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Economic And Agronomic Evaluation Of Rice-MaizeInterceoppingOn Ferasol In Central-Western Côte D'Ivoire

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ABSTRACT: The profitability of crop associations shouldbepromoted in the peasantenvironment. Hence, the a need to show land management for sustainable agriculture. The presentstudywascarried out at the experimental site of the National Agency for Rural Development Support (NARDS) training center in Gagnoa, more precisely at Coffee Cutting Center toevaluate the profitability in terms of land management and the economicprofitability of the rice-maizeintercropping. To do this, an agronomic trial wascarried out on a Ferralsolaccording to Randomized Complete Block Design (RCBD*)*, seven (07) treatments and four (04) replicates (T1: pure rice; T2: pure cassava; T3: pure maize; T4:improvedrice-maizeintercropping; T5:improvedrice-cassavaintercropping; T6:traditionalrice-maizeintercropping and T7:traditionalrice-cassavaintercropping). Agronomic data werecollected on the threecrops and supplemented by soil data. No significanteffect of cultivation practice on ricegrowth and yieldat the threshold of α = 0.05. However, at the maizelevel, thereis a significanteffect of cultivation on maize grain yield (p-value < 0.0001). Maize grain yieldincreasedwithplantingdensity. The rice-maizeintercropping has proven to bea quantifiedadvantage (e.g., LER=1.26 vs 1.00; MAI=59,566 CFA) than a pure cultivation of rice and maize. In addition, the improvedrice-maizeintercroppinghad a gain of 59.566 CFA,while the farmers' practice of this association recorded a loss of 27.115 CFA. That demonstratesagain the importance of modernizingcrop association for achievingfoodsecurity and environmental management.

Keywords: Intercropping, economicprofitability, rice, maize, Côte d'Ivoire

INTRODUCTION

Intercroppingis the cultivation of two or more plant species on the same plot, withtheircropping cycles overlapping, withoutnecessarilybeingplanted or harvested at the same time (Manasa et al., 2020). According to Kéliet *al.* (2005)and Maitra et al. (2021), intercroppingis the simultaneous cultivation of two or more crops on the same plot withdifferentbiologicalcharacteristics and farming techniques.Today, these association systems have greatersustainability in soilfertility management and are more suited to restricting agricultural land. This ishighlyrecommended for the biodiversitymaintained by these agro-ecosystems as a method of resilience in the currentcontext of climate change (Olesen et al., 2011; Maitra et al., 2019; Sarath Kumar & Maitra, 2020).Indeed, according to Young (1989), intercropping affects the microclimate, the distribution of water, the soil'sphysicalcharacteristics, and the interactions among the crops. To providethisecosystem service, itrequires a strongmastery of the practice, whichrequires a precisecharacterization of the cropping system (Konan, 2021).

Recentworkacrossdifferentregions of Côte d'Ivoire has highlighted the importance of intercropping practices in rainfedrice-basedcroppingsystems in rural areas(Bahan et al., 2012). Additionally, Bahan's (2017) workshowedthatuplandrice-maize associations weremostfrequent in the West. Konan's (2021)studiesshowed a 20% increase in production in the uplandrice association system compared to pure ricecroppingsystems. Significantlyfewerstudies have addressed the profitability of crop associations, and evenfewer have examinedeconomicprofitability. This study proposes to examine the profitability of land management and the economicprofitability of rice-basedcroppingsystems, particularly the rice-maize combination, in the Gagnoa area, the leadingricedevelopment pole in Côte d'Ivoire. This workwas made possible thanks to the Science, Technology and Innovation Fund (STIF) and the Science GrantingCouncils Initiative (SGCI).

The general objective is to contribute to achievingfood self-sufficiencythrough rational land management. Specifically, itis a question of : (i) Determining the optimum spatial arrangement rate in the rice-maizeintercropping; (ii) To evaluate the profitability of the rice-maizeintercropping in the use of space; (iii) Toevaluate the economicviability of thiscrop association.

MATERIAL AND METHODOLOGY

Presentation of the study area

The studywascarried out on the experimental site of NARDS Training Center in Gagnoa, more precisely at Coffee Cutting Center with site coordinates 05° 90'316’’W longitude, 06° 13'723’’N latitude and 188 m in elevation (figure 1). The climate is tropical, characterized by twowetseasons (May to July and September to November), whichalternatewithtwo dry seasons. The averageannualrainfallis 1320 mm (Kouamé et al, 2007 citedin Bahan et al, 2012).

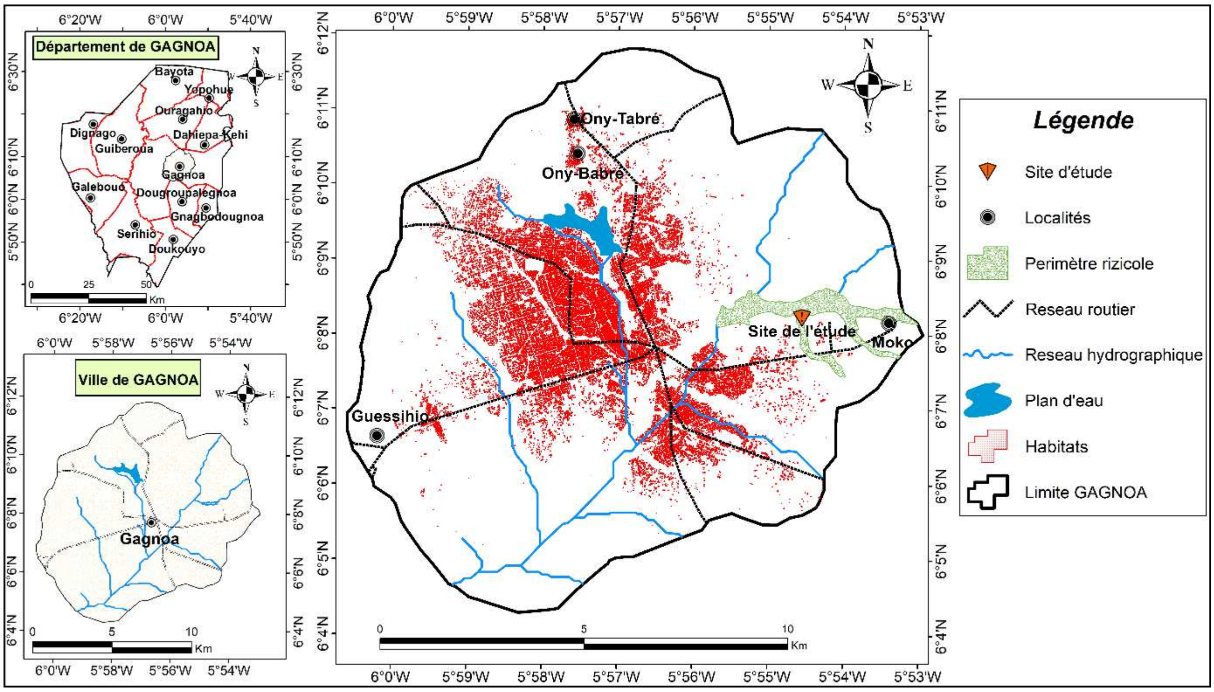

Figure 1 : Gagnoa Study Site

Plant Material

The plant material in the trial isa CRAM 3 (Man Agricultural Research Centre) ricevariety, whichisearly-maturing andresistant to drought and diseasessuch as blast and helminthosporiosis. It has a cycle of 104 days and a potentialyield of 4.90 t. ha^{-1}(Noumouha et al., 2022). On the other hand, a variety of maizeFerké 7635, with a cycle of 105 days and a potentialyield of 4 t ha-1 (N’Da et al., 2022; Kouakou et al., 2024).

Fertilizingmaterial

The fertilizingmaterialconsists of base fertilizer (NPK) with a formulation of 12% N, 22% P, and 22% K, and Pearl Urea (46% N).

Technicalmaterial

The technicalequipmentconsists of a cylindrical tube for soil sampling, a decameter for delineating the experimental plot, a humidimeter for measuring the water content of rice grains, a GPS for takingcoordinates and creatingmaps, and a precisionelectronicscale for weighing.


Figure 2:Cylindrical tube (Scale: 1/2)


Figure 3:Decameter (Scale: 1/2)

Figure 3:Humidimeter (Scale: 1/10)

Figure 4: GPS (Scale: 1/10)

Figure 5 : Electronicscale (Scale : 1/3)

METHODOLOGY

Expérimental design

The experimentwasconducted in a Randomized Complete Blocks Design (RCBD) of seven (7) treatments and fourreplications (blocks). The treatments are as follows :

Table 1. Description of the treatments

Treatment	Rice sowing	Maizesowing	Cassavaplanting	system
T1	0.20 m × 0.20 m	0	0	Pure rice
T2	0	0	0.20 m × 0.20 m	Pure cassava
T3	0	0.75 m × 0.40 m	0	Pure maize
T4	0.20 m × 0.20 m	3 m × 0.40 m	0	Rice + maize in improvedintercropping
T5	0.20 m × 0.20 m	0	3 m × 1 m	Rice + cassava in improvedintercropping
T6	broadcast	broadcast	0	Rice + maize in traditionalintercropping
T7	broadcast	0	broadcast	Rice + cassava in traditionalintercropping

Eachelementary plot has an area of 15 m² (3 m × 5 m). The distance between the blocks is 1 m. The micro plots are separated by 0.50 m. The trial area is 680 m² (17 m × 40 m).

Trial conducted

Land preparationbeganwith land clearing, followed by tillage, whichconsisted of a first superficialmechanicalploughing and a second manualploughing,whichwascarried out threedaysbeforesowing. Just before the synchronized establishment of crops, NPK base fertilizerwith formulation 12%-22%-22% wasapplied at a rate of 200 kg/ha. Rice and maizeweresown in alignedpockets in improvedcroppingsystems and broadcast in traditionalcroppingsystems. Direct sowingwasperformedin 5-seed and 2-seed pockets for rice and maize, respectively,at a depth of 5 cm in the soil. The two-strandrice plants wereunmarried 32 daysago in wetsoil. The cover fertilizer (Urea at 46% N) wasapplied 25 daysapart at a rate of 50 kg/ha at the beginning of tillering (50% of the total Ureaquantity) and 50 kg/ha at the heading of rice. Observations and measurementswere made in the yield squares.

Data collection

Rice height

The height of the plant ismeasuredfrom the base to the tip of the highestleafusing a woodenruler. Measurementswere made on 10 ricepocketsrandomlyselectedfrom the yield square. The Rice heightfor eachtreatmentisthe average of the measurements.

Rice grain yield

Rice yieldis the production of rice grains per unit area. Commonly, RGY isdeterminedfromthe dry weight of grains at the standard moisture content of 14% corrected by the actualmoisture content, measuredusing a moisturemeter.

$$\text{RGY (t ha-1)} = (\text{dry grain weight (g)} / 15\ \text{m}^2) \times (10000/1000000) \times ((100\text{-H}) / 86) \quad (1)$$

H = moisture rate (Konan et al., 2023).

Harvest index

The riceharvest index is the ratio of the dry weight of grains to the weight of dry above-groundbiomass.

$$\text{HI (\%)} = \frac{dry\ grain\ weight}{dry\ above{-}ground\ biomass} \times 100 \quad (2)$$

Land Equivalent Ratio

It isdefined by Willey and Osiru (1972) as the area of land required in pure cultivation to obtain the sameyields (Rdt) as in intercropping.

$$\text{LER} = \frac{Yield\ of\ Rice\ in\ the\ intercrop}{yield\ of\ Rice\ in\ the\ monocrop} + \frac{yield\ of\ Maize\ in\ the\ intercrop}{yield\ of\ Maize\ in\ the\ monocrop} \quad (3)$$

This index measures the overallproductivity of the intercroppingcompared to single crops. If LER > 1, wemay have an "over-performance" of the intercropping system compared to the single system. On the other hand, if LER < 1, the intercroppingisless productive than single cropping.

Monetary Advantage Index (MAI)

The economicfeasibility of intercroppingrelative to sole croppingwasassessedusing the monetaryadvantage index (MAI). MAI is an important indicator ofthe economicviability of intercropping. It wascalculatedaccording to Willey (1979,cited by Glaze-Corcoran et al,2020;Soniya et al., 2021;

$$\text{MAI} = \text{value of combined intercrops} \times (\text{LER} - 1)/\text{LER} \quad (4)$$

Statisticalanalysis

The mean values of height, tillers, yield, harvest index, and Land Equivalent Ratio weresubjected to an analysis of variance to determine the effect of intercropping on theseagronomicparameters of rice and maize. All thiswasdoneusing SAS version 9 software at the 5% threshold.

RESULTS

Physical and chemicalcharacteristics of the experimentalsoil

Table 1 shows the soilparticle-size distribution at the experimental site. This horizon has a greater proportion of clay (45.15 %) thansand (32.94 %) and silt (21.91 %). According to the structural triangle, thissoil has a silty-sandy-clay texture.

Table 1:Soilparticle size of the experimental site

Particle size	Clay	Sand	Silt
0 – 20 cm	45,15	32,94	21,91

Table 2 presents the soilchemicalcharacteristics of the experimental site. The site soilisweaklyacidic, with a pH-water of 5.9. It has a C/N ratio of 10-15. This soil has a good cation exchange capacity (CEC = 21.54 cmol kg-1) and exchangeable cations. The assimilable phosphorus and free iron contents appearhigh withthismethod of determination;however, the nitrogen and organiccarbon contents are low. At the level of cation balance, the reports (Ca / Mg) = 2.74 and (K / Mg) = 0.31 indicate an excess of Ca in relation to Mg,whereas K isdeficient in relation to Mg.

Table 2:Soilchemicalcharacteristics of the experimental site

Chemical parameter (0 – 20 cm)	Value	Normative value
pH-$_{water}$	5.9	6.6 – 7.3
Corg (%)	1.11	12.6 – 25
N (%)	0.09	1.2 – 2.2
C/N (%)	12.33	11 - 15
CEC (cmolc/kg)	21.54	10 - 25
P_{avai} (ppm) (Melhich 3)	63.42	3 - 8
K ($cmol^+$/kg)	1.31	0.15 – 0.25
Mg ($cmol^+$/kg)	4.21	1.5 – 3.0
Ca ($cmol^+$/kg)	11.57	5 - 8
Fe (ppm)	255.9	25 - 50
Ca/Mg	2.74	1 - 2
K/Mg	0.31	0.05 – 0.10
(Ca + Mg)/K	12	12 - 15
K/CEC (%)	6	1 – 2

C_{org}:Organic Carbon, N: Total Nitrogen, Pavai:AvailablePhosphorus, Ca: Calcium, Mg:Magnesium, K: Potassium, CEC: Cation Exchange Capacity(Source Doucet, 2006; SORO et al, 2023)

Rainfall data of the study site

Figure 6 shows the rainfallevolution on the study site. July, being part of the greatrainyseason, was dry monthwith 30 mm of rain in twodays.

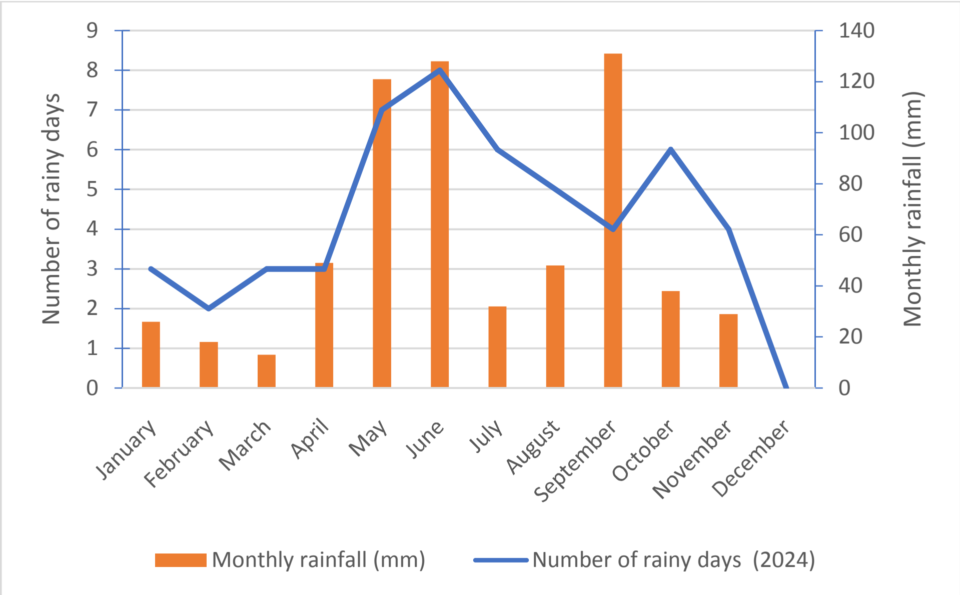

Figure 6:Rainfallevolution of the study site in 2024

EFFECT OF CULTIVATION PRACTICE ON RICE DEVELOPMENT AND PRODUCTION

Rice height

Figure 7 shows the Rice height of the differenttreatments.No significanteffect of cultural practice on riceheight(*P-value* > 0.05).

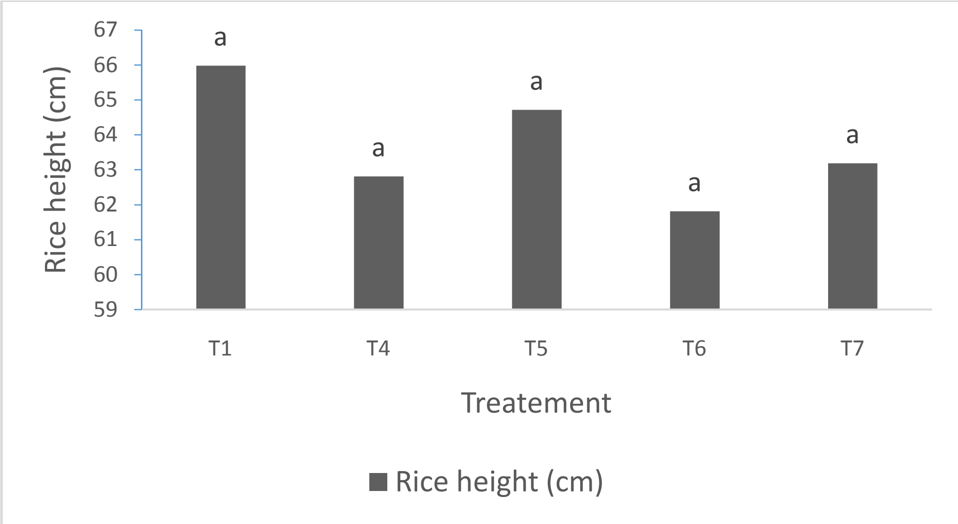

Figure 7: Rice height of the differenttreatments

Rice grain yield

Figure 8 shows the Rice grain yield of the treatments.There is no significantdifferencebetween the grain yield of rice single cropping and that of intercropping(*P-value* > 0.05).

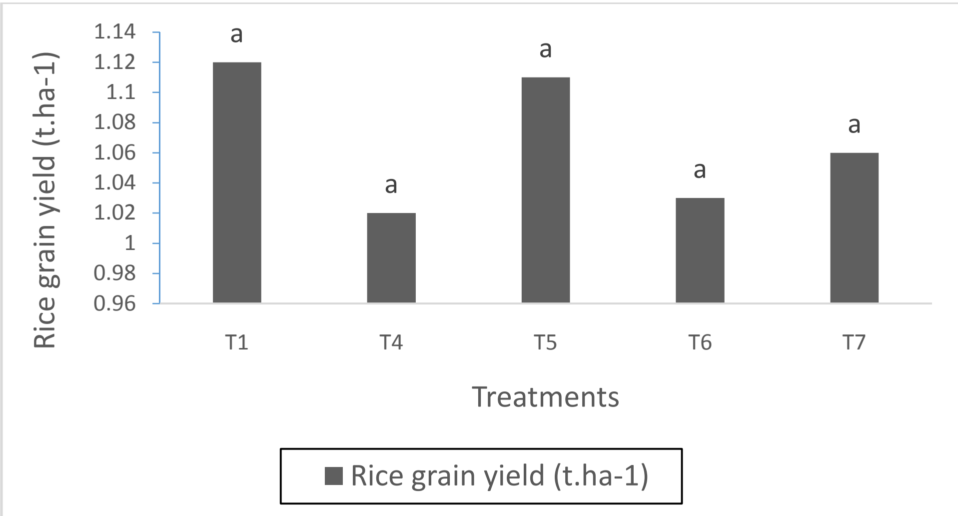

Figure 8: Rice grain yieldaccording to treatments

Rice strawyield

Figure 9 shows the averagestrawyield of ricetreatments.There is a significanteffect of cultivation practice on the ricestrawyield(*P-value* > 0.05).There is a significantdifferencein ricestrawyieldbetween the cultivation practices. The highest value wasobtainedwith the T4 treatment, while the lowestwasobtainedwith the T5 treatment.

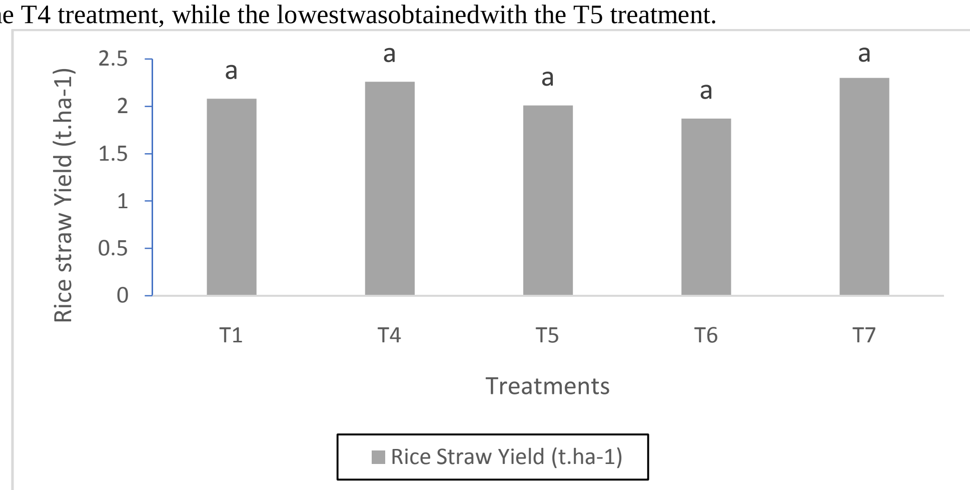

Figure 9 : Rice strawyieldaccording to treatments

Rice Harvest Index (HI)

Figure 10 shows the riceharvest index of the treatments. No significanteffect of cultural practice on riceharvest index (*P-value* > 0.05). The highest value wasobtainedwith the T5 treatment (36.78%), while the lowestwasobtainedwith the T4 (31.46%) and T7 (31.54%) treatments.

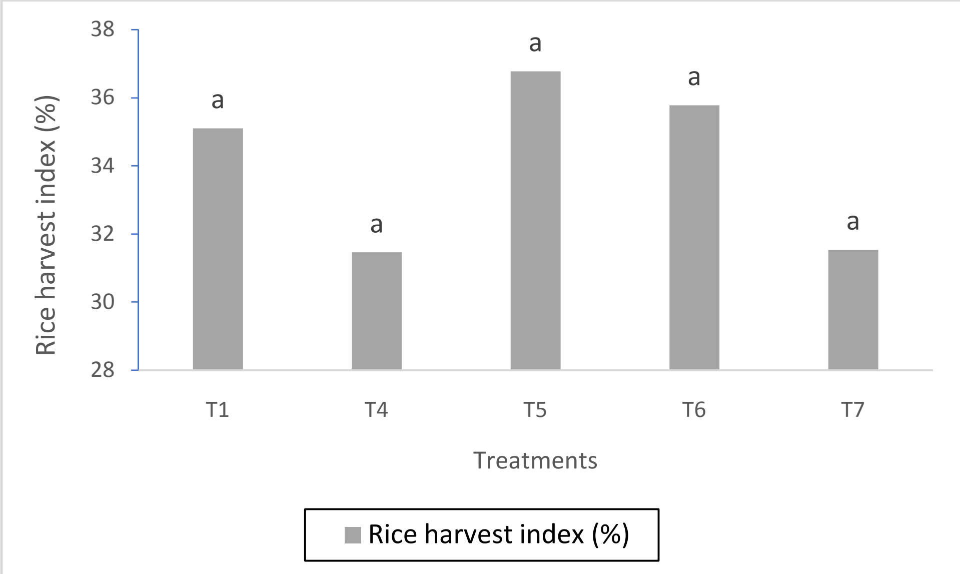

Figure 10: Rice harvest index according to treatments.

EFFECT OF CULTIVATION PRACTICE ON MAIZE PRODUCTION

Table 7 shows the averagemaizeyield of the treatments. There is a highlysignificanteffect of cultural practice on maizeyield (*P-value*<0.0001). Indeed, the yield of the single crop (T3) of maizewashigherthanthat of the crop associations (T4 and T6).

Table 7a:Another standard element of ANOVA

Source	LD	SS	MS	Prob. F
Treat	3	7.553	3.776	<0.0001

LD : Liberty Degree ; SS : Sum of Squares of deviations ; MS : Meduim Square ; Prob : Probability.

Table 7b:Maize grain yield of treatments.

TREAT	Maize grain yield (t. ha^{-1})
T3	2.07a
T4	0,69b
T6	0,20c
GM (t. ha^{-1})	0,99
CV (%)	13.25
P > F	<0,0001
$LSD_{.05}$	0,21

AGRONOMIC PROFITABILITY OF THE RICE-MAIZE INTERCROPPING

Table 8 presents the variance in the land use ratio. Crop association has a highlysignificanteffect on the land-use ratio (P-value < 0.0001). Indeed, the improved practice has had a more positive impact on the land use ratio.

Table 8a:Another standard element of ANOVA

Source	LD	SS	MS	Prob. F
Treat	3	0.267	0.089	<0.0001

LD : Liberty Degree ; SS : Sum of Squares of deviations ; MS : Meduim Square ; Prob : Probability.

Table 8b: Variance of Land Equivalent Ratio

TREAT	Land Equivalent Ratio (LER)
T1	1.00b
T3	1.00b
T4	1.26a
T6	0.92b
GM	1.05
CV (%)	5.40
P > *F*	<0.0001
$LSD_{.05}$	0.087

ECONOMIC PROFITABILITY OF THE RICE-MAIZE INTERCROPPING

Figure 11 shows the index of the monetaryadvantage of the rice-maizeintercropping. It isnotedthat the rice-maizeintercropping in improved practice has a gain of 59.566 CFA francs compared to the single cropping of rice or maize, whilethisintercropping in traditional practice leads to a loss of 27.115 CFA francs in parallelwith single cropping.

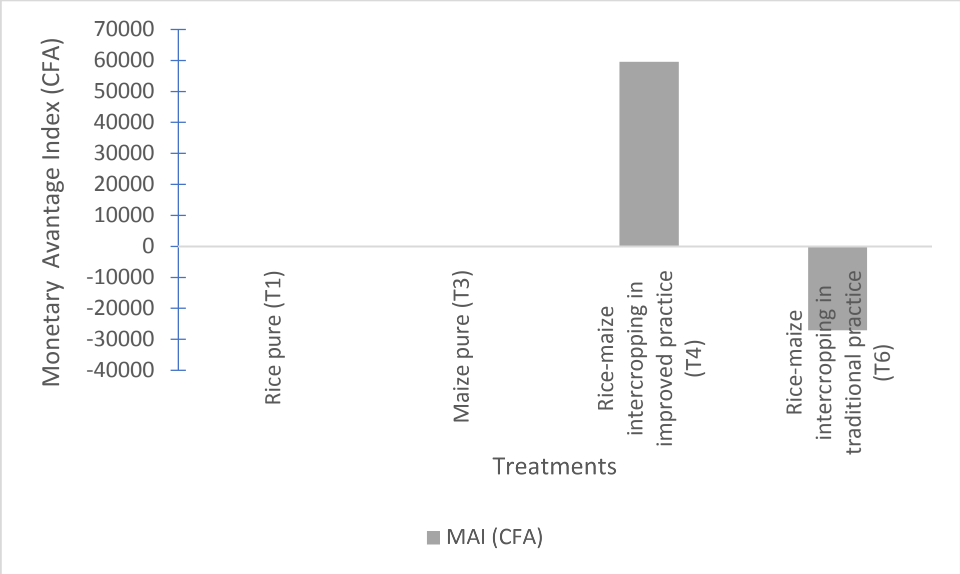

Figure 11:MonetaryAdvantage Index of rice-maizeintercropping

DISCUSSION

The soil has a silty-sandy-clay texture. This type of soilseemschallenging to cultivate, but the presence of gravel (40-50%) givesit a completelydifferentcharacter. In the absence of soilorganicmatter, this type of clay-gravel mixture couldreducesoil drying, a commonphenomenon in the currentclimatecontext. At the same time, the load of coarseelements has been identified as the cause of the yieldreduction. At the chemicallevel, this fertile soil is suitable for the experimentwith a fertilizer application.

Overall, the cultivation practice did not have a significanteffect on ricegrowth and production. This resultindicatesthat the combination did not affect rice, evenafterremovingthe ricerow. There is no competitionbetweenassociatedcrops. On the one hand, thatdenotes the state of soilfertility. Indeed, in fertile soil, whether in single-cropping or intercroppingsystems, the crops do not sufferfromcompetition for nutrientresources. On the other hand, the absence of significantcompetitionisbecausethesetwocereals exploit differentsoil horizons. Maize has deeproots (1 m) whilerice has shallowroots (0.20 m). In contrast to Ido's (2017) assertions, thereis no evidencethatthesetwospecies, belonging to the samefamily, Poaceae, have identicalnutritionalrequirements, whichcouldaccentuateintraspecificcompetition. It shouldbenotedthatriceis a weakcompetitorcompared to maize, whichexerts an inhibitoryeffect on riceagromorphologicalparameterswhen the optimal maizesowingdensityis not maintained in rice-maizeintercropping.

This studyrecordedlowyields of rice and maize. That is due to a drynesspocket. Indeed, during the reproduction phase, a droughtpocket lasting a monthwasobserved. That enabledverification of the resistance of the selected CRAM 3 ricevarietyunder water-stress conditions. This resultconfirms the riceharvest index, whichshowedthatriceproduced more strawthan grain.

For maize, cultivation has had a highlysignificanteffect on maize grain yield. indeed, grain maizeyieldincreasedwithplantingdensity (high yield for pure maizecropping) compared to the pure maizecroppingsystem; the maizedensity in the association is a reduceddensity to allow for a betteryield of the staplecrop (rice). The rice-maize combination isreferred to as the optimal maizedensity. It wasnotedthatmaize grain yielddepended on cropdensity. Indeed, the maize grain yieldincreasedwith the cropdensity(Saleem et al.,2011; Mandal et al., 2014). Cropdensityis a crucial factor in agriculture by influencingyield and production quality.Determining the optimal plantingdensityinvolvesconsideringvariousfactors, such as plant size and growth habit, soilfertility, water and nutrientavailability, and climate and weather conditions (Haque&Sakimin,2022). If plants are spacedtoocloselytogether, theymaycompete for resourcessuch as sunlight, water, and nutrients. This competition can result in reducedgrowth, loweryields, and increasedsusceptibility to pests and diseases. On the other hand, if plants are spacedtoo far apart, the potentialyieldmight not beachieved(Singh & Singh,2002;Onat et al., 2017). Soilfertility alsoplays a significantrole in determiningplantingdensity. Soilswith high nutrient and water-holding capacity can support higherplantingdensities, whilepoorersoilsmayrequirelowerdensities to preventnutrientdepletion and ensure optimal plant growth(Heneghan, 2021;Andrianirina et al., 2019; Asik et al., 2020).

Theseresultsagreewiththose of Belay et al. (2008). Indeed, theseauthors have shownthatwhenmaizeiscombined (withcassava or soybean), the maizeyield in association islowerthanthat of maize in pure stand. Theyexplainedtheseresults by the factthatassociatedspeciescompete for access to light and for nutrientresources, which can negatively influence yield. This competitionbecomesstrongerwhen the associatedspecies have identicalnutritionalrequirements. Also, according to Coulibaly et al. (2017), whenmaize plants are combinedwithothercrops, the reduction in cropdensity due to the association has a considerable impact on the yield of intercroppedcropscompared to their pure stands.

COST-EFFECTIVENESS IN FARMLAND MANAGEMENT

The land use ratio values are greaterthan 1 (LER >1), whichmeansthat the rice-maizeintercroppingisquantifiedas an advantage over a sole rice and maizecrop(Konan et al.,2021; Konan et al.,2023; Zheng et al., 2022). That demonstrates an additionalyield gain and an efficient use of arable land, whichisprone to scarcity,whencrops are intercropped. Theseresultscorroboratethose of Tchegueni et al. (2022) and Kouakou et al. (2021). Indeed, theseauthors have shownthatcombiningmaizewith a legumeallows a more efficient use of land than single cropping. The profitability of rice-maizeintercropping in land management depends on the cultivation practice. This profitabilityis more appreciable in the modernizedrice-maizeintercroppingwith the knownmaizedensity (intercropping). It is important to note thatthis association has been approachedas rice-basedcroppingsystems,wherericeis the main or dominant crop.

ECONOMIC PROFITABILITY

About the economicprofitability of the rice-maizeintercropping, according to the formula proposed by Willey (1979), and taking an averageprice of 300 CFA francs and 350 CFA francs per kilogramrespectively for paddy rice and dry maize, the values of the monetaryadvantage index of the modernizedrice-maizeintercropping show a gain of (59.566 CFA francs) comparedwith the rice and maize pure cropping. Whereas the traditional practice of the same association shows a loss of 27.115 CFA compared to pure rice and maizecropping, thissuggests the need to rationalizeintercroppingsystems.This economicprofitability, added to that of land management, makes the rice-maizeintercropping, whichis in practice improved, a system thatresponds to farmers' concerns (land problems and net income). The rice-maizeintercropping has severaladvantages:maize, because of its shorter growing cycle compared to rice, wasused as food to motivate the guarding of rice, as livestockfeed, and for trade,bothfresh and dry. At the edaphiclevel, maize cultivation benefits the soil by providingsubstantialamounts of organicmatter(Konan, 2016). Rice–maizeintercroppingsystems have shownsomeresilience to climatevariability. Rice–maizeintercroppingsystems are crucial in ensuringfoodsecurity,according to Erythrina et al. (2022). The currentcontext of climate change leads us to examine the resilience of thisintercropping, which has not been addressed in thisstudy but willundoubtedlybe the subject of future work by calculating the resilience index of rice-maizeintercropping.

CONCLUSION

This studyenabledevaluation of land management profitability and the economicprofitability of rice-maizeintercropping. The economicprofitability, added to that of land management, makes the rice-maizeintercropping, whichis in practice improved, a system thatresponds to farmers' concerns (land problems and net income). In the currentcontext of climate change, itwouldbedesirable to check the resilience of thiscrop association.

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Conflict of Interest

The authors declare no conflict of interest.

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