The Role of Rice Cultivation in Food Security: Case Study of Senegal

A thesis submitted to the Faculty of the International Studies Program and the Economics Department in partial fulfillment of the requirements of the degrees of Bachelor of Arts

Abstract:

Using data available from the World Bank's Living Standard Measurement Study (LSMS) collected in Senegal between 2018-2019, a logit regression is used to analyze the impact of rice production on food security. Findings show that, in rural areas, households with greater rice production are less food secure. This could reflect a number of factors, including imperfect consideration of high entry risks, a decline in crop diversification, and climate change. The results of this analysis emphasize the need for further research on the microeconomic effects of cash crop policies, particularly in relation to household food security.

Keywords: Food Security, Rice, International Development, Microeconomics, Senegal

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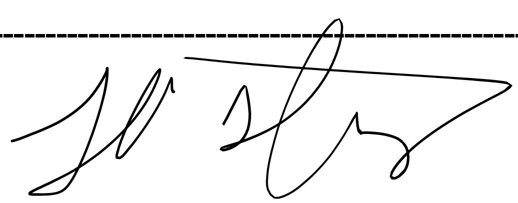
I pledge my word of honor that I have abided by the Washington College Honor Code while completing this assignment.



Chapter 1: Introduction

Globally, human population growth is expected to hit 9.6 billion by 2050 and, coupled with lower relative increases in productivity (Mensah et al. 2), economists, policy makers, and those concerned with international development are being driven to increase food production. Their goal is to avoid resource strain introduced by this mismatch; a popular solution is increasing food production so it can keep up with population growth, ensuring these rising numbers of vulnerable people are fed. Another particularly concerning facet of this trend in population growth is its concentration to globally poor areas, especially West Africa (Fuglie et al. 5), creating an urgency to identify the most efficient policies before a lack of food resources cumulates as dangerous social pressures. The development process to alleviate these pressures has already begun in West Africa, where, over the last fifty years, initiatives to increase cash crop production in rural areas have consistently attracted funding from government bureaus, non-governmental organizations (NGOs), and intergovernmental organizations (IGOs) both in the region and internationally. Food production has been a popular policy in West Africa for two main reasons: to prevent the repeat of a food supply crisis in the 1970s and 1980s caused by severe regional drought (Kago Ilboudo Nébié et al. 1) and a desire to stabilize regional prices against changes in international food product markets (Adjao 4). Both these factors are directly related to the food security of West African households, which, in the context of economic development, refers to a group's ability to obtain nourishment (United States Department of Agriculture (USDA) Economic Research Service). As population increase contributes to mounting resource pressures, the consideration of household food security must become an essential step in the process of creating efficient, successful food security policies.

Of the West African region, Senegal is a food security success story, earning the honor of being the region's greatest improvement in nutrition over the past twenty years. This can be accredited to their prioritization of food security policies in response to the aforementioned droughts of the twentieth century and their continuation of such policies into the twenty-first (Kampman et al. 57). In these policies, increasing rice production is of particular importance to the Senegalese government due to the crop's cultural significance, necessity to caloric intake (Wailes et al. 258), and contribution to the national trade deficit, as most rice is imported from Asia despite being produced locally at more affordable prices (Demont & Rizzoto 460). Thus, for those looking to advance Senegal's economic development and tackle prevalent food insecurity in rural areas, promoting local rice production kills two birds with one stone. However, simply subsidizing rice growers introduces problems, as this encourages farmers to undertake unmitigated risk (Schneider & Gugerty 2) and could attribute to a decrease in diet diversity (Smith et al. 17). Thus, it is important to analyze if rice production in rural Senegal benefits those who grow it, as predicted by food security policy implementors, or if risks overcome positive impacts and correlate to decreased food security. In literature, there is emphasis on the macroeconomic impacts of rice farming in West Africa as governments aim to become self-sufficient in the crop production to control price against international markets, balance international trade, and encourage economic growth (Boutsen & Aertsen 17). However, the microeconomic impacts of rice farming, particularly on those who participate in production, are less explored. To fill this absence, we explore here if household food security is increased through household rice production in rural Senegal to estimate the effects of participation in rice production on household food security.

In exploring this question, we use data collected via a household survey conducted in all regions of Senegal between 2018 and 2019 by the World Bank's Living Standards Measurement Study (LSMS) initiative. Measurements of household demographics and wealth were pulled to control for preexisting differences between households which might influence food security experienced, then placed in logit regression alongside a variable measuring rice growth in square meters. To provide representation of acute (FS_1), severe (FS_2), and overall food security (FS_3), we conduct three separate analyses, with demographic, wealth, and rice measurement remaining consistent between them. Our acute estimation (FS_1) represents those households which responded "yes" to the question, "In the past twelve months, have you been hungry without eating?" The more severe measurement (FS_2) represents those responding that they experienced going an entire day without eating in the past twelve months. The third analysis (FS_3) is a combination of the two for an estimate of overall food security. Using margin analysis on these results, we can interpret the correlation between each additional square meter of rice grown per household and food security experienced to estimate the microeconomic effect of rice production on food security in Senegal. We also separate households into two groups, urban and rural, and focus on the results from rural households, as urban ones are much less likely to participate in agricultural activities.

Our results found that, in the most acute food security measurement (FS_1), household rice production correlates to an increase in the likelihood of experiencing food insecurity, and results for the cumulative measurement (FS_3) concur with this finding. However, our severe measurement of food security (FS_2) did not output statistically significant results, which could be due to a decreased sample size of respondents who experienced food insecurity more severely, or because rice production only corresponds to smaller experiences of food insecurity more generally.

This study is divided into four chapters which includes this introduction but excludes our final conclusion. In the second chapter, we cover the background and theoretical framework behind measuring food security in international development research, elaborating on the four "elements" required to obtain the title of "food secure" for any human group. In the third chapter, we cover why rice production is a popular policy for those trying to improve food security and domestic economies in West Africa, briefly outlining international and domestic market contexts and the region's historical participation in rice markets. Here, we also justify narrowing our scope of analysis to a case study of Senegal-grown rice and explore some potential drawbacks to encouraging rice production amongst rural West African households. This brings us to our fourth chapter, where we analyze the LSMS data and explain in-depth the data handling, methodology, and results, ending with a discussion of why household rice production might correlate to decreased household food security. We conclude with recommendations for future studies, a brief summary of the findings, and a reminder of the importance of this study in development policies.

Chapter 2: Background & Theoretical Framework

Food Security

Food security took center stage in the world of international development after the United Nations announced its placement in the Millennium Development Goals (MDG), setting priority to halve the proportion of hungry people in the developing world by 2015. When pressures on resource supply, as introduced by this population growth, begin to threaten people's health, quality of life, and ability to contribute to economic activity, we use the term "food security" to explain the level of nutrition people can obtain. This is defined more formally by the USDA as "physical and economic access to adequate amounts of nutritious, safe, and culturally appropriate foods, which are produced in an environmentally sustainable and socially just manner, and that people are able to make informed decisions about their choices without resorting to emergency food supplies, scavenging, stealing, or other coping strategies" (United States Department of Agriculture (USDA) Economic Research Service). In contrast, economists and social scientists frequently use the term "food insecurity" to reference when people have a smaller quantity of food than is necessary for a productive and happy life.

Acknowledging food security is especially important in the context of informing domestic economic development, particularly for countries in West Africa where resource pressure is strong in the face of growing populations and impacts of climate change. However, to accurately acknowledge the presence of this issue and to properly inform policymaking decisions, it is important to establish efficient measurement methods to identify where food insecurity is at its worst. In international development literature, a popular method of quantifying food security is through household data sets (Madsen) and by observing elements including food availability, accessibility, utilization, and system stability (Mensah et al. 18) on a microeconomic level. According to the UN Food and Agriculture Organization (FAO), data on these factors is available through FAOSTAT, UNICEF, the World Bank, the World Health Organization (WHO), and a variety of other international organizations with the common goal of improving the human condition (FAO et al. 58).

To observe the first element, food availability, it is important to establish the common understanding that food availability refers to its' capacity to be produced, hence interrelated with supply (Mensah et al. 18). In West Africa, where rice is a popular food staple (Ogundari 76) supplemented by other staple crops (Mensah et al. 13), small hold, rural farmers play a large role in its' local production (Fall 13,175) and help to supplement the import market, which introduces more expensive but traditionally preferred Asian rice (Demont & Rizzoto 468). Because the role of small farmers is so great in West African food supply (Madsen), there are a variety of variables which influence the measurement of regional food availability. For example, agricultural output is dependent on farm size, climate conditions, pest and disease resistance (Tambo et al. 105), length of growing season, number of family members able to participate in cultivation processes (size of household) (Mokwena & Muzindutsi 268), irrigation capacity, and connectivity to markets (Fall 13,183). Of these variables, all correlate with food availability in West Africa in either a negative or positive fashion to contribute to changes in regional food security. It is important to acknowledge that this also includes other aspects of agriculture and food availability, such as livestock rearing (Dube et al. 110), which contributes to food security through supply of animal product including meats and dairy. However, for the purpose of this study, we will focus on crop cultivation.

The second factor influencing food security, food accessibility, refers to "the ability of people to obtain food, either through production, purchase, or transfers" (Mensah et al. 18). It is important to note that the production aspect of accessibility is touched upon above, interrelated with food availability. However, to expand this scope of analysis, we use accessibility here explicitly to measure people's ability to purchase food; it is included under the accessibility umbrella because the relationship between relative poverty and food product prices plays a role in if a group can afford to properly nourish themselves. To analyze this, we use income to observe a household's purchasing power in food markets to "obtain or access food in sufficient quantities" (Mokwena & Muzindutsi 265), but this purchasing power is interrelated with the supply of appropriate food items, as insufficient supply will drive up food prices. Here, to analyze food supply we consider variables with a positive relationship to food security and a negative relationship to food prices such as value chain efficiency (Demont & Rizzoto 458), market accessibility (Dube et al. 110), the presence of social inclusion programs with the goal of increasing food access (Khalid et al. 5), presence of substitutes for staple items, and infrastructure (Ogundari 90). As these variables increase, food prices will decrease, thus increasing food accessibility and security in the region.

The third element of food security, food utilization, refers to variables influencing nutritional value, interaction with physiological condition, and safety of products for consumption (Mensah et al. 18). This is important to analyze because, although households might have access to food, it needs to be safe to consume and culturally appropriate. For example, an average household in the United States may not know how to cook or preserve urchin effectively because it is not culturally appropriate, but if it is all they have it may be eaten regardless, increasing risk for food-related illnesses if not cooked properly. The same principle goes for households in West Africa, where food security is related to variables of utilization, which, according to Mokwena and Muzindutsi, include social relevance, usage of expiration dates, preservation practices and other storage methods, selection of food items, preparation, and final consumption. An example similar to the one given above, which applies directly to the global region of focus, is the cultural relevance of rice produced in Asia versus produced in Africa. In many West African households, imported Asian rice is preferred over that which is produced locally due to its lack of impurities and consistent grain sizes, a persisting problem in the African counterpart due to limited infrastructure and value chain capacities. This suggests that Asian rice is more socially relevant in the households which can afford its higher import prices, and that poorer households may be accustomed to cleaning the sticks and stones out of cheaper African rice as an element of food preparation (Demont & Rizzoto 460). Therefore, depending on household, food utilization differs slightly for rice consumption. Additionally, food waste rates can indicate if food is being utilized properly because it correlates with other variables, such as expiration date usage or preservation practices. Food utilization is also influenced by external issues such as availability of safe water, sanitation practices, health education, and healthcare services (Mokwena & Muzindutsi 265), because it affects the cleanliness of food consumed and treatment of food-related illness.

Food system stability refers to the ability to respond to food system emergencies (Mensah et al. 18), which will increasingly occur as climate change continues to force adaptation to warming temperatures and a growing number of natural disasters (Oyekale 320). This emphasizes its importance in the discussion of food security, especially in low-developed countries where infrastructure may not be well-enough established to withstand these pressures. Current practices in food system stability include sustainable land management (SLM), which encourages crop rotation and other sustainable farming methods to decrease soil degradation (Oyekale 320), and plant clinics to educate on irrigation and pesticide practices (Tambo et al. 98). Although system stability is difficult to measure empirically at the household level, economists can use variables related to infrastructure, technology access, and presence of safety nets to ensure connectivity between rural and urban areas remains during and after shocks and that food security is not changed by economic or natural emergencies (Mokwena & Muzindutsi 266).

To emphasize the interconnectivity of all four elements of food security—availability, accessibility, utilization, and system stability—we can observe the impacts of the COVID-19 pandemic on West African households' level of food security. According to Mokwena and Muzindutsi, "COVID-19 has disturbed the food supply chain in terms of food production, processing, distribution, and pricing," of which food production impacts availability, pricing and supply chains generally relate to accessibility, and distribution interacts with system stability. In this case, food production, distribution, and supply chains shrunk as the number of participating workers decreased with increased illness transmission, and pricing of food items rose because of their decreased quantity in the markets. All of these contributed to "increased likelihood of food insecurity in rural households," and subjected urban households to "other forms of uncertainties based on international traded commodities" (Mokwena & Muzindutsi 266), which could include the Asian rice from our utilization example. Altogether, in addition to distribution, the pandemic is an example of low food system stability in West Africa because the shock of global illness "destabilized markets and created imbalance between demand and supply of food" (Guina et al., 2021 35), ultimately demonstrating that one change to an element of food security is interconnected with others, but that as a whole they either increase or decrease food security for the region.

Chapter 3: Context of Rice in Senegal

Household Food Security and Rice

Considering this four-pronged approach to food security observation and measurement, we can take the case of one crop, rice, and analyze its role in West African food security within this context. Rice plays an important role in West African food culture, with a rich history paralleling that of modern Homo sapiens between the Senegal River and Lake Chad (Olga). It is also the core of many regional dishes, including Senegal's yassa, jollof rice from the Gambia, and maafe of Benin, indicating its importance to West African diets and culturally appropriate nutrition patterns. As mentioned by Mensah et al., this consideration of cultural relevance is a core element in the definition of food security, illuminating the relevance of using rice to demonstrate how food security is observed in West African contexts. Additionally, this definition highlights the importance of nutrition value in foods deemed culturally appropriate.

To analyze this second value in defining the ability of a product to amplify food security, it is noteworthy that several scholars find rice to be working *against* nutrition increases in the West African region. In the case of Smith et al.'s analysis on nutrition trends in West Africa, they found that diet diversity in the region has decreased in response to a historically wide variety of crop types slowly transitioning towards heterogenic crops with higher market value, including rice (Smith et al. 17). This shift in local crop production choice and an accompanying preference shift toward easy to cook, readily available staple crops such as rice is associated with increased micronutrient deficiency and other diet related diseases (Smith et al. 17). We can further accredit this decrease in diet variation to regional rice cultivation because, between 1981 and 2011, rice has accounted for the largest share in increase of staple crop production (Wailes et al. 258), indicating that many changes in the regional food market will be affected by its rise.

Despite these drawbacks to using rice in food sustainability-improvement development practices, these scholars also acknowledge its' importance in increasing regional caloric nourishment (Wailes et al. 258) through mechanisms including popularity, ease of preparation, low price, and market availability, and ultimately rice is irreplaceable in development because it is the largest source of food calories in the region (Demont et al. 578). Additionally, average energy contributed by rice between 2009 and 2013 increased from 367 to 384 kcal per capita per day, indicating that rice is a "strategic commodity to tackle food insecurity in the region" (Soullier et al. 2). Therefore, considering rice is "a necessary step toward reducing undernourishment of the (West African) population" (Wailes et al. 259), we can overlook its influence on dietary diversity for this study in consideration of its widely popular regional consumption patterns, and arguably more important influence on the rise in caloric intake. However, to please the parties most concerned with diet diversity or nutrition density in rice, some scholars propose pursuing the production of nutritionally fortified rice by adding iron, folic acid (vitamin B_9), Cobalamin (vitamin B_{12}), and vitamin A (Kraemer 72), which is already mandated for all ECOWAS nations except the Gambia in wheat flour production (Kraemer 30), proving its feasibility as a policy approach. This possibility should be explored in detail in future research.

Additionally, it is important to contextualize that domestic production, in sustainable capacities, has become increasingly relevant in food-related development efforts following the food crisis associated with the 2007-2008 economic shock, which saw imported food prices in West Africa increase to where families were unable to buy imported staple crops in sufficient quantities (Demont et al. 578). In West African rice markets, prices are especially volatile to shifts in the global economy because the region imports between 50-80% of their rice consumed (Demont et al. 579), falling only behind China in global regional rice imports (Soullier et al. 2). This could be dangerous to future food security levels because, if another global economic crisis were to occur without the region decreasing food price vulnerability, price levels may rise again, leaving families unable to afford food. Considering this, in theory, by introducing more local rice production, a repeat of the 2007-2008 food crisis may be avoided or severity of food price change may be reduced (Adjao 4) in rice markets.

Because of the aforementioned role rice plays in West African caloric nutrition and its price volatility to international economic shocks, it is used in economic development practices as a method of increasing food supply and stabilizing domestic food markets. This is seen in the presence of organizations such as the Africa Rice Center based in Côte d'Ivoire (*Africa Rice*) and the International Rice Research Institute (IRRI) who do research on the subject, and in generous grants given to improve rice production, such as the $14 million grant given to Cornell by the Adaptation Fund to improve West African rice's resilience to climate change (Ramanujan). Additionally, West African rice production is the subject of World Bank initiatives, funding from the Bill & Melinda Gates Foundation, USAID projects, and a variety of other high-profile development-oriented organizations. Their initiatives range from value chain connectivity to genetic modification of increasingly resilient rice strains and demonstrate the importance of identifying how regional food security can be most improved upon through increased household rice production.

To further narrow our scope of food security analysis, we focus on Senegal as a representative case study of the West African region, which has held food security as a "top government and regional issue since the repeated, severe droughts of the 1970s and 1980s" (Kago Ilboudo Nébié et al. 1). This prioritization of food security policy has reaped reward, resulting in Senegal now having the region's lowest rate of nutrition-related growth stunting (Kago Ilboudo Nébié et al. 1) and being cited by Kampman et al. to serve as the region's greatest domestic improvement in nutrition over the last 20 years. In the context of rice, Senegal also acts as an important rice producer, having decreased their domestic ratio of rice imports to total consumption while holding a top-three rank amongst regional rice importers (Soulliera et al. 2). This could indicate a larger increase in rice production relative to the increase in imports, a shift in preference toward domestic rice while overall consumption increases, or a mixture of other factors. However, we do know that between 2009 and 2019, Senegal has been a main contributor to the 10.1% regional annual average increase in the growth rate of rice production, with Senegal specifically growing rice production by between 9.1% and 19.4% per year (Soulliera et al. 2). Finally, considering Senegal's average annual rice consumption rate of between 50 and 90 kg per capita per year, which falls amongst median West African consumption rates (Soulliera et al. 2), and its shared use of the Senegal river basin between Mali, Mauritania, and Guinea (Kotzé 18) for rice cultivation, the country holds an important position in West African food security policies and rice production. Thus, we ask ourselves, "Is household food security increased through household rice production in Senegal?"

Chapter 4: The Case of Rice Production and Food Security in Senegal

To answer this question about rice production as a means of achieving food security in Senegal, we use the Living Standards Measurement Study (LSMS): an initiative started by the World Bank in the 1980's with the mission to "foster the development and facilitate the adoption of new methods and standards in household data collection for evidence-based policymaking" (*The World Bank).* Its cutting-edge household statistical services have increased the accessibility of detailed and accurate microeconomic data available to development policymakers and analysts by providing guidance in quality data collection to low-developed countries. Specifically, the data here is sourced from the publicly available "Enquête Harmonisée sur le Conditions de Vie des Ménages Sénégal 2018-2019" (Harmonized Survey on Households Living

Standards Senegal 2018-2019), the "first edition of a nationally representative household survey conducted within the West Africa Economic Monetary Union (WAEMU)" (WAMEU Commission 2). It covers all regions in Senegal, representing 7,100 households and all geopolitical zones. Additionally, the survey was conducted using an individual household questionnaire and a community-level questionnaire in two waves (vagues). The first wave, between September 2018 and December 2018, included the first half of the sample, and the second wave, between April 2019 and July 2019, covered the other half to "account for seasonality of consumption" across household and community levels (WAMEU Commission 2). To identify each respondent across questionnaires, each is assigned an aforementioned "vague," followed by a "grappe," and "ménage" number, which translates from French as "wave," "cluster," and "household." The first questionnaire solicited to individual households explores demographics, education, health, employment, financial status, food security and consumption, agricultural activities, wealth, and relative poverty (WAMEU Commission 4). However, for the purpose of this study, we focus on demographic information, location, food security, wealth, and agricultural activities. The second questionnaire type focuses on community identification, such as infrastructure, socioeconomic type, social participation, local pricing, and social services (WAMEU Commission 5).

Treatment of the Data

In using the data provided by LSMS Senegal 2018-2019, we focus on the first questionnaire to maintain focus on the household level of analysis. Additionally, although weights are provided by the World Bank based on household, vague, and grappe, we ignore them here for regression analysis. Including weights in regression is a debated practice amongst economists, with support in literature claiming that regressions already give more importance to some observations than others and that depending on heteroskedasticity, endogenous sampling, and heterogenous effects, weighting is often used with little rationale (Solon et al., 302). Thus, we ignore the weighted factor in our analysis of the survey presented.

Variables

i. Dependent Variables

The dependent variables in this study measures experience of food insecurity over the twelve months preceding conducting the questionnaire. The first dependent variable is if the household under observation experienced being hungry without eating, (FS_1) and the second is if the household went an entire day without eating (FS_2). Should either of these be answered with "yes," we assign their observation, β_1 or β_2 respectively, a value of 1, and should they not experience an event where they did not eat, β_1 or β_2 will equal zero accordingly. Following this, an accompanying question asks how frequently they experienced this type of food insecurity, assigning E_1 or E_2 a value associated to their frequency as an indicator of level of food insecurity. For this variable, we assign E_1 or E_2 one of four values with zero being "no experiences," one being "once or twice over twelve months," two being "some months but not every month," and three being "almost every month." Thus, we hypothesize that households experiencing a higher level of food insecurity will have a higher $\beta_1 * E_1$ and $\beta_2 * E_2$ value. In this case, the value of $\beta_1 * E_1$ gives us the value of FS_1 and $\beta_2 * E_2$ gives the value of FS_2.

Total values measuring food security will range between zero, for no food insecurity, to six, indicating maximum potential food insecurity, as FS_1 and FS_2 are added for a Total Food Insecurity Level Indicator (FILI) level (Figure 1). Accounting for the limited nature of this study, we will sort total food insecurity level indicators into two groups, assigning no food insecurity experienced to values equaling zero and food insecurity experienced to values greater than zero. Future studies should incorporate the expanded zero through six values, but due to the limited scope of this analysis we use them in a binary fashion. This limitation enables a logit regression to take place, with the final food security variable (FS_3) valuing either zero or one where zero is "in neither instance, FS_1 nor FS_2, did the household experience food insecurity" and one is "in either or both instances, FS_1 and/or FS_2, the household did experience food insecurity."

$\beta_5 E_1 = FS_1$ $\beta_6 E_2 = FS_2$ $FS_1 + FS_2$ = Total Food Insecurity Level Indicator		
Total Food Insecurity Level Indicator (FILI)	**Indicator of Food Security**	**Final Food Security Value FS_3**
0	Maximum potential for food insecurity: Perfectly food secure	0
1	Low food insecurity	1
2	Moderate-low food insecurity	1
3	Moderate food insecurity	1
4	Moderate-high food insecurity	1
5	High food insecurity	1
6	Minimum potential for food security: Perfectly food insecure	1

Figure 1: FILI Indicator

However, it is important to note that, with FS_2 representing an entire day of eating and FS_1 representing a missed meal or other instance of hunger less than or including an entire day, FS_2 includes a smaller group with a more severe experience of food insecurity. This limits the sample size, as seen in Table 1, of the group reporting FS_2's measurement of food insecurity. This could account for future insignificance in using regression analysis where FS_2 is the dependent variable and misrepresentation in FS_3 as those groups who experienced food insecurity in FS_2 could also have experienced it in FS_1, thus being counted twice. However, where we use the binary approach, the "double count" will not influence our study, but it may in non-binary approaches like the proposed FILI. Additionally in this study, for those respondents who answered, "do not know" or "refuse" to either question, the FILI will be valued outside of the $0 \leq FILI \leq 6$ bounds, so we count their data on food security as missing.

$$\beta_1 E_1 = FS_1$$
$$\beta_2 E_2 = FS_2$$
$$FS_1 + FS_2 = \text{Food Insecurity Level Indicator } (FILI)$$
$$\text{Where } FILI = 0,\ FS_3 = 0$$
$$\text{Where } 0 < FILI \leq 6,\ FS_3 = 1$$

Table 1. Summary of Dependent Variables and Measurement

Variable	Percent	n
FS1		7,118
0	80.23	
1	19.77	
FS2		7,145
0	92.18	
1	7.82	
FS3		7,018
0	79.38	
1	20.62	

ii. Independent Variables

To control for socioeconomic differences between households, we use variables including household size, the head of household's gender and education level, and the permanence of home structure materials. Household size controls for distribution of resources between household members and sources of labor and is measured as a count of the number of people, adult or child, living in each household. Information on the head of household's gender accounts for employment opportunities, assuming paid employment is more readily available to men (Sow), and alignment with the expectations of Senegalese society, considering that men are traditionally expected to be in charge of a household financially (Sow). Finally, head of household's education level further accounts for differences in socioeconomic status, on the assumption that higher education will increase food security (Sangoné 130). Here, education is observed such that those heads of household with no education are assigned one, maternelle is assigned two, primaire is assigned three, secondary general one is assigned four, secondary technical one is assigned five, secondary general two is assigned six, secondary technical is assigned seven, postsecondary is assigned eight, and above postsecondary is assigned nine. This measurement of education levels follows that of the French education system, as Senegal was colonized by France during much of the twentieth century. Reference Figure 2: *French to American Education Systems* for the American education system equivalents (Vocational Education).

	American Equivalent	French Name	Grade Level	Age
Primary School	Nursery School	Pré-maternelle	Pré-maternelle	2
	Preschool / Kindergarten	Maternelle	Petit Section	3
			Moyenne Section	4
			Grande Section	5
	Elementary School	École élémentaire	Cours préparatoire	6
			Cours élémentaire première année	7
			Cours élémentaire deuxième année	8
			Cours moyen première année	9
			Cours moyen deuxième année	10
Secondary School	Middle School	Collège	Sixième (6th Grade)	11
			Cinquième (5th Grade)	12
			Quatrième (4th Grade)	13
			Troisième (3rd Grade)	14
	High School	Lycée	Seconde (2nd Grade)	15
			Première (1st Grade)	16
			Terminale (Final)	17 - 18
Higher Education	College	Public University	Grandes écoles	

Figure 2: French to American Education Systems (Vocational Education)

A second method of controlling for socioeconomic differences between households which may relate to food insecurity experienced is their existing level of wealth, which we measure representatively using variables for the construction material of the household's walls, roof, and floor. We assume here that those homes with more wealth will have permanent features, and thus be less likely to experience food insecurity. For this variable, depending on feature observed (roof, wall, or floor), it will be assigned a value of zero or one, where zero indicates that the feature is nonpermanent and one indicates that the feature is permanent.

An essential facet of this study to acknowledge is region where the household resides, differentiating between those in rural, suburban, and urban communities. Given that urban and suburban households will be much less likely to grow crops in a significant quantity, while observing food security as influenced by rice cultivation, we must focus on the results of rural homes who will be more likely to participate in agriculture as a means of income or sustenance. In our study, we do this by separating each FS analysis in to two separate regressions, rural and suburban/urban, with the expectation that those households in rural areas growing rice will have a significant coefficient result while those in the suburban/urban grouping will not. In the LSMS data, World Bank collectors originally assign each household one of fourteen values based on their regional location, in association with those outlined by Senegal's Counseil Régional. Here, we rely on an analysis of regional poverty in Senegal by Amadou Camara to assign each of these formal regions one of our three community types: rural, suburban, or urban (Table 2).

Table 2. Senegal Region to Community Type (n = 7,156)

Region	Community Type	Percent
Dakar	Urban	14.3
Ziguinchor	Suburban	6.7
Diourbel	Suburban	7.7
Saint-Louis	Rural	7.0
Tambacounda	Rural	6.0
Kaolack	Rural	7.4
Thies	Suburban	8.0
Louga	Rural	6.7
Fatick	Rural	6.4
Kolda	Rural	6.0
Matam	Rural	5.7
Kaffrine	Rural	6.0
Kedougou	Rural	6.4
Sedhiou	Rural	5.7

The independent variables of main interest in this study are those related to rice, showing correlation between the choice to produce rice on the household level and food security experienced. Using the LSMS dataset, variables were pulled which count number of land plots owned by each household observed, the area of each plot, and the units of measurement used to estimate area in either hectares or square meters. Additionally, each respondent identified the principal crop on each plot. In order to create uniform area measurement and further organize the rice-related data, a new variable was created by multiplying the number of plots and estimated area of each, then converting all hectare measurements to square meters for uniformity.

Additionally, to focus the data available on principal crop per parcel towards those observations which concern rice, we assign rice parcels a value of 1 and all others the value 0.

However, in analyzing the quantity of rice produced by each household, we must also control for total farm size, assuming that those with larger farms may have more diversified crops, higher income, or better market connections, thus increasing food security in the home. To control for this effect, we include the total square meters of cultivated land for each household, not differentiating between principal crop grown, as an additional independent variable to be included in the final analysis. The creation of this variable follows that of the one measuring rice, multiplying number of plots by estimated area and then converting all observations measured as hectares to square meters.

Table 3. Summary of Independent Variables and Measurement

Variable	Percent	Mean	Std. Dvtn.	n
Socioeconomic Differences				
Household Size (hhsize)		9.23	5.96	7,156
Head of Household Gender (hgender)				7,156
Female	26.22			
Male	73.78			
Head of Household Education				7,157
No Education	67.53			
Primary	14.80			
Secondary	7.98			
High School	4.12			
More than High School	5.57			
Home Build Material				7,156
Roof (toit) Permanent				
No	18.01			
Yes	81.99			
Walls (mur) Permanent				
No	20.23			
Yes	79.77			
Floor (sol) Permanent				
No	25.66			
Yes	74.34			
Region				7,156
Rural	63.36			

Suburban	22.39			
Urban	14.25			
Farm				
Total Area Growing Rice (m^2)		3,063.55	95,272.83	7,118
Total Farm Area (m^2)		20,872.31	234,961.7	9,460

Results

To answer, "Is household food security increased through household rice production in Senegal?" we conduct our logit regressions and marginal analysis on $FS_{1\text{-}3}$, sorting those homes in rural or suburban/urban settings, finding coefficients and associated p-values as outlined below in Tables 4-9. To start, we hypothesize that those households which cultivate rice in rural areas are more food secure and that those who do in urban areas are insignificantly affected by their cultivation practice. We form this hypothesis for rural areas considering rice is a major source of caloric intake in West African households (Demont et al. 578), is a cultural meal staple, and is a popular tool for increasing regional food security used by international development practitioners (Ramanujan). The hypothesis that urban and suburban households are insignificantly impacted by the decision to cultivate rice cannot be rejected, given that rice has an insignificant correlation with any of the three food security measurements in these regions, and thus Tables 6-9 are included in an appendix beginning on page 37.

i. FS_1 Rural

As predicted, total farm size and presence of permanent walls have a significant (at the $P < 0.05$ level) (Table 4) and negative correlation to food insecurity, meaning that as farm size and instance of permanent walls in the home increase, food insecurity decreases. However, an unexpected outcome was that household size also has a negative correlation to food insecurity, indicating that the number of people living in the home is correlated to an increase in likelihood to be food secure. This correlation is consistent to a study done on infant mortality rate in

Senegal in 2007, where it was found that larger households have significantly higher incomes (Badji 18), which here would translate to less frequent experiences of food insecurity. This could be due to richer families in Senegal choosing to have more children, as they are financially able to care for them, or higher infant mortality rates amongst poorer households (Badji 18). Another predicted outcome in our results for FS_1 was the correlation between increasing education level for the head of household and a decrease in the likelihood to experience food insecurity. Thus, those households where the head goes to school longer are more food secure, as suggested by Sangoné in "Déterminants microéconomiques du lien entre éducation et bien-être au Sénégal." However, it is important to note that, for those respondents who had a high school education, their education did not significantly decrease their likelihood to be food secure in comparison to those with more than a high school education. This could be because of fewer employment opportunities in rural areas seeking candidates with high levels of education (Kane). Our final independent variable to discuss, aside from rice cultivation, is head of household gender, which we expected would negatively influence likelihood to experience food insecurity if the head of household was male. However, our results show that gender does not significantly influence food insecurity, which could be because of rising emphasis on gender equality in Senegalese society, politics, and international aid (Bop 61).

Our independent variable of interest, rice, has a significantly positive effect to food insecurity, which we interpret as, that for every additional square meter of rice a farmer grows, their likelihood of experiencing food insecurity increases by $5.22*(10^{-7})$, or 0.000522%, where 0% is no food insecurity and 100% is food insecurity. While this figure may seem small, it is important to remember that the average farm in our sample grows 3,063.55 square meters of rice, which magnifies this effect. The found correlation between rice cultivation in rural areas and food insecurity could be accounted to a number of factors, including imperfect consideration of high entry risks (Schneider & Gugerty 2), a decline in crop diversification (Schneider & Gugerty 7), and climate change. This is discussed in further detail in our discussion section, following FS_3.

Table 4. Summary of Logit Regression Margin Analysis Results (FS_1 Rural)
n = 2,673

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$5.22*(10^{-7})$	$2.14*(10^{-7})$	0.015
Total Farm Area (m^2)	$-5.04*(10^{-7})$	$2.08*(10^{-7})$	0.015
Household Size (hhsize)	-0.0032	0.0014	0.026
Head of Household Gender	0.0068	0.0199	0.730
Permanent Walls	-0.1223	0.0170	0.000
No Education	0.3600	0.0873	0.000
Primary Education	0.2951	0.0898	0.001
Secondary Education	0.2524	0.0954	0.008
High School	0.1789	0.1055	0.090
More than High School	Omitted	-	-

ii. FS_2 Rural

The results for our analysis of food security factor FS_2 are less favorable than that of FS_1, coming up as insignificant for the correlation between FS_2 and rice cultivation and FS_2 and total farm area (Table 5). As mentioned earlier in brief, this could be because FS_2 measures an entire day of not eating while hungry, a more severe experience of food insecurity than FS_1 or FS_3, which included missed meals as an experience. The number of respondents who did experience FS_2's measurement of food insecurity here is considerably smaller than that of FS_1 or FS_3 (Table 1), which may have resulted in our insignificant findings. Additionally, it could be true that agriculture choices in rural households do not correlate to severe cases of food insecurity in Senegal and that they do correlate with less severe cases, which should be explored further in future studies.

Our control independent variables including household size, permanent walls, and education had a similar correlation to the ones from our results for FS_1. Head of household gender still insignificantly correlated to food security, an observation also made in FS_1, which is described in further detail there.

Table 5. Summary of Logit Regression Margin Analysis Results (FS_2 Rural)
n = 2,685

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$2.25*(10^{-8})$	$6.81*(10^{-7})$	0.974
Total Farm Area (m^2)	$-2.09*(10^{-7})$	$1.51*(10^{-7})$	0.166
Household Size (hhsize)	-0.0022	0.0010	0.043
Head of Household Gender	-0.0099	0.0135	0.461
Permanent Walls	-0.0821	0.0117	0.000
No Education	0.1802	0.0821	0.028
Primary Education	0.1789	0.0830	0.031
Secondary Education	0.1651	0.0855	0.054
High School	0.1462	0.0896	0.103
More than High School	Omitted	-	-

iii. FS_3 Rural

In our analysis of correlation between rice cultivation and food insecurity as measured by FS_3, our results are consistent with those found in FS_1, turning up that rice has a significantly positive effect to food insecurity. We interpret the results from Table 6 as, that for every additional square meter of rice a farmer grows, their likelihood of experiencing food insecurity increases by $5.32*(10^{-7})$, or 0.000532%, where 0% is no food insecurity and 100% is food insecurity. Our control variables again remained constant with those from FS_1 and FS_2 and are discussed further in section i. where we observe them in the context of preexisting literature.

Table 6. Summary of Logit Regression Margin Analysis Results (FS_3 Rural)
n = 2,617

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$5.32*(10^{-7})$	$2.17*(10^{-7})$	0.014
Total Farm Area (m^2)	$-5.15*(10^{-7})$	$2.11*(10^{-7})$	0.014
Household Size (hhsize)	-0.0032	0.0014	0.022
Head of Household Gender	0.0032	0.0204	0.872

Permanent Walls	-0.1375	0.0174	0.000
No Education	0.3379	0.0811	0.000
Primary Education	0.2765	0.0839	0.001
Secondary Education	0.2405	0.0898	0.007
High School	0.1411	0.1016	0.165
More than High School	Omitted	-	-

Discussion

In returning to our hypothesis from page 21, that those households which cultivate rice in rural areas are more food secure, we can reject the null hypothesis for results FS_1 and FS_3 and accept the alternative, that those households which cultivate rice in rural areas are, in contrast, *less* food secure. We can account this association between increased rice cultivation and food insecurity to be influenced by high entry risks in the rice industry for small hold farmers (Schneider & Gugerty 2), decreasing crop diversification, and climate change's contribution to rising temperatures in the region (The World Bank), so long as we operate under the assumption that rice farmers cultivate it to participate in markets, given the product's need to be milled before safe consumption (Demont & Rizotto 2). Therefore, we do not consider factors driving the relationship between food security and rice production for those households which produce for household subsistence, as this will be uncommon practice. Regarding our results from food security measurement FS_2, we fail to reject the null hypothesis given statistically insignificant results for a correlation between rice cultivation and food security (Table 5).

Returning to discussion of FS_1 and FS_3, risks to rural farmers aiming to begin participating in rice production include forgoing production of crop for own-consumption, volatile market prices, and up-front investment, all of which require rice farmers to have sufficient liquidity before beginning to grow rice (Schneider & Gugerty 3). Given recent pushes by West African governments, IGO's, and international NGOs to increase regional rice production as a preventative response to future repetition of the 2008 food crisis (Adjao 4), it is possible many of Senegal's rice producers recently entered the market because of external incentives including subsidies, grants, and other aid availability without thoroughly analyzing availability of household finances to respond to these risks as they occur. For example, the government of Senegal's 2020-2021 Agricultural Program includes a significant portion of budget expenditures (50%) being allocated to seed subsidies, with rice being one of the listed priority crops (Osinski). While this does allow households to forgo initial investment costs of seed purchasing, it does not provide a safety net against the reallocation of land previously used for staple crops nor against changing rice market prices, which have been seen to fluctuate in relation to rice import quantities (Demont et al. 579), the current state of rice processing facilities (Mokwena & Muzindutsi 266), and presence of substitute crops (Ogundari 90). Entering rice production without the liquidity necessary to cushion against these risks could increase households' risk to experiencing food insecurity, as reflected in our results for FS_1 and FS_3. Additionally, these experiences would be magnified as households increase the quantity of land allocated to rice, given that more rice means less land where they can grow crops for self-consumption and more rice they need to sell at an unfixed price.

To elaborate, producing crops for self-consumption is commonly practiced by poorer farmers as means of filling gaps in food supply introduced by lack of market connectivity or unaffordable prices, and thus to forgo this use of the land in favor of growing a cash crop (such as rice), the cost to buy staple foods at market must be lower than the producer price (Schneider & Gugerty 2). Wealthy cash crop producers recognize this and will often produce both a cash crop and various staple crops, as they are able, to cushion for market inaccessibility or changes in staple crop price (Schneider & Gugerty 7). This diversified approach is even encouraged in some cases, with initiatives to transition small hold farmers from staple to cash crops allowing program resources to be used both for cash and staple crop production, as it has been cited to "raise farmers' ability to sustainably and profitably produce (the staple crop in question)" (Schneider & Gugerty 7). Thus, we might see in our analysis that the policies previously discussed which encourage rice production *only* encourage rice production, and not that of any other crop, which decreases farmers' incentives to diversify crops, their ability to cushion against shifts in market, and overall profitability. Therefore, it could be that, as households increase rice production, they forgo staple crop production, which decreases their overall wellbeing and accumulates as a decline in food security.

A third potential factor in driving the association between rice production and increased food insecurity could be regional manifestations of climate change, given that rice is a rain-dependent crop whose output quality is directly associated to temperature changes (Wenzhe et al.). Given the already inferior quality of African-produced rice to Asian, further decline in grain consistency, texture, and starch density could make locally grown rice even less competitive on the market. In a ten-year experiment done by Wenzhe et al, researchers found that a temperature increase of 1.6°- 3.1°C decreased the output of rice by 21%, while chalkiness increased by nearly 200%, estimating the future impact of climate change on West African rice production. However, we may already see some of these effects here, given that the ideal rice growing range is between 24 - 30°C (Nagai & Markino), and between 2018-2019, when the LSMS survey was conducted, the average temperature was 28.82°C (The World Bank). This is approaching the northern border of our "ideal temperature bandwidth," and if the increase is already leading a decline in output and quality, those households which produce rice could have seen a decline in profitability, decrease in income, and increased food insecurity, as reflected in this study. The region is also susceptible to drought, which, in the 1970s, was a major source of widespread food insecurity (Kago Ilboudo Nébié et al. 1) and could be a future issue for West African rice growers' food security rates as climate change persists. Future studies might analyze rising temperatures or drought as a more specific cause of higher food insecurity amongst households which grow more rice.

Future Studies

Given the limited nature of this study in both technical approach and applicability, the potential for future studies to expand upon this analysis has a wide range of approaches. From a technical approach, further studies could firstly conduct an ordinal logit regression analysis using the seven Total Food Insecurity Level Indicator levels, between 0 and six, as outlined in Figure 1. Additionally, further studies could use more recent data to observe the impacts of food price surges initiated by the COVID-19 pandemic and the conflict in Ukraine, both of which have driven up food prices in West Africa (Lô & Sy 26). However, given that the LSMS survey is collected in variation depending on country, and the 2018-2019 Enquête Harmonisée sur le Conditions de Vie des Ménages was the first to be conducted in Senegal, it is currently unclear when the next study will be publicly available. Finally, future studies should analyze in detail those potential factors in driving the negative correlation between food security and rice production. For example, to analyze our first and second argument, that government, IGO, and NGO programs do not properly cushion program participants for various risks, an analysis should be done analyzing correlations between those households which are participants and produce rice versus those who are not participants and produce rice.

To increase applicability, future studies may also replicate this analysis using LSMS data collected in other West African nations, such as Benin or Burkina-Faso, to approve or disprove that the results in Senegal can be used to guide food security policies regionally. Conducting the ordinal logit regression analysis will also be a method of increasing applicability as it will be more accurate than the logit regression used here. It would also be impactful for the subject of food security to explore how household production of other crops aside from rice relate to household food security levels. This could include peanut, maize, and other cash crops, or staple crops such as tomatoes, carrot, or lettuce.

Conclusion

Food policy implementation requires serious consideration of not only consequences for availability, accessibility, utilization, and system stability of food product markets, but also for these elements as seen on both macro and microeconomic levels. Although much research is available on the macroeconomic impacts of rice production policies in West Africa, the correlations between rice production and food security experienced by rice producers is less studied, so here we fill that gap using data from the World Bank's LSMS household survey in Senegal. The results of this study show that households who participate in rice production are less likely to be food secure, which could be due to high entry risk, forgoing crop use for self-sustainment, or negative impacts climate change. This has the opposite desired effect of policies in Senegal promoting rice production, of which many aim to improve domestic food security (Osinski).

Given this opposite effect, it is essential that those domestic government bureaus, NGOs, and IGOs who pursue policies promoting the production of rice in West Africa consider the microeconomic effects of rice cultivation, in addition to the already-emphasized macroeconomic outcomes. As population growth persists in West African regions, the consideration of rural households' wellbeing will become increasingly important, as their population is expected to see the largest proportional increase in poverty rates (Maitima & Gumbo 139). Additionally, each year billions of dollars are contributed to policies which encourage the growth of West African rice, and for those whose goal is to improve regional food security, it is essential they consider those households who grow the rice in their target group. Overall, these factors create an urgency for food security in West Africa, and although Senegal is a "success story" for improving their people's ability to obtain nourishment, the evidence given here shows that much more research on food security is needed to determine the best path to widespread food security in West Africa.

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Appendix

Table 7. Summary of Logit Regression Margin Analysis Results (FS_1 Suburban/Urban)

n = 2,161

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$-3.38*(10^{-6})$	$3.98*(10^{-6})$	0.396
Total Farm Area (m^2)	$-5.68*(10^{-7})$	$3.79*(10^{-7})$	0.134
Household Size (hhsize)	-0.0048	0.0014	0.001
Head of Household Gender	-0.0020	0.0135	0.882
Permanent Walls	-0.0417	0.0183	0.023
No Education	0.1315	0.0416	0.002
Primary Education	0.1552	0.0427	0.000
Secondary Education	0.0777	0.0466	0.095
High School	0.0535	0.0569	0.347
More than High School	Omitted	-	-

Table 8. Summary of Logit Regression Margin Analysis Results (FS_2 Suburban/Urban)

n = 1,897

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$-4.90*(10^{-6})$	$5.18*(10^{-6})$	0.344
Total Farm Area (m^2)	$-5.67*(10^{-7})$	$3.99*(10^{-7})$	0.156
Household Size (hhsize)	-0.0042	0.0012	0.001
Head of Household Gender	-0.0131	0.0094	0.166
Permanent Walls	-0.0367	0.0123	0.003
No Education	0.0102	0.0158	0.521
Primary Education	0.0163	0.0174	0.349
Secondary Education	Omitted	-	-
High School	Omitted	-	-
More than High School	Omitted	-	-

Table 9. Summary of Logit Regression Margin Analysis Results (FS_3 Suburban/Urban)

n = 2,151

Variable	dy/dx Coefficient	S.E.	P > | z |
Total Area Growing Rice (m^2)	$-3.86*(10^{-6})$	$4.21*(10^{-6})$	0.359
Total Farm Area (m^2)	$-6.66*(10^{-7})$	$4.00*(10^{-7})$	0.096
Household Size (hhsize)	-0.0051	0.0014	0.000
Head of Household Gender	-0.0073	0.0137	0.591
Permanent Walls	-0.0494	0.0185	0.008
No Education	0.1400	0.0430	0.001
Primary Education	0.1606	0.0441	0.000

Secondary Education	0.0862	0.0478	0.072
High School	0.0552	0.0589	0.349
More than High School	Omitted	-	-