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Agricultural sustainability promotion: Impact on rice productivity in Lower Limpopo Irrigation, Gaza, Mozambique

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ABSTRACT

Agricultural promotion seeks to strengthen family farming and boost socio-economic development in vulnerable rural communities. In the Lower Limpopo River (LLR), these initiatives have focused on transforming rice production, which is essential for local livelihoods and socio-economic development. However, the impact of these actions on the productive efficiency and sustainability of the family sector remains poorly explored. This study assessed the impact of agricultural promotion on rice productivity in the family sector of the RBL irrigated area. Data was obtained from a representative sample of 106 family rice producers, considering demographic profiles and diversified agricultural practices. Semi-structured interviews were conducted to analyze indicators such as economic income, job creation, agricultural productivity and cultivation practices. The results indicated a significant improvement in the productive efficiency and income generation of the families. Rice yields increased from 2 to 6 tons per hectare between 2016/2017 and 2020/2021. The number of workers also increased, from 17 temporary workers per hectare in 2016/2017 to 252 temporary workers and 7 permanent workers in 2020/2021. Economic revenue increased significantly, from 65,900.00 MZN (1,032.21 USD) to 91,440.00 MZN (1,432.25 USD) in the same period. The results show the potential of agricultural promotion strategies to transform family farming, promote sustainable development and improve the living conditions of small farmers. It is recommended that these practices be expanded and that public policies be implemented to ensure their long-term sustainability.

INTRODUCTION

In the face of growing global challenges such as food security, climate change, and rural poverty, family farming emerges as a pivotal approach to sustainable agricultural development. This model, deeply rooted in local knowledge and practices, plays a crucial role in preserving biodiversity, fostering economic resilience, and maintaining the social fabric of rural communities. This global relevance is particularly evident in Mozambique, where family farming has been instrumental in supporting small farmers, increasing productivity, and producing essential food crops (MOSCA, 2014; GUANZIROLI; GUANZIROLI, 2015; MARASSIRO et al., 2021). In this context, family farming constitutes a cornerstone of the national economy, employing more than 75% of the population and occupying over 95% of the arable land, primarily in plots of less than five hectares (MEDINA et al., 2015; GRAEUB et al., 2016). Beyond its economic importance, this practice contributes to creating employment opportunities in rural areas, mitigating rural exodus, and promoting social welfare (MERCANDALLI, 2018; ENCARNAÇÃO; ZWANE, 2020; MARASSIRO et al., 2021). These characteristics highlight the vital role of family farming in achieving both national and global sustainability goals.

Although the family sector accounts for approximately 25 to 30% of GDP and more than half of Mozambican export earnings (GUINA et al., 2023), its economic performance is influenced by several factors. These factors include the impacts of climate change, such as recurrent droughts and floods, difficulties in accessing rural credit for purchasing agricultural inputs and expanding cultivation areas, challenges in transporting food products from rural to urban areas, a lack of static storage capacity, and insufficient post-harvest technologies (OPITZ et al., 2016; SEARCHINGER et al., 2018; WEISS et al., 2018).

The necessity of making agriculture and smallholder food systems more nutrition-sensitive has been a pivotal subject in the post-2015 development agenda and the United Nations Sustainable Development Goals (GPAFSN, 2016; SIBHATU; QAIM, 2017). To achieve these goals, it is essential to implement measures that will stimulate economic growth, create employment opportunities, significantly reduce poverty

levels and ensure the production of sufficient food to feed families (LOKURUKA, 2020; GUINA et al., 2023).

The evidence that is currently available indicates that both the public and private sectors have significantly improved smallholder farmers' agricultural operations. The mechanization of agriculture, enhancements to agricultural extension services, ease of access to rural finance, and dissemination of innovative agricultural practices are noteworthy projects carried out by governments and partners (GRAEUB et al., 2016; MOYO, 2016). These initiatives are essential for assessing the socioeconomic viability of rural production, supporting family farm operations, and formulating plans to improve and/or protect the production process (ROEST et al., 2018; COLUCCIA et al., 2020). According to Ruben (2024), public-private cooperation is frequently a key component of successful strategies for reducing poverty among smallholder farmers, highlighting the necessity of matching support systems to the unique requirements of rural farmers.

In the Gaza province, Limpopo district, family rice farming is conducted in conjunction with a private agricultural development programme that furnishes technical assistance. The objective of this initiative is to mitigate the uncertainty faced by small-scale producers and ensure the sustainability of the local production model through the implementation of innovative production techniques. The techniques employed include the utilisation of improved seed varieties, effective pest and disease control, fertiliser application based on prior soil analysis, irrigation and soil soaking technology during land preparation. It is thus imperative to evaluate the impact of the agricultural development facilitated by the private technical assistance company on productivity and rice production within the family sector of Lower Limpopo. This data could assist in elucidating the influence of these initiatives and establishing a foundation for formulating strategies that promote a sustainable increase in family production within the Lower Limpopo region. The objective of this study was to evaluate the impact of agricultural promotion on rice productivity in the family sector of the RBL irrigated area.

MATERIAL AND METHODS

Field of study

The research was conducted at the Baixo Limpopo Irrigation Scheme in Gaza Province, Mozambique (Figure 1). Table 1 presents the geographical coordinates of the data collection points. The agro-ecological characteristics and economic infrastructure of the region under examination exert a significant influence on population distribution along the river basin. The main perennial waterway that irrigates agricultural land is the Limpopo River, which flows between 3 and 5 billion cubic meters on average each year. Small-scale agriculture is the primary source of income for the rural and resident population of the Lower Limpopo. Furthermore, the region's economy is supported by the prevalence of handicrafts and fishing. The soils in the area are typically moist, facilitating the annual production of various crops (INGC; UEM; FEWS NET, 2003). The Lower Limpopo irrigation infrastructure, established in the 1950s, was designed with the objective of transforming Gaza into a commercial agricultural center (GANHO, 2013).

A tropical climate with distinct wet and dry seasons defines the Lower Limpopo region. This climate is characterized by high temperatures and humidity, typically ranging from 25°C to 32°C throughout the year. During the rainy season, which lasts from November to April, average annual rainfall is approximately 600 mm, with about 85% of the precipitation concentrated between October and March. These rainfall levels can occasionally lead to flooding. In contrast, the dry season, extending from May to October, is marked by minimal precipitation. The variability of this climate adversely affects agricultural productivity, which is inherently susceptible to climatic factors such as floods and droughts (GPG, 2014).

Table 1. Geographic coordinates of data collection points in Lower Limpopo, Gaza-Mozambique.

Data collection sites	Geographic coordinates	
	X	Y
1	-24^0 96.68447’	33^0 58.46167’
2	-24^0 97.50373’	33^0 58.43220’
3	-24^0 98.17830’	33^0 58.46093’
4	-24^0 98.20471’	33^0 57.69710’
5	-24^0 96.65538’	33^0 57.81633’
6	-24^0 95.44310’	33^0 57.23828’

Data collection

The data collection process was designed in accordance with the statistical formula specified in Equation 1 (TORRES et al., 2006; SITOE et al., 2020), which is appropriate for finite populations. This formula was selected for its capacity to adjust the calculation in consideration of the total population size, the confidence level, the probability of success, and the margin of error, thereby ensuring the representativeness and reliability of the sample.

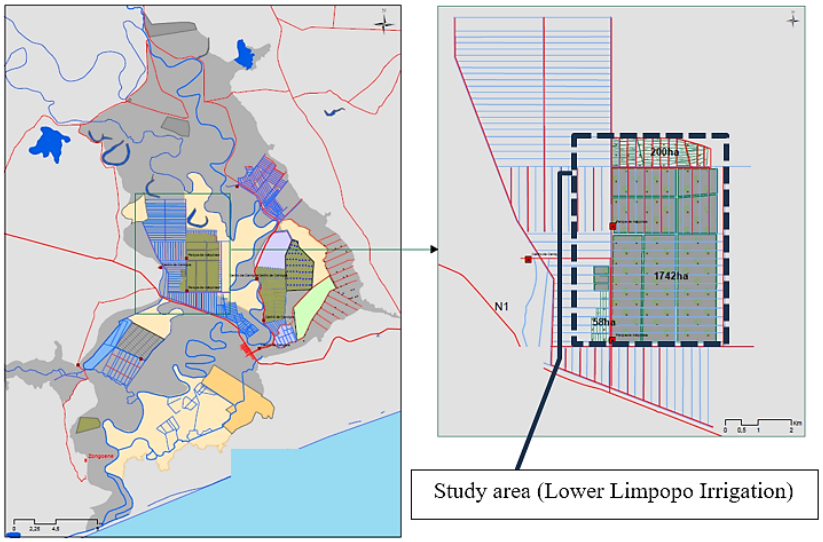

Figure 1. Geographical location map of the Baixo Limpopo Irrigation Scheme in Gaza Province, Mozambique.

$$n = \frac{Z^2 PQN}{D^2(N-1) + Z^2 PQ} \quad (1)$$

Where: N = population size, Z = 95% confidence level (Z = 1.96), P = probability of success (90%), Q = probability of failure (10%) e D = precision (5%).

The sample size comprised 106 producers, calculated to ensure representativeness and encompass the diversity of the target population, includes producers of varying farm sizes, productivity levels and participation in development initiatives. The research methodology involved semi-structured interviews with producers, complemented by direct visual observation to gain insight into local phenomena. Furthermore, the data set was augmented by secondary information sourced from the Agricultural Campaigns Register of the Gaza Provincial Directorate of Agriculture (DPASA, 2016-2020). The impact of development initiatives on family rice productivity was assessed by analyzing a number of key indicators, including:

i. Demographic Data – Collected following the methodology of Domingos et al. (2023). Information on the gender (M-male/F-female), age groups, and educational levels of family farmers engaged in rice production at RBL was recorded.

ii. Cultivation System – The assessment was based on the methodology proposed by Leite et al. (2015), with modifications. On each of the sampled properties, the producers' farming practices were visually inspected. The data was collected through questionnaires, which included assessments of the average area used for rice production, the types of farming tools employed, and the presence and functionality of irrigation and drainage systems for water management. This comprehensive approach was employed to ensure a thorough examination of cultivation practices within the region.

iii. Employment Generation – The data was obtained based on the methodology described by Barrientos-Fuentes and Torrico-Albino (2014), with some modifications. The total number of workers, including permanent and casual workers, employed by family rice producers was determined. This data was then compared with existing statistics from the Provincial Directorate of Agriculture and Food Security (DPASA) on the number of temporary and permanent workers before the intervention. This comparison makes it possible to assess the impact of agricultural development carried out by a private technical assistance company on productivity and rice production in the family sector in Lower Limpopo, with a focus on improving family rice farming systems.

iv - Rice productivity per hectare (ha) – measured as per Fageria (2007). The quantity of clean and dry grains harvested per unit area was evaluated. The Average grain yield was expressed in kilograms per hectare (kg ha^{-1}). The results were compared to DPASA database records, referring to the average rice productivity from the 2016 to 2020 agricultural campaigns.

v - Economic revenue (*RE)* – Obtained through the Equation 2.

$$RE = VA - (J + S + I) \quad (2)$$

Where: *RE:* Farmer's economic income (USD); *VA:* Value added (USD), defined as the difference between the value of production and production costs*; J:* Interest paid to the private technical assistance company (USD)*; S:* Wages paid for labor activity (USD) and *I:* Taxes and fees paid to the Lower Limpopo irrigation system for the use of irrigation water (USD).

Statistical Analysis

The data were entered into an Excel spreadsheet and analyzed using the Origin 2023b statistical software, with graphical displays produced for illustrative purposes. The normality of the productivity data (ton/ha) was assessed using the Shapiro-Wilk test, while the homogeneity of variances for the economic yield data (USD) was evaluated using Levene's test. Subsequently, an analysis of variance (ANOVA) was performed. To compare the means, the Tukey Honestly Significant Difference (HSD) test was employed, with a significance level of 5%.

RESULTS AND DISCUSSION

Demographic characteristics

A review of the data reveals a notable gender disparity in the family rice production sector within the Lower Limpopo Irrigated Region, with a higher proportion of males (56.6%) engaged in this activity compared to females (43.4%), as illustrated in Figure 2A. This inequality can be attributed to broader social concerns pertaining to the empowerment of women and the advancement of gender equality. Previous studies indicate that men are more likely to cultivate high-value crops, while women are more likely to produce food crops with lower-value products (BRAUW, 2015; NAVARRA, 2019). Balancing agricultural work with domestic responsibilities poses a significant challenge for many Mozambican women living in rural areas, limiting their ability to fully participate in the lucrative agricultural sector (O'LAUGHLIN, 2013; ARORA, 2015; STEVANO, 2022). This dual responsibility frequently constrains the advancement of women and the attainment of gender parity in rural enterprises.

To promote greater female participation in agricultural production and improve gender equality in the Lower Limpopo region, targeted interventions are essential. These should include measures to ensure equitable access to productive resources, technical training, adequate funding and social support. It is also imperative that public policies be enacted to encourage women's participation in more profitable and sustainable agricultural activities. Creating a more inclusive and equitable environment in the agricultural sector would be beneficial not only to women, but also to the wider community and the local economy in general (FAO, 2021).

The ages of farmers ranged from 20 to 81, with an estimated average age of 52±0.31 years for the group (Figure 2B). The lower representation of farmers aged over 60 (14.15%) in comparison to farmers aged between 21 and 60 (66.03%) suggests a trend towards rejuvenation in the agricultural workforce. This may indicate an adaptation to population ageing and a potential migration of younger individuals to urban areas in search of enhanced economic opportunities (FAO, 2020).

The majority of producers (66.03%) were in the most productive age group (40-60 years), suggesting that the agricultural workforce in the Lower Limpopo may be well placed to implement technological improvements and agricultural practices that increase productivity and long-term sustainability. However, it is essential to consider that an ageing workforce may encounter challenges related to physical resilience to strenuous work and adapting to new agricultural technologies (KENNY et al., 2016).

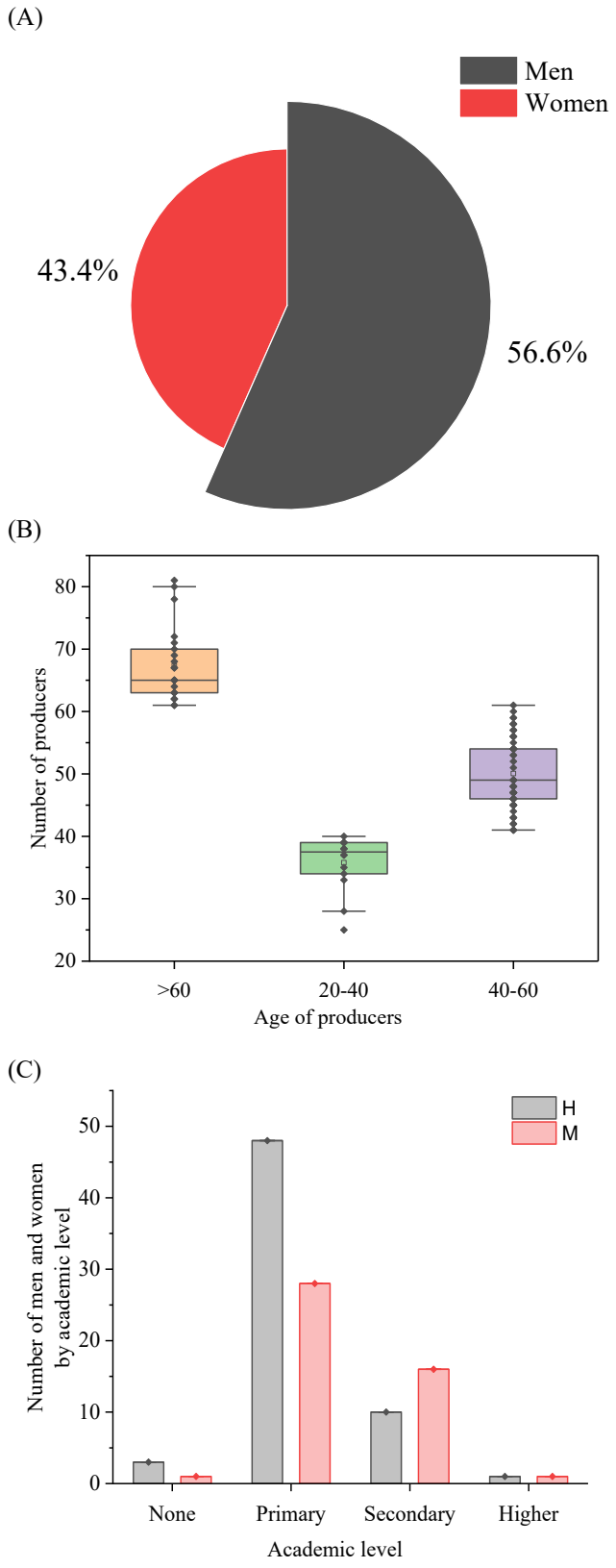

Figure 2. Demographic characteristics of family rice farmers in the Lower Limpopo irrigation system. (A) - Distribution by gender; (B) - Farmers‘ age group; (C) - Farmers’ level of education. The values refer to the 2016/2017 to 2020/2021 agricultural season.

Furthermore, most producers (71.69%) have only completed primary education, with secondary education representing the second most common level of education (Figure 2C). The relatively low level of education among these demographic groups may impede the uptake of more sophisticated and environmentally conscious agricultural techniques, as well as access to technical data and financial resources that could enhance efficiency and economic yields. Farmers must be given academic training in order to enable them to make well-informed decisions and apply innovations in the field (FAO, 2019; HANGGANA, 2024).

The results of this study indicate that there is a significant opportunity to promote female empowerment and enhance gender parity in family farming in Lower Limpopo. By addressing the structural inequalities that limit women's participation in agricultural production, it is possible to achieve more balanced and sustainable rural development, which will benefit all farmers and society in general.

Cultivation system

The cultivation of rice in the Lower Limpopo irrigation scheme (RBL) is undergoing a transition towards mechanized practices, with plots ranging from 1 to 2 hectares and an average cultivation area of 1.83±0.05 (Figure 3A-B). This transition align with Amare and Endalew (2016), who emphasize the benefits of agricultural mechanization for food security, increased productivity and job creation. Furthermore, Sims and Kienzle (2017) indicate that mechanization results in a reduction in labour costs and an increase in production efficiency. In the context of the RBL, the technical supervision of a private company, responsible for the management of tractors and self-propelled combine harvesters, has been pivotal in facilitating the expansion of cultivated areas.

The RBL's consolidation of rice production has been greatly aided by the construction of water infrastructure (Table 2). As a hygrophytic crop, rice has a high demand for water, making the implementation of efficient distribution systems that favor nutrient availability, thermoregulation and weed management essential (COVSHOFF et al., 2016; HANAFIAH et al., 2019; PRASAD et al., 2017; BHATERIA; JAIN, 2016; KOROTENKO et al., 2019; KIRKHAM, 2023). The rehabilitation and expansion of irrigation and drainage systems, undertaken with the assistance of a private technical assistance company, proved pivotal in meeting the crop's water requirements. Furthermore, these improvements prompted farmers to extend their cultivation areas, exceeding the previous average of 0.5 hectares. These developments illustrate how the integration of specialized technical assistance and robust infrastructure can facilitate the modernization of family farming, thereby promoting sustainability and productivity. The model adopted in the RBL serves to reinforce the importance of integrated strategies for agricultural development in regions with productive potential.

Creation of Job

The results show the influence of rice cultivation in the RBL on the creation of job opportunities and labor productivity. A notable increase was observed in the number of temporary jobs between the 2016/2017 and 2020/2021 cropping seasons, with a total of 160 for men and 92 for women in the latter harvest (Figure 4A). Conversely, the number of permanent jobs remained relatively limited, with a maximum of 10 for men and 2 for women in 2019/2020 (Figure 4B). These data illustrate the direct impact of the agricultural initiatives implemented, particularly with the technical assistance of the private company, which was involved at various stages of the production process.

Table 2. Distribution of rice farmers in the Lower Limpopo Irrigated Region with access to irrigation and drainage systems, by gender. The values refer to the 2016/17 to 2020/21 agricultural season.

Gender	Presence of irrigation and drainage system	Number of producers	Percentage (%)
Men	Yes	60	100
	No	-	-
Women	Yes	46	100
	No	-	-

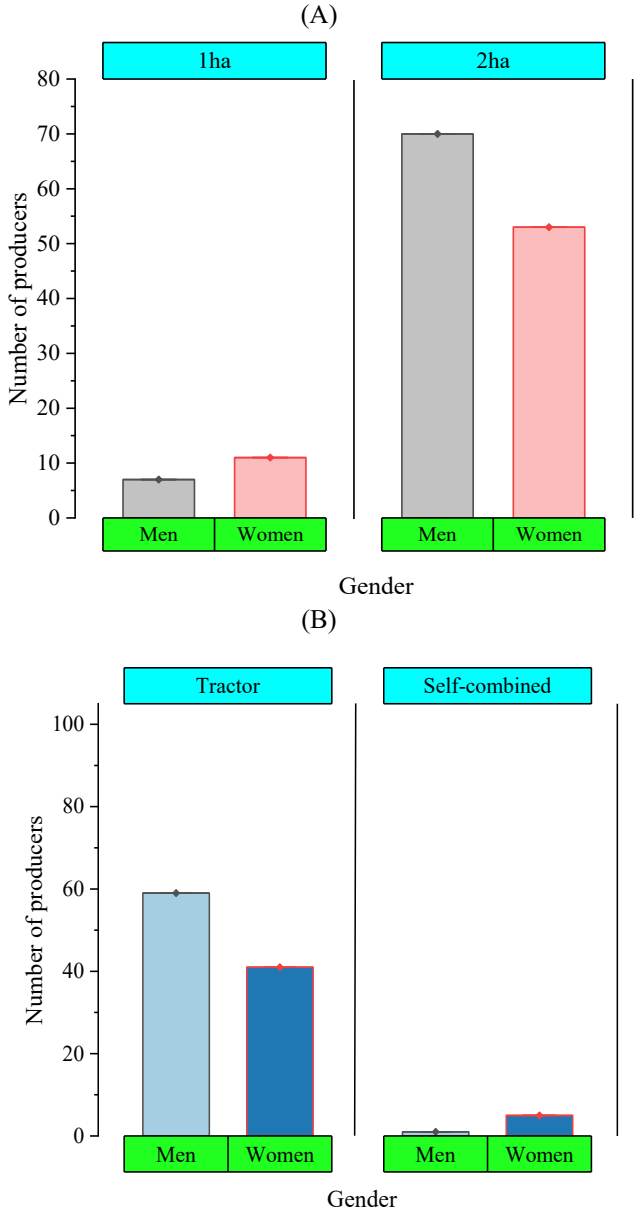

Figure 3. Size of cultivated area (A) and types of agricultural implements used in family rice production (B) in the Lower Limpopo irrigation scheme. The values refer to the 2016/2017 to 2020/2021 agricultural seasons.

França (2001) points out that agricultural activities have a high potential for job creation, with labor requirements ranging from 0.8 to 1.2 direct jobs and 1.0 to 1.2 indirect jobs per hectare of irrigated rice. The results corroborate these observations, highlighting the increased demand for seasonal labor, driven by the expansion of cultivated areas and rising production levels. This trend aligns with Suess-Reyes and Fuetsch (2016) and Hall et al. (2017), who emphasize the importance of integrated agricultural systems for generating jobs in rural areas.

Recent research has also highlighted the critical role that mechanization and effective agricultural planning play in reducing production costs and increasing labor productivity (QING et al., 2019; TENÓRIO-LIMA, 2021; MIN et al., 2021; HAMILTON et al., 2022). Mechanization in RBL has helped to lessen the need for permanent workers, but the increased reliance on seasonal labor remains problematic and could raise operating expenses. To evaluate the efficacy and sustainability of the selected model, it is imperative to conduct a comprehensive assessment of labor productivity, taking into account the correlation between the workforce size, cost per hectare and economic return.

Furthermore, one of the main factors affecting agricultural productivity has been found to be the restoration of irrigation and drainage systems, which has been a major project in the RBL. The recent literature emphasizes that the combination of adequate water infrastructure and modern technologies can significantly improve labor efficiency and increase agricultural yields (KOECH; LANGAT, 2018; SHAMDASANI, 2021; JAVAID et al., 2022). Prior restrictions, such as the average cultivation area of 0.5 hectares, have been easier to overcome with the RBL's integration of water systems and technical assistance. As a result, there is now more stability in the supply of jobs and output.

Ultimately, the discrepancies in job creation between men and women, as evidenced in the study's data, underscore the necessity for policies that foster enhanced inclusion and gender equity in agricultural activities. This aligns with the global guidelines for sustainable agricultural development, which identify female empowerment as a critical factor for rural and economic growth (FAO, 2021).

Rice productivity (ton/ha) and revenue (USD)

Table 3 illustrates the positive impact of agricultural development initiatives in the RBL, with notable increases in rice productivity (from 2 to 6 tons/ha) and sales revenue (from 1032.21 to 1432.25 US dollars) between the 2016-2017 and 2020-2021 harvests ($p<0.05$). These advances reflect the success of the technological package introduced by the private technical assistance company, which included practices such as efficient water management, adequate fertilization, high-yielding varieties and integrated weed control, as described by Pandey et al. (2016) and Tiffen (2018).

The modernization of agricultural practices has resulted in greater efficiency in the utilization of resources and an increase in labour productivity. The findings of studies such as those by Danso-Abbeam et al. (2018) and Alwarritzi et al. (2015) support the assertion that technical and organizational interventions in family farming systems significantly increase income per unit area, thereby promoting greater economic and productive resilience. Furthermore, the observed increase in income reflects the strengthening of family farming as a source of income and employment (VAN-VLIET et al., 2015; BRITO; MELLO, 2019).

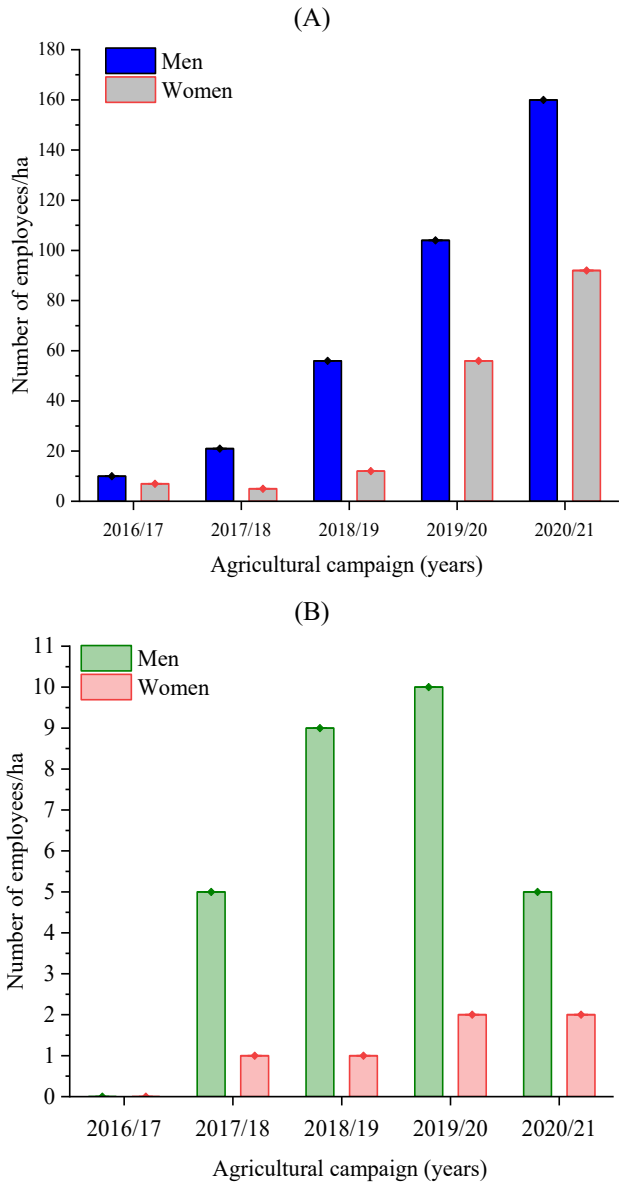

Figure 4. Number of temporary (A) and permanent (B) labourers employed in family rice production units per hectare in the Lower Limpopo Irrigated Region. The values refer to the 2016/2017 to 2020/2021 agricultural season.

The expansion of cultivated areas and the hiring of skilled labour, financed by the income obtained, demonstrate that family farming plays a pivotal role in local food security and in supplying regional markets (APPENDINI; QUIJADA, 2016; PALMIOLI et al., 2020). Wittman and Blesh (2017) and Matemilola (2017) have observed that family farming not only reduces the need for food imports, but also increases local availability, thereby contributing to socio-economic sustainability.

It is also noteworthy that the observed increase in productivity aligns with global trends towards sustainable intensification of agriculture. This underscores the significance of integrated strategies to enhance both productive and economic efficiency (RAYMOND, 2013; QIN; ZHANG, 2016). This study shows how important it is to invest in adapted technologies and technical assistance to turn small farmers into important players in rural development.

Table 3. Average rice yield (ton/ha) and economic revenue (USD) obtained by 106 family producers in the irrigated area of Lower Limpopo. The values refer to the 2016/2017 to 2020/2021 agricultural season.

Agricultural Campain	Rice yield (ton/ha)	Revenue (USD)
2016/17	2 d	1032.21 e
2017/18	3 c	1187.28 d
2018/19	4 b	1272.65 c
2019/20	4 b	1334.52 b
2020/21	6 a	1432.25 a

* Means followed by the same letter in the column do not statistically differ from each other at a 5% probability level using the Tukey test.

Future studies should investigate the potential of family production to contribute to food security, environmental sustainability and the development of other high-value crops such as maize and sugar cane, with the aim of maximising regional benefits.

CONCLUSION

The agricultural incentive to enhance rice productivity in the family sector within the Lower Limpopo irrigation scheme has yielded a notable positive outcome. Significant gains in the economic income of producers and a notable rise in rice productivity in family farming systems serve as proof of these advancements. Between the 2016/2017 and 2020/2021 agricultural seasons, there was a notable increase in productivity, rising from 2 to 6 ton/ha. This improvement can be attributed to enhancements in agricultural techniques. These developments have led to enhanced local socio-economic conditions, substantiating the efficacy of the implemented strategies.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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