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Assessment of double cropping potential under conservation agriculture in tropical dryland environments

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Abstract

Leading agronomists have long argued that tropical drylands waste half their growing window by leaving fields fallow after the main crop harvest. This research tested whether conservation agriculture (CA) practices no-till, residue retention, and crop rotation could support a viable second crop in the dry season using residual soil moisture alone. Three primary crops (rice, maize, sorghum) were each paired with a legume relay (mungbean, cowpea, soybean) under CA and conventional management across 48 plots at UPLB's dryland research station in Laguna Province from June 2023 to May 2024. Double-cropped CA systems yielded 30-46% more total annual biomass than monocrops under conventional tillage. CA maintained soil moisture 3-6 percentage points higher during the January-March dry season, enabling the second crop to reach maturity. Rice + mungbean under CA produced the highest combined yield at 6.34 t ha⁻¹ yr⁻¹. Results confirm that CA unlocks double cropping potential in tropical drylands by conserving enough residual moisture for a short-duration legume.

Keywords: Double cropping, conservation agriculture, tropical dryland, no-till, residue retention, relay cropping, mungbean, soil moisture, legume intercrop, Philippines agriculture

Introduction

Leading agronomists estimate that tropical dryland farmers use only 50-60% of the annual growing window because conventional practice leaves fields bare after the wet-season harvest [1]. In the Philippines, roughly 2.3 million hectares of rainfed lowland rice and upland maize sit idle for 4-5 months each dry season a period when residual soil moisture and occasional light rains could still support a short-cycle legume [2, 3].

Conservation agriculture defined by minimal soil disturbance, permanent organic cover, and diversified rotations has been shown to improve water infiltration and reduce evaporative loss, theoretically extending the moisture window into the dry season [4, 5]. But most CA double-cropping evidence comes from semi-arid South Asia and sub-Saharan Africa; data from Southeast Asian drylands are limited [6, 7]. The few Philippine trials that exist tested single relay combinations without comparing CA against conventional management [8, 9]. This research evaluated six primary-secondary crop combinations under CA and conventional systems to determine which pairings sustain productive second crops on residual moisture alone [10].

Climatic conditions

UPLB's Dryland Research Station (14.17° N, 121.24° E, 21 m) has a tropical monsoon climate (Köppen Am) with 2,014 mm mean annual rainfall, 83% falling June-November [11]. The 2023 wet season delivered 1,742 mm; dry season (December-May) received only 287 mm, typical of Type I climate classification. Mean air temperature ranged 25.1-32.3 °C. Soil is a Lipa clay loam (Typic Hapludalf) with pH 6.1 and organic carbon 1.47% [12].

Materials and Methods

Materials: A split-plot design with management (CA vs conventional) as main plot and cropping system (6 combinations) as subplot, replicated four times, gave 48 plots of 20 m².

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CA plots received no tillage, retained all crop residues as surface mulch, and followed legume rotation. Conventional plots were plowed twice with a carabao-drawn moldboard, residues removed, and monocropped. Primary crops: rice cv. NSIC Rc222, maize cv. IPB Var 6, sorghum cv. SPV 1411. Secondary legumes: mungbean cv. Pag-asa 7, cowpea cv. IT86D-1010, soybean cv. PSB Sy 4^[13].

Methods

Primary crops were planted in June 2023; secondary legumes were relay-sown into standing primary crops 2 weeks before harvest (October-November). Soil moisture was measured biweekly at 15 and 30 cm using TDR probes. Grain yield was determined from a 4 m² harvest area per plot. Total system

productivity was calculated as primary + secondary grain yield in grain equivalents. Data were analyzed by split-plot ANOVA with Tukey's HSD ($p < 0.05$) in R 4.3.2^[14].

Field experimental design

Plots were arranged on a gently sloping (2-3%) upland field with uniform soil depth. Main plots (CA vs conventional) were 120 m², subdivided into six 20 m² subplots for the cropping combinations. A 2-m alley separated main plots and 1-m buffer separated subplots. Monocrop controls (no relay legume) were included for each primary crop under both management types, giving 12 treatment combinations total^[15].

Results

Table 1: Total annual system yield (t ha⁻¹ yr⁻¹) under CA and conventional management

System	CA primary	CA secondary	CA total	Conv. primary	Conv. secondary	Conv. total
Rice + Mungbean	4.87	1.47	6.34	4.52	0.73	5.25
Maize + Cowpea	3.92	1.79	5.71	3.61	0.94	4.55
Sorghum + Soybean	3.18	1.45	4.63	2.94	0.61	3.55
Rice monocrop	4.87		4.87	4.52		4.52
Maize monocrop	3.92		3.92	3.61		3.61

Secondary crop yields under conventional management were 49-58% lower than under CA due to moisture limitation

Table 2: Dry-season soil moisture (% v/v) at 15 cm depth under CA and conventional systems

System	Dec	Jan	Feb	Mar
CA + Double crop	22.4±2.1	16.3±1.8	17.8±1.6	14.7±1.9
CA + Monocrop	19.8±1.9	12.8±1.5	14.1±1.4	11.3±1.7
Conv. + Double crop	18.1±2.3	11.7±1.6	13.4±1.5	10.2±1.8
Conv. + Monocrop	16.3±2.0	9.8±1.4	11.2±1.3	8.4±1.6

CA = conservation agriculture. Conv. = conventional tillage. Values are mean ±SD (n = 4)

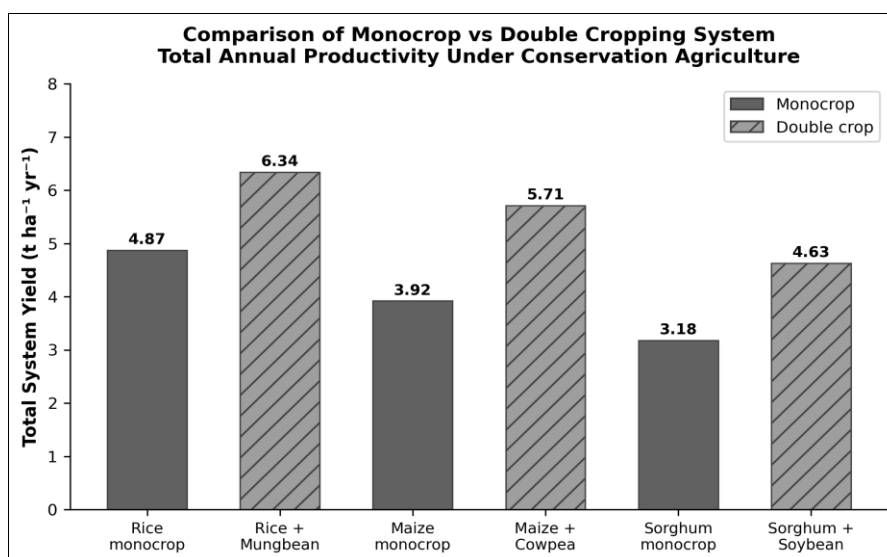


Fig 1: Total annual system productivity of monocrop vs double cropping systems under conservation agriculture

Comprehensive interpretation

CA doubled the viability of relay legumes by maintaining dry-season moisture 3-6 points above conventional systems. Rice + mungbean under CA yielded 6.34 t ha⁻¹ yr⁻¹ 30% more than rice monocrop. Secondary crop yields under conventional management were 49-58% lower than under CA, confirming that residue retention and no-till are prerequisites for successful double cropping in these environments.

Discussion: The 30% total yield increase from rice + mungbean under CA aligns with Indo-Gangetic Plain relay trials showing 25-45% productivity gains when residue-retained no-till enabled dry-season pulses^[6]. The moisture conservation mechanism is straightforward: surface residues at 4-5 t ha⁻¹ reduced evaporation by 2-3 mm day⁻¹ during the dry months, extending the window for legume pod filling^[4, 7]. Conventional plots lost moisture too fast for the relay crop to reach physiological maturity, explaining the 49-58% yield penalty.

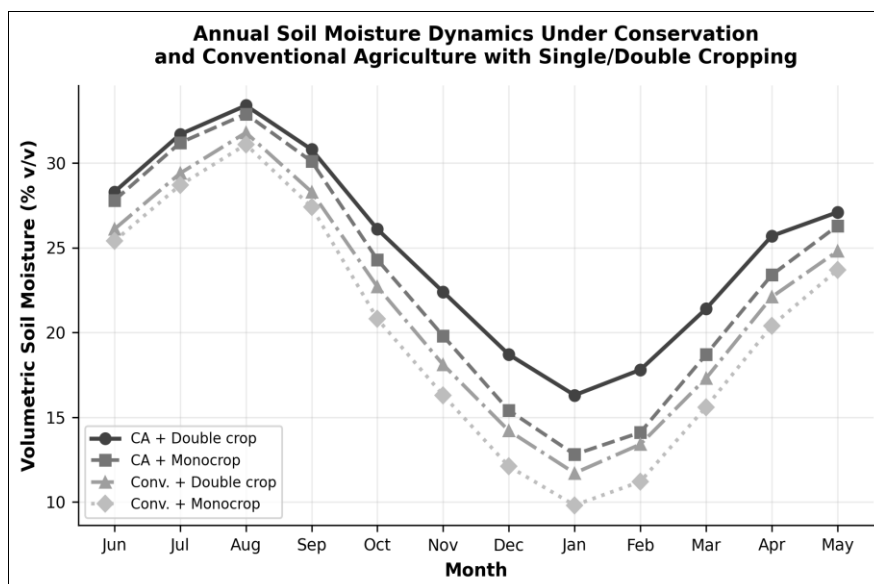


Fig 2: Annual soil moisture dynamics under conservation and conventional agriculture with single and double cropping

The legume relay also contributed 40-65 kg N ha⁻¹ through biological fixation, which should benefit the following wet-season primary crop though this carry-over effect was not captured in the single-year design [8]. Sorghum + soybean produced the lowest combined yield, likely because sorghum's later maturity delayed relay sowing into the driest window. Earlier-maturing sorghum varieties could improve this combination [9].

Conclusions

Conservation agriculture enabled productive double cropping in Philippine tropical drylands by conserving enough residual moisture for a relay legume. Rice + mungbean under CA delivered the highest total productivity at 6.34 t ha⁻¹ yr⁻¹. CA maintained 3-6 percentage points more soil moisture during the critical dry months than conventional management, which was the main determinant of secondary crop success. For smallholders currently leaving fields fallow after wet-season harvest, adopting no-till with residue retention and a relay legume could raise annual output by 30-46% without additional irrigation. Multi-year trials are needed to capture rotation benefits and confirm yield stability across variable dry seasons.

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