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Review of Advanced Research on Quantitative Economics, Applied Finance and Business VOL. 1 Issue 3 (2026)
ISSN: 3119-6640

The Determinants of Female Farmers' Productivity in the Sub-Prefecture of Damara - Central African Republic: An Econometric Analysis in a Post-Conflict Context

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Abstract

In a post-conflict context where women are responsible for most of the food production, this study seeks to understand why the majority of women farmers in Damara remain low in productivity. It analyses, at the microeconomic level, the extent to which human capital, collective organisation, technical supervision and family structure influence the probability of achieving a high yield (≥ 650 kg/ha). The analysis is based on a survey conducted in 2019-2020 among 200 women farmers. Productivity is measured in kg/ha and then transformed into a binary variable (high/low productivity). A binary logit model is estimated from twelve explanatory variables describing individual characteristics, household size and composition, cultivation practices, access to agricultural organizations and services, and investment expenditure on tools. The average yield is only 635 kg/ha and only 27.5% of women farmers cross the high productivity threshold, with spectacular differences between farms. The model highlights some powerful levers: education, agricultural experience, membership of a group, harnessed farming, technical supervision and investment in tools greatly increase the probability of being productive. Conversely, living in a polygamous household significantly reduces this probability, even though age, marital status taken in isolation, rainfall and simple help from NGOs play no statistically significant role. The model correctly classifies 72.5% of cases, which confirms the robustness of these results.

This study shows that the productivity of women farmers is mainly stimulated by education, collective organization and supervision, and strongly hampered by polygamy. These findings call for agricultural policies that empower women and address intra-household inequalities.

Keywords: Agricultural productivity; Female farmers; Post-conflict context; Binary logit model; Central African Republic; Damara

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1. Introduction

In the Central African Republic (CAR), subsistence agriculture, which employs 75% of the working population, is mainly based on the work of women, who represent 50 to 70% of the agricultural workforce. However, the average yields observed in Damara (634.6 kg/ha) remain well below regional potential, estimated at between 1,200 and 1,500 kg/ha for crops such as cassava or maize. This underperformance is due to multiple structural constraints: only 15% of women farmers use improved seeds (compared to 40% for men), less than 10% have access to formal credit, and 75.5% do not benefit from any technical supervision.

This study aims to identify the socio-economic determinants of women farmers' productivity in Damara, by combining a field survey of 200 women farmers and a binary logit model. It assesses the impact of key variables such as level of education (where 71% of respondents have not completed secondary school), membership in an agricultural group (only 29% of women farmers join), expenditure on tools (average of 15,000 CFA francs/year), and technical supervision (only 24.5% of women farmers benefit from it). The originality of this research lies in its anchoring in a post-conflict context, where 60% of rural infrastructure is destroyed and where social norms, such as polygamy (practiced by 45% of households), strongly influence productivity dynamics.

2. Literature review

2.1 Theoretical framework

Three theoretical frameworks shed light on this study. First, the theory of human capital (Schultz, 1961; Mincer, 1974) emphasizes that education and training improve farmers' ability to adopt technologies, manage their resources, and make optimal decisions. Several empirical studies confirm that producer education is positively correlated with productivity, in particular through a better understanding of technical itineraries and an increased ability to interact with extension services (Lockheed et al., 1980; World Bank, 2018).

Second, the theories of collective organizations (Ostrom, 1990) show that agricultural groups facilitate access to inputs, credit, information and markets, while strengthening the bargaining power of producers. Empirical studies in sub-Saharan Africa confirm that membership in a group improves farmers' productivity and incomes, including for women (Fischer & Qaim, 2012; Doss, 2014).

Finally, gender analyses (FAO, 2011; Meinzen-Dick et al., 2014) reveal that women face additional constraints in terms of access to land, inputs, credit and extension services. These inequalities partly explain the differences in performance between men and women. In polygamous households, resources (land, labour, capital) are often divided among several wives, which can reduce the area under cultivation and the inputs available per female farmer (Jacoby, 1995; World Bank, 2019).

These three theoretical streams should not be read as separate bodies of knowledge but as complementary lenses whose predictions are reshaped by post-conflict institutional fragility. Human capital theory assumes functioning labour and information markets through which education is rewarded; collective-action theory presupposes institutions stable enough to

enforce cooperation; and gender analyses describe resource inequalities within otherwise predictable household structures. In fragile Sub-Saharan settings, however, these assumptions are only partially met: markets are thin or destroyed, extension and credit institutions are intermittent, and property and mobility are insecure. Under such conditions, the returns to education increasingly depend on self-reliance and on the ability to reorganise production without external support, agricultural groups act as substitutes for missing input, credit and information markets rather than as mere efficiency-enhancing devices, and intra-household bargaining becomes a central allocation mechanism because formal institutions no longer arbitrate access to land, labour and capital. A growing literature on structural fragility in Sub-Saharan Africa (Meinzen-Dick et al., 2014; World Bank, 2019; Doss, 2014) shows precisely that women's bargaining power and the division of resources within the household condition the effectiveness of macro-level agricultural policy. Situating our study at this intersection bridges the persistent gap between macroeconomic agricultural strategies and the micro-level realities of women farmers, and directly motivates the choice of household structure, group membership and human capital as core explanatory variables in the empirical model.

2.2 Specific context of the CAR and Damara

The Central African Republic, marked by recurrent conflicts, has a fragile agricultural sector: degraded rural infrastructure, limited access to inputs and markets, and high levels of food insecurity (World Bank, 2021). The sub-prefecture of Damara (Ombella-M'Poko) illustrates these constraints: an essentially subsistence economy, roads that are often impassable during the rainy season, restricted access to health services and water, and limited presence of humanitarian and development support (Action Against Hunger, 2020). These factors reduce the investment capacity of women farmers and largely explain the low returns observed. Initiatives (seed fairs, input distributions, stimulus programmes) are underway but require sustained strengthening to improve local resilience (FAO, 2020).

3. Methodology

3.1. Data collection

This study is based on primary data collected between October 2019 and March 2020 from 200 women farmers in the sub-prefecture of Damara, in the Central African Republic. The sample was constructed using a stratified sampling method, taking into account criteria such as the age and size of the farms in order to ensure a representativeness of local agricultural profiles.

A blended questionnaire was used to collect both quantitative and qualitative data. Quantitative data include agricultural yields, level of education, membership in an agricultural group, annual expenditure on tools, access to technical supervision and marital status. The qualitative data, obtained through semi-structured interviews, explore the constraints perceived by women farmers, including access to inputs, domestic workload and social norms limiting their decision-making autonomy.

Table 1: List of variables

Variables	Description	Terms and conditions	Hypothesis
Z	Production in kg/hectare	*0 = ‹ 650 kg/Ha and 1= ≥ 650 kg/Ha*	Dependent variable
Age	Age of the farmer	*1 = Under 20 years of age; 2 = [20 - 40] and 3 = Over 40 years of age*	Nonlinear effect (±)
N-ins	Farmer's level of education	*0 = Without level 1 = Primary; 2 = Secondary 3=Higher*	Positive effect (+)
Tle	Household size	*1 = Minus 4 people; 2=] 4 - 8] persons; 3 =] 8-12] 4 = More than 12 people*	Positive effect (+)
Stam	Marital status	*1 = Single; 2 = Bride; 3 = Widow; 4 = Divorced; 5 = Common-law union*	
Group	Membership of a group	*1 = Yes and 0 = No*	Positive effect (+)
Prac	Cultivation practice	*1 = Manual; 2 = Hitch and 3 = Other*	Positive effect (+)
Pluv	Assessment of annual rainfall	*1 = Deficit 2 = Sufficient and 3 = Surplus*	Positive effect (+)
ONG	NGO assistance received	*1 = Yes and 0 = No*	Positive effect (+)
Exp	Number of years of experience	*1 = Minus 4 years; 2 =] 4 -6] years 3 =] 6 - 8] years; 4 = Over 8 years*	Positive effect (+
Entec	Technical supervision received	*1 = Have been mentored; 0 = No*	Positive effect (+)
Coe	Existence of at least one co-wife	*1 = if Yes and 0 = if No*	Negative effect (–)
Dpiv	Capital expenditure on tooling	*Annual amount in FCFA*	Positive effect (+)

Control variables include farming experience (years), farm size (ha) and distance to market (km). The dependent variable of this study is productivity, defined in a binary way:

• High productivity for a yield of 650 kg/ha or more (30% of the sample).

• Low productivity for a yield of less than 650 kg/ha (70% of the sample).

The choice of a productivity threshold of 650 kg per hectare as the benchmark separating high- and low-productivity women farmers is not arbitrary but rooted in the agronomic and socio-economic realities of Damara. In the Central African Republic, average cereal and groundnut yields obtained under rain-fed, low-input smallholder conditions typically range between 500 and 800 kg per hectare, so that 650 kg per hectare corresponds closely to the median technically attainable yield for women farmers who mobilise family labour without mechanisation. This value is consistent with the yield ranges reported for comparable Central African farming systems by Yaketé-Wetonnoubena and Mbétid-Bessane (2019), who show that educated producers cluster above this level while poorly-endowed households remain durably below it. Fixing the threshold at this median therefore isolates a meaningful discontinuity: crossing 650 kg per hectare signals that a woman farmer has combined enough human capital, labour and tooling to move from pure subsistence towards a marketable

surplus. Because 70% of the sample falls below this line, the threshold also captures the structural nature of low productivity in a fragile setting rather than a marginal statistical cut-off.

3.2. Limitations of the study

This research has certain limitations that should be highlighted. First of all, the sample, although stratified, remains non-random and restricted to the sub-prefecture of Damara, which limits the generalization of the results to other regions. Second, because yield data is self-reported, it may be subject to over- or under-estimation biases. Finally, some important variables could not be included, such as soil quality, climatic shocks or unobservable intra-household dynamics.

4. Results and discussion

4.1. Descriptive statistics

Table 2 below summarizes the main characteristics of the sample (n = 200) of women farmers surveyed in the sub-prefecture of Damara between 2019 and 2020.

Table 2: Descriptive analysis of variables

Variables	Medium	Standard deviation	Minimum	Maximum
Production (en kg/hectare)	635	682,5	58	5319
Household size	7	3,8	1	19
Number of people in charge	5	3,2	0	15
Age of the farmer (in years)	36	12,4	16	72
Investment expenditure on tools (in FCFA)	20314	18750	1000	111000

Source: Damara Field Survey (2019–2020)

Descriptive statistics reveal a highly constrained socio-economic profile for women farmers in Damara. The average age is 36 years, with a standard deviation of 12.4 years, which shows a strong generational heterogeneity within the sample (from 16 to 72 years). The average household size is 7 people, with an average number of people in charge of 5, which represents a significant family burden weighing on the productive capacities of women farmers. The average yield observed is 635 kg/ha, with a particularly high standard deviation of 682.5 kg/ha, reflecting a strong disparity in performance between farms. This high variability ranges from a minimum of 58 kg/ha to a maximum of 5,319 kg/ha, suggesting considerable differences in access to productive resources, cultivation techniques and agro-ecological conditions. Based

on the productivity threshold of 650 kg/ha, about 27.5% of women farmers are classified as "high productivity", while 72.5% remain below this threshold.

Average expenditure on agricultural implements amounts to 20,314 CFA francs per year, but with a very high standard deviation of 18,750 CFA francs, indicating extremely unequal investment capacities between farms. The minimum amount invested (1,000 CFA francs) contrasts sharply with the maximum (111,000 CFA francs), revealing a very differentiated access to productive capital. Even on average, this amount remains well below the 50,000 FCFA per hectare recommended by the FAO (2020) to ensure basic mechanization and viable farming.

4.2. Socio-economic and institutional characteristics

The analysis of qualitative variables completes this picture by revealing major structural constraints. Educational attainment is particularly low: 71 per cent of women farmers have no formal education, 21.5 per cent have completed primary education, and only 7.5 per cent have secondary or higher education. This low human capital severely limits access to technical information, the ability to adopt agricultural innovations and the optimal management of farms.

In terms of marriage, 89% of women farmers are married, 6.5% are single and 4.5% are widowed or divorced. Among married women, 45% live in polygamous households (presence of at least one co-wife), a high proportion that strongly influences the distribution of resources within the household (land, inputs, financial support) and the time available for agricultural activities due to an increased domestic burden.

Access to collective and institutional resources also remains limited. Only 42% of women farmers belong to a farmers' group, which is essential to facilitate access to inputs, credit and technical information. In addition, only 28% of women farmers receive regular technical support from extension agents or NGOs. Although 60% of women farmers report the presence of an NGO in their village, this presence does not systematically translate into direct support for productive activities.

Finally, 38.5% of women farmers practice harness farming, a technique that improves labour productivity and expands the cultivated areas. However, the majority of women farmers (61.5%) remain dependent on manual techniques, which limits their production capacity and yield. These figures illustrate the multiple structural constraints faced by women farmers in Damara, particularly in terms of access to education, inputs, extension services, physical capital and collective organizations. The high heterogeneity in yields and investments also suggests that some women farmers are overcoming these constraints, while others remain trapped in low-productivity situations. The econometric analysis presented in the next section aims precisely to identify the factors that explain these differences in performance.

4.3. Econometric model

A binary logit model was used to identify the determinants of productivity. This model is formalized by the following equation:

$$Y = C + \alpha_1\ Age + \alpha_2\ N\text{-}ins + \alpha_3\ Tle + \alpha_4\ Stam + \alpha_5\ Group + \alpha_6\ Prac + \alpha_7\ Pluv + \alpha_8\ ONG + \alpha_9\ Exp + \alpha_{10}\ Entec + \alpha_{11}\ Coe + \alpha_{12}\ Dpiv + £$$

where ($Y = 1$) if productivity is high, and, ($X_1, X_2, \dots, X_K$) represent the explanatory variables.

This section presents the results of the binary logit model estimate to explain the probability of a female farmer in Damara achieving a high level of productivity. The estimate was made from a sample of 200 women farmers using the SPSS Statistics 21 software.

Table 3: Logit Model Results

Variables	Coefficients	Significance
Constante	-0,969	0
AGE	2,046	0,153
NINS	20,672*	0
Tle	0,036***	0,1
Stam	0,009	0,926
Group	6,915*	0,009
Prac	0,067**	0,033
PLUV	1,548	0,42
Ong	0,001	0,81
EXP	0,741*	0
Entec	4,789**	0,029
Coe	-0,741***	0,1
Dpiv	4,469**	0,035
N = 200 Cox and Snell R-two = 0.303 Chi-square = 221.807 Nagelkerke's R-two = 0.472 Model predictability = 72.5%		
*Significance : * p < 0,01 ; ** p < 0,05 ; *** p < 0,1*		

The model has good overall performance. The chi-square test is significant at the 5% level (χ^2 = 221,807), indicating that all explanatory variables significantly improve fit compared to a model without regressors. The pseudo-coefficients of determination of Cox and Snell (R^2 = 0,303) and Nagelkerke (R^2 = 0,472) show that a substantial part of the variance in productivity is explained by the variables used. In addition, the overall predictive capacity of the model is 72.5%, which reflects a satisfactory power of discrimination between women farmers with highand low productivity.

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ISSN: 3119-6640

Of the twelve explanatory variables introduced into the model, eight appear to be statistically significant at the usual thresholds. These include the level of education, the size of the household, the membership of an agricultural group, the cultivation practice, the number of years of agricultural experience, technical supervision, investment expenditure on agricultural tools and the existence of at least one co-wife. The other variables (age, rainfall, presence of NGOs in the village, marital status taken in isolation) are not significantly associated with productivity in this model.

The level of education of the farmer is the variable with the highest explanatory power, with a coefficient that is largely positive (20.672) and significant at the 1% threshold. The probability of achieving high productivity thus increases sharply with the level of education. The two modalities of productivity are therefore not evenly distributed according to educational attainment: women farmers with higher levels of education are much more likely to be productive. These results support the idea that human capital accumulation improves the ability to understand and apply better farming techniques, access information and better farm management.

Household size, measured by the number of people in the labour force available for agricultural work, also has a positive and significant effect (coefficient of 0.036 at the 10% threshold). A larger household provides a more abundant family workforce, which makes it easier to complete agricultural work on time and increase productivity. In the context of Damara, where mechanization remains limited, the availability of family labour force remains a determining factor.

The post-conflict environment fundamentally alters the way several explanatory variables operate, which justifies their inclusion and expected signs. Ruined or intermittently functioning local markets, recurrent insecurity and severely reduced mobility mean that family labour cannot be freely substituted by hired workers or by outsourced mechanised services. In this context, household size stops being a mere demographic descriptor and becomes the principal accessible production factor: an additional working-age member directly relaxes the labour constraint at sowing, weeding and harvesting peaks, when travelling to recruit external labour is dangerous or impossible. Tooling expenditure is affected in the opposite way: with disrupted supply chains and thin, insecure input markets, the acquisition and maintenance of implements represents a scarce and risky investment, so that the women who nonetheless sustain such expenditure reveal both higher managerial capacity and privileged access to what remains of local trade. Its positive and significant coefficient must therefore be read as the combined effect of physical capital and of the ability to secure resources under structural fragility, and not simply as a routine purchase of equipment.

Belonging to an agricultural group has a very marked positive impact on productivity. The coefficient associated with this variable (6.915) is significant at the 1% level. Women farmers who are members of a group are therefore much more likely to achieve a satisfactory level of productivity. This result can be explained by the advantages linked to belonging to a collective organization: easier access to inputs (seeds, tools), dissemination of technical information, sharing of experience between members and sometimes institutional or NGO support via these structures.

Cultivation practices, in particular the use of harness farming, have a positive and significant influence on productivity (coefficient of 0.067, significant at 5%). Women farmers who use

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ISSN: 3119-6640

more capital-intensive and animal-drawn farming techniques are able to make better use of their cultivated area, expand the area under cultivation and optimize the work schedule, resulting in higher yields.

The number of years of experience in agriculture also helps to explain productivity. The coefficient associated with experience (0.741), significant at the 1% level, indicates that greater seniority in agricultural activity is associated with an increased probability of high productivity. The experience allows a better mastery of technical itineraries, a detailed knowledge of the soils and local climatic cycles, as well as a capacity to gradually adapt to hazards.

Technical supervision is another important lever. The coefficient for this variable (4.789) is positive and significant at the 5% threshold, which shows that women farmers who have benefited from technical support (agricultural advice, training, monitoring) are significantly more likely to be in the category of the best performing producers. Technical support thus plays a key role in the dissemination of good agricultural practices and the adoption of technologies adapted to the local context.

Investment expenditure on agricultural tools also has a positive and significant effect (coefficient of 4.469 at the 5% threshold). The increase in the amounts devoted to the purchase and maintenance of tools makes it possible to improve work capacity, the quality of cultivation operations (soil preparation, weeding, harvesting) and, ultimately, productivity. Even if investment levels remain modest on average, the results show that an increase in tooling expenses translates into a tangible gain in terms of performance.

Conversely, the existence of at least one co-wife in the household has a negative effect on productivity. The coefficient associated with this variable (–0.741), significant at the 10% level, indicates that the presence of co-wives reduces the likelihood that a female farmer is in the group of the best performing producers. This can be explained by increased competition for access to household resources (land, inputs, financial and moral support from the spouse) and by a greater domestic burden, which limits the time and energy that co-wives can devote to their farming activities.

Beyond the additional domestic workload, the negative effect of polygamous household structures operates through precise mechanisms of resource allocation and agricultural focus. In such households, a single pool of land, draught animals, tools and cash is divided among several co-wives, so that each woman typically cultivates a smaller and often less fertile plot and receives a reduced share of inputs and of the husband's financial and decision-making support. Agricultural focus is further diluted because co-wives compete not only for material resources but also for the labour time of shared dependants and for the husband's arbitration in prioritising one field over another. This fragmentation lowers the critical mass of land and capital needed to cross the productivity threshold and weakens incentives to invest in a plot whose returns must be shared or reallocated. These intra-household bargaining mechanisms, documented for rural women's activities in northern Benin by Yabi (2010) and consistent with the gender-and-resource analyses of Meinzen-Dick et al. (2014), explain why the presence of at least one co-wife durably reduces the probability of belonging to the group of the most productive farmers.

The econometric results show that the productivity of women farmers in Damara is mainly determined by human capital (level of education, experience), social capital (membership in a

group), technical capital (supervision, tools, cultivation practices) and household configuration (household size, presence of co-wives). The model has a satisfactory quality of fit and a high predictive capacity, which confirms its relevance for analysing the determinants of productivity in this post-conflict context.

Translated into concrete terms, these coefficients carry direct implications for agricultural development and food-security planning. Because the model is estimated in logit form, each coefficient measures a shift in the log-odds of belonging to the high-productivity group, and the associated marginal effect indicates how the probability of crossing the 650 kg per hectare threshold changes when a determinant improves. The dominant effect of education implies that moving women farmers from no schooling to a basic level markedly raises their probability of reaching a marketable surplus, so that literacy and technical training should be treated as first-order food-security investments rather than as social add-ons. The positive effects of group membership, technical supervision and tooling expenditure indicate that a combined package (organising women into functioning groups, guaranteeing regular extension contact and facilitating access to affordable implements) raises the predicted probability of high productivity far more than any single instrument used in isolation. Conversely, the negative co-wife effect quantifies a structural penalty that planning must offset through targeted support. For local food-security planning, these probability shifts help identify which households are most likely to remain below subsistence and therefore where scarce resources should be concentrated to generate the largest aggregate yield gains.

These interpretations must be read against the practical limitations of the data. Yields are self-reported by women farmers who rarely weigh their harvest, so figures are reconstructed from memory and from local volumetric units, which introduces recall and rounding biases and may compress the observed distribution around focal values close to the threshold. In an unstable environment, such measurement error is likely to be non-random: insecurity, displacement and the fear of taxation or requisition can lead respondents to under-report output, while enumeration itself is constrained by impassable roads and restricted access to certain villages. Moreover, the cross-sectional design captures a single agricultural cycle and therefore identifies robust statistical associations rather than dynamic causal effects; it cannot fully disentangle the direction of causality between, for example, tooling expenditure and productivity, nor track how households recover over time. These constraints do not invalidate the findings, which remain consistent with the regional literature, but they call for cautious, association-based language and for future panel data collection once the security situation permits.

5. Discussion

5.1. Comparative analysis of the determinants of agricultural productivity

The econometric results from the logit model show that, among the twelve explanatory variables selected, eight have a significant effect on the probability for a farmer in Damara to achieve a high level of productivity: level of education (NINS), household size (Tle), membership of an agricultural group (Group), cultivation practice (Prac), agricultural experience (EXP), technical supervision (Entec), investment expenditure on tools (Dpiv) and the existence of at least one co-wife (coe), the latter having a negative effect (Mémoire, 2020: 95). The other variables (age, marital status, rainfall, presence of NGOs) are not statistically

significant. The challenge of this discussion is to compare these results with existing studies in order to see to what extent they confirm or qualify them.

Educational attainment appears to be the most powerful determinant of productivity, with the highest positive coefficient in the model. This finding supports the widely held view in the literature that education strengthens women farmers' ability to understand technical advice, adopt innovations and better manage their farms. It is consistent with the work carried out in CAR by Yaketé-Wetonnoubena and Mbétid-Bessane, which already show a positive relationship between educational attainment and agricultural productivity (Yaketé-Wetonnoubena & Mbétid-Bessane, 2019), as well as with Sow's findings on the contribution of education to Senegal's economic growth (Sow, 2019). On the other hand, it contrasts with the panel analysis of 27 countries in sub-Saharan Africa, where education, measured by aggregated proxies (primary school enrolment rate), has a positive but not systematically significant effect (Agbe and Atake, 2023). This divergence can be explained by the fact that a microeconomic study directly measures the level of education of women farmers and better captures the effect of human capital relevant to agriculture, whereas macro indicators of schooling do not perfectly reflect the skills that can actually be mobilized in agricultural activity.

Household size also has a positive and significant effect on productivity. This result suggests that, in a context where mechanization remains low, the availability of an abundant family workforce is an asset to carry out agricultural work in the required schedules. It confirms the analyses according to which the surface area per worker and the quantity of available family work strongly condition productivity trajectories (Vergez, 2015). However, other studies in sub-Saharan Africa sometimes find a neutral or negative effect of household size when it is accompanied by strong consumption pressure and few agricultural assets (Agbe and Atake, 2023). Damara's results therefore seem to reflect a context where the share of the working population in the household is relatively high and where family labour is effectively mobilised on the farm.

Membership in an agricultural group is strongly and positively linked to productivity. This result confirms numerous studies showing that membership in farmers' organizations improves access to inputs, information and sometimes credit, which translates into productivity gains, especially for women (Doss, 2014; Araujo et al., 1999). It is also consistent with the panel analysis of 27 countries in sub-Saharan Africa, which highlights the central role of agricultural credit and infrastructure in conveying the impact of collective organizations on productivity (Agbe and Atake, 2023). However, while some multi-country studies find moderate effects of the groupings, the Damara results suggest a particularly strong effect, which can be explained by the low initial level of individual access to resources: for highly constrained women farmers, joining a group represents a significant qualitative leap in terms of access to information and inputs.

Cultivation practices, in particular the use of harness farming, also have a positive and significant effect (coefficient of 0.067, significant at 5%). This result is consistent with studies that show that the introduction of more capital-intensive techniques (animal traction, improved tools) makes it possible to increase the area worked, improve the quality of cultivation operations and, ultimately, increase yields (Yaketé-Wetonnoubena & Mbétid-Bessane, 2019; FAO, 2020). It also confirms the broader findings that the adoption of appropriate technologies

is a critical channel for increasing agricultural productivity in sub-Saharan Africa (Agbe and Atake, 2023).

The number of years of agricultural experience (EXP) has a positive and very significant effect on productivity (coefficient of 0.741, significant at 1%). This result confirms the idea that the accumulated experience makes it possible to refine technical decisions, to anticipate climatic hazards, to know the most suitable soils and crops, and therefore to make better use of the available resources. It is in line with the work of Lamaute-Brisson in Haiti, who identifies seniority in agriculture as a factor in the productivity of women farmers (Lamaute-Brisson, 2013). However, it qualifies some studies in sub-Saharan Africa that find a more ambivalent effect of age and experience, linked to the fact that older farmers may be less inclined to adopt innovations (Agbe and Atake, 2023). In our case, the effect of experience seems to dominate this eventual conservatism.

The technical supervision (Entec) has a positive and significant effect (coefficient of 4.789, significant at 5%). This finding confirms the literature that emphasizes the role of agricultural extension and advisory services in improving practices and adopting better technologies (FAO, 2020; World Bank, 2021). It is consistent with the panel analysis of sub-Saharan African countries, for which access to services and infrastructure is a major determinant of productivity (Agbe and Atake, 2023). The case of Damara illustrates this relationship in a microeconomic way: women farmers who benefit from targeted supervision better transform inputs and work into production.

Investment expenditure on agricultural tools (IPD) is also positively and significantly associated with productivity (coefficient of 4.469, significant at 5%). This result confirms theoretical and empirical analyses that make physical capital – in particular tools and light mechanization – a lever for productivity, by reducing arduousness, increasing work capacity and improving the quality of cultivation operations (FAO, 2020; Agbe and Atake, 2023). It is also consistent with multi-country studies showing that agricultural credit, by enabling precisely this type of investment, has a significant positive effect on productivity (Agbe and Atake, 2023).

Conversely, the existence of at least one co-wife (coe) has a negative and significant effect on productivity (coefficient of –0.741, significant at 10%). This finding confirms Yabi's work in northern Benin, which shows that polygamy reduces the economic profitability of rural women's activities due to competition for access to household resources and increased domestic burden (Yabi, 2010). It is also consistent with analyses conducted in Uganda, where polygamy is associated with a decline in agricultural productivity, even if the magnitude of the effect appears to be smaller than in Damara (World Bank, 2019). The results of our study therefore confirm the importance of taking into account family structure and intra-household relationships in productivity analysis, an aspect that is still poorly integrated in macroeconomic studies on sub-Saharan Africa (Agbe and Atake, 2023).

Finally, the lack of significance of age, marital status taken in isolation, rainfall (PLUV) and the presence of NGOs in the village can be interpreted in the light of the literature. The effect of age is probably absorbed by the experience variable, which is more directly related to agricultural activity, which explains why it is not significant once the two variables are included simultaneously. Rainfall, measured in aggregate, may not account for intra-seasonal variability or effective access to irrigation water, which limits its explanatory capacity, as highlighted by other work on productivity in sub-Saharan Africa (Agbe and Atake, 2023). Similarly, the

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ISSN: 3119-6640

presence of NGOs does not necessarily translate into direct support for productive practices: its effect may be indirect or conditioned by other factors (adherence to projects, targeting of beneficiaries) and become insignificant in a regression controlling technical supervision, groups and tools.

Overall, the results obtained in Damara confirm the major trends in the literature on women's agricultural productivity in sub-Saharan Africa the importance of human capital, social capital, technical capital and intra-household constraints while highlighting particularly strong effects for certain variables (education, groupings, polygamy) in a post-conflict context characterized by a high scarcity of resources and infrastructure.

5.2. Implications for public policies

The comparison of our results with existing studies also makes it possible to identify economic policy implications that are in line with the recommendations made for sub-Saharan Africa, while adapting them to the specific context of Damara.

The very strong effect of educational attainment on productivity confirms the need to strengthen rural education and functional literacy for women farmers, consistent with work on human capital and agricultural growth (Becker, 1964; World Bank, 2018; Yaketé-Wetonnoubena & Mbétid-Bessane, 2019). Training programmes tailored to the needs of women farmers, combining basic knowledge and technical skills, can have a particularly high impact in a context where the majority of women have not completed secondary school.

The positive and significant role of agricultural groups, technical supervision and investment in tools calls for integrated policies to support farmers' organizations and extension services. Our results confirm the analyses according to which these instruments are privileged vectors of access to information, inputs and credit (Doss, 2014; Araujo et al., 1999; FAO, 2020). This involves strengthening the capacities of groups, professionalizing supervisors and developing targeted financing mechanisms for the acquisition of agricultural tools by women farmers.

The negative effect of polygamy on productivity, also confirmed by other studies in West Africa (Yabi, 2010) and East Africa (World Bank, 2019), shows that a policy to support women farmers cannot ignore the family dimension and gender relations. Specific measures in favour of women living in polygamous households (priority access to inputs, specific training, support in resource management) appear necessary to compensate for the structural disadvantages observed in our study.

Finally, the coherence between our microeconomic results and macroeconomic analyses on 27 sub-Saharan African countries, in particular regarding the role of human capital, tools, collective institutions and agricultural finance (Agbe and Atake, 2023), suggests that the policies implemented in Damara should be part of a broader rural development strategy based on infrastructure investment, agricultural credit and advisory services. By specifically targeting women farmers, these policies could help not only improve agricultural productivity, but also reduce gender inequalities and strengthen the resilience of rural households in a post-conflict context.

5. Conclusion

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This study shows that, in the sub-prefecture of Damara, education, membership of a group and investment in tools are robust levers for improving the productivity of women farmers, while polygamy is a major obstacle. These results, obtained in a post-conflict context marked by deteriorating infrastructure and limited access to inputs, make the case for multidimensional policies that combine human capital building, organizational support, and improved access to resources.

Proposed interventions should be designed in a contextual and participatory manner, involving beneficiaries (women's groups, local NGOs, local authorities) and providing for impact evaluations to measure the effectiveness of actions. In the longer term, strengthening rural infrastructure and stabilizing the security environment will be crucial to create an enabling environment for sustainable improvements in agricultural productivity.

Building on these findings, local extension services and non-governmental organisations can design tailored, gender-sensitive interventions rather than generic programmes. Because education carries the strongest effect, extension actors should pair functional literacy and numeracy modules with practical agronomic training delivered in local languages, at times and locations compatible with women's domestic schedules and with the mobility restrictions imposed by insecurity. Given the leverage of group membership and technical supervision, NGOs can prioritise the formation and durable accompaniment of women's producer groups that pool the purchase and maintenance of tools, negotiate access to inputs and host recurrent extension visits, thereby substituting for missing markets. For women in polygamous households, interventions should include individualised targeting (priority allocation of inputs, dedicated coaching and support in intra-household resource negotiation) so that structural disadvantages are explicitly compensated. Finally, because the evidence is cross-sectional and based on self-reported yields, programmes should embed simple monitoring of objectively measured plots and built-in impact evaluations, allowing services to verify which combinations of literacy, organisation and tooling most reliably move women farmers above the 650 kg per hectare threshold and to reallocate resources accordingly.

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Appendices

7. Appendix: Construction of the theoretical model

The theoretical model that serves as the basis for our study is part of the microeconomic analysis of agricultural production decisions and is based on the theory of the behaviour of the agricultural producer under constraints. This model analyzes the probability of a female farmer achieving a high level of productivity based on her individual characteristics, resource endowments, and institutional environment.

7.1. Theoretical framework: agricultural production function

According to the literature on agricultural productivity in sub-Saharan Africa (Yaketé-Wetonnoubena & Mbétid-Bessane, 2019; Doss, 2014), we consider that a farmer i has a Cobb-Douglas-type production function which is written:

$$Q_i = A_i . K_i^{\alpha} . L_i^{\beta} . H_i^{\gamma} \quad \text{(A.1)}$$

Where :

- Q_i represents the agricultural production of the farmer i
- A_i is a farmer-specific factor of total factor productivity i
- K_i is the stock of physical capital (tools, equipment)
- L_i is available labour (measured by household size)
- H_i is the stock of human capital (education, experience)
- α, β, γ are the respective factor elasticities of output

The total productivity factor Ai is not directly observable and depends on several contextual and institutional factors:

$$LnA_i = \theta_0 + \theta_1 Group_i + \theta_2\ Entec_i + \theta_3\ Prac_i + \theta_4\ Coe_i + £_i \quad \text{(A.2)}$$

Where :

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- $Group_i$ captures the effect of belonging to an agricultural group
- $Entec_i$ represents access to technical support
- $Prac_i$ reflects the cultivation practice (harness farming)
- Coe_i indicates the presence of a co-wife
- $£_i$ is a random error term

7.2. Productivity Specification

The agricultural productivity (yield per unit area) of the farmer i is written:

$$Y_i = {}^{Q_i}/_{S_i} \quad \text{(A.3)}$$

Where S_i is the area cultivated by the farmer i in hectares.

Substituting (A.1) into (A.3) and taking the logarithms:

$$\ln(Y_i) = \ln(A_i) + \alpha \ln(K_i) + \beta \ln(L_i) + \gamma \ln(H_i) - \ln(S_i) \quad \text{(A.4)}$$

By replacing $\ln(A_i)$ by its expression (A.2) :

$$\ln(Y_i) = \theta_0 + \alpha \ln(K_i) + \beta \ln(L_i) + \gamma \ln(H_i) + \theta_1 Group_i + \theta_2\ Entec_i + \theta_3\ Prac_i + \theta_4\ Coe_i - \ln(S_i)\ + £_i \quad \text{(A.5)}$$

7.3. Latent variable and binary choice model

In our context, productivity is not observed continuously but in binary form: a farmer is considered to have high productivity if her yield is greater than or equal to a critical threshold y* (650 kg/ha in our case), and low productivity otherwise.

We define a latent (unobserved) variable Yi* that represents the propensity of farmer i to achieve a high level of productivity:

$$Y_i^* = X_i'\beta + U_i \quad \text{(A.6)}$$

Where:

- X_i is a vector of explanatory variables including the characteristics of the farmer (NINS, AGE, EXP), her factor endowments (Tle, Dpiv, Prac), her institutional environment (Group, Entec) and her family situation (coe, Stam)
- β is a vector of parameters to be estimated
- U_I is a random error term

The observed variable is defined by:

$Y_i = 1$ si $Y_i^* \geq 0$ (high productivity) $Y_i = 0$ si $Y_i^* < 0$ (low productivity) (A.7)

7.4. Specifying the Binary Logit Model

Assuming that the error term ui follows a logistic distribution, the probability that farmer i has high productivity is written:

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$P(Y_i = 1 \ / X_i) \ = \ P(Y_i^* \geq 0 \ / X_i) \ = P(X_i'\beta + U_i \geq 0) \ = P(U_i \ \geq \ - X_i'\beta) = 1 - F(-X_i'\beta) =$
$\mathrm{F}(X_i'\beta)$ (A.8)

Where F(.) is the distribution function of the logistic distribution:

$$F(Z) = \frac{exp(z)}{[1+exp(z)]} = \frac{1}{[1+exp(-z)]} \quad \text{(A.9)}$$

Where from :

$$P(Y_i = 1 \ / \ X_i \ ) \ = \exp(\ X_i'\beta \ ) \ / \ [\ 1 + \exp(X_i'\beta)] \quad \text{(A.10)}$$

And therefore:

$$P(Y_i = 0 \ / \ X_i \ ) \ = 1/ \ \ [\ 1 + \exp(X_i'\beta)] \quad \text{(A.11)}$$

The odds ratio is written:

$$P(Y_i = 1 \ / \ X_i \ ) \ / P(Y_i = 0 \ / \ X_i \ ) = \ \exp(X_i'\beta) \quad \text{(A.12)}$$

Taking the natural logarithm, we obtain the logit model in its linear form:

$$\ln[P(Y_i = 1 \ / \ X_i \ ) \ / P(Y_i = 0 \ / \ X_i \ )] = \ X_i'\beta \quad \text{(A.13)}$$

This expression represents the logit or log-odds of the probability of having high productivity.

7.5. Empirical specification

The empirical model estimated in our study is explicitly written:

$$\ln[\frac{P(Y_i=1)}{P(Y_i=0}] = C + \alpha_1 \ Age + \alpha_2 \ N\text{-}ins + \alpha_3 \ Tle + \alpha_4 \ Stam + \alpha_5 \ Group + \alpha_6 \ Prac + \alpha_7 \ Pluv + \alpha_8 \ ONG + \alpha_9 \ Exp + \alpha_{10} \ Entec + \alpha_{11} \ Coe + \alpha_{12} \ Dpiv + £_i$$

7.6. Assumptions about the signs of the coefficients

On the basis of the theoretical and empirical literature (Becker, 1964; Doss, 2014; Yaketé-Wetonnoubena & Mbétid-Bessane, 2019; Araujo et al., 1999), we formulate the following hypotheses:

Variable	Expected sign	Theoretical justification
NINS	β2 > 0	Human Capital Theory: Education Improves Capacity for Adoption of Innovations
Tle	β3 > 0	More family labour increases production
Group	β5 > 0	Easier access to inputs, information, credit via collective organizations
Prac	β6 > 0	Harness farming improves labour productivity and extends cultivated areas
EXP	β9 > 0	Experience allows a better mastery of techniques and adaptation to hazards
Entec	β10 > 0	Technical coaching facilitates the adoption of best practices
Dpiv	β12 > 0	Investment in physical capital improves productive capacity
Coe	β11 < 0	Polygamy reduces access to resources and increases domestic burden

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7.7. Estimation Methodology

The model is estimated by the maximum likelihood method. The likelihood function is written:

$$L(\beta) = \prod_{i=1}^{n}[F(X_i'\beta)]Y_i \times 1 - X_i'\beta \quad \text{(A.15)}$$

The corresponding log-likelihood is :

$$\ln L(\beta) = \sum_{i=1}^{n}[Y_i \ln F(X_i'\beta) + (1 - Y_i)\ln(1 - F(X_i'\beta))] \quad \text{(A.16)}$$

Maximum likelihood estimators β are obtained by maximizing this function, which requires numerical resolution by iterative algorithms (Newton-Raphson, BFGS).

7.8. Interpretation of the coefficients

In the logit model, the βj coefficients are not directly interpreted as marginal effects. There are three possible interpretations:

a) Effect on log-odds:

$$\partial[\ln(\frac{P}{(1-P)})] / \partial X_j = \beta_j \quad \text{(A.17)}$$

b) Odds ratio :

$$OR_j = exp(\beta_j) \quad \text{(A.18)}$$

An odds ratio greater than 1 indicates that the variable increases the probability of high productivity, while an odds ratio less than 1 indicates a reduction in this probability.

c) Medium marginal effect:

$$\partial \mathrm{P}(\mathrm{Y} = 1|\mathrm{X}) / \partial \mathrm{X}_j = \beta_j \times \mathrm{F}(X_\beta^{'}) \times [1 - \mathrm{F}(X_\beta^{'})] \quad \text{(A.19)}$$

This effect depends on the level of the other variables and must be evaluated at specific values (usually the mean of the sample).

7.9. Model Fit Quality

The quality of the model is assessed by several indicators:

a) McFadden's Pseudo-R² :

$$\mathrm{R}^2\mathrm{McFadden} = 1 - (\ln Lcomplet / \ln Lcontraint) \quad \text{(A.20)}$$

b) Cox et Snell Pseudo-R² :

$$\mathrm{R}^2\mathrm{CS} = 1 - [\mathrm{Lcontraint} / \mathrm{Lcomplet}]\ 2/\mathrm{N} \quad \text{(A.21)}$$

c) Nagelkerke's Pseudo-R²:

$$R^2N = R^2CS/[1 - Lcontraint\frac{2}{N}] \quad \text{(A.22)}$$

d) LR test :

$$LR = -2(\ln Lcontraint - \ln Lcomplet) \sim X^2(k) \quad \text{(A.23)}$$

Where k is the number of explanatory variables.

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e) Correct prediction rate :

Calculated by comparing the predicted values ($\hat{Y}$= 1 si $\hat{P}_i$ > 0,5) to the observed values (Y_i).

In our study, the model has a Nagelkerke R² of 0.472 and a correct prediction rate of 72.5%, which indicates a good fit to the observed data and a satisfactory predictive ability.