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## Predicting Food Crop Production in Times of Crisis: The case of Wheat in Mozambique

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THE UKRAINE CRISIS AND AFRICAN ECONOMIES

### 1. Introduction

With the many challenges related to agricultural trade that countries currently face, it is important for policymakers who are tasked with the duty of protecting the vulnerable to be aware of potential food production disruptions that their countries may experience due to these challenges. For example, both Russia and Ukraine are key exporters of many agricultural products including sunflower oil and seed, wheat, barley, rapeseed and maize. The two countries jointly account for 27% of global wheat trade, 23% of global barley trade, as well as 16% and 14% of global trade in colza and maize respectively. Further, Russia and Ukraine account for over 28% of the world's nitrogen, potassium and phosphorous fertilizer[a] production. Consequently, the Russia-Ukraine war has destabilized global food and agricultural input value chains, a condition that will only worsen the longer and harder the war is fought. As net importers of both fertilizers and wheat, African countries are already experiencing rises in wheat and fertilizer prices as well as in the prices of their substitutes. The dynamic effects of the fertilizer and wheat price increases mean that production in coming seasons will be negatively impacted, and many more households may need support from various sources to survive the food and fertilizer price hikes.

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[a] https://www.cnbc.com/2022/04/06/a-fertilizer-shortage-worsened-by-war-in-ukraine-is-driving-up-global-food-prices-and-scarcity.html

Better and timely statistics on domestic food supplies, especially on production, are critical in any attempt to protect livelihoods under these conditions. Unfortunately, while Mozambique is relatively advanced in terms of the capacity to generate agricultural statistics relative to other African countries, data on wheat production forecasts that is disaggregated per location remains scanty, is often of low quality and is usually made available months after harvesting. In this brief, an attempt is undertaken to use remote sensing data together with machine learning techniques to predict future wheat production in Mozambique. The model used for predictions is selected partly because of its ability to correctly predict already existing wheat production data. The importance of using these methods is that, although they are skill intensive, their use limits the amount of time and the costs needed for calculating production levels from surveys and field visits, whereas the inherent precision in these techniques contributes to better availability of quality data for Mozambique.

In times of crisis such as the current one, the earlier food production patterns can be predicted, the sooner policymakers can take corrective measures to avert a full-blown food and nutritional security crisis. More accurate and timely information on food crop production, therefore, makes it possible for countries to design targeted interventions to protect access to food among many including the most vulnerable communities[b]. Once equipped with these predictions, policymakers can start developing interventions that target various areas depending on their levels of production.

The data scientists at AKADEMIYA2063 used the in-house developed Africa Crop Production (AfCP) model to predict upcoming wheat production levels in Mozambique. The model uses satellite remote sensing data as explanatory variables and machine learning techniques as a predictive modelling framework to provide production quantities at the pixel level, before the harvesting period. Remote sensing data makes it possible to uniquely characterize features on the earth's surface on several wavelengths without requiring someone's physical presence on the ground in addition to producing more extensive and better-quality data within a short time period. On the other hand, machine learning makes it possible to extract many hidden features in vast amounts of data to unlock the mechanisms behind the inner workings of very complex systems. In this brief, the two techniques mentioned above have been combined to forecast the quantity and spatial distribution of wheat production in Mozambique in 2022 amidst the Ukraine-Russia crisis.

## The Importance of Wheat in Mozambique

Wheat is one of the foods consumed in Mozambique, although not in the same quantities as cassava, maize, groundnuts and rice. However, with rapid urbanization, the demand for bread and hence wheat is rising. Mozambique's annual wheat production was 20,000 tonnes in 2019 compared to the domestic wheat demand which was 634,000 tonnes. In 2020, Mozambique's wheat production decreased significantly to approximately 18,000 tonnes and in 2021 production decreased further to 15,000 tonnes. The area under wheat cultivation in Mozambique is small (ranging from 3,000 to 5,000 hectares) compared to other countries (Tanzania's wheat area is 104,000 hectares, Rwanda's is 45,000 hectares and Uganda's is 12,000 hectares). Though Mozambique's production of wheat cultivated has fluctuated substantially in recent years, it increased overall from 2010 to 2019. Wheat is one of the crops that comprise the bulk of primary agricultural imports in Mozambique. The country sources 21% of its total wheat imports from Russia, 18.7% from Canada, 8.2% from Ukraine and 7.55% from Poland and other countries to supplement the local wheat production.

[b] Dia Khadim and Ly Racine. 2020. Predicting Food Crop Production in Times of Crisis: The Case of Sorghum in Burkina Faso. AKADEMIYA2063.

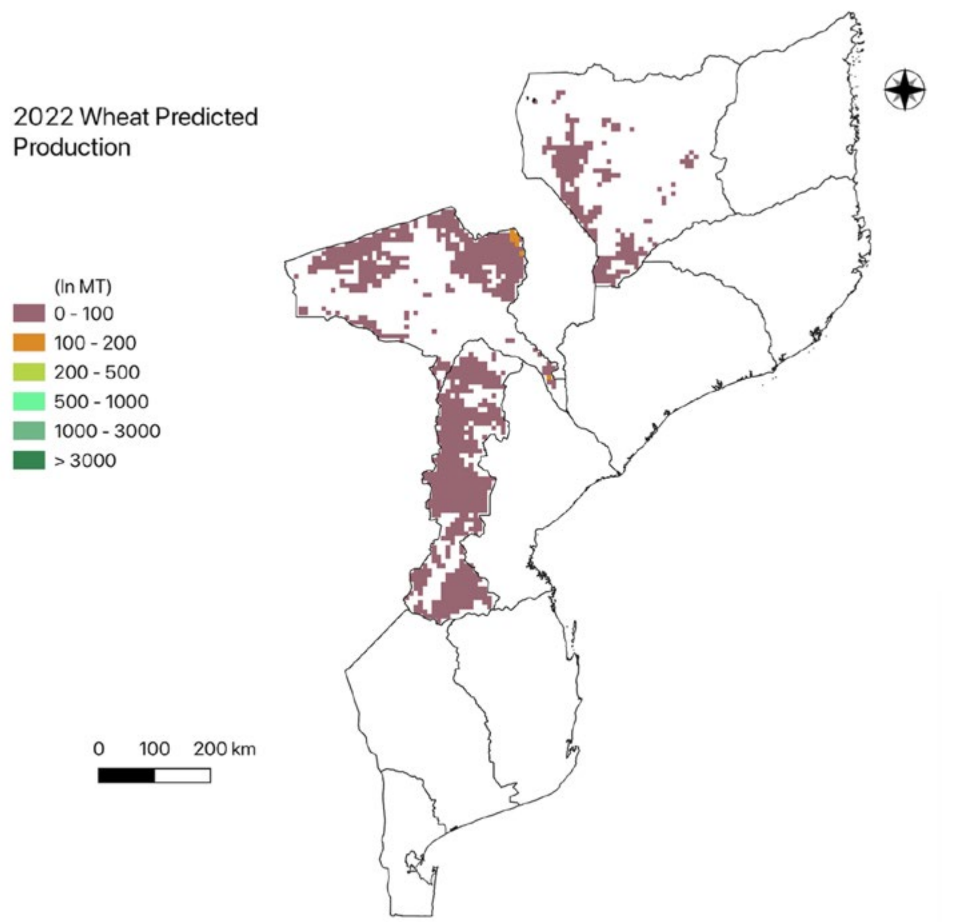
## *Wheat production prediction methodology*

Wheat production forecasts for Mozambique are generated using the AfCP model. The model uses satellite-based, bio-geophysical time-series data such as the normalized difference vegetation index (NDVI), land surface temperatures (LST), rainfall and evapotranspiration rates as explanatory variables. An artificial neural network was built to learn the relationships between the same biophysical data and historical staple food crop production data available at the pixel level. The crisis started several months before the beginning of Mozambique's wheat-growing season which starts in October and ends in April. Therefore, full information about in-season bio-geophysical data was not available when the predictions were implemented. Consequently, a random forest predictor was used to forecast in-season, bio-geophysical data profiles using data from the last 20 years, and the outputs were used as inputs for the AfCP model to predict Mozambique's wheat production in 2022.

## *Mozambique's 2022 wheat production forecast*

Using the methodology described above, the AfCP model provided Mozambique's 2022 wheat production forecast, as illustrated in Figure 1 below. The pixels considered for this map are those where wheat is believed to be grown and have a size of ten-by-ten kilometers on the ground.

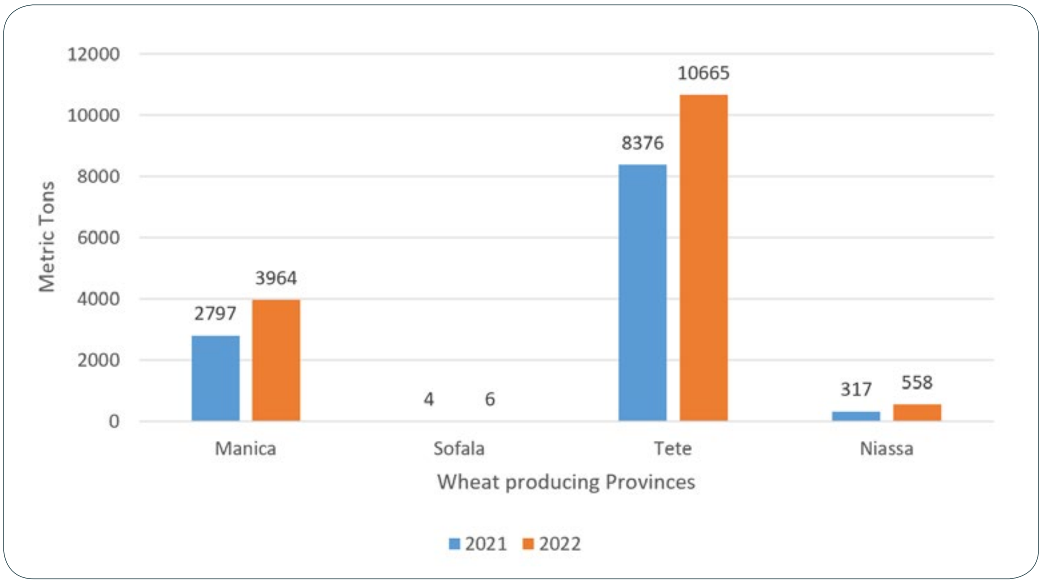
***Figure 1:*** *Wheat production forecast in Mozambique for 2022.*




***Source:*** *AKADEMIYA2063, 2022.*
*Notes: Mozambique 2022 wheat production forecast is at a pixel level size of ten-by-ten kilometers. The boundaries and names shown, and the designations used on maps do not imply any official endorsement or acceptance by AKADEMIYA2063. MT= Metric Tons*

Figure 1 presents Mozambique's predicted wheat production for 2022. The model predicts the production of about 15,198 metric tons of wheat in the upcoming 2022 harvest, which is an increase when compared with 2021 production (15,000 metric tons). Tete is by far the largest producer of wheat in Mozambique. In the 2022 harvesting season, it is expected that the highest level of wheat production in Mozambique will be in Tete province (where production is concentrated in Angónia, Tsangano and Macanga District), with a production of over 10,660 metric tons. This will be followed by Manica (where the top three producing areas are Gondola, Manica and Barue districts) with a production of over 3,900 metric tons and Niassa (where the top three producing areas are Mecanheals, Lichinga and Cuamba). When compared to the 2021 actual production levels, it is clear that there are important deviations over time which emphasizes the need for advanced predictions to enhance preparedness (Figure 2).

***Figure 2:*** *Comparison of wheat production in Mozambique, 2021 and 2022.*




***Source:*** *AKADEMIYA2063*

In Mozambique's four wheat-producing provinces (Manica, Sofala, Tete and Niassa provinces), the predicted 2022 production is expected to be higher than the 2021 actual production as depicted in Figure 2. Currently, rates of growth in wheat production appear to be the highest in Niassa (76%), Sofala (50%), Manica (42%) and Tete (27%). Despite the increase in wheat production predicted for 2022, it is still not sufficient to meet the local demand for wheat in Mozambique. The country's current wheat consumption is 437,000 metric tons annually, meaning that Mozambique produces approximately 4% of the wheat required for its annual domestic consumption.

In Tete province, Chibabava, Zumbu and Chiuta were predicted to be the districts with the largest increases in wheat production in 2022, recording 50%, 42% and 40% increases, respectively. On the other hand, in Manica province, the three districts that were predicted to have the largest increases in wheat production in 2022 were Macossa (77%), Tambara (59%) and Guro (56%). In Niassa province, Mecanheals (86%), Cuamba (83%) and Lago (82%) were predicted to be the districts that would see the largest increases. Lastly, Sofala, the only district (Sanga) producing wheat was also predicted to improve in 2022 by 69%. As depicted in Table 1 in the Appendix, all 37 wheat-producing districts located in the four provinces were expected to experience an increase in wheat production in 2022. This shows that Mozambique has the potential to raise production and reduce the deficit in wheat.

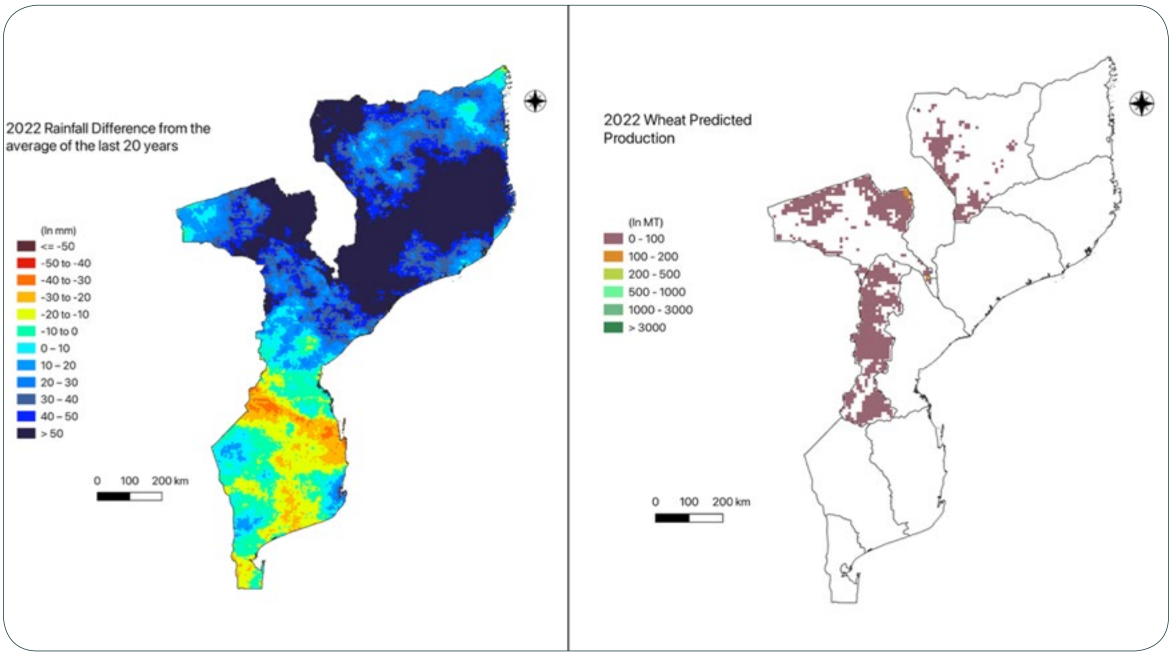
As annual wheat consumption in Mozambique is over 437,000 metric tons per annum, and since the demand for wheat is price inelastic (quantities of wheat demanded do not change much with changing prices), the rise in wheat prices as a result of the Russia-Ukraine war will have negative consequences on consumers unless domestic production is increased. This increase would have to occur despite the input price hikes exacerbated by the war. It should also be noted that both Russia and Ukraine are among the top three countries that Mozambique imports wheat, meaning that the net effects of the war on Mozambique will be negative. The economic sanctions imposed on Russia will interrupt the supply of wheat to Mozambique, which will result in rising wheat prices. On the other hand, the supply of wheat from Ukraine will also be interrupted as a result of Russia's invasion, and Ukraine will not be able to deliver its grain harvest to the rest of the world. Hence, it is important to ensure that steps are taken to increase consumer access to local production within Mozambique to limit the exposure of the low-producing areas to the negative, price-related impacts of the war on international trade flows.

## *Crop growing conditions in Mozambique*

This brief further examined crop growing conditions by computing anomalies of the same bio-geophysical parameters during the ongoing growing season[c]. The parameters were aggregated from January to June over the last 20 years. The data for 2022 were then compared with the aggregated trends recorded over the past 20 years.

Figure 3 shows the spatial correlation between rainfall anomalies and wheat production forecasts in Mozambique. To a large extent, areas with moderate rainfall anomalies appear to be associated with high wheat production forecasts.

***Figure 3:*** *Rainfall anomalies in Mozambique and wheat production in 2022.*



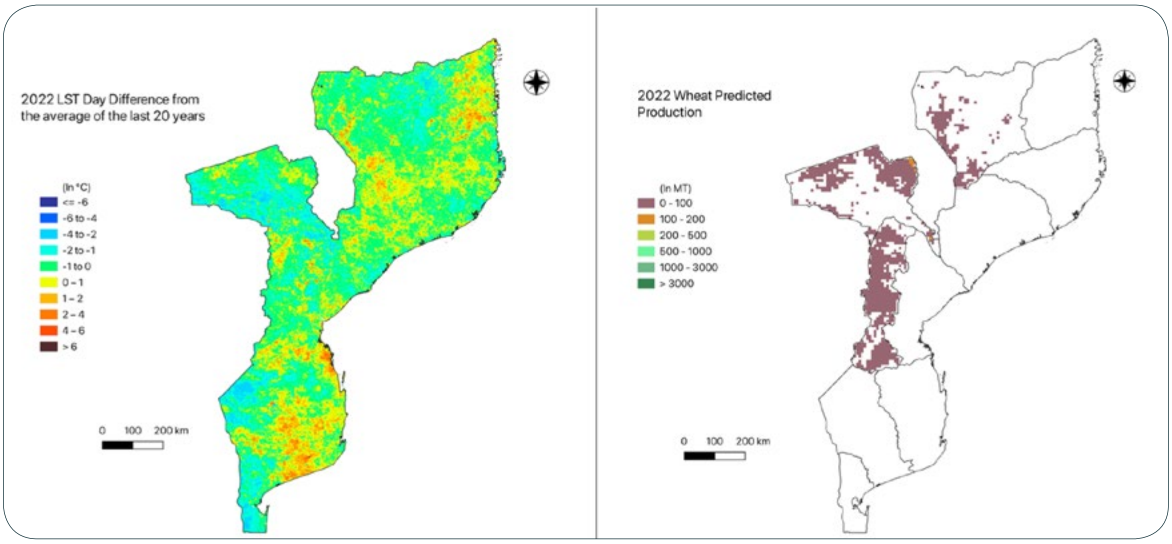

**Source:** *AKADEMIYA2063. (Left) Mozambique 2022 rainfall anomalies; (Right) Mozambique 2022 wheat production forecast.*

Figure 4 shows that at locations with the highest (above 4 degrees Centigrade) and lowest (below 4 degrees Centigrade) land surface temperature anomalies, predicted wheat production is at its lowest level. In contrast, wheat production is predicted to reach its highest levels at locations with moderate land surface temperature anomalies (between -4.0 and +4.0 degrees Centigrade). Similarly, the areas with the largest negative rainfall anomalies are associated with little to no wheat production compared to areas with moderate to high positive anomalies.

[c] Except for the evapotranspiration data due to data availability issues.

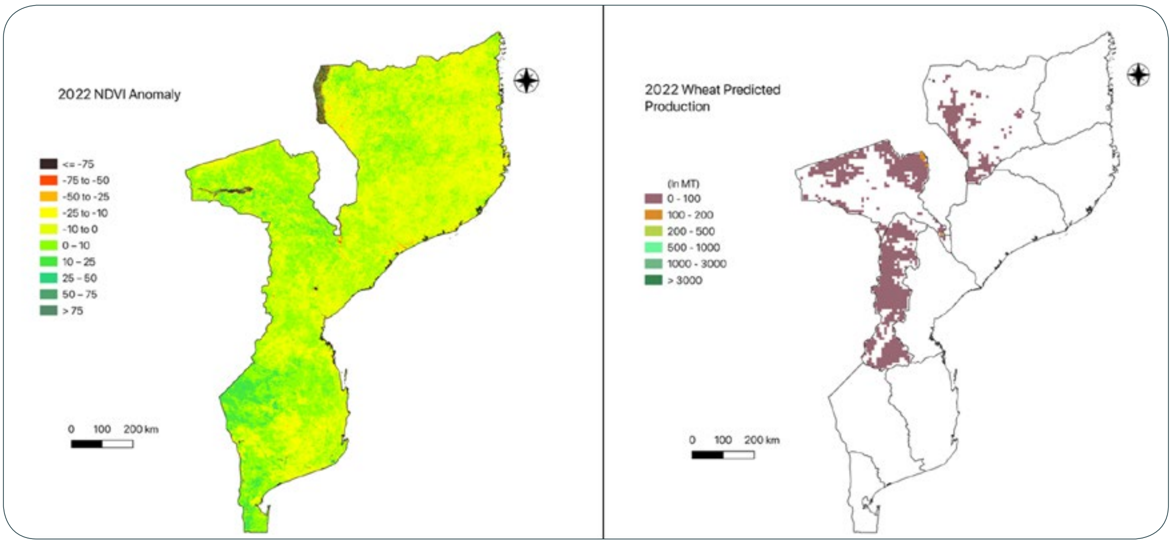
In Mozambique, irrigated wheat cultivars are planted from early June to mid-August. Spring wheat is planted from August to September[d], depending on soil moisture and warmer day and night temperatures during growth and reproduction. Paying attention to these temperature anomalies during planting can make production more resilient.

***Figure 4:*** *Temperature anomalies in Mozambique and wheat production forecasts for 2022.*




***Source:*** *AKADEMIYA2063. (Left) Mozambique 2022 land surface temperature anomalies at wheat cropland pixels; (Right) Mozambique 2022 wheat production forecast.*

***Figure 5:*** *NDVI anomalies in Mozambique and wheat production forecast for 2022.*




***Source:*** *AKADEMIYA2063. (Left) Mozambique 2022 NDVI anomalies at wheat cropland pixels; (Right) Mozambique 2022 wheat production forecast.*

Similarly, areas with very high positive deviations in NDVI as well as those with very low anomalies in NDVI did not appear to be correlated with high production of wheat, although modest changes in NDVI appear to favor greater wheat production.

[D] The yield predictions covered all wheat that was harvested within the year specified.

## Key Messages/Recommendations

The Russia-Ukraine war presents a challenge to global food security and household resilience, especially in those countries that depend on international trade for agricultural inputs as well as food in general. Predicting future agricultural production is critical to being able to anticipate and craft timely interventions that will limit the negative effects emanating from the war.

This brief applied state-of-the-art innovations that combine remote sensing and artificial intelligence techniques to predict Mozambique's wheat production for the 2022 period, with the aid of information on bio-geophysical characteristics (rainfall, evapotranspiration, NDVI and land surface temperatures).

The predictions obtained are consistent with actual production ranges observed recently in Mozambique, indicating an increase in wheat production in the upcoming harvest. It is therefore important for authorities to start putting in place mechanisms to increase consumer access to local production and limit the exposure of households in areas with declining production levels to greater threats than those already emanating from the disruption of global wheat supply chains.

Going into the next growing season, farmers should be encouraged to plant more wheat by expanding cropped areas where possible to limit the effects of further hikes to already high global prices. Furthermore, the government should embark on revitalizing previously operated wheat farms and milling companies to revive their activities to produce more wheat and tackle food insecurity and unemployment. It is also important that there is a good share of irrigated wheat production in total production, and to make sure that good water management practices are employed in periods of peak demand to ensure increased yields. This would address some of the water-related challenges in wheat production (see Dube et al., 2020) as well as the observed negative correlations between rainfall anomalies and future wheat production. Since Mozambique has expansive land areas relative to its population, allocating more land to wheat production can also increase production and limit domestic price increases in future.

Inputs such as water and fertilizers will continue to be limiting factors for wheat production in the medium- to long-term due to the frequent and disruptive global crises and climate change. To strengthen food system resilience, Mozambique's Institute of Agricultural Research (IIAM), should consider embarking on wheat yield improvement breeding programs which would look to produce wheat varieties with low input requirements (i.e., that require less water, fertilizer and pesticides per unit of wheat produced). Targeting low fertilizer and water requirements in breeding will reduce the importance of input costs in wheat production while also increasing production, productivity and profitability. Currently, fertilizer and water abstraction costs are a huge constraint to wheat production in Mozambique, similar to its neighbouring countries.

## Appendix

***Table 1.*** *Mozambique level 2 (sub-county) wheat production in 2021, 2022, and 2022-2021 ratio. A ratio below one means wheat production in 2021 was greater than in 2022. A production ratio above one means wheat production in 2022 was greater than in 2021. Both 2021 and 2022 data were extracted from the Africa Agriculture Watch (AAgWa) platform (www.aagwa.org).*

| Province | District Municipality | 2021 wheat production (tons) | 2022 wheat production (tons) | Wheat production ratio (2022/2021) |
|---|---|---|---|---|
| Manica | Barue | 452.9 | 629.8 | 1.390 |
| Manica | Gondola | 525 | 713.4 | 1.359 |
| Manica | Guro | 156.7 | 244.2 | 1.558 |
| Manica | Machaze | 347.3 | 536.5 | 1.545 |
| Manica | Macossa | 132 | 233.2 | 1.767 |
| Manica | Manica | 507.8 | 674.2 | 1.328 |
| Manica | Mossurize | 317.5 | 414.2 | 1.304 |
| Manica | Sussundenga | 304.4 | 437.5 | 1.437 |
| Manica | Tambara | 53.3 | 84.5 | 1.586 |
| Niassa | Cuamba | 44.6 | 81.7 | 1.835 |
| Niassa | Lago | 9.4 | 17.2 | 1.823 |
| Niassa | Lichinga | 48.7 | 85 | 1.744 |
| Niassa | Majune | 17.1 | 30.7 | 1.798 |
| Niassa | Mandimba | 10.1 | 17.9 | 1.772 |
| Niassa | Marrupa | 10.6 | 18.6 | 1.749 |
| Niassa | Maúa | 6.9 | 12.4 | 1.793 |
| Niassa | Mavago | 11.3 | 20.2 | 1.78 |
| Niassa | Mecanhelas | 70.7 | 131.5 | 1.86 |
| Niassa | Mecula | 0 | | |
| Niassa | Metarica | 2.9 | 5.2 | 1.816 |
| Niassa | Muembe | 23.6 | 42.2 | 1.788 |
| Niassa | N'gauma | 23 | 40.6 | 1.764 |
| Niassa | Nipepe | 0 | | |
| Niassa | Sanga | 38.2 | 67.7 | 1.772 |
| Sofala | Chibabava | 3.8 | 5.7 | 1.497 |
| Tete | Angónia | 2544.2 | 3180.2 | 1.25 |
| Tete | Cahora Bassa | 126.4 | 173.4 | 1.372 |
| Tete | Changara | 145.2 | 145.4 | 1.002 |
| Tete | Chifunde | 431.2 | 543.9 | 1.261 |
| Tete | Chiuta | 155.7 | 218.4 | 1.403 |
| Tete | Macanga | 1212.4 | 1634.1 | 1.348 |
| Tete | Magoe | 197.5 | 287.1 | 1.454 |
| Tete | Maravia | 459.6 | 631.3 | 1.374 |
| Tete | Moatize | 412.1 | 536 | 1.3 |
| Tete | Mutarara | 600.3 | 617.4 | 1.028 |
| Tete | Tsangano | 1870 | 2388.3 | 1.277 |

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