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Rice Farming Systems in Maniema (DRC): Socio-Generational Determinants and Spatial Heterogeneity of Biotic Pressions

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Abstract

This study highlights a clear spatial segmentation within the rice-growing sector of the Maniema province (DRC), where gender asymmetry is highly pronounced—with males accounting for 69.0% of the workforce—and decision-making power is concentrated among individuals aged 36 to 55. The results reveal profound territorial contrasts driven by a generational gradient and the geographical specialization of biotic pressures (explaining 56.4% of the overall variance, divided between a primary trend of 30.8% and a secondary trend of 25.6%). The historical hub of Kasongo is characterized by an aging farming population (46.78 ± 5.20 years) and strong agricultural anchoring (more than 10 years of experience for 27.34% of them). These senior farmers secure plots larger than 1 hectare and widely adopt the improved cultivar IRAC13 (30.5%) ; however, they suffer exclusively from avian pest pressure, where continuous bird-scaring significantly compromises their economic profitability. Conversely, Kailo and Kibombo mobilize younger farming communities (averaging 39 years of age). In Kibombo, newly established smallholders (1 to 3 years of seniority) cultivate micro-plots of less than 1 hectare, rely heavily on local landraces or non-certified seed stocks (12.5%), and face a critical convergence of insect pests and phytopathogenic diseases, which confines them to low yields (1 to 5 bags). Meanwhile, damage caused by wild mammals remains diffuse and uniform across the entire province. The study also underscores a clear duality in risk perception : younger farmers (31.74 ± 7.86 years) overwhelmingly report plant pathologies (87.0%) and specifically identify brown spot disease (Bipolaris oryzae, syn. Helminthosporium oryzae) (24.6%), whereas veterans largely deny its occurrence (71.8%) or resort to generic terminology (73.4%). Finally, in response to erratic rainfall patterns, the heightened vulnerability observed among senior farmers (44.31 ± 9.22 years) relies on long-term climate memory.

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Introduction

In the Democratic Republic of the Congo (DRC), and specifically within the Maniema province, rainfed rice cultivation constitutes a strategic socio-economic pillar for food security and rural household livelihoods [1,2]. However, this sector remains dominated by extensive, smallholder family farming systems characterized by low adoption rates of modern agricultural inputs and a high vulnerability to biophysical hazards [3,4]. Historically, agronomic literature in Sub-Saharan Africa has approached production constraints from a purely technical or environmental perspective. Yet, agricultural dynamics are primarily driven by human actors whose sociodemographic characteristics structure agrotechnical choices [5,6]. Access to critical production factors—namely secure land tenure, capital, and labor—is intimately linked to the gender, age, and seniority of the farmers, parameters governed by customary and patrilineal modes of devolution.

In Maniema, this socio-technical equation is further complexified by a regional economic context marked by the high attractiveness of artisanal gold and coltan mining sites. This phenomenon triggers a rural exodus of the young labor force and disrupts generational renewal in Kasongo in favor of an aging core of producers, whereas the youth establishing themselves in Kibombo and Kailo face severe resource precarity. Against this background, this study poses the central research question : to what extent do producers' sociodemographic characteristics and risk perceptions influence the technical structuring and performances of rainfed rice cultivation in Maniema? This breaks down into specific sub-questions regarding the geographic structuring of producer profiles, the influence of age on the choice of plant material, and the impact of farming experience on the perception of climatic and biotic constraints.

To guide our investigations, this research relies on the general hypothesis that the performance of rainfed rice cultivation in Maniema is conditioned by a generational and geographical divide, where demographic maturity dictates access to innovation and modulates resilience. Specifically, we test : (H1) that a distinct aging of the producer population in Kasongo stands in contrast to the emergence of a young but inexperienced workforce in Kibombo and Kailo; (H2) that capital accumulation over the years grants senior farmers a monopoly over high yields through the use of high-performing seeds (such as the IRAC13 cultivar); and (H3) that risk perception evolves across the life cycle—younger farmers being constrained by a lack of technical extension services, whereas seniors, equipped with empirical memory and sanitary habituation, bear the full brunt of erratic rainfall patterns and the high labor costs of bird-scaring against bio-aggressors. Ultimately, the goal of this work is to provide empirical evidence to guide public policies toward an inclusive revitalization of the sector. The overarching objective is to characterize the socio-economic typology of Maniema's rice farmers and evaluate the determinants of their agrotechnical performances under environmental risks. This is achieved by mapping demographics across river basins, assessing the effect of farming experience on yields, and identifying the technical, climatic, and phytosanitary constraints perceived across the farmers' life cycles.

Materials and Methods

Study Area

This research was conducted in the Maniema province, a geographic entity situated in the east-central region of the Democratic Republic of the Congo. The investigations were spatialized and deployed across three strategic and contrasting rice-growing basins: Kasongo, Kibombo, and Kailo. The biophysical environment of the study area is globally governed by a transitional humid tropical climate—classified as Aw under the Köppen system—characterized by the alternation between a predominant rainy season and a short dry season, although the zone

currently experiences contemporary perturbations manifested by erratic rainfall distribution patterns. The soils, predominantly ferralsols subjected to intense leaching, support a mosaic of vegetation combining remnants of secondary dense humid forests and savanna formations. From a socio-economic standpoint, the region is a theater for complex sectoral trade-offs : while rainfed family smallholding remains the historical subsistence activity, the rural fabric—particularly within the Kasongo basin—suffers from aggressive competition from artisanal gold and coltan mining [7]. This extractive sector preferentially captures the young labor force to the detriment of generational renewal within rice-growing agricultural holdings [8-11].

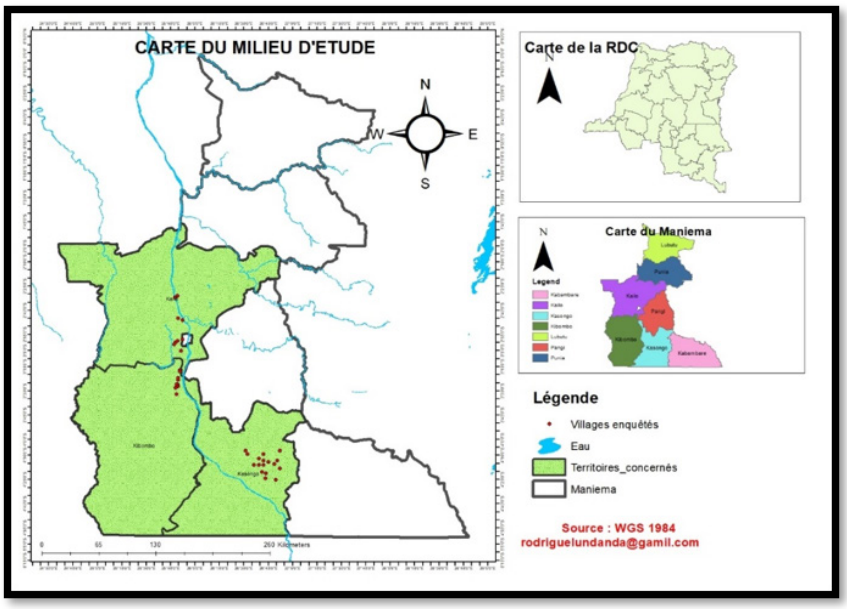

Figure 1: Map of the Study Area.

Data Collection and Survey Design

Quantitative and qualitative data acquisition was executed through a distinct field survey conducted from June 15 to December 2025. The study specifically targeted rice farmers located within the territories of Kailo, Kasongo, and Kibombo in the Maniema Province. Data collection was performed digitally in the field using the KoboCollect mobile application, ensuring direct, reliable, and real-time data entry.

A sample size of 384 rice farmers, equally distributed across the three territories (i.e., 128 respondents per entity), was selected using a voluntary sampling approach with no financial compensation. Interviews were conducted orally and directly in the participants' local languages. The responses were subsequently translated and transcribed into French by the enumerator during the fieldwork phase.

Data Analysis and Statistical Interpretation

Raw data were initially encoded and structured using Microsoft Excel before being exported for computational processing and statistical modeling within the R environment (v4.5.1) using the FactoMineR and Factoshiny packages. The significance threshold for all tests was set at $\alpha = 0.05$. Following preliminary data screening, which included normality testing, homoscedasticity verification, and outlier removal, data were synthesized using descriptive statistics (frequencies and percentages). Spatial and structural interdependencies between the three agricultural basins (Kasongo, Kibombo, Kailo) and farming characteristics (plot sizes, farming experience, varietal choices) were evaluated using Fisher's Exact Test, whereas Pearson's Chi-square Test measured the effect of farming seniority on the diagnosis of phytopathogenic complexes. To isolate the determinants associated with the farmers' age, a Type II Analysis of variance (ANOVA) linear model was implemented. Conversely, the Kruskal-Wallis test was used as a non-parametric alternative to analyze the effect of the generational factor on crop yields, global technical constraints, and biotic pressures. Finally, the systemic complexity of the rice-growing landscape was modeled via two multivariate statistical methods

: Multiple Factor Analysis (MFA), to establish a synthetic typology integrating mixed variable blocks, and Principal Component Analysis (PCA), restricted to bio-aggressors (avian pests, insect pests, phytopathogenic diseases, weeds, and wild mammals) to map the geographical specialization of the sustained biological pressures.

Results

Sociodemographic Characteristics of Respondents

The analysis of the respondents' sociodemographic characteristics (n = 384) reveals a distinct structural profile within the study area. The sampled population is perfectly balanced across the three territories, with 33.3% of respondents coming from Kailo, Kasongo, and Kibombo, respectively. Gender distribution is characterized by a strong male predominance (69.0%) compared to only 31.0% female participation. Regarding marital status, a clear preponderance of married rice farmers is observed (83.3%), relative to single (4.7%), divorced (6.3%), or widowed (5.7%) individuals.

In terms of educational attainment, the cohort is mostly divided between primary education (45.6%) and secondary education (44.5%), while farmers with no formal schooling and those with higher education represent 9.4% and 0.5%, respectively. Finally, distribution by age group indicates a high concentration of active farmers within the 36–45 age bracket (40.6%), followed by the 46–55 bracket (24.0%) and the 25–35 bracket (19.8%). The age cohorts under 25 years (6.8%) and over 55 years (8.9%) remain a minority (Table 1).

Table 1: Sociodemographic Characteristics of Respondents (n = 384)

Variables	Categories	%
Rice-growing Basin	Kailo	33.3
	Kasongo	33.3
	Kibombo	33.3
Gender	Female	31.0
	Male	69.0
Age	< 25 years old	6.8
	25–35 years old	19.8
	36–45 years old	40.6
	46–55 years old	24.0
	> 55 years old	8.9
Marital Status	Single	4.7
	Married	83.3
	Divorced	6.3
	Widowed	5.7
Educational Attainment	None	9.4
	Primary	45.6
	Secondary	44.5
	Higher Education	0.5

To decipher the decision-making frameworks, organizational dynamics, and cultural anchoring within the farming communities, an analysis of religious affiliations was also conducted. The data reveal a predominance of the Protestant denomination, which accounts for 33.6% of the sampled population. This representation is accompanied by a diversified distribution wherein nearly a quarter of the surveyed producers are Roman Catholic (23.7%). The remaining cohort is distributed homogeneously between adherents of Evangelical and

Revivalist Churches (Églises de réveil) (17.7%) and the Muslim community (17.2%), whereas Kimbanguists represent a more restricted proportion of 7.6%. Other religious beliefs remain entirely marginal (0.3%) (Figure 2).

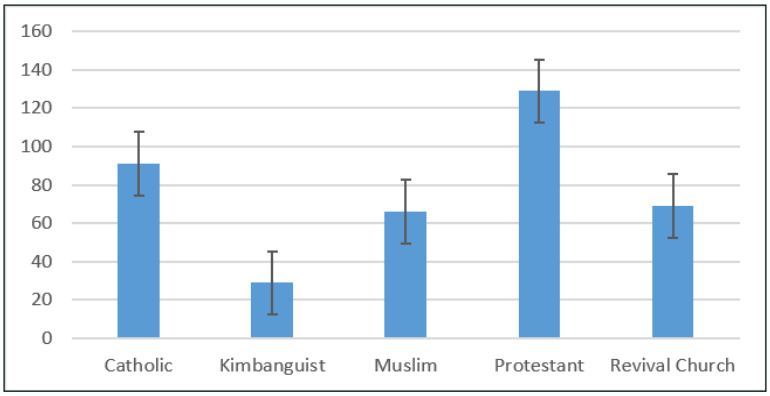

Figure 2: Religious affiliation of respondents (n = 384)

Technical Profile, Farming Experience, and Crop Germplasm

The analysis of farmers' seniority in rainfed rice cultivation highlights a well-established agricultural expertise within the study area. Highly experienced producers predominate, with rice farmers totalizing more than 10 years of farming practice accounting for 46.1% of the respondents. This high representation is coupled with a major intermediate cohort of smallholders possessing 4 to 10 years of experience (35.9%), whereas respondents with limited seniority of 1 to 3 years remain a minority, representing only 18.0% of the surveyed population, as illustrated in the figure below (Figure 3).

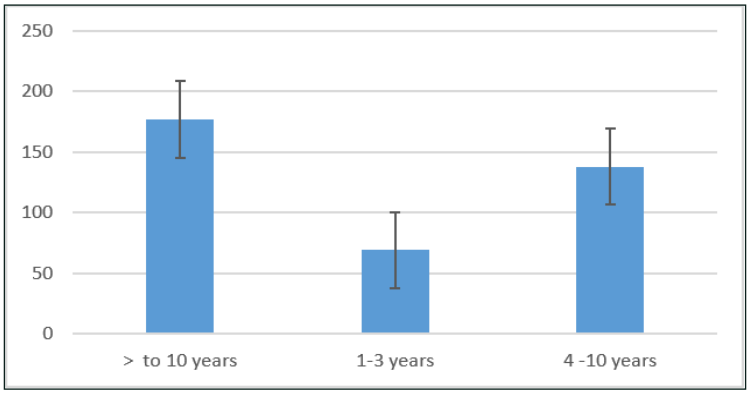

Figure 3: Farming Experience of Respondents (n = 384)

Regarding the orientation of biological material, the diagnosis highlights the hegemony of traditional genetic resources, with local varieties being utilized by 55.7% of the surveyed farmers. Alongside this core cohort lies a notable transitional component, represented by the use of improved seed varieties among nearly a third of the producers (31.8%). Conversely, the utilization of non-certified seed stocks (tout-venant), lacking any prior selection or sorting, remains a minority practice and concerns only 12.5% of the sampled population (Table 2).

Table 2: Types of Rice Cultivars grown by Respondents (n = 384)

Variable	Frequency	Percent %
Improved	122	31,8
Local	214	55,7
Unselected	48	12,5

Total	384	100

The inventory of genetic resources utilized by smallholders across the three study areas highlights a substantial level of local agrobiodiversity, evidenced by the identification of 19 distinct vernacular names. However, the seed landscape remains highly polarized around three dominant varieties that concentrate nearly 80% of the producers' choices. The IRAC13 cultivar leads, being grown by 30.5% of the sampled population, closely followed by Kisasa at 29.9%, and Dimena, which occupies a structural share of 19.0%.

Behind this leading trio, an intermediate group exhibits a more modest representation, led by Piram (4.4%), Nerica 4 (4.2%), and ONU (2.3%), as well as Mombe (2.1%) and Mwezi (2.1%). In contrast, the remaining biological material is characterized by high fragmentation and marginal adoption rates, ranging from Ndjate (1.6%) to a suite of rare landraces fluctuating between 0.5% (Lofalanga, Mukokoli, SAIDIA, Tobishi, Tule) and 0.3% (Kabisi, Kitumbe, Omombo, Sofia, Yelela). This patterns reflects the persistence of a traditional seed conservation culture maintained by a minority of rice farmers (Table 3).

Table 3: Vernacular Names of Rice Cultivars Grown by Respondents (n = 384)

Variable	Frequency	Percent %
Dimena	73	19,0
IRAC13	117	30,5
Kabisi	1	0,3
Kisasa	115	29,9
Kitumbe	1	0,3
Lofalanga	2	0,5
Mombe	8	2,1
Mukokoli	2	0,5
Mwezi	8	2,1
Ndjate	6	1,6
Nerica 4	16	4,2
Omombo	1	0,3
ONU	9	2,3
Piram	17	4,4
SAIDIA	2	0,5
Sofia	1	0,3
Tobishi	2	0,5
Tule	2	0,5
Yelela	1	0,3
Total	384	100,0

Furthermore, a bivariate analysis using Fisher's Exact Test was performed to evaluate the existence of geographical disparities among the different production basins in the region. Its specific objective was to verify whether the spatial location of the rice-growing basin significantly influences the technical and structural choices of the agricultural holdings. The two-dimensional statistical analysis reveals a highly significant dependency between the rice-growing basin and the technical characteristics of the farms, as demonstrated by the results of Fisher's exact tests ($p < 0.05$; Table 4).

Table 4: Results of Fisher's Exact Test (α = 0.05)

Statistical Test	Interacted Variables	p-value
Fisher's Exact Test	Rice-growing basin vs Farmers' seniority	2.2e-16
	Rice-growing basin vs Cultivated area	2.2e-16
	Rice-growing basin vs Type of plant material (Variety)	2.2e-16

In the field, these geographical discrepancies delineate highly contrasting agro-economic profiles:

- The Kasongo basin stands out spectacularly as a historical, large-scale, and intensive production hub. It concentrates the highest proportion of veteran farmers with more than 10 years of experience (27.34% of the total producers) alongside a total absence of beginners (0%). Concurrently, it dominates through large holdings exceeding 1 hectare (32.29%) and a massive adoption rate of improved rice cultivars (26.04%).
- Conversely, Kibombo embodies a dynamic of revitalization or transition driven by smallholders. This area exhibits the highest rate of novice farmers with 1 to 3 years of experience (11.72%) and intermediate producers (16.93%). They predominantly exploit limited land areas of 1 hectare (18.23%) or less (10.68%), while relying almost exclusively on local landraces (31.51%).
- Between these two extremes, Kailo presents the most diversified and balanced profile. It combines a well-distributed experience structure (dominated by mid-career farmers at 13.02% and veterans at 14.06%) with evenly fragmented plot sizes (showing a slight predominance of smallholdings under 1 hectare at 13.80%), and a production share split between local varieties (17.45%) and non-certified seed stocks (11.98%).

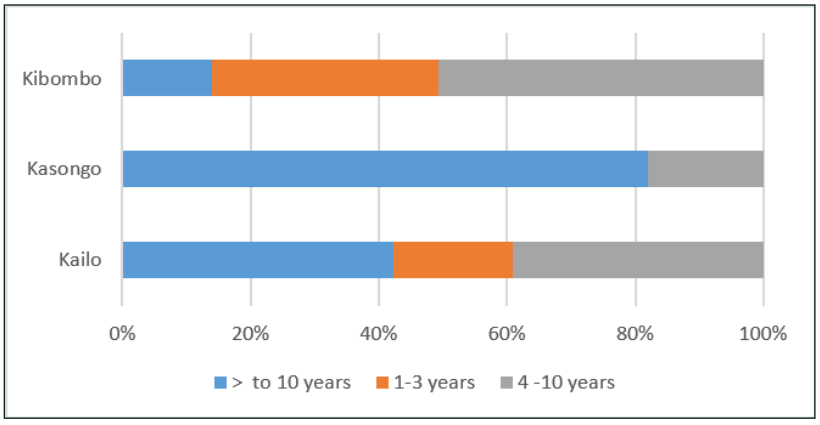

Figure 4: Distribution of Rice-Growing Basins According to Farming Experience (n = 384)

Modeled Determinants of Farmers' Age: Analysis of Variance (ANOVA)

To comprehensively ascertain which structural, environmental, and technical factors linearly influence or characterize the age of the farm heads, an Analysis of Variance (ANOVA) was performed prior to our field segmentations (Table 5).

Table 5: ANOVA Results Explaining the Age of Rice Producers

Explanatory Variables	Sum Sq	Df	F-value	p-value
Rice-growing basin	2231.5	2	13.1105	3,207e-6***
Production constraints (global)	1920.6	4	5.6420	0,00021 ***
Technical constraints to yield	939.0	3	3.6778	0,01239 *
Number of cropping seasons	258.4	1	3.0361	0,08229
Average annual production (bags)	358.6	3	1.4045	0,24120

Rainfall occurrence/regularity	400.9	3	1.5704	0,19621
Soil fertility assessment	131.0	1	1.5395	0,21551
Rice cropping season	27.0	1	0.3170	0,57375
Compliance with the agricultural calendar	9.4	1	0.1109	0,73935
Biotic constraints (bio-aggressors)	120.1	4	0.3528	0,84203
Abiotic constraints	104.6	4	0.3071	0,87316

Note: Asterisks indicate highly significant (***) and significant (*) differences.

The results reveal that only the rice-growing basin ($p < 0.05$), global production constraints ($p < 0.05$), and technical constraints to yield ($p < 0.05$) exert a statistically significant influence on the farmers' age. Conversely, isolated biophysical factors—such as soil fertility assessment, compliance with the agricultural calendar, or direct pest and disease pressures—do not exhibit a direct linear causal relationship with overall age.

Influence of the Generational Factor on Agricultural Performance and Constraints (Kruskal-Wallis Test)

A Kruskal-Wallis test was executed to precisely evaluate structural characteristics, yield levels, and production constraints through the prism of the farmers' age (Table 6). The objective was to determine to what extent this demographic component constitutes a discriminating factor for technical performance and producer vulnerability.

Table 6: Age Profile of Rice Farmers According to Technical, Climatic, and Environmental Variables (Kruskal-Wallis)

Variables	Mean Age (years)	χ2	p-value
Rice-growing Basin			
Kailo	38,93 ±11,38	57,15	3.888e-13
Kasongo	46,78 ±5,20		
Kibombo	39,68 ±10,74		
Average Annual Production			
Less than 1 bag	38,81 ±10,77	40,62	7.865e-09
1 to 5 bags	39,29 ±11,16		
5 to 10 bags	40,98 ±11,36		
More than 10 bags	45,31 ±7,27		
Global Production Constraints			
Lack of technical extension & training	31,74 ±7,86	22,09	0.0001925
Technical & crop management practices	38,14 ±10,93		
Abiotic and climatic constraints	40,86 ±11,07		
Biotic constraints (Bio-aggressors)	42,69 ±9,39		
Economic, structural & input constraints	45,75 ±10,87		
Rainfall Patterns			
Scarce rainfall	38,65 ±10,45	32,97	3.266e-07
Heavy rainfall	39,38 ±9,84		
Frequent rainfall	42,66 ±10,48		
Erratic rainfall distribution	44,31 ±9,22		
Biotic Constraints			

Phytopathogenic diseases	38,63 ±10,55	39,71	4.96e-08
Weeds	39,03 ±12,45		
Insect pests	39,39 ±9,39		
Wild mammals	42,80 ±11,14		
Avian pests (Birds)	45,15 ±7,15		

Geographically, the Kasongo basin stands out as an aging hub of agricultural expertise, displaying the highest mean age (46.78 ± 5.20 years) and a clear deficit in generational renewal, whereas Kailo and Kibombo mobilize significantly younger productive forces (averaging around 39 years). This demographic configuration directly influences productivity ($x2 = 40.62$; $p < 0.05$) : the lowest yields (less than one bag) characterize young smallholders in their establishment phase (38.81 ± 10.77 years), while high performances (more than 10 bags) remain the prerogative of the oldest rice farmers (45.31 ± 7.27 years), who benefit from accumulated experience and a stronger land-tenure and financial foundation.

Furthermore, the perception of agricultural constraints and climate perturbations evolves markedly across the farmers' life cycles. Younger producers (31.74 ± 7.86 years) report being primarily limited by the lack of technical extension services and training, whereas senior farmers (45.75 ± 10.87 years) confront severe structural barriers, notably economic constraints and limited access to essential inputs required to offset their declining physical labor capacity.

This generational divide is equally reflected in environmental risk management: older smallholders exhibit heightened sensitivity toward erratic rainfall distribution (44.31 ± 9.22 years) —their empirical memory providing the historical perspective necessary to identify climatic shifts—and bear the brunt of avian pest pressure (45.15 ± 7.15 years), which demands continuous, strenuous, and costly human guarding.

Perception of the Phytopathogenic Complex According to Farmers' Seniority (Chi-Square Test)

The dependency analysis using Pearson's Chi-square test (Table 7) reveals a highly significant statistical influence of the farmers' seniority on their perception of the agricultural phytosanitary environment.

Table 7: Pearson's Chi-Square Test Results ($\alpha = 0.05$) regarding the Phytopathogenic Complex

Statistical Test	Interacted Variables	$\chi 2$	Df	p-value
Chi-square Test	Seniority vs Perception of rice diseases	85.717	2	2.2e-16**
	Seniority vs Common phytopathogenic diseases	80.776	8	3.411e-14**

* indicates a significant difference ($p < 0.05$). **indicates a highly significant difference ($p < 0.05$).

On the one hand, the confirmation of the very existence of diseases affecting rice crops is significantly correlated with the respondents' seniority ($x^2 = 85.717$, $p < 0.05$). A clear divergence in risk perception is observed : novice producers (1 to 3 years of experience) overwhelmingly report the presence of phytopathogenic diseases (87.0%), followed by the intermediate cohort with 4 to 10 years of experience (66.7%). Conversely, an overwhelming majority of veteran rice farmers (more than 10 years of seniority) assert that there are no diseases affecting crops in their environment (71.8%).

On the other hand, the specification of common disease types is also highly significantly associated with farming experience ($x^2 = 80.776$, $p < 0.05$). Producers established for more than 10 years predominantly resort to the "other (to be specified)" category (73.4%), identifying specific pathologies only marginally. In sharp contrast, diagnostic accuracy diversifies among younger smallholders : rice blast disease (Magnaporthe oryzae,

syn. Pyricularia oryzae) is primarily highlighted by the 4–10 years seniority bracket (26.1%), whereas brown spot disease (Bipolaris oryzae, syn. Helminthosporium oryzae) is the most documented pathology among beginners with 1 to 3 years of experience (24.6%).

Multivariate Analysis Exploration and Typology of Rice Farming Systems in Maniema

The Multiple Factor Analysis (MFA) (Figure 5) synthesizes the complex interactions between geographic anchoring, the socio-technical characteristics of the holdings, and the nature of the constraints reported by producers in Maniema. The factor scores plot, defined by the first two axes, accounts for 28.12% of the total inertia (19.10% for Dim 1 and 9.02% for Dim 2).

The Kasongo territory isolates itself on the negative side of Axis 1 and slightly on the positive side of Axis 2 (Dim 1 < 0, Dim 2 > 0). Its geometric proximity to a cluster of specific categories reveals a homogeneous and structured profile :

- **Socio-Technical Profile:** This pole is intimately associated with experienced producers possessing more than 10 years of seniority (> 10 years), who exploit large-scale areas (> 1 ha). On a technical level, there is a clear adoption of improved varieties (Improved).
- **Constraint Complex:** Risk perception is focused on the Birds factor as a specific biotic threat, along with other unclassified constraints (Other).
- Conversely, the Kibombo territory projects onto the positive side of both axes (Dim 1 > 0, Dim 2 > 0), characterizing a distinct cropping model:
- **Socio-Technical Profile:** Kibombo groups together less experienced producers (1-3 years of seniority) and is linked to intermediate holdings (1 ha), with a trend towards higher education levels (University level) further up the axis. It is also strongly tied to cropping activities during Season B and the use of local seed varieties (Local).
- **Constraint Complex:** This pole is heavily burdened with diverse bio-aggressors. It associates directly with Insects, Mammals, and a wide range of phytosanitary pathologies categorized under Diseases, including brown spot (Helminthosporium), Bacterial diseases, leaf spot (Cercospora), and rice blast (Pyricularia).

The Kailo territory isolates itself in the lower-right quadrant, on the positive side of Axis 1 and negative side of Axis 2 (Dim 1 > 0, Dim 2 < 0), reflecting a separate agronomic reality:

- **Socio-Technical Profile:** The production system here relies predominantly on the use of non-certified seed stocks (Unselected), managed by rice farmers with intermediate experience (4 -10 years) and frequently characterized by a lack of formal schooling (No formal education). This system operates closely within smallholder dynamics (<1 ha) and is positioned near Season A.
- **Constraint complex:** Within this quadrant, the primary biotic stress shifts heavily toward weed pressure (Weeds).

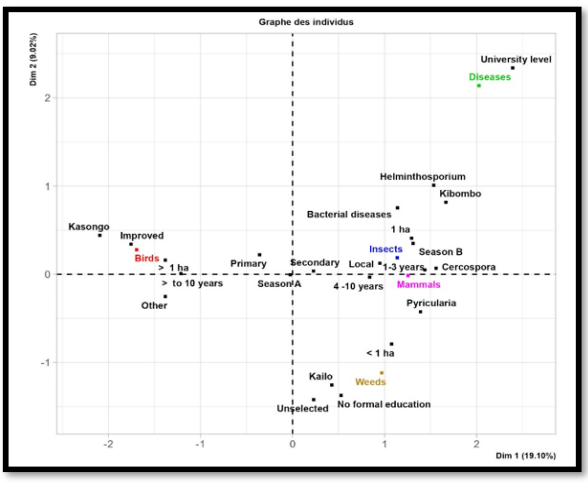

Figure 5: First factor scores plot of the MFA representing the typology of agricultural holdings

To isolate and clarify the structure of solely the biological pressures weighing on the rice-growing area, a targeted Principal Component Analysis (PCA) was applied to the biotic constraints (Figure 6). This restricted factor plot displays a higher explanatory power, capturing 56.4% of the total inertia (30.8% for Dim 1 and 25.6% for Dim 2).

This approach graphically confirms the spatial specialization of pest and disease pressures by territory: avian pest pressure (Birds) confirms its exclusive anchoring in Kasongo, whereas the Kibombo hub undergoes the convergence and interconnection of insect infestations and phytopathogenic diseases. Finally, the Kailo territory stands out in stark opposition, aligning almost systematically with the Weeds (weed infestation) vector.

Conversely, damage caused by Wild mammals is positioned very close to the origin of the factor axes. This indicates their marginal contribution to territorial differentiation, revealing a diffuse, secondary, and uniform distribution of this constraint across the entire province, as illustrated in the following figure:

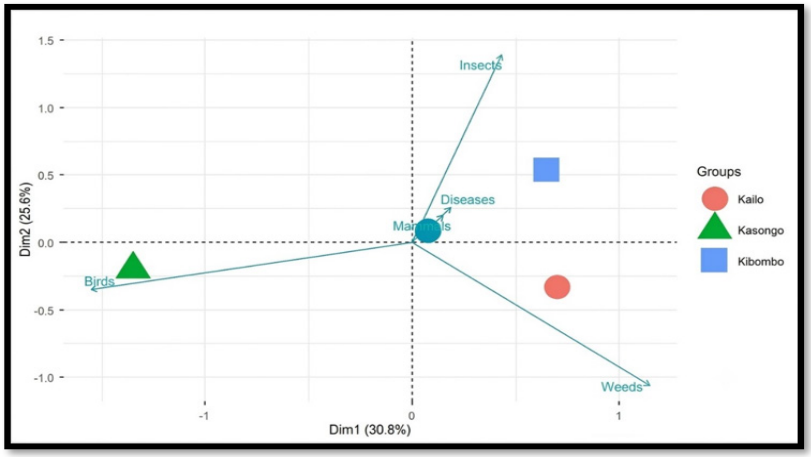

Figure 6: Principal Component Analysis (PCA) : Biplot of the distribution of rice biotic constraints by study territory in Maniema.

Discussion

The investigations conducted within the Maniema province highlight a profound segmentation of the rice-growing area. The convergence of bivariate and multivariate approaches demonstrates that the technical trajectories and agronomic vulnerabilities of agricultural holdings are not randomly distributed. Instead, they result from a complex trade-off between the demographic profile of household heads, their territorial anchoring, and their level of technological integration. This finding aligns with the work of Gasselin et al. (2014), who reminded that technical choices are intrinsically dependent on the household's demographic structure [12].

The observed gender asymmetry (69.0% male) and the concentration of decision-making power among middle-aged individuals (36 to 55 years old) reflect traditional land devolution mechanisms in Sub-Saharan Africa. In both forest and savanna environments, access to land remains largely governed by patrilineal customary rights. As highlighted by the work of Chauveau & Jacob (2006), secure access to land tenure is often the privilege of social elders [13]. Furthermore, initial land development operations (clearing, slash-and-burn, heavy tillage) require physical strength and a financial foundation that are primarily available to established household heads—a phenomenon documented by Toulmin (2009) regarding barriers to entry for youth and women in African pioneer systems [14].

The absence of a simple linear relationship between age and annual production volume, confirmed by the ANOVA ($p > 0.05$; see Table 3), highlights the extensive nature of this rice farming system. In these

agroecosystems, gross yield at the regional scale remains heavily subservient to seasonal climatic fluctuations and immediate biophysical constraints, rather than a simple linear correlation tied to farmer maturity. This result corroborates those of Diop (2015) and Jacquemot (2023) on rainfed rice farming in Sub-Saharan Africa, which demonstrate that the lack of inputs and rainfall dependence level down yields, regardless of the farmer's experience [15,16].

While global trends smooth out disparities, non-parametric tests reveal deep territorial contrasts. The spatial opposition revealed by Fisher's exact test ($p < 0,05$; $p=2.2e-16$) isolates the Kasongo territory as a historical basin characterized by a marked aging of its active population (46.78 ± 5.20 years) and a solid professional anchoring (exceeding 10 years of experience for 27.34% of them). This deficit in generational renewal evidences a flight of vital labor forces toward sectors with high immediate profitability, notably artisanal gold or coltan mining, which is particularly attractive to rural youth in Maniema. This phenomenon of de-peasantization and competition between the mine and the field has been widely confirmed by Bryceson (2002) and Kamundala et al. (2014), who demonstrate that the attraction of mining trading posts siphons off young agricultural labor, thus precariousing the transmission of agricultural knowledge [17,18].

Conversely, Kailo and Kibombo mobilize younger communities (averaging 39 years old). In Kibombo, this rejuvenation is accompanied by major technical precarity, as producers are in their establishment phase (1 to 3 years of seniority). For this segment of the population, returning to the land resembles a survival and resilience strategy in response to the saturation of the formal job market, echoing the conclusions of Losch et al. (2012) on the role of agriculture as a refuge sector for youth employment in Sub-Saharan Africa [19].

The configuration of plant material and economic performances align rigorously with this generational gradient. The Kruskal-Wallis test validates the hypothesis that the accumulation of social, land, and technical capital over time conditions productivity ($p < 0.05$). Thanks to their financial foundation and community mutual-aid networks, the elders of Kasongo manage to secure large-scale plots (> 1 ha) and integrate innovation dynamics through the use of improved cultivars (Improved). This dynamic of selective adoption by producers endowed with high social capital corroborates the findings of Faure [20].

At the other end of the spectrum, the young agricultural population of Kibombo and Kailo suffers from a technological lock-in effect, though through different patterns. Confined to intermediate plots (1 ha) and highly active during Season B, young smallholders in Kibombo depend almost exclusively on local landraces (Local). Meanwhile, producers in Kailo evolve within micro-holdings (< 1 ha) during Season A, relying on uncertified seed stocks (Unselected), often paired with lower formal education levels (No formal education). In both cases, this initial capital deficit heavily penalizes their yields and confines them mostly to structurally low production levels (one to five bags). This situation perfectly illustrates the agronomic poverty trap described by Masumbuko et al., where the inability to access initial production factors (land and quality inputs) condemns young smallholders to near-survival agriculture [21].

A central contribution of this study lies in the shifting perception of agricultural risks throughout the farmer's life cycle. For young rice farmers (31.74 ± 7.86 years), the main obstacle lies in the disruption of the empirical transmission of knowledge and their exclusion from agricultural extension networks, leading to a strong feeling of helplessness regarding crop management requirements. For the elders, constraints shift toward direct environmental and economic barriers. Their sensitivity to erratic rainfall distribution relies on a long-term climatic memory, allowing them to conceptualize contemporary disruptions. This duality in risk perception matches the work of Vignola et al., indicating that the climatic memory of older farmers often constitutes the only reliable baseline for adaptation in the absence of formal meteorological services [22,23].

Furthermore, the highly significant results of Pearson's Chi-square test introduce a striking epidemiological paradox regarding the phytosanitary management of rice paddies. While novice producers (1 to 3 years of experience, typified by Kibombo) overwhelmingly report the presence of pathologies (87.0%) and

accurately isolate specific fungal and bacterial threats—such as brown spot (Helminthosporium), leaf spot (Cercospora), rice blast (Pyricularia), and Bacterial diseases—veteran farmers (more than 10 years of experience) mostly deny the existence of diseases (71.8%) or resort to generic categories.

This divergence reflects a visual and psychological habituation among senior farmers, who integrate pathological symptoms as a normal background noise within the agroecosystem. Conversely, beginners exhibit heightened epidemiological vigilance, although their diagnosis occasionally targets physiological accidents or abiotic stresses that they misinterpret as diseases due to their lack of training.

Finally, the distribution of biotic stressors within the factor scores plots highlights logistically demanding challenges linked to the contrasting socio-technical setups of the territories. In Kasongo, the strong predominance of avian pest pressure (Birds, 45.15 ± 7.15 years) represents a major bottleneck. Bird control imposes a continuous, daily guarding routine during the panicle maturation phase. Faced with the scarcity of household labor—exacerbated by schooling or youth exodus—older rice farmers suffer from increased physical labor strenuousness or are forced to allocate financial resources to hire salaried guards, which severely undermines their profitability. Conversely, within the Kailo cluster, the primary biotic burden shifts toward weed pressure (Weeds), a constraint intimately tied to the management limits of micro-holdings operating on small plots of less than one hectare (< 1 ha).

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