20 Agricultural Land-Use Systems and Management Challenges

Reimund P. Rötter, Mandla Nkomo, Johannes Meyer zu Drewer, and Maik Veste

Abstract

This chapter aims at providing an overview of the diversity of agroecological conditions, features of main farming systems, agricultural land use, its dynamics and drivers during the last two decades as well as major threats in ten countries of southern Africa (SA10). Based on this, we attempt to identify the resultant challenges for sustainable land management and outline potential interventions with a focus on smallholder farmers. By analyzing cropland dynamics during 2000–2019, we show how land use has been shaped by climate, demographic development, economic imperatives and policy realities. Concrete examples of these complex interactions illustrate both considerable shrinkage in South Africa and Zimbabwe or expansion of cropland in Mozambique and Zambia.

R. P. Rötter (✉)
Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), and Centre of Biodiversity and Sustaianble Land Use (CBL)
e-mail: reimund.roetter@uni-goettingen.de

M. Nkomo
Solidaridad Southern Africa, Johannesburg, South Africa

CGIAR Excellence in Agronomy 2030 Initiative, IITA, Kasarani, Nairobi, Kenya
e-mail: M.Nkomo@cgiar.org

J. M. zu Drewer
Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), University of Göttingen, Göttingen, Germany

Ithaka Institute for Carbon Strategies, Arbaz, Switzerland
e-mail: mzd@ithaka-institut.org

M. Veste
CEBra – Centrum für Energietechnologie Brandenburg e.V., Cottbus, Germany
e-mail: veste@cebra-cottbus.de; maik.veste@b-tu.de

G. P. von Maltitz et al. (eds.), *Sustainability of Southern African Ecosystems under Global Change*, Ecological Studies 248,
https://doi.org/10.1007/978-3-031-10948-5_20

During the past 20 years, cropland increased by 37% on average across SA10 mainly at the expense of forestland—showing huge spatiotemporal heterogeneity among countries. Most smallholders face shrinking farm size and other resource limitations that have resulted in soil nutrient mining and low agricultural productivity—a highly unsustainable situation. We conclude with an outlook on potential transformation pathways ("TechnoGarden" and "AdaptiveMosaic") for the near future and thereby provide a frame for further studies on sustainable land management options under given local settings.

20.1 Overview of Agricultural Land-Use and Related Management Challenges

20.1.1 Introduction

Agricultural land use and management in southern Africa has always followed a pathway driven and shaped by climate and its variability, policy realities, economic imperatives and demographic development. The data gathered on land under production and agricultural productivity in the last two decades seems to confirm these realities. There is also huge variation regarding the dependence of livelihoods and the economic importance of the agricultural sector among the various countries in southern Africa. Although the Republic of South Africa's economy is not as dependent on agriculture (sector contributes less than 3% to GDP), in value and volume terms, *South Africa* has the largest agricultural economy in the region and therefore provides a good case study of a postagrarian economy, that, however, still depends to some extent on its agricultural sector. In the rest of the Southern African Development Community (SADC), agriculture's role in the economy is much more pronounced, contributing to the bulk of employment for citizens (on average 70%), as well as being a major contributor to GDP (on average 25%). Prominent agricultural economies in the region, such as *Zambia, Zimbabwe* and *Mozambique,* provide good, but different examples of the complex combination of factors that continue to influence land use and management within the agricultural sector in developing, largely agrarian-based economies. Whereas Zambia and Mozambique have been investing in agricultural development, in different ways and for different reasons, and have seen expansion of agricultural land use during the last one to two decades, Zimbabwe has paid much less attention to agricultural development and seen reductions in agriculturally used land.

Other countries considered here for an overall analysis of the agroecological conditions and agricultural developments of southern Africa are *Angola, Botswana, Eswatini, Lesotho, Malawi* and *Namibia.* Cutoff points, i.e., not included were the Democratic Republic of the Congo and Tanzania, commonly perceived as belonging to central, respective eastern Africa. Due to its geographical particularities, also Madagascar is not included in the analysis. Mainland southern Africa represents one interconnected agroecological region with often common, but distinct socioeconomic characteristics and varied biophysical constraints in terms of water availability and soil conditions across this geographical region. For easier reference, from here the *10 countries of southern Africa* listed above will be referred to as *SA10*.

The objectives of this chapter are:

1. To introduce agroecological features, agricultural land use and recent land-use dynamics in southern Africa (SA10).
2. To describe major farming systems including current production levels, resource use and constraints.
3. To present global change threats and discuss the quest for sustainable intensification and key constraints to achieving this.
4. To identify promising options that respond to key management challenges and sketch alternative future agricultural transformation pathways.

20.1.2 The Agroecological Conditions of Southern Africa

According to the original agroecological zone (AEZ) definition by FAO, an AEZ is mainly defined by its temperature regime and moisture availability conditions. Temperature regime is characterized by temperature belts with specific ranges chosen for mean, minima and maxima to coincide with temperature thresholds demarcating thermal suitabilities for major crops, whereas moisture availability is at first level characterized by the ratio of annual precipitation to potential evapotranspiration (expressed as aridity or humidity index) (see Fig. 20.1) (Fischer et al. 2012). There is a very strong gradient in annual rainfall spanning from well above 1500 mm in the northeastern parts of the southern African region to less than 50 mm along the Namibian coast (Hijmans et al. 2005) (Figs. 20.2 and 20.4). Rainfall seasonality and associated atmospheric circulation processes are other important factors for agriculture (Richard et al. 2001). Overall, most areas in southern Africa receive predominantly convective rainfall from October to March or all-season rainfall. On the contrary, the important agricultural region of the southwestern Cape receives predominantly frontal winter rainfall from April to September, driven by westerly derived mid-latitude cyclones. In South Africa a transition zone receives rainfall from both summer and winter rainfall systems along the southern coast. Characteristic "Walter-climate diagrams" illustrate rainfall seasonality in the different "eco-climatic zones" (Fig. 20.2).

An important additional characteristic of AEZs is the length of the growing period (LGP) expressed in days during which (on average) moisture availability conditions are considered "agrohumid," that is, with sufficient water supply to allow crop growth. For detailed agricultural and farm management planning at local scales, different authors (e.g., Jätzold and Kutsch 1982) have introduced the consideration of rainfall seasonality and the probability of rainfall received per growing season instead of only using mean values, for specifying the LGP. These authors also emphasized the role of soil conditions, especially soil depth and soil

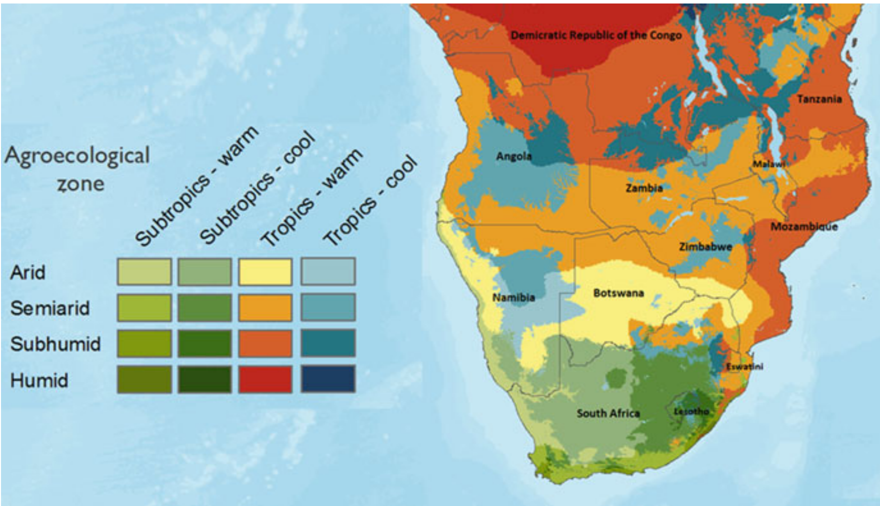

Fig. 20.1 Agroecological zones of southern Africa (AEZ16 System) [*Adapted from* Kate (2009). Permission to use granted as per open access status under creative common license: Attribution 4.0 International (CC BY 4.0)]

water retention to accurately describe the potential of AEZs including LGP. Since the 1970s, there have been numerous local to global AEZ classification systems (see Rötter et al. 2016). Most used is the Global Agroecological Zones (GAEZ) as defined by IIASA (Fischer et al. 2012). In Fig. 20.1, we present the main AEZs of southern Africa as compiled in the version of IFPRI (Kate 2009). We find that in most of the 10 countries (SA10) considered in our analysis the tropical warm, semiarid (dry savanna) zone is prevalent, followed by: the semiarid to semihumid tropical highland climates of Angola, Malawi, Namibia, South Africa, Zambia and Zimbabwe; the arid to subhumid subtopics of Namibia, South Africa and Lesotho, and the arid tropical warm zone covering large parts of Botswana and Namibia, and finally, the humid tropical lowland zone that is mainly found in Mozambique. Most of these zones except for the arid ones have a moderate to high agricultural potential. This is reflected clearly in the LGP map (Fig. 20.3), where LGPs with durations of less than 60 days are restricted to the arid zones of Botswana, Namibia and South Africa—with the marginal agricultural zones (LGPs from 60–119 days) wrapped around these (in pink).

Another serious constraint to agriculture is the fairly high variability of rainfall, both interannual/-seasonal and intraseasonal (e.g., Davis-Reddy and Vincent 2017). A detailed account of current and recent past climate variability is given in Chap. 5. The bad news is that ongoing climate change has already amplified the severity of weather phenomena causing high rainfall variability, such as El Nino Southern Oscillation (ENSO). Especially the strong El Nino events have led to extended drought and also yield loss (Verschuur et al. 2021). Figure 20.4 shows the long-term annual precipitation pattern averaged over the 118 years period (1901–2018),

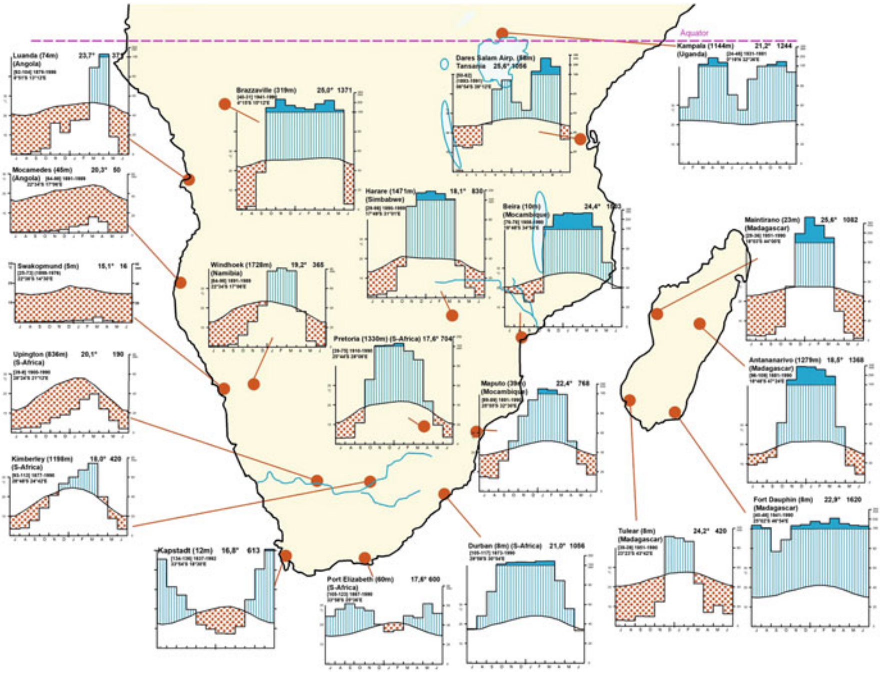

Fig. 20.2 Climate diagrams after Heinrich Walter showing different climate types and seasonal precipitation patterns in southern Africa [*Adapted from* Breckle and Rafiqpoor (2019). Permission to use granted as per written communication by S.W. Breckle (Author), 2022]

and Fig. 20.5 illustrates the difference between cumulative seasonal precipitation (in mm) over the months November to February (i.e., the main rainy season in most of our target region) averaged over the 30 year period 1981–2010 (Fig. 20.5a, *left*) *vis a vis* the cumulative precipitation averaged only over the years with strong El Nino events (Fig 20.5b, *right*). In strong El Nino years the area with low to very low rainfall (<150 mm) is considerably extended (especially in Namibia, South Africa and Botswana) compared to average conditions, and, on the other hand, the area with high to very high rainfall (>950 mm) is also expanded—in particular in Zambia (Fig. 20.5).

As for soil conditions (see Figs. 20.6 and 20.7), the region shows a very complex pattern due to the high spatial heterogeneity of the major soil building and forming factors and processes such as geology, including tectonic stability (factor time), topography, hydrological conditions, vegetation types and cultivation history (Sikora et al. 2020) next to the factor climate. Among the most predominant soil groups, we find the deeply weathered Ferralsols from the old land surfaces from Angola and Zambia, constituting low natural fertility mainly due to poor soil chemical properties. Also quite prevalent are the Arenosols poor in water holding capacity and low in nutrients, stretching from Angola in the north via Namibia

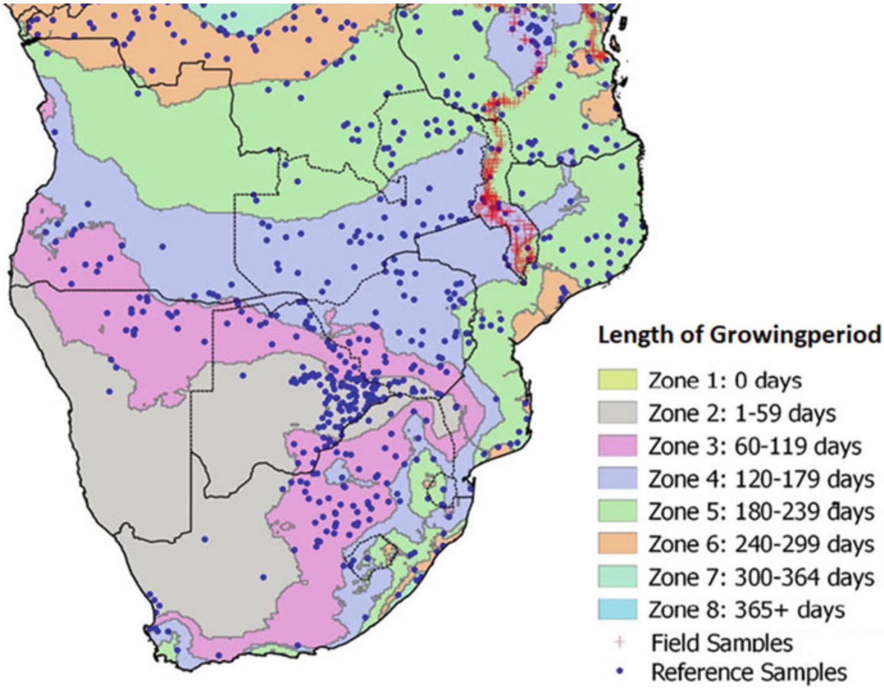

Fig. 20.3 The length of growing period in southern Africa [*Adapted from* Xiong et al. (2017). Permission to use granted as per open access status under creative common license: Attribution Non-Commercial, No Derivatives 4.0 International (CC BY-NC-ND 4.0)]

and Botswana further south to the northern tips of South Africa. Widespread are the fairly fertile Cambisols of Zimbabwe and South Africa, and the Phaeozems of northern Mozambique, South Africa and central Zimbabwe.

Leptosols show a broad band that mainly stretches from the arid zones of Namibia to South Africa. The spatial pattern of selected soil properties is shown in Fig. 20.7 extracted from the high resolution iSDA digital soil map shows (from left to right): total soil carbon, extractable P and total soil N. A more detailed overview of soil conditions and soil fertility issues in the region is provided by Vlek et al. (2020).

20.1.3 Major Farming Systems in Southern Africa: Their Characteristics and Dynamics

The agroecological conditions along with the influence of socioeconomic factors such as market access generate a distinct geographical pattern of generic farming systems (see Fig. 20.8). Dominating in terms of land use is the group of maize-based cropping systems, widespread in the northern and eastern realms of southern Africa,

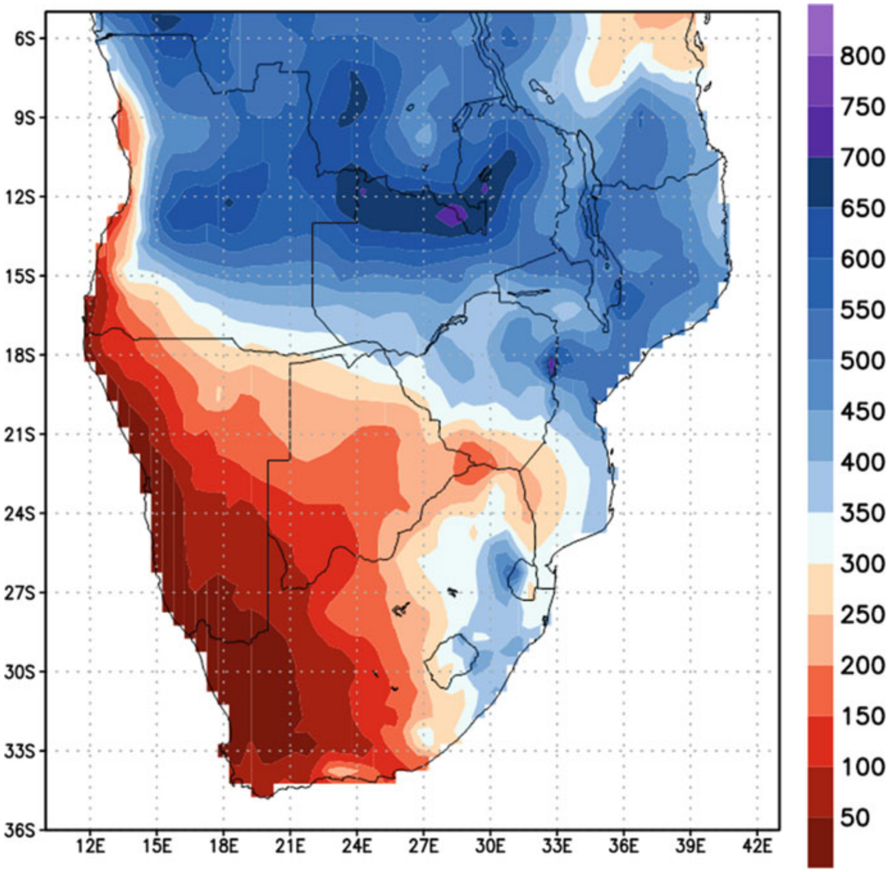

Fig. 20.4 Annual precipitation (mm) in southern Africa (1901–2019) [*Data: Climatology CRU TS4 (1901–2019) (extraction and mapping by NRC Ferreira, TROPAGS/University of Göttingen)*]

and a pocket of agroecological suitability stretching south through Zimbabwe and South Africa. Maize-mixed farming systems represent the livelihood basis for 100 million rural people in Sub-Saharan Africa (Auricht et al. 2014). The central and western parts of southern Africa, experiencing a semiarid to arid climate, are dominated by agropastoral systems, with Namibia and central South Africa being able to only sustain pastoralism on a large scale. Only the eastern coast and Western Cape region of South Africa, as well as the state of Eswatini, can naturally sustain perennial cropping systems on a large scale.

To a large extent, these cropping systems rely on rainfed water exclusively, with irrigation being common only in some limited areas. Future climate projections point toward reduced rainfall and increased variability for most of southern Africa, with severe reductions in the already marginal, western part (Nhemachena et al. 2020) (Fig. 20.9).

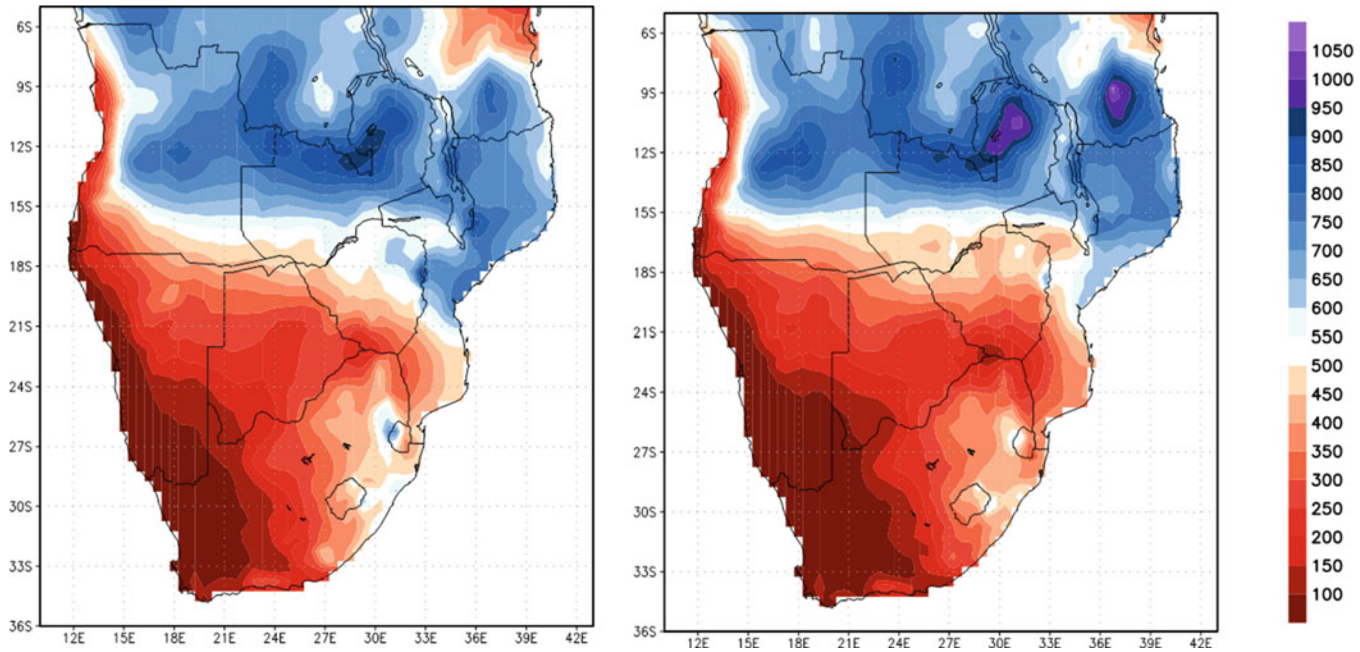

Fig. 20.5 Cumulative, seasonal precipitation in southern Africa (November–February) *(own analyses by NRC Ferreira, TROPAGS/University of Göttingen).* The left panel indicates baseline conditions, considering all years from 1981–2010. The right panel considers only years with strong El Niño occurrence [*Data source: Climatology CRU TS4 (1981–2010)*]

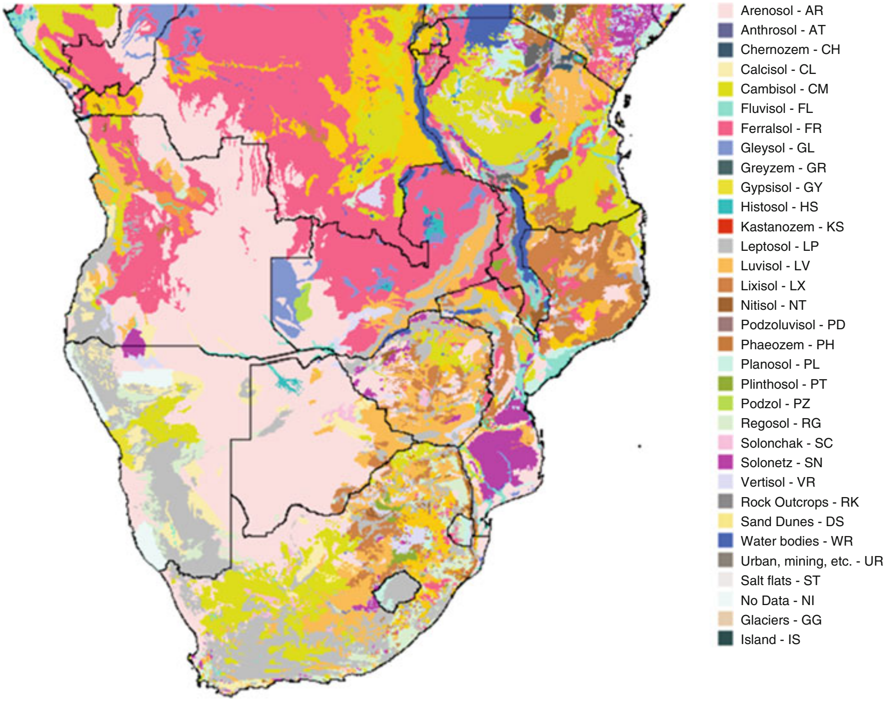

Fig. 20.6 FAO classification of southern African soils [*Adapted from* Fischer et al. (2008). Permission to use granted by written communication with FAO-GSP secretariat, chief publication branch, 2022]

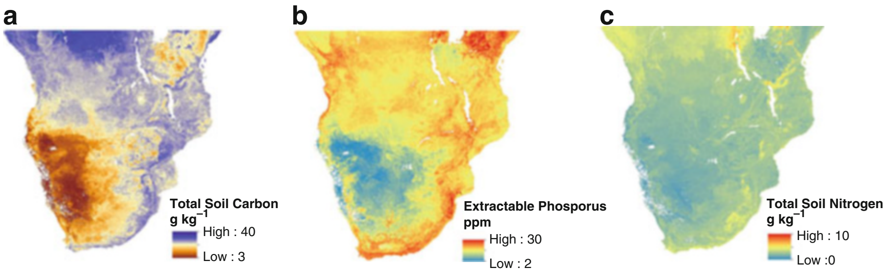

Fig. 20.7 Key soil characteristics in southern Africa, indicating total soil carbon (**a**), extractable phosphorus (**b**) and total soil nitrogen (**c**) [*Adapted from* iSDA Africa (2021). Permission to use granted as per open access status of iSDA database, attribution is given, and the original authors were notified]

These projections of a diminishing resource basis are alarming. That is, in first place, water resources for agriculture (Meza et al. 2021; Chap. 22 on macadamia) and fertile soils (Vlek et al. 2020). Especially improved water management and adaptation measures to drought and rainfall variability become imperative if the

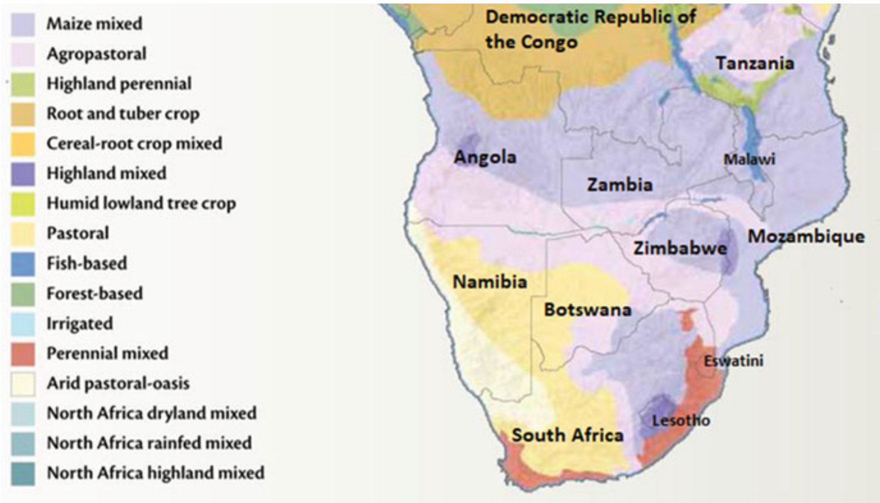

Fig. 20.8 Major farming systems of southern Africa [*Adapted from* Auricht et al. (2014). Permission to use granted as per open access status of IFPRI publication, attribution is given, and the original authors were notified]

region is to sustain agriculture in the future (see Chap. 5 on hydroclimate, Chap. 22 on macadamia and Chap. 23 on the potential of agricultural technologies).

Besides climate change, the other factor exerting considerable pressure on the natural resource quality and environment is the continuous expansion of agricultural land. In just two decades, from 2000 to 2019, the cropland in southern Africa has expanded by 37% to a total of 28 million ha in 2019 (see Fig. 20.10). While maize has clearly remained to be the dominating crop, novel industrial crops such as soybean have emerged rapidly and found their place within the major cropping systems (FAOstat 2021). Climate change and population growth and increasing food demand are directly mirrored in a shift and expansion of agricultural production, provoking conflicts with other land-use objectives (conservation, forestry). In the last decades, an unsustainable trend of deforestation has emerged. Drastic deforestation is observed in the Miombo woodlands across southern Africa where strong agricultural expansion and charcoal production are the major drivers of land-use changes (Ribeiro et al. 2020).

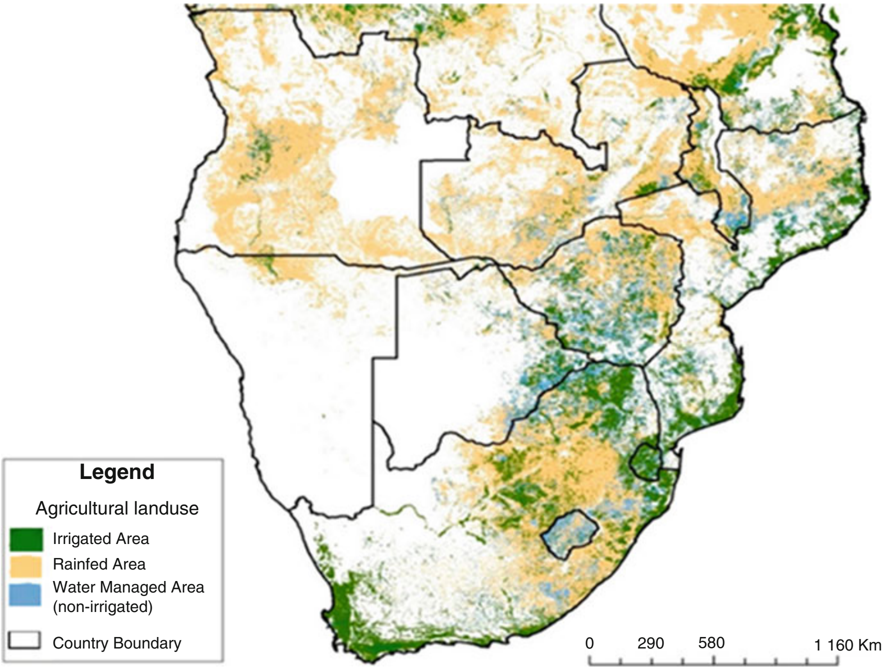

Fig. 20.9 Agricultural land-use patterns by type of water source [A*dopted from* Nhemachena et al. (2020). Permission to use granted as per open access status under creative common license: Attribution 4.0 International (CC BY 4.0)]

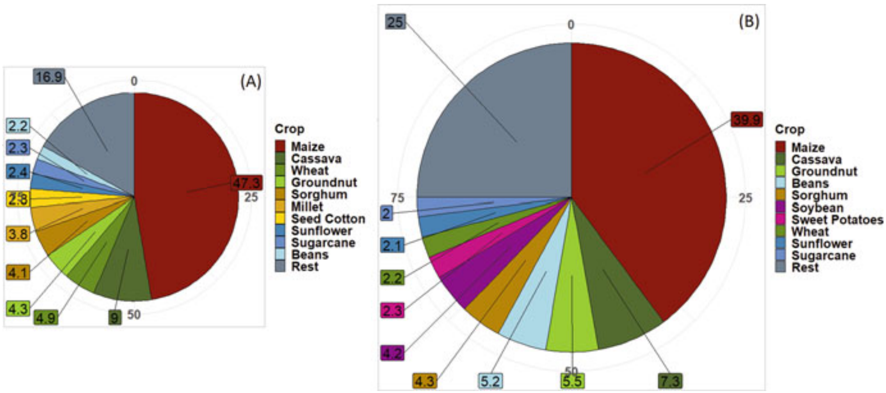

Fig. 20.10 Cropland composition and expansion in southern Africa (SA10) 2000–2019. (**a**) Composition of cropland in SA10 in 2000 (20 million ha). (**b**) Composition of cropland in SA10 in 2019 (28 million ha) [own analyses, J Meyer-zu-Drewer, based on *FAOstat* (*2021*)]

20.2 Selected Case Country Studies Illustrating Land-Use Dynamics and Its Drivers

In the following we have chosen four contrasting examples and country cases illustrating shrinkage (South Africa and Zimbabwe) as well as expansion (Zambia and Mozambique) of cropland for the period 2000–2019 and the different causes that led to such developments.

20.2.1 South Africa

Based on official national data and FAO estimates on the major 31 cropping systems, a decline of 22% of cropland has been observed in South Africa between 2000 and 2019 (FAOstat 2021). This change points toward the development of a partly postagrarian community. Remarkable is an observed increase of +679% in cropland dedicated to the production of soybean, which comes at the expense of o.a. maize (−43%) and wheat (−42%) production area. Further dominating crops include sunflower and sugarcane. The land-use patterns within South Africa between 2000 and 2019 are indicative of a number of factors that the country has been influenced and impacted by during the last two decades (Fig. 20.11).

Climate Factors

South Africa being largely a country with limited water resources has limited options for irrigation. Rainfed agriculture prevails with reliable crop production typically found in the higher rainfall areas (Eastern Cape, KwaZulu Natal, Free State, Mpumalanga, parts of the North West and Limpopo). In recent years, the likelihood of severe droughts has been increasing for the arable lands (Conway et al. 2015). The drier regions of the country are largely put to livestock production and wildlife farming, and high value crops under intensive irrigation in areas where infrastructure and water resources have been available. Due to the limited availability of irrigation water, one of the major areas of conflict in those areas in the period under review is related to the allocation and use of water rights for agricultural purposes. In both rainfed crop and rangeland-based livestock farming, trends indicate that the last two decades have been about increasing crop yields from less and less land, and increasing the productivity of the rangelands for livestock production. In the Western Cape, traditionally the wheat production area, successive poor seasons have led to a constant reduction in land under production, especially since most production subsidies from the wheat board fell away in 1996. The region is highly dependent on sufficient winter rainfall. The last multiyear droughts of 2015–2018 have led to drastic crop losses in the Western Cape region, likely to be exacerbated under future climate change (Theron et al. 2021).

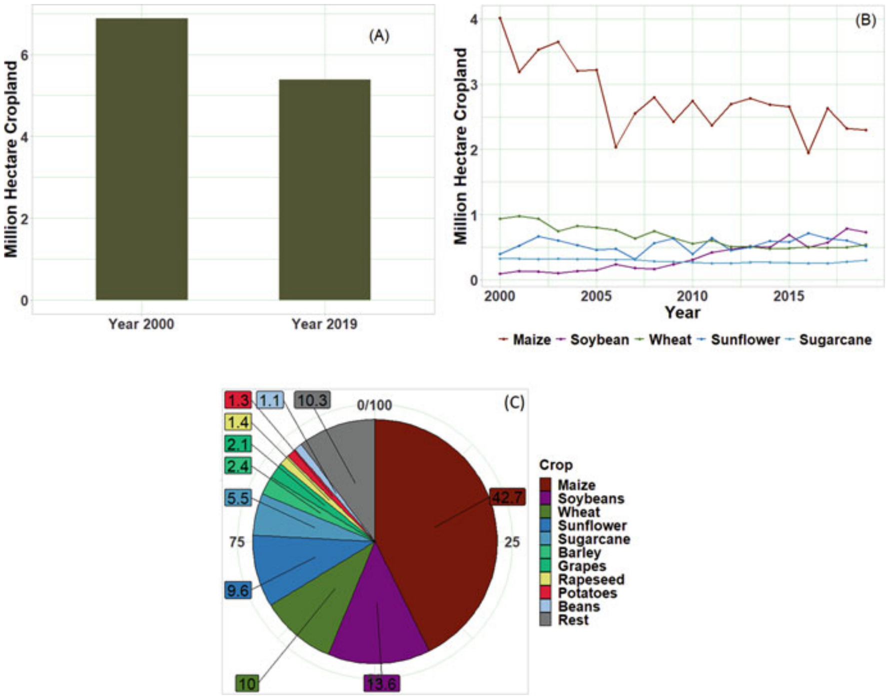

Fig. 20.11 Cropland dynamics: South Africa. (**a**) Total cropland area as of 2000 and 2019 in million hectares. (**b**) Area dynamics of five dominating cropping systems (2000–2019) in million hectares. (**c**) Composition of cropland as of 2019 [*FAOstat* (*2021*)]

Policy and Institutional Factors

The trend-line on land use for agriculture points to a steady decline in land use for agricultural purposes during 2000–2019, which to a large extent has been influenced by fundamental agropolicy changes that preceded the 2000s. The main influence has come from deregulation, land reform, land redistribution and changes in the agricultural finance and insurance environment. Prior to 1996, South Africa's agriculture was managed through the activities of statutory commodity boards, which were constituted under the Marketing Act 1968 to oversee the agricultural activities of various commodities such as the Wheat Board, the Maize Board, the Wool Board, etc. Their functions were to regulate the production and marketing of various commodities, by ensuring access to inputs, mechanization and favorable pricing through single market channels. For that reason from the 1930s up to the late 1980s, there was rapid expansion of land use for agricultural production. When the Marketing Act was replaced by the Marketing of Agricultural Products Act No 47 in 1996, the price protection afforded to farmers fell away, and only the market could determine price. As a result, marginal producers left the various sectors, as they could not compete, and the producers in favorable agroclimatic zones improved their productivity. Access to improved technology such as GMO maize also contributed to rapid yield increases in maize, albeit with reduced hectares. The Commodity Boards were converted into trusts with a narrower role of administering statutory commodity based levies, which in turn were mainly used to fund industry functions and board activities relating to information, grading, quality standards, training and inspection services for local producers. This policy change had the biggest impact on land-use patterns for agriculture in South Africa.

The other factor, land reform and restitution, resulted in the transfer of previously white controlled agricultural land to black occupants. This transfer of land did not come with the necessary transfer of skills and resources that the previous administration had invested in sustaining agriculture by marginal producers. The result has been a further reduction in land under production, which has been to a large part been offset by the increased productivity of the commercial farming sector in terms of yield. Further reduction was due to the reorganization of the former Homeland/Bantustans agricultural systems and the defunding of agriculture leading to the collapse of production in large parts of these areas. Nick Vink from the Department of Agricultural, University of Stellenbosch makes a key point that state-driven farmer assistance grew to a peak of 25% of all agricultural income in 1984, and although steadily decreasing thereafter, remained at about 20% up to commencement of democracy (1990/1991) (personal communication). Thereafter we saw a steep decline. With the safety net removed, less land was made available for production. An additional factor that impacted the grain production areas in the last decade has been the virtual collapse of the multiperil insurance system in South Africa. Successive poor seasons have made insuring crops such as maize and wheat unviable for the insurance industry and the multiperil insurance product was largely withdrawn from the market.

Economic and Demographic Factors

The economic and demographic impact on land use for agriculture in the review period, was driven by the rapid economic growth in the late 1990s and early 2000s which saw GDP growth of about 5% on average, and a massive postdemocracy increase in the middle class from 1.7 million individuals in 2004, to over 4.2 million individuals by 2012. The sheer spending power within this group grew the poultry industry (i.e., the largest part of the SA agricultural complex by revenue at over 15% of gross value generated by the agricultural sector) so much that South Africa currently needs to import up to 30% of its poultry feed requirements annually. This is because poultry demand has grown faster than supply, pushing consumption of maize and soy for feed, and resulting in imports to close the gap. Per capita poultry consumption between 2000 and 2017 has increased from 18.5 kg to 40.0 kg per capita. Since poultry relies on maize and soybeans, these grain sectors have shown massive increase in productivity (maize) and increase in plantings (soybean) in response to greater local demand.

20.2.2 Zimbabwe

Considering official FAO data on 71 dominant cropping systems in Zimbabwe, a decrease of −19% in total cropland was identified. A decrease can be observed both in staple crops such as maize (−36%), and commercial crops such as seed-cotton (−45%).

Climate Factors
Zimbabwe has experienced increasingly erratic rains over the past two decades and has been impacted by the El Nino phenomena seemingly more than neighboring countries (Setimela et al. 2018). The rainfall pattern is a major factor in influencing land use for rain-fed crops, livestock and irrigated crops. The variability between seasons and periods in land put under crop production has largely tracked rainfall amount and its variability. Extremely dry seasons recently, such as 2015/2016 and 2019 have led to drops in the area planted to maize—the main staple crop in Zimbabwe. Wheat is exclusively produced under irrigation and the variability in production has been linked to availability of irrigation water, and stability of electricity supply. Zimbabwe's primary source of power is hydroelectric generation from the Kariba dam. Successive drought has resulted in reduced inflows into the dam, and this has ultimately rendered the hydroelectric scheme inoperable due to low water levels. In turn, power supply has been erratic in the last decade, with load shedding reaching 18 h of planned power outages per day. Wheat production under irrigation was near impossible under these conditions. However, when considering the area put under cash crops such as tobacco and soybeans (Fig. 20.12), counterintuitively, the production of these cash crops was not subject to this distortion. After a land reform inspired collapse in the early 2000s, tobacco production has shown a rapid upward trend (Government of Zimbabwe 2018) driven largely by the financial incentive the crop offers to all sizes of producers where the producer price is in US dollars. A crop like soybean has stabilized due to the economic importance of the crop especially to the livestock sector in Zimbabwe. The reason, therefore, lies in a combination of policy and economic factors.

Policy Factors
The Zimbabwean agropolicy environment in the last two decades, after climate, has had the largest influence on agricultural land-use patterns in Zimbabwe (e.g., ZAIP 2013). The major policy was the start in 2000 of the Fast-Track land reform process that summarily stopped production in most acquired farms, as well as disruption to the agro inputs sector. The impact was a drop in area planted in the first few years of land reform, although there was a recovery midway into the first decade (2000–2010). In addition to land acquisition and transfer, state policies related to marketing of agricultural produce, in particular maize and wheat, created a disincentive to produce the crops, as government controlled prices were lower than regional benchmarks, and were paid in an unstable and failing local currency. Maize and wheat's loss seemed to have been tobacco and soybean's gain. These crops were

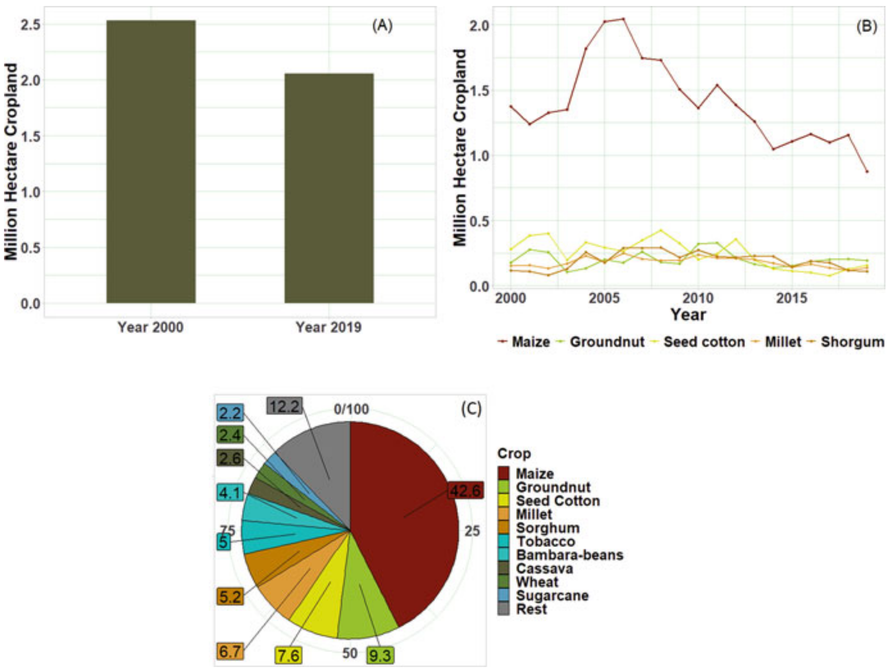

Fig. 20.12 Cropland dynamics: Zimbabwe. (**a**) Total cropland area as of 2000 and 2019 in million hectares. (**b**) Area dynamics of five dominating cropping systems (2000–2019) in million hectares. (**c**) Composition of cropland as of 2019 [*FAOstat* (*2021*)]

governed by a free market pricing regime and could be sold in foreign currency, and farmers could realize real value and returns. The explosive growth in tobacco and soybean is a reflection of the policy impacts of how they are marketed in Zimbabwe. The high growth in tobacco has come at the expense of the environment, due to the use of greenwood as the fuel source for curing the tobacco. The environmental damage associated with tobacco, will in the future become an existential challenge in the high rainfall areas of the country (Tatenda 2019).

Economic and Demographic Factors

Zimbabwe's economy has generally experienced erratic growth from the mid-1960s as a result of armed conflict and postindependence economic management issues. Agriculture has been a stabilizing factor since it impacts the majority of the population. However, a mismanaged post-2000 land reform pushed even this sector over the brink, with additional negative impacts by frequent droughts. In a country where 70% of the population derive their livelihood from agriculture, 20% of the GDP, 40% of all exports and 60% of manufacturing raw materials come from agriculture, economics and land use are intricately connected.

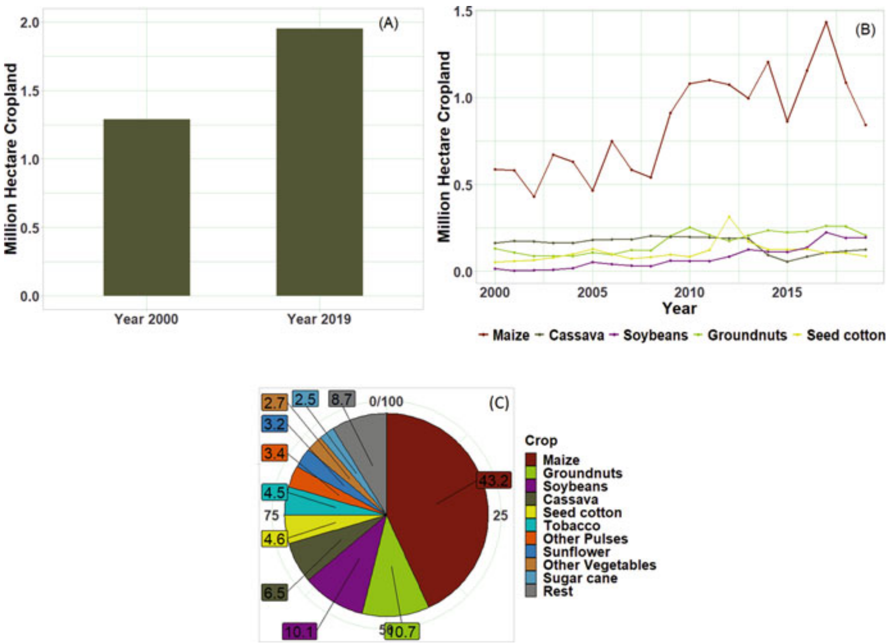

Fig. 20.13 Cropland dynamics: Zambia. (**a**) Total cropland area as of 2000 and 2019 in million hectares. (**b**) Area dynamics of five dominating cropping systems (2000–2019) in million hectares. (**c**) Composition of cropland as of 2019 [*FAOstat* (*2021*)]

20.2.3 Zambia

Considering the 28 dominating crops, an increase of cropland by 51% was observed, totaling 1.9 million ha in 2019 (FAOstat 2021). While the traditional crops maize and groundnut are still dominating, a strong development toward industrial and export-oriented crops can be observed. The soybean production area experienced a growth of +1083% since 2000, turning it into the top 3 crops (Fig. 20.13).

Climate Factors

Zambia's tropical climate and low population density are advantages that the agricultural sector has benefitted from. The country's agroclimatic conditions have remained favorable for crop production in most cultivation areas in the last two decades, and that has created a level of predictability within the agricultural sector. The main crop production areas of Central, Eastern and Southern Provinces lie along the fertile belt of so called agroecological zones I and IIa which combine high rainfall and good soils for crop production.

Policy Factors

The biggest impact on Zambia's agricultural production and land use has been the government policy of farmer input support program (FISP) which for over two decades has ensured that the government subsidizes inputs for farmers, thereby ensuring that any farmer who wants to grow crops has all the requisites. Additional policy stability with regards to maize pricing and trade has contributed to growing confidence in crop production. Further evidence of this has been farmers' reaction to unfavorable contracts in cash crops like cotton, which saw a rapid market based response as farmers turned to more profitable crops. Zambia has therefore seen a rapid increase in land use for agricultural production as a direct consequence of progressive agricultural policies.

Economic and Demographic Factors

Traditionally, the Zambian economy depends on mineral commodity prices; however, food security has always depended on the country's ability to maintain good agricultural production.

The longest run of agricultural surpluses (ReNAPRI 2014) ensured there is a safety net for the population and created opportunities for economic participation by the greater part of the citizens. The economic stability has created a growing middle class and increase in demand for agro-based commodities. According to the Global Yield Gap Atlas (www.yieldgap.org/zambia), Zambia's average yield for maize has averaged 1.1 million t ha^{-1}, against an achieved average 6.5 million t ha^{-1} in the much drier South Africa. Considering these current yields, there is still a long way for Zambia to achieve high productivity. Growth in agriculture, that has driven rising incomes and rapid urbanization has also created unintended consequences in that there is a serious energy deficit that has created unsustainable wood harvesting for of charcoal for energy. The Centre for Forestry Research (CIFOR) estimates that 30,000 ha of forest cover are lost annually (Day et al. 2014) The main drivers for forest cover loss are listed as agricultural expansion, urban infrastructure development, wood extraction (e.g., for charcoal and wood fuel) and uncontrolled fires. The impact of this rapid and large-scale deforestation has the potential to have negative and serious environmental impacts for Zambia in the near future and calls for corrective measures.

20.2.4 Mozambique

Considering the 40 dominant cropping systems, Mozambique experienced a strong expansion of cropland of +87% during 2000–2019. Remarkable is the strong increase in production area for staple crops such as maize (+109%), paddy rice (+293%) and sorghum (+109%) (FAOstat 2021) (Fig. 20.14).

Climate Factors

The tropical to subtropical climatic conditions of the region are largely influenced by the monsoons from the Indian Ocean and Mozambique current with warm

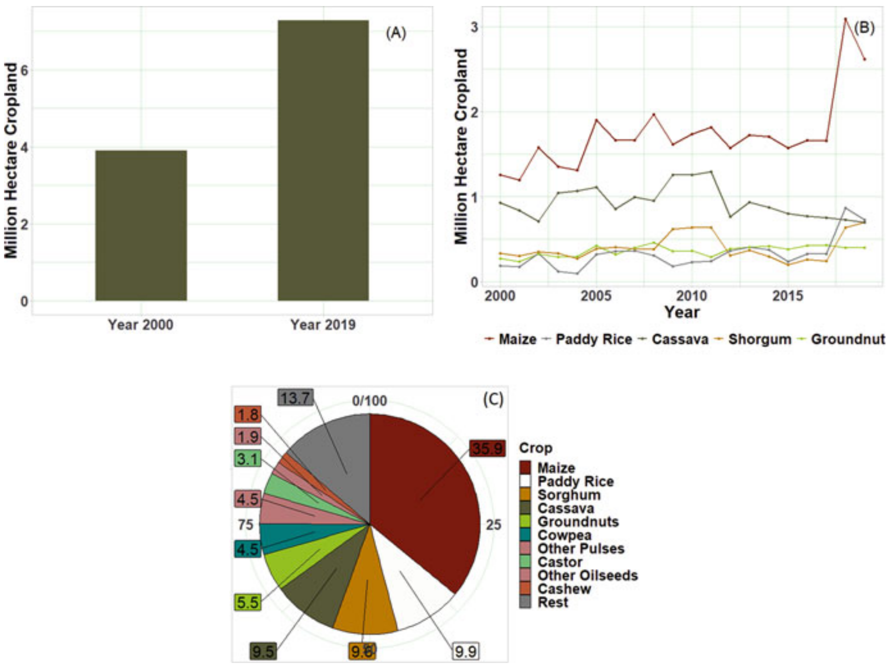

Fig. 20.14 Cropland dynamics: Mozambique. (**a**) Total cropland area as of 2000 and 2019 in million hectares. (**b**) Area dynamics of five dominating cropping systems (2000–2019) in million hectares. (**c**) Composition of cropland as of 2019 [*FAOstat* (*2021*)]

surface waters flowing south along the African east coast, while the southern area of Zambezi River is influenced by the subtropical anticyclonic zone. The south of Mozambique is generally drier with an average rainfall lower than 800 mm, decreasing to as low as 300 mm. Mozambique is already highly susceptible to climate variability and extreme weather events. Periods with floods are followed by droughts. Meanwhile, climate change has raised the frequency of extreme weather such as tropical cyclones with destructive effects on agriculture. In 2020 for example, Mozambique had two such cyclones making landfall on the country. Manuel et al. (2021) emphasize regional differences in climate change impacts due to differences in agroecological conditions. Higher negative impacts of climate change are expected on the agricultural outcomes in the central and northern regions, which are currently characterized by more favorable agroecological conditions than the drier southern regions (Swain et al. 2011).

Policy Factors

While Mozambique probably has the best agroclimatic conditions in southern Africa, it yet is one of the poorest countries in the region. A combination of decades of internal conflict since independence has held back the country's agricultural potential. However, after the 1992 Rome Peace Agreement, sufficient stability returned to the country for agriculture to take advantage of its agroecological potential.

The Mozambican government's limited fiscal capacity meant that they have limited capacity to directly support agriculture in the same way other SA10 countries like Zambia and Malawi are able to. In trying to manage this reality the government adopted a policy of concession agriculture wherein private companies are given concessions to operate outgrower schemes exclusively in a district, for a single commodity. Farmers in that district, growing that commodity, can only sell to the concession holder. In return, the concession holder must provide inputs and technical support to farmers.

This model worked well in the early years and drove a lot of the strong increase in agricultural production and land use for agriculture. However, in recent years, farmers have switched to nonconcessional crops like soybeans and sesame, that reward farmers fairly for their labour. Cotton and tobacco, the main concession crops have been under pressure as farmers turn to more open market traded crops. Mozambique has also been subject to controversial "land grab" issues as a result of the land concession system. It remains to be seen if and when the government will be able to start playing a bigger role in agricultural support and if this will result in greater utilization of land for agriculture.

Economic and Demographic Factors

The end of the civil war gave the economy a chance to grow almost exponentially, for slightly over a decade (World Bank 2006). Demand for basic commodities such as poultry, previously all imported, created the impetus for local production. The economic situation has deteriorated in the last decade, but local consumer demand remains (World Bank 2021). It is anticipated that land use for agriculture will grow multiple times as market systems take root and stabilize across a number of commodities.

20.3 Global Change Threats and the Quest for Sustainable Intensification and Diversification

20.3.1 Changes in Demography, Food Demand and Food Insecurity

Changes in Demography One of the big challenges for Africa in the twenty-first century is its rapid population growth. Looking at the medium variant of the United Nations projections for the continent as a whole, its population will nearly double between 2020 and 2050 to an estimated 2.6 billion people. Globally, the population is expected to grow by just 30% (UN DESA 2017), Africa accounting for half of this growth in that period. When we look at the SA10 treated in this chapter, the population of these countries together amounted to about 45 million in 1960. The population count increased to about 175 million in 2017 (UN DESA 2017) and projections suggest that by 2050 approx. 350 million people (Klingholz 2020) will live in the region—a doubling in just 33 years. Most of the population growth is still happening in rural areas and this increase in rural population is very unlikely to be absorbed by employment in the primary agricultural sector (Sikora et al. 2020).

Changes in Food Demand and Food Insecurity Changes in food demand is not just a matter of more people needing more calories, but depends on various factors such as demographic structure, changes in diet, economic development, etc. (Rötter et al. 2007). Changes in diets due to more wealth and associated changes in lifestyles and food consumption patterns (toward more meat) possibly have the strongest influence on increased per capita calorie demand (Tilman et al. 2011). There is a large food demand-supply gap for southern Africa that may even widen in the future decades as a consequence of rapid population and income growth. The World Food Summit (1996) defined: "food security represents a state when all people at all times have physical and economic access to safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." Among the rural population in southern African countries about 16% have consistently been classified as "food insecure" (SADC 2018). Geo-referenced data on the current status of food insecurity and related indicators at (sub-)national scale can be found in WFP. The ongoing COVID-19 pandemic has again since 2020 increased the total number and relative share of people experiencing chronic hunger—globally by about 120 million people, with a considerable share of those in Sub-Saharan Africa (FAO, IFAD, UNICEF, WFP and WHO 2021).

20.3.2 Climate Variability and Change, Natural Resource Limitations and Low Agricultural Productivity

Climate Variability Southern Africa is one of the world regions characterized by high rainfall variability (Davis-Reddy and Vincent 2017). There is evidence that inter-annual rainfall variability over southern Africa has increased since the late 1960s and that droughts have become more intense and widespread in the region (e.g., MacKellar et al. 2014). Among the many factors influencing rainfall variability, the El Nino Southern Oscillation (ENSO) phenomenon has possibly the strongest impact over large parts of southern African regions. Here, El Niño conditions are generally associated with below-average rainfall years over the summer rainfall regions (see Fig. 20.5, above), while La Niña conditions are associated with above-average rainfall. The 1982/1983 and 2015/2016 droughts in many parts of SA10 coincided with strong El Niño events. Chapter 5 gives more details on current and recent past climate variability.

Observed Impacts: In 2015/2016 South Africa experienced the worst drought since 1930. Large parts of maize (83%) and wheat (53%) are produced under rainfed conditions, making them especially vulnerable. In 2015, The Free State, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape and North-West provinces were declared drought disaster areas. Also other countries (Lesotho, Swaziland,

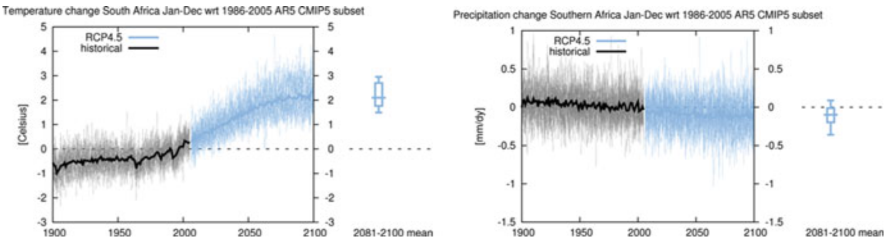

Fig. 20.15 Climate change scenarios: temperature change for South Africa, and precipitation change for southern Africa, 1900–2100 plotted from KNMI Climate Explorer website based on CMIP 5 multimodel ensemble—42 models, using one ensemble member per model (Source: http://climexp.knmi.nl/plot_atlas_form.py)

Zambia, Zimbabwe) experienced yield reductions and associated increases in maize prices (WFP 2016). Verschuur et al. (2021) showed that drought in South Africa and Lesotho in 2007 resulted in severe food insecurity in Lesotho.

Climate Change For southern Africa, Engelbrecht et al. (2015) report drastic increases in surface temperature for the region—about twice as high as the global rate of warming. A decrease in late summer rainfall (JF, i.e., January and February) has been reported over the western regions including Namibia and Angola. Long-term records have shown significant increases in average rainfall intensity and the length of the dry season (New et al. 2006). Trends in flood occurrences have been decreasing prior to 1980 and increasing afterward. Mean annual temperatures have increased in the last five decades and have reached 0.2–0.5°C/decade in some regions such as in south-western Africa. Under the highest emission scenarios (RCP8.5 or SSP5–8.5), almost all African regions will very likely experience a warming larger than 3°C, while under a low emission scenario (RCP2.6 or SSP1–2.6), the warming probably remains below 2°C (IPCC 2021). Some projections of annual temperature and precipitation changes (as anomalies referring to 1986–2005) are presented in Fig. 20.15. Chapter 7 gives information about the latest climate change projections for the region.

Consequences: Accelerated climate change will put additional pressure on the multifunctionality of southern African savanna ecosystems and the Western Cape winter rain area (Midgley and Bond 2015). Ecosystem services such as provision of food, feed, fuel, carbon sequestration, nutrient cycling, habitat quality, pollination and natural pest control are under threat (Rötter et al. 2021). Both agricultural and hydrological drought are projected to increase in southern Africa—most severe for agriculture will be the projected significant increase in the probability of extremes, especially heat waves and severe droughts (IPCC 2021). The number of days with maximum temperature exceeding 35°C is projected to increase in the range of 50–100 days by 2050 under high emission scenario SSP5–8.5 for most regions in Africa. Some adaptations are possible, e.g., through judicious choice of more suited crop cultivars (see Sect. 20.4.1.2). Global warming will very likely increase the frequency of extreme El Niño events.

Natural Resource Limitations, Land Degradation and Low Agricultural Productivity

Vlek et al. (2020) described the natural resource situation in southern Africa as "land rich but water poor," at the same time stressing the need for agricultural intensification and emphasizing options to stop soil nutrient mining and land degradation by integrated nutrient management practices (Vanlauwe et al. 2010) with special attention to soil organic matter.

Sub-Saharan Africa is dominated by low input agriculture with associated low farmer's yield which may be well below 20% of the climatic potential (Van Ittersum et al. 2016). This has often been compensated by additional land clearing and "over-cropping" of already marginalized land (Nkonya et al. 2016). Yield levels for major staples such as maize remain low (at 1–2 t ha^{-1}) due to low inputs. Average fertilizer application rates in 2017 in sub-Saharan Africa were still below 17 kg ha^{-1} (NPK together) (Vanlauwe and Dobermann 2020). The huge nutrient gaps, i.e., the gaps between the nutrients actually applied and those required to replenish the nutrients removed by harvested products (Ten Berge et al. 2019), resulting in soil nutrient depletion, are a main cause of stagnating low agricultural productivity, land degradation and poverty of smallholders (Vlek et al. 2020). Land clearing and deforestation to expand agricultural land use has led to rapid degradation of more than 95 million ha of land in SSA (Nkonya et al. 2016). The loss of vegetative cover, depletion of soil organic matter, lack of management skills and appropriate technologies are recognized factors codetermining soil degradation (Kuyah et al. 2021). Little fertilizer, no irrigation is what we may call the "status quo management practice" of smallholder farmers in southern Africa (Chap. 23). On the other hand, it has been demonstrated at many on-station and on-farm field experiments and by yield statistics of commercial farms that cereals yields of 6–7 ha^{-1} are achievable at high nutrient and water use efficiencies. Such yields can be sustained if applying appropriate technologies and good management, such as site-specific nutrient management, smart crop rotations and deficit irrigation (e.g., Swanepoel et al. 2018). Yet, the considerable increases in cropland and harvested area for the main crops are largely responsible for the recent increases in crop productivity in southern Africa (FAOSTAT 2021) (Sects. 20.1–20.2).

20.3.3 The Quest for Sustainable Intensification and Diversification

Southern Africa has also been identified as a hotspot for biodiversity, whereby agricultural expansion is a key driving force for the declining species diversity (Midgley and Bond 2015). The demographic and climate change projections underline the urgency of science-informed identification of sustainable land management options that, on the one hand, lead to sustainable increase of crop yields per unit area so as to meet increasing food demand and, on the other hand, protect biodiversity in forests and natural vegetation by saving these areas from agricultural expansion (IPCC 2019; Sikora et al. 2020).

From Definitions to Implementation Sustainable agricultural intensification (SI) means "to produce more with less land, water and labour to meet growing food demands and save space for biodiversity." This definition has been phrased during the 1990s in the context of market liberalization and economic growth in countries with densely populated areas in S, SE and E Asia (Rötter et al. 2007). Godfray et al. (2010) emphasizes that SI is the logical response to the threefold challenge of a further strong increase in food demand, increasing competition for natural resources and decline in resource availability and quality, and climate change threats. While under some conditions SI can be achieved through specialization on one/few crops, diversification of crop production, horticulture and livestock toward mixed farming systems can increase the economic viability and resilience of farms and farm households (Kuyah et al. 2021), especially climate variability and change. Tibesigwa et al. (2017), among others, found that such mixed farming systems are less vulnerable compared to specialist crop farms. SI is commonly defined as an increase of agricultural production and improvement of ecosystem services from the same area of land—with constant or reduced inputs and reduced negative externalities such as the agricultural carbon footprint (Garnett et al. 2013). In order to minimize greenhouse gas emissions from the African land-use sector, SI must be favored over an expansion scenario, as the latter leads to higher greenhouse gas emissions and jeopardizes climate protection more than intensification (Tilman et al. 2011; Van Loon et al. 2019). But so far, the contrary has been practiced.

Multiple techniques for SI in Africa, both traditional and novel, are already at hand (Rötter et al. 2007; Jeffery et al. 2017; Kuyah et al. 2021) Yet, still ongoing is the generation of knowledge on appropriate, site-specific measures that take the various sustainability dimensions (environmental, economic and social) into account. Likewise, the associated knowledge diffusion for wider adoption for a broad spectrum of crop and livestock systems is receiving increased attention. Besides efficiency and environmental impacts also cultural and financial limitations affecting adoption rate of sustainable management practices need to be considered. Market access, education, land rights and availability of inputs will finally steer the direction of the implementation and the magnitude of impact. In Sect. 20.4, a brief synthesis of recent review publications on SI with technologies suitable for southern Africa is made.

20.4 Agricultural Management Challenges and Transformation Pathways for a Sustainable Future

20.4.1 Most Pressing Agricultural Management Challenges

Key to a sustainable transformation of agriculture in SA10 will be to convert low productivity and food insecure subsistence farms to productive and economically viable commercially oriented systems applying sustainable land management practices (Sikora et al. 2020). Current smallholder systems suffer from vulnerability to climate variability and change, rapid soil nutrient depletion, shrinking farm size, lack of agricultural knowledge and technology and poor access to input and output markets. Hence, the most pressing management challenges include improving soil health, germplasm and water management from field to watershed in conjunction with climate change adaptation and mitigation, natural pest control and protection of biodiversity through its integration into farm management. Moreover, existing commercial farms have to become more resource-efficient, climate-smart and environment-friendly (e.g., Vanlauwe and Dobermann 2020; Kuyah et al. 2021). A few examples are given below.

20.4.1.1 The Need of Improving Soil Health in the Face of Climate Change

Soil fertility is broadly defined as the suitability of soil physical, chemical and biological characteristics, at a given site to match the site specific production and management objective. Measures counteracting nutrient-mining, as well as for preventing soil erosion (Chap. 13) and carbon-stock degradation must be implemented. It has often been reported that soil carbon losses are associated with a decline in soil quality and crop yield (Lal 2004). Given the many nutrient poor soils, year-round high temperatures and the (semi-) humid to semiarid conditions, soil organic carbon (SOC) concentrations in southern Africa are generally low. Swanepoel et al. (2016) found that 58% of the top soils have SOC concentrations of <0.5% or less and that conventional farming has further depleted native SOC stocks, on average by 46%. The protection of the remaining SOC is therefore imperative. Conservation agriculture (CA) represents a possible avenue to enhance climate change adaptation and mitigation in conjunction with soil fertility improvement and increased yields (Thierfelder et al. 2017). The central challenge is to develop and implement measures enabling soil fertility improvements by smallholders, such as shown for Integrated Nutrient Management (INM) techniques in Africa (Vanlauwe et al. 2010).

20.4.1.2 Water Management from the Crop via Farm to the Watershed

According to Vlek et al. (2020), agriculture in SA10 consumes about 85% of the water withdrawn from nature (rivers, streams, aquifers, etc.). Nhemachena et al. (2020) provided a comprehensive analysis of the projected climate change impacts on the interrelated agriculture and water sectors of the Southern African Development Community (SADC); the largest share of this geo-region (75%) is characterized as marginal with arid to semiarid climatic conditions (<650 mm precipitation year^{-1}). The share of irrigation in SA10 is somewhere between 10% and 15%, whereby The Republic of South Africa keeps the lion's share with about 1.5 million ha in 2010 (Vlek et al. 2020). The overall picture is that of a fragile region with high livelihood dependence on variable rainfall regimes and prevalence of largely inefficient irrigation technologies—with climate change likely to even worsen that picture. Consequently, the SADC region may face losses in agricultural productivity ranging from 15% to 50%. This baseline situation and the projected outlook require rapid and widespread adaptations in water management from crop/field to watershed level (Chap. 22).

Watersheds and River Basins Major rivers such as the Okavango, Sambesi, Limpopo or Oranje have a transboundary character. Unsustainable management of these resources also has geo-political implications. From a hydrological perspective only in Mozambique and Zambia, and, to a lesser extent in Zimbabwe, viable options for increasing the share of irrigated crops exist (Vlek et al. 2020). Increasing water demands from urban areas is also lowering the agricultural use of the water resources.

Farm Level On farm water-harvesting structures must be mainstreamed and efficient irrigation schemes and technologies developed and deployed. Efficient drip irrigation systems can save water and extend watering times. Further, soil moisture conserving agronomic practices and rainwater harvesting must be adopted (e.g., Kuyah et al. 2021).

Field and Crop Level Varietal choice regarding water consumption and water-use complementarity, and adopted planting dates can improve the water use and utilization at plant level. Additionally, development of new breeds with reduced transpiration, increased water use-efficiency and deeper rooting must be developed. Breeding of climate-smart plants is a key-stone for the adaptation of the agricultural sector to future climates (Chap. 23).

20.4.1.3 Integration of Biodiversity at Farm and Landscape Level

Southern Africa landscapes harbor a significant part of global biodiversity. The Cape Floristic Region, the Succulent Karoo and the Maputaland-Pondoland-Albany biodiversity hotspot are recognized as a global priority for nature conservation in the context of the world's 34 biodiversity hotspots. Meanwhile, habitat loss has been accelerated by the ongoing transformation and fragmentation of landscapes. Unique biomes like fynbos, renosterveld and strandveld have been converted for fruit and cereal production. Nowadays, only 5% of the original renosterveld biome remains in the agricultural lowlands. According to the South African "Threatened Plant Species Program" (South African National Biodiversity Institute, SANBI), 67% of all threatened plant species occur in the fynbos biome of the Cape region. Many of these species have a very limited distribution range and only persist in small areas or even in a single location. Remaining patches are situated on private lands: implying that the integration of natural habitats into agricultural landscapes is a priority issue. In general, a functioning mosaic of agricultural fields, orchards, conservation areas and landscape-scale ecological networks can increase ecological resilience at watershed/landscape level. The direct interactions between crops and natural vegetation and fauna can have positive effects on crop production (Chap. 22). The increased introduction of natural and seminatural vegetation into the agricultural landscape promotes the settlement of animals. This is particularly important for predator-prey relationships for natural pest control and the abundance and diversity of pollinators. On the other hand, with the decrease of habitats and the simultaneous increase in population, the animals are driven toward closer contact with humans, which leads to a significant increase in human–wildlife conflicts with crop raiding by wildlife having become an important negative commercial factor for farmers (Seoraj-Pillai and Pillay 2017). Development of large-scale ecological networks serving as corridors that connect the remaining natural habitats in fragmented landscapes can improve structural and functional connectivity for the exchange of biodiversity, and increase the effective size of local protective areas. Redesign of integrated landscapes can result in a win-win situation for agriculture and conservation, but needs further strategic research and practical implementation.

20.4.2 Outlook on Sustainable Transformation Pathways

Southern Africa is in need of doubling its food production within the next two decades. Facing the contemporary challenges of climate change, land degradation, biodiversity loss and other interferences with the planetary boundaries, it is clear that staying within “safe operation space” (Rockström et al. 2020) will be a challenge but must be achieved without compromise.

Key to a sustainable transformation of agriculture in southern Africa will be to convert low productivity and food insecure smallholder farming systems, suffering from vulnerability to climate variability and change, rapid soil nutrient depletion, shrinking farm size, lack of agricultural knowledge and technology and poor access to input and output markets, to more productive and economically viable systems. This calls for sustainable land management practices (Sikora et al. 2020) and continued policy support of the ongoing structural transformation of African farming systems (Barrett et al. 2018). Transformation of agricultural land-use systems requires a systemic, integrative multiscale and multidisciplinary approach (HLPE 2020). The challenges that evolve—e.g., to develop climate-smart and resilient farming systems—are often studied with a reductionist approach (e.g., investigating single plants or animal breeds on their drought or heat tolerance) without subsequent integration of its findings with required adjustments of other system components of the farm or landscape. However, if the whole system is transformed, it is essential to study the mutual interactions of crop and livestock production systems jointly with other major land uses in a region and their interrelations with the natural resource base. Moreover, all agents (agricultural producers, extension services, other resource managers, etc.) have to be involved in the process, and apart from evaluating the systems for efficiency gains, also the impacts on economic, ecological and social aspects have to be taken into account. There are only a few projects that look at the multifunctionality of agricultural landscapes in view of possible transformation pathways, using such a systemic integrative approach. Exceptions include SPACES2-SALLnet that develops such scenarios for Limpopo (Rötter et al. 2021; Chaps. 22 and 23) and SPACES2-ASAP that integrates agroforestry systems into land management in southern Africa (Sheppard et al. 2020). There are strong arguments for the development and implementation of SI strategies tailored to the local biophysical and socioeconomic settings (Cassman and Grassini 2020). Plenty of choices exist on how to implement these strategies on the ground in terms of cropping systems, agronomic practices, breeding and other enabling technologies and support systems/infrastructure. A common goal is to move from the current situation, which most often is unsustainable (economically and/or ecologically) to desirable sustainable farming systems. Such transformations require SI and diversification strategies (Vanlauwe and Dobermann 2020). While the availability of many options for intervention may create the need to prioritize the means (i.e., the interventions/technology options), we think that it is equally important that solutions are codesigned by multiple stakeholders including scientists as otherwise they will not turn out to be sustainable. The best strategy will not only depend on the prevailing agroecological conditions but also on several other factors such as human capabilities (e.g., education, practical skills; entrepreneurship), as discussed by Gatzweiler and von Braun (2016).

There are many possible or conceivable transformation pathways for agriculture globally and for world regions such as southern Africa. Construction of agricultural development scenarios have been an integral part of future-oriented assessments for many years (IAASTD 2009). Also more recent agricultural development scenarios (e.g., Antle et al. 2017) go back to four archetype scenarios: Global orchestration; Fortress; TechnoGarden; AdaptiveMosaic (Du-Lattre-Gasquet et al. 2009). Here, we only consider the two archetype scenarios "TechnoGarden" and "Adaptive Mosaic" since both aim at environment-friendly sustainable management practices, although with slightly different foci (Fig. 20.16).

According to Du-Lattre-Gasquet et al. (2009), (1) TechnoGarden combines new technologies with focus on high resource use efficiency as globally developed/exchanged with site-specific knowledge, whereas (2) AdaptiveMosaic tailors diverse low cost management practices to the local specificities, continuously adapting them to changes and largely utilizing local resources & knowledge focusing on soil health and biodiversity conservation. A prerequisite for any sustainable

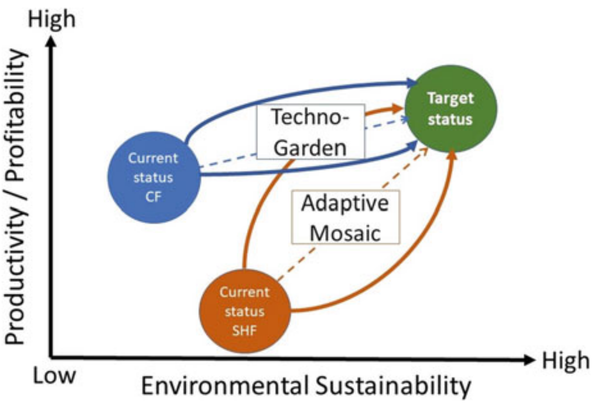

Fig. 20.16 Anticipated (schematic) transformation trajectories of TechnoGarden (upper arrows) and AdaptiveMosaic (lower arrows) from the current status of commercial farming (CF) and smallholder farming systems (SHF) to a sustainable future status

transformation pathway is that it is: (1) economically viable (2) environmentally sound, (3) resource-use efficient, (4) climate-resilient with (5) a low or negative carbon footprint and (6) based on equity among the various actors.

Here, we sketch some features of two potential future transformation pathways (Fig. 20.16), but refrain from prescribing where and under what conditions exactly these should be developed. Principally, we also do not claim that a "TechnoGarden" pathway would best fit to high or medium agroecological potential areas (e.g., where maize-mixed or root and tuber-based systems dominate), and the "AdaptiveMosaic" suits more to the marginal semiarid ecozones (e.g., Karoo) and savanna zones (where mixed crop-livestock/agropastoral systems dominate). Yet, there may be some argument that, initially, the "High Tech" would often be found rather closer to urban centers or in well-connected rural areas, while the "Adaptive local" pathway would initially rather be found in remote, less accessible rural areas. In the longer term we will likely see that the more commercially oriented, "TechnoGarden" with High Tech and relatively capital-intensive input will converge with the smallholder low input local "AdaptiveMosaic" systems that are based on diversity and agroecological principles. Both need to lead to systems that are profitable, highly productive and environmentally sound (Fig. 20.16).

TechnoGarden This will lead smallholders to become more commercial farmers, and current commercial farmers to apply environmentally sound practices using the best available technologies (e.g., precision farming). Apart from being capital-intensive, TechnoGarden recycles resources (water, nutrients) whether land-based or decoupled (e.g., vertical farming; cultivating insects for protein, etc.). Furthermore, it integrates renewable energy networks like photovoltaic, wind power, biogas and energy storage. This requires a high level of technical and managerial skills, and tailors technologies to local conditions by utilizing agroecological principles, complemented by local knowledge & resources. For southern Africa, this pathway could comprise climate-smart crop rotations or legume-based intercropping systems (e.g., Hoffmann et al. 2020), efficient irrigation or season-specific management of input use (based on weather forecasts & crop monitoring)—whatever is technically feasible/reasonable under the given local settings. Practices can include (climate- and pest-) resilient and new (food and fodder) crops/cultivars (Chaps. 19 and 23), integrated and site-specific nutrient management (INM and SSNM) (Vanlauwe and Dobermann 2020; VanLauwe et al. 2010) and natural pest control/integrated pest management (Chap. 22). Wherever feasible, such technology packages should be combined with mechanization (e.g., shared machinery at community level). A few studies have explored the impacts on yield, environment and/or farm economics of some elements of such technology packages in Africa (see, e.g., Rötter et al. 2016; Swanepoel et al. 2018; Hoffmann et al. 2020 and Chap. 23). Crop yield increases in the range of 100% to 300% compared to status quo have been reported—narrowing the yield gap from the usual 0.2 of the climatic potential yield to 0.5 or more (e.g., Van Ittersum et al. 2016). The TechnoGarden will aim to reduce different agricultural risks by newest technologies and adequate, if necessary capital-intensive, resource use and recycling technologies.

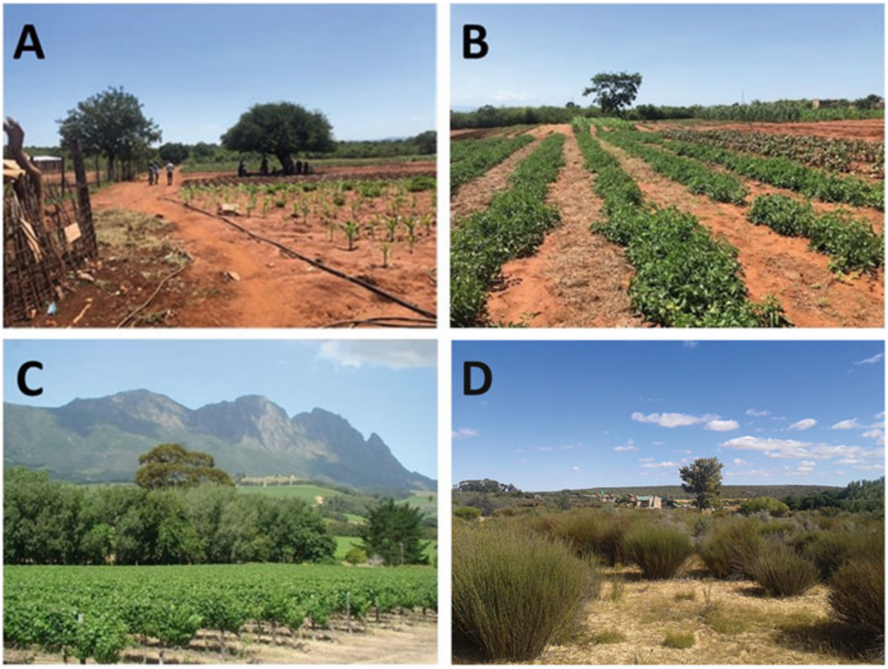

Fig. 20.17 Diversification and integrated farming concepts: (**a**, **b**) diversified cropping enabled by water-saving mulching and drip irrigation (Photo: Frank's smallholder at Ndengeza Village), Limpopo Province, South Africa; and Integrated Farming supporting sustainability, biodiversity and crop productivity: (**c**) in the Winelands of the Western Cape and (**d**) in the rangelands at the Bokkeveld Mountains in the Northern Cape, South Africa (Photo: Farm Papkuilsfontein, Niewouldtville)

AdaptiveMosaic will allow smallholders that are currently mainly subsistence-oriented to become more commercially oriented. The pathway will largely build on local resources and adaptive management (e.g., Kuyah et al. 2021). The term "adaptive" indicates that risk reduction takes place by continuously adapting/adjusting to changing conditions. It may comprise different local means of integrated soil nutrient and residue management, combining use of available organic materials with (little) industrial fertilizer (Vlek et al. 2020; Thierfelder et al. 2017). Furthermore, it applies the principles of conservation agriculture (CA) and natural pest control. Often irrigation will not be possible, but rainwater harvesting may be applied. Crop diversification and intercropping options need to be tailored to (the often limited) water availability (Fig. 20.17a, b). In more humid areas, diversification through diverse agroforestry (Chap. 21) and crop rotations consisting of cereals, legumes and root crops might be introduced. In their comprehensive review, Kuyah et al. (2021) identified fertilizer micro-dosing, planting basins, push and pull technologies (pest control), conservation agriculture, agroforestry and double-up legume cropping as appropriate SI measures for Sub-Saharan Africa.

Whenever possible, management practices/use of material inputs such as fertilizers should be season-specific based on weather forecasts (Phillips et al. 1998). The agronomic application of pyrogenic carbon, i.e., biochar has been recognized by IPCC (2019) as an appropriate and scalable negative emission technology with high impact potential. Biochar application as a means to amend soil fertility and sequester carbon should be an integral management component, especially in agroforestry systems. The cultivation of new indigenous cash crops can contribute to an integrated and sustainable farming system. Medical plants (e.g., Devil's claw *Harpagophytum procumbens*) and Rooibos tea (*Aspalatus linearis*) and honeybush (*Cyclopia* spec.) are good examples for increased use of indigenous crops. Integrated farming in combination with biodiversity and nature conservation can be observed in marginal regions of southern Africa (Fig. 20.17c, d). Nature-based tourism can generate income, which contributes significantly to the revenues obtained from traditional sheep and crop farming. This requires a good understanding of ecosystem services and their uses in the heterogeneous landscapes of the farms.

20.5 Conclusions

The high diversity of agroecologcial conditions in southern Africa in conjunction with the different economic and sociopolitical settings creates a multitude of agricultural management challenges. In most of the region, high to medium potential agricultural land is amply available, but water resources are scarce. While commercial farmers are usually well-endowed with resources, the many smallholders increasingly face serious resource limitations that have resulted in negative environmental impacts and persistently low productivity. It is very likely that climate change will further reduce water security and food security. This situation is unsustainable and, in conjunction with rapid increase in population and food demand, is likely to lead to social unrest and ecological disaster for the region, if no major transformation of agricultural systems will take place. Key future management challenges, required policy interventions and research needs include:

- agronomic means for smallholder farms to restore soil health, implement climate-resilient cropping systems, integrate biodiversity for pest control and increase productivity must be complemented by policy measures
- policy interventions must be tailored to smallholder needs so they get access to required inputs, technologies and knowledge, markets, etc. so that farming becomes more profitable and environmentally sound in the long term
- investments into training of extension services and farmers on sustainable management of soil, water, crops and livestock to increase resource use efficiencies, productivity and reduce undesired outputs
- investments into the design of local solutions for new technologies including precision farming, digitalization (e.g., weather and market information via mobile-phone), production of renewable energy, techniques for the recycling of

nutrients and water, GMO and advanced breeding tools for breeds resilient to climate extremes, pests, etc.

- prioritize research into climate-neutral and adaptive farm management
- stimulate systemic, multiscale and multidisciplinary research approaches to explore and evaluate options that support the multifunctionality of the diverse agricultural landscapes
- support research on the redesign of agricultural landscapes and integration of biodiversity to maintain ecosystem services and for conservation

The two agricultural transformation pathways sketched, each with somewhat different means, (1) aim to boost productivity by overcoming key constraints to agricultural production, (2) lead to economically viable farming systems, (3) restore/maintain ecosystem services and (4) reduce the environmental/carbon-footprint agricultural production.

References

Antle J, Mu JE, Zhang H et al (2017) Design and use of representative agricultural pathways for integrated assessment of climate change in U.S. Pacific Northwest cereal-based systems. Front Ecol Evol 5:99. https://doi.org/10.3389/fevo.2017.00099

Auricht C, Dixon J, Boffa JM, Garrity DP (2014) Farming systems of Africa. In: Sebastian K (ed) Atlas of African agriculture research and development: revealing agriculture's place in Africa. International Food Policy Research Institute (IFPRI), Washington, D.C., pp 14–15

Barrett CB, Christian P, Shimeles A (2018) The processes of structural transformation of African agriculture and rural spaces. World Dev 105:283–285. https://doi.org/10.1016/j.worlddev.2018.02.019

Breckle S-W, Rafiqpoor MD (2019) Vegetation und Klima. Springer Spektrum, Heidelberg

Cassman KG, Grassini P (2020) A global perspective on sustainable intensification research. Nat Sustain 3:262–268. https://doi.org/10.1038/s41893-020-0507-8

Conway D, van Gaderen EA, Derying D, Dorling S, Krueger T, Landman W et al (2015) Climate and southern Africa's water-energy-food nexus. Nat Clim Chang 5:837–846. https://doi.org/10.1038/nclimate2735

Davis-Reddy CL, Vincent K (2017) Climate risk and vulnerability: a handbook for Southern Africa, 2nd edn. CSIR, Pretoria

Day M, Gumbo D, Moombe KB, Wijaya A, Sunderland T (2014) Zambia country profile: monitoring, reporting and verification for REDD+. Occasional Paper 113. Centre for International Forestry Research. CIFOR, Bogor Barat

Du-Lattre-Gasquet M, Rötter RP, Kahiluoto H (2009) Looking into the future of agricultural knowledge, science and technology (Chap. 5). In: Watson R, Herren H, Wakungu J, MacIntyre I (eds) IAASTD, Washington

Engelbrecht F, Adegoke J, Bopape M, Naidoo M, Garland R, Thatcher M, McGregor J, Katzfey J, Werner M, Ichoku C (2015) Projections of rapidly rising surface temperatures over Africa under low mitigation. Environ Res Lett 10:085004

FAO, IFAD, UNICEF, WFP and WHO (2021) The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. FAO, Rome. https://doi.org/10.4060/cb4474en

FAOSTAT (2021) Food and Agriculture Organisation of the United Nations Statistical Database; Statistical Division; FAO: Rome, Italy, 2021; Available online: http://www.fao.org/statistics/en/ (accessed on 15 February 2021).

Fischer G, Nachtergaele F, Prieler S, Van Velthuizen HT, Verelst L, Wiberg D (2008) Global agro-ecological zones assessment for agriculture (GAEZ 2008). IIASA/FAO, Laxenburg/Rome, p 10

Fischer G, Nachtergaele FO, Prieler S, Teixeira E, Tóth G, Van Velthuizen H, Verelst L, Wiberg D (2012) Global Agro-Ecological Zones – Model Documentation GAEZ v. 3.0. IIASA/FAO, Laxenburg/Rome, p 179

Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, Bloomer P, ... Godfray HCJ (2013) Sustainable intensification in agriculture: premises and policies. Science 341(6141):33–34

Gatzweiler FW, von Braun J (eds) (2016) Technological and institutional innovations for marginalized smallholders in agricultural development. Springer, Cham. ISBN 978-3-319-25718-1 (eBook). https://doi.org/10.1007/978-3-319-25718-1

Godfray HCF, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C (2010) Food security: the challenge of feeding 9 billion people. Science 327(5967):812–818. https://doi.org/10.1126/science.1185383

Government of Zimbabwe (2018) National Agricultural Policy Framework (2018–2030). Ministry of Lands, Agriculture and Rural Resettlement, Harare

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A (2005) Very high resolution interpolated climate surfaces for global land areas. Int J Climatol 25:1965–1978. https://doi.org/10.1002/joc.1276

HLPE (2020) Food Security & Nutrition. Report 15 report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. FAO, Rome

Hoffmann MP, Swanepoel CM, Nelson WCD, Beukes DJ, van der Laan M, Hargreaves JNG, Rötter RP (2020) Simulating medium-term effects of cropping system diversification on soil fertility and crop productivity in southern Africa. Eur J Agron 119:126089. https://doi.org/10.1016/j.eja.2020.126089

IAASTD (2009) Agriculture at a cross-roads. North America-Europe report. In: Watson R, Herren H, Wakungu J, MacIntyre I (eds) International Assessment of Agriculture, Agricultural Science and Technology (IAASTD), Washington

IPCC (2019) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]

IPCC (2021) Summary for policymakers. In: Climate Change 2021: the physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press, UK and New York. pp. 3–32. https://doi.org/10.1017/9781009157896.001

iSDA Africa (2021) Innovative Solutions for Decision Agriculture Ltd

Jätzold R, Kutsch H (1982) Agro-ecological zones of the tropics with a sample from Kenya. Der Tropenlandwirt 83:15–34

Jeffery S, Abalos D, Prodana M, Bastos AC, Van Groenigen JW, Hungate BA, Verheijen F (2017) Biochar boosts tropical but not temperate crop yields. Environ Res Lett 12(5):053001

Kate S (2009) Agro-ecological zones of Africa. Washington, DC, International Food Policy Research Institute

Klingholz R (2020) Twice as many people in 2050: the need for agricultural transformation in Southern Africa (Chap. 3). In: Sikora AS, Terry ER, Vlek PLG, Chitjja J (eds) Transforming agriculture in southern Africa: constraints, technologies, policies and processes. Routledge, pp 17–26

Kuyah S, Sileshi GW, Nkurunziza L, Chirinda N, Ndayisaba PC, Dimobe K, Öborn I (2021) Innovative agronomic practices for sustainable intensification in sub-Saharan Africa. A review. Agron Sustain Dev 41(2):1–21

Lal R (2004) Soil carbon sequestration to mitigate climate change. Geoderma 123(1–2):1–22

MacKellar N, New M, Jack C (2014) Observed and modelled trends in rainfall and temperature for South Africa: 1960–2010. S Afr J Sci 110(7 & 8):51–63

Manuel L, Chiziane O, Mandhlate G, Hartley F, Tostão E (2021) Impact of climate change on the agriculture sector and household welfare in Mozambique: an analysis based on a dynamic computable general equilibrium model. Clim Chang 167:6. https://doi.org/10.1007/s10584-021-03139-4

Meza I, Rezzaei EE, Siebert S et al (2021) Drought risk for agricultural systems in South Africa: drivers, spatial patterns, and implications for drought risk management. Science of the Total Environment 799:149505

Midgley G, Bond W (2015) Future of African terrestrial biodiversity and ecosystems under anthropogenic climate change. Nat Clim Chang 5:823–829. https://doi.org/10.1038/nclimate2753

New M, Hewitson B, Stephenson DB, Tsiga A, Kruger A, Manhique A, Gomez B, Coelho CA, Masisi DN, Kululanga E (2006) Evidence of trends in daily climate extremes over southern and West Africa. J Geophys Res 111(7):14102

Nhemachena C, Nhamo L, Matchaya G, Nhemachena CR, Muchara B, Karuaihe ST, Mpandeli S (2020) Climate change impacts on water and agriculture sectors in Southern Africa: threats and opportunities for sustainable development. Water 12(10):2673

Nkonya E, Mirzabaev A, Von Braun J (2016) Economics of land degradation and improvement–a global assessment for sustainable development. Springer Nature, p 686

Phillips JG, Cane MA, Rosenzweig C (1998) ENSO, seasonal rainfall patterns and simulated maize yield variability in Zimbabwe. Agric For Meteorol 90:39–50. https://doi.org/10.1016/S0168-1923(97)00095-6

ReNAPRI, Regional Network of Agricultural Policy Research Institutes (2014) Presentation at annual ReNAPRI symposium, Lusaka, Zambia

Ribeiro NS, Katerere Y, Chirwa PW, Grundy IM (eds) (2020) Miombo woodlands in a changing environment: securing the resilience and sustainability of people and woodlands. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-50104-4

Richard Y, Fauchereau N, Poccard I, Rouault M, Trzaska S (2001) 20th century droughts in southern Africa: spatial and temporal variability, teleconnections with oceanic and atmospheric conditions. Int J Climatol 21(7):873–885

Rockström J, Edenhofer O, Gaertner J, DeClerck F (2020) Planet-proofing the global food system. Nat Food 1:3–5

Rötter RP, Van Keulen H, Kuiper M, Verhagen J, Van Laar HH (eds) (2007) Science for agriculture and rural development in low-income countries. Springer, Dordrecht

Rötter RP, Sehomi FL, Höhn JG, Niemi JK, van den Berg M (2016) On the use of agricultural system models for exploring technological innovations across scales in Africa: a critical review ZEF. Discussion papers on Development Policy 223, Center for Development Research, Bonn, July 2016, p 85

Rötter RP, Scheiter S, Hoffman MP, Pfeiffer M, Nelson WCD, Ayisi K, Taylor P, Feil J-H, Bakhsh SY, Isselstein J et al (2021) Modeling the multi-functionality of African savanna landscapes under global change. Land Degrad Dev 32:2077–2081. https://doi.org/10.1002/ldr.3925SADC

SADC (2018) SADC Regional Vulnerability Assessment & Analysis (RVAA) synthesis report on the state of food anad nutrition security and vulnerability in southern Africa. SADC, Gaborone

Seoraj-Pillai N, Pillay N (2017) A meta-analysis of human–wildlife conflict: South African and global perspectives. Sustainability 9:34

Setimela P, Gasura E, Thierfelder C, Zaman-Allah M, Cairns JE, Boddupalli PM (2018) When the going gets tough: performance of stress tolerant maize during the 2015/16 (El Niño) and 2016/17 (La Niña) season in southern Africa. Agric Ecosyst Environ 268:79–89

Sheppard JP, Bohn Reckziegel R, Borrass L, Chirwa PW, Cuaranhua CJ, Hassler SK, Hoffmeister S, Kestel F, Maier R, Mälicke M, Morhart C, Ndlovu NP, Veste M, Funk R, Lang Seifert F, du Toit TB, Kahle HP (2020) Agroforestry: an appropriate and sustainable response to a changing climate in Southern Africa? Sustainability 12(17):6796

Sikora AS, Terry ER, Vlek PLG, Chitjja J (eds) (2020) Transforming agriculture in southern Africa: constraints, technologies, policies and processes, 1st edn. Routledge, New York. https://doi.org/10.4324/9780429401701
Swain A, Bali Swain R, Themnér A, Krampe F (2011) Climate change and the risk of violent conflicts in Southern Africa. Global crisis solutions. Menlo Park, Pretoria
Swanepoel CM, van der Laan M, Weepener HL, Du Preez CC, Annandale JG (2016) Review and meta-analysis of organic matter in cultivated soils in southern Africa. Nutr Cycl Agroecosyst 104(2):107–123
Swanepoel CM, Rötter RP, Van der Laan M, Annandale JG, Beukes DJ, du Preez CC, Hoffmann MP (2018) The benefits of conservation agriculture on soil organic carbon and yield in southern Africa are site-specific. Soil Tillage Res 183:72–82
Tatenda GN (2019) Natural resource degradation through tobacco farming in Zimbabwe: CSR implications and the role of the government. Communicatio 45(3):23–39. https://doi.org/10.1080/02500167.2019.1569541
Ten Berge HFM, Hijbeek R, van Loon M, Rurinda J, Tesfaye K, Zingore S, Craufurd P, van Heerwaarden J, Brentrup F, Schröder JJ, Boogaard HL, de Groot HLE, van Ittersum MK (2019) Maize crop nutrient input requirements for food security in sub-Saharan Africa. Glob Food Sec 23:9–21
Theron SN, Archer E, Midgley SJE, Walker S (2021) Agricultural perspectives on the 2015–2018 Western Cape drought, South Africa: characteristics and spatial variability in the core wheat growing regions. Agric For Meteorol 304–305:108405. https://doi.org/10.1016/j.agrformet.2021.108405
Thierfelder C, Chivenge P, Mupangwa W, Rosenstock TS, Lamanna C, Eyre JX (2017) How climate-smart is conservation agriculture (CA)?–its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. Food Secur 9(3):537–560
Tibesigwa B, Visser M, Turpe J (2017) Climate change and South Africa's commercial farms: an assessment of impacts on specialised horticulture, crop, livestock and mixed farming systems. Environ Dev Sustain 19:607–636. https://doi.org/10.1007/s10668-015-9755-6
Tilman D, Balzer C, Hill J, Befort BL (2011) Global food demand and the sustainable intensification of agriculture. Proc Natl Acad Sci U S A 108(50):20260–20264
UN DESA (2017) World population prospects: the 2017 revision. United Nations Department of Economic and Social Affairs, New York
Van Ittersum MK, van Bussel LGJ, Wolf J, Grassini P, van Wart J, Guilpart N, Claessens L, de Groot H, Wiebe K, Mason-D'Croz D, Yang H, Boogaard H, van Oort PA, van Loon MP, Saito K, Adimo O, Adjei-Nsiah S, Agali A, Bala A, Chikowo R, Kaizzi K, Kouressy M, Makoi JH, Ouattara K, Tesfaye K, Cassman KG (2016) Can sub-Saharan Africa feed itself? Proc Natl Acad Sci U S A 113(52):14964–14969. https://doi.org/10.1073/pnas.1610359113
Van Loon MP et al (2019) Impacts of intensifying or expanding cereal cropping in sub-Saharan Africa on greenhouse gas emissions and food security. Glob Chang Biol 25:3720–3730. https://doi.org/10.1111/gcb.14783
Vanlauwe B, Dobermann A (2020) Sustainable intensification of agriculture in sub-Saharan Africa: first things first! Front Agric Sci Eng 7(4):376–382. https://doi.org/10.15302/J-FASE-2020351
Vanlauwe B, Bationo A, Chianu J, Giller KE, Merckx R, Mokwunye U, Ohiokpehai O, Pypers P, Tabo R, Shepherd KD, Smaling EMA, Woomer PL, Sanginga N (2010) Integrated soil fertility management: operational definition and consequences for implementation and dissemination. Outlook Agric 39(1):17–24. https://doi.org/10.5367/000000010791169998
Verschuur J, Li S, Wolski P et al (2021) Climate change as a driver of food insecurity in the 2007 Lesotho-South Africa drought. Sci Rep 11:3852. https://doi.org/10.1038/s41598-021-83375-x
Vlek PLG, Tamene L, Bogardi J (2020) Land rich but water poor: the prospects of agricultural intensification in southern Africa (Chap. 5). In: Sikora AS, Terry ER, Vlek PLG, Chitjja J (eds) Transforming agriculture in southern Africa: constraints, technologies, policies and processes. Routledge, pp 36–44
WFP (2016) El Niño: undermining resilience - implications of El Niño in Southern Africa from a food and nutrition security perspective. World Food Programme

World Bank (2006) Post-conflict Mozambique's reconstruction: a transferable strategy in Africa. Multisectoral Report Number 35527
World Bank (2021) Mozambique economic update, setting the stage for recovery. The World Bank, IBRD, IDA
Xiong J, Thenkabail PS, Gumma MK, Teluguntla P, Poehnelt J, Congalton RG, Thau D (2017) Automated cropland mapping of continental Africa using Google Earth Engine cloud computing. ISPRS J Photogramm Remote Sens 126:225–244
ZAIP (2013) Zimbabwe Agricultural Investment Plan (2013–2017). A comprehensive framework for the development of Zimbabwe's Agricultural sector