The Effects of Rising Prices on Corn Production in Western African Countries

Marco Rogna*

European Commission, Joint Research Centre (JRC–Seville), Calle Inca Garcilaso 3, 41092, Sevilla.

*marco.rogna@ec.europa.eu

Abstract

The intensification of the Russo–Ukrainian war started in February 2022 with the Russian invasion of Ukraine has generated a dramatic increase in the price of several goods. In particular, energy, gas and oil have been the most interested by this spike in prices, followed by several agricultural commodities. Fertilizers, whose production is energy intensive and/or directly dependent from oil derivatives, have also experienced a sharp increase in prices. This has risen concerns for food insecure countries, particularly in Africa, since, besides a lower possibility to purchase food commodities on the international market, they will likely decrease their own production due to a lower utilization of fertilizers. Quantifying this potential decrease in agricultural production is important in order to fully assess their vulnerability in terms of food security. The present paper tries to accomplish this task by forecasting the change in maize production in 2022 and 2023 compared to 2021 in seven Western African countries. We find an overall decline in maize production of 10% circa in both years with a strong heterogeneity among countries. Trivial users of fertilizers, such as Niger, experience a very modest decline in production (less than 2%) whereas others, such as Benin and Togo, have a double digit decline: approximately 13% the former and 32% the latter.

Keywords: Crop models; Food security; Maize yields; Western Africa; Yields forecast.

J.E.L. Code: Q12; Q17; Q18.

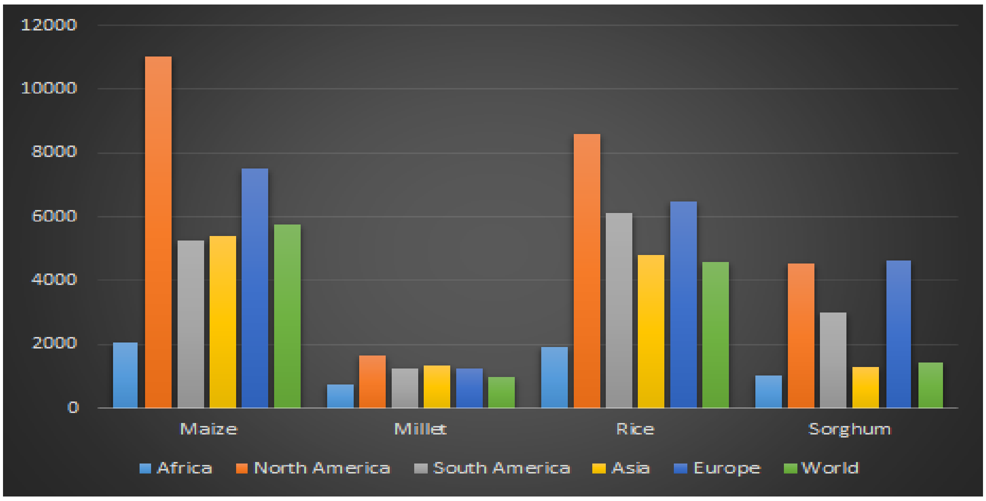
Disclaimer

1 Introduction

A large portion of the increase in agricultural production that has been necessary to sustain the sharply rising world population and to reduce hunger worldwide has come from the intensification of agricultural inputs use. This has been particularly true for Asia and Latin America, able to reach, in a relatively short span of time, significant improvements in agricultural productivity thanks to the adoption of modern inputs (Johnson et al., 2003). This process, namely the utilization of yield–enhancing technologies such as improved seeds varieties combined with the intensification of inputs use and irrigation, has conventionally taken the name of Green Revolution (Evenson and Gollin, 2003). Despite there are controversies on the environmental sustainability of these practices (Singh, 2000) and even on their effect on farmers' profitability (Kijima et al., 2011), it is almost universally accepted their contribution to improve land productivity. Actually, the concerns about farmers' profitability are mainly due to the fact that the prices of agricultural output have generally decreased as a consequence of the increased yields (Diao et al., 2008), further confirming the positive impact on productivity.

Although Africa has been mostly excluded by this phenomenon, spurring a long debate on the causes of this failure (Tsusaka and Otsuka, 2013) and on the possible remedies to ignite a Green Revolution on this continent (Otsuka and Muraoka, 2017), the amount of used fertilizers has slowly increased in this region too, despite per–hectare quantities have mostly stagnated between the beginning of the sixties and the late nineties (Kelly and Naseem, 2009). This debate has resulted in a second attempt to boost agricultural productivity in the continent through the use of similar technologies. Started in 2006, the Alliance for a Green Revolution in Africa (AGRA) has attempted to create a New Green Revolution, with results that, however, have been below the expectations (Wise, 2020; Fischer, 2022). Therefore, African agriculture is still mainly characterized by a low inputs–low output pattern, with an average land productivity among the lowest in the world (Fuglie and Rada, 2013). Figure 1 shows the 2018 average yields per hectare in different regions of the world for some typical cereal crops used as a staple in Africa. For most crops, the African average yields per hectare compared to the ones of other regions are between two and up to five folds lower. Exceptions are millet and sorghum, crops scarcely grown in industrialized countries, for which the African average productivity is still lower than any other region although to a lesser extent.

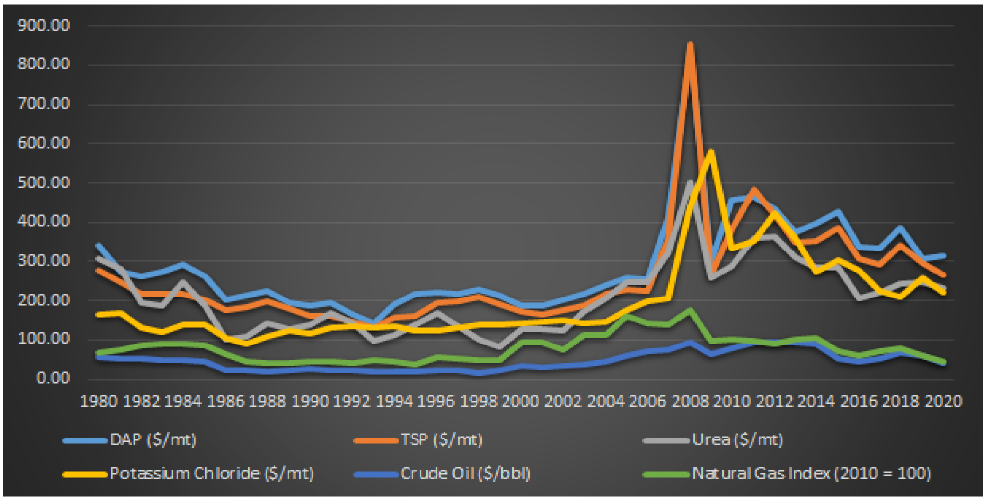
Figure 1: Average Yield (kg/ha) for Selected Crops and Regions in 2018



Source: Own elaboration on FAOSTAT data

With African agriculture being characterized by a low use of inputs per hectare and a consequent low per hectare output, the situation may become even worse due to the current international circumstances. The COVID–19 pandemic has caused a first important shock to the African agriculture, imposing mobility barriers to people and significantly reducing the international trade of goods (Kerr, 2020; Barlow et al., 2021). The recovery from the pandemic has also been a factor of stress since the demand for several goods has rapidly increased in a moment in which the supply side was still weak, thus causing a general increase in prices, namely high inflation (Gharehgozli and Lee, 2022). The Russian invasion of Ukraine on the 24^{th} of February 2022, a major escalation in the Russo–Ukrainian war started in 2014, has been the real starter of a dramatic price increase in energy and agricultural commodities (Vasileiou, 2022). If the increase in the price of agricultural commodities poses a burden for the African urban areas, but it may potentially advantage the rural population, at least for the portion of yield that is commercialized, the increase in energy prices is a sure disadvantage for both categories. The production of fertilizers, in fact, is very energy intensive and the price of the two commodities is strongly correlated[1], as it can be observed in Figure 2, that shows the prices of some common fertilizers and of crude oil and natural gas (this last as a price index).

Figure 2: Historical Prices of Selected Fertilizers and Energy Commodities



Source: Own elaboration on World Bank data

Given the serious problem of food security in Africa and the cash constraints faced by farmers in this region, it is important to estimate the likely effects caused by the increase in fertilizers price due to the Ukrainian war. In particular, the effect on agricultural productivity appears to be the most important element to evaluate. The present paper, therefore, tries to forecast the changes in productivity for maize (corn) in seven Western African countries, namely the countries using the CFA franc (Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo) with the exclusion of Guinea Bissau due to data issues. The choice of the countries has been made on the base of data availability. Given the recent release of a harmonized and nationally representative household survey in all these countries – the Enquête Harmonisée sur le Conditions de Vie des Ménages (EHCVM) – covering the year

[1]The correlation between the price of fertilizers and energy commodities ranges from a minimum of 0.45 (Potassium Chloride with the natural gas price index) to a maximum of 0.91 (Urea with crude oil)

2018/19, it is possible to build a fairly recent and wide database with rich information on agricultural plots. The choice of the crop, maize, is due to its diffusion, resulting, in fact, the second crop with the largest dedicated acreage in the examined countries. A further reason is the fact that, contrary to other common food sources in the area, such as sorghum and millet, it is generally cultivated more intensively, thus being more prone to show negative consequences for increases in fertilizers prices.

The method to estimate the potential production loss due to the increase in fertilizers price follows two steps. First of all, the response function of maize to nitrogen (N), the most important macronutrient in corn production, is computed by using a crop model opportunely calibrated on local conditions. Subsequently, by making use of the fertilizer own price elasticity and of its elasticity to maize price, it is calculated the percentage variation in fertilizers demand and application. Combining the two pieces of information, namely inserting the predicted applied quantities of fertilizers in the response curve functions, it is then estimated the variation in maize production.

2 Literature Review

The analysis of the effects of the Russian invasion of the Ukrainian territory on February 2022 has become a very hot topic. If some consequences, such as the sharp increase in the price of energy commodities, particularly the one of natural gas in the European Union, are immediately observable, others are more subtle and require in depth studies. Wang et al. (2022) study how the Ukrainian war impacts the relation between geopolitical and systemic risk in the commodities market, Orhan (2022) focuses on the effect of the conflict on global trade, underlying the potentially long lasting negative effects due to the disruption of supply chains. By using a macro–econometric model, Liadze et al. (2022) attempt to estimate the global impact of the war for the year 2023, concluding that it should be expected a 1% loss in global GDP, approximately 1 trillion US$.

The vast majority of research efforts, however, are focused on the effects of the war on food security, given its potentially catastrophic consequences. Saâdaoui et al. (2022)

measure the impact of geopolitical risk on food prices, taking into consideration the Russo–Ukrainian war together with other shocks such as COVID–19 and other conflicts. Behnassi and El Haiba (2022) list and examine all channels through which the Russo–Ukrainian war may threaten global food security, mentioning the reduced export of wheat, maize and sunflower oil from both countries, with the export from Ukraine being blocked by the military operations while the one from Russia by the international sanctions. Similarly, the export of fertilizers from both countries is contracting due to the same reasons (Glauben et al., 2022). The work of Hellegers (2022), instead, is primarily focused to envisage a methodology to identify countries facing a strong risk in food security due to the war. According to the study, Middle East and North African (MENA) countries are the ones at higher risk both for their high import of wheat and of other food commodities from Russia and Ukraine and for their scarce ability to increase home production in the short–medium term. Sub–Saharan Africa, specifically the horn of Africa, faces a very similar risk.

Despite its relevance, this topic is so recent that it is not easy to find published papers discussing it. In particular, what seems to lack are quantitative estimates of the effects of the war on famine and poverty worldwide. A technical report from the European Commission, ECKCFNS (2022), tries to summarise the most recent literature on the topic and to provide some figures in order to understand the magnitude of the problem. According to the data provided by ECKCFNS (2022), 30% of Ukrainian agricultural land will be unproductive in 2022. Furthermore, wheat prices are expected to increase of more than 40% in 2022 and the ones of fertilizers of more than 30%. Together with the fact that export restrictions affect the 16–17% of globally traded food calories, all these figures are clearly showing potentially catastrophic consequences for nutritionally vulnerable countries. Besides the increase in international prices and the reduced amount of food purchasable on the international market, the situation is made even worst by the fact that domestic production is also likely to decrease in vulnerable countries. The same report, in fact, estimates a potential decrease in food production up to 20% in Africa due to the lower utilization of fertilizers (ECKCFNS, 2022). The present paper aims at investigating this last aspect more in depth. In particular, by combining household level data with fertilizers response functions derived from a crop model, our objective is to estimate more reliably the potential reduction in production for some selected countries in Western Africa and for one of the most diffused food crop in this region: maize.

3 The Estimation of Maize Yields Response to Fertilization and Irrigation

The first step in order to forecast the potential decrease in maize production due to the reduced application of fertilizers is to understand how yields respond to fertilization. Only once we have a sound mathematical relation describing maize yields as a function of applied fertilizers – and of irrigation – we can estimate the variation in production for different levels of fertilization. As mentioned earlier, in order to perform this task, we rely on a crop model. Despite the survey used for deriving information at plot level, the EHCVM, provides data on both inputs and outputs quantities, thus rendering theoretically feasible to build a yield response function through econometric estimation, there are several reasons for discarding this possibility.

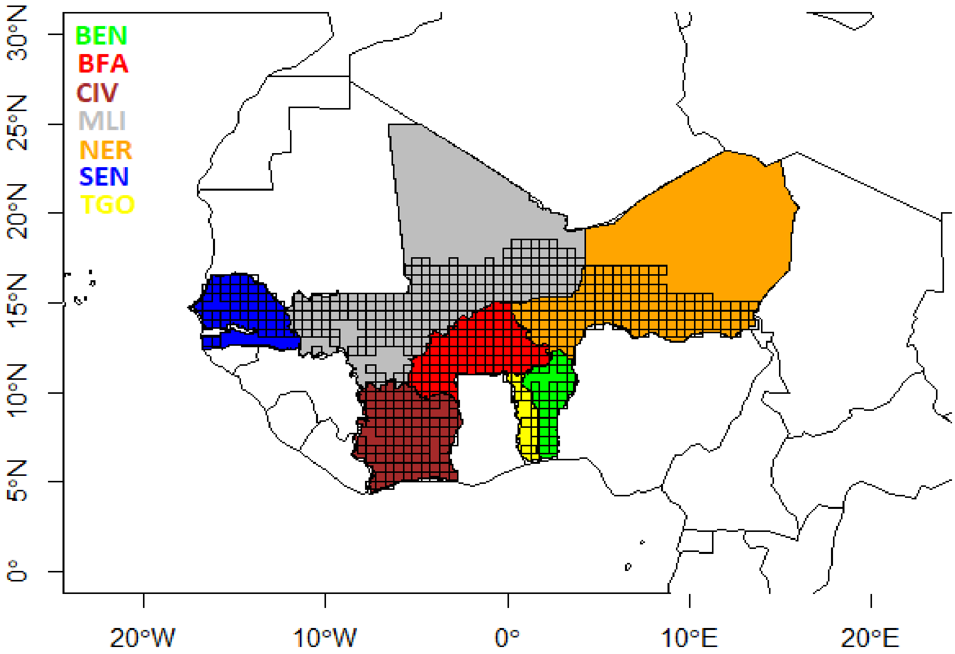
First of all, the EHCVM is cross sectional, therefore the estimated relation would be subject to a specific climatic season, rather than to an average of several years with relative weather conditions[2]. Furthermore, despite a crop model is more abstract and less respondent to local conditions, household surveys cover a very broad range of topics, thus being scarcely precise on agricultural inputs and outputs. The amount of noise present in household level data from large scale surveys such as EHCVM is another important limitation that generally prevents to retrieve meaningful response functions. For all these reasons, in absence of a household survey complemented with detailed plot and soil information such as the one used in Chamberlin et al. (2021), we prefer to use a crop model for estimating the yield response function to fertilization.

[2]The simulation with the crop model is run for 20 years, 2001–2020, for each considered spatial unit.

The crop model used to perform the simulation is EU–Rotate_N (C. Rahn et al., 2008). As mentioned in the description of the model in C. Rahn et al. (2008): "The model can simulate root development, the mineralization and release of N from soil organic matter and crop residues, the effect of freezing conditions and water movement". Simplifying considerably, we can say that the model is able to capture the effects of watering, nitrogen (N) fertilization and soil organic matter on crop growth and yields. According to the model specifications, Nitrogen can be introduced through organic fertilization or directly, with this last possibility being equivalent to inorganic fertilization. Phosphorus (P) and Potassium (K), as well as all the micro–nutrients, are instead disregarded. Despite this last element is surely a limitation, N is often considered the very crucial macro–nutrient for several crops and maize is no exception on this regard. Furthermore, by considering a single macro–nutrient, the response function to be estimated is much easier since it does not require a complex interaction among all various nutrients. Despite EU–Rotate_N has been primarily envisaged for Europe, once it is fed with the appropriate soil and weather data inputs, it can be used for other locations as it has already been done for Iran (Fazel et al., 2017) and for North China (Sun et al., 2013).

By having the spatial coordinates of the farmers present in the EHCVM, a tailored response function for each of them could be built by feeding the model with inputs data for that specific coordinates. However, since we lack this information, our objective is to build response curves at the regional level and, when these are missing or problematic, to use response curves at national level. However, using whole regional or even national averages for soil parameters or for weather conditions is rather meaningless given the territorial extension of such administrative units. Therefore, we use a grid with squared $0.5°$ cells, with these last being the basic units of analysis. Meteorological conditions are taken at the coordinates corresponding to the centroid of each cell, whereas soil parameters are averages of all values inside a cell. In order to avoid using cells in locations where agriculture is unfeasible, that may bias our estimation of response functions, the European Space Agency (ESA) land cover classification map has been used to identify them. Specifically, if a cell

Figure 3: Cells Object of Simulation in Selected Western African Countries



does not contain any pixel identified as cropland in the ESA classification map, the cell is dropped. Figure 3 shows the selected countries and the 615 grid cells used as the spatial units to perform the crop simulation.

3.1 Data inputs and the crop simulation

In order to work, EU–Rotate_N requires three sets of inputs: weather data, site data (mostly related to soil characteristics) and agronomic data. For the first type of data input, the used source is the NASA POWER global meteorology database accessed through the R application interface (API) "nasapower" (Sparks, 2018). Daily weather conditions have been collected from first of January 2001 to 31st of December 2021. These include: minimum, maximum and average daily air temperature, precipitation, average relative humidity and global radiation. With regard to the site data, all parameters describing soil characteristics have been obtained from the Africa Soil Information Service (AfSIS) project, an open source repository offering maps of the African soil at a resolution of 250 meters (Hengl et al., 2015).

For the elevation, GTOPO30, a global digital elevation model (DEM) with 30 arc–seconds of resolution, has been used. Table 1 lists all the site related inputs required by the crop model together with the used data source.

Table 1: Site Inputs for EU–Rotate_N and Data Sources

Data Input	**Source**
Altitude	GTOPO30 30 arc–sec DEM
Max. rooting depth	Africa SoilGrids – Root zone depth (cm)
Volumetric water content in soil at field capacity	Africa SoilGrids – Root zone plant available water holding capacity aggregated at top 30 cm
Volumetric water content in soil at permanent wilting point	Africa SoilGrids – Root zone moisture content at wilting point aggregated at top 30 cm
Volumetric water content in soil at saturation	Africa SoilGrids – Root zone moisture content at saturation aggregated at top 30 cm
Clay content in soil	Africa SoilGrids – Clay content
Sand content in soil	Africa SoilGrids – Sand content
Soil bulk density	Africa SoilGrids – Bulk density (BD)
Spoil Ph	Africa SoilGrids – Soil pH in H2O
Organic matter (OM) content*	Africa SoilGrids – Soil organic carbon (SOC)
C/N ratio**	Africa SoilGrids – Total nitrogen (N)

* Soil organic carbon assumed to be 58% of organic matter: OM = SOC / 0.58.

** C / N ratio obtained as SOC / Total N.

The last set of inputs required by the crop model are the agronomic practices, including information about the time of planting and harvesting, the spacing of plants, the incorporation of previous residues, etc. Clearly, information on organic and inorganic fertilization, together with irrigation, are included in this input file. Note that the most of parameters are kept identical for all locations except for the planting and harvesting dates that are country specific. For each country, planting is assumed to take place in the mid of the planting season and the same applies to harvesting. The cropping seasons for each country have been obtained from the agricultural crop calendars provided by the US Development

Agency (USDA), available at the following link.

The other parameters to vary are the ones related to fertilization and irrigation. These are our "control variables" in the simulations. Five levels of organic fertilization, assumed to be cow manure, are tested: 0, 4000, 8000, 17860 and 35720 kilograms per hectare. The quantity of nitrogen is varied between 0, 30, 70, 107 and 214 kg/ha. Finally, irrigation is inserted as a dummy, namely or it is absent or it is optimal, with this last taking the form of a drip irrigation providing 15mm of water each time a water deficit in the soil is observed. For each of the 615 locations, therefore, a total of 50 different simulations[3] have been performed, each one repeated for 20 years (2001–2021).

3.2 The estimation of the response function parameters

Once obtained all the yields for each location, for each year and for each tuple of organic and inorganic level of fertilization and irrigation, it is possible to use these data to estimate a simplified response function to fertilization and irrigation. The adopted method of estimation is a panel regression model with time averages for each variable[4]. The values of the coefficients and their statistical significance are exactly the same that would be obtained through a random effect model with the addition of years dummies. From a theoretical point of view, however, the model with time averages is more in line with our objectives since the intercept can be interpreted as the attained yield, without any fertilization and without irrigation, during an average year. Since response curves are generally used to predict future yields, it is advisable to assume expected (average) weather conditions. The estimated model is the following:

$$\overline{yield}_i = \alpha + \beta_1 \overline{manure}_i + \beta_2 \overline{manure}_i^2 + \beta_3 \overline{N}_i + \beta_4 \overline{N}_i^2 + \beta_5 \overline{manure}_i \overline{N}_i + \beta_6 \overline{irr}_i + \overline{u}_i.$$

The regression equation is fairly simple and intuitive. We have the level and the square of cow manure (*manure*), the level and the square of nitrogen (N), the interaction between

[3]Five different quantities of organic fertilizer times five different quantities of inorganic fertilizer times two possible irrigation options.

[4]Corresponding to the "between" option in the R package plm.

the two types of fertilizers and the irrigation dummy (irr), while the dependent variable is the yield. The over–bar indicates that a variable is a time average. All quantities are in kilograms per hectare except for the yield that is expressed in tons per hectare. Note that a fixed–effect model is unfeasible since each observation i is defined by a spatial location and a combination of organic and inorganic fertilizer quantities plus the irrigation status. These lasts, however, are kept constant over time and, therefore, cannot be estimated through a fixed–effect model. Finally note that, since the quantities of both types of fertilizers are clearly exogenous, being chosen by us, and the same applies to the irrigation status, the problem of correlation with the error component is absent. In the present case, therefore, the coefficients resulting from a random effect model should not be biased even if fixed–effects are not accounted for.

Table 2 shows the estimated coefficients at country level. In their estimation, all cells inside a country with all possible combinations of fertilizers quantities and irrigation status have been used for the estimation. In the forecast of 2022 and 2023 maize yields that will be presented in the next section, regional response curves have been preferred when available. In fact, a finer spatial dimension should guarantee a better representation of local conditions. However, for the regions lacking enough data to have reliable estimates, we have used the national response curves. The coefficients retrieved from the estimation at regional level are shown in Table A1 in the Appendix. Note that such response curves, as the ones at country level, may be considered a useful contribution to the literature in themselves. In fact, they can be used in agricultural partial equilibrium models or in similar economic modeling frameworks where the use of crop models is precluded by the excess of complexity that would be generated.

With regard to the estimated coefficients, some remarks are worth to be done. While the level of manure and of N fertilizer are always significant, their respective squared terms are not. The coefficient of manure squared is significant in only two regions, whereas the one of N squared is significant in all countries and in all regions except for seven (over 38). The signs for the N coefficients are as expected, with the one of the level being positive and the

Table 2: Estimated Response Curve Coefficients at Country Level

Country	Intercept	manure	manure^2	N	N^2	manure x N	irr
BEN	1.78450739 ***	0.00008619 ***	0.00000001	0.03250788 ***	-0.00005338 ***	-0.000000001 ***	0.44312483 ***
BFA	1.97257674 ***	0.00007675 ***	0.00000002	0.00486425 ***	-0.00000912 ***	-0.000000001	0.03965429
CIV	2.10340070 ***	0.00007833 ***	0.00000002	0.00894920 ***	-0.00001690 ***	-0.000000001	0.15500261
MLI	1.91531824 ***	0.00007264 ***	0.00000001	0.00911099 ***	-0.00001596 ***	-0.00000000	0.22539463 ***
NER	1.75200070 ***	0.00008327 ***	0.00000001	0.03756307 ***	-0.00006111 ***	-0.000000001 ***	0.40062208 ***
SEN	1.88246195 ***	0.00007766 ***	0.00000001	0.01191351 ***	-0.00002081 ***	0.00000000	0.08118553 ***
TGO	1.94080844 ***	0.00008454 ***	0.00000002	0.02548277 ***	-0.00004511 ***	0.00000000	0.32920308 ***

Significance levels: + = 10%, * = 5%, ** = 1%, *** = 0.1%, blank space = Not significant.

one of the squared term negative. In the few cases where manure squared is significant, its coefficient is positive, contrary to our expectations, but the trivial magnitude of the coefficient renders it scarcely relevant. Another unexpected sign is found for the interaction term between organic and inorganic fertilizers, that is always negative when significant. Organic matter should actually improve the plant efficiency in absorbing macro–nutrients, therefore a positive coefficient was expected. Also in this case, the magnitude of the coefficient is rather trivial, therefore its impact is minimal. Finally, irrigation has a positive coefficient, as expected, but not always significant. Considering that some regions are in the tropical zone whereas others belong to semi–desert areas, this result is not surprising.

4 Simulating Maize Yields in 2022 and 2023

The response functions to fertilizers and irrigation are a first step to perform our simulation on predicting maize yields for 2022 and 2023 in Western Africa. The procedure to perform the simulation is rather straightforward. By using the predicted prices of maize and inorganic fertilizers offered by the World Bank (Price Forecasts – April 2022), it is possible to compute the percentage increase in their prices for the years 2022 and 2023 compared to 2021. By using our estimates of fertilizers' own price elasticity and the fertilizers elasticity to output (maize) price, we can compute the variation in fertilizers demand and application[5]. These new quantities are then used in combination with the estimated response functions to compute the variation in yields for each maize plot in our dataset. Although straightforward, this method requires some assumptions that need to be discussed.

Intercepts at Plot level

First of all, our response functions have an intercept that is identical at regional or at country level. However, when inserting the observed values of the quantities of organic and inorganic fertilizers into the estimated functions, it is rare to obtain the observed yield. In order to solve this problem, we have recomputed the plot specific intercepts under the assumption that all deviations from the regional or national functions are due to plot specific characteristics:

$$\alpha_i = yield*_i - \hat{\beta}_1 manure*_i - \hat{\beta}_2 manure*_i^2 - \hat{\beta}_3 N*_i - \hat{\beta}_4 N*_i^2 - \hat{\beta}_5 manure*_i N*_i - \hat{\beta}_6 irr*_i;$$

where the asterisk indicates that these are the actual quantities observed in the EHCVM dataset and the "hat" identifies an estimated coefficient. In our simulation, these individual intercepts, α_i, will be used instead of the country or regional intercepts, α. Note, however, that in so doing we are implicitly assuming that plot specific elements such as the agronomic practices followed by the farmer are only influencing the intercept but not the response to fertilizers or to irrigation which are instead common over countries or regions. This is clearly a simplification, but due to the impossibility of estimating plot level response functions, it is a necessary second best.

Elasticities

When considering the demand for inorganic fertilizers, besides the own price elasticity, it is further considered the elasticity to the output price. In fact, since the prices for agri-

[5]The demanded quantity is assumed to be identical to the applied quantity.

cultural commodities are expected to rise, excluding this last element may over–represent the reduction in fertilizers demand. Elasticities have been estimated from the EHCVM dataset through a standard OLS regression with the natural logarithm of applied fertilizer per hectare as dependent and the natural logarithm of fertilizer price (own price elasticity) and the one of maize price (output price elasticity) as main regressors, with additional controls. The retrieved values are $\varepsilon_f = -1.226$ for the own price elasticity and $\varepsilon_m = 0.351$ for the elasticity with respect to the price of maize. Note that such elasticities are common for all countries, since the lack of sufficient variation among prices at country level does not allow to have significant estimates of the elasticities for each country. Finally, other cross–price elasticities, such as the one to the price of organic fertilizers, have not been computed lacking information on their prices. The quantity of manure in our simulation is therefore assumed to be constant over time. Despite some estimates of fertilizers own price elasticity are very inelastic (e.g. the estimated elasticity for phosphate at world level by Al Rawashdeh (2022) is between -0.003 and -0.061), it is not uncommon to find much higher values for African countries. Komarek et al. (2017), for example, find a value for the fertilizers own price elasticity in Malawi equal to -0.92, while Chianu et al. (2011) provide the values -0.38, -1.43, and -2.24 for, respectively, Ethiopia, Côte d'Ivoire and Ghana.

Variations in Prices

Table 3 shows the prices of the commodities of our interest for the years 2021, 2022 and 2023, with the relative percentage variations among years. All prices are obtained from the World Bank Price Forecasts (April 2022), except for the ones of the NPK fertilizer. Since there are several types of this last fertilizer, differing in the percentage of the 3 macro–nutrients composing it, there is no possibility to have a unique international price for NPK fertilizer. We have therefore built a composite price as a weighted average of the prices of Urea (25%), DAP (50%) and Potassium Chloride (25%). Since a very common NPK formula in maize production is 12–24–12, meaning 12% of N and K and 24% of P, we assume its price to be mostly determined by the proportional amount of these components. Finally, the price of each macro–nutrient has been proxied by its main source fertilizer (Urea for N, DAP for P and Potassium Chloride for K).

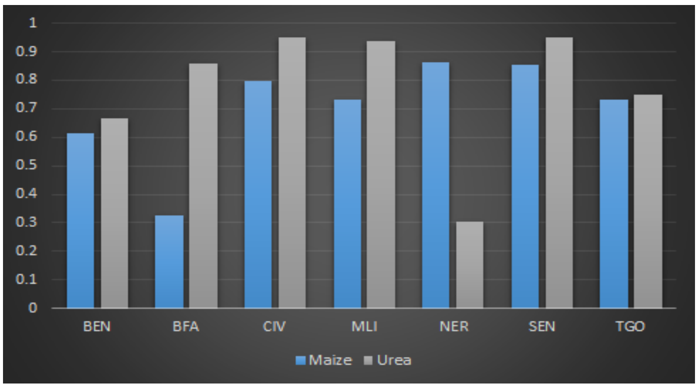
Table 3: Commodities Prices and Variations in 2021, 2022 and 2023

	Price ($/t)			Yearly Percentage Variation (%)		
Commodity	***2021***	***2022***	***2023***	***2022-2021***	***2023-2021***	***2023-2022***
Urea	483	850	750	75.98	55.28	-11.76
DAP	601	900	800	49.75	33.11	-11.11
Phosphate Rock	123	175	160	42.28	30.08	-8.57
Potassium Chloride	210	520	470	147.62	123.81	-9.61
NPK	414.75	767.5	680	67.28	48.81	-11.40
Maize	260	310	280	19.23	7.69	-9.68

Variations in the Demanded Quantities of Fertilizers

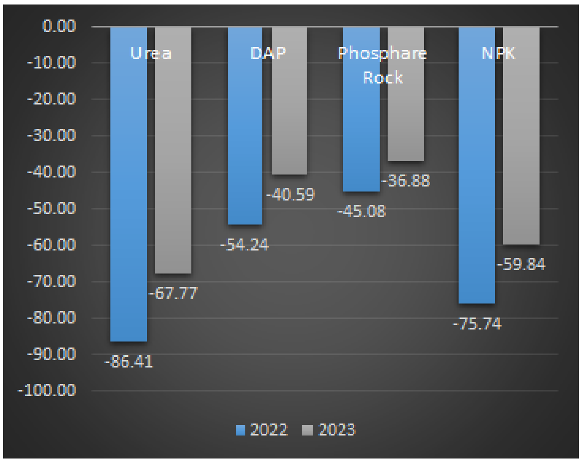
In the EHCVM, four types of inorganic fertilizers are reported: Urea, DAP, Phosphate rock and NPK. All of them are present in Table 3 that includes also Potassium Chloride, used to compute the price of NPK. From the price variations reported in Table 3 and the elasticities previously mentioned, it is immediate to estimate the percentage variation in the demanded quantities of fertilizers: $\%\Delta_i^Q = \varepsilon_f \%\Delta_i^P + \varepsilon_m \%\Delta_m^P$. Here, $\%\Delta_i^Q$ is the percentage change in the demanded quantity of fertilizer i, $\%\Delta_i^P$ the percentage change in its price, $\%\Delta_m^P$ the percentage change in the price of maize and ε_f and ε_m are, respectively, the fertilizer own price elasticity and the elasticity to output price.

Figure 4: Correlation of International and Domestic Prices for Maize and Urea



The prices shown in Table 3 are international prices. It could be argued that local prices are not so respondent to international prices, particularly in African countries that are generally not so well integrated into international trade. In reality, since very few African country produces fertilizers in a minimally significant amount, they mostly depend on imports for this commodity, thus making local prices very respondent to variations in international prices. For maize, however, the situation may be different since a large portion of this crop is produced and consumed locally, theoretically lowering the tie between local and international prices. Figure 4 shows the Pearson correlation coefficient between the international (retrieved from the World Bank annual commodity prices "Pink Sheet") and the domestic prices for Urea and maize in the countries under examination. For the domestic prices, data provided from FAOSTAT have been used, with the price of Urea being the import price, computed dividing the total value of imports by the total imported quantity. The correlation is taken on data from 2001 to 2020.

Figure 5: Percentage Variation in the Consumption of Fertilizers in 2022 and 2023 Compared to 2021



As expected, the correlation in the prices of Urea is generally very strong, being above 0.9 in three countries and below 0.5 only in Niger. Despite being lower, also the correlation between the international and the domestic price of maize is generally strong, with most values ranging around 0.8. For this reason, we will consider the transmission mechanism between international and domestic prices as working perfectly both for fertilizers and for maize. Note that, even assuming a lower transmission mechanism for maize prices, for example a variation in the domestic price of maize equal to 80% of the change in its international price, this will result in a trivial effect on the demanded quantity for fertilizers given the low elasticity of fertilizers to output price[6].

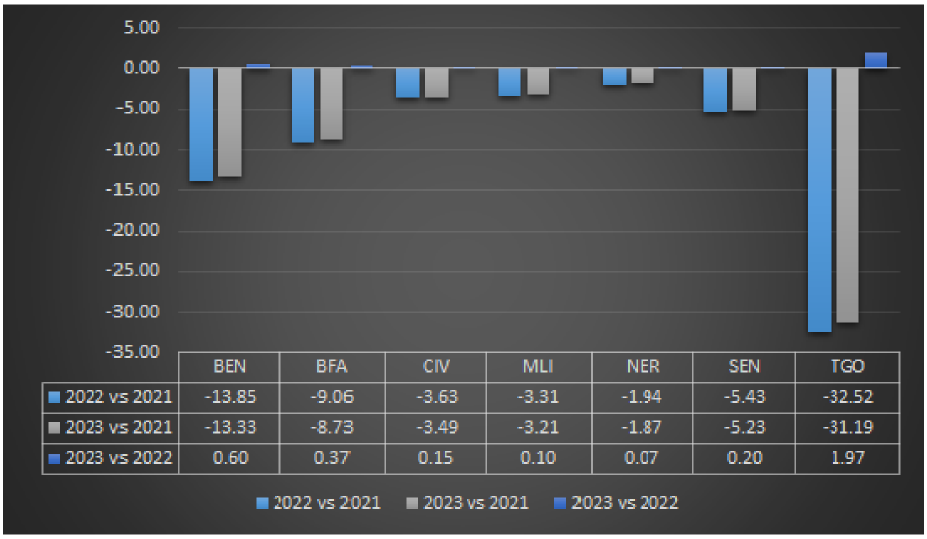
[6]The difference is in the range of 2 or 3 percentage points.

Figure 5 shows the percentage drop in the consumption of the four different types of fertilizers reported in the EHCVM dataset for the years 2022 and 2023 compared to 2021. The consumption drop is higher in 2022 when the fertilizers prices are supposed to peak, but the reduction of prices in 2023 is rather modest and, in fact, the consumption of fertilizers still remains far below the levels of 2021. The most affected fertilizer is Urea, whose consumption in 2022 faces a decline above 85%, followed by the NPK compound, with a decrease of 75% circa.

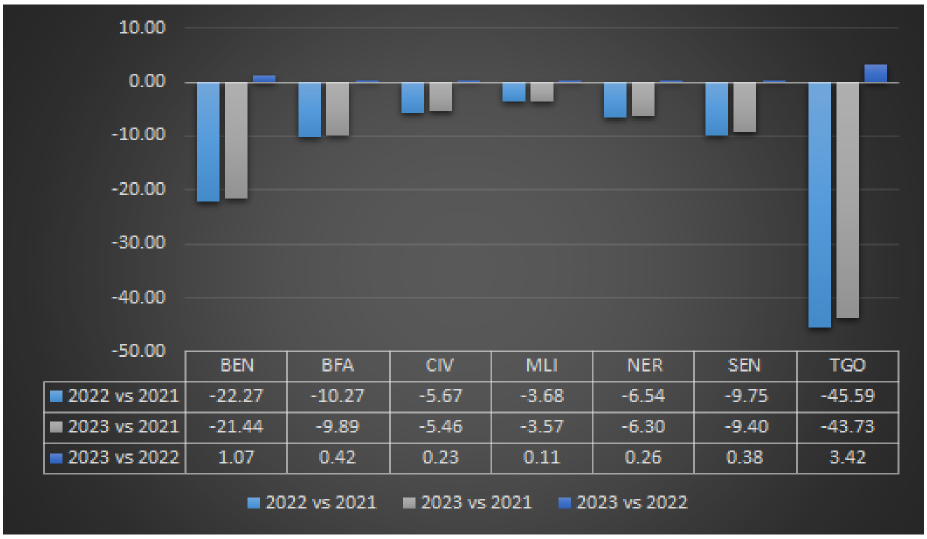
Maize Production in 2022 and 2023

Once having computed the hypothetical variation in fertilizers demand due to the increase of prices following the Ukrainian war, it is possible to estimate the maize yields with the updated quantities of fertilizers. The results of our analysis at country level are shown in Figure 6, where the percentage variation of yields by country is reported. The first graph (a), where all cropped land is taken into account, shows the change in the total produced quantity of maize. Being the EHCVM nationally representative and having being used the provided weights to compute the yields, these percentages should represent the likely variation in maize production at national level. Two facts are immediately observable. The first is the strong heterogeneity of the impact between countries, with the production in Togo being reduced by more than 30% in both 2022 and 2023 compared to 2021, whereas the production in Niger faces a decline of less than 2% in the same years. Such considerable difference is due to the starting amount of fertilizers used in maize production in the various countries. Clearly, for countries with a very modest starting level (in 2021) of fertilization, the impact of the price increase on maize yields will be far less consistent. In particular, in countries such as Niger, Mali and Côte d'Ivoire, more than half of the plots are left completely unfertilized, thus no variation in yields is expected for them. The second element to note is that the impact of the price increase on yields will last at least till 2023. The decline in prices expected for this year is rather modest and this translates into an equally modest gain in yields. The grey bars in Figure 6, in fact, depict the percentage change between 2023 and 2021, that is almost identical to the light blue bars, representing the difference between 2022 and 2021. The right most bars (dark blue), instead, directly show the difference between 2023 and 2022. The highest gain is for Togo, the country with the highest drop in production, that, however, is less than 2 percentage points.

Figure 6: Percentage Variation of Maize Production by Country



(a) All Plots



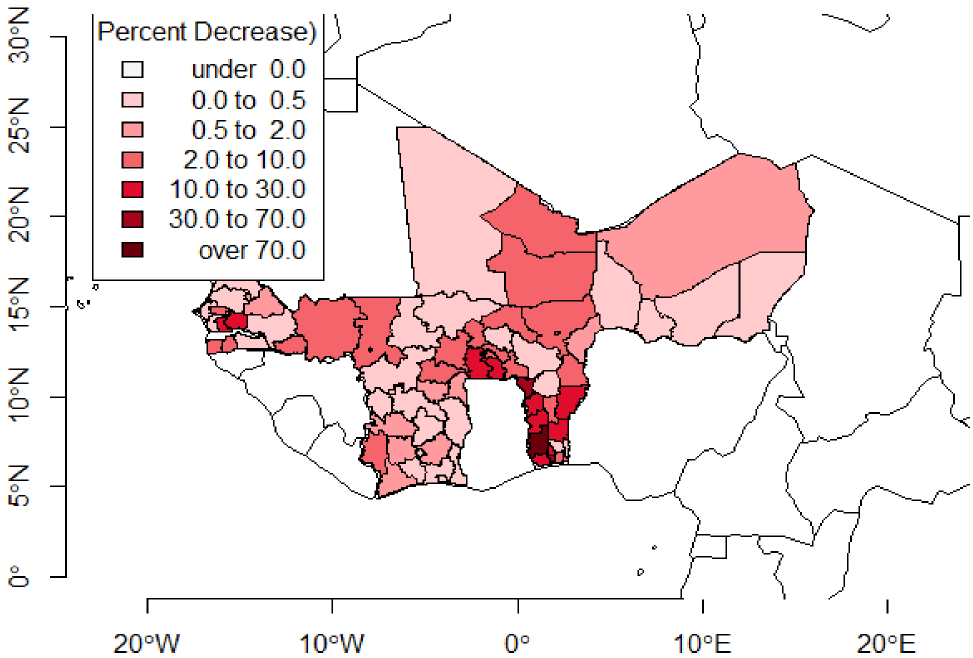
(b) Only Fertilized Plots

The second plot (b) is rather similar to the first, with the exception that only parcels receiving a positive quantity of fertilizers are taken into account when considering the yearly variation in yields. As seen, the drop in production seems to be rather modest for several countries, being far below the 20% decrease estimated in ECKCFNS (2022). We mentioned as likely reason the presence of a large portion of unfertilised cropland for which an increase in fertilizers prices is obviously inconsequential. When only fertilized land is taken into account, we can see that the drop in production is effectively more pronounced. However, there is a very strong correlation between the drop in production when all land is considered and when only fertilized land is accounted for. This implies that the countries with large portions of unfertilized land are also the countries in which fertilized land receives less quantities of fertilizers. Not very surprisingly, therefore, there is an inverse relation between the portion of land remaining unfertilized and the quantity of applied fertilizers in fertilized plots.

There are, however, interesting differences among countries with regard to the just mentioned relation. If we look at Burkina Faso, for example, we can see that the drop in production in 2022 is almost identical if we consider all plots or only fertilized plots (-9.06% vs -10.27%). This implies that Burkina Faso is characterized by a diffuse use of fertilizers, but in very low amounts. For Senegal, instead, the difference is almost double when considering only fertilized plots compared to all plots (-9.75% vs -5.43%) and for Niger it is more than triple (-6.54% vs -1.94%). Compared to Burkina Faso, this implies that fertilized plots tend to receive higher amounts of fertilizers, but that there is a much larger proportion of totally unfertilized cropland.

The overall decline in maize production in 2022 compared to 2021 considering all countries together is approximately 9.7%, decline that remains almost unchanged when considering 2023 instead of 2022, namely 9.3%. Therefore, the gain in 2023 compared to 2022 will be lower than half percentage point. Since maize is a crop receiving a relatively high amount of fertilization compared to other food crops such as sorghum or millet, it is likely that the effect on these latter crops is less dramatic. However, for cash crops such as cotton or for another important food crop such as rice, where the use of fertilizers is more diffused than in maize production, the reverse is true. ECKCFNS (2022) estimate an overall 20% decline in food production in Africa in 2022, a figure that is double of our estimates for maize. A possible explanation is that our examined countries use quantities of fertilizers below the African average, thus facing milder consequences for increasing fertilizers prices. Nigeria, Malawi and South Africa, for example, all use far higher amounts of fertilisers per hectare (Sheahan et al., 2013), therefore the examined countries may not be a representative sample of the whole African continent.

Figure 7: Percentage Decrease in Maize Yields at Regional Level (2022 vs 2021)



Finally, Figure 7 shows the difference in yields between 2022 and 2021 disaggregated at regional level. From the figure it is possible to observe that most of the regions have a very mild decrease in maize yields, being it lower than 0.5%. Niger is probably the country with the lowest regional variability since the decrease in production is always confined between 0 and 2%, while Senegal faces a strong variability. Benin and Togo, instead, have a rather homogeneous outcome at regional level with an average decrease in production that is higher than in other regions, mostly between 10 and 30 percent.

5 Conclusions

With the recrudescence of the Russo–Ukrainian war, there has been a spike in the international prices of several commodities, in particular of energy and agricultural products. The ban to Russian exports and the decrease in Ukrainian agricultural production are believed to be serious threads to food safety for several vulnerable countries that depend on food imports from at least one of the nations in conflict. The situation is made even worst since food insecure countries not only will find more difficult to purchase agricultural commodities on the international market, but they will likely decrease their own production as well. In fact, the price of fertilizers, strongly correlated with the price of energy commodities, is expected to grow steeply in 2022 and to decline only mildly in 2023. Food insecure countries, which already have scarce levels of fertilization, may easily further reduce the use of this agricultural input, thus reducing their yields.

The present paper tries to estimate the effect of the fertilizers price increase on the production of maize in seven Western African countries, all the users of the CFA franc except for Guinea Bissau. The estimation is made in several steps: first, response curves to fertilization and irrigation in maize production are estimated for all countries; second, the decline in fertilizers demand is estimated through the use of the fertilizers own price elasticity and the elasticity to output price; finally, through the response curves to fertilization and the forecasted levels of fertilizers application, yields are estimated for the years 2022 and 2023 and compared with the yields of 2021. The base data source for all calculations is a nationally representative dataset for all examined countries, the EHCVM, while the response curves to fertilization and irrigation are estimated through a crop model: EU–Rotate_N.

Our analysis shows that the impact of the prices peak on maize production in the examined countries is strongly diversified and, overall, not excessively dramatic. When considering all countries together, in fact, the overall maize production in 2022 results to be less than 10% lower than in 2021. The level of 2022 remains substantially equal in 2023.

In countries already facing problems of food security and generally having more than 30% of the population under the absolute poverty line, a 10% decrease in an important food crop such as maize is a serious issue. However, it is lower than the 20% decrease in food production estimated for the whole African continent from other sources. Furthermore, other food crops such as millet and sorghum are generally cultivated using less quantities of fertilizers, thus their yields may experience a significantly lower contraction.

When considering each country separately, it is possible to observe a great heterogeneity in the impact of the increase in prices. Togo and Benin are the countries with the largest decrease in maize yields: -32% and -13%, respectively. Niger, Mali and Côte d'Ivoire, instead, are far less impacted, with declines in production that are below 5%. In general, the lower is the starting level of fertilizers use of a country, the lower is the impact due to the increase in the price of this input. This is rather obvious, but it is also partially reassuring since countries with low starting levels of fertilizer use are very likely the most vulnerable ones, but, as shown in the present paper, their production will also be marginally impacted by the rise in fertilizers prices.

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Appendix

Table A1: Estimated Response Curve Coefficients at Regional Level

Country	Region	Intercept	manure	manure^2	N	N^2	manure x N	irr
BEN	Alibori	2.0972825800	0.0000790998	0.0000000214	0.0081099800	-0.0000110100	-0.0000000002	0.1902000000
		9.0853 ***	3.085 ***	0.3227	2.0574 **	-0.6167	-0.4078	1.1532
	Zou	1.6369880000	0.0000903680	0.0000000117	0.0476107400	-0.0000765200	-0.0000000009	0.5625400000
		12.0367 ***	5.9824 ***	0.2989	20.5013 ***	-7.2760 ***	-3.8143 ***	5.7893
	Atakora	2.0291057300	0.0000809557	0.0000000186	0.0125225000	-0.0000259900	-0.0000000001	0.2385000000
		6.6732 ***	2.3971 **	0.2130	2.4118 **	-1.1054	-0.2036	1.0978
	Borgou	1.5400754000	0.0000912202	0.0000000079	0.0473515100	-0.0000712500	-0.0000000009	0.7250555600
		17.8409 ***	9.5141 ***	0.3190	32.1236 ***	-10.6729 ***	-6.3620 ***	11.7559 ***
	Collines	1.7224557400	0.0000918463	0.0000000077	0.0608231300	-0.0000990800	-0.0000000014	0.2632850000
		15.915 ***	7.6405 ***	0.2476	32.9112 ***	-11.8386 ***	-7.8371 ***	3.4048 ***
	Donga	1.7095631800	0.0000875456	0.0000000116	0.0308565300	-0.0000621500	-0.0000000002	0.7607350000
		16.8099 ***	7.7503 ***	0.3957	17.7682 ***	-7.9030 ***	-1.0708	10.4694 ***
	Sud-Ouest	1.9065813100	0.0000806024	0.0000000159	0.0154953000	-0.0000267600	-0.0000000003	0.2008666700
		6.7473 ***	2.5682 **	0.1959	3.2114 **	-1.2248	-0.5399	0.9949
	Cascades	1.8030165600	0.0000881685	0.0000000102	0.0389237000	-0.0000690800	-0.0000000006	0.3385566700
		8.1707 ***	3.5973 ***	0.1611	10.3297 ***	-4.0482 ***	-1.5910	2.1473 *
	Haut-Bassins	2.0291244900	0.0000776428	0.0000000198	0.0050740500	-0.0000100600	0.0000000000	0.0157366700
		14.0766 ***	4.8495 ***	0.4766	2.0614 *	-0.9028	-0.0728	0.1528
CIV	Savanes	2.0176329600	0.0000806473	0.0000000205	0.0147575200	-0.0000318600	0.0000000001	0.6111127300
		20.2961 ***	7.304 ***	0.7159	8.6936 ***	-4.1447 ***	0.3621	8.604 ***
	Vallee du Bandama	2.3046277700	0.0000795587	0.0000000205	0.0122572200	-0.0000262900	0.0000000000	0.0671400000
		19.9109 ***	6.1884 ***	0.6165	6.2015 ***	-2.9375 **	-0.1917	0.8119
	Woroba	2.3987301900	0.0000757950	0.0000000239	0.0006082000	-0.0000015600	0.0000000000	0.0006250000
		215.8906 ***	61.4179 ***	7.49 ***	3.2056 **	-1.8103 +	-0.2916	0.0787
	Yamou ssoukro	1.7679619500	0.0000907058	0.0000000119	0.0550190700	-0.0000894500	-0.0000000012	0.4179400000
		14.8801 ***	6.8734 ***	0.3484	27.1183 ***	-9.7355 ***	-5.9897 ***	4.9233 ***
	Zanzan	2.0474631000	0.0000800687	0.0000000188	0.0117182800	-0.0000195700	-0.0000000001	0.4062636400
		14.3363 ***	5.0476 ***	0.4568	4.8051 ***	-1.7720 +	-0.3729	3.9814 ***
	Denguele	2.5098524300	0.0000758250	0.0000000255	0.0000828600	-0.0000002200	0.0000000000	-0.0051366700
		226.9742 ***	61.7366 ***	8.0108 ***	0.4388	-0.2589	-0.0764	-0.6502
	Lacs	1.9559759800	0.0000880081	0.0000000119	0.0433982700	-0.0000760300	-0.0000000009	0.2972400000
		7.8944 ***	3.198 **	0.1671	10.2575 ***	-3.9680 ***	-2.1679 *	1.6791 +
	Lagunes	1.9249148500	0.0000763109	0.0000000191	0.0040082900	-0.0000082900	0.0000000000	0.0053228600
		15.3762 ***	5.4881 ***	0.5301	1.875 +	-0.8560	-0.0083	0.0595
	Sassandra-Marahoue	2.0909885100	0.0000789540	0.0000000190	0.0136089500	-0.0000254800	-0.0000000001	0.0527766700
		10.8267 ***	3.6806 ***	0.3428	4.1265 ***	-1.7058 +	-0.4521	0.3825

Significance levels: + = 10%, * = 5%, ** = 1%, *** = 0.1%, blank space = Not significant.
t–statistics reported below the coefficients' values together with significance levels.

Table A1 Continued

Country	Region	Intercept	manure	manure ^{2}	N	N^2	manure x N	irr
MLI	Gao	1.9101056400	0.0000744161	0.0000000147	0.0094956500	-0.0000167200	0.0000000000	0.4959545100
		30.2611 ***	10.6144 ***	0.8082	8.8098 ***	-3.4247 **	0.2847	10.9971 ***
	Kayes	1.8765644200	0.0000773701	0.0000000146	0.0074728600	-0.0000101900	-0.0000000001	0.0389613300
		19.0396 ***	7.0676 ***	0.5167	4.4402 ***	-1.3367	-0.7597	0.5533
	Kidal	1.7947304000	0.0000514041	0.0000000112	0.0071729100	-0.0000135000	0.0000000002	0.6829666700
		9.1942 ***	2.3709 *	0.1996	2.1519 *	-0.8943	0.4674	4.8969 ***
	Koulikoro	1.9200895100	0.0000792961	0.0000000132	0.0146159400	-0.0000224000	-0.0000000002	0.0805658300
		14.4045 ***	5.3559 ***	0.3434	6.4213 ***	-2.1729 *	-0.9773	0.8459
	Mopti	1.9548986500	0.0000705086	0.0000000128	0.0078068700	-0.0000150500	0.0000000000	0.0327386700
		21.1458 ***	6.8666 ***	0.4813	4.9453 ***	-2.1051 *	-0.2970	0.4956
	Sikasso	1.8926089600	0.0000779165	0.0000000116	0.0177162600	-0.0000295300	-0.0000000002	0.0428120000
		9.5229 ***	3.5297 ***	0.2025	5.2203 ***	-1.9217 +	-0.6862	0.3015
	Timbuktu	1.9414785200	0.0000620542	0.0000000109	0.0105776600	-0.0000228000	0.0000000000	0.3800046700
		20.119 ***	5.7896 ***	0.3941	6.4192 ***	-3.0549 **	0.2633	5.5115 ***
NER	Agadez	1.8054784300	0.0000696851	0.0000000107	0.0155141200	-0.0000250900	-0.0000000001	0.6256046200
		11.2776 ***	3.9189 ***	0.2328	5.675 ***	-2.0269 *	-0.2992	5.4693 ***
	Diffa	1.8342357700	0.0000759557	0.0000000070	0.0444395900	-0.0000677700	-0.0000000010	0.1878500000
		7.4643 ***	2.7829 **	0.0984	10.5905 ***	-3.5664 ***	-2.4733 *	1.0699
	Dosso	1.7156716100	0.0000910874	0.0000000026	0.0540309800	-0.0000879200	-0.0000000010	0.1389727300
		13.105 ***	6.2642 ***	0.0700	24.1692 ***	-8.6840 ***	-4.6688 ***	1.4857
	Maradi	1.7239331200	0.0000905265	0.0000000057	0.0600099300	-0.0000910200	-0.0000000014	0.2080415400
		25.7101 ***	12.1552 ***	0.2966	52.4109 ***	-17.5544 ***	-12.9102 **	4.3425 ***
	Tahoua	1.7183566300	0.0000886502	0.0000000047	0.0413653500	-0.0000637100	-0.0000000006	0.5220073300
		21.2854 ***	9.8867 ***	0.2016	30.0069 ***	-10.2054 ***	-4.6375 ***	9.0501 ***
	Tillabery	1.8591261400	0.0000852939	0.0000000064	0.0225549000	-0.0000483600	0.0000000001	0.2913254500
		23.7851 ***	9.8246 ***	0.2867	16.8987 ***	-7.9999 ***	0.5698	5.2166 ***
	Zinder	1.6443960000	0.0000787464	0.0000000044	0.0410744100	-0.0000625900	-0.0000000007	0.5561037500
		12.4258 ***	5.3573 ***	0.1158	18.1762 ***	-6.1163 ***	-3.4147 ***	5.8814 ***
SEN	Saint-Louis	1.8416623500	0.0000865601	0.0000000019	0.0219853300	-0.0000424100	0.0000000000	0.3656457100
		8.4414 ***	3.5721 **	0.0300	5.9014 ***	-2.5136 **	-0.0638	2.3457 *
	Thies	2.1386	0.0001	0.0000000179	0.0300870900	-0.0000441700	-0.0000000008	-0.1924800000
		3.2446 **	1.0630	0.0944	2.6732 **	-0.8666	-0.7113	-0.4087
	Louga	1.7492780600	0.0000875498	0.0000000018	0.0395610000	-0.0000678500	-0.0000000006	0.2344514300
		7.4897 ***	3.3749 ***	0.0271	9.9195 ***	-3.7566 ***	-1.4945	1.4050
TGO	Centre	1.7264653900	0.0000876190	0.0000000114	0.0336862300	-0.0000637900	-0.0000000003	0.7295900000
		15.9149 ***	7.2719 ***	0.3656	18.1851 ***	-7.6039 ***	-1.7068 +	9.4132 ***
	Kara	1.9852560800	0.0000850439	0.0000000156	0.0228715700	-0.0000505600	0.0000000000	0.4036800000
		9.0549 ***	3.4923 ***	0.2473	6.1091 ***	-2.9823 **	-0.0474	2.577 **
	Maritime	1.9981601200	0.0000827360	0.0000000165	0.0215585600	-0.0000363300	-0.0000000004	0.2040066700
		4.8183 ***	1.7962 +	0.1382	3.0444 **	-1.1329	-0.5349	0.6885
	Plateaux	1.6713776500	0.0000916364	0.0000000087	0.0491651600	-0.0000777100	-0.0000000009	0.4670266700
		14.7146 ***	7.2634 ***	0.2667	25.3481 ***	-8.8465 ***	-5.0134 ***	5.7547 ***

Significance levels: + = 10%, * = 5%, ** = 1%, *** = 0.1%, blank space = Not significant.
t–statistics reported below the coefficients' values together with significance levels.