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Perceptions of COVID-19 shocks and adoption of sustainable agricultural practices in Ghana

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ABSTRACT
Most studies on the novel COVID-19 pandemic have focused mainly on human health, food systems, and employment with limited studies on how farmers implement sustainable agricultural practices (SAPs) in response to the pandemic. This study examines how perceptions of COVID-19 shocks influence the adoption of SAPs among smallholder farmers in Ghana. We find that perceptions of COVID-19 shocks influence the probability and intensity of SAPs adoption. Secondly, households who anticipated COVID-19 shocks recorded heterogeneity effects in the combinations (complementarity and substitutability) of SAPs. Farmers who anticipated an increase in input prices and loss of income due to COVID-19 recorded the highest complementarity association between pesticide and zero tillage while farmers who expected limited market access reported the highest complementarity between mixed cropping and mulching. Farmers who projected a decrease in output prices complements pesticides with mixed cropping. The findings suggest that understanding the heterogeneity effects in the combinations of SAPs due to COVID-19 shocks is critical to effectively design, target and disseminate sustainable intensification programs in a post-pandemic period.

1. Introduction

The COVID-19 pandemic is a recent major health crisis that has disrupted every sector of the economy and a challenge to meeting the sustainable development goals (SDGs), especially among developing countries. Several strategies including as lock-downs, widespread shelter-in-place orders, and limited in-person contacts have been adopted globally to contain the spread of the virus (Wang et al., 2020). These restrictions have disrupted domestic and global agricultural production and value chain systems (Barrett, 2020; Elleby et al., 2020). For example, the supply-side shocks such as availability and cost of labour have impacted negatively on production costs and distribution (Sumner, 2021). The economic costs of these measures are extremely high, with several implications on food security, income, and poverty (Amare et al., 2021; Kansiime et al., 2021; Ayanlade and Radeny, 2020; Chen et al., 2022). In developing countries, the pandemic has resulted in about 115 million additional people being extremely poor (World Bank, 2020).

The impact of the COVID-19 pandemic on food systems is one of the major priorities of scholars and policy-makers (Amare et al., 2021; Arndt et al., 2020; Barrett, 2020). Several empirical studies have reported a negative effect of increased food prices on food security due to external shocks. According to Bellemare (2015), high food prices result in social unrest, nutritional deficiency, a decline in social capital, psychosocial stress, and increase in poverty (Ravallion, 2020; Headey and Fan, 2008; Hadley et al., 2012; Ferreira et al., 2013). Ruan et al. (2021) analyzed the effect of nationwide lockdown on vegetable price in China and the findings show that the lockdown and resurgence of COVID-19 led to an increase in vegetable prices. Akter (2020) finds that COVID-19 stay-at-home restrictions increase food prices (meat, fish and seafood, and vegetables) in 31 European countries. In Bangladesh, Gatto and Islam (2021) used panel data to show that COVID-19 reduces agricultural production, the share of output sold, diet diversity, and education expenditure. In Nigeria, Amare et al. (2021) find that exposure to COVID-19 and lockdowns increase food insecurity due to a significant reduction in labour market participation. Ahmed et al. (2021) revealed that households who experience negative income shock due to
COVID-19 resulted in increased food insecurity, especially among hired labourers. Regarding the food and agricultural supply chains, the pandemic leading to restrictions in movement affected labour supply, input distribution (Kumar et al., 2021; Afridi et al., 2020; Kabir et al., 2020; Karim et al., 2020; Laborde et al., 2020), and limited access to input and output markets for both sellers and buyers (Zahir et al., 2021). According to Barrett (2020), the COVID-19 lockdown and movement restriction threaten the livelihoods of poor people due to the loss of jobs, businesses and limited access to markets. The disruption in the transportation sector due to concerns over safety and requirements for COVID-19 tests for truckers have resulted in delayed supply of food in Kenya (Roussou, 2020). Restriction and closure of informal markets in some urban and peri-urban areas disrupted the supply of fresh produce such as eggs and milk, fruits and meat especially among low-income urban households that depends on informal food markets (FAO, 2020). Labour shortages in the informal markets also impacted negatively on food processing, particularly for meat processing plants thus, leaving women in particular without access to informal markets (FAO, 2020). In terms of job and income losses, a study has shown that women were more affected than men, thus reducing their food consumption and increasing their savings (Dang and Nguyen, 2021). The lockdown measures have also disrupted the agricultural extension and advisory services by reducing farmers’ access to extension services (FAO, 2020).

Despite the growing number of studies on the pandemic on national and global indicators, there is limited research on coping mechanisms or mitigation strategies due to the COVID-19 shocks. A study by Pagani et al. (2020) show that coping strategies employed by farmers due to the pandemic includes keeping vegetable gardens, reduction in spending, change of diets, and expansion of area under food cultivation. Tripathi et al. (2021) find that in Tanzania farmers operated a more localized system by trading more among themselves whiles farmers in South Africa relied on family labour to reduce cost, consume own production, reduce the quantity of crops cultivated, share labour and rent out land, and sell assets such as livestock. However, there is limited understanding of how the pandemic influence the adoption of sustainable agricultural practices (SAPs). It is important to understand how perceptions of the COVID-19 shocks influence farm-level decisions and strategies employed to mitigate the negative effects.

This study examines how perceptions of COVID-19 shocks influence farm-level decisions on adoption and combination of SAPs among smallholder farmers in Ghana. More specifically, we examine the complementarity and substitutability associations among SAPs due to farmers’ experience of the disruptive effect of the pandemic on agriculture. SAPs are knowledge and labour-intensive agricultural practices that influence crop yields with subsequent effect on the environment depending on how they are combined and implemented on farmers’ plot. Understanding how external shocks influence combinations of SAPs is important in guiding development practitioners on the mitigation strategies to promote, taking into consideration the environmental impact. This study makes two contributions to the agricultural intensification literature. First, the paper extends the analysis beyond possibility to the intensity of SAPs adoption by considering the effects of COVID-19 shocks. We find that the intensity of SAPs adoption is significantly determined by socio-economic, demographic, production, social capital and increased input price due to the COVID-19. Second, the study contributes to the understanding of how perceptions of COVID-19 shocks influence the coping strategies (choice and combinations of SAPs) employed to sustain crop yields. Our results show heterogeneity in the combinations of SAPs either as complements or substitutes depending on the type of COVID-19 shocks.

The remainder of this paper is organized as follows. Section 2 describes the data and summary statistics followed by the empirical strategy in section 3. Section 4 discusses the empirical results while section 5 provides the concluding remarks and policy recommendations.

2. Data and descriptive statistics

2.1. Study area and data

This study relies on a survey conducted in July 2020 that assessed farmers’ crop yields, fertilizer use, food security, and COVID-19 shocks in Ghana’s Guinea, Sudan, and Transitional agroecological zones. Farmers in the Guinea and Savanna zones experience a unimodal annual average rainfall of about 1000 mm and 1100 mm, respectively lasting between May to October (Owusu, 2018) while farmers in the Transitional zone record an annual average rainfall of 1300 mm for the major season spanning from April to July (MoFA, 2017). The zone experiences a minor season which occurs between September and October and a dry spell in mid-August before the prolonged dry season between November and March. Fig. 1 shows the location of the farm households across the sampled regions of Ghana in the survey.

The study employed a multi-stage sampling technique to sample 1450 farmers in the three agroecological zones of Ghana. In the first stage, three districts were purposively selected based on their participation in the Planting for Food and Job (PFJ) program. Four communities were selected in the second stage due to their engagement in crop production. These communities were selected from different geographical points in relation to the district capital to capture diversity in the district. We employ systematic random sampling to select 15 farmers in each community in the final stage. To accommodate potential attrition, we further sampled 10 extra farmers to bring the total sample to 1450. Table 1 shows the distribution of the sampled households per region.

The primary data includes the socio-economic characteristics, type and fertilizer use, sustainable agricultural practices, food expenditure, crop production and utilization, crop commercialization, food security, poverty, household assets, and perceptions of COVID-19 shocks. This study relied on the sections of the data on SAPs and perceptions of COVID-19 shocks. The main SAPs considered based on their impact on the environment (Table A1), soil and plant are no tillage, mulching, mixed cropping, pesticides, and inorganic and organic fertilizer. The perceptions of COVID-19 shocks variables are decreased output prices, increased input prices, limited access to input and output markets, and inability to maintain farm activities due to loss of income. We complemented the survey data with secondary data on monthly food inflation from January 2018 to February 2021.

2.2. Descriptive statistics

Fig. 2 shows the monthly food inflation in Ghana from January 2018 to February 2021. Ghana experienced fluctuations in the monthly food inflation over the entire period. Except for July–October 2018, Ghana experienced inflationary prices with a spike observed in April 2020. The COVID-19 pandemic partly explains the monthly food inflationary price hike in April 2020. Ghana implemented a partial lockdown in March 2020 coupled with restrictions in input and commodities transportation due to the rising number of COVID-19 cases. This resulted in a disruption in the food systems and subsequent effects on food prices.

Table 2 reports farmers’ perception of COVID-19 shocks on

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1 The transition zone represents an area where the forest is quickly becoming wooded lands due to climatic factors such as increasing temperatures and decreasing precipitation.

2 Planting for Food and Jobs is a flagship agricultural Campaign of the Government, with five (5) implementation modules (Food Crops (PFJ), Planting for Export and Rural Development (PERD), Greenhouse Technology Villages (3 Villages), Rearing for Food and Jobs (RFJ), and Agricultural Mechanization Services (AMSECs)). The goal of the project is to modernize the agriculture sector of the economy in order to improve food security, create employment opportunities and reduce poverty (MoFA, 2019; https://mofa.gov.gh/site/images/pdf/PFJ.pdf).
agriculture, including decreased output prices, increased input prices, limited access to input and output markets, and inability to maintain farm activities due to loss of income. Gauging farmers’ response against

Table 1
Distribution of sampled households by region and agroecological zones.

| Regions     | Zone     | Districts | Communities | Households |
|-------------|----------|-----------|-------------|------------|
| Northern    | Guinea   | 3         | 12          | 180        |
| North East  | Guinea   | 3         | 12          | 182        |
| Savannah    | Guinea   | 3         | 12          | 180        |
| Upper East  | Sudan    | 3         | 12          | 180        |
| Upper West  | Sudan    | 3         | 12          | 180        |
| Bono        | Transition | 3     | 12          | 183        |
| Bono East   | Transition | 3     | 12          | 185        |
| Ahafo       | Transition | 3     | 12          | 180        |
| Total       |          | 24        | 96          | 1450       |

Notes: The total sample is supposed to be 1440 but 10 extra households were interviewed to accommodate future attrition thus increasing the sample size to 1450.

Fig. 1. Administrative map of Ghana showing the location of the farm households in the survey.

Fig. 2. Monthly food inflation due to COVID-19 pandemic. Note: The line shows the announcement of the lockdown by the government of Ghana in March 2021.
existing secondary data, we observed that output prices fluctuated over the study period. The majority (70%) of the farmers projected a decrease in output price. This may be due to the fact that most traders from the south were unable to travel to the north to buy grains (old stock) due to movement restrictions and uncertainties regarding community spread of the diseases; thus, farmers had to reduce the price of their grains to sell quickly to avoid colossal storage costs and losses. About 61% and 66% of the farmers projected that COVID-19 will lead to an increase in input prices, and limited access to input and output markets. About 62% of the farmers perceive that COVID-19 pandemic will result in income loss.

The result shows statistically significant differences in the responses of the farmers across the agro-ecological zones. In the Sudan agro-ecological zones, increase in input prices (74%), limited access to input and output markets (76%), and loss of income (71%) were the most cited COVID-19 shocks. In the Guinea and Transitional zones, a decrease in output prices (73%) was the most cited COVID-19 shock.

Fig. 3 shows the adoption of SAPs based on farmers’ perceived effects of COVID-19 shocks on their production. Organic fertilizer recorded the lowest adoption among all the SAPs, while inorganic fertilizer shows the highest adoption. Compared to other responses, farmers who projected decreased output prices recorded the highest adoption (51%) of no tillage. With reference to farmers who projected income loss and decrease in output prices, about 27% and 22% adopt mulching, tillage. With reference to farmers who projected income loss and decreased output prices recorded the highest adoption (51%) of no tillage. Compared to other responses, farmers who projected decreased output prices recorded the highest adoption (51%) of no tillage. With reference to farmers who projected income loss and decrease in output prices, about 27% and 22% adopt mulching, tillage. With reference to farmers who projected income loss and decreased output prices recorded the highest adoption (51%) of no tillage. Compared to other responses, farmers who projected decreased output prices recorded the highest adoption (51%) of no tillage. With reference to farmers who projected income loss and decrease in output prices, about 27% and 22% adopt mulching, tillage. With reference to farmers who projected income loss and decreased output prices recorded the highest adoption (51%) of no tillage. Compared to other responses, farmers who projected decreased output prices recorded the highest adoption (51%) of no tillage. With reference to farmers who projected income loss and decrease in output prices, about 27% and 22% adopt mulching, tillage.

3. Empirical strategy

This section presents the empirical model that identifies the potential possible combinations of SAPs and their relationship. We use the principal component analysis (PCA) to identify the possible combinations of SAPs and subsequently employ the multivariate probit model (MVP) to determine the relationships (complements or substitutes) among the SAPs based on farmers’ perception of COVID-19 shocks. The data was further subjected to Poisson regression to ascertain the factors influencing the intensity of adoption of SAPs.

3.1. Principal component analysis

The PCA’s detailed description and application in identifying the possible combinations of SAPs have been published elsewhere (Martey and Kuwornu, 2021). The PCA was applied to determine the possible combinations of all the SAPs that farmers adopted on their farm plots. The weights generated by the PCA is used to construct household-specific SAPs index.

3.2. Multivariate probit analysis of the adoption of SAPs

The study explores the heterogeneity of SAPs, emphasizing perceptions of COVID-19 shocks at the extensive margin. At the extensive margin, the study explores farmers adoption (binary indicator) of SAPs using the MVP model with emphasis on COVID-19 shocks in the agricultural sector. The MVP model allows for the control of the interdependence between the SAPs. Complementarity and substitute associations between SAPs are one of the primary sources of correlation (Green, 2012; Belderbos et al., 2004).
Table 3
Summary statistics of explanatory variables by adoption status.

| Variables                             | Non-adopters | Low adopters | High adopters |
|---------------------------------------|--------------|--------------|--------------|
|                                       | Mean         | Std. dev.    | Mean         | Std. dev.    | Mean         | Std. dev.    |
| Gender (1 = male)                     | 0.869        | 0.340        | 0.823        | 0.382        | 0.803        | 0.398        |
| Age (years)                           | 44.525       | 14.058       | 42.961       | 12.574       | 45.555       | 12.641       |
| Years of education (years)            | 2.951        | 4.533        | 4.359        | 5.090        | 4.777        | 5.058        |
| Marital status (1 = married)          | 0.918        | 0.277        | 0.854        | 0.353        | 0.858        | 0.349        |
| Nativity (1 = household head native)  | 0.820        | 0.388        | 0.802        | 0.399        | 0.838        | 0.369        |
| Female household members (number)     | 6.508        | 6.959        | 4.938        | 4.915        | 5.284        | 5.390        |
| Male household members (number)       | 7.525        | 7.226        | 5.423        | 5.855        | 5.380        | 4.461        |
| Number of dependents (number)         | 7.541        | 6.862        | 7.137        | 4.988        | 7.664        | 6.251        |
| Farm size (hectares)                  | 2.059        | 1.665        | 2.117        | 2.224        | 2.149        | 2.567        |
| Own farmland (1 = yes)                | 0.607        | 0.493        | 0.569        | 0.496        | 0.607        | 0.489        |
| Farming experience (years)            | 21.262       | 13.393       | 20.358       | 12.155       | 21.430       | 12.304       |
| Engaged in other economic activities (1 = yes) | 0.262        | 0.444        | 0.457        | 0.499        | 0.477        | 0.500        |
| Engaged in contract farming (1 = yes) | 0.213        | 0.413        | 0.175        | 0.380        | 0.158        | 0.365        |
| Access to extension services (1 = yes) | 0.410        | 0.496        | 0.408        | 0.492        | 0.465        | 0.499        |
| Number of extension access (number)   | 1.148        | 1.558        | 1.293        | 2.309        | 1.706        | 2.992        |
| Migration due to farming (number)     | 0.607        | 1.370        | 0.216        | 0.660        | 0.216        | 0.650        |
| Member of farmer-based organization (1 = yes) | 0.164        | 0.373        | 0.216        | 0.412        | 0.294        | 0.456        |
| Household members seeking non-farm jobs (number) | 1.033        | 2.065        | 0.723        | 1.392        | 0.817        | 1.389        |
| Farm area insured (hectares)          | 15.000       | 34.448       | 24.633       | 50.131       | 25.332       | 59.376       |
| Total household income (Ghana cedi)   | 2015         | 5927         | 2417         | 4570         | 3218         | 4415         |
| Number of family members (number)     | 5.869        | 4.573        | 4.201        | 3.629        | 4.635        | 5.133        |
| Number of hired labour (number)       | 4.852        | 6.633        | 5.518        | 9.068        | 8.310        | 12.359       |
| Decrease in output price (1 = yes)    | 0.623        | 0.489        | 0.687        | 0.464        | 0.722        | 0.448        |
| Increase in input price (1 = yes)     | 0.541        | 0.502        | 0.561        | 0.497        | 0.667        | 0.472        |

Table 3 (continued)

| Variables                             | Non-adopters | Low adopters | High adopters |
|---------------------------------------|--------------|--------------|--------------|
|                                       | Mean         | Std. dev.    | Mean         | Std. dev.    | Mean         | Std. dev.    |
| Limited access to input and output markets (1 = yes) | 0.475        | 0.504        | 0.651        | 0.477        | 0.696        | 0.460        |
| Income loss (1 = yes)                 | 0.541        | 0.502        | 0.579        | 0.494        | 0.674        | 0.469        |
| Regions                               |              |              |              |              |              |              |
| Northern (1 = yes)                    | 0.230        | 0.424        | 0.127        | 0.333        | 0.113        | 0.317        |
| North East (1 = yes)                  | 0.049        | 0.218        | 0.104        | 0.305        | 0.155        | 0.362        |
| Bono (1 = yes)                        | 0.262        | 0.444        | 0.209        | 0.407        | 0.026        | 0.160        |
| Upper West (1 = yes)                  | 0.131        | 0.340        | 0.159        | 0.366        | 0.090        | 0.286        |
| Bono East (1 = yes)                   | 0.082        | 0.277        | 0.098        | 0.298        | 0.162        | 0.369        |
| Ahafu (1 = yes)                       | 0.164        | 0.373        | 0.153        | 0.360        | 0.088        | 0.284        |
| Observations                          | 61           | 697          | 692          |              |              |              |

Notes: Low adopters are statistically significant different from non-adopters in terms of years of education (**), nativity (*), number female household members (**), farm size (*), participation in other economic activities (**), migration due to farming (**), farm area insured (**), total household income (**), family labour (**), limited access to input and output markets (**), and residence in Northern (*), North East (**), Bono (**), and Bono East (**). High adopters are statistically significant different from non-adopters in terms of years of education (**), number female household members (**), participation in other economic activities (**), number of extension access (**), migration due to farming (**), member of FBO (**), farm area insured (**), total household income (**), family labour (**), hired labour (**), anticipated increase in input price (**), limited access to input and output markets (**), loss of income (**), and residence in Northern (**), North East (**), Bono (**), and Bono East (**). High adopters are statistically and significant different from low adopters in terms of age (**), marital status (**), male household members (**), access to extension services (**), number of extension visits (**), member of FBO (**), total household income (**), family labour (**), hired labour (**), anticipated increase in input price (**), limited access to input and output markets (**), loss of income (**), and residence in North East (**), Savannah (**), Upper East (**), Bono (**), and Bono East (**). High adopters are statistically and significant different from low adopters in terms of age (**), marital status (**), male household members (**), access to extension services (**), number of extension visits (**), member of FBO (**), total household income (**), family labour (**), hired labour (**), anticipated increase in input price (**), limited access to input and output markets (**), loss of income (**), and residence in North East (**), Savannah (**), Upper East (**), Bono (**), and Bono East (**). High adopters are statistically and significant different from low adopters in terms of age (**), marital status (**), male household members (**), access to extension services (**), number of extension visits (**), member of FBO (**), total household income (**), family labour (**), hired labour (**), anticipated increase in input price (**), limited access to input and output markets (**), loss of income (**), and residence in North East (**), Savannah (**), Upper East (**), Bono (**), and Bono East (**).

Following from theory, adoption of SAPs is realized when the net benefit is greater than zero, $K_{ij}^* = E[U_iAi)E[U_iki)]$. The net benefit $K_{ij}^*$ derived by a farmer from the adoption of jth SAPs is a latent variable determined by household and farm characteristics, COVID-19 shocks, institutional and regional level characteristics ($\chi_k$) (Table 3) and the error term ($\mu_i$). The model is formally expressed as:

$$K_{ij}^* = X_{ij}\beta_j + \mu_i$$

where $NT$ is no tillage, $M$ is mulch, $MC$ is mixed cropping, $P$ is pesticide, $IP$ is inorganic fertilizer, and $OF$ is organic fertilizer. The explanatory variables are motivated by the literature on SAPs adoption and COVID-19 shocks on agricultural production (Martey and Kuwornu, 2021; Liverpool-Tasie et al., 2020; Waldman et al., 2017; Meijer et al., 2015; Wise et al., 2014). The unobserved preferences in equation (1) translate into the observed binary outcome equation for each choice based on the indicator function as follows:
K = \begin{cases} 1 & \text{if } K_o > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)

In the multivariate probit model, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean, and variance-covariance matrix V which is normalized to unity (for identification of the parameters). The non-zero off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic components of the different SAPs. This correlation coefficient establishes the complementary (positive correlation) and substitution associations (negative correlation) among the SAPs.

### 3.3. Poisson and negative binomial regression analysis of adoption intensity

The study employs the Poisson and negative binomial regression models to analyze the factors influencing the intensity of SAPs adoption given the count nature of the data. The Poisson and Negative Binomial regression models are standard count models in the literature (Greene, 2000; Grogger and Carson, 1991; Cameron and Trivedi, 1986). A detailed description of the Poisson and negative binomial regression models have been published elsewhere (Martey and Kuwornu, 2021).

### 4. Empirical results

#### 4.1. Packages of SAPs: principal component analysis

The PCA determined the packages of SAPs. Fig. 4 shows the plot of the eigen values against the number of components to include in the PCA. Six factors were considered in the PCA but only two components were retained although about three of the components had eigen values above one.

Table 4 shows the two component loadings of the SAPs and Kaiser-Meyer-Olkin (KMO) values for each SAPs. The estimated overall KMO measure was 0.605, indicating sampling adequacy of the PCA. Mulching and organic fertilizer contributed more in terms of the overall KMO. Twenty-eight percent (28%) and 48% of the variations in the use of inorganic fertilizer and pesticides, respectively, are unexplained by the retained components. About 54%, 59%, and 56% of the variations in the use of mulch, no tillage, and mixed cropping, respectively, are unexplained, while 75% of the variation in the use of organic fertilizer is unexplained by the retained components. No tillage, mulching, mixed cropping, pesticides, and organic fertilizer highly loaded on component one. No tillage, mulching, mixed cropping, pesticides, and inorganic fertilizer are highly loaded on component two. This indicates the pattern of SAPs adoption on farmers’ plots, but there is limited information regarding the relationship among the SAPs.

Fig. 5 presents the distribution of the SAPs index for the first (panel A) and second components (panel B). Panel A is more normally distributed than panel B. The majority of the respondents recorded SAPs index between −2 and −1.5 (panel A) and 0.5 to 1 (panel B). The distribution of panel B is more skewed towards the right, where the majority of the respondents recorded SAPs index between −1 and 1.5.

#### 4.2. Determinants of adoption of SAPs

Table 5 presents the results of the MVP regression which measures the probability of adopting one of the SAPs. The Wald test suggests that the explanatory variables included in the MVP model provide a good explanation regarding the choice of SAPs. The results vary across the different SAPs. Farmers are 19 percentage points less likely to adopt mixed cropping and 48 percentage points more likely to adopt organic fertilizer. Older farmers are 2.4 and 0.9 percentage points more likely to adopt no tillage and mixed cropping, respectively. In contrast, older farmers are 1.6 percentage points less likely to adopt inorganic fertilizer. Nativity and number of dependents are associated with a 25.7 and 1.8 percentage points adoption of pesticides, respectively.

The probability of adopting no tillage and mixed cropping is 11.9 and 19.2 percentage points lower for farm households with migrants. Similarly, farm household members seeking off-farm jobs are 7.1 percentage points and 7.8 percentage points less likely to adopt no tillage and pesticides. Migration has both negative and positive effects on technology adoption. In our case, SAPs adoption is associated with high labour demand, and because migration reduces household family labour, it thus reduces the probability of adopting SAPs. Job seekers may reduce their labour effort in farming activities in anticipation of ‘better’ employment opportunities with high remuneration. The log of household income leads to 6.9 percentage points, 3.6 percentage points, 11.4 percentage points and 4.8 percentage points adoption no tillage, mulching, pesticide, and organic fertilizer, respectively. Statistically, the effect is higher for pesticide adoption relative to zero tillage. Farmers who earn more income are more likely to use pesticides to control pests than farmers with low income. For example, the fall armyworm is a typical example that requires pesticides to control. A study by Tambo and Kiru, (2021) finds that severe fall armyworm infestation reduced per capita household income by 44% and increased households’ likelihood of experiencing hunger by 17%. To avert this negative effect of pests, farmers who earn more income will invest in pesticides.

Apart from the demographic characteristics, an increase in farm size leads to 4.9 percentage points and 3.3 percentage points less likely to influence the adoption of no tillage and mixed cropping, respectively. The results also show that farmers who cultivated own land are 31 percentage points, 28 percentage points, and 25 percentage points more likely to adopt mulching, mixed cropping, and organic fertilizer, respectively but 17.4 percentage points less likely to use inorganic fertilizer. Experienced farmers are 2.3 percentage point less likely to adopt no tillage but 1.7 percentage point more likely to adopt inorganic fertilizer. Farmers who engaged in contract farming are 35 percentage points, 19 percentage points, and 24 percentage points less likely to...
adopt zero tillage, mixed cropping, and pesticides, while farmers who engaged in other economic activities apart from farming are 13.3 percentage points and 25.4 percentage points more likely to use pesticides and organic fertilizer. Contract farming specifies the terms of conditions of the contract which may not necessarily accommodate some SAPs. Participation in other economic activities improves household income which can be invested in protectants and soil fertility management practices to reduce pest infestations and enhance soil fertility. Farmers area under insurance program are 0.1 percentage points less likely to influence zero tillage and 0.2 percentage points more likely to use of inorganic fertilizer. The number of family labour is positively associated with all the SAPs except pesticide and inorganic fertilizer adoption. The effect is highest for organic fertilizer adoption. Organic fertilizer is bulky and requires more labour to transport and apply on the field. Consistent with family labour, the number of hired labour is positively associated with no tillage and mulching but negatively associated with pesticide adoption. The results suggest that hired and family labour is used for land management activities rather than for crop protection.

Institutional factors such as access to extension services are positively associated with no tillage, pesticide, and inorganic fertilizer. The positive association between extension and inorganic fertilizer use is consistent with the findings of Martey and Kuwornu (2021). This result is likely because SAPs are knowledge-based technologies and require demonstration to fully appreciate and adopt. Farmers who belong to farmer associations are 26.5 percentage points and 25.4 percentage points more likely to use pesticides. The adoption of mixed cropping could be a strategy to reduce pest infestations and enhance soil fertility. Farmers who reported an increase in input price are less likely to adopt mulching. The result suggests rationality in farmers decision of substituting inorganic fertilizer with no tillage. The results indicate that these farmers are environmentally friendly given that no tillage protects the soil from erosion and helps retain soil moisture, organic matter, and nutrient cycling. In addition, organic fertilizer releases nutrients slowly into the soil to reduce losses. It ensures that nutrients are retained for longer periods, and improving soil structure to hold water and nutrients, conserving moisture in the soil, reduces evapotranspiration, reduce risk of crop failure due to environmental stress, increases soil fertility, reduce pest infestation, and increases crop yield due to the complementary effects of each practice. We observed unique combinations of SAPs for farmers who projected limited access to input and markets recorded the highest complementarity association (0.405) between mixed cropping and mulching. The complementary pair of SAPs includes mulching and no tillage, mixed cropping and no tillage, pesticide and no tillage, mixed cropping and mulching, pesticide and mulching, pesticide and mixed cropping and inorganic fertilizer and pesticide are common to all farmers. The results indicate that farmers combine these practices irrespective of their perceptions of COVID-19 shocks on agriculture.

Table 6 presents the correlation matrix of the MVP model for the entire sample and sub-sample of farmers based on their anticipated COVID-19 shocks on agriculture. The correlation coefficient is restricted to only significant combinations of SAPs. The full result is reported in Table A2 in the appendix. The first, second, third, fourth, and fifth columns show how farmers combine SAPs based on the entire sample and experiences regarding decreased output prices, increased input prices, limited access to input and output markets, and loss of income, respectively. A positive correlation coefficient between the error terms of two SAPs suggests complements and a negative correlation indicates substitutes. Our results indicate that most of the SAPs complement each other, with few substitutes.

Regarding the full sample, the highest complementarity relationship among the SAPs is observed between pesticide and no tillage (0.437) and is consistent for farmers who anticipated an increase in input prices (0.484) and income loss (0.496). Farmers who anticipated decrease in output price recorded the highest complementarity association (0.325) between pesticide and mixed cropping. In contrast farmers who projected limited access to input and markets recorded the highest complementarity association (0.405) between mixed cropping and mulching. The complementary pair of SAPs includes mulching and no tillage, mixed cropping and no tillage, pesticide and no tillage, mixed cropping and mulching, pesticide and mulching, pesticide and mixed cropping, and inorganic fertilizer and pesticide are common to all farmers. The results indicate that farmers combine these practices irrespective of their perceptions of COVID-19 shocks on agriculture. Adopting these practices generally improve soil structure, conserve moisture in the soil, reduces evapotranspiration, reduce risk of crop failure due to environmental stress, increases soil fertility, reduce pest infestation, and increases crop yield due to the complementary effects of each practice. We observed unique combinations of SAPs for farmers who projected limited access to input and output markets and loss of income due to COVID-19 pandemic.

Farmers who anticipated a decrease in output price and an increase in input price are unique in their likelihood of complementing organic fertilizer with no tillage. The results indicate that these farmers are interested in the long-term benefit of soil productivity practices that are environmentally friendly given that no tillage protects the soil from erosion and helps retain soil moisture, organic matter, and nutrient cycling. In addition, organic fertilizer releases nutrients slowly into the soil to reduce losses. It ensures that nutrients are retained for longer periods, and improving soil structure to hold water and nutrients. Perception of a decrease in output price and limited access to input and output markets influences farmers’ decision of substituting inorganic fertilizer for mulch or vice versa. The effect is higher for farmers who anticipated a decrease in output price relative to farmers who reported
limited access to input and output markets. An expectation of a future output price decrease may influence farmers to adopt only inorganic fertilizer to improve land, and crop productivity to meet household consumption relative to commercialization.

Farmers who anticipated a decrease in output prices and limited market access shift production investment decisions from short-term SAPs (inorganic fertilizer) to long-term SAPs (mulch). Alternatively, farmers may opt for mulch to retain soil moisture to mitigate evapotranspiration and subsequently reduce yield losses. The substitution effect is consistent with the findings of Martey and Kuwornu (2021) and Waldman et al. (2017) who find that when farmers are faced with risks, they are more likely to make risk averse decisions (such as adopting practices that maintain soil moisture and reduce weed) that has the potential of influencing farm productivity. Our results further confirm the findings of Shikuku et al. (2017) that farmers are likely to invest in technologies with high level of associated risk.

Table 5
Coefficient estimates of the multivariate probit model of SAPs adoption.

| Variables | (1) No tillage | (2) Mulching | (3) Mixed cropping | (4) Pesticides | (5) Inorganic fertilizer | (6) Organic fertilizer |
|-----------|---------------|-------------|-------------------|---------------|-------------------------|----------------------|
| Gender of household head (1 – male) | −0.039 | −0.064 | −0.187** | 0.114 | −0.150 | 0.477*** |
| Age of household head | 0.024*** | 0.002 | 0.009* | 0.004 | −0.016** | 0.010 |
| Years of education | 0.004 | −0.011 | 0.003 | −0.016* | −0.013 | −0.033*** |
| Nativity (1 = household head is native) | 0.027 | −0.021 | −0.056 | 0.024 | 0.257** | 0.041 |
| Female household members | 0.006 | 0.008 | 0.009 | 0.014 | −0.010 | −0.017 |
| Male household members | −0.001 | 0.008 | −0.005 | 0.009 | 0.002 | −0.002 |
| Number of dependents | 0.004 | −0.015 | −0.002 | 0.018* | 0.009 | −0.001 |
| Household members migrated due to farming | −0.119** | −0.192*** | −0.034 | −0.083 | −0.048 | 0.034 |
| Household members seeking off-farm jobs | −0.071** | 0.049 | −0.009 | −0.078** | −0.021 | −0.043 |
| Log of total household income | 0.069*** | 0.036* | 0.013 | 0.114*** | 0.015 | 0.048* |
| Farm size | −0.049*** | −0.006 | −0.033* | 0.019 | −0.002 | −0.004 |
| Marital status (1 = married) | −0.099 | −0.099 | 0.007 | −0.160 | −0.008 | −0.056 |
| Own farm land (1 = yes) | −0.038 | 0.310*** | 0.278*** | 0.047 | −0.174* | 0.249** |
| Farming experience (years) | −0.023*** | −0.008 | −0.007 | −0.009 | 0.017** | −0.003 |
| Engaged in contract farming (1 = yes) | −0.350*** | 0.072 | −0.191* | −0.240** | 0.047 | −0.083 |
| Engaged in other economic activities (1 = yes) | 0.014 | 0.039 | 0.059 | 0.123** | 0.062 | 0.254** |
| Farm area insured | −0.001** | 0.001 | −0.000 | 0.001 | 0.002* | 0.001 |
| Number of family labour | 0.024** | 0.039*** | 0.032*** | −0.027** | −0.029** | 0.052*** |
| Number of hired labour | 0.009** | 0.011*** | 0.001 | −0.009** | 0.002 | −0.005 |
| Access to extension services (1 = yes) | 0.172* | −0.024 | 0.003 | −0.060 | −0.093 | −0.007 |
| Number of times of extension access | 0.013 | −0.013 | −0.025 | 0.054*** | 0.102*** | −0.012 |
| Member of FIO (1 = yes) | 0.110 | 0.078 | 0.095 | 0.265*** | −0.042 | 0.028 |
| COVID-19 shocks | 0.114 | −0.493*** | −0.058 | 0.039 | 0.141 | −0.029 |
| Increase in input price | −0.163* | 0.424*** | 0.214** | 0.475*** | −0.039 | −0.083 |
| Limited access to input and output markets | 0.022 | −0.170* | −0.025 | 0.359*** | 0.173* | 0.133 |
| Inability to maintain farm due to income loss | −0.184** | 0.087 | 0.022 | 0.014 | −0.032 | −0.297** |
| Constant | −0.853*** | −0.561* | −0.572** | −1.509*** | −0.505 | −2.862*** |
| Region fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1444 | 1444 | 1444 | 1444 | 1444 | 1444 |
| Wald chi2 (198) | 1320*** | | | | | |
| Log-likelihood | −4061.0538 | | | | | |

Notes: Robust standard errors are in parentheses. ***p < 0.01; **p < 0.05; *p < 0.1.
in input price, and loss of income, perception of limited access to input and output markets is associated with unique complementarity association of organic fertilizer and mulch. The result is consistent with our expectation, given that farmers with limited market access will rely on readily available factor inputs to enhance soil fertility and maintain soil moisture for optimum crop yield. Similarly, farmers who experienced income loss uniquely substitute inorganic fertilizer for mixed cropping. The inorganic fertilizer is costly, but when applied appropriately using site-specific recommended rate, the economic reward especially yield gains is high. However, income loss may reduce farm investment in terms of input purchase but increase the likelihood of farmers engaging in crop diversification strategy to reduce the high risk of income loss. The result suggests that farmers sacrifice short-term benefits of crop yield for crop diversification as a mechanism for reducing risks of crop and income loss.

Finally, farmers who reported decreased output price and income loss complemented organic fertilizer with pesticides. The highest complementary association is observed for farmers who reported income loss due to the COVID-19. Consistent with the earlier findings, farmers who reported income loss due to the COVID-19. Consistent with the earlier findings, farmers who reported income loss uniquely substitute inorganic fertilizer for mixed cropping. The inorganic fertilizer is costly, but when applied appropriately using site-specific recommended rate, the economic reward especially yield gains is high. However, income loss may reduce farm investment in terms of input purchase but increase the likelihood of farmers engaging in crop diversification strategy to reduce the high risk of income loss. The result suggests that farmers sacrifice short-term benefits of crop yield for crop diversification as a mechanism for reducing risks of crop and income loss.

### 4.4. Intensity of SAPs adoption

The results of the Poisson model employed to measure the extent or the number of SAPs adopted are reported in Table 7. Models 1 and 3 are the Poisson and the negative binomial regression models that include non-adopters of SAPs. In contrast, models 2 and 4 are the Poisson and the negative binomial regression models that exclude non-adopters of SAPs. Comparing the AIC values across models, models 2 and 4 recorded lower AIC than models 1 and 3. In the interest of brevity but without loss of generalizations for the conclusions, we discuss the restricted Poisson model (model 2), which is similar in terms of the magnitude of effect to the negative binomial regression model. Our result is consistent and robust across model specifications.

The intensity of SAPs adoption is significantly determined by age, years of formal education, farm size, ownership of farmland, farming experience, contract farming, migration, membership of FBO, household income, family labour, and increase in input price due to COVID-19 pandemic. Age of farmer is positively associated with the intensity of SAPs adoption. This indicates that older household heads are more likely to adopt multiple SAPs. Older farmers may have experimented with SAPs adoption. This indicates that older household heads are more likely to adopt multiple SAPs. Older household heads are 1.4 percentage points less likely to adopt multiple SAPs. The result is consistent with Martey and Kuwornu (2021) who find that education reduces the intensity of adopting soil fertility management practices. The result indicates that education enables farmers to make an informed decision given that multiple adoptions of SAPs which are labour intensive.

Farmers with smaller farm sizes are 2.8 percentage points more likely to adopt multiple SAPs than those with large farms. Most smallholder farmers are resource-poor; thus, they are more likely to adopt multiple SAPs on a small parcel of farmland for effective management (Martey and Kuwornu, 2021). The result suggests farm intensification, which has been proven to positively impact yield and household welfare (Shew et al., 2019; Varma, 2019; Van Campenhout and Bizimungu, 2018;
Farmers that own land are more likely to make long-term investments to adopt improved cassava varieties (Adams et al., 2021; Manda et al., 2020). Previous studies that find that member of FBO increases the adoption of maize and cowpea technologies, use of inorganic fertilizer, crop rotation, and adoption of improved cassava varieties (Adams et al., 2021; Wossen et al., 2017). Household income is positively associated with the adoption of multiple SAPs. Membership of FBO enhances knowledge sharing, learning, and intensity of SAPs adoption.

Table 7

| Variables                      | Poisson regression models | Negative binomial regression models |
|-------------------------------|---------------------------|-------------------------------------|
|                               | Model 1                   | Model 2                             |
|                               | Marginal Effect | Robust Effect | Marginal Effect | Robust Effect | Marginal Effect | Robust Effect |
| Gender of household head (1 – male) | -0.009 | 0.092 | -0.003 | 0.089 | -0.009 | 0.092 | -0.003 | 0.089 |
| Age of household head | 0.009*** | 0.005 | 0.010** | 0.004 | 0.009*** | 0.005 | 0.010** | 0.004 |
| Years of education | -0.014* | 0.008 | -0.014* | 0.008 | -0.014* | 0.008 | -0.014* | 0.008 |
| Nativity (1 – household head is native) | 0.040 | 0.088 | 0.048 | 0.085 | 0.040 | 0.088 | 0.048 | 0.085 |
| Female household members | 0.002 | 0.007 | 0.004 | 0.006 | 0.002 | 0.007 | 0.004 | 0.006 |
| Male household members | 0.002 | 0.008 | 0.008 | 0.008 | 0.002 | 0.008 | 0.008 | 0.008 |
| Number of dependents | 0.003 | 0.008 | -0.002 | 0.007 | 0.003 | 0.008 | -0.002 | 0.007 |
| Farm size | -0.026* | 0.015 | -0.028* | 0.015 | -0.026* | 0.015 | -0.028* | 0.015 |
| Marital status (1 – married) | -0.141 | 0.095 | -0.087 | 0.094 | -0.141 | 0.095 | -0.087 | 0.094 |
| Own farm land (1 – yes) | 0.193*** | 0.072 | 0.168** | 0.068 | 0.193*** | 0.072 | 0.168** | 0.068 |
| Farming experience (years) | -0.011*** | 0.005 | -0.012*** | 0.004 | -0.011*** | 0.005 | -0.012*** | 0.004 |
| Engaged in other economic activities (1 – yes) | 0.111* | 0.066 | 0.064 | 0.064 | 0.111* | 0.066 | 0.064 | 0.064 |
| Engaged in contract farming (1 – yes) | -0.239*** | 0.095 | -0.187*** | 0.090 | -0.239*** | 0.095 | -0.187*** | 0.090 |
| Access to extension services (1 – yes) | 0.046 | 0.084 | 0.037 | 0.081 | 0.046 | 0.084 | 0.037 | 0.081 |
| Number of times of extension access | 0.020 | 0.015 | 0.021 | 0.014 | 0.020 | 0.015 | 0.021 | 0.014 |
| Migrated due to farming | -0.146** | 0.062 | -0.100* | 0.057 | -0.146** | 0.062 | -0.100* | 0.057 |
| Member of FBO (1 – yes) | 0.168** | 0.076 | 0.141* | 0.073 | 0.168** | 0.076 | 0.141* | 0.073 |
| Non-farm jobs | -0.048 | 0.030 | -0.036 | 0.027 | -0.048 | 0.030 | -0.036 | 0.027 |
| Farm area insured | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Log of total household income | 0.086*** | 0.017 | 0.064*** | 0.015 | 0.086*** | 0.017 | 0.064*** | 0.015 |
| Number of family labour | 0.025*** | 0.009 | 0.031*** | 0.008 | 0.025*** | 0.009 | 0.031*** | 0.008 |
| Number of hired labour | 0.002 | 0.003 | 0.002 | 0.003 | 0.002 | 0.003 | 0.002 | 0.003 |
| Decrease in output price | -0.044 | 0.090 | -0.052 | 0.088 | -0.044 | 0.090 | -0.052 | 0.088 |
| Increase in input price | 0.267*** | 0.083 | 0.281*** | 0.081 | 0.267*** | 0.083 | 0.281*** | 0.081 |
| Limited access to input and output markets | 0.131 | 0.085 | 0.048 | 0.082 | 0.131 | 0.085 | 0.048 | 0.082 |
| Income loss | -0.088 | 0.078 | -0.070 | 0.075 | -0.088 | 0.078 | -0.070 | 0.075 |
| Region fixed effects | Yes | Yes | Yes | Yes |
| Pearson goodness-of-fit (Prob > Chi2) | 824 (1.000) | 661 (1.000) | 824 (1.000) | 661 (1.000) |
| AIC | 4526 | 4752 | 4526 | 4752 |
| BIC | 5005 | 4750 | 5005 | 4750 |
| Pseudo R-squared | 0.053 | 0.043 | 0.053 | 0.043 |

Notes: ***p < 0.001; **p < 0.05; *p < 0.1.

5. Conclusion

Sustainable agricultural practices have long been studied and proven to positively impact yield, welfare, and environmental outcomes. However, there is no empirical evidence on how perceptions of exogenous shocks such as the novel COVID-19 pandemic influences the adoption and combinations of SAPs. Our study assessed how farmers adapt and combine SAPs in response to their anticipation of COVID-19 shocks such as decrease in output price, increase in input price, limited access to input and output market, and loss of income. The shocks are linked directly with the synergistic and trade-offs associations in the combinations of SAPs with subsequent effect on environmental outcomes.

The main results of the study lead to two major conclusions. First, the intensity of SAPs adoption is significantly influenced by age, years of education, farm size, ownership of farmland, farming experience, contract farming, migration, membership of FBO, household income, family labour, and COVID-19 shocks. These findings indicate that the promotion of SAPs among farm households must prioritize these factors to ensure broad and sustained adoption of SAPs. Second, we find heterogeneity in the combinations of SAPs adopted by farmers based on their experience of COVID-19 shocks. The adaptive response to these shocks is expressed in the combinations of the SAPs. Farmers who reported a decrease in output price, and an increase in input prices are unique in their likelihood of adopting organic fertilizer with no tillage. Decrease in output price and limited access to input and output markets coupled with the ravages of the pandemic on the rural economy may influence households to adopt strategies such as the adoption of SAPs to ensure sustainable food production.

Garnett et al., 2013), Farmers who own land are 16.8 percentage points more likely to adopt multiple SAPs relative to farmers who rent land. Land productivity investment is highly correlated with land ownership. Farmers that own land are more likely to make long-term investments to improve their welfare, unlike renters who may invest in short-term land productivity enhancing practices to fulfill their contractual requirements from the land returns. Farming experience is negatively associated with the adoption of multiple SAPs. Comparing the results with age suggest that the elderly may increase the adoption of SAPs but years of farming experience reduces the intensity of adoption of SAPs. Farmers who engage in contract farming are 18.7 percentage points less likely to adopt multiple SAPs relative to farmers who do not engage in contract farming. Contract farming is associated with specifications that require strict compliance with little or no shirking. The migration of household members reduces the intensity of the adoption of SAPs by 10 percentage points due to the reduction in family labour to support the implementation of SAPs. Consistently, family labour increases the intensity of SAPs adoption.

Membership of FBO is positively associated with the adoption of SAPs. Membership of FBO enhances knowledge sharing, learning, and support services to members. The positive association between membership of FBO and technology adoption is consistent with previous studies that find that member of FBO increases the adoption of maize and cowpea technologies, use of inorganic fertilizer, crop rotation, and adoption of improved cassava varieties (Adams et al., 2021; Manda et al., 2020; Wossen et al., 2017). Household income is positively associated with multiple SAPs adoption. The result is consistent with expectations due to the costly nature of the SAPs. Farmers who projected an increase in input price due to the COVID-19 are 28.1 percentage points more likely to adopt multiple SAPs. The anticipated price increase
influences farmers’ decision of substituting inorganic fertilizer for mulch or vice versa. The correlation effect is higher for farmers who reported a decrease in output price relative to farmers with limited access to input and output markets. Farmers who reported a decline in output price and loss of income complements organic fertilizer with pesticides. In contrast, limited access to input and output markets is associated with unique complementary combinations of organic fertilizer and mulch. Income loss due to COVID-19 is associated with a substitution effect between inorganic fertilizer for mixed cropping. The results imply a trade-off decision in terms of soil and plant protection and environmental impact. Furthermore, the results suggest that farmers are adjusting appropriately to the COVID-19 shocks to enhance their resilience.

The importance of this finding is that the adoption and combinations of SAPs recommended for increasing yield are less likely to be implemented if economic agents’ interest or personal relationships that could have appeared to influence the work reported in this paper.

Declarations

Availability of data and manual

The authors do not have the right to share the data but available upon request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.115810.

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