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The bio-economic impact of conservation agriculture on food security in southern Africa under drought

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About the project

Southern Africa –Towards Inclusive Economic Development (SA-TIED)

SA-TIED is a unique collaboration between local and international research institutes and the government of South Africa. Its primary goal is to improve the interface between research and policy by producing cutting-edge research for inclusive growth and economic transformation in the southern African region. It is hoped that the SA-TIED programme will lead to greater institutional and individual capacities, improve database management and data analysis, and provide research outputs that assist in the formulation of evidence-based economic policy.

The collaboration is between the United Nations University World Institute for Development Economics Research (UNU-WIDER), the National Treasury of South Africa, the International Food Policy Research Institute (IFPRI), the Department of Monitoring, Planning, and Evaluation, the Department of Trade and Industry, South African Revenue Services, Trade and Industrial Policy Strategies, and other universities and institutes. It is funded by the National Treasury of South Africa, the Department of Trade and Industry of South Africa, the Delegation of the European Union to South Africa, IFPRI, and UNU-WIDER through the Institute's contributions from Finland, Sweden, and the United Kingdom to its research programme.

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ABSTRACT

This study analyses the potential impact of conservation agriculture (CA) on maize production and food security under drought conditions in southern Africa. The study combines biophysical and socio-economic approaches. The biophysical approach is used to estimate the potential impact of CA on maize yields under drought conditions in southern Africa; this result is then inserted into an economic model to estimate the potential bio-economic impact of CA on food security under those conditions. The results suggest that CA could increase regional maize production and slightly enhance regional food security under drought conditions in southern Africa. The positive impact of CA on regional food security would occur under randomly distributed droughts and under consecutive two-year regional droughts. However, the slight positive impact of CA on regional food security implies that it would need to be complemented with additional measures, such as rainwater harvesting, to substantially enhance food security under severe drought conditions in southern Africa.

1 INTRODUCTION

Southern Africa was listed in 2019 among the world's hotspots for increased temperature and increased drying (Hoegh-Guldberg et al., 2018). More specifically, projections on weather extremes imply an increase in the intensity and duration of droughts (Seneviratne et al., 2012). The northern region of southern Africa has experienced an increase in the frequency of droughts, whereas the whole region has experienced an increase in the duration and intensity of droughts (Fauchereau et al., 2003).

This study builds on Gbegbelegbe et al. (n.d.) to assess the potential for conservation agriculture (CA) to mitigate the negative effects of future droughts on regional food security in southern Africa. Gbegbelegbe et al. (n.d.) used a process-based structural framework to show that with moderate but unequal economic growth most countries in southern Africa would not be able to mitigate food insecurity by 2035. In this context, recurrent droughts would further undermine food security. In addition, consecutive two-year droughts similar to what the region experienced in 2015 and 2016 would affect most countries in the region and have serious implications for humanitarian aid.

Proposed measures to enhance food security under drought include CA (Shiferaw et al., 2014). This study contributes to the literature by analysing the bio-economic impact of conservation agriculture on food security under drought in southern Africa. The rest of the paper is organized as follows. Section 2 presents a literature review on drought and CA. Section 3 describes the methodological approach used in this study. Section 4 presents the results from this study while Section 5 presents a discussion of these, and section 6 provides conclusions.

2 LITERATURE REVIEW

Conservation agriculture involves three principles: minimum tillage, soil cover with crop residues, and crop rotation (Silici et al., 2011). There are few studies which analyse the relationship between CA and drought. Steward et al. (2018) used data from 42 publications to assess the capacity of maize-based CA systems to adapt to abiotic climatic stresses, more particularly water and heat stress. Their results suggest that agricultural systems based on CA perform better than conventional systems in terms of crop yields in conditions characterized by drought and/or high temperatures. However, the advantage of CA seems to wane in conditions characterized by very wet weather and clay-rich soils (Steward et al., 2018) . Steward et al. (2019) used research field trials to demonstrate that with drought lasting 19 consecutive days at anthesis, long-term systems (7-8 years) based on CA performed better than conventional systems on a sandy clay loam soil (moderate clay content). However, with a drought lasting 28 consecutive days around anthesis, the performance of CA-based systems was not different from that of conventional systems (Steward et al., 2019).

Another study, by Araya et al. (2015), assessed the impact of two technologies, namely DER+ and TER+, which combine selected CA practices and farmers' practices. TER+ involved the techniques used in conventional tillage (CT) and a traditional water conservation technique used by farmers. DER+ was also based on a traditional water conservation technique used by farmers, consisting of raised beds. The technique was augmented with no tillage and residue retention on the raised beds. The study results implied that CA can increase green water in the root zone for crops; in return, this can help crops mitigate the negative effect of dry spells on yields in semi-arid areas.

Thierfelder et al., (2016) tried to assess the performance of CA and drought-tolerant (DT) maize along the rainfall gradient in Mozambique. The selected sites mainly fell into the humid subtropical and tropical savanna zones. The experiments ran over seven years in the selected sites that had loamy sand or sandy loam texture. In two sites, namely Lamego and Pumbuto, total annual rainfall did not exceed 1000 mm over five years. The results showed that sites involving CA performed better than sites with conventional agriculture; in addition, DT maize outperformed conventional maize varieties across all sites under rainfed conditions. However, the yield of DT maize in sites with CA did not increase over time, and this suggests no direct linkage between DT maize and CA.

Most studies show that CA, by increasing soil moisture, yields benefits in soils with low or moderate clay content and under dry conditions (Thierfelder & Wall, 2009, 2010). In addition, conservation agriculture tends to perform worse than conventional agriculture in terms of yields in very wet years (Thierfelder & Wall, 2009, 2010)(Thierfelder & Wall, 2009, 2010). A study by Tessema et al. (2015) shows that in drought-prone areas where CA can be beneficial in terms of enhancing yields under drought, adoption can be hindered by socio-economic factors such as high interest rates, difficult access to credit, high transaction costs (including transport) that drive a wedge between selling and buying prices for farmers, and high risk-aversion levels by farmers.

3 CONCEPTUAL FRAMEWORK

This study uses a framework which involves both biophysical and economic approaches. For the biophysical approach, results from Steward et al. (2018) were used to quantify the potential biophysical impact of conservation agriculture on maize yields under drought across southern Africa. These estimated results were then inserted into an economic model to estimate the potential bio-economic impact of conservation agriculture on food security under drought in southern Africa.

3.1 Biophysical approach

In Steward et al. (2018), the yield ratio of conservation agriculture over conventional agriculture was estimated based on heat and precipitation balance. For soils with less than 5% of clay, the yield advantage of CA was about 22% with strong rainfall deficit and high heat stress. Similarly, for soils with 2%-50% clay content, the yield advantage from CA was about 65%, and for soils with more than 50% clay content, the yield advantage was about 123%.

It is likely that the previous results involve moderate drought situations, since it has been shown that CA has no yield advantage over conventional agriculture under long-lasting droughts (Steward et al., 2019). For the purposes of this study, which focuses on relatively severe droughts similar to what the region experienced in 2015 and 2016, the results from Steward et al. (2018) are cut in half to reflect the plausible yield advantage of CA over conventional agriculture (Table 1). Soil classifications for each country are then used to quantify the plausible yield advantage of CA under drought for maize production in each country in southern Africa (Table 1). For example, in Angola, 1% of the agricultural soil contains less than 5% clay whereas 99% of the agricultural land has a clay content between 5% and 50%. Given that the plausible impact of conservation agriculture on maize yields is 11% for soils with less than 5% clay content and 32% for soils with clay content between 5% and 50%, the overall estimated impact of conservation agriculture on maize yields under severe drought is around 32% (Table 1).

Table 1: Estimated biophysical impact of conservation agriculture on maize yields under severe droughts in southern Africa

	Soil classification based on clay content (%)			Gain from conservation agriculture (%)			Plausible gain from conservation agriculture under severe droughts (%)			Growth rate from conservation agriculture - country (%)
	< 5% clay	5–50% clay	> 50% clay	< 5% clay	5–50% clay	> 50% clay	< 5% clay	5–50% clay	> 50% clay	
Angola	1	99	0	22	65	123	11	32	61	32
Botswana	0	97	3	22	65	123	11	32	61	33
Lesotho	0	100	0	22	65	123	11	32	61	32
Madagascar	1	100	0	22	65	123	11	32	61	32
Malawi	0	100	0	22	65	123	11	32	61	32
Mozambique	1	99	0	22	65	123	11	32	61	32
Namibia	9	92	0	22	65	123	11	32	61	31
South Africa	0	100	0	22	65	123	11	32	61	32
Swaziland	0	100	0	22	65	123	11	32	61	32
Zambia	0	100	0	22	65	123	11	32	61	32
Zimbabwe	0	100	0	22	65	123	11	32	61	32

Source: Author's computations using results from Jawoo Koo (personal communication) and Steward et al. (2018)

3.2 Socio-economic approach

The socio-economic model used in this study is a multi-market multi-commodity global model called the International Model for the Policy Analysis of Commodities and Trade (IMPACT). It uses outputs from crop and hydrology models in a partial equilibrium economic model to project future food production, consumption, and trade, along with food security (Robinson et al., 2015).

The same model was used by Gbegbelegbe et al. (n.d.) to project the impact of future severe droughts in southern Africa. Their results serve as a base for this study. More specifically, it uses their results on the bio-economic impact of droughts in southern Africa as a baseline to assess the potential impact of CA on food security in southern Africa under droughts. Projected droughts were randomly linked to countries using past data on drought occurrence across the region (Table 2). With projected future droughts, regional crop production and food security would be negatively affected, based on results from IMPACT. In some years, droughts could affect enough countries to have a strong negative regional effect on agricultural production. For example, in 2023, if both South Africa and Zimbabwe are both affected by drought, regional maize production would decrease by more than 20% and this would lead to an increase of 9% in the number of people at risk of hunger (Table 2). South Africa is the largest maize producer and exporter within the region. Future consecutive two-year droughts were also defined using past data on drought occurrence; here too, the impact of consecutive two-year droughts on food production and food security was estimated using IMPACT. With future consecutive two-year droughts, regional food security would worsen, given that most countries would experience an increase of more than 10% in the number of people at risk of hunger (Table 3).

The effect of conservation agriculture is modelled as an exogenous positive shock to maize yield in IMPACT for each drought year. The following year, maize yield is brought back to trend using the following equation:

$$TCAm_{cty,t+1} = \frac{1}{1 + CAYm_{cty,t}}$$

where:

> $TCAm_{cty,t+1}$ is the proportional rate for bringing maize yield back to trend for country, 'cty' in the year following the drought, '$t+1$'; and
>
> $CAYm_{cty,t}$ is the proportional maize yield gain from CA under drought for country 'cty' in drought year 't'.

Here, it is assumed that, in non-drought years, maize yield under CA is the same as that of conventional agriculture. Such assumption is unrealistic as it has been shown that in normal rainfall years, conventional agriculture can generate higher yields than CA (Michler et al., 2019). The study also assumes that CA only affects maize yields, when, in reality, the yields of other crops grown in rotation with maize could experience an increase. Such crops include soybean and pigeon pea (Naab et al., 2017).

Table 2: Projected impact of random droughts on agricultural production and food security in southern Africa

	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	'31	'32	'33	'34	'35
Angola		d	d													
Botswana	d	d			d		d	d				d		d		d
Lesotho		d	d				d	d	d		d	d			d	
Madagascar			d									d		d		d
Mozambique	d		d			d	d				d					
Malawi		d				d		d				d	d			
Namibia								d	d		d					
Eswatini	d					d		d	d	d		d				d
South Africa	d			d		d						d				d
Zambia							d	d								
Zimbabwe	d		d	d	d		d		d		d				d	
Regional change in production due to projected droughts (%) - 2020 to 2035																
Maize	-27	-14	-12	-23	-4	-33	-13	-14	-5	2	-8	-26	-8	3	-4	-15
Rice	-2	0	-6	2	1	-3	-3	1	2	2	-4	-1	2	0	3	0
Cassava	-8	-12	-20	-1	-1	-10	-7	-1	-1	0	-8	-1	-2	0	0	0
Soybean	4	0	1	5	3	14	5	3	6	4	2	9	3	5	4	7
Groundnut	-3	-3	-7	-6	-5	4	-1	0	-6	-2	-3	1	0	-1	-5	-2
Pigeon pea	2	-4	-1	0	-1	-5	-1	-8	-4	-1	-1	-6	-7	-3	-3	-1
Cotton	-8	0	-7	-19	-17	-1	-10	-1	-15	-3	-6	-8	0	-2	-13	-2
Tobacco	-5	0	-4	-16	-12	1	-12	-7	-12	-2	-3	-6	0	-1	-9	0
Impact of projected droughts on food security (% change in number of people at risk of hunger)																
Angola	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	26	38	57	20	0	32	38	58	76	0	19	39	0	0	19	0
Madagascar	6	0	5	4	0	7	0	0	0	0	0	6	0	5	0	5
Mozambique	15	1	13	12	0	19	23	0	0	0	12	12	0	0	0	0
Malawi	8	11	0	6	0	9	0	6	0	0	0	7	10	0	0	0
Namibia	15	0	0	12	0	20	0	14	27	0	15	19	0	0	0	0
Eswatini	12	0	0	9	0	15	0	9	18	27	0	12	0	0	0	10
South Africa	49	0	0	41	0	71	0	0	0	0	0	29	0	0	0	0
Zambia	5	0	1	4	0	7	8	12	0	0	0	5	0	0	0	0
Zimbabwe	20	0	15	29	41	24	29	0	16	0	16	21	0	0	17	0
Southern Afr.	10	2	6	9	4.1	12	9	4	2	0.2	4	8	1	1	1.4	1

d: Projected drought year; randomly allocated per country based on past drought occurrence; impact on food production and food security were estimated from IMPACT 3.2.
Source adapted from Gbegbelegbe et al. (under review)

Table 3: Projected impact of consecutive two-year droughts on agricultural production and food security in southern Africa

	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	'31	'32	'33	'34	'35
Angola			d					d								
Botswana	d	d	d				d	d				d		d		d
Lesotho		d	d				d	d	d		d	d			d	
Madagascar		d	d				d	d								
Mozambique		d	d				d	d			d					
Malawi		d	d				d	d				d	d			
Namibia		d	d					d								
Eswatini		d	d				d	d		d		d				d
South Africa		d	d				d	d								d
Zambia							d	d								
Zimbabwe		d	d	d	d		d	d			d				d	
Regional change in production due to projected droughts (%) - 2020 to 2035																
Maize	0	-38	-42	-5	-5	0	-42	-47	-1	-1	-9	-9	-9	1	-4	-16
Rice	0	-6	-6	1	1	1	-6	-6	1	1	-3	1	1	2	2	2
Cassava	0	-9	-21	-1	-1	-1	-8	-20	-1	-1	-9	-1	-2	0	0	0
Soybean	0	8	15	8	9	8	17	23	14	15	11	6	5	6	3	7
Groundnut	-1	0	-2	-6	-4	-1	1	-1	-4	-2	-3	0	0	-2	-5	-2
Pigeon pea	0	-5	-7	-3	-3	-1	-5	-7	-3	-3	-1	-6	-7	-3	-3	-1
Cotton	0	-9	-12	-18	-19	0	-9	-11	-3	-3	-6	0	0	-2	-13	-1
Tobacco	0	-6	-8	-13	-13	-1	-13	-14	-3	-2	-3	0	-1	-1	-10	0
Impact of projected droughts on food security (% change in number of people at risk of hunger)																
Angola	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lesotho	0	36	39	0	0	0	40	40	57	0	19	38	0	0	19	0
Madagascar	0	8	9	0	0	0	9	9	0	0	0	0	0	0	0	0
Mozambique	0	21	24	0	0	0	24	24	0	0	12	0	0	0	0	0
Malawi	0	10	12	0	0	0	12	12	0	0	0	5	11	0	0	0
Namibia	0	21	23	0	0	0	26	30	0	0	0	0	0	0	0	0
Eswatini	0	17	18	0	0	0	19	19	0	9	0	10	0	0	0	10
South Africa	0	69	78	0	0	0	92	95	0	0	0	0	0	0	0	0
Zambia	0	7	9	0	0	0	9	9	0	0	0	0	0	0	0	0
Zimbabwe	0	27	29	40	51	0	30	30	0	0	16	0	0	0	17	0
Southern Afr.	0	14	16	4	5.2	0	15	16	0	0.1	4	1	1	0	1.4	0

d: Projected drought year; two-year droughts allocated per country based on past drought occurrence; impact on food production and food security were estimated from IMPACT 3.2
Source: adapted from Gbegbelegbe et al. (under review)

4 IMPACT OF CONSERVATION AGRICULTURE ON MAIZE PRODUCTION AND FOOD SECURITY UNDER DROUGHTS

4.1 Impact of conservation agriculture under projected random droughts across southern Africa

With CA for maize, droughts would still negatively affect agricultural production in southern Africa. However, their impacts on maize production would be less severe than under CA (Figure 1a). Without CA, the largest reduction in maize production would occur in 2025, a year when three of the large maize producers (South Africa, Malawi and Mozambique) would experience a drought. In 2025, the projected regional maize production would be 33% lower with the droughts than in a scenario involving no droughts. However, with CA, the droughts would reduce regional maize production by 15% compared to a scenario involving no droughts (Figure 1a).

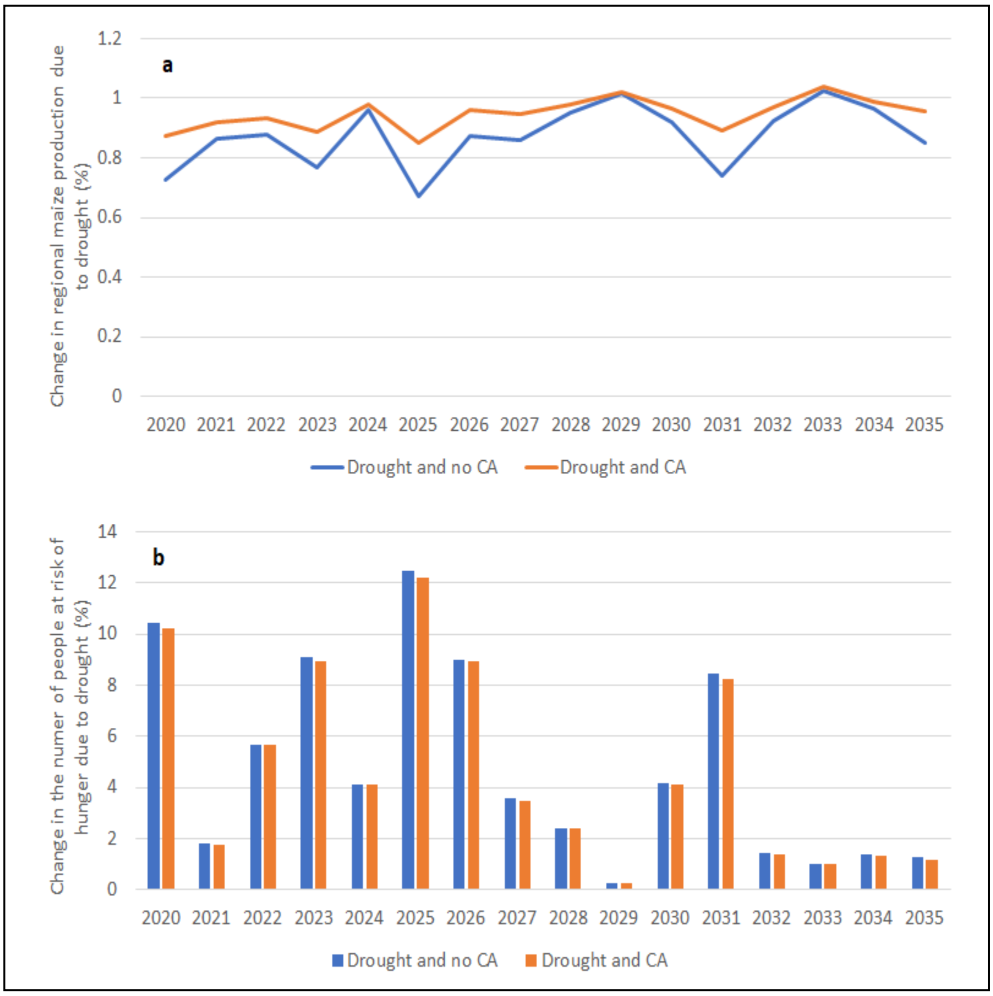


Figure 1: projected impact of conservation agriculture on maize production and food security under droughts in southern Africa

Source: Author's computations using simulated results from IMPACT

In the same year, the higher production of maize with conservation agriculture would be accompanied by a reduction in the production of all other crops, except rice (Table 4). For example, with CA applied to maize, droughts would reduce the production of rice, cassava, pigeon pea, and cotton by 3%, 10%, 13%, and 4% respectively (Table 4). Without CA, the reduction would be 3%, 10%, 5%, and 1% respectively (Table 2). These results suggest that, if the region was practising CA for maize and was hit by a severe regional drought, farmers would have an incentive to move resources like land away from pigeon pea and cotton towards maize. A similar conclusion applies for tobacco. Without CA, regional tobacco production would increase by 1% with a severe regional drought in 2025 (Table 2). However, with CA in the same year, regional tobacco production would decrease by 3% (Table 4).

Table 4: Projected impact of random droughts on agricultural production and food security in southern Africa under conservation agriculture

	'20	'21	'22	'23	'24	'25	'26	'27	'28	'29	'30	'31	'32	'33	'34	'35
Angola		d	d													
Botswana	d	d			d		d	d				D		d		d
Lesotho		d	d				d	d	d		d	D			d	
Madagascar			d									D		D		d
Mozambique	d		d			d	d				d					
Malawi		d				d		d				D	d			
Namibia								d	d		d					
Eswatini	d					d		d	d	d		D				d
South Africa	d			d		d						D				d
Zambia							d	d								
Zimbabwe	d		d	d	d		d		d		d				d	
Regional change in production due to projected droughts with CA for maize (%) - 2020 to 2035																
Maize	-13	-8	-7	-11	-2	-15	-4	-5	-2	2	-4	-11	-3	4	-1	-4
Rice	-2	0	-8	2	1	-3	-3	1	2	2	-4	-2	2	-2	3	-2
Cassava	-9	-13	-21	-1	-1	-10	-8	-2	0	0	-8	-2	-2	0	0	0
Soybean	3	0	1	4	3	12	5	3	6	4	2	7	3	5	4	5
Groundnut	-5	-5	-8	-7	-5	1	-3	-2	-6	-2	-5	-2	-1	-1	-5	-3
Pigeon pea	2	-12	0	1	0	-13	-1	-15	-2	-1	-1	-13	-13	-2	-2	0
Cotton	-12	-1	-10	-20	-18	-4	-14	-2	-16	-2	-10	-9	0	-1	-14	-2
Tobacco	-9	-2	-6	-16	-12	-3	-15	-8	-12	-1	-6	-8	-1	0	-10	-1
Impact of projected droughts on food security with CA for maize (% change in people at risk of hunger)																
Angola	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1
Lesotho	25	38	57	19	0	31	38	57	76	0	19	38	0	0	19	0
Madagascar	6	0	5	4	0	7	0	0	0	0	0	6	0	5	0	5
Mozambique	15	1	13	12	0	19	23	0	0	0	12	12	0	0	0	0
Malawi	7	11	0	5	0	9	0	5	0	0	0	7	10	0	0	0
Namibia	15	0	0	12	0	20	0	13	27	0	14	19	0	0	0	0
Eswatini	12	0	0	9	0	14	0	9	18	27	0	12	0	0	0	10
South Africa	48	0	0	40	0	70	0	0	0	0	0	28	0	0	0	0
Zambia	5	0	1	4	0	6	8	11	0	0	0	5	0	0	0	0
Zimbabwe	19	0	15	29	41	24	29	0	16	0	16	21	0	0	17	0
Southern Afr.	10	2	6	9	4.1	12	9	3	2	0.2	4	8	1	1	1.3	1

d: Projected drought year; randomly allocated per country based on past drought occurrence
Source: Author's computations using simulated results from IMPACT

This tendency of moving resources away from other crops to CA for maize under drought occurs not only with a severe regional drought but with milder regional droughts too. For example, in 2030, four countries would be affected by a severe drought; these countries (Lesotho, Mozambique, Namibia, and Zimbabwe) would account for 18% of regional maize production in 2030 in a scenario involving no drought. Drought in these countries would reduce regional maize production by 8%, if CA for maize was not practised (Table 2). With CA, regional maize production in 2030 would decrease by 4% under drought, compared to a scenario involving no drought and no CA (Table 4). With this less severe regional drought in 2030, resources would still be moved from other crops towards maize produced under CA. More specifically, resources would be moved away from all crops except pigeon pea and allocated to maize grown with CA.

The higher maize production brought by conservation agriculture should translate into enhanced food security in the region. The results show that conservation agriculture has a slight positive effect on regional food security (Figure 1b). Such results imply that with droughts, CA alone would not be able to increase maize production so as to substantially enhance food security.

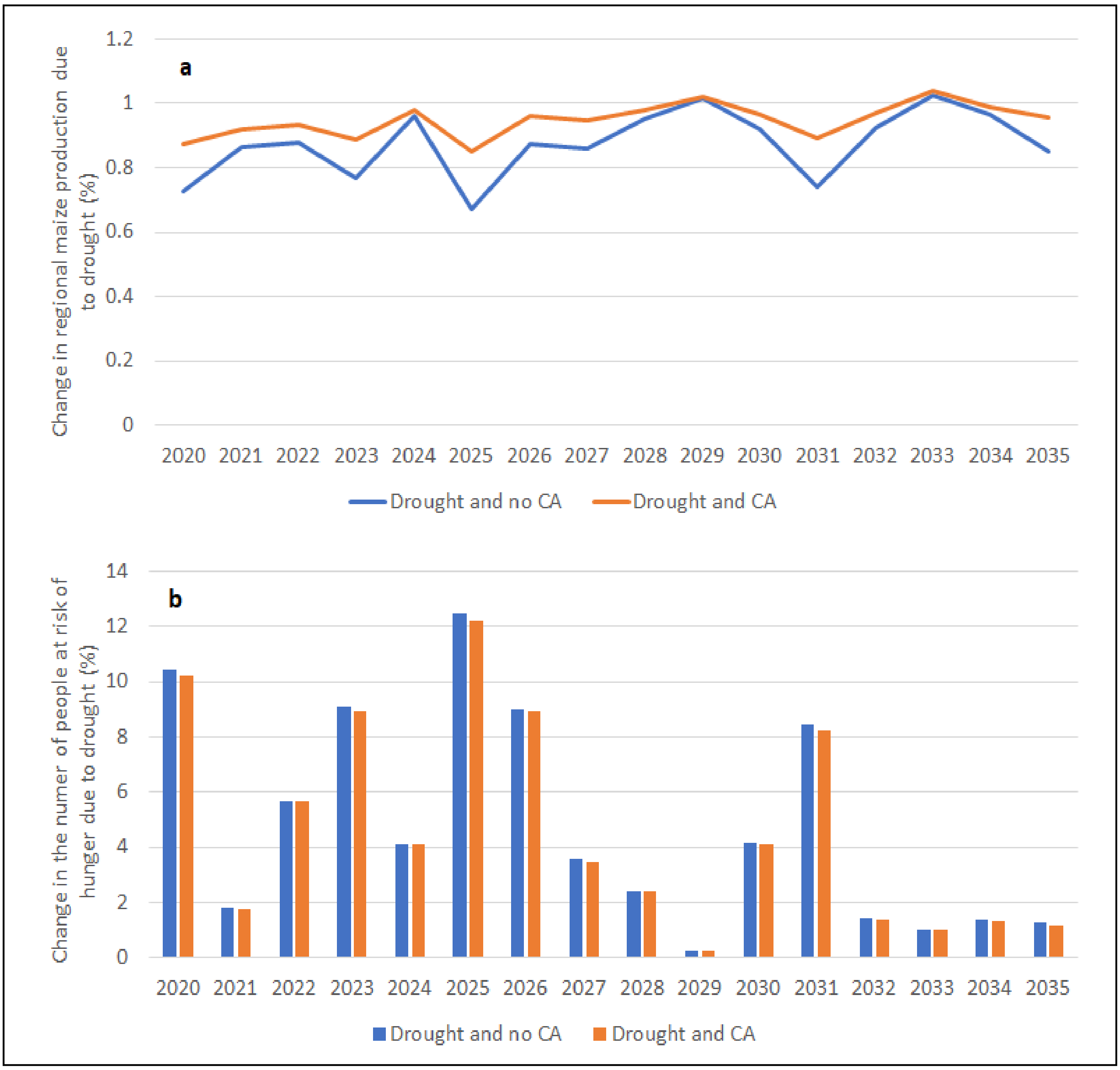
5 IMPACT OF CONSERVATION AGRICULTURE ON MAIZE PRODUCTION – PROJECTED CONSECUTIVE TWO-YEAR REGIONAL DROUGHT ACROSS SOUTHERN AFRICA

This section assesses the impact of CA for maize with projected consecutive two-year regional droughts. Here too, CA seems to have a strong positive impact on maize production under consecutive droughts. In the model, 2021 and 2022 would be years characterized by consecutive two-year regional droughts. Drought would affect all countries except Angola in 2021 and all countries in 2022. In a scenario without conservation agriculture, drought would reduce regional maize production by 38% and 42% in 2021 and 2022 respectively; this is compared to a scenario involving no drought. If conservation agriculture for maize was adopted in the region, the droughts in 2021 and 2022 would reduce regional maize production by 18% and 22% respectively (Figure 2a).

The higher regional maize production brought by CA would be accompanied by a reallocation of resources from other crops towards maize produced under CA. Such reallocation would come about through price changes which would affect farmers’ allocation of resources towards agricultural crops. This effect seems stronger with two-year consecutive regional droughts (Table 5) compared to a scenario which does not involve consecutive regional droughts (Table 3). With CA for maize, drought in 2022 would lead to a reduction of 7%, 22%, 6%, 13%, 16%, 13% in the production of rice, cassava, groundnut, pigeon pea, cotton and tobacco; for soybean, production would increase by 13% (Table 5). Without CA for maize, the reductions for rice, cassava, groundnut, pigeon pea, cotton and tobacco would be 6%, 21%, 2%, 7%, 12%, and 8% respectively; for soybean, the increase in production would be 15% (Table 3). A similar tendency would be observed for the simulated drought in 2021, where resources would be reallocated from all other crops towards maize produced under conservation agriculture.

The increased maize production brought by CA during consecutive regional two-year droughts seems to enhance food security (Figure 2b). The simulated second-year drought in 2022 would increase the number of people at risk of hunger by 16% in a scenario involving no CA (Table 3). If the simulated drought occurred in a scenario where the region had adopted CA for maize, the increase in the number of people at risk of hunger due to drought would be 15% (Table 5). Here too, it can be concluded that CA would lead to slight positive changes in food security, although these changes would be more pronounced with a consecutive two-year regional drought than a scenario which does not involve consecutive regional droughts. Again, such results imply that CA alone would not be enough to mitigate the negative impact of consecutive regional droughts on food security in southern Africa. Additional measures should be considered, including: adopting drought-tolerant crop varieties that do not yield penalty losses in years characterized by normal rainfall, diversifying consumer diets away from maize towards more drought-tolerant crops like cowpea and cassava, and rainwater harvesting.

Figure 2: projected impact of conservation agriculture on maize production and food security under



consecutive two-year regional droughts in southern Africa

Source: Author's computations using simulated results from IMPACT

Table 5: projected impact of consecutive two-year regional droughts on agricultural production and food security in southern Africa under conservation agriculture

	Projected occurrence of consecutive 2-year droughts in southern Africa															
	'20	**'21**	**'22**	**'23**	**'24**	**'25**	**'26**	**'27**	**'28**	**'29**	**'30**	**'31**	**'32**	**'33**	**'34**	**'35**
Angola			d					d								
Botswana	d	d	d				d	d				d		d		d
Lesotho		d	d				d	d	d		d	d			d	
Madagascar		d	d				d	d								
Mozambique		d	d				d	d			d					
Malawi		d	d				d	d				d	d			
Namibia		d	d					d								
Eswatini		d	d				d	d		d		d				d
South Africa		d	d				d	d								d
Zambia							d	d								
Zimbabwe		d	d	d	d		d	d			d				d	
Regional change in production due to projected droughts (%) - 2020 to 2035																
Maize	0	-18	-22	-2	-2	1	-20	-23	1	1	-5	-5	-5	2	-2	-6
Rice	0	-8	-7	1	1	1	-8	-8	2	2	-3	1	1	2	2	2
Cassava	0	-10	-22	-1	-1	0	-10	-22	-1	-1	-9	-2	-2	0	0	0
Soybean	0	6	13	8	9	8	15	21	14	15	11	6	5	6	3	6
Groundnut	-1	-5	-6	-6	-4	-1	-4	-7	-3	-2	-5	-2	-2	-2	-6	-3
Pigeon pea	0	-13	-13	-2	-1	0	-12	-13	-2	-1	-1	-14	-13	-2	-2	0
Cotton	0	-14	-16	-18	-20	0	-15	-16	-2	-2	-10	-1	-1	-1	-14	-1
Tobacco	0	-11	-13	-13	-13	0	-18	-19	-2	-1	-6	-1	-2	-1	-10	0
Impact of projected droughts on food security (% change in number of people at risk of hunger)																
Angola	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Botswana	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	0	0
Lesotho	0	35	38	0	0	0	39	39	57	0	19	38	0	0	19	0
Madagascar	0	8	9	0	0	0	9	9	0	0	0	0	0	0	0	0
Mozambique	0	21	24	0	0	0	23	24	0	0	12	0	0	0	0	0
Malawi	0	10	11	0	0	0	11	11	0	0	0	5	10	0	0	0
Namibia	0	21	23	0	0	0	26	30	0	0	0	0	0	0	0	0
Eswatini	0	16	18	0	0	0	18	18	0	9	0	10	0	0	0	10
South Africa	0	68	77	0	0	0	91	94	0	0	0	0	0	0	0	0
Zambia	0	7	8	0	0	0	8	8	0	0	0	0	0	0	0	0
Zimbabwe	0	26	29	40	51	0	30	30	0	0	16	0	0	0	17	0
Southern Afr.	0	14	15	4	5.2	0	15	15	0	0.1	4	1	1	0	1.4	0

d: Projected drought year; two-year droughts allocated per country based on past drought occurrence
Source: Author's computations using simulated results from IMPACT

6 DISCUSSION

This study uses an integrated modelling approach to assess the projected impact of CA on food security under drought in southern Africa. It shows that CA has the potential to increase maize production and enhance food security in southern Africa when the region is hit by droughts, including consecutive two-year droughts. However, CA alone would not be enough to mitigate the negative effects of droughts on food security. Additional measures would be required to achieve this. Such measures include the adoption of drought-tolerant crop varieties which do not yield penalty losses in years characterized by normal rainfall, a diversification of consumer diets away from maize towards more drought-tolerant crops like ***cowpea*** and cassava, rainwater harvesting; and social protection measures.

This study used results from Steward et al. (2018) to estimate the potential impact of CA on maize yields under drought conditions. Ideally, a gridded crop model should be used for this purpose. The model would be used to simulate the impact of CA on soil conditions and crop yields under a normal climate and under drought conditions. Given that previous studies have shown that CA yields no advantage over conventional agriculture under prolonged drought conditions (Steward et al., 2019), it could be that the estimates used in this study on the biophysical impact of CA are too optimistic. A gridded crop modelling approach similar to that used by Chung et al. (2014) should be used to estimate the rain and heat conditions associated with recent droughts in southern Africa and assess their biophysical impacts. In addition, this study assumes that only maize would be affected by CA. However, the literature shows that CA also affects the yields of other crops involved in rotation or intercropping (Naab et al., 2017) . Some of the crop rotation systems that could be tested for southern Africa include maize, in rotation with soybean, pigeon pea or cowpea. Further research would involve using a gridded crop model to quantify the biophysical impact of minimum tillage, soil cover and crop rotation in each country for southern Africa.

The economic model used in this study is well calibrated and validated (Gbegbelegbe et al., n.d.). However, this model, as a partial equilibrium model, cannot capture the net effect that CA would have on food security. Increased maize yields under droughts could translate into higher incomes for farmers and this could further enhance food security. Such effect is not captured in this study. Additional research would involve linking IMPACT with a computable general equilibrium model to capture the net effects of CA on incomes and food security.

7 CONCLUSIONS

This study aims to assess the potential impact of conservation agriculture on food security in southern Africa under drought conditions. The results suggest that conservation agriculture could increase regional maize production and slightly enhance regional food security even under consecutive two-year regional droughts. The results also suggest that additional measures would be required to fully mitigate the negative impact of conservation agriculture on regional food security.

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