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# Differences in Agricultural Productivity Among Women and Men on Small-Scale Farms in Senegal: Contributions of Agricultural Innovations

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**Abstract**

This study aims to measure the contribution of technological innovations in gender gaps in agricultural productivity in Senegal. This study uses data from the 2018 Annual Agricultural Survey (AAS) conducted under the FAO Integrated Agricultural Survey Program (AGRISurvey). Using the Kitagawa-Oaxaca-Blinder decomposition method, results indicated a 69.6% productivity gap between plots managed by men and those managed by women, with plots managed by women on average more productive than those managed by men. There are two main reasons for this unexpected result. First, women on average cultivate much smaller plots of land, with higher production per hectare cultivated. Second, rainfed rice, which is considered a women's crop, is a highly productive crop that is often grown on very small plots, especially in southern Senegal and has much higher productivity among women than men. 85.5% of the overall productivity gap observed is explained by endowment effects: characteristics of the plot managers and the plots themselves, and unequal access to resources across women and men. The adoption of certified seeds and the use of chemical fertilizers (NPK, urea, and phosphate) were agricultural innovations associated with the gender productivity gap. The use of certified seeds, fertilizers, and motorized equipment during soil preparation and harvesting are all positively associated with increased agricultural productivity among women and men. Findings suggest increasing women's access to land and technological innovations could further unleash the productivity potential of Senegalese agriculture.

**Keywords:** productivity, agriculture, gender, innovation, Senegal

**Code JEL:** D24, J16, Q16

## 1. Introduction

In Africa, agriculture constitutes the main source of income for much of the population (Ken et al., 2016). Thus, the development of the agricultural sector occupies an important place both for policymakers and analysts on the continent. In 2014, Senegal adopted the Plan Senegal Emergent (PSE), whose first axis aims at the structural transformation of the economy. This transformation involves the development of agriculture, fisheries, and the agri-food industry, by developing competitive integrated sectors with high added value and intensified production. Aware that these development objectives of the PSE cannot be achieved without eliminating gender disparities, the Government of Senegal has adopted a national Gender Equity and Equality Strategy (SNEEG), one of the objectives of which is to create an institutional and socio-economic environment conducive to gender equality.

Despite this political will, gender disparities remain in the agricultural sector. Indeed, Senegalese agriculture, which employs more than 60% of the rural population, contributed only 15% of GDP in 2018. Heavily dependent on rainfall, the agricultural sub-sector accounts for 9.4% of GDP and 62.8% of the value-added (VA) of the primary sector (ANSD, 2020). This poor performance can be explained in part by the sector's low productivity. Indeed, the use of modern production technologies remains very low for both women and men

(FAO, 2015). According to Diagne (2013), Senegalese agriculture is marked by both low and fluctuating growth due to inefficient public resource allocation and low factor productivity. The level of mechanization in agriculture remains very low, with motorized equipment rarely used (3% of plots) and primarily used among men for soil preparation (EAA, 2020).

Agricultural policies, from the Loi d'Orientation Agro-Sylvo-Pastorale (LOASP) through the Stratégie Nationale de Sécurité Alimentaire et de Résilience (SNSAR), to the Programme d'Accélération de la Cadence de l'Agriculture Sénégalaise (PRACAS) the Lettre de Politique Sectorielle de Développement de l'Agriculture (LPSDA) and the Programme National d'Investissement Agricole pour la Sécurité Alimentaire et la Nutrition (PNIASAN), all aim to achieve food and nutrition security and reduce poverty, but few policies have integrated gender into their goals and objectives (FAO, 2018). In 2015, 80.7% of plots in Senegal were farmed by men compared to only 19.3% by women in 2015 (EAA, 2020). It is widely accepted that reducing gender inequalities in Africa can significantly improve agricultural production and reduce poverty (FAO, 2011).

The literature on the differences in agricultural productivity between women and men is quite extensive. However, few works focus on the role of innovation in gender gaps in agricultural productivity. According to Njikam et al. (2019), differences in endowments across women and men include access to land and agricultural inputs, tenure security and related investments in land, improved technologies, and access to market and credit (Peterman et al., 2011; Croppenstedt et al., 2013).

Studies assessing differences across women and men in agricultural productivity conduct the analysis either at the household or plot level (Njikam et al., 2019). Previous studies at the household level use a dummy variable with the gender of the household head as a gender indicator (see *e.g.*, Chavas et al., 2005; Horell & Krishnan, 2007). The main limitation of this work is that the use of the head of household as a gender indicator does not indicate who conducts the agricultural activities and who makes the decisions in these activities, but simply indicates the gender of the head of the household. Other works (Kilic et al., 2015; Oseni et al., 2015; Arturo et al., 2014; Njikam et al., 2019; Nkamuke et al., 2020) have corrected this limitation by using the gender of the plot manager as a gender indicator. Using the Oaxaca-Blinder (1973) decomposition method, such studies have examined the agricultural productivity gap and some of the sources of this gap in the African context. Most have shown that plots are managed by men (Njikam et al., 2019; Arturo et al., 2014; Yetna & Mc Gee, 2015) or households headed by men (Horell & Krishnan, 2007; Donald et al., 2020) are more productive than those headed by women.

In Senegal, the literature on agricultural productivity is quite extensive (Diagne et al., 2007; Diagne, 2013; Diop, 2020; Ndiaye & Kabou, 2021; Gueye, 2021). Much of the existing work on the Senegalese agricultural sector focuses on the efficiency of public spending (Diagne, 2013), the impact of trade reforms (Diagne et al., 2007), technical efficiency, or the productivity of a particular commodity chain (Gueye, 2021; Ndiaye & Kabou, 2021; Diop, 2020). For example, Ndiaye and Kabou (2021) analyze the impact of the adoption of new rice technologies on the technical efficiency of farmers in Senegal. Diop (2020) examines agri-food innovation in the mango sector in Senegal but doesn't control gender and innovation.

Despite the importance of this work, important gaps remain in understanding the roles of technology in increasing agricultural productivity, as well as gender gaps in technology use and production outcomes. This paper seeks to help fill this gap by responding to the following questions:

- ✓ What is the gender gap in agricultural productivity in Senegal?
- ✓ What is the contribution of agricultural innovations to the productivity of plots managed by women and men in Senegal?
- ✓ What are the explanatory factors associated with agricultural productivity in Senegal by gender?

Through these research questions, this study aims to fill gaps in the literature on agricultural productivity and identify policy levers to increase agricultural productivity and improve decision making within the framework of the National Agricultural Investment Program for Food Security and Nutrition (PNIASAN) in Senegal. It will provide the necessary context to decision-makers on the extent of gender disparities in technology adoption and productivity, enabling them to better formulate policies that support farm households. This research addresses gender mainstreaming policies and the focal areas of the PNIASAN, particularly the fourth, which aims to improve the productivity of strategic and promising sectors.

The remainder of the paper proceeds as follows. Section 2 provides an overview of the theoretical background; Section 3 presents the data from the 2018 Annual Agricultural Survey (AAS) and Section 4 introduces the methodology used in the analysis. Results are summarized in Section 5, and Section 6 concludes and provides policy recommendations.

## 2. Background

The literature on gendered differences in agricultural productivity highlights several key barriers that women face, including barriers in access to land agricultural inputs, and to technologies that contribute to productivity gaps. Njikam et al. (2019) find endowment differences explain the productivity gap in Cameroon, including differences in access to land, innovations, credit, and market and agricultural inputs (see notably Petermann et al., 2011; Croppenstedt et al., 2013). In addition, the difference between plot manager characteristics (Aguilar et al., 2015), plot characteristics (Donald et al., 2020), and locality-specific fixed effects (Njikam et al., 2019) may help explain the gender productivity disparity. This study focuses on the association between innovation and productivity but also examines the contribution of innovations to productivity gaps.

Innovation can explain gender gaps in agricultural productivity to the extent that there is a difference in the level of access to and adoption of agricultural innovations across women and men. Indeed, access to new technologies is often essential for maintaining and improving agricultural productivity. However, women face gendered barriers in accessing and adopting a range of agricultural assets and technologies, from machinery and tools to fertilizers, pest control measures, and management techniques. Several studies show that adoption rates of improved seeds and fertilizers are much lower for female-headed households or plots managed by women (Doss & Morris, 2001; Aguilar et al., 2015; Njikam et al., 2019; Donald et al., 2020). And Oseni et al. (2015) in Nigeria, Kilic et al. (2015) in Malawi, Yetna and McGee (2015) in Niger, Aguilar et al. (2015) in Ethiopia, Njikam et al. (2019) in Cameroon, and Donald et al. (2020) in Cote d'Ivoire all found that men have higher agricultural productivity than women.

However, there is also a body of research that shows that women's productivity may be higher than that of men in some circumstances. Adeleke et al. (2008) found no significant difference in productivity after controlling for input use by comparing the production of female and male maize farmers in Nigeria. And Oladeebo and Fajuyigbe (2007) conducted a plot-level analysis of plot productivity across women and men in Nigeria and found that female farmers were technically more efficient than male farmers, with mean technical efficiency indices of 0.904 and 0.897 respectively (though the difference was not significant). One factor contributing to such patterns may be the fact that women cultivate plots that are much smaller compared to men, and a large body of previous scholarship on the "inverse farm size-productivity relationship" suggests the size of landholdings is negatively associated with agricultural productivity (Burke & Jayne, 2021; Savastano & Scandizzo, 2017) (Note 1).

## 3. Data

This study uses data from the 2018 Annual Agricultural Survey (AAS) conducted under the FAO Integrated Agricultural Survey (AGRISurvey) program. The AGRIS methodology was developed by the Food and Agriculture Organization of the United Nations as part of a global strategy to improve agricultural and rural microdata. The 2018 AAS covers a sample of 6,340 farm households and 16,607 plots across Senegal's 14 regions. This sample is representative at the national and departmental levels. This analysis is conducted at the plot level, so from the total sample, 10,181 plots were selected, of which 1,606 are managed by women and 8,375 by men. Figure 1 shows the distribution of average agricultural productivity by gender and by crop. The analysis shows that for rainfed rice and fonio, the plots managed by women are more productive than those managed by men. In contrast, for cash crops such as groundnuts, maize, and watermelons, plots managed by men are more productive than those managed by women.

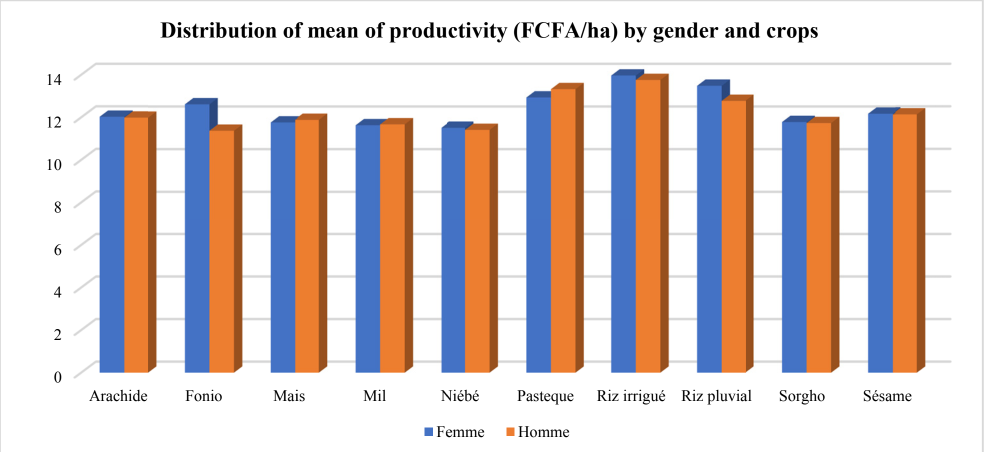


Figure 1. Distribution of mean of productivity (FCFA/ha) by gender and crops

Table 1 shows the simple averages of the overall sample, and then of the sample separated by gender of the plot manager. The level of significance of the variables is assessed by t-statistics.

Table 1. Descriptive statistics of the grouped sample and by gender of the plot manager

| | **Female plot manager** | **Male plot manager** | **Total** | **Difference Averages** | **T-statistics** |
|---|---|---|---|---|---|
| Log_productivity (FCFA/ha) | 12.376 | 11.860 | 11.933 | 0.518 | 19.323*** |
| Log production value (FCFA) | 11.456 | 11.858 | 11.801 | -0.374 | -12.181*** |
| *Characteristics of the parcel manager* | | | | | |
| Age | 42.218 | 49.020 | 48.034 | -7.235 | -19.502*** |
| Married | 0.811 | 0.924 | 0.908 | -0.107 | -13.738*** |
| Nursery/Elementary | 0.865 | 0.800 | 0.809 | 0.054 | 5.035*** |
| Secondary | 0.013 | 0.028 | 0.026 | -0.017 | -3.929*** |
| Superior | 0.002 | 0.015 | 0.013 | -0.012 | -4.246*** |
| Literacy | 0.092 | 0.184 | 0.171 | -0.087 | -8.527*** |
| Agricultural training | 0.010 | 0.033 | 0.030 | -0.022 | -4.995*** |
| *Plot characteristics* | | | | | |
| Size | 0.702 | 1.368 | 1.271 | -0.694 | -20.912*** |
| Water shortage constraint | 0.147 | 0.051 | 0.065 | 0.105 | 15.914*** |
| Phytosanitary problem | 0.036 | 0.067 | 0.063 | -0.025 | -4.153*** |
| Presence of dyke/dike | 0.220 | 0.052 | 0.076 | 0.185 | 27.212*** |
| Presence of cordon/stone | 0.008 | 0.006 | 0.006 | 0.001 | 0.315 |
| *Agricultural innovations* | | | | | |
| Certified seed | 0.164 | 0.198 | 0.191 | -0.053 | -3.884*** |
| Chemical fertilizers | 0.263 | 0.279 | 0.277 | -0.004 | -0.296 |
| Soil preparation with motorized equipment | 0.033 | 0.022 | 0.023 | 0.008 | 2.156** |
| Harvesting with motorized equipment | 0.002 | 0.004 | 0.004 | -0.005 | -2.333** |
| *Inputs* | | | | | |
| Phytosanitary product | 0.332 | 0.328 | 0.328 | 0.034 | 2.631*** |
| Quantity of seed per ha | 81.859 | 37.833 | 44.203 | 46.157 | 23.201*** |
| Seed purchased on the local market | 0.267 | 0.337 | 0.327 | -0.100 | -7.352*** |
| Natural fertilizers | 0.182 | 0.368 | 0.341 | -0.164 | -12.994*** |
| Non-certified seed | 0.726 | 0.763 | 0.756 | -0.007 | -0.500 |
| Sample | 1606 | 8575 | 10181 | 10181 | |

Overall, the results show that plots managed by women have higher agricultural productivity (measured by the logarithm of the value of output per hectare) than plots managed by men. This advantage is significant at all thresholds considered. This result can be explained in part by the fact that male-headed households farm greater areas of land and plot size (area in hectares) are negatively correlated with productivity. Another factor that accentuates the observed productivity gap in favor of women is rainfed rice cultivation, which is a self-sufficiency activity generally practiced by women on very small plots, particularly in the Ziguinchor and Sédhiou regions. Traditional rainfed rice cultivation is on average much more productive among women as opposed to men plot managers.

The descriptive statistics also reveal that men on average adopt more agricultural innovations than women. Male plot men report greater use of innovations related to the use of certified seeds, the use of chemical fertilizers, and the use of motorized equipment during the harvesting phase than their female counterparts. The only innovation that more women have adopted than men is the use of motorized equipment during soil preparation.

Regarding the other variables related to the characteristics of the farm plot manager, the results indicated that men in the sample on average are older than women (49 *vs.* 42 years). Compared to plots managed by married men, plots managed by married women are less productive. Women plot managers on average are less educated (including literacy and training) than their male counterparts. The results show a greater incidence of phytosanitary problems in plots managed by women. Also, the results reveal a larger number of stone cordons and dikes, which protect crops against rainwater damage, in Female-managed plots.

Concerning access to inputs, male-managed plots on average use a greater number of seeds per hectare than Female-managed plots. This is mainly due to the size of the plots cultivated, which is larger for men. Women plot managers use more seed from personal reserves, while their male counterparts are more likely to use seed purchased from the local market.

**4. Methodology**

The typical method for examining differences in agricultural productivity between women and men is to estimate a yield function that models the value of output per hectare as a function of a set of factors that influence production as well as an indicator of the gender of the household head or plot manager (Quisumbing, 1996). This approach can be used to determine whether differences in production observed on plots managed by women and men can be explained by factors other than gender. Following the work of Kilic et al. (2013), Oseni et al. (2015), Aguilar et al. (2015), Njikam et al. (2019), and Nkamuke et al. (2020), we use the Kitagawa-Oaxaca-Blinder (KOB) decomposition method to assess the effect of innovation on agricultural productivity and other explanatory factors of the gender productivity gap. A production function is estimated that models agricultural productivity at the plot level as a function of the gender of the plot manager and other factors that may contribute to productivity. The model is estimated as follows:

$$\ln P_{ij} = A + \alpha G_{ij} + \gamma Z_{ij} + \beta X_{ij} + \delta_j + \mu_{ij} \quad (1)$$

$\ln P_{ij}$ is the natural logarithm of the production per hectare on plot i of manager j. A is the constant. $G_{ij}$ is the dummy variable representing the gender of the manager of plot j. $\delta_j$ is a fixed effect capturing time-invariant characteristics related to manager j. $Z_{ij}$ is a vector of variables capturing the adoption of different innovations by manager j in plot i (*e.g.*, use of motorized equipment, use of certified seed and fertilizer). $X_{ij}$ is a set of explanatory variables for productivity. It includes the characteristics of the plot manager (age, education, training, marital status), the characteristics of the plot (size, types of constraints, presence of dikes), and the set of inputs used on the plot (pesticides, herbicides, manure, compost, seeds, equipment). $\mu_{ij}$ is the error term. Accounting for the gender of the head of the household, the specification is as follows:

$$\ln P_{ijM} = A + \alpha G_{ijM} + \gamma Z_{ijM} + \beta X_{ijM} + \delta_{jM} + \mu_{ijM} \quad (2)$$

$$\ln P_{ijF} = A + \alpha G_{ijF} + \gamma Z_{ijF} + \beta X_{ijF} + \delta_{jF} + \mu_{ijF} \quad (3)$$

F and M characterize the gender of the manager of plot j.

The gender of the plot manager is the variable of interest. In the first multivariate examination, a stepwise approach (including additional control variables to the model at each step) is favored, to try to explain the gender difference in productivity (Oseni et al., 2013, Njikam et al., 2019). The logic of this approach is to identify how each set of factors influences the conditional gender gap. The initial step (step zero) considers the plot manager's gender as the only variable regressed against the value of the plot harvest, with no location fixed effects or control variables. The first stage adds the variables capturing innovation. The second step includes further variables related to the characteristics of the plot manager and farm management without fixed effects. The third step includes Region fixed effects, capturing differences in cropping practices across geographies.

$$E(lnP_{ij}) = \alpha_g + E(X_g)'\beta_g \quad (4)$$

Where, g is used as a subscript to denote male (M) or female (F) plot manager. The intercept term is α. β is a vector of parameters (coefficients) corresponding to each explanatory variable in equation (1). The difference in average outcome between male and female plot managers can now be expressed as the difference between the expected harvest values per plot for each gender. The difference (*i.e.*, the difference in productivity between women and men) is:

$$Gap = E(lnP_{ijM}) - E(lnP_{ijtM}) = \alpha_M + E(X_M)'\beta_M - \alpha_F - E(X_F)'\beta_F \quad (5)$$

The harvest value per expected plot pooled ($P_{ij}$) is then:

$$E(lnP_{ij}) = \alpha + \gamma g + E(X)'\beta^* \quad (6)$$

Where, β* is the vector of non-discriminant coefficients. This is the methodology favored by Jann (2008) to obtain the non-discriminative coefficients. By including this result in the variance equation, it is possible to obtain the dual decomposition:

$$Gap = Q + U \quad (7)$$

Where, Q refers to the portion explained by group differences in the explanatory variables (Jann, 2008). Fortin et al. (2011) call it the composition effect and is equal to:

$$Q = [E(X_M)' - E(X_F)']\beta^* \quad (8)$$

According to Jann (2008), the remaining part (U) is the unexplained part and is attributed to discrimination (or performance differences).

$$U = (\alpha_M - \alpha) + [E(X_M)'(\beta_M - \beta)] + (\alpha - \alpha_F) + [E(X_F)'(\beta^* - \beta_F)] \quad (9)$$

This equation can be broken down into two distinct parts. One part quantifies the discrimination in favor of one group (or structural advantage), in this case presumed to be men:

$$Um = (\alpha_M - \alpha) + [E(X_M)'(\beta_M - \beta)] \quad (10)$$

The other part, which quantifies discrimination against (or structural disadvantage to) the other group, in this case women:

$$Uf = (\alpha-\alpha_F) + [E(X_F)'(\beta^* - (\beta_F)] \quad (11)$$

This method then makes it possible to discern the part of the gap that may be due to differences in inputs or characteristics, and the differences due to the structural effect. The structural effect allows the disaggregation of a possible advantage for men and a possible disadvantage for women. Thus, the method estimates an output structure that is not necessarily identical to that of either group (Oaxaca, 2007).

The estimation of (2) and (3) identifies the factors that explain the difference in productivity on male and female managed plots but does not isolate the relative importance of different factors. To better understand the importance of these factors, including innovation, we follow Uzoamaka et al. (2019), Kilic et al. (2013) and decompose the yield gap using the Kitagawa-Oaxaca-Blinder decomposition method as described in Kitagawa (1955), Blinder (1973) and Oaxaca (1973). This model allows us to quantify the contributions of the explanatory variables to the productivity differential of plots managed by women and men.

## 5. Results

First, the results of the estimation of the factors associated with productivity differences will be presented, followed by comments on the results of the estimates of its decomposition.

### *5.1 Factors Associated With Gender Gaps in Agricultural Productivity*

A simple ordinary least squares (OLS) regression of agricultural productivity (logarithmic value of output per hectare) on plots managed by women and men gives the following results The results are presented in Table 2. Column 1 presents the estimation results where the only regressed variable is the gender of the plot manager. Column 2 includes variables related to agricultural innovation in addition to the gender of the plot manager variable. Column 3 includes control variables such as household and plot characteristics and inputs, without controlling for fixed effects. The fourth column controls for fixed effects.

Table 2. OLS regression of household agricultural productivity (FCFA/ha) by gender of plot manager

| Dependent variable: Log_productivity (FCFA/ha) | | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **Female-managed plot** | **0.518*****(0.027) | **0.699*****(0.047) | **0.241*****(0.057) | **0.102****(0.048) |
| *Agricultural innovations* | | | | |
| Certified seed | | 0.257***(0.041) | 0.223***(0.047) | 0.100**(0.047) |
| Chemical fertilizers | | 0.362***(0.030) | 0.356***(0.025) | 0.305***(0.024) |
| Soil preparation with motorized equipment | | 0.777***(0.093) | 0.626***(0.119) | 0.450***(0.122) |
| Harvesting with motorized equipment | | 0.694***(0.222) | 0.003(0.312) | 0.108(0.318) |
| *Characteristics of the plot manager* | | | | |
| Age | | | -0.000(0.001) | 0.002*(0.001) |
| Married | | | -0.098**(0.039) | -0.143***(0.045) |
| Nursery/Elementary | | | -0.045(0.032) | -0.018(0.031) |
| Secondary | | | -0.025(0.061) | 0.057(0.053) |
| Higher education | | | -0.015(0.098) | 0.006(0.087) |
| Literacy | | | -0.109***(0.035) | -0.066*(0.033) |
| Agricultural training | | | 0.133(0.083) | 0.105(0.082) |
| *Plot characteristics* | | | | |
| Plot size | | | -0.111***(0.015) | -0.088***(0.014) |
| Water shortage constraint | | | 0.350***(0.060) | 0.321***(0.058) |
| Phytosanitary problem | | | 0.096(0.070) | 0.166**(0.065) |
| Presence of dyke/dike | | | 0.157**(0.067) | 0.206***(0.060) |
| Presence of a stone cordon | | | 0.007(0.154) | 0.101(0.190) |
| Phytosanitary product | | | -0.178***(0.024) | -0.208***(0.029) |
| *Inputs* | | | | |
| Quantity of seed | | | 0.003***(0.001) | 0.003***(0.001) |
| Seed purchased on the local market | | | 0.037(0.026) | -0.046*(0.028) |
| Natural fertilizers | | | -0.256***(0.029) | -0.226***(0.030) |
| Non-certified seed | | | -0.051(0.043) | -0.005(0.043) |
| Constant | 11.856***(0.011) | 11.841***(0.020) | 12.170***(0.102) | 11.088***(1.008) |
| **Gap (%)** | **67.86** | **101.17** | **27.25** | **10.73** |
| **Fixed effects** | **No** | **No** | **No** | **Yes** |
| **Sample** | **9908** | **4773** | 4619 | 4619 |
| **R-squared** | **0.036** | **0.161** | 0.315 | 0.477 |
| **Adjusted R-squared** | **0.036** | **0.160** | 0.312 | 0.473 |

*Note*. ***, **, * indicate statistical significance at the 1%, 5% and 10% level respectively.

The results show a productivity gap of 67.86%, without the control variables, in favor of the plots managed by women (Column 1). This gap increases by 33.31 percentage points to 101.17% (Column 2) when the variables capturing innovation, measured red by the use of the certified seed, fertilizer (NPK, urea, and phosphate), and the use of motorized equipment during different phases of the agricultural season, are controlled. The variables related to agricultural innovation are all significantly associated with agricultural productivity. This reflects the important role of innovation adoption by farmers contributing to the improvement of agricultural productivity. Agricultural innovations enable farmers to increase yields, manage inputs more efficiently, adopt new crops and production systems, improve the quality of their products, and adapt to climatic disturbances.

Furthermore, when innovation, household, and plot characteristics are introduced, without fixed effects (Column 3), Female-managed plots have a productivity difference of +27.25% compared to their male counterparts. Controlling for region-fixed effects (Column 4), the difference in productivity is still 10.73% in favor of plots managed by women. These productivity differences are all statistically significant, though the estimated agricultural productivity gap decreases substantially if fixed effects are controlled for in addition to the other variables. This is explained by the fact that male plot managers in our sample have more access to agricultural inputs, land, seeds, and other agricultural technologies, and the region fixed effects account for substantial differences in crops cultivated by women (especially rainfed rice) across regions.

*5.2 Decomposition of the Difference in Agricultural Productivity by Kitagawa-Oaxaca-Blinder Method*

The Kitagawa-Oaxaca-Blinder decomposition analysis measures the contributions of the different factors to the observed gender productivity gaps. The results are presented in Table 3.

Table 3. Decomposition of the gender gap in agricultural productivity by Kitagawa-Oaxaca-Blinder method

| **Dependent variable: log_productivity (FCFA/ha)** | | |
|---|---|---|
| | **Coefficients** | **Standard deviation** |
| **Female-managed plot** | **12.739*** ** | **(0.065)** |
| **Male-managed plot** | **12.045*** ** | **(0.013)** |
| **Difference** | **0.693*** ** | **(0.065)** |
| **Explained** | **0.591*** ** | **(0.055)** |
| **Unexplained** | **0.102** ** | **(0.044)** |
| **Explained** | | |
| *Characteristics of the plot manager* | | |
| Age | -0.008*** | (0.003) |
| Married | 0.014* | (0.007) |
| Nursery/Elementary | 0.003 | (0.004) |
| Secondary | -0.001* | (0.001) |
| Superior | 0.000 | (0.001) |
| Literacy | 0.008 | (0.006) |
| Agricultural training | -0.001 | (0.002) |
| *Plot characteristics* | | |
| Size | 0.075*** | (0.014) |
| Water shortage constraint | 0.037*** | (0.013) |
| Phytosanitary problem | -0.005* | (0.002) |
| Presence of dikes | 0.034** | (0.015) |
| Presence of a stone cordon | 0.000 | (0.000) |
| *Agricultural innovations* | | |
| Certified seed | -0.005 | (0.005) |
| Chemical fertilizers | -0.004 | (0.003) |
| Soil preparation with motorized equipment | 0.001 | (0.001) |
| Harvesting with motorized equipment | -0.000 | (0.000) |
| *Inputs* | | |
| Phytosanitary product | 0.005 | (0.008) |
| Quantity of seed per ha | 0.120** | (0.049) |
| Purchase of seeds on the local market | -0.021*** | (0.005) |
| Natural fertilizers | -0.005 | (0.007) |
| Non-certified seed | 0.000 | (0.001) |
| **Unexplained** | | |
| *Characteristics of the plot manager* | | |
| Age | 0.244*** | (0.083) |
| Married | 0.066 | (0.071) |
| Nursery/Elementary | 0.072 | (0.082) |
| Secondary | -0.003 | (0.002) |
| Superior | -0.003 | (0.002) |
| Literacy | 0.016** | (0.007) |
| Agricultural training | 0.000 | (0.001) |
| *Plot characteristics* | | |
| Size | -0.193*** | (0.046) |
| Water shortage constraint | 0.026*** | (0.009) |
| Phytosanitary problem | 0.001 | (0.005) |
| Presence of dyke/dike | -0.044* | (0.023) |
| Presence of a stone cordon | 0.005* | (0.003) |

| | | |
|---|---|---|
| *Agricultural innovations* | | |
| Certified seed | 0.054*** | (0.009) |
| Chemical fertilizers | -0.039** | (0.017) |
| Soil preparation with motorized equipment | -0.015 | (0.019) |
| Harvesting with motorized equipment | 0.002 | (0.002) |
| *Inputs* | | |
| Phytosanitary product | -0.034** | (0.017) |
| Quantity of seed per ha | 0.186** | (0.084) |
| Purchase of seeds on the local market | 0.029** | (0.014) |
| Natural fertilizers | 0.009 | (0.021) |
| Non-certified seed | 0.056 | (0.044) |
| Constant | 2.488*** | (0.131) |
| **Sample** | **4619** | |

*Note*. ***, **, * indicate statistical significance at the 1%, 5% and 10% level respectively.

The average productivity is 12.74 for the plots managed by women and 12.04 for those managed by men (Note 2). This differential is decomposed into two components: the explained component, which is the part of the gender gap due to the level of observable attributes, and the unexplained component, which is the part of the gap attributable to differences across women and men's plots in how productivity responds to various inputs and other covariates. 85.9% of the overall gap (0.599/0.697) in productivity is explained by endowment effects: plot manager characteristics, plot characteristics, and unequal access to resources. Since it is the female-managed plots that have a baseline productivity advantage, positive coefficients in the explained portion of Table 3 correspond to a larger gap and negative coefficients to a smaller gap. A difference of 10.18% in productivity across women's and men's plots remains unexplained.

Within the endowments (the "explained" component), the results show that the cultivation of a smaller total area of land is the main factor contributing to the productivity advantage of female-headed plots. This reinforces the observation from the descriptive statistics that women manage much smaller plots, which tend to be more productive. If the endowments of female-managed plots were adjusted to the same level as those of male-managed plots, women's productivity would decline – or inversely if the endowments of male-managed plots were adjusted to the same level as those of female-managed plots, we would observe higher average productivity on male-managed plots.

Concerning the variables related to agricultural innovation, it was found in the descriptive statistics that men adopt, on average, more agricultural innovations (use of certified seed, use of NPK, urea, phosphate, and use of motorized equipment during harvesting) than women and that these innovations are positively associated with agricultural productivity. By decomposing the productivity difference, the results suggest that if women and men had the same level of adoption of certified seeds and chemical fertilizers (NPK, Urea, and Phosphate), for example, then the overall productivity gap would increase by about 0.5% and 0.4% respectively (though these variables have no significant association with the explained component of the overall productivity gap across women and men). Innovations are also significantly associated with the unexplained component (potentially reflecting differences in returns to these inputs across women and men). These results show the fact that men have an advantage in the adoption of agricultural innovations narrowing the productivity gap between women and men in the sample, further underscoring the importance of innovations in agricultural productivity.

In addition, the difference in the quantity of corrected seed per hectare used by women and men and the fact that they use dikes or bunds in the plots significantly explain the gap in agricultural productivity in favor of women plot managers. On the other hand, being married, having a low level of education, having phytosanitary problems, and buying seeds on the local market significantly affect the productivity gap to the disadvantage of women.

### 5.3 Robustness Tests

One of the assumptions of the decomposition method is that omitted variable bias is not a concern. However, it is possible that some unobservable characteristics jointly determine agricultural productivity and other covariates associated with the gender of the plot manager. Given the limitations of cross-sectional data and the unavailability of a suitable instrumental variable, we follow Altonji et al. (2005) and d'Oseni et al (2013), to assess the possibility of omitted variable bias by adding other variables to the model, including fixed effects. It is expected that if the coefficients of the variables in our baseline model, including the dummy variable for gender, are unaffected, it is unlikely that unobservable characteristics not included in the model will affect our main results. Table 3 shows the results of the Oaxaca-Blinder decomposition estimates of agricultural productivity with fixed effects. Overall, the estimates are found to be consistent in terms of significance and sign across models, suggesting the robustness of our main results.

## 6. Conclusion and Policy Implications

This research is based on the 2018 Annual Agricultural Survey (AAS) in Senegal. Focusing on the agricultural productivity of female- and male-managed plots, using the Kitagawa-Oaxaca-Blinder decomposition method to assess the contributions of agricultural innovations. Agricultural innovations were measured by the adoption of certified seeds, the use of chemical fertilizers (NPK, urea, and phosphate), and the use of motorized equipment during soil preparation and harvesting.

The results of the study show that female-managed plots on average have higher agricultural productivity (measured by the log of the value of output per hectare) than male-managed plots. Cultivating a smaller total area of land is the main factor explaining the productivity advantage of female-managed plots: in our sample, men cultivate plots measuring on average 1.4 hectares, while women manage plots measuring an average of barely half that. Thus, consistent with the large literature on the inverse relationship between plot size and productivity (Kimhi, 2006; Larson et al., 2014), the results of this study found that women who manage small plots are more productive per hectare than men managing larger plots. In addition to the size of the plot, how women grow rainfed rice widens this productivity gap. Indeed, rainfed rice cultivation, which is a self-sufficiency activity, is generally practiced by women in very small plots, especially in the Ziguinchor and Sédhiou regions. Although it is traditional, rainfed rice cultivation has higher productivity among women than among men.

Moreover, the results reveal that plots managed by men more often use agricultural innovations than those managed by women. This implies that women are at a disadvantage when it comes to accessing innovations, which is an important factor that can boost their agricultural productivity. The challenge is therefore to identify the factors that promote access to agricultural innovations among women farmers. For some authors, the adoption of agricultural innovations by farmers depends on their perceptions of the technology, their experiences, their knowledge, their needs, the information available, and their socio-economic status (Kouboura et al., 2019). In addition, given that the cost of access to motorized equipment, seeds, and good quality fertilizers are high, women's lower incomes and more limited access to finance and credit make them less likely to use these innovations. Socio-economic status is a key prohibitive factor to the adoption of innovations among women in Senegal.

The results suggest that the variables capturing innovation, measured by the use of the certified seed, fertilizers (NPK, urea, and phosphate), and the use of motorized equipment during the different phases of the agricultural season, are all significantly associated with agricultural productivity. This reflects the important role of the adoption of innovations and innovative methods in improving agricultural productivity. Agricultural innovations are therefore an essential lever enabling farmers to increase their productivity.

Through the Kitagawa-Oaxaca-Blinder decomposition method, the results reveal that the average productivity (logged) is 12.74 per hectare for women and 12.04 for men, a gap of 0.70. Decomposing this gap, the results show that 85.9% of the overall productivity gap is explained by the difference in endowment effects: plot manager characteristics, plot characteristics, and unequal access to resources. The cultivation of a smaller total area of land is the main factor contributing to this productivity gap.

An interesting result of this paper concerns the contribution of agricultural innovations to the productivity gap by gender of the plot manager. Indeed, the results show that because men have an advantage in the adoption of agricultural innovations, this contributed to mitigating the productivity gap between men and women. This implies that if women and men had the same level of adoption of certified seeds and chemical fertilizers (NPK, Urea, and Phosphate), then the overall productivity gap will decrease by 0.5% and 0.4% respectively. This result further illustrates that innovation is a source of productivity growth.

The analytical framework of this paper is based on the gender of the plot manager, thus contributing valuable nuance to a body of literature that mostly focuses on the gender of the household head (who often does not decide on the management of the plot). Given that research on the same topic (agricultural productivity) in Senegal focuses more on technical efficiency and the adoption of innovations, this research also contributed to the discussion on the role of innovation in improving agricultural productivity by gender.

It should be noted this paper evaluates the contribution of innovation to agricultural productivity, and other research on the subject could evaluate the impact of these innovations. Other research could also look at the dynamics of productivity with panel data. This will require, to the extent possible, greater harmonization of agricultural surveys at the household and plot levels across years.

In terms of economic policy implications, the results suggest levers that could further stimulate agricultural productivity growth and reduce endowment access gaps between male and female farmers in Senegal. As this research shows, women's limited access to land leads them to farm in small areas. Consequently, improving land tenure systems and legislation in terms of access to land is essential to unlocking women's productivity potential. This implies the popularization of land management tools integrating gender in agricultural sectoral policies and sensitizing religious and customary leaders for better access to land for women. To achieve wide adoption of agricultural innovations among women, it is important to guarantee the availability of innovations and to increase the capacity of women to bear the cost of innovations. In this regard, the Government of Senegal can ensure availability of credit for women, flexibility in repayment of credit, encourage diversification of women's income, promote the sale of certified seeds during marketing seasons, increase fertilizer distribution points by encouraging competition. The Government could also consider subsidizing motorized equipment for women.

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**Disclaimer**



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**References**

AAS (Annual Agricultural Survey). (2020). *Annual agricultural survey report of 2017-2018, 2018-2019, and 2019-2020 conducted by the Directorate of Agricultural Forecasting Analysis and Statistics (DASPA)*.

Adeleke, O. A., Adesiyan, O. I., Olaniyi, O. A., Adelalu, K. O., & Matanmi, H. M. (2008). Gender Differentials in the Productivity of Cereal Crop Farmers: A Case Study of Maize Farmers in Oluyole Local Government Area of Oyo State. *Agricultural Journal, 3*(3), 193-98.

Aguilar, A., Carranza, E., Golstein, M., Kilic, T., & Oseni, G. (2015). Decomposition of gender differentials in agricultural productivity in Ethiopia. *Agricultural Economics, 46*, 311-334. https://doi.org/10.1111/agec.12167

Altonji, J., Elder, T., & Taber, C., (2005). Selection on observed and unobserved variables: Assessing the effectiveness of Catholic schools. *Journal of Political Economy, 113*, 151-184. https://doi.org/10.1086/426036

Blinder, A. (1973). Wage discrimination: reduced form and structural estimates. *Journal of Human Resources, 8*, 436-455. https://doi.org/10.2307/144855

Burke, W. J., & Jayne, T. S. (2021). Disparate access to quality land and fertilizers explain Malawi's gender yield gap. *Food Policy, 100*, 102002. https://doi.org/10.1016/j.foodpol.2020.102002

Croppenstedt, A., Goldstein, M., & Rosas, N., (2013). Gender and Agriculture: Inefficiencies, Segregation, and Low Productivity Traps. *The World Bank Research Observer, 28*, 79-109. https://doi.org/10.1093/wbro/lks024

Diagne, A. (2013). Public expenditure efficiency, productivity, and growth in Senegalese agriculture. *CRES research paper* (Series 2013/49).

Diop, M. N. (2020). *l'importance de l'innovation agroalimentaire en Afrique: Cas de la mangue au Sénégal.* Université du Québec à Chicoutimi, Quebec, Canada.

Donald, A., Lawin, G., & Rouanet, L. (2020). *Gender Differences in Agricultural Productivity in Côte d'Ivoire: Changes in Determinants and Distributional Composition over the Past Decade* (Working paper 9113). World Bank, Policy Research. https://doi.org/10.1596/1813-9450-9113

Doss, C. R., & Morris, M. L. (2001). Appear to be gender-linked differences in technology adoption rates. *Agricultural Economics, 25*, 27-39. https://doi.org/10.1016/S0169-5150(00)00096-7

FAO and ECOWAS Commission. (2018). *National Gender Profile of the Agriculture and Rural Development Sectors-Senegal* (p. 108). Gender Country Assessment Series, Dakar.

FAO. (2011). The role of women in agriculture: Closing the gender gap to support development. *The State of Food and Agriculture*. Rome, Italy. http://www.fao.org/docrep/013/i2050e/i2050e.pdf

Gueye, F. (2021). Analysis of the Determinants of Rice and Maize Productivity in the Southern Zone of Senegal. *Asian Journal of Agricultural Extension Economics & Sociology, 39*(1), 112-122. https://doi.org/10.9734/AJAEES/2021/v39i130514

Jann, B. (2008). The Blinder-Oaxaca decomposition for linear regression models. *The Stata Journal, 8*(4), 453-479. https://doi.org/10.1177%2F1536867X0800800401

Ken, B. J., & Ojukwu, C. (2016). *Feeding Africa: A strategy for agricultural transformation in Africa for the period 2016-2025*. Working paper, African Development Bank (AfDB).

Kilic, T., Palacios-Lopez, A., & Goldstein, M. (2013). Caught in a Productivity Trap: A Distributional Perspective on Gender Differences in Malawian Agriculture. *Policy Research Working Paper 6381.* The World Bank, Washington, D.C. https://doi.org/10.1016/j.worlddev.2014.06.017

Kitagawa, E. M. (1955). Components of a Difference between Two Rates. *Journal of the American Statistical Association, 50*(272), 1168-1194. https://doi.org/10.1080/01621459.1955.10501299

Kouboura, A., Djinadou, A., & Acacha, V. H. (2019). Perception of innovations by gender. The case of cowpea production in Benin. *Economie Rurale, 370*(2019/4), 61-80. https://doi.org/10.4000/economierurale.7251

Ndiaye, B., & Kabou, A. B. (2021). *Adoption of new rice technologies on technical efficiency in Senegal*.

Njikam, O., Elomo, T. Z., Mbengono, C. P., & Abossolo, I. (2019). The Gender Gap in Smallholder Agricultural Productivity: The Case of Cameroon. *WP Partnership for Economic Policy (PEP), No PMMA 20386.*

Nuama, E. (2010). The Technical Efficiency of Rice Producers in Côte d'Ivoire: Extension Services in Question. *Rural Economy, 316*(2), 36-47. https://doi.org/10.4000/economierurale.2598

Oaxaca, R. L. (1973). Male-Female Wage Differentials in Urban Labor Markets. *International Economic Review, 14*, 693-709. https://doi.org/10.2307/2525981

Oladeebo, J. O., & Fajuyigbe, A. A. (2007). Technical Efficiency of Men and Women Upland Rice Farmers in Osun State, Nigeria. *Journal of Human Ecology, 22*(2), 93-100. https://doi.org/10.1080/09709274.2007.11906006

Oseni, G., Corral, P., Goldstein, M., & Winters, P. (2015). Explaining gender differentials in agricultural production in Nigeria. *Agricultural Economics, 46*, 285-310. https://doi.org/10.1111/agec.12166

Peterman, A., Quisumbing, A., Behrman, J., & Nkonya, E., (2011). Understanding the complexities surrounding gender differences in agricultural productivity in Nigeria and Uganda. *Journal of Development Studies, 47*(10), 1482-1509. https://doi.org/10.1080/00220388.2010.536222

Quisumbing, A. R. (1996). Male-female differences in agricultural productivity: methodological issues and empirical evidence. *World Development, 24*(10), 1597-1595. https://doi.org/10.1016/0305-750X(96)00059-9

Savastano, S., & Scandizzo, P. L. (2017). Farm Size and Productivity: A "Direct-Inverse-Direct" Relationship. *World Bank Policy Research Working Paper No. 8127*. SSRN. https://doi.org/10.1596/1813-9450-8127

Uzoamaka, J.-N., Kehinde, O. O., Esther, N.-M., & Kai, M. (2020). Is there any gender gap in the production of legumes in Malawi? Evidence from the Oaxaca-Blinder decomposition model. *Review of Agricultural, Food, and Environmental Studies, 100*(1-4), 69-92. https://doi.org/10.1007/s41130-019-00090-y

Yetna, P. B., & McGee, K. (2015). *Gender Differentials and Agricultural Productivity in Niger* (Working Paper 7199). World Bank, Policy Research.

## Notes

Note 1. For a more comprehensive review of the literature see: Donald et al. (2020); Aguilar et al. (2015) and Njikam et al. (2019).

Note 2. Productivity is expressed as a logarithm, following Jann (2008), to obtain the percentage differences we pose: [Exp(coefficients) − 1] × 100.

## Appendix A

**Description of variables**

| Variables | Types of variables | Description of the variables and measurement |
|---|---|---|
| *Dependent variable* | | |
| Productivity | Digital | Quantity harvested in FCFA/ha |
| Gender indicator | Dummy | Gender of the plot manager 1 = Male, Female = 0 |
| *Agricultural technological innovation* | | |
| Use of chemical fertilizers | Dummy | 1 = if using NPK, or Urea or Phosphate<br>0 = No |
| Use of motorized equipment for soil preparation | Dummy | 1 = Yes<br>0 = No |
| Use of motorized harvesting equipment | Dummy | 1 = Yes<br>0 = No |
| Use of certified seed | Dummy | 1 = Yes<br>0 = No |
| *Characteristics of the plot manager* | | |
| Age | Digital | The average age of the plot manager in years |
| Married | Dummy | 1 = Yes<br>0 = No |
| Agricultural training | Dummy | 1 = Yes<br>0 = No |
| Kindergarten/Elementary | Dummy | 1 = Yes<br>0 = No |
| Secondary | Dummy | 1 = Yes<br>0 = No |
| Superior | Dummy | 1 = Yes<br>0 = No |
| Literacy | Dummy | 1 = If he/she can read or write in the local language<br>0 = No |
| *Plot characteristics* | | |
| Plot size | Digital | Area in ha |
| Phytosanitary problem | Dummy | 1 = Yes<br>2 = No |
| Water shortage constraint | Dummy | 1 = Yes<br>2 = No |
| Presence of dyke/dike | Dummy | 1 = Yes<br>2 = No |
| Presence of a stone cordon | Dummy | 1 = Yes<br>2 = No |
| *Agricultural inputs* | | |
| Quantity of seed per ha | Digital | Quantity in seed |
| Seed purchased on the local market | Dummy | 1 = Yes<br>0 = No |
| Use of natural fertilizers | Dummy | 1 = if using manure, compost, or fertilizer<br>0 = No |
| Use of plant protection products | Dummy | 1 = Yes if herbicide, fungicide, or insecticide used<br>0 = No |
| Non-certified seed | Dummy | 1 = Yes<br>0 = No |
| *Fixed Effects* | | |
| Regions | dummy | For each region |