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**UNDERSTANDING AND REDUCING  
AGRICULTURAL DROUGHT RISK:  
EXAMPLES FROM SOUTH AFRICA AND UKRAINE**

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# Summary

Drought is the most relevant hazard in South Africa and Ukraine in terms of economic losses. Both countries experience drought conditions on a regular basis with particular impact on the agricultural sector. Ukraine has experienced severe drought conditions every two to four years, whereas in South Africa extreme droughts have occurred every two to seven years along with El Niño events. The impact of drought on agriculture does not only depend on the lack of rainfall and/or soil moisture deficit in a region, but also on the exposure and the vulnerability of the agricultural system and the people depending on it. The Sendai Framework for Disaster Risk Reduction (SFDRR), adopted by the United Nations member states in 2015, highlights the urgent need to shift thinking from reactive, hazard-centred disaster management to proactive disaster risk management and risk reduction.

In order to do so, understanding disaster risk is a high priority. This policy report informs disaster risk managers how the planning and decision-making process can benefit from considering vulnerability in drought risk assessments by complementing existing drought monitoring systems. We present an indicator-based assessment of agricultural drought risk in South Africa and Ukraine, which provides an opportunity to define entry points for the identification of targeted response measures for both the reduction of drought impacts and the planning of preventive drought risk reduction measures. Hence, integrating information on exposure and vulnerability into the current drought monitoring systems in South Africa and Ukraine is in line with the SFDRR as it provides the basis for understanding drought risk and supporting activities towards drought risk reduction.



# Introduction: Understanding drought risk

Drought has wide-ranging impacts on human health, water supply and a variety of economic sectors, of which agriculture is usually the first to be hit. While drought events have been monitored in the past, with the adoption of the SFDRR in 2015 the shift from hazard-centred disaster management to disaster risk management and disaster risk reduction has become the first priority. Decision makers worldwide are challenged with understanding and managing drought risk and its underlying drivers in order to reduce the negative impacts of droughts.

In many countries drought hazard-centred monitoring systems prevail, which implies that most decisions on drought response measures are taken based on information on meteorological and hydrological conditions, such as lack of rainfall (meteorological drought) or low water levels in rivers or reservoirs (hydrological drought). Agricultural drought refers to low soil moisture, which results in a reduction of crop yield or crop failure. However, in order to better understand drought risk and reduce potential impacts it is important to take into account systematically the exposure and vulnerability of the assets of potentially affected sectors (for example agriculture, water supply), and the people depending on them in terms of their susceptibility and capacity to cope with drought (see Box 1 for detailed clarification of the terminologies). The integration of this information into existing hazard monitoring systems can support targeted responses and the identification of entry points for drought vulnerability and risk reduction measures in order to assist national governments and local

communities. This is particularly important as climate and global changes such as population growth, changes of land and resource use are likely to exacerbate the risk and thus the negative impacts such as yield losses in the future.



Figure 1: Conceptual risk framework after the IPCC (2014)

Box 1: Terminology of drought risk components with focus on agriculture.

## Drought hazard

Drought is a slow-onset hazard, which is generally defined as a deficiency of average precipitation. An agricultural drought is described as a soil moisture deficit, which results in plant stress and thus yield loss and crop failure. Drought hazard information includes occurrence, intensity and frequency (Boken, and others, 2005; Hayes, and others, 2012; IPCC, 2014).

## Exposure to drought

Exposure describes the people, property, livelihoods and systems which are subject to potential harms and losses due to the hazard. In the context of an agricultural drought, mainly the agricultural land, which includes crop and grassland, as well as the farmers and people working in the agricultural sector – mainly in crop and livestock farming – are spatially exposed to drought hazard conditions and therefore potentially affected (IPCC, 2014).

## Vulnerability to drought

Vulnerability describes how sensitive (susceptible) agricultural land and production, as well as people dependent on exposed agriculture, are to drought hazard impacts (susceptibility), and what skills or resources people or the agroecosystem can make use of to reduce the hazard impacts (coping capacities). Examples for (i) susceptibility and (ii) coping capacities are: (i) farmers without access to irrigation are more susceptible in a drought year than those with access to irrigation, and (ii) farmers who have alternative or higher incomes are better able to cope with periods of drought (UNISDR, 2016).





# Importance of drought risk reduction in South Africa and Ukraine

In the following paragraph the individual context of drought risk will be explained for South Africa, with a specific focus on the Eastern Cape province (Figure 2), and for Ukraine, with a specific focus on the Kiev region (Figure 3), representing the case study areas.

## South Africa



Figure 2: Study area of Eastern Cape, South Africa

Source: UNU-EHS

### Data sources

Borders: GADM (2018); Esri, DeLorme Publishing Company, Inc. (2017)

Major cities: ssemms\_hmhs (2015)

Basemap: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community (2018)

## Ukraine



Figure 3: Study area of Kiev region, Ukraine

Source: UNU-EHS

### Data sources

Borders: ThematicMapping.org (2009); UNOCHA (2018)

Cities: Esri, DeLorme Publishing Company, Inc. (2001)

Basemap: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community (2018)

## South Africa

Although the agricultural sector in **South Africa** accounts for only 2.4 per cent of the gross domestic product (GDP), it is an important source of livelihood for approximately 14 per cent of the households, with a focus on livestock farming (43%) and crop farming (35%) (DAFF, 2018; StatSA, 2011b). Drought events in South Africa usually correlate with El Niño years, which also holds true for the severe drought in 2015/16 (Malherbe, and others, 2016). While typically a net exporter of food, this drought turned South Africa into a net importer in 2015/16. Moreover, the drought led to increased unemployment and substantial water restrictions in many regions (Baudoin, and others, 2017).

In **Eastern Cape**, agriculture is an important source of income and livelihood for more than 35 per cent of the households in mainly rural areas. The farming system is characterized by commercial and communal crops and more importantly livestock farming: approximately 80 per cent of the land is used for natural grazing, mainly for cattle and sheep (StatSA, 2007, 2011b; DAFF, 2016).

The Agricultural Research Council (ARC) monitors climate and vegetation response and provides near-real-time products, such as maps and bulletins. Additionally, the South African National Space Agency (SANSA) provides information on the state of vegetation, whereas dam and groundwater levels are monitored by the Department of Water and Sanitation (DWS).

## Ukraine

**Ukraine** as a major global food supplier is particularly exposed to drought: the agricultural sector employs about 18 per cent of the population and accounts for 12-15 per cent of the GDP (Adamenko and Prokopenko, 2011; UkrStat, 2018). From 2000 to 2010 Ukraine experienced five drought events (2003, 2007, 2008, 2009 and 2010), each of which affected up to 80 per cent of the grain crop area (Kogan, and others, 2013). The 2003 and 2007 drought events generated losses in grain production worth up to around €3 billion (Adamenko, 2017). Thus, in Ukraine drought represents a substantial risk to the agricultural sector and the people depending on it.

In the **Kiev** region the predominant farming system is agro holdings specialized in the production of profitable crops (for example rapeseed), cereals and fodder crops particularly in the fertile southern parts. The rural population relies on agriculture both as an employer in agro holdings as well as for self-supply (Kozlovska, 2015).

Based on 164 monitoring stations, the Ukrainian hydro-meteorological centre (UHMC) provides weather forecasts, agro-meteorological newsletters, and adjusted information for different user groups – such as farmers and government – and agro-meteorological conditions of crops and forecasts of yields (UHMC, 2012).

# Drought hazard assessment

A time-series of open-source satellite remote sensing data<sup>1</sup> was used to derive drought hazard information. While the Standardized Precipitation Index (SPI) can indicate abnormal precipitation conditions, it is based on precipitation information which is only available with a coarse resolution and is not very reliable using remote sensing data only. The Vegetation Condition Index (VCI), based on the Enhanced Vegetation Index (EVI), on the other hand can measure the response of vegetation before, during or after the drought event and

thereby also includes information on water availability to a certain extent. The VCI can detect plant stress during drought conditions by measuring its performance over a defined time period (Didan, and others, 2015; Liu and Kogan, 1996). The VCI was classified with regard to drought severity and further reclassified into five hazard severity classes: no drought (D0: VCI>40) to extreme drought (D4: VCI<10) (Table 1) (Bhuiyan, and others, 2017).

Table 1: Drought hazard severity classification scheme

Source: Bhuiyan, and others, 2017

Severity Class	Drought class	VCI value
No drought	D0	>40
Mild drought	D1	>30-40
Moderate drought	D2	>20-30
Severe drought	D3	10-20
Extreme drought	D4	<10

<sup>1</sup> For the Eastern Cape province and the Kiev region Moderate Resolution Imaging Spectroradiometer (MODIS) data with 250m resolution from 2000 to 2017 were used.



# Drought hazard versus drought risk in Eastern Cape and the Kiev region

State-of-the-art drought risk assessments consider risk as the product of hazard, exposure and vulnerability (IPCC, 2014). The aim of comprehensive drought risk assessment versus drought hazard assessment is to understand why moderate drought hazard can lead to extreme impacts while extreme drought hazard, in some cases, causes only low or no impacts. The maps below indicate the hazard severity (Figure 4 and Figure 6) and the risk (Figure 5 and Figure 7) for the example of agricultural drought in Eastern Cape (South Africa) and the Kiev region (Ukraine), respectively.

## Eastern Cape South Africa

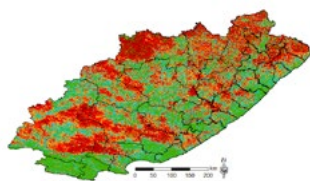


Figure 4: Median VCI  
11/2015-05/2016

Source: ZFL



Figure 5: Agricultural  
drought risk after 2015/2016

Source: UNU-EHS

## Kiev region Ukraine



Figure 6: Median VCI  
04/2015-03/2016

Source: ZFL

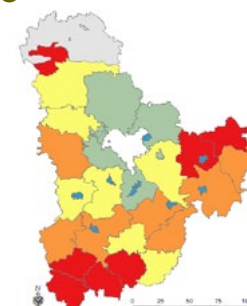
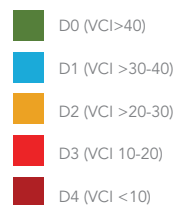


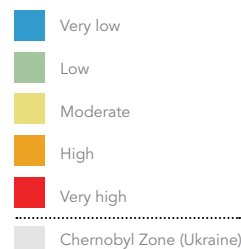
Figure 7: Agricultural  
drought risk after 2015/2016

Source: UNU-EHS

### Legend Hazard (Figure 4 and Figure 6)



### Legend Risk (Figure 5 and Figure 7)



## South Africa

The vegetation response (median VCI) over the growing season of 2015/2016 indicates that a significant proportion of Eastern Cape is affected by extreme drought conditions (*Figure 4*). The low VCI values in the north eastern parts mostly occur in the pasture and croplands of communal lands receiving usually high precipitation rates of about 800-1000mm/year. Also, the northern and south western parts show very low VCI values during the 2015/2016 season. Both areas are predominantly shrubland and grassland receiving lower precipitation rates than the rest of the country, and mainly under commercial land tenure. Better conditions can be detected in the central and southern (coastal) parts. While the coastal areas received relatively more rainfall also during the dry periods in 2015/2016 this area is also under commercial farming and partly irrigated.

On the contrary, the risk pattern follows a gradient from east (high) to west (low): the highest drought risk is indicated in the inland north eastern municipalities and the lowest risk is in the coastal western municipalities (*Figure 5*).

## Ukraine

In the Kiev region the vegetation response (median VCI) over the growing season of 2015 indicates few areas with severe drought conditions, mainly in the north. On the contrary, the southern counties are hardly affected by drought hazard according to the classification of the VCI (*Figure 6*). The areas in the northern part that have low VCI values are mainly grassland and forest that have undergone several changes during recent years. In other regions, with predominantly agricultural land use, both summer crops and some fields with winter crops experienced high hazard severity (=low VCI values). If we compare the VCI among different growing seasons, the results show that more vegetation is affected in the period of summer crops, whereas winter crops are not impacted during the key periods of the growing season.

In contrast, the risk pattern indicates highest risk in the south west and east, moderate risk in the north and south east and lowest risk around the capital Kiev and in the urban counties (*Figure 7*).

The VCI is based on vegetation response regardless of the type of vegetation, which is considered a relevant measure for drought hazard in the context of agricultural drought. In a next step, the exposure needs to account for the distribution of agricultural land by category, if possible with information on the distribution of individual crop types.

In summary, the comparison of risk and hazard maps reflects that severe drought hazard conditions do not imply per se high drought risk at the same time. Drought impacts are the manifestation of drought risk in a corresponding drought event. Hence, the next sections focus on exposure and vulnerability as two additional dimensions of drought risk in order to understand how they influence drought risk and how understanding these drivers can serve as entry points for drought risk management and drought risk reduction.

# Exposure

Recognising the strong interdependencies between agricultural land, production and the population depending on it, UNU-EHS applied a social-ecological system approach in the risk assessment: agricultural exposure is composed of human exposure (=people dependent on agriculture) and exposure of agroecosystems (=agricultural land).

## Eastern Cape South Africa

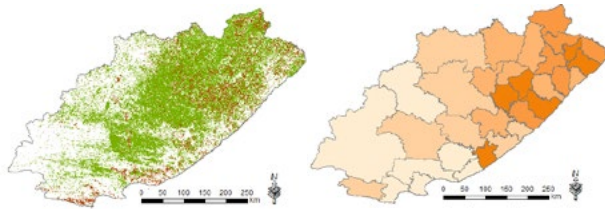


Figure 8: Distribution of grassland and cropland in Eastern Cape.

Data source: DEA, 2015

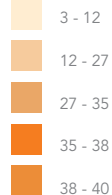
Figure 9: Share of agricultural households (HH) per municipality (%) based on quantile classification in Eastern Cape.

Data source: StatSA, 2011a

### Land cover



### Share of agricultural HH (%)



## Kiev region Ukraine

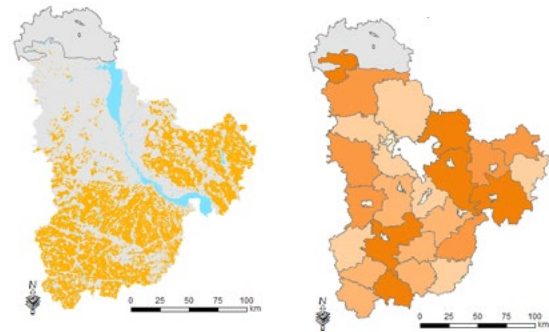


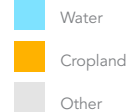
Figure 10: Distribution of cropland in Kiev region.

Data source: based on NASU-SSAU, 2015

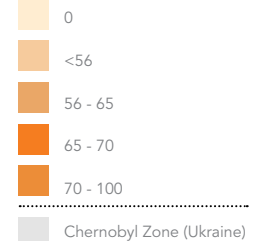
Figure 11: Share of rural population per county (%) based on quantile classification in Kiev region.

Data source: UkrStat, 2015b

### Land cover



### Share of rural pop. (%)





## South Africa

In **Eastern Cape** the main source of agricultural livelihoods is livestock: up to 84 per cent of the land is used for natural grazing (Jordaan, 2017a). Most of the crop production takes place in the eastern parts of the province, which is dominated by communal dryland farming. Intensive commercial fruit production is located mainly in the coastal south west, whereas irrigated agriculture is situated in the southern central parts of the province (*Figure 8*).

*Figure 9* displays the east-west gradient of the agriculture-dependent population. In the eastern municipalities, which are the former homelands, the high population density results in a high pressure on the agricultural land and resources, because many small-scale communal farmers share access to the land. In total, there are more than 300,000 communal and 4,000 commercial farmers in Eastern Cape (Jordaan, 2017a).

## Ukraine

The **Kiev** region is characterized by large forest areas in the north and mostly agricultural land in the south (*Figure 10*). Major crop types are wheat, maize, soybeans, vegetables, sunflower, barley, winter rapeseed and sugar beet. The predominant agro holdings generally farm on plots which exceed 250 ha, whereas most small individual farmers do not have access to land larger than 50 ha in total (Keyzer, and others, 2012; Shelestov, and others, 2017).

The exposure of agriculture-dependent population is approximated by the share of rural population per county due to lack of more specific data. The underlying assumption is that people in rural areas either work in agro holdings or they farm on smaller or household plots. There is no clear pattern except for urban counties with the lowest share of rural population and the highest shares in the east-of-Kiev region (*Figure 11*).

# Vulnerability

Vulnerability to drought is assessed in both case studies by a set of 13 social-ecological vulnerability indicators, selected by local stakeholders and project partners for a vulnerability assessment on aggregated administrative units. In South Africa, a set of 45 vulnerability indicators to agricultural drought has been derived for parts of Eastern Cape on a water catchment level by Jordaan (2017a). This set of indicators was reduced to the 13 most relevant and aggregated on the local municipality level for Eastern Cape. In Ukraine, the drought vulnerability indicators have been derived by a comprehensive literature review and data acquired to conduct the assessment for the Kiev region. Data availability further influenced the final set of indicators (for the overview of the comprehensive set of indicators refer to Annex 1). Five similar indicators have been used in Eastern Cape and Kiev, which are unemployment, social dependency, income, soil quality and surface water supply, while each case study is further characterized by unique indicators, such as livestock theft in the case of Eastern Cape or outmigration in the case of the Kiev region.

## Eastern Cape South Africa

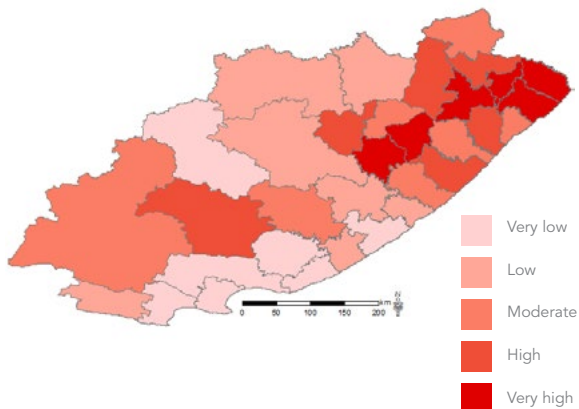


Figure 12: Drought vulnerability in Eastern Cape based on indicator set for South Africa (see Annex 1). Map classification according to quantile method.

Source: UNU-EHS

## Kiev region Ukraine

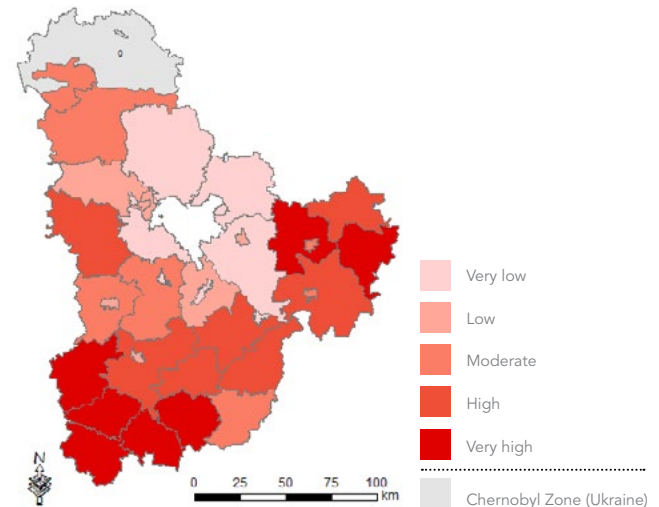


Figure 13: Drought vulnerability in Kiev region based on indicator set for Ukraine (see Annex 1). Map classification according to quantile method.

Source: UNU-EHS

## South Africa

The result of the vulnerability assessment – just like the exposure assessment – displays an east-west gradient. Communal farmers and communal land in the former homelands are more vulnerable than commercial farmers and land in the west (*Figure 12*).

The vulnerability in the eastern municipalities is driven by extensive soil erosion, which is a result of the communal land-use system, but also low education standards, limited access to information and infrastructure as well as low income levels and high unemployment. The dependency on agriculture in combination with limited alternative on-farm income further aggravates the vulnerability. Thus, communal farmers are more vulnerable to drought because almost all their livelihood income depends on farming, the unemployment rate is very high, and opportunities for alternative jobs are scarce. In the western municipalities low soil fertility, lack of access to surface water for irrigation and high stock theft rates are major contributors to the high and moderate vulnerabilities (Jordaan, 2017b, 2017a).

## Ukraine

The vulnerability map indicates that counties closest to the capital Kiev are the least vulnerable in contrast to the counties in the south, which are most vulnerable, and the districts in the north, which are moderately vulnerable (*Figure 13*).

Social vulnerability is driven by unemployment, outmigration and social dependency. Again, the least socially vulnerable counties are located around Kiev, whereas the most socially vulnerable are situated in the south west. Thus, Kiev as a large and prosperous city probably has positive impacts and spill-over effects on income and access to fertilizer and irrigation on its surrounding counties. Ecological vulnerability on the other hand looks very different: the north is indicated to be less susceptible because of, among other things, large forest areas, which are a natural protection against soil erosion and furthermore improve the water holding capacity. In the south, the violation of the planned crop rotation, higher soil erosion and less surface water supply drive the indicated ecological vulnerability.

# Identifying entry points for drought risk reduction

The differences between the spatial patterns of hazard and risk (Figure 4 to 7) have demonstrated that exposure and vulnerability assessments are crucial in order to understand where and how people and agricultural land are potentially impacted by drought. In order to reduce risk, these assessments can serve as a basis for the identification of entry points for risk reduction measures.

## South Africa

The risk assessment reveals that communal farmers and land in the east of Eastern Cape are subject to highest risk. This is in line with the risk assessment of Jordaan (2017a) who assessed three districts in different parts of Eastern Cape. Based on this local-level risk assessment, Jordaan (2017a) proposed a set of entry points and risk reduction measures for the selected municipalities of Eastern Cape, which have been developed in a participatory process with multi-sectoral stakeholders. Potential entry points are education, information access and networks, market access and insurance, awareness for land degradation and drought contingency plans. Measures may include:

## Ukraine

Ukraine has a highly advanced hazard monitoring system in place. With this policy report, we demonstrate the value of complementing the current monitoring system with information on drought exposure, vulnerability and risk. Based on this assessment, hotspots of drought vulnerability can be identified and drought risk can be better understood.

As the farming system in Ukraine is very different compared to South Africa, targeted risk reduction measures will most probably be different, although various drivers of vulnerability are comparable. Specific risk reduction measures need to be developed together with relevant stakeholders and affected people during a participatory process in the region. Based on the current assessment, general entry points may include:

- Effective mentorship programme based on experienced and successful farmers.
- Integration of communal farmers' interests in the country-wide farmers' association.
- Enhanced information access through mobile phones or information boards at, for example, district municipalities.
- Introduction of more drought-resistant crops and livestock.
- Establishment of micro-cooperatives to ensure high-quality market access.
- Reintroduction of soil conservation committees.
- Establishment of fodder banks/water reservoirs.

- Rural development programmes, in order to reduce unemployment, low income levels and outmigration.
- Conservation area planning, to improve robustness of the (agro)ecosystem.
- Agroforestry, to improve water holding capacity of the agroecosystem.



# Discussion and recommendations

This policy report demonstrates the importance of amending information on drought hazard conditions with knowledge and data on exposure and vulnerability based on case studies in South Africa and Ukraine. Such a comprehensive drought risk assessment allows for the identification of hotspots of drought risk and the defining of targeted entry points for disaster risk management and disaster risk reduction. Levels of exposure and vulnerability explain why moderate drought hazard conditions can lead to high impacts, while in other cases extreme droughts might not do so. This interplay of hazard, exposure and vulnerability determines the risk, which manifests in respective impacts during or after an event, such as crop failure or loss of income. However, it is very important to document the risk assessment approach in a transparent manner and critically reflect the results of any assessment before translating this into decision-making processes on the ground. The most relevant aspects that influence the outcome of such an assessment are quality and availability of appropriate data to quantify vulnerability indicators. In some cases, proxy data have been used for indicators, where specific data were missing. One example is the approximation of the indicator 'agriculture-dependent population' with the percentage of rural population per county in the Ukraine, which does not fully correspond to the agriculture-dependent population. Another example is that crop-specific vulnerability could not be considered in this assessment due to limited availability of crop-specific field data. Socio-economic data is often not available for all years considered and oftentimes does not cover for recent years.

In both countries, the drought hazard monitoring system is already well established. As a result of this research a combination of rainfall information, for example based on the SPI, and

a measure of vegetation response, for example based on the VCI, is considered the most accurate approach to assess agricultural drought hazard. Data on precipitation rates is still the most accurate when measured in situ based on meteorological stations. Moreover, the response to certain amounts of rainfall or its variability can be different depending on the region and its preconditions. VCI is considered a representative index to inform about the vegetation condition on the ground. Recommendations for further improvement of the methodology in the future may include the consideration of crop rotation while calculating the VCI, specifically in Ukraine, as well as improved data on soil moisture and more generally soil conditions in assessments.

Conducting a risk assessment builds on data that are hosted by different governmental agencies and institutions and requires multi-sectoral collaboration, both for assessing risk and defining targeted measures for reducing risk in a participatory approach. Besides the need for multi-sectoral stakeholder engagement, it is essential to consider and reflect the local and regional context on the ground.

With this policy report, we showcase the importance and relevance of combining hazard, exposure and vulnerability into one comprehensive risk assessment, which can complement existing drought hazard monitoring systems in order to understand drought risk better and develop specific measures for targeted drought risk reduction.

## EVIDENZ

The research has been conducted in the context of the collaborative EVIDENZ<sup>2</sup> project (Earth observation-based information products for drought risk reduction on the national level), which has been supported by the German Aerospace Center (DLR) Space Administration with funding from the German Federal Ministry for Economic Affairs and Energy (BMWi). It aims at demonstrating the relevance of exposure and vulnerability to understand agricultural drought risk in two selected case study areas, the Eastern Cape in South Africa and the Kiev region in Ukraine. It showcases how comprehensive risk assessments allow for customized designs of risk management strategies to support decision-making. The University of Bonn – Center for Remote Sensing of Land Surfaces provided the hazard assessment, while the United Nations University – Institute for Environment and Human Security was responsible for the assessments of exposure, vulnerability and risk. All procedures were further discussed and refined in close collaboration with the other partners of the EVIDENZ project, namely UN-SPIDER, as well as the partners from respective countries: the University of the Free State in South Africa and the Space Research Center in Ukraine.



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<sup>2</sup> <https://ehs.unu.edu/research/evidenz-earth-observation-based-information-products-for-drought-risk-reduction-on-the-national-level.html#outline>

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# Annex 1

Indicator	Measure	Author(s)	Data Source (Eastern Cape)	Data source (Kiev region)
<b>Unemployment</b>	Unemployment rate in % (+)	Borodina, 2009; Borodina and Borodina, 2007; Frayer, 2011; Keyzer, and others, 2012; Moroz, 2015; Skryzhevskaya and Karácsonyi, 2012 Jordaan, 2017b Jordaan, 2017a	StatSA, 2011b	UkrStat, 2015a
<b>Social dependency</b>	Rate of population at the age of 0-14 and >65 in % (+)	Keyzer, and others, 2012	StatSA, 2011b	UkrStat, 2015a
<b>Outmigration</b>	Outmigration 2011-2015 in % (2011=100) (+)	Frayer, 2011	-	Bespyatov, 1970-2018
<b>Government support</b>	Subsidies/capita in UAH (+)	Acs, and others, 2013; Borodina, 2009; Borodina and Borodina, 2007; Frayer, 2011; Lioubimtseva, and others, 2013; Lioubimtseva, and others, 2015; Moroz, 2015	-	KSE, 2014-2015; UkrStat, 2015a
<b>Income</b>	Average monthly wage (UAH) (-)	Borodina and Borodina, 2007; Chreneková, and others, 2016; Fileccia, and others, 2014; Frayer, 2011; Keyzer, and others, 2012; Moroz, 2015; Skryzhevskaya and Karácsonyi, 2012	-	UkrStat, 2015a
	Share of HH living from less than R9600/year (+)	Jordaan, 2017b	StatSA, 2011b	-
<b>Fertilizer use</b>	Fertilizer use (organic and mineral) in kg/ha (-)	Fileccia, and others, 2014; Frayer, 2011; Keyzer, and others, 2012; Lioubimtseva, and others, 2013; Lioubimtseva, and others, 2015; van Leeuwen, and others, 2012	-	UkrStat

Indicator	Measure	Author(s)	Data Source (Eastern Cape)	Data source (Kiev region)
<b>Soil quality</b>	Annual losses of soil in t/ha from water erosion (+)	Borodina, 2009; Bulygin, 2006; Fileccia, and others, 2014; Keyzer, and others, 2012; van Leeuwen, and others, 2012	-	Bulygin, 2000
	Soil erosion index (+)	Jordaan, 2017b	UCT, 2000	
<b>Crop rotation violation</b>	Area of crop rotation violation from 2013-2016 (+) (%)	Fileccia, and others, 2014; Frayer, 2011; Keyzer, and others, 2012	-	NASU-SSAU, 2013-2016
<b>Conservation areas</b>	Conservation area in % (-)	Keyzer, and others, 2012	-	OSM, 2018
<b>Surface water supply</b>	Surface water in % (-)	Mens, and others, 2015	-	KSE, 2014-2015
	Surface water/agricultural land ratio (+)	Jordaan, 2017b	DEA, 2015	
<b>Forest area</b>	Ratio of forest area and agricultural land (-)	Keyzer, and others, 2012	-	KSE, 2014-2015
<b>Education</b>	% of HH without formal education (+)	Jordaan, 2017b	StatSA, 2011a	
<b>Stock theft</b>	Number of stock thefts per 1000 HH (+)	Jordaan, 2017b	ECSECC Database, 2016	
<b>Age</b>	% of HH between the age of 15 and 55 (-)	Jordaan, 2017b	StatSA, 2011a	
<b>Gender</b>	Gender parity (% unemployment female/% unemployment male) (+)	Jordaan, 2017b	StatSA, 2014	
<b>Access to infrastructure</b>	Infrastructure index (+)	Jordaan, 2017b	ECSECC, 2012	
<b>Access to information</b>	% of HH with access to internet (+)	Jordaan, 2017b	StatSA, 2011b	
<b>Alternative on-farm income</b>	% of agricultural HH in other agricultural activities (+)	Jordaan, 2017b	StatSA, 2011a	
<b>Soil fertility</b>	Clay content and base status of the soil index (+)	Jordaan, 2017b	UCT, 2000	
<b>Legend</b>	(+) the higher the value, the higher the vulnerability (-) the lower the value, the higher the vulnerability			

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