul and Red Phkar Rumdoul are strongest upstream. In irrigated systems, Prich and Champei Sar 70 perform best. Beyond these specialists, some varieties show broader adaptation: Neang Ork suits both lowland and upstream areas, and Kraches favors irrigated systems with small success upstream. Sen Kro Oub 01 and Champei Sar 70 stand out further for their wider adaptability, performing reliably in both irrigated and lowland systems.



MANAGEMENT ADAPTATION

Neang Sar, Kraches, Neang Ork, Prich, and Red Phkar Rumdoul all perform better under green manure (GM), but show poorer grain yield under conventional practice (CT). In contrast, Neang Om, Phkar Rumdoul, Champei Sar 70, and Sen Kro Oub 01 display the opposite trend, performing relatively better under conventional management while yielding less under agroecological systems.



MAIN DRIVERS: CLIMATE, WATER AVAILABLE AND BIOMASS

- **Neang Om & Neang Ork:** Highly resilient, optimal under elevated precipitation/humidity, with minor yield reduction under extreme heat stress.
 - **Kraches:** High phenotypic stability, sustained high yield across climatic gradients, ideal for stress-prone environments.
 - **Champei Sar 70 & Sen Kro Oub 01:** Low stress tolerance, negative responses to heat, humidity, and solar radiation, and poor adaptability.
 - **Neang Sar:** Variable stress response, positive thermal tolerance but susceptible to heat stress and radiation.
 - **Phkar Rumdoul, Prich, Red Phkar Rumdoul:** Moderate stability, relatively stable across different rainfall conditions, but variable in response to thermal/radiation stress.
- **Neang Om & Neang Ork:** Superior biomass efficiency and water stress resilience; optimal for heterogeneous or resource-abundant systems.
 - **Kraches:** Highly stable yield performance; recommended for risk-minimized strategies.
 - **Champei Sar 70 & Sen Kro Oub 01:** Low stress tolerance; poor biomass/water-use efficiency, unsuitable for variable environments.
 - **Neang Sar:** Show potential but sensitive to biomass accumulation
 - **Phkar Rumdoul, Prich, Red Phkar Rumdoul:** Reliable, low-variability performance; suitable for balanced agroecological conditions.

Variety	Recommendation
Kraches	Stable high-yielding: suitable for variable environments. Best with GM management. Best in Irrigated.
Neang Om	Good general adaptation: suitable for most environments. Recommend CT management. Performs well in Irrigated.
Neang Ork	Stable average yielding: suitable for marginal environments. Use GM if possible. Performs better in Lowland.
Neang Sar	Conditional recommendation: unclear environment matching Best with GM management in Lowland.
Phkar Rumdoul	Conditional recommendation: unclear environment matching Best with CT management in Upstream.
Prich	Conditional recommendation: unclear environment matching Best with GM management in Irrigated.
Red Phkar Rumdoul	Conditional recommendation: unclear environment matching Best with GM management in Upstream.
Champei Sar 70	Performing reliably in both irrigated and lowland systems Best with CT
Sen Kro Oub 01	Performing reliably in both irrigated and lowland systems. Best with CT

MAIN IMPLICATIONS

While improved varieties have driven agricultural progress, their adaptation to diversified agroecological systems remains limited. This gap underscores the urgent need to breed within emerging cropping systems, leveraging local varietal diversity to develop resilient, high-performing varieties tailored to specific environments.

The duration of land cultivation played a crucial role in shaping ecosystem responses, directly influencing absolute yield performance. These site-specific baseline fertility differences masked varietal and management effects, making it essential to standardize yield measurements when comparing varieties across diverse systems. By accounting for inherent site fertility, varietal performance can be assessed more accurately.

Our research reveals that no single variety dominates across all conditions. In agroecological rice systems, site-specific recommendations are both essential and highly challenging. Success depends on distinguishing varieties that can take advantage of the localized soil fertility generated from green manure, from those that deliver stability and resilience across heterogeneous environments.

KEY FINDINGS



High Performing Varieties



Neang Om



Kraches



Kraches



Neang Ork

Most Responsive Varieties (Specific Adaptation)



Sen Kro Oub 01

Best Overall Varieties (High Yield & Broad Adaptation)



Kraches

Environmental Adaptation

- 2 varieties show strong radiation response
- 2 varieties show high ecosystem specificity

Management Adaptation

- 5 varieties were adapted to GM
- 2 varieties show high management responsiveness



Landscape in the dry season without cover crops

STATISTICAL SUMMARY:

Overall dataset:

- Mean yield across all varieties and environments: 2017 kg/ha
- Overall coefficient of variation: 50.7 %

Variety performance range:

- Lowest variety mean: 1399 kg/ha
- Highest variety mean: 2203 kg/ha
- Range between varieties: 804 kg/ha

Ecosystems performance range:

- Upstream mean: 2555 kg/ha
- Lowland mean: 1765 kg/ha
- Irrigated environments: 1512 kg/ha

Management performance range:

- Conventional tillage mean: 2033 kg/ha
- Green manure mean: 2000 kg/ha

Credit:

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