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RICE: SEED SYSTEMS, PRODUCTION CHARACTERISTICS, AND FUNGAL INFECTIONS OF STORED GRAINS IN MAJOR PRODUCTION ZONES OF LIBERIA

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ABSTRACT
The inadequacy of information on rice farmers' situations, particularly their access to propagation materials and grain storage and the impact thereof on Liberia's food security scenario, curtails the development of strategies and interventions meant to optimize rice production. This study investigated the rice seed systems, storage methods of the harvested rice grains, and degree of fungal contamination of stored rice seeds in the major rice-producing counties of Liberia: Lofa, Bong, Montserrado, and Nimba. A mixed data collection method, comprising interviews and focus group discussions (FGDs) was adopted. Five hundred (500) farmers were purposefully selected for one-on-one interviews, and 12 FGDs were held (three in each county). The results indicated that 94.7% of farmers source seeds through informal channels. Grain for use as seed in the subsequent farming season is mainly stored in kitchen attics, a practice reported by 83.8% of the farmers, while 7.8%, 3.8%, and 4.6% of farmers stored seeds in plastic containers, nylon sacks, and jute bags, respectively. Land size was identified as the primary factor determining rice yield across the studied counties, $R2 = 0.944$, $p = 0.001$. Farmers in high-rainfall regions had a high likelihood of experiencing fungal infections on their stored grains; however, only 19.6% of farmers were aware of the health implications of consuming affected grains. Therefore, policies and support frameworks should be directed towards actualizing modern seed channels and extension services and creating awareness of the different nodes of the rice value chain.

Contribution/Originality: Liberia's poor food security status is underlined by the challenges facing rice production. This study provides new information on seed systems and their characteristics. By examining farmers' perceptions of seed sources and their impact on productivity, the study highlights farmers' awareness of several production-consumption aspects.

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1. INTRODUCTION
The lack of established formal seed systems in Liberia is a major constraint to achieving sufficient crop production, particularly rice (SDCA, 2016). The sluggish efforts in developing a supportive infrastructure and policies can be attributed to many interlocking factors, including the country's economic state, civil war, and lack of

concerted effort amongst stakeholders, such as the government, farmers, non-governmental organizations, and other stakeholders, to modernize the seed system. Currently, farmers rely on community seed systems for their planting materials and acquire them through traditional seed channels (MOA, 2014b). Seeds circulating within such channels are often of poor quality due to a decline in genetic yield potential over many years of use (Finch-Savage, 1995). The seeds and planting materials sourced through community seed systems are also highly susceptible to diseases and pests, and their tolerance to climatic and environmental stresses is usually low (McGuire & Sperling, 2016). Farmers' overreliance on such seeds has been pointed out as a significant factor contributing to the decline of crop productivity (SDCA, 2016). Rice has been the most affected crop, given that the Liberian population is highly dependent upon it as a staple food (Luther et al., 2017).

Rice (*Oryza sativa L.*) is globally the most important cereal crop in consumption and production, followed by corn and wheat (Cosslett & Cosslett, 2018). China is the leading rice producer worldwide with more than 200 million metric tons of rice grain produced in 2018 (FAOSTAT, 2020), while Nigeria leads the African continent with 6.8 million metric tons of grain rice production in 2018, followed by Egypt with 4.9 million metric tons (FAOSTAT, 2020). The consumption of rice is projected to increase due to the growing population and the effects of climate change restraining the production of alternative cereals.

In Liberia, rice is a primary preferred staple food (Hilson & Van Bockstael, 2012), depended upon by more than 80% of people (Republic of Liberia, 2019). Liberia's annual rice consumption is the highest in Africa and was estimated to be more than 140 kg per capita in 2010 (Chauhan, Jabran, & Mahajan, 2017). The crop is mainly produced by smallholder farmers scattered across the country (Ashmun, 2020). Rice cultivation in Liberia is extensive and characterized by low inputs that do not meet the essential crop requirement in terms of best agronomic practices and technical and post-harvest handling strategies. These facts translate to an annual decline in yield. For instance, in 2018, grain production was 257,995 tons produced from 238,090 hectares of land, averaging 1.083603 tons per hectare compared to Nigeria's 2.035084 tons per hectare (FAOSTAT, 2020).

In the decade since the end of the civil war (Vorrath, 2018), the area under rice production has steadily increased. Many people have taken up rice farming; the sector now employs more than 51% of the Liberian population (Knoema, 2019). In recent years, concerted efforts of the government, the World Bank, and non-governmental organizations have seen the rice sector receive support in the form of agriculture equipment and inputs such as fertilizers and improved varieties (MOA, 2014a). The efforts indicate an acknowledgment from the stakeholders of the role of rice in national food security. Nevertheless, rice production has continuously declined compared to the area under cultivation, despite the synergies created by value chain stakeholders and farmers' increased involvement (MOA, 2014a). Therefore, this study was conducted to provide critical information on rice farming and seed systems, focusing on Liberia's major rice-producing counties.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted in four counties of Liberia located in the rice agroecological zones, namely, Bong, Lofa, Montserrado, and Nimba, as illustrated in Figure 1.

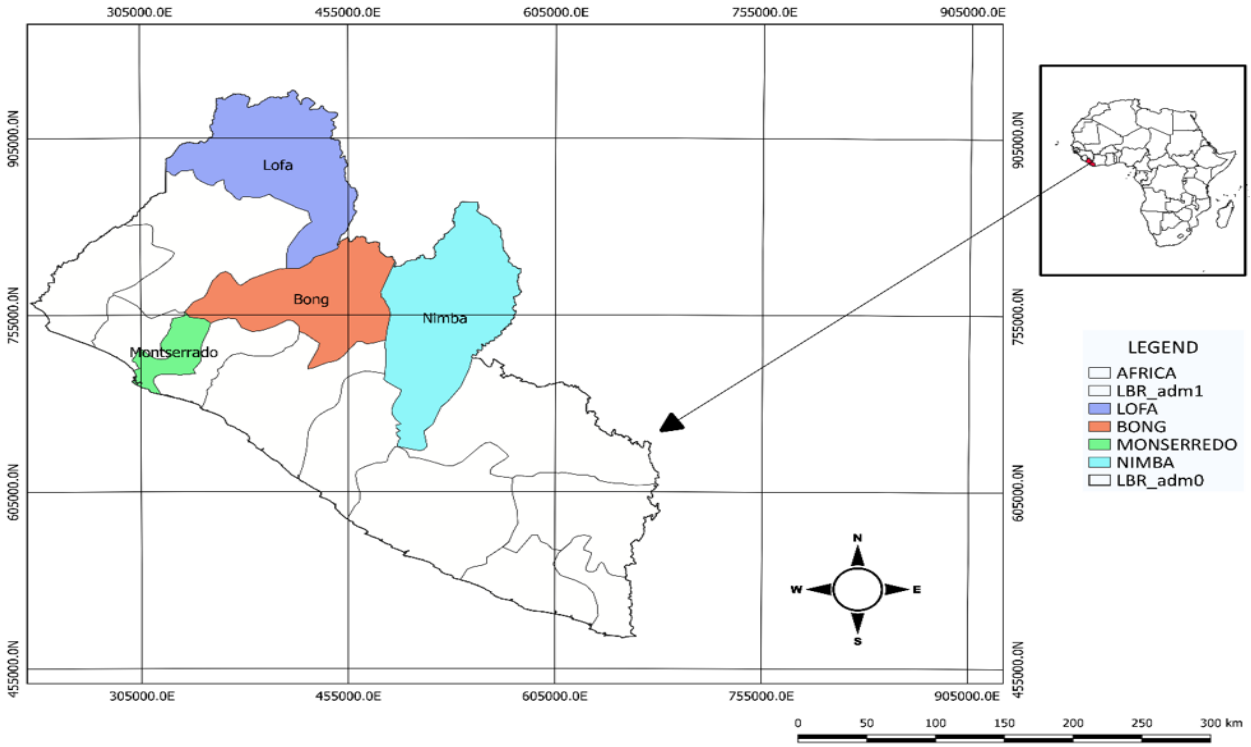

Figure 1. The four major rice-producing counties of Liberia.

Bong County is situated 8-75 meters above sea level. The county is located between 6° 24' 7" N and 7° 25' 48" N longitude and 10° 28' 34" W and 9° 5' 38" W latitude, covering an area of 11,846.931 km² (Schroth, Läderach, Martínez-Valle, & Bunn, 2015). Lofa County is categorized within two agroecological zones: upper highland tropical forest and northern savanna. It experiences bimodal rainfall seasons with an annual range of 700-2900 mm. The county's highlands support coffee and cocoa production while the lowlands produce rice, plantain, and cocoyams, among other crops (Schroth et al., 2015). Montserrado is the smallest county in Liberia, covering an area of 1,912.7 square kilometers. It is located between longitude 6° 12' 56" N and 6° 49' 57" N and between latitude 10° 48' 48" W and 10° 12' 0" W (Lisgis, 2008). The county has a tropical climate driven by the Harmattan winds. Nimba County lies at an altitude range of 63-1730 meters above sea level and is situated at 5° 49' 26" to 7° 41' 46" N longitudes and 9° 11' 43" to 8° 16' 24" W latitudes. The county has a tropical climate categorized by alternating wet and dry seasons, driven by inter-tropical convergence zoning (Schroth et al., 2015).

2.2. Sampling and Data Collection

A cross-sectional study was conducted among the four counties, utilizing one-on-one interviews and focus group discussions (FGDs). Weather data, including temperature and rainfall amounts, were obtained from weather stations in each of the selected counties.

2.3. One-on-One Interviews

One-on-one interviews were used to establish farmers' levels of awareness regarding how their activities enhanced or deteriorated rice seeds' quality. Mixed structured questions were developed to assess farmers' seed quality status, seed fungal contamination, source of rice seeds, storage conditions, and utilization of fungus-infected grains. Participating farmers were purposively sampled on the criterion of active rice farming. A total of 500 respondents were recruited based on the formula suggested by Kotrlik and Higgins (2001) and Taherdoost (2017).

$$\eta = \frac{p(100-p)Z^2}{E^2}$$

Where

η is the required sample size.

P is the percentage occurrence of a state or condition (50).

E is the maximum percentage error required (0.05).

Z is the value corresponding to the level of confidence required (1.96), which was applied to sample frames provided in each county.

2.4. Focus Group Discussions (FGDs)

FGDs were conducted to reinforce the information obtained from the interviews, get expert opinions on the rice seed sector, and compensate for the lack of literature on the institutional framework and developments. Two FGDs were held in each county, for which active rice farmers were targeted, including women and men aged 18-75. In each FGD, the facilitator ensured equal gender participation. Each FGD constituted 12-15 participants, one facilitator, one translator, and one camera person. Videos and pictures were only taken upon receiving consent from all participants. Expert FGDs were also conducted among six organizations: the Bangladesh Rehabilitation Assistance Committee (BRAC), the County Agriculture Coordinator (CAC), the College of Agriculture and Forestry (CAF), the Centera Agriculture Research Institute (CARI), the Liberia Agriculture Commodity Regulatory Authority (LACRA), and the Ministry of Agriculture (MOA). Unlike the farmer FGDs, the expert discussions had small participant numbers and no gender requirements because of the small number of seed experts in the organizations. However, the discussion process followed a similar protocol to that of the farmer FGDs.

The discussions were centered on five thematic issues: rice production in the country, characteristics of the rice seed systems, contribution of research institutions to the development of seed systems, quality control of seeds distributed through formal systems, and participants' take on Liberia's rice system. Before the start of the general discussion, identified lead farmers (in the case of farmer FGDs) or the most senior officer (in the case of expert FGDs) were requested to provide an overview of rice production trends in Liberia, and from there the discussion expanded to include the other participants. The facilitator only moderated the discussions and ensured they did not get off-topic by interjecting guiding questions. These questions were developed prior to the FGDs and aimed at expounding the discussion on the identified themes. Sample questions included "What is your take on the current rice production trends?" for theme one, and "What channels do farmers use to source their planting materials?" and "Who are the main actors in distributing community-sourced seeds?" for theme two (a full list of guiding questions can be found in Appendix 1). The FGDs had a maximum two-and-a-half-hour duration. Recorded videos were transcribed and the content was narratively analyzed.

3. RESULTS

3.1. Focus Group Discussion Summaries

The FGDs with the farmers and experts provided concordant information on some themes; however, other themes received contradictory information. Both groups were in agreement regarding the impact of the civil war on the entire agriculture sector and the slow development of the seed sector, particularly that of non-horticultural crops like rice. The discussions were synthesized into the following points:

1. Post-civil war rice production has been on the decline, and the government seems to have no plans in place to salvage the situation, despite the crop being the staple food of the Liberian population. Lofa and Nimba are the

top producers among the major rice-producing counties. All the FGDs agreed that Liberian rice production is very poor when compared with neighboring countries like Nigeria. Liberian farmers suggested a lack of inputs, poor irrigation systems, and the use of obsolete agriculture techniques as impediments to adequate rice production. The argument was supported by experts; however, they indicated that there was a coordinated plan to revamp the sector, which they claimed had started with the implementation of improved local rice varieties for lowland use (Liberia Agriculture Company (LAC) 23) and the adoption of globally improved New Rice in Africa (NERICA) varieties for both lowlands and highlands.

2. The community seed system is the sole channel through which rice farmers obtain planting materials. Farmers use their own saved seeds or obtain them from other farmers or open-air markets, while a few farmers benefit from non-governmental organization-supplied seeds. The quality of the community seeds varies according to the source. Farmers' own saved seeds are considered better quality because they are selected from the field and stored in the kitchen attic where they are subject to minimal disease and pest attacks. Seeds sourced from markets are of unknown quality and tend to provide poor yields. Farmers and experts agreed on the indicators of quality in seeds; these included color grading, grain size, and grain shape. Farmers were of the opinion that the formal seed sector had never existed, but this opinion was countered by the experts, who argued that before the war, the sector was in development. Farmers never experienced it, however, because it was in the policy and law-making stages. The war is blamed for the destruction of the gains that had been made.
3. Farmers had no information on research institutions or their roles in rice production and denied their existence. They were only aware of a few non-governmental organizations. On the other hand, the experts acknowledged the existence of research institutions, which play an important role in germplasm banking and conducting research on various improvements. Some of the named institutions were African Rice and CARI.
4. The lack of a formal seed system has made it impossible to put in place a monitoring organization to check and ensure seed quality.

3.2. Farmers' Characteristics

Rice farming in Liberia is not biased toward one gender; the results show that 49.8% and 50.2% of the farmers in the selected counties were men and women, respectively. However, in Bong and Montserrado Counties, more men took part in rice farming, as shown in Figure 2.

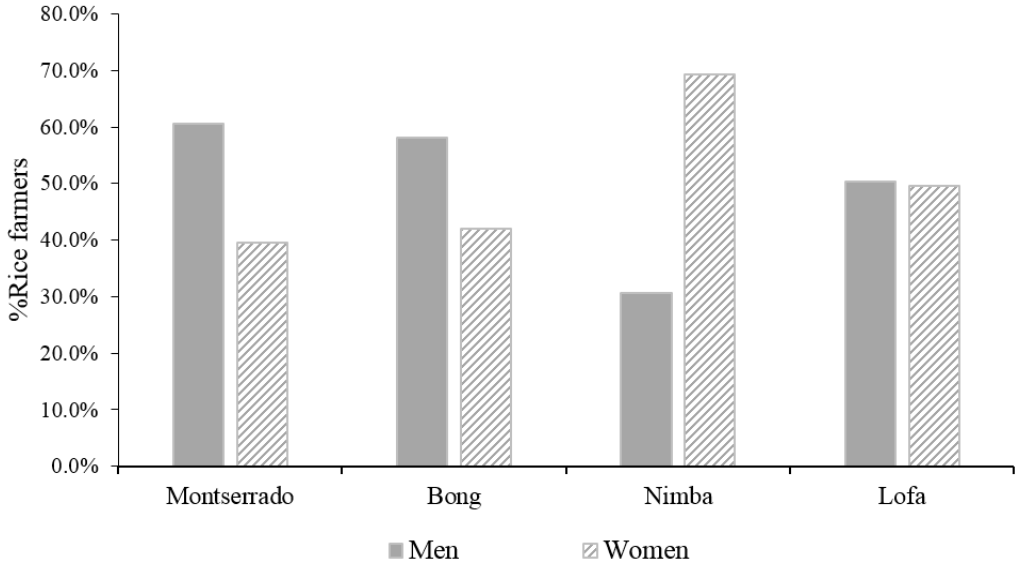

Figure 2. Distribution of farmers' gender in the four selected counties.

The sector is dominated by farmers with a low level or no education, who account for 63.8% of farmers. In contrast, 26.8% have achieved secondary school education (either junior high school or senior high school), and only 9.4% have completed tertiary education (post-secondary vocational training or college degree). Despite rice being the nation's staple food and almost every household allocating land to its cultivation, it is not farmers' primary source of income; the study established that only 16.2% of farmers depend on the rice crop as their household's primary source of income. Other reported sources of income are shown in Figure 3. The study also found that rice farmers have an average of 6 ± 3 (standard deviation (SD)) dependents in their households.

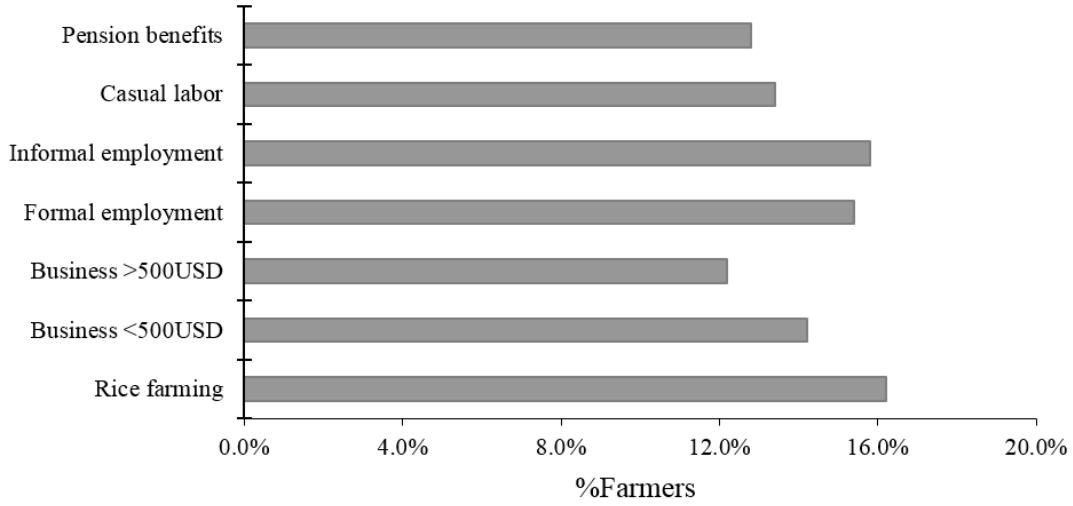

Figure 3. The main household sources of income for farmers engaged in rice production.

3.3. Rice Seed Systems

The study found that local channels of seed supply and maintenance dominate the Liberian rice seed system. About 94.7% of farmers source their seeds from local open-air markets, borrow from neighbors, or save seeds from previous harvests. Only 5.3% of rice farmers use certified seeds from agro-dealers and aid from non-governmental organizations. The various channels of seed access are not dependent on farmers' characteristics or county of residence as there is no significant association between these factors and farmers' sources of seeds, as shown by the chi-square test of independence, $p > 0.05$, and lambda (ʎ) association of 0.00.

The grains for next season planting are mainly stored in the kitchen attic, as indicated by 83.8% of the farmers who reported this practice; 7.8%, 3.8%, and 4.6% of farmers store their seeds in their house attic, containers, and sacks, respectively. The chi-square test of independence revealed a significant association between the different storage methods and farmers' experience of fungal infections on their stored grains; $\chi 2(3) = 25.210$, $p < 0.001$, and ʎ association of 0.164 indicated that farmers who stored seeds in the kitchen attic experienced low fungal infection rates compared to farmers using other storage methods.

The selected counties were nationally ranked as the major rice producers; however, the production levels varied significantly among them, as indicated by the Kruskal Wallis (KW) test of the quantity of shelled rice across the four counties in three consecutive years; $H(3) = 115.032$, $p = 0.001$ in 2018, $H(3) = 125.84$, $p = 0.001$ in 2019, and $H(3) = 125.603$, $p = 0.001$ in 2020. Lofa had the highest rice production level among the counties. Figure 4 illustrates the mean ranks of rice production in the four counties over the selected three years. The study found that the land area allocated to rice production was the primary regressing factor of yield and correlated linearly with the yield reported. For instance, in 2020, $R^2 = 0.944$, $p = 0.001$. The land area allocated to rice in the counties also varied significantly, $H(3) = 140.344$, $p = 0.001$, with Lofa leading in the land area allocated to rice. Apart from land area, management aspects like fertilizer applications were also positively correlated with the obtained yield, as shown in Table 1.

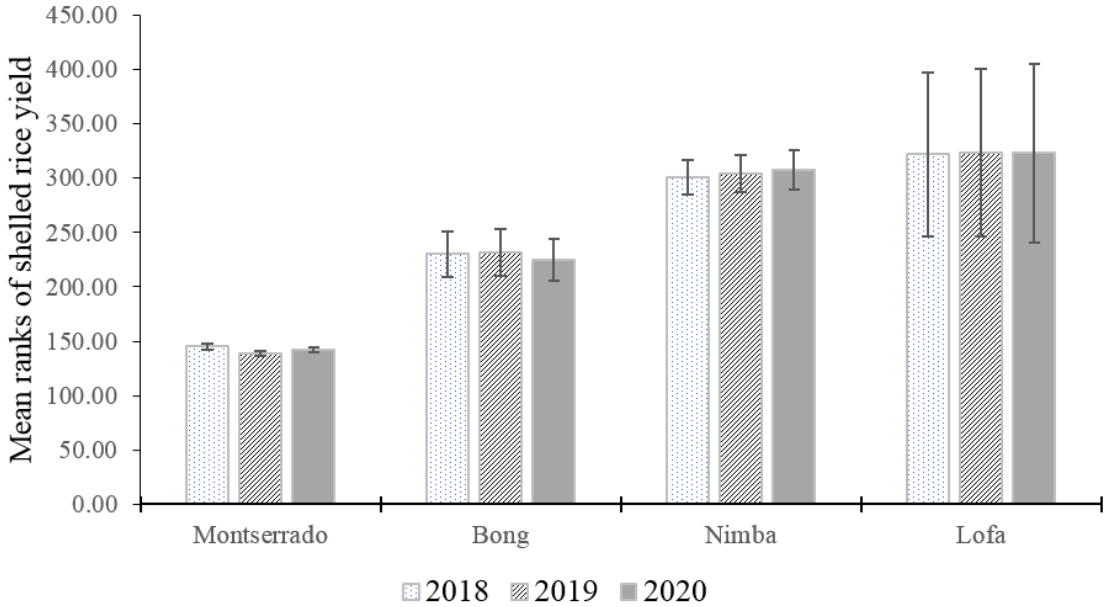

Figure 4. Mean ranks of the shelled rice yield in the four studied counties. Error bars: standard deviation.

Table 1. Correlation of rice yield in the studied counties with predictive factors.

		Land under rice	Rice yield 2018	Rice yield 2019	Rice yield 2020	Basal fertilizer	Topdressing fertilizer
Land under rice	R^2	1	0.914**	0.940**	0.944**	0.141**	0.134**
	p		0.000	0.000	0.000	0.002	0.003
	N		499	499	499	500	500
Rice yield 2018	R^2		1	0.953**	0.950**	0.433**	0.398**
	p			0.000	0.000	0.000	0.000
	N			499	499	499	499
Rice yield 2019	R^2			1	0.965**	0.390**	0.392**
	p				0.000	0.000	0.000
	N				499	499	499
Rice yield 2020	R^2				1	0.382**	0.336**
	p					0.000	0.000
	N					499	499
Basal fertilizer	R^2					1	0.750**
	p						0.000
	N						500

Note: ** indicates correlation is significant at the 0.01 level (2-tailed).

A logistic regression was conducted using farmer characteristics (training in agriculture, age, and county of residence), climatic factors (annual average temperature and rainfall), rice variety (local or exotic), fertilizer used, and land area to assess their influence on farmers' likelihood of experiencing fungal infection on their stored grains. The binomial logistic regression model indicated statistical significance, χ^2 (9) = 110.105, p < .001. The model explained 26.4% (Nagelkerke R^2) of the variance in farmer experience of rice grain fungal invasion in 2020 and correctly classified 70.4% of cases. Farmers who resided in Lofa or Nimba, received a high amount of rainfall, and applied fertilizers were likely to experience fungal infestations on their stored grains, as shown in Table 2. The likelihood was also found to increase by 88.5% among farmers who had training in agriculture.

The study also revealed that 19.6% of farmers in the Liberian rice sector understood the health concerns related to the consumption of fungal-contaminated grains, which is a significantly low proportion and correlates linearly with the percentage of farmers who experienced fungal infections on their stored grains. This result indicates that most farmers lack the knowledge to evaluate the quality of their grains.

Table 2. Contribution of selected predictor factors on the likelihood of a farmer experiencing fungal invasion on their stored rice grains.

Predictors	B	S.E.	Wald	df	Sig.	Exp(B)
Training in agriculture	-2.037	0.435	21.929	1	0.000	0.130
Annual average rainfall (mm)	0.079	0.023	11.377	1	0.001	1.082
Annual average temp (°C)	-0.221	0.473	0.217	1	0.641	0.802
Land area allocated to rice	0.002	0.002	1.588	1	0.208	1.002
Application of fertilizer	0.703	0.334	4.440	1	0.035	2.020
Age of the farmer	-0.291	0.210	1.929	1	0.165	0.747
Rice variety	0.271	0.347	0.609	1	0.435	1.311
County of residence	0.867	0.228	14.481	1	0.000	2.380
Source of seed	-0.672	0.663	1.027	1	0.311	0.511
Constant	-6.792	8.962	0.574	1	0.448	0.001

Note: Average rainfall and temperature data were all for 2020; Significance is measured at 0.05.

4. DISCUSSION

4.1. Rice Farmer Characteristics and Seed Systems in Liberian Rice Production

The results revealed that the Liberian rice sector is dominated by small-scale farmers who have limited knowledge and resources. The latter is evidenced by the small land area and obsolete management techniques allocated to rice farming, despite the crop being regarded as a staple. The low level of formal education among the farmers and the inadequacy of their agricultural training makes farming experience a driver of farming success; similar observations have been made across the rice-producing countries of West Africa (Zossou, Arouna, Diagne, & Agboh-Noameshie, 2020). From a different perspective, the results also reflect the tendency of a large part of the population to engage in subsistence farming of rice while intensively cultivating high-value crops like rubber, cocoa, and palm. Such scenarios are prevalent across Africa. Dowswell, Paliwal, and Cantrell (2019) put this practice into context when they realized that East African households grow maize despite clearly not attaching commercial value to it. This practice gives the false impression that there are a high number of farmers in a certain cropping value chain. The observed low literacy level is a problem cutting across several sectors in Liberia, which has its roots in the nation's shaky development. The observations on literacy are confirmed by United Nations Children's Fund findings that place Liberia behind other African countries in terms of literacy level (UNICEF, 2016).

The informal seed system is the primary channel through which farmers acquire their planting materials. The results were anticipated given Liberia's poor policies and lack of institutions and technical infrastructure to advance the formal seed system, particularly for rice. Farmers, therefore, use their own saved seeds from the previous harvest, farmer-farmer exchange, or buy from local markets. The finding corroborates that of Bèye and Wopereis (2014), who concluded that informal, traditional seed supply systems are the primary framework for acquiring seeds among rice farmers in sub-Saharan Africa. Despite the system's dominancy, it is rife with challenges that directly affect the yield and quality of the grains. Munyi and De Jonge (2015) stated that planting materials acquired from such channels are often of poor quality and prone to spreading diseases.

4.2. Rice Yield Variations Among the Main Producing Counties

Rice production levels, even in high-potential areas, are low, averaging below 1.5t/ha (Lnrds, 2012; Saysay, Gabagambi, Mlay, Minde, & Kikuu, 2018); however, the results showed that Lofa and Nimba have consistently led the production ranking, which may be attributed to the rice research that has continuously been conducted in these two counties. There is a lack of significant yield increases over time (between 2018 and 2020, as reported by farmers) in the studied counties, despite efforts by stakeholders to surmount production constraints.

4.3. Storage Method Influence on Fungal Infection of Stored Rice Grains

Fungal infection of the stored grains has particularly affected the grains stored using methods other than kitchen attic storage. Grains stored in kitchen attics are usually subject to the drying heat and smoke coating generated by household cooking activities. Storing rice grains at high temperatures has been found to reduce fungal infections (Kamara et al., 2019). As observed by Hell, Cardwell, Setamou, and Poehling (2000), the smoke coating deprives fungi of the capacity to grow, while the heat constantly destroys any growing fungi, which explains the low infection rates. Knowledgeable farmers seem to experience more fungal infections than their counterparts, indicating that the former group is keener to identify the infections than farmers with no education. Farmers' awareness of the dangers of infection makes them cautious about utilizing infected grains, unlike farmers without this knowledge.

5. CONCLUSION

Rice farming in Liberia is dominated by resource-poor, small-scale farmers with limited knowledge and resources to enhance productivity. The farmers' rice production is primarily for subsistence purposes, and informal seed systems form the main channel for farmers to acquire seeds for agricultural activities. The lack of a well-established formal seed system compromises other efforts to increase productivity. Reforming seed system-related policies is core to the long-term realization of profitable rice farming in Liberia.

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REFERENCES

Ashmun, J. (2020). Liberia. Encyclopedia.com. Retrieved from: https://www.encyclopedia.com/places/africa/liberian-political-geography/liberia.

Bèye, A. M., & Wopereis, M. C. (2014). Cultivating knowledge on seed systems and seed strategies: Case of the rice crop. *Net Journal of Agricultural Science, 2*(1), 11-29.

Chauhan, B. S., Jabran, K., & Mahajan, G. (2017). *Rice production worldwide.* Switzerland: Springer International Publishing AG.

Cosslett, T. L., & Cosslett, P. D. (2018). *Sustainable development of rice and water resources in Mainland Southeast Asia and Mekong River Basin.* Singapor: Springer.

Dowswell, C. R., Paliwal, R. L., & Cantrell, R. P. (2019). *Maize in the third world.* New York: CRS Press.

FAOSTAT. (2020). *Food and agricultural organization of the united nation statistics.* Rome: Food and Agricultural Organization.

Finch-Savage, W. E. (1995). Influence of Seed Quality on Crop Establishment, Growth, and Yield. In A. S. Basra (Ed.), *Seed Quality* (pp. 24). Boca Raton: CRC Press.

Hell, K., Cardwell, K. F., Setamou, M., & Poehling, H.-M. (2000). The influence of storage practices on aflatoxin contamination in maize in four agroecological zones of Benin, West Africa. *Journal of Stored Products Research, 36*(4), 365-382.Available at: https://doi.org/10.1016/s0022-474x(99)00056-9.

Hilson, G., & Van Bockstael, S. (2012). Poverty and livelihood diversification in rural Liberia: Exploring the linkages between artisanal diamond mining and smallholder rice production. *Journal of Development Studies, 48*(3), 413-428.Available at: https://doi.org/10.1080/00220388.2011.604414.

Kamara, M. M., Katta, Y. M., Abd El–Aty, M. S., Elgamal, W. H., Soleiman, R. M., Mousa, K. M., & Ueno, T. (2019). Effect of storage temperature on storage efficacy, germination and physical characters of some paddy rice cultivars during different storage periods. *Journal Faculty of Agriculture Kyushu University, 6*(1), 61–69.Available at: https://doi.org/10.5109/2232279.

Knoema. (2019). Production statistics - crops, crops processed in Liberia. Retrieved from: https://knoema.com/FAOPRDSC2017/production-statistics-crops-crops-processed?country=1001110-liberia [Accessed 2020].

Kotrlik, J., & Higgins, C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43-50.
Lisgis. (2008). *Counties of Liberia*. Monrovia, Liberia: Liberia Institute of Statistics and Geo-Informatics Services.
Lnrds. (2012). *National rice development strategy of Liberia: Doubling rice production by 2018. In: Agriculture, M. O. (ed.)*. Monrovia, Liberia: GoL.
Luther, Z., Akromah, R., Nyadanu, D., Tokpah, D. P., Page, Z., Voor, V. M., & Kwaloe, A. D. (2017). Evaluation of genetic diversity in rice (Oryza sativa and Oryza glaberrima) germplasm from Liberia and Ghana using simple sequence repeat (SSR) markers. *African Journal of Biotechnology*, *16*(41), 1990-1996.Available at: https://doi.org/10.5897/ajb2017.16212.
McGuire, S., & Sperling, L. (2016). Seed systems smallholder farmers use. *Food Security*, *8*(1), 179-195.Available at: https://doi.org/10.1007/s12571-015-0528-8.
MOA. (2014a). *Annual agriculture reports*. Monrovia: Ministry of Agriculture Republic of Liberia.
MOA. (2014b). *Ministry of agriculture strategy 2015-2019. In: Agriculture, M. O. (ed.)*. Monrovia, Liberia: The Ministry of Agriculture.
Munyi, P., & De Jonge, B. (2015). Seed systems support in Kenya: Consideration for an integrated seed sector development approach. *Journal of Sustainable Development*, *8*(2), 161-172.Available at: https://doi.org/10.5539/jsd.v8n2p161.
Republic of Liberia. (2019). *Food fortification initiative: Enhancing grains for healthier lives. In: Agriculture (ed.)*. Liberia: Republic of Liberia.
Saysay, J. L., Gabagambi, D. M., Mlay, G. I., Minde, I. J., & Kikuu, C. (2018). Technical efficiency in rice production among smallholder farmers in central Liberia: A stochastic production frontier analysis. *Journal of Economics and Sustainable Development*, *9*(20), 47-53.
Schroth, G., Läderach, P., Martínez-Valle, A. I., & Bunn, C. (2015). *Climate vulnerability and adaptation of the smallholder cocoa and coffee value chains in Liberia. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)*. Copenhagen, Denmark: International Fund for Agricultural Development.
SDCA. (2016). *The liberia seed development and certification agency act*. Monrovia, Liberia: Government of Liberia.
Taherdoost, H. (2017). Determining sample size; how to calculate survey sample size. *International Journal of Economics and Management Systems*, *2*, 237-239.
UNICEF. (2016). *Liberia education sector analysis*. New York, USA: United Nations Children's Fund.
Vorrath, J. (2018). What drives post-war crime? Evidence from illicit economies in Liberia and Sierra Leone. *Third World Thematics: A TWQ Journal*, *3*(1), 28-45.
Zossou, E., Arouna, A., Diagne, A., & Agboh-Noameshie, R. A. (2020). Learning agriculture in rural areas: The drivers of knowledge acquisition and farming practices by rice farmers in West Africa. *The Journal of Agricultural Education and Extension*, *26*(3), 291-306.

Appendix 1. Focus group discussions (FGDs) guiding questions.

Greetings ladies and gentlemen,

Welcome to the focus group discussions (FGDS) regarding different rice seed systems and consequential rice production in this county. I am Ousman Dorley, a PhD student at the University of Eldoret (Kenya) and my colleague assisting me with video recording is […….] We are glad to welcome you to these discussions aimed at providing the information on the state of rice production in Liberia with focus on the seed systems, challenges and local made solutions by farmers and other stakeholders. Similar discussions have/are planned to be conducted in other counties.

You were selected to participate in these discussions because we understand and appreciate the roles and responsibilities you undertake to make crop production by our farmers efficient and sustainable. Your experience in dealing with farmers is of paramount importance to

Data collected from this FGDs will be used to inform the relevant stakeholders on the state of rice production and seed systems that exists in the value chain. The data will also be used to contribute towards achievement of the PhD course requirement in seed science and technology

Before we start the discussions let me highlight some of the guidelines that will help our discussions to be successful;

1.0 All participants are encouraged to air out their opinions freely without fear of discrimination

2.0 We appreciate that every opinion matters and none is considered better than the other or wrong. We believe the more we differ the better our understanding is in regard to the subject matter

3.0 We'll use the first name in this discussion and don't feel offended when I miss out on yours

4.0 We will also be video recording every person's contribution, however this should not compromise your opinions. The video will be handled with utmost confidentiality and will only be used for information analysis towards the said objectives.

5.0 I request that all the participants switch off their mobile phone devices or put them on the silent mode. In case of an important call, kindly walk out silently and after you have responded rejoin the meeting quickly

6.0 I as the moderator, my role will be to guide the discussions. Feel free to discuss the matter within yourselves if need arises.

Questions

Introduction to the subject matter

1.0 What is your take on the current rice production trend?

2.0 Which County has better rice production in the country?

3.0 When you compare our national general rice production with other neighbor countries like Nigeria, how can you rate our production?

4.0 Which range of production do you think is optimal given our country soil, climatic condition, agronomic practices and germplasm?

5.0 What are the common rice varieties grown in this county?
6.0 What are the challenges facing our rice production sector?

Characterization of seed industry components in Liberia

1.0 What channels farmers use in sourcing their planting materials?
2.0 How developed is the community seed channels?
3.0 How are the informal seeds produced and prepared?
4.0 Who are the main actors in distributing community seeds?
5.0 How do the buyers ensure quality of the seeds sourced through informal channels?
6.0 Is there an established framework that regulates sale and purchase of seeds in the informal seed system?
7.0 How developed is the formal seed system channels?
8.0 Who are the actors in the formal seeds value chain?
9.0 Does the country has designated institutions and organization conducting rice breeding programs?
10.0 What is the government doing in spearheading establishment of seed companies?
11.0 What are characteristics of existing seed companies? (companies privately owned or parastatals)
12.0 Do the companies have their specific rice germplasms?

Contribution of research institutions to development of seed systems

1.0 What type of research institutions are actively engaged in seed research?
2.0 Do the institution conduct seed rice variety developments or import already processed seeds?

If they do productions;

3.0 What is their average land put under rice seed production?
4.0 What is their average annual rice seed quantity?
5.0 How do these institution process and package seeds?
6.0 How are the processed seeds distributed to the farmers?
7.0 How affordable are the rice seeds when they reach the farmers?
8.0 Does the quantity of seeds meet farmers demand?

Quality control of seeds distributed through formal system

1.0 How many governmental and non-governmental agencies mandated with ensuring seed quality?
2.0 At what stage of seed production is the monitoring and evaluation conducted?
3.0 Does the formal seed sector have policies and guidelines on importation and exportation of seeds?
4.0 What protocol does a new seed company follow to acquire certificate of operation?
5.0 What are the policies guiding pertinent properties in regard to rice seeds?

Participants take on rice seed industry in Liberia

6.0 What is the government doing to provide a solution to the rice challenges in the country?
7.0 What are farmers doing to ensure the planting materials are of good quality?
8.0 What measures is the government and other agriculture stakeholders putting in place to manage rice diseases?
9.0 What is your suggestions to the problems in the rice production sector?

Conclusion

I wish to thank you all from my heart for your substantial participation and every opinion registered will be considered in providing information to stakeholders and contribution towards my PhD requirement.