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**Impact of the COVID-19 pandemic on food security and income
in developing countries of stakeholders: a case study of rice
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Impact of the COVID-19 pandemic on food security and income in developing countries of stakeholders: a case study of rice value chain actors [†]

Aminou Arouna^{1,*}, Rachidi Aboudou¹, Wilfried Gnipabo Yergo¹, Gaudiose Mujawamariya²

¹ Africa Rice Center (AfricaRice), 01 BP 2551, Bouaké 01, Cote d'Ivoire

² Africa Rice Center (AfricaRice), Antananarivo, Madagascar

* Corresponding author: a.arouna@cgiar.org

Abstract

Since February 2020, the World is facing unprecedented challenges caused by the corona virus disease (COVID-19). Different measures including complete lockdown were taken to contain the pandemic. This study aimed to assess the impact of the COVID-19 pandemic on income and food security of rice value chain actors. A total of 1,330 rice value chain actors were randomly sampled in Cote d'Ivoire and Madagascar. Descriptive statistics and fixed effect regression models were used to assess the impact of the pandemic on rice value chain actors. Results showed that 90% of actors perceived that their income decreased due to the pandemic. Access to credit became difficult for 43% of actors. Access to inputs and hired labor became difficult and expensive. Quantity of parboiled and milled rice decreased for more than 87% of parboilers and millers. We find evidence that the pandemic decreased the income of rice farmers by about US\$ 169 per month. This led to a reduction of the number of meals by 0.14 unit per day and put 32% of rice farmers in food insecurity. The facilitation of credit and input access for smallholder farmers could be one strategy to avoid food shortages and deficits among value chain actors.

Keywords: Rice value chain actors, COVID-19 pandemic, short-term impact, food security, Africa

JEL Code: Q12, Q18, C93

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1. Introduction

Agriculture is a key sector of the economy in many developing countries and remains the basis of any development strategy. It provides employment for about two-thirds of the continent's working population and for each country contributes an average of 30 to 60% of gross domestic product and about 30% of the value of exports (World Bank, 2020). Agriculture can help reduce poverty, raise incomes and improve food security for 80% of the world's poor, who live in rural areas and work mainly in farming. Agricultural development is one of the most powerful tools to end extreme poverty, boost shared prosperity and feed a projected 9.7 billion people by 2050. It can therefore contribute towards sustainable development goals and major continental priorities, such as eradicating poverty and hunger, boosting intra-Africa trade and investments, rapid industrialization and economic diversification, sustainable resource and environmental management, and creating jobs, human security and food security. In the agricultural sector, cereal production especially rice, wheat and maize have become essential to food security as they provide more than 60% of daily calorie in developing countries.

Rice is an important staple crop that plays an important economic role and feeds approximately half the world's population (Fahad *et al.*, 2019). Rice represents the staple food for more than 750 million people in Sub-Saharan Africa (USDA, 2018). Rice consumption in Africa is growing fast than any part of the World. However, local production has not kept pace with the increase in demand and the gap is being filled through importation of Asia rice whose characteristics are more preferred by consumers (Demont *et al.*, 2013). These renders Africa very vulnerable to international trade disruptions such as the ones currently inflicted by the corona virus disease (COVID-19) crisis (Arouna *et al.*, 2020).

On December 31st, 2019, the World Health Organization (WHO) was informed of a cluster of cases of pneumonia of unknown cause detected in Wuhan City, Hubei Province, Republic of China. This was subsequently confirmed as an outbreak of a new type of coronavirus, 2019

novel Coronavirus (2019-nCoV) by China and the WHO. Since then, the world is facing unprecedented challenges caused by the COVID-19 pandemic, one of the most serious public health emergencies since last century. According to the World Health Organization (WHO), as of March 26th, 2021, more than 125,614,782 and 4 178 672 cases of COVID-19 have been reported in the world and Africa, respectively, with about 2,757,339 and 111,348 deaths, respectively¹. In Africa, South Africa was the most drastically affected country, with more than 1,541,563 infections following by Morocco (493,353 cases), Tunisia (24,967 cases), Egypt (197,350), Ethiopia (194,524) and Nigeria (162,178 cases). The first case of COVID-19 in Africa was recorded by February 2020. Within one month, the virus had spread to all countries in Africa. COVID-19 enters in Madagascar on 21th March. In Cote d'Ivoire, a state of emergency was declared on March 23, while the country had only 25 confirmed cases. Cote d'Ivoire is among the African countries with the highest toll of confirmed COVID-19 cases (42,074 cases), particularly in the economic capital Abidjan and its suburbs. To slow down the speed of contamination, movement restrictions, maintenance of strict hygiene practices, social distancing rules, wearing of face masks, travel restrictions, quarantines, curfews and complete lockdowns were imposed in many countries of Africa including Cote d'Ivoire and Madagascar. While these measures are important to contain the pandemic and arrest the spread of coronavirus, they are, however, adversely impacting livelihoods, jobs, food and nutrition security and economic activities. Since the end of the second world-war, the COVID-19 pandemic is the first international health crisis which is likely to result simultaneously to economic, social and food crisis. Around the world, governments and populations continue to grapple with the effects of the coronavirus outbreak. Concerns are the potential impacts of the COVID-19 pandemic and related lockdown measures on agriculture and food security.

¹ See WHO (March 26, 2021):
<https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6>

To address these needs and help inform the responses of policy makers, we conducted a rapid perception survey to provide a snapshot of the impact on COVID-19 pandemic on rice farmers in Cote d'Ivoire and Madagascar. This study aimed to assess the impact of the COVID-19 pandemic on all rice value chain actors in Cote d'Ivoire and Madagascar. Although literature exists on the potential impact of the pandemic in Africa (e.g. Arouna *et al.*, 2020. Kalle *et al.*, 2021), this is among the scarce studies using primary data to estimate the impact of COVID-19 on smallholder farmers in rural areas of sub-Saharan Africa.

2. Methodology

2.1. Study area and sampling

The study was conducted in two countries of Africa, namely Cote d'Ivoire (in West Africa) and Madagascar (in East Africa) (Figure 1). The regions selected are the major rice growing areas named hubs. Rice hubs are areas where rice research products are integrated across the rice value chain to achieve development outcomes and impact (Arouna and Aboudou, 2020). In the hubs, AfricaRice and national scientists have introduced validated new rice technologies, and work with development partners to facilitate the training of farmers, dissemination of technologies and establishment of a network of stakeholders along the rice value chain. In Madagascar, the survey was conducted in the hub of Antananarivo, the capital and largest city of Madagascar, two hubs (Ambohibary and Ankazomiritra) located in the region of Vakinankaratra (in central Madagascar) and one hub (Antsimo-andrefana) in the region of Antsimo-Andrefana (Figure 1). The region selected in Cote d'Ivoire were part of the e-registration survey for technology dissemination in Cote d'Ivoire (Arouna and Aboudou, 2020). The study was conducted in four districts of Cote d'Ivoire: Korhogo and Ferkessédougou in Savane district, Hambol and Gkeke in Vallée du Bandama district, Guiglo and Man in Montagne district, and Gagnoa in Goh-Djiboua district (Figure 1). Savane district is located in

the north of Côte d'Ivoire. It has an area of 40,323 km² and characterizes by a hot and dry Sudanese climate with the Harmattan in January and February. Vallée du Bandama has an area of 28,530 km² and locates in the center of the country. Montagne district is located in the western part of the country has an area of 31,050 km². Gôh-Djiboua district is located in the southwest corner of the country and has an . area of 7327 km². In Madagascar, the combination of southeastern trade winds and northwestern monsoons produces a hot rainy season (November–April) with frequently destructive cyclones, and a relatively cooler dry season (May–October).

In each region, a two-stage random sampling technique was used. In the first stage, villages were randomly selected and 15 rice producers were randomly selected and surveyed in each village (Table 1). The number of actors surveyed for each category is presented in table 1 and 2.

Table 1. Statistics of actors surveyed per country with one activity

Countries	Producers		Post-harvest actors		Service provider		Overall
	Number	Per cent	Number	Per cent	Number	Per cent	Total number
Cote d'Ivoire	692	74.49	300	32.29	48	5.17	1,040
Madagascar	368	91.77	53	13.22	1	0.25	422
Total	1,060	79.70	353	26.54	49	3.68	1,462

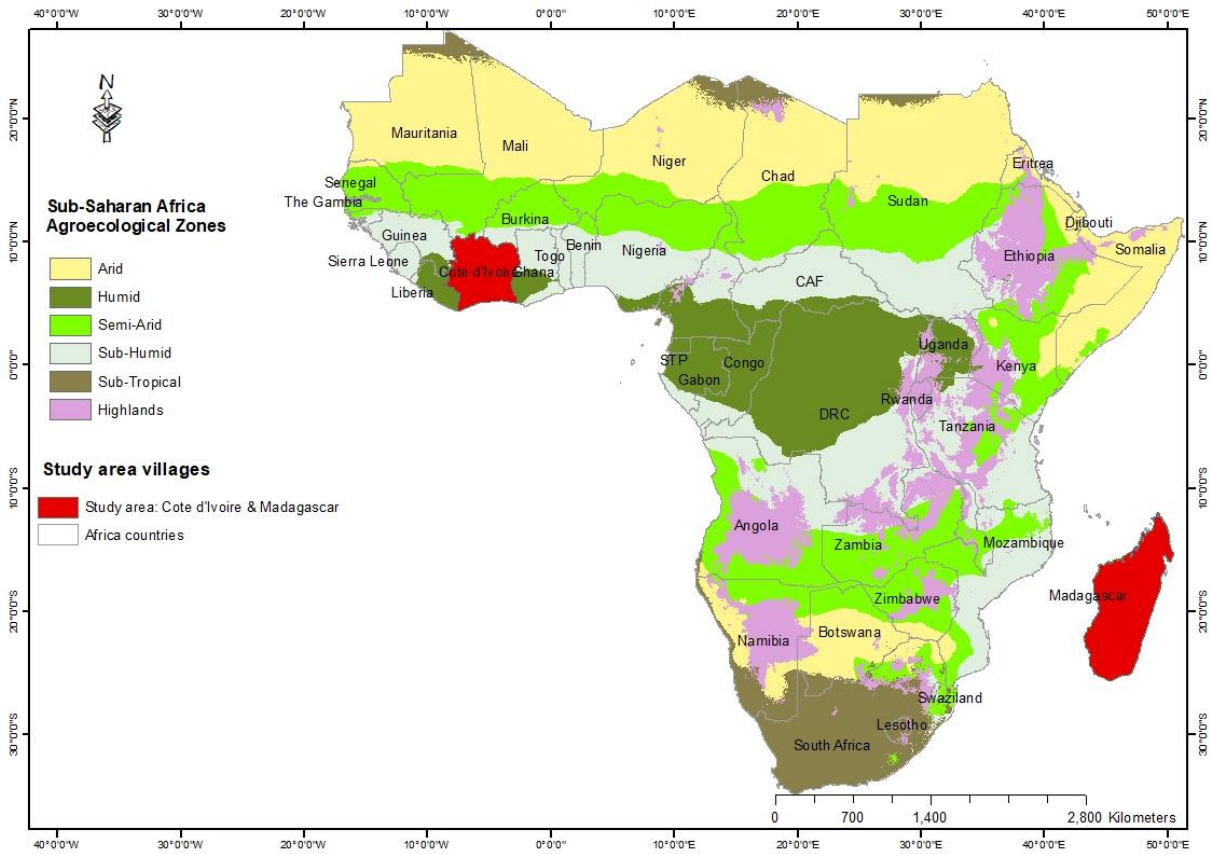


Figure 1. Map of sub-Saharan Africa highlighting the study area

2.2. Data collection and analysis

2.2.1. Data collection

Data collection was conducted between June and July, 2020. Data were collected by enumerators trained using the web-based application ONA and Android terminals using the ODK collect installed on tablets (Nexus 7 & Lenovo). Computerized data collection has avoided many of the biases associated with paper questionnaires, such as errors in recording responses, changing variable values, and recoding test responses for numeric variables. Data collection was implemented outside in a socially distanced fashion. As there was no complete lockdown in the study areas during the data collection period, face-to-face interview with strict respect of the social and protection measures was adopted.

Socio-economic characteristics, demographics, perception of farmers on COVID-19 and geographic data were collected. With regard to the attitudes toward COVID-19 virus, the questionnaire included perception of rice farmers toward COVID-19 on their activities, the sources of knowledge of the COVID-19 pandemic, measures taken and applied to prevent the spread of the coronavirus. In particular, farmers were asked to assess the effect of coronavirus disease on agriculture production during the 2020 first production season (March to June 2020), named during COVID-19, compared to the same period last year (March to June 2019), named post-COVID-19.

2.2.2. Data analysis

Data analysis was conducted using descriptive statistics (mean, standard deviation, percentile, etc.), correlation coefficients and regression models. The fixed effect regression models was used to identify the impact of COVID-19 pandemic on food security and income of rice farmers.

To quantify the impact of COVID-19 on households' food security and income (the main outcome of interest), we exploit the temporal variations in our outcomes of interest before and during COVID-19 pandemic. We specifically estimate the following fixed effects regression specification to quantify the impact of COVID-19.

Using pre-COVID-19 and during COVID-19 information, on rice farmers socioeconomic status and livelihood, we quantify the differential impact of the pandemic on households' food security and income using the following empirical specification:

$$Y_{ht} = \alpha_h + \beta_0 COVIDDummy_t + Sex_h * COVIDDummy_t + FinAssist_h * COVIDDummy + Worried_h * COVIDDummy + Country_h * COVIDDummy + ManyActiv_h * COVIDDummy + \varepsilon_{ht} \quad (1)$$

Where Y_{ht} (dependent variables) stands for food insecurity and income for each household h . α_h capture household fixed effects. $COVIDDummy_t$ is a dummy variable, assuming a value of 1 for the during-COVID-19 and 0 for the pre-COVID-19. The parameter associated with this dummy captures aggregate trends in food security and income. ε_{ht} is an error term that is assumed to be uncorrelated with COVID-19 cases, at a conditional fixed affects. The household fixe effect in equation (1) capture time-invariant heterogeneities across households. The potential temporal variation in food security and income are likely to be driven by government responses to the pandemic (FinAssist), the household of being worried during the pandemic (Worried), the gender of the farmer (Sex), the country (Country), the fact that the actor is involved in other activity in the rice value chain such as rice parboiling, rice milling and rice trading (ManyActiv). We interact the COVID Dummy with these variables. Indeed, the economic repercussions of the pandemic are expected to vary depending on individuals' precautionary measures and government responses (Abay et al., 2020; Koren and Peto, 2020).

3. Results

In the first part, socio-economic characteristics of respondents are presented. Secondly, we present the main sources of knowledge of the COVID-19 pandemic and the measures applied to prevent its spread. This is followed by the impact of the COVID-19 pandemic on different outcomes such as income (farm and non-farm income) and household food security.

3.1. Socio-economic characteristics of rice value chain actors

Table 2 described the characteristics of rice value chain actors (rice farmers, and postharvest actors) in Cote d'Ivoire and Madagascar. The average age of all rice value chain actors surveyed is 45 years with 12 persons per the household. Millers tends to be younger. About 97% of parboiler were women and found in Cote d'Ivoire. This highlight the fact that parboiling activity is mainly done in West Africa and the stakeholders were female.

Table 2 also reveals that majority (66%) of the farmers were male. The finding implies that both gender were involved in rice farming. Results showed that about 70% of actors surveyed have agriculture as main activity. About 58 % of actors with about 63% of rice farmers had formal education.

Results also showed that 33% of respondent worried because of the pandemic and 7% said that they received assistant from government. Furthermore, 77% of farmers said that the main solution to reduce the negative effect of the pandemic was financial assistant.

Table 2. Socio-economic characteristics of rice value chain actors

Variables	Overall (n=1,330)	Rice producers (n=1,060)				Post-harvest actors (n=353)			Service provider (n=49)
		Foundation seed producers (n=8)	Certified seed producers (n=92)	Paddy producers (n=1,038)	Total producers (n=1,060)	Parboiler (n=122)	Miller (n=60)	Trader (n=269)	
Household characteristics									
Age (years)	44.67 (12.21)	48.13 (17.95)	48.25 (11.40)	45.84 (12.04)	45.80 (12.03)	42.47 (12.13)	39.70 (12.27)	42.11 (11.25)	41.37 (14.15)
Household size (Number)	12.73 (6.13)	13.63 (7.22)	14.44 (6.84)	12.47 (6.21)	12.49 (6.19)	14.53 (5.20)	13.58 (6.74)	13.40 (5.47)	14.63 (5.36)
Number of children	2.66 (2.41)	4.37 (1.84)	3.27 (2.07)	2.57 (2.31)	1.14 (2.30)	3.08 (2.93)	3.1 (3.20)	2.93 (2.60)	2.38 (1.95)
=1 if male (%)	0.66 (0.47)	0.63 (0.51)	0.80 (0.39)	0.74 (0.43)	0.74 (0.43)	0.03 (0.15)	0.85 (0.36)	0.40 (0.49)	0.43 (0.5)
=1 if farmer has a formal education (%)	0.58 (0.49)	0.87 (0.35)	0.66 (0.47)	0.62 (0.48)	0.63 (0.48)	0.27 (0.45)	0.56 (0.05)	0.41 (0.49)	0.40 (0.49)
=1 if agriculture is the main activity	0.70 (0.46)	1.00 (0)	0.87 (0.33)	0.87 (0.34)	0.87 (0.33)	0.04 (0.19)	0.23 (0.42)	0.28 (0.44)	0.29 (0.46)
=1 if Cote d'Ivoire	0.69 (0.45)	0.63 (0.52)	0.78 (0.41)	0.64 (0.47)	0.65 (0.47)	1 (0)	0.75 (0.43)	0.85 (0.35)	0.97 (0.14)
=1 if Madagascar	0.30 (0.45)	0.37 (0.52)	0.21 (0.41)	0.35 (0.47)	0.35 (0.47)	0 (0)	0.25 (0.43)	0.14 (0.35)	0.02 (0.14)
=1 if foundation seed is main activity	0.01 (0.07)	0.87 (0.35)	0.05 (0.22)	0.00 (0.04)	0.01 (0.08)	0 (0)	0 (0)	0 (0)	0 (0)
=1 if certified seed is main activity	0.03 (0.17)	0 (0)	0.47 (0.50)	0.02 (0.16)	0.04 (0.20)	0 (0)	0 (0)	0 (0)	0.02 (0.14)
=1 if paddy production is main activity	0.74 (0.44)	0.12 (0.35)	0.44 (0.49)	0.95 (0.21)	0.93 (0.25)	0.03 (0.17)	0.2 (0.40)	0.31 (0.46)	0.30 (0.46)
=1 if parboiling is main activity	0.08 (0.27)	0 (0)	0.01 (0.10)	0.00 (0.03)	0.00 (0.04)	0.88 (0.32)	0 (0)	0.28 (0.45)	0.57 (0.5)
=1 if milling rice is main activity	0.03 (0.18)	0 (0)	0 (0)	0.00 (0.06)	0.00 (0.06)	0 (0)	0.78 (0.42)	0.02 (0.14)	0 (0)
=1 if trading is main activity	0.07 (0.26)	0 (0)	0.01 (0.10)	0.01 (0.11)	0.01 (0.11)	0.08 (0.27)	0.02 (0.12)	0.37 (0.48)	0 (0)
=1 if service providing is main activity	0.03 (0.16)	0 (0)	0 (0)	0.00 (0.04)	0.00 (0.04)	0 (0)	0 (0)	0 (0)	0.10 (0.30)

COVID-19 perception variables									
= 1 if aware of the COVID-19	0.99 (0.03)	1 (0)	1 (0)	0.99 (0.03)	0.99 (0.03)	1 (0)	1 (0)	0.99 (0.06)	1 (0)
=1 if source of knowledge of COVID is TV	0.52 (0.49)	0.25 (0.46)	0.53 (0.50)	0.50 (0.50)	0.50 (0.50)	0.61 (0.48)	0.62 (0.49)	0.64 (0.47)	0.45 (0.50)
= 1 if worried because of the pandemic	0.33 (0.47)	0.37 (0.51)	0.43 (0.49)	0.32 (0.46)	0.32 (0.47)	38 (0.48)	0.43 (0.50)	0.42 (0.49)	0.57 (0.5)
=1 if receive assistant from government	0.07 (0.25)	0.00 (0)	0.04 (0.21)	0.07 (0.26)	0.07 (0.26)	0.00	0.03 (0.18)	0.01 (0.06)	0.02 (0.14)
= 1 if main solution is financial assistant	0.77 (0.41)	0.63 (0.52)	0.78 (0.41)	0.74 (0.44)	0.74 (0.43)	0.97 (0.17)	0.68 (0.46)	0.83 (0.37)	0.96 (0.19)
= 1 if movement of people in the household	0.20 (0.40)	0.25 (0.46)	0.25 (0.43)	0.23 (0.42)	0.23 (0.42)	0.11 (0.31)	0.25 (0.43)	0.20 (0.39)	0.06 (0.24)

() Standard deviations; n=Number of observations

3.2. Source of information on the COVID-19 pandemic

Results showed that in terms of awareness, all rice farmers were aware of coronavirus. The main sources of knowledge of the coronavirus disease by rice farmers was television (52%) (Table 2, Figure 2). This means that, for 1 out of 2 rice farmers, television was the main source of information on COVID-19 followed by radio (33%). Only 2% of farmers got information on coronavirus disease through social media such as WhatsApp and Facebook, 5% from a parent, and 6% from a friend of the village (Figure 2). Most farmers had a smartphone but most were afraid of “fake news” and relied on the national channel (radio and television).

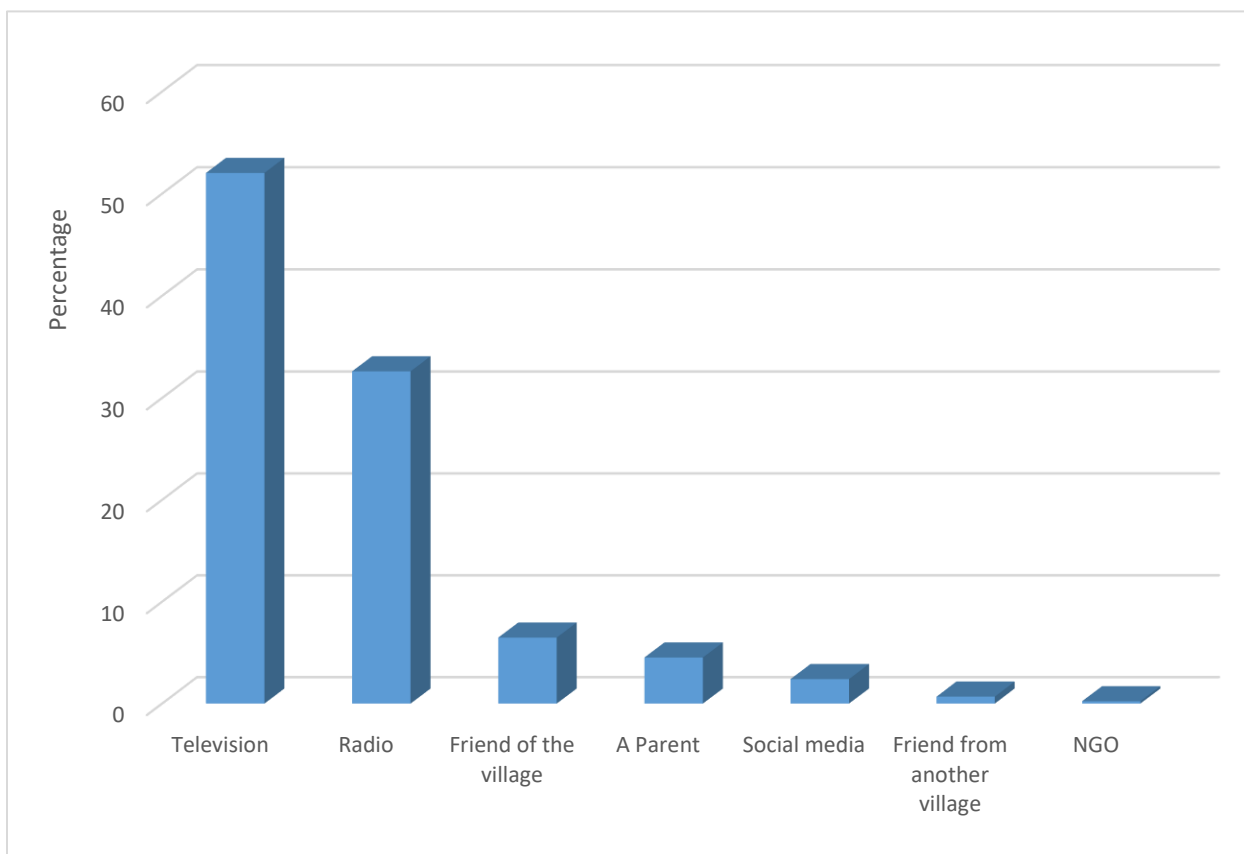


Figure 2. Main sources of information on the COVID-19 pandemic

3.3. Measures applied to prevent the spread of the coronavirus by rice value chain actors

Rice value chain actors took several health precautionary measures to prevent the spread of the COVID-19 pandemic in rural area of Africa. All respondents were aware of different sanitary and prevention measures such as: wearing a mask, regular hand washing, closure of schools, cough or sneeze into the elbow of the hand, prohibition of intra-regional movement, lockdown, and quarantine. The most used sanitary measures applied to prevent the spread of coronavirus disease in rural areas were: wearing a mask (94%), regular hand washing (90%), cough or sneeze into the elbow of the hand (47%), prohibition of intra-regional movement (17%), confinement/lockdown (18%) and quarantine (3%) (Figure 3).

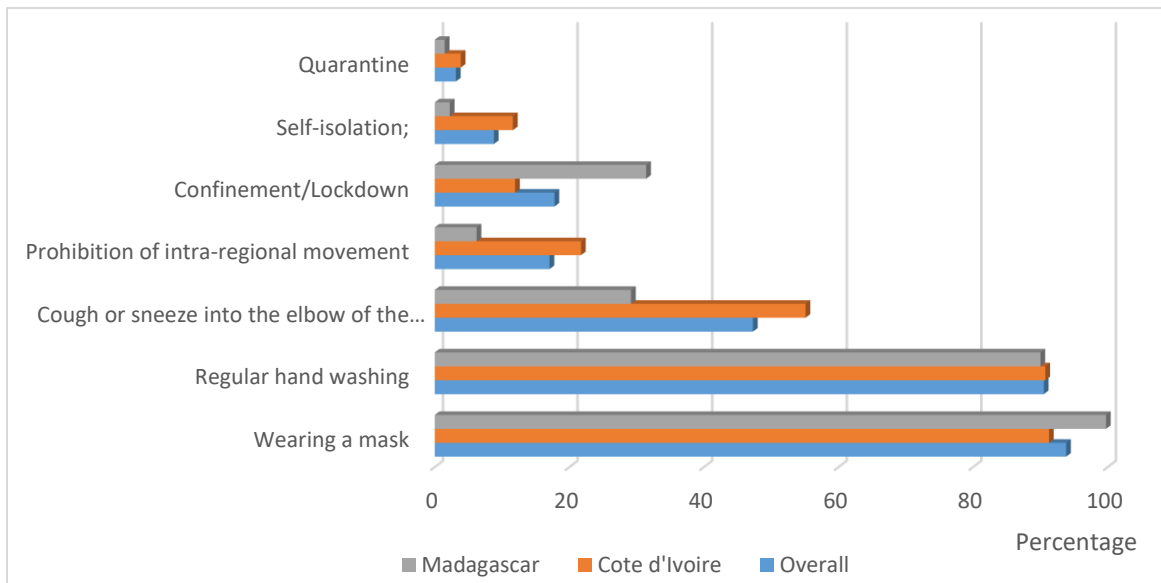


Figure 3. Measures applied to prevent the spread of the coronavirus in the communities

3.4. Rice value chain actors perception on the impact of coronavirus disease on rice production

▪ Overall perception of actors on COVID-19 pandemic impact

Individual farmer-level questionnaires revealed that the COVID-19 pandemic had effect on access to hired labor for production activities and postharvest activities. Results showed that access to hired labor for production activities has not changed for about 57% of actors surveyed (Table 3). However, about 43% of actors found that access to hired labor for production and postharvest activities became difficult. About 3% experienced changes in cost of labor. Male and female farmers had experienced the negative impact of the coronavirus disease (Table 3). Results showed that the coronavirus disease has decreased income of most actors and also put them in a food insecure situation. About 90% of actors declared a negative impact from the coronavirus pandemic on income. During the COVID-19 pandemic, about 47% and 83% declared to face lack of food in the household and decreased their ability to feed the household members. Access to credit became more difficult for 43% of actors (Table 3).

Table 3. Impact of COVID-19 pandemic on rice value chain actors per country

Variables	Total (n=1,330)	Cote d'Ivoire			Madagascar		
		Male (n=704)	Female (n=225)	Overall (n=929)	Male (n=174)	Female (n=227)	Overall (n=401)
Access to hired labor (%)	43	53	48	52	20	24	22
Changes in cost of the labor (%)	3	1	2	1	10	4	7
Availability of rice in the market (%)	54	54	74	59	46	40	43
Ability to support the household (%)	83	80	88	82	84	86	86
Rice income (%)	90	87	95	88	90	96	94
Access to credit (%)	43	41	43	42	52	40	45
Face lack of food in the household (%)	47	47	64	51	36	39	38

- **Producers perception on the impact of coronavirus disease**

Results showed that access to farm for production activities has not changed for about 82% of rice farmers (Table 4). However, about 18% of farmers found that access to farm for production activities became more difficult. Access to agricultural advice became more difficult for about 31% of rice farmers. The COVID-19 pandemic had negative impact on access to agricultural inputs (fertilizers, seeds, herbicides, insecticides, etc.) for agricultural production. Access to rice seed for production became more difficult for about 52% of farmers (Table 4). During the COVID-19 pandemic, farmers experienced difficulties in access to organic fertilizer, access to chemical fertilizer and access to herbicide fertilizer.

Table 4: Impact of COVID-19 pandemic on rice producers

Variables	Total (n=1,060)	Cote d'Ivoire			Madagascar		
		Male (n=619)	Female (n=73)	Overall (n=692)	Male (n=164)	Female (n=204)	Overall (n=368)
Access to the farm became more difficult	18%	19%	19%	19%	14%	19%	17%
Access to seeds became more difficult	52%	61%	60%	61%	42%	33%	37%
Access to organic fertilizer became more difficult	42%	55%	52%	55%	19%	19%	19%
Access to chemical fertilizer became more difficult	65%	78%	81%	78%	43%	39%	41%
Access to agricultural advice became more difficult	31%	35%	51%	36%	18%	25%	21%
Access to herbicide became more difficult	64%	77%	79%	77%	44%	37%	40%

- **Post-harvest actors perception on the impact of coronavirus disease**

The COVID-19 pandemic also had negative impact on postharvest actors. For rice parboilers and millers, access to the workplace became difficult. Quantity of rice parboiled and milled decreased and the purchase of paddy rice for parboiling became more expensive. Access to parboiling place became difficult for 11% of parboiler and access to place of work became difficult for about 12% of millers (Table 5). Availability of paddy rice for parboiling became difficult for 84% of parboilers, while 82% of millers said that availability of paddy rice became difficult. Also, the quantity of rice parboiled and milled decreased for about 93% and 87%, respectively. Purchase of paddy rice for parboiling and milling activity became more expensive.

Table 5. Impact of coronavirus disease on parboilers and millers

Variables	Total	Cote d'Ivoire			Madagascar		
		Male	Female	Overall	Male	Female	Overall
Parboilers (n=122)							
Access to parboiling place became more difficult (%)	11%	33%	10%	11%	0	0	0
Availability of paddy rice for parboiling became more difficult (%)	84%	100%	84%	84%	0	0	0
Purchase of paddy rice for parboiling became more expensive (%)	70%	100%	70%	70%	0	0	0
Quantity of rice parboiled decreased (%)	93%	100%	92%	93%	0	0	0
Millers (n=60)							
Access to place of work became more difficult (%)	12%	12%	0%	11%	22%	0%	13%
Availability of paddy rice for milling became more difficult (%)	82%	81%	67%	80%	89%	83%	87%
Purchase of paddy rice for milling became more expensive (%)	52%	57%	100%	60%	33%	17%	27%
Quantity of rice milled decreased (%)	87%	86%	67%	84%	100%	83%	93%

3.5. Status of food security and income for rice farmers per country before and during COVID-19 pandemic

Table 6 presented the households' income (farm income and non-farm income) and food security (number of meals per day and food security status) in before and during the pandemic. Difference between the two periods were observed. Total income decreased by about US\$ 159 for rice producers. Non-farm income (US\$ 95.75) decreased more than farm income (US\$ 64.17) (Table 6). This can be explained by the fact that non-farm activity needs more contact with people. All restrict measure put in place to reduce the spread of the COVID-19 pandemic decreased the interaction between people, leading to decrease of non-farm income. The number of meals eating per day decreased by about 0.32 unit during the pandemic. The COVID-19 pandemic put 21% of rice farmers in food insecurity (Table 6). Also, during the coronavirus disease the proportion of rice sold decrease by about 6.82%. Our empirical estimations explore whether these changes and decreases in household food security and income can be attributed to COVID-19 and associated mobility restrictions.

Table 6. Descriptive results of key outcome variables for rice producers before and during COVID-19 pandemic

Key outcome variables	Pre-COVID-19			During-COVID-19			Difference test		
	Overall	Cote d'Ivoire	Madagascar	Overall	Cote d'Ivoire	Madagascar	Overall	Cote d'Ivoire	Madagascar
Income									
Farm income (\$US per month)	183.06 (3.85)	183.02 (5.43)	183.13 (4.34)	118.88 (2.65)	121.88 (3.72)	113.23 (3.04)	64.17*** (3.24)	61.13*** (4.36)	69.89*** (4.45)
Non-farm income (\$US per month)	162.59 (3.53)	127.84 (3.38)	227.94 (6.74)	66.84 (0.76)	63.40 (0.87)	73.31 (1.41)	95.75*** (3.36)	64.44*** (3.21)	154.63*** (6.54)
Total Income (\$US per month)	345.65 (5.41)	310.86 (6.71)	411.07 (8.16)	185.72 (2.85)	185.28 (3.96)	186.54 (3.50)	159.92*** (4.83)	125.57*** (5.65)	224.52*** (7.96)
Food security									
Number of meals per day	2.96 (2.96)	2.96 (0.01)	2.98 (0.01)	2.64 (2.64)	2.53 (0.02)	2.85 (0.01)	0.32*** (0.32)	0.43*** (0.02)	0.12*** (0.02)
Good food security in the household (%)	0.60 (0.60)	0.79 (0.01)	0.26 (0.02)	0.21 (0.21)	0.28 (0.01)	0.10 (0.01)	0.38*** (0.01)	0.51*** (0.02)	0.16*** (0.01)
Average food security in the household (%)	0.38 (0.38)	0.20 (0.01)	0.71 (0.02)	0.56 (0.56)	0.49 (0.01)	0.68 (0.02)	-0.17*** (0.02)	-0.29*** (0.02)	0.04 (0.03)
Food insecurity in the household (%) =1 if household is in food security	0.01 (0.00)	0 (0)	0.02 (0.01)	0.22 (0.01)	0.21 (0.01)	0.22 (0.02)	-0.21*** (0.01)	-0.22*** (0.06)	-0.19*** (0.02)
	0.99 (0.00)	1 (0)	0.97 (0.01)	0.78 (0.01)	0.78 (0.01)	0.77 (0.02)	0.21*** (0.01)	0.22*** (0.01)	0.20 (0.02)
Labour									
Number of family labour	3.45 (0.09)	4.15 (0.12)	2.13 (0.07)	3.03 (0.07)	3.42 (0.10)	2.30 (0.08)	0.41*** (0.05)	0.72*** (0.07)	-0.16*** (0.04)
Number of hired labour	7.30 (0.35)	4.84 (0.23)	11.92 (0.88)	4.93 (0.32)	2.28 (0.13)	9.90 (0.83)	2.37*** (0.12)	2.55*** (0.15)	2.02*** (0.19)
Selling of rice									
Proportion of rice sold (%)	26.78 (0.95)	28.20 (1.09)	24.11 (1.83)	19.95 (0.81)	20.88 (0.93)	18.21 (1.55)	6.82*** (0.58)	7.31*** (0.73)	5.90*** (0.98)
No. observation	1,060	692	368	1,060	692	368	692	692	368

***, ** and * are significantly higher than the other group mean at 1%, 5% and 10% level. () standard error; n=Number of farmers.

3.6. Estimation of impact of COVID-19 pandemic on household food security and income of rice farmers

Results of the impact of the COVID-19 pandemic and associated lockdowns on incomes and food security of rice farmers were presented in Table 7. We found evidence that the COVID-19 pandemic has affected farm income, non-farm income, total income and food security outcomes. The interaction between the five variable (sex, financial assistance, being worried, country and being involved in more activities) and the *COVIDDummy* dummy captures the temporal variation in the evolution of our outcomes of interest associated with varying exposure to the spread of the pandemic. A negative and significant impact showed that the COVID-19 pandemic were likely made farmers experienced greater increases in the probability of food insecurity and decrease in incomes.

During the COVID-19, non-farm income decreased by about US\$ 100, farm income decreased by about US\$ 68.79 and the total income decreased by US\$ 168. Coronavirus disease puts 32% of rice farmer's household in food insecurity and reduced the number of meal per day for 0.14 unit (Table 7).

Table 7. Impact of COVID-19 pandemic on household food security and income for rice farmers

Variables	Income			Food security	
	Non-farm income (US\$ per month)	Farm income (US\$ per month)	Total Income (US\$ per month)	Number of meal per day	Food security status
COVIDDummy	-100.01***	-68.79***	-168.80***	-0.14***	-0.32***
	7.30	9.51	12.32	0.04	0.03
Sex*COVIDDummy	2.29	11.35	13.65	-0.04	0.07***
	6.54	8.52	11.05	0.04	0.02
Assistance*COVIDDummy	-0.35	-0.40	-0.76	-0.01	0.08***
	6.00	7.82	10.13	0.03	0.02
Worried*COVIDDummy	1.59	-6.46	-4.87	0.16***	0.08***
	5.40	7.04	9.12	0.03	0.02
Country*COVIDDummy	1.20	5.30	6.50	-0.31***	-0.02
	6.31	8.22	10.65	0.03	0.02
MoreActivity*COVIDDummy	3.84	-14.84*	-11.01	0.03	-0.05**
	6.46	8.41	10.90	0.04	0.02
Constant	177.38***	180.90***	358.27***	2.99***	1.00***
	3.89	5.07	6.57	0.02	0.01
Household fixed effect	Yes	Yes	Yes	Yes	Yes
R-squared	0.28	0.11	0.28	0.18	0.14
No. observations	2120.00	2120.00	2120.00	2120.00	2120.00

***, ** and * are significantly higher than the other group mean at 1%, 5% and 10% level.

4. Discussion

The objective of this study was to assess the impacts of COVID-19 on smallholder rice farmer's livelihood and food security in Cote d'Ivoire and Madagascar after one season of production under the pandemic conditions. Results provided evidence that all rice farmers were aware of coronavirus disease. Television and radio were the primary sources of knowledge. The pandemic had a negative impact in rural areas, especially on the acquisition of inputs, access to hired labor, yield and income. After one growing season, the pandemic had negative impact on income, food security, access to inputs, access to hired labor, quantity of rice sold. We found that rice value chain actors experience a significant increase in measures of food insecurity during the COVID-19 pandemic. COVID-19 decreased the income of rice farmers by about US\$ 168 per month. This leading to a reduction of the number of meal taking per day by 0.14 unit and put 32% of rice farmers in food insecurity. Countries lock-down and borders' closures had strongly impacting rice farmers' access to input like seeds, fertilizers, and agrochemicals. These finding are in line with previous prediction

of the potential impact of the pandemic. Arouna *et al.* (2020) expected that both traditional and upgraded rice value chains will be seriously affected by the COVID-19 pandemic. The report based on survey data collected in April by the World Bank in Cote d'Ivoire finds that the COVID-19 pandemic had several direct repercussions on businesses: reduced working hours, lower sales and revenue (World Bank, 2020). However, movement restrictions, curfews and complete lockdowns in urban area in order to reduce the speed of contamination, were expected to have negative impacts in large towns and urban settlements (Nguyen *et al.*, 2020). Possible disruptions to food value chains are more detrimental to urban households because they typically do not grow their own food (Kalle *et al.*, 2021). However, we find evidence that the pandemic had also negative impacts in rural areas as well. The negative impact of coronavirus in rural areas is due to the fact that agricultural inputs come from urban areas, which made obtaining them difficult and expensive due to the restriction measures put in place (Arouna *et al.*, 2020). Our results are also in line with finding of other studies that COVID-19 pandemic had affected farmers and agricultural workers in various ways (Rawal and Verma, 2020; Narayanan and Saha, 2020; Narayanan, 2020; Kim *et al.*, 2020).

Regional and global cooperation is necessary to address the effects of COVID-19 pandemic and climate change. Policy choices should focus both on resolving urgent needs of food and health and on ensuring long-term resilience and sustainability in agriculture while taking into account the impact of climate change (Engström *et al.*, 2020). This study highlights that special attention should be devoted to the smallholder farmers in rural areas, particularly for access to agricultural inputs. Different policy options proposed to help Sub-Saharan African governments mitigate the impacts of the COVID-19 crisis on smallholder farmers should be considered (e.g. Arouna *et al.*,

2020). The facilitation of access to credit in Cote d'Ivoire could be one strategy to avoid food shortages and deficits among value chain actors.

4. Conclusion

Across Sub-Saharan Africa, while rice farmers are still battling the negative impact of climate change, the COVID-19 pandemic has brought a new risk that threatens not only farmers' livelihoods but also the most important global food security crop "rice". This study aimed to estimate the impacts of COVID-19 on rice production and food security. Results showed that four months after the start of the COVID-19 pandemic in Africa and one rice growing season, all rice farmers were aware of coronavirus. Most respondents stated that television and radio were their main sources of information on COVID-19 and the majority was aware of the different ways by which the coronavirus is transmitted. After one growing season, the pandemic had negative impact on income, food security, access to inputs, access to hired labor, quantity of rice sold. We find that rice value chain actors experience a significant increase in measures of food insecurity during the COVID-19 pandemic. Results also contribute to better understanding the impact of COVID-19 in rural area. The facilitation of credit and input access for smallholder farmers could be one strategy to avoid food shortages and deficits among value chain actors.

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