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September 2022
No. 011

UKRAINE CRISIS BRIEF SERIES

Predicting Food Crop Production in Times of Crisis: The Case of Wheat in South Africa

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THE UKRAINE CRISIS AND AFRICAN ECONOMIES

1. Introduction

With the numerous challenges related to agricultural trade that African countries currently face, it is crucial for policymakers tasked with the duty of protecting the vulnerable to be aware of potential food production disruptions that their countries may experience as a result of 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. Jointly, the two countries account for 27% of global wheat trade, while they account for 23%, 16% and 14% of global trade in barley, colza and maize, respectively[1]. Furthermore, Russia and Ukraine, which are currently at war with each other, account for over 28% of the world's nitrogen, potassium and phosphorous fertilizer exports[2] The Russia-Ukraine war has therefore destabilized global food and agricultural value chains, a situation that is expected to continue and even worsen, the longer and more intensely the war is fought. As net importers of both fertilizers and wheat, African countries are already experiencing a rise in the prices of these commodities as well as their substitutes. The fertilizer and wheat price increases will negatively impact agricultural production in the current and coming seasons. Many more households may therefore need support from various sources in order to survive the resulting food price hikes.

[1] UNCTAD (United Nations Conference on Trade and Development). 2022. The Impact on Trade and Development of the War in Ukraine. UNCTAD Rapid Assessment. Geneva, Switzerland.

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

More accurate and timely statistics on domestic food supplies, especially related to production, are critical in any attempt to protect livelihoods under these conditions. Among African countries, South Africa is relatively advanced in terms of the capacity to generate agricultural statistics. However, the country's data on wheat forecasts disaggregated per location is still scanty. When available, its quality is often low, and its release is usually untimely, occurring months after harvesting. This brief uses remote sensing data together with machine learning techniques to predict future wheat production in South Africa. The models used for prediction are selected partly based on their ability to predict already existing wheat production data correctly. The benefits of using these methods are that, although they are skill intensive, their use reduces the time and costs needed for calculating production levels from surveys and field visits. At the same time, the inherent precision of the techniques contributes to the availability of better quality data on South Africa.

In times of crisis such as the current one, the earlier food production patterns can be predicted, the sooner policymakers can take appropriate 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 for many, including the most vulnerable communities. Equipped with these predictions, policymakers can start developing interventions early enough, targeting various areas depending on their production levels.

The AKADEMIYA2063 data scientists used the Africa Crop Production (AfCP) model developed in-house to predict South Africa's wheat production in 2022. The model uses satellite remote sensing data as explanatory variables and machine learning techniques as a predictive modelling framework to provide production quantities before the harvesting period at the pixel level. The remote sensing data makes it possible to uniquely characterize features on the earth surface on several wavelengths even without a physical human presence on the ground. Remote sensing also enables the production of more extensive and better-quality data over a shorter period. On the other hand, machine learning makes it possible to extract the many hidden features in the vast amount of remotely sensed 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 South Africa's wheat production in 2022 amidst the Ukraine-Russia crisis.

2. The Significance of Wheat in South Africa

Wheat is one of South Africa's staple foods, with an annual production of close to two million metric tons (over an area of 500,000 hectares)[4] , while its sales value accounts for 10% of the total value of South Africa's field crops, estimated to be 19 billion rands[5]. Wheat is the second most important grain commodity consumed in South Africa after corn. The country is a net importer of wheat and annually imports around 1.7 million metric tons. This quantity may increase in future as local production declines due to limited fertilizer use associated with the rising prices sparked by the Russia-Ukraine war[6].

Wheat Production Prediction Methodology

The wheat production forecasts for South Africa were 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 quantities and evapotranspiration rates as explanatory variables. An artificial neural network was built to learn the relationships between the same bio-geophysical data and historical staple food crop production data available at the pixel level. The Russia-Ukraine war started several months before South Africa's wheat growing season, between mid-April to mid-July (for winter wheat) and from early June to mid-August for irrigated wheat[7]. Therefore, information about bio-geophysical data might not be available. A random forest predictor was instead 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 South Africa's wheat production in 2022.

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

[4] Esterhuizen D. 2022. Grain and Feed Annual. United States Department of Agriculture. Washington DC

[5] Stats SA. 2021. Agricultural survey, 2019. Department of Statistics, South Africa. Johannesburg

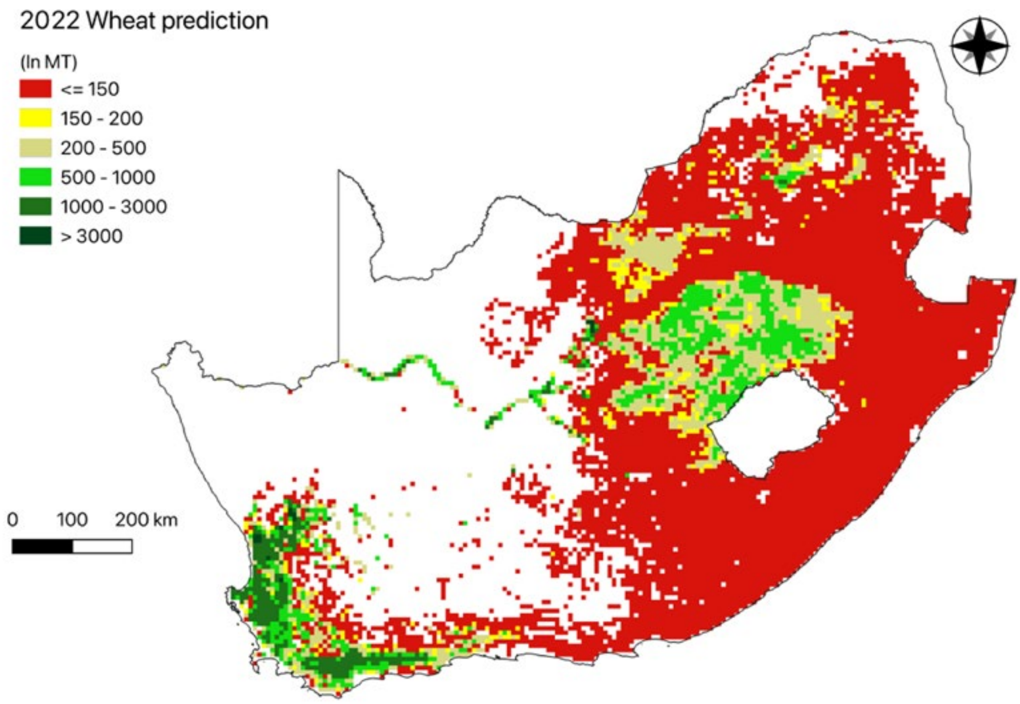
[6] Esterhuizen D. 2022. Grain and Feed Annual. United States Department of Agriculture. Washington DC

[7] DAFF, 2009. Wheat. **https://www.nda.agric.za/docs/brochures/wheat.pdf**

South Africa's 2022 Wheat Production Forecast

Using the methodology described, the AfCP model developed South Africa's 2022 wheat production forecast, as illustrated in Figure 1 below. The pixels considered for this map represent those areas where wheat is grown, with a size of ten-by-ten kilometers on the ground.

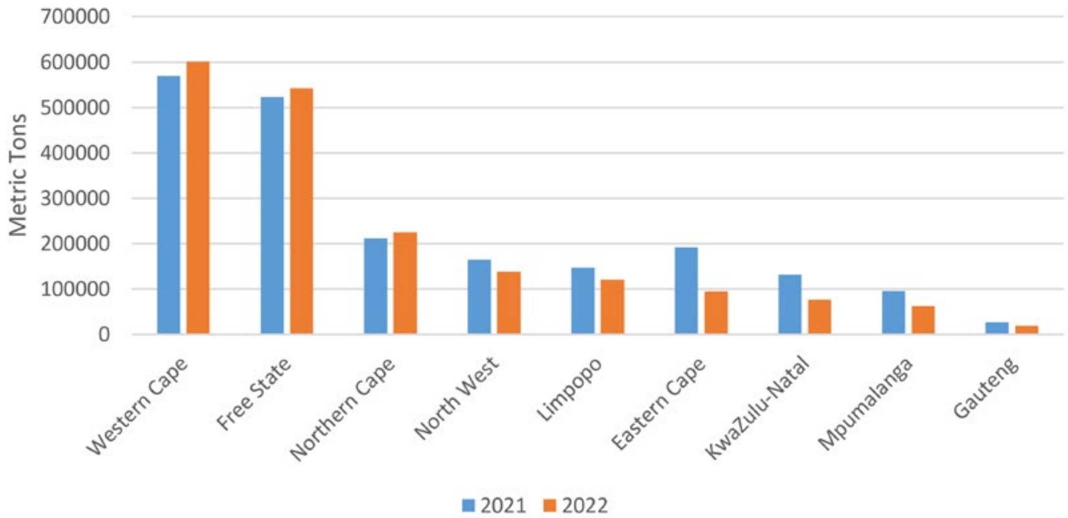
Figures 2b: *Changes in Gross Income vs Baseline (%)*



Source: *AKADEMIYA2063, 2022.*
Notes: *South Africa's 2022 wheat production forecast is at a pixel level size of ten-by-ten kilometers. The boundaries and names shown, as well as the designations used on maps, do not imply official endorsement or acceptance by AKADEMIYA2063.*

Figure 1 presents South Africa's predicted wheat production for 2022. The model predicts about 1,881,000 metric tons of wheat production in the upcoming 2022 harvest, indicating that production will slightly decline from 2021 levels of 2.15 million metric tons. In the 2022 harvesting season, it is expected that the highest level of wheat production will be in the Western Cape (where production is concentrated in the West Coast, Overberg, and the Cape Winelands) with a production of over 600,000 metric tons; Free State (where the top three producing areas are Thabo Mofutsanyane, Lejweleputswa and Fezile Dabi) with a production of over 540,000 metric tons; and Northern Cape (where the top three producing areas are Namakwa, Pixley ka Seme, and Frances Baard). The Gauteng province (19,200 metric tons), Mpumalanga (under 63,000 metric tons) and KwaZulu-Natal (76,200 metric tons) will produce the lowest quantities of wheat. When compared to the 2020 actual production levels, it is evident that there are important deviations in production over time which confirms the need for advanced predictions to enhance preparedness (**Figure 2**).

Figures 2*: Comparison of Wheat Production in South Africa, 2021 and 2022*



Source: *AKADEMIYA2063, 2022.*

In Gauteng, Mpumalanga, KwaZulu-Natal, Eastern Cape, Limpopo and North West provinces, the forecasted production for the 2022 period is expected to be lower than actual production in 2021, while wheat production is expected to increase in Western Cape, Free State and Northern Cape provinces in the 2022 harvesting season. However, the 2022 national harvest will be lower than in 2021 and will not be sufficient to meet the country's consumption demand of over 3.6 million metric tons per annum[8]. Most of this decline in production is predicted to occur in Eastern Cape, KwaZulu-Natal, Mpumalanga and Gauteng (see Table 1 in the Appendix), seen in the lower ratios of 2022 wheat production as a share of 2021 production.

As demand for wheat is price inelastic (quantities of wheat demanded do not vary much with changing prices), the rising wheat prices resulting from the Russia-Ukraine war will have negative consequences on consumers unless domestic production is increased even in the face of rising input prices exacerbated by the war. It is also important to ensure that steps are taken to increase consumer access to South Africa's locally produced wheat to limit the exposure of the low-producing areas to the price-related negative effects of the trade disruptions arising from the war.

Status of Crop-growing Conditions

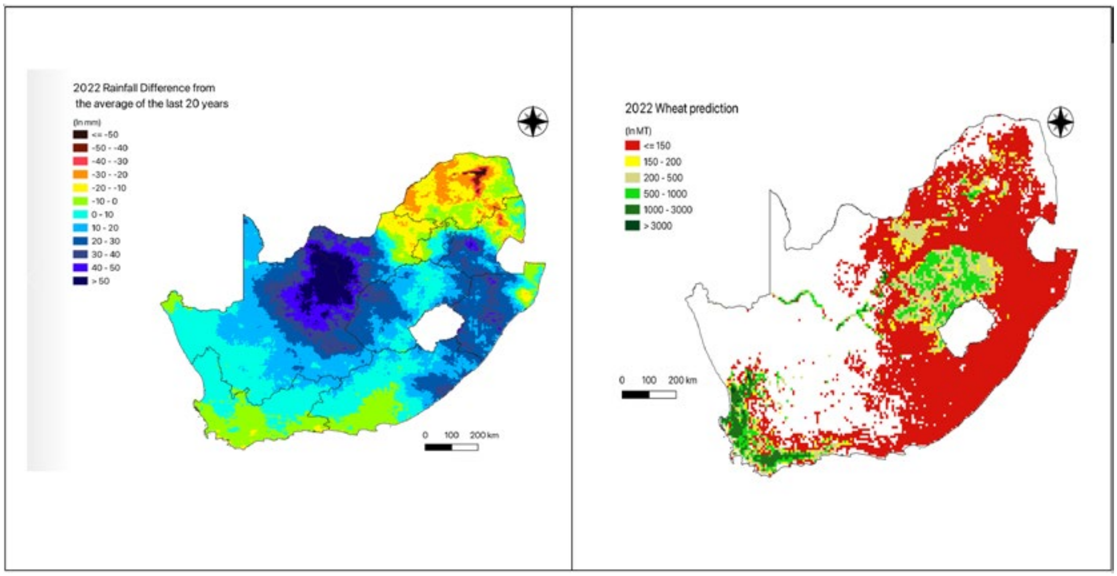
This brief further examined crop growing conditions by computing anomalies in the same bio-geophysical parameters over the ongoing growing season[9]. The parameters were aggregated from January to June for the last 20 years. The aggregated data for 2022 were then compared to the 20-year trends.

Figure 3 shows the spatial correlation between rainfall anomalies and wheat production predictions. To a large extent, areas with moderate anomalies appear to be associated with high wheat production forecasts, for example, in the Free State and parts of the Western Cape.

[8] Esterhuizen D. 2022. Grain and Feed Annual. United States Department of Agriculture. Washington DC.

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

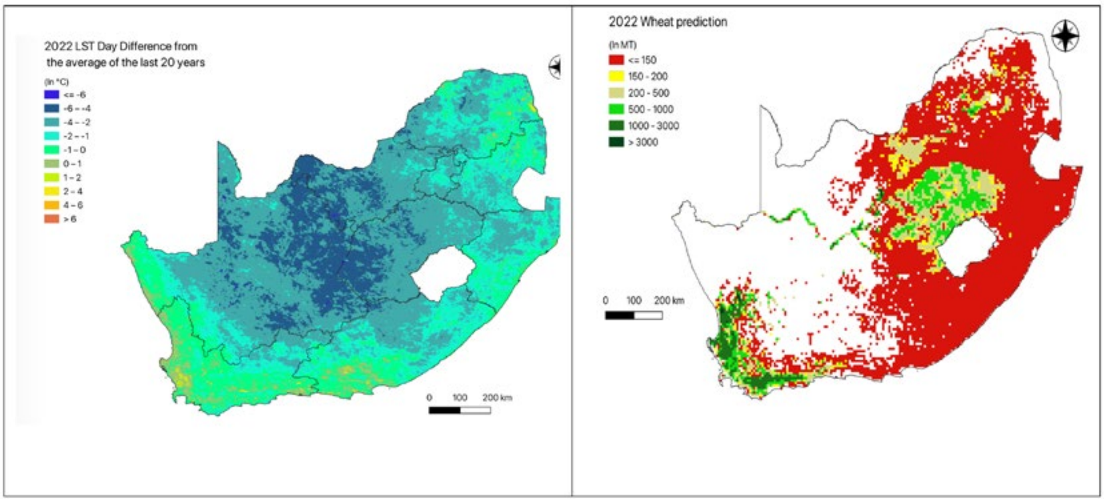
Figures 3: *Rainfall Anomalies and Predicted Wheat Production in South Africa for 2022*



Source: *AKADEMIYA2063. (Right) South Africa 2022 wheat production forecast - (Left) South Africa 2022 rainfall anomalies.*

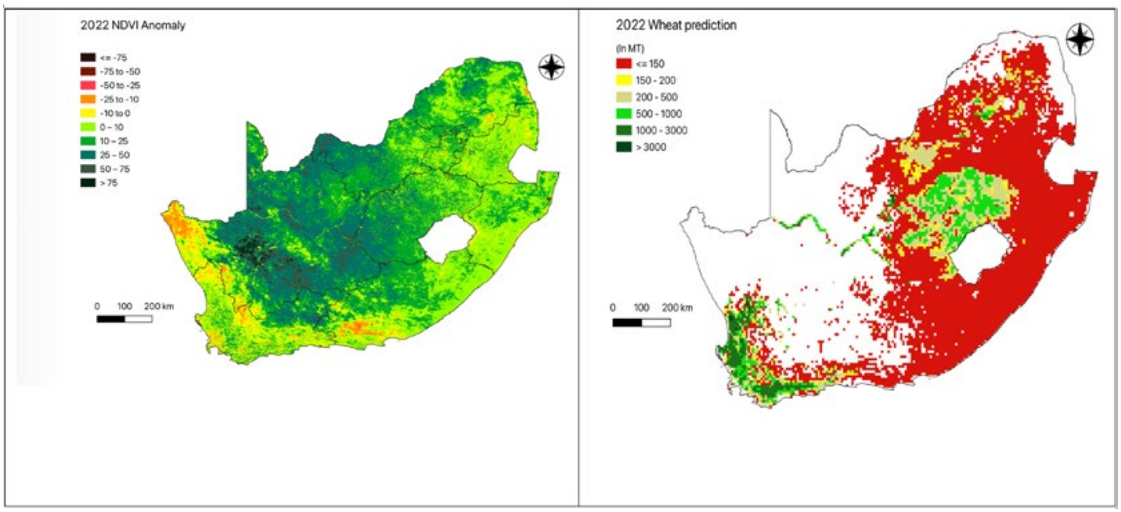
Figure 4 shows that in locations with the highest (above 4 degrees Centigrade) and lowest (below 4 degrees Centigrade) land surface temperature anomalies, predicted wheat production is at its lowest level. In contrast, wheat production is predicted to reach its highest level in those locations with moderate land surface temperature anomalies (between -4.0 and +4.0 degrees Centigrade). Similarly, areas with the most negative rainfall anomalies seem to show the lowest levels of wheat production forecasts compared to areas with moderate to high positive anomalies. In South Africa, irrigated cultivars are planted from early June to mid-August. Spring wheat is planted from August to September, depending on soil moisture and warmer temperatures (day and night) during growth and reproduction. Paying attention to these temperature anomalies during planting can make production more resilient.

Figures 4: *Temperature Anomalies and Predicted Wheat Production in South Africa for 2022*



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

Figures 5: *: NDVI Anomalies and Predicted Wheat Production in South Africa for 2022*



Source: *AKADEMIYA2063. (Right) South Africa 2022 wheat production forecast - (Left) South Africa 2022 NDVI anomalies at wheat cropland pixels.*

Likewise, areas with very high positive deviations in NDVI and those with very low NDVI anomalies did not appear to be correlated with high wheat production. However, modest changes in NDVI appear to favor greater wheat production.

3. Key Messages and 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 and food in general. Predicting future agricultural production is critical to anticipating and crafting timely interventions that limit the negative effects emanating from the war.

This brief applied state-of-the-art modelling that combines remote sensing and artificial intelligence techniques to predict South Africa's wheat production for 2022. This was done with information on bio-geophysical characteristics (rainfall, evapotranspiration, NDVI and land surface temperatures).

The predictions are consistent with actual production ranges observed recently in South Africa, indicating a slight decline in wheat production in the upcoming harvest. It is, therefore, important for authorities to start putting in place mechanisms that increase consumer access to local production and minimize the threat emanating from the disruption of global wheat supply chains for those households in areas with declining production levels.

Going into the next growing season, farmers should be encouraged to plant more wheat by expanding cropped areas where this is possible to limit the effects of rising global prices. Furthermore, although there is a good share of irrigated wheat production, it is equally essential to ensure that good water management practices are employed in periods of peak demand to ensure increased yields. This would address some of the reported water challenges in wheat production (see Dube et al., 2020) as well as the observed negative correlations between rainfall anomalies and predicted wheat production.

Inputs such as water and fertilizers will continue to be limiting factors in wheat production in the medium to long term, given the frequent, disruptive global crises as well as the impacts of climate change. To develop food system resilience, the Agricultural Research Council of South Africa should consider embarking on wheat yield improvement breeding programs that focus on wheat varieties with low input requirements (i.e., use less water, fertilizer, and pesticides per unit of wheat produced). Targeting low fertilizer and water requirements in breeding will reduce the input costs in wheat production while also increasing production, productivity, and profitability. Currently, fertilizer and water abstraction costs are a huge constraint on wheat production in South Africa.

4. References

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

Dube E, Tsilo TJ, Sosibo NZ, Fanadzo M. Irrigation wheat production constraints and opportunities in South Africa. S AfrJ Sci. 2020;116(1/2), Art. #6342, 6 pages. https://doi.org/10.17159/sajs.2020/6342

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Appendix

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

Province	District Municipality	2021 Wheat Production (MT)	2022 Wheat Production (MT)	Wheat Production Ratio (2022/2021)
Mpumalanga	Nkangala	25,720.05	18,000.49	0.70
North West	Bojanala	32,198.21	25,634.02	0.80
Northern Cape	John Taolo Gaetsewe	3,502.19	2,021.87	0.58
Northern Cape	Namakwa	84,751.40	91,938.86	1.08
North West	Ngaka Modiri Molema	64,049.81	58,309.12	0.91
Northern Cape	Frances Baard	35,520.16	41,222.17	1.16
Western Cape	Cape Winelands	94,265.35	85,324.74	0.91
Western Cape	Central Karoo	7,571.02	5,118.48	0.68
Northern Cape	Pixley ka Seme	55,615.91	53,326.06	0.96
Northern Cape	Siyanda	32,406.22	36,406.78	1.12
Western Cape	Overberg	109,065.19	115,529.03	1.06
Western Cape	West Coast	271,846.76	308,652.69	1.14
Western Cape	City of Cape Town	10,565.03	9,068.85	0.86
Western Cape	Eden	76,451.89	76,959.46	1.01
Eastern Cape	Buffalo City	4,063.81	1,723.22	0.42
Eastern Cape	Cacadu	44,656.11	22,876.11	0.51
Eastern Cape	Alfred Nzo	15,374.96	7,889.43	0.51
Eastern Cape	Amathole	30,409.15	13,911.78	0.46

Province	District Municipality	2021 Wheat Production (MT)	2022 Wheat Production (MT)	Wheat Production Ratio (2022/2021)
Eastern Cape	Nelson Mandela Bay	2,115.19	1,001.43	0.47
Eastern Cape	O.R. Tambo	17,688.94	8,395.26	0.47
Eastern Cape	Chris Hani	43,860.85	22,425.90	0.51
Eastern Cape	Joe Gqabi	33,596.64	16,896.09	0.50
Free State	Mangaung	25,708.98	26,876.72	1.05
Free State	Thabo Mofutsanyane	170,240.53	182,929.89	1.07
Free State	Fezile Dabi	110,797.80	120,262.98	1.09
Free State	Lejweleputswa	130,248.06	13,6635.83	1.05
Gauteng	City of Tshwane	8,698.80	6,089.84	0.70
Gauteng	Ekurhuleni	4,694.26	3,237.05	0.69
Free State	Xhariep	86,528.24	76,167.14	0.88
Gauteng	City of Johannesburg	1,661.03	897.74	0.54
KwaZulu-Natal	Amajuba	9,862.35	5,829.75	0.59
KwaZulu-Natal	eThekwini	2,323.38	1,261.28	0.54
Gauteng	Sedibeng	5,220.80	4,193.79	0.80
Gauteng	West Rand	6,597.22	4,833.72	0.73
KwaZulu-Natal	Ugu	8,750.50	4,850.64	0.55
KwaZulu-Natal	Umgungundlovu	14,227.58	8,719.67	0.61
KwaZulu-Natal	iLembe	4,959.81	2,905.44	0.59
KwaZulu-Natal	Sisonke	15,850.89	9,875.30	0.62
KwaZulu-Natal	Uthukela	14,652.38	9,043.82	0.62
KwaZulu-Natal	Uthungulu	11,022.22	6,011.76	0.55
KwaZulu-Natal	Umkhanyakude	15,511.15	7,900.99	0.51
KwaZulu-Natal	Umzinyathi	12,668.25	7,343.12	0.58
Limpopo	Mopani	19,843.25	15,202.85	0.77
Limpopo	Sekhukhune	23,657.89	19,122.46	0.81
KwaZulu-Natal	Zululand	21,452.21	12,423.44	0.58
Limpopo	Capricorn	22,824.06	19,061.34	0.84
Mpumalanga	Ehlanzeni	21,307.32	12,772.20	0.60
Mpumalanga	Gert Sibande	48,711.00	32,486.97	0.67
Limpopo	Vhembe	15,568.70	10,714.27	0.69
Limpopo	Waterberg	64,804.85	56,212.13	0.87
North West	Dr Kenneth Kaunda	29,259.24	24,554.04	0.84
North West	Dr Ruth Segomotsi Mompati	38,682.27	29,940.77	0.77

Suggested Citation: Ly, R., Matchaya, G., and Dia, K. Predicting Food Crop Production in Times of Crisis: The Case of Wheat in South Africa. AKADEMIYA2063 Ukraine Crisis Brief Series, No. 11, AKADEMIYA2063, Kigali, Rwanda.

AKADEMIYA2063 is supported financially by the United States Agency for International Development (USAID), the Bill and Melinda Gates Foundation (BMGF), the German Federal Ministry for Economic Cooperation and Development (BMZ), the African Development Bank (AfDB), the UK's Foreign, Commonwealth & Development Office (FCDO), the Global Center on Adaptation (GCA), and the Food and Agriculture Organization of the United Nations (FAO). The views expressed in this publication do not necessarily reflect those of the funders.

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