UNITED NATIONS
UNIVERSITY

UNU-EHS
Institute for Environment
and Human Security

UNU-EHS PUBLICATION SERIES
POLICY REPORT 2018
NO. 3

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

Authors: Yvonne Walz, Karen Dall,
Valerie Graw, Juan-Carlos Villagran de Leon,
Nataliia Kussul, Andries Jordaan

**This report should be cited as:**

Walz, Y., and others (2018). Understanding and reducing agricultural drought risk:
Examples from South Africa and Ukraine, Policy Report No.3.
Bonn: United Nations University – Institute for Environment and Human Security (UNU-EHS).

EvIDENz

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

UNIVERSITÄT BONN

ZFL

UNITED NATIONS UNIVERSITY
UNU-EHS
Institute for Environment and Human Security

UNITED NATIONS
Office for Outer Space Affairs
UN-SPIDER

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

ІКД

# Table of contents

# 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: ssemmens_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[1] 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 |

[1] *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

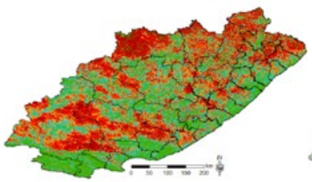

*Figure 4: Median VCI 11/2015-05/2016*

*Source: ZFL*

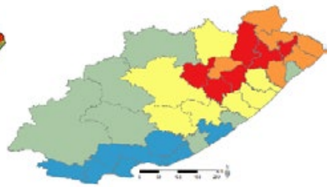

*Figure 5: Agricultural drought risk after 2015/2016*

*Source: UNU-EHS*

## Kiev region

### Ukraine

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

*Source: ZFL*

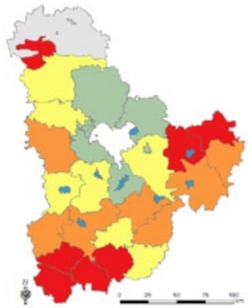

*Figure 7: Agricultural drought risk after 2015/2016*

*Source: UNU-EHS*

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

- D0 (VCI>40)
- D1 (VCI >30-40)
- D2 (VCI >20-30)
- D3 (VCI 10-20)
- D4 (VCI <10)

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

- Very low
- Low
- Moderate
- High
- Very high
- Chernobyl Zone (Ukraine)

## 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

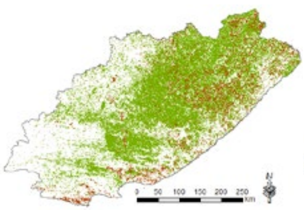


*Figure 8: Distribution of grassland and cropland in Eastern Cape.*

*Data source: DEA, 2015*

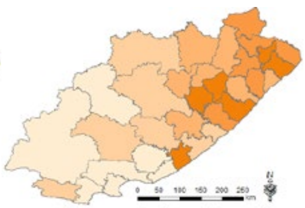


*Figure 9: Share of agricultural households (HH) per municipality (%) based on quantile classification in Eastern Cape.*

*Data source: StatSA, 2011a*

**Land cover**

- Grassland
- Cropland

**Share of agricultural HH (%)**

- 3 - 12
- 12 - 27
- 27 - 35
- 35 - 38
- 38 - 40

## Kiev region

### Ukraine


*Figure 10: Distribution of cropland in Kiev region.*

*Data source: based on NASU-SSAU, 2015*

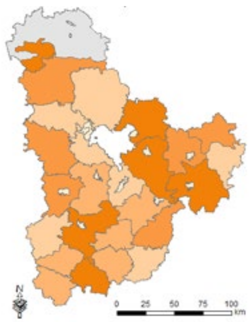


*Figure 11: Share of rural population per county (%) based on quantile classification in Kiev region.*

*Data source: UkrStat, 2015b*

**Land cover**

- Water
- Cropland
- Other

**Share of rural pop. (%)**

- 0
- <56
- 56 - 65
- 65 - 70
- 70 - 100
- Chernobyl Zone (Ukraine)

## 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

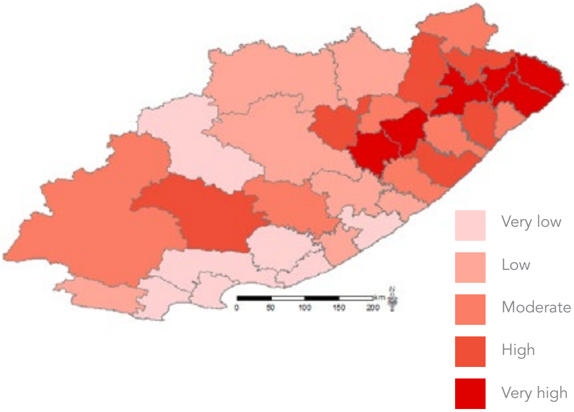


*Figure 12: Drought vulnerability in Eastern Cape based on indicator set for South Africa (see Annex 1). Map classification according to quantile method.*

*Source: UNU-EHS*

## Kiev region

### Ukraine

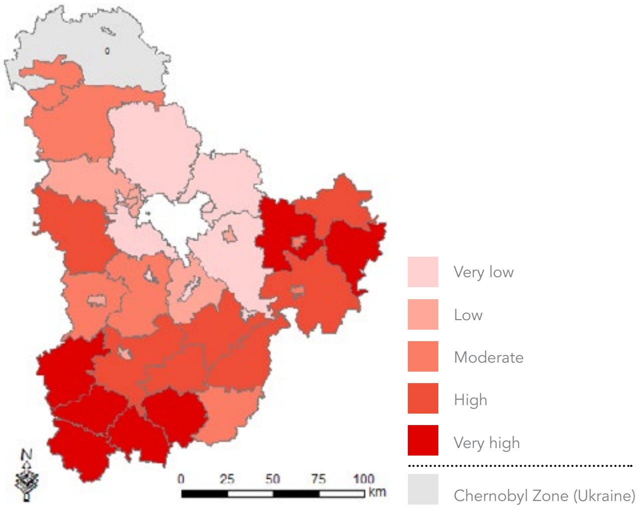


*Figure 13: Drought vulnerability in Kiev region based on indicator set for Ukraine (see Annex 1). Map classification according to quantile method.*

*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[2] 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.

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

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

# References


Acs, Szvetlana, and others (2013). Ukraine's agriculture: potential for expanding grain supply. Economic and institutional challenges. European Commission, Joint Research Centre. Available at https://ideas.repec.org/p/ipt/iptwpa/jrc84652.html

Adamenko, Tatyana (2017). *Agricultural drought monitoring in Ukraine: Presentation during EvIDENz Workshop 2017*. Ukrainian Hydrometeorological Centre.

Adamenko, Tatyana, and Anatoly Prokopenko (2011). Monitoring Droughts and Impacts on Crop Yields in Ukraine from Weather and Satellite Data. In *Use of Satellite and In-Situ Data to Improve Sustainability*, Felix Kogan, and others, eds. Available at https://link.springer.com/content/pdf/bfm%3A978-90-481-9618-0%2F1.pdf

Baudoin, Marie-Ange, and others (2017). Living with drought in South Africa: Lessons learnt from the recent El Niño drought period. In *International Journal of Disaster Risk Reduction*, Vol. 23, pp. 128–137. Available at https://www.sciencedirect.com/science/article/pii/S2212420917300985?via%3Dihub

Bespyatov, Tim (1970-2018). Division of Ukraine. Available at http://pop-stat.mashke.org/ukraine-division-monthly2018.htm. Accessed on 18 July, 2018.

Bhuiyan, Chandrashekha, and others (2017). Analyzing the impact of thermal stress on vegetation health and agricultural drought – a case study from Gujarat, India. In *GIScience and Remote Sensing*, Vol. 54, No.5, pp. 678–699. Available at https://doi.org/10.1080/15481603.2017.1309737

Boken, Vijendra, and others (2005). *Monitoring and predicting agricultural drought: A global study*. Oxford: Oxford University Press.

Borodina, Elena, and Alexandra Borodina (2007). Transformation of agricultural sector of Ukrainian economics: some social and economic results. *What was expected, what we observed, the lessons learned*. Budapest, Hungary. 6 – 8 September, pp. 1–11.

Borodina, Oleksandra (2009). *Food Security and Socioeconomic Aspects of Sustainable Rural Development in Ukraine*. International Institute for Applied Systems Analysis. Available at http://pure.iiasa.ac.at/9103/1/IR-09-053.pdf. Accessed 21 July, 2017.

Bulygin, Sergey (2000). Potential annual loss of soil. Ukrainian National Scientific Institute for Soil Science and Agrochemistry.

Bulygin, Sergey (2006). Ukraine. In *Soil erosion in Europe*, John Boardman and Jean Poesen, eds. Chichester, England: J. Wiley & Sons, pp. 199–204. Available at https://onlinelibrary.wiley.com/doi/10.1002/0470859202.ch36

Chreneková, Marcela, and others (2016). Informal Employment and Quality of Life in Rural Areas of Ukraine. *In European Countryside*, Vol. 8, No. 2, pp. 135–146. Available at https://content.sciendo.com/view/journals/euco/8/2/article-p135.xml

DAFF (2016). *Abstract of agricultural statistics*. South African Department of Agriculture, Forestry and Fisheries. Available at https://www.daff.gov.za/Daffweb3/Portals/0/Statistics%20and%20Economic%20Analysis/Statistical%20Information/Abstract%202016%20.pdf. Accessed 11 July, 2018.

DAFF (2018). *Abstract of agricultural statistics*. South African Department of Agriculture, Forestry and Fisheries. Available at http://www.daff.gov.za/Daffweb3/Portals/0/Statistics%20and%20Economic%20Analysis/Statistical%20Information/Abstract%202018.pdf. Accessed 10 July, 2018.

DEA (2015). *2013-14 National Land-Cover – 72 classes*. Department of Environmental Affairs. Available at https://egis.environment.gov.za/gis_data_downloads. Accessed 1 June, 2018.

Didan, Kamel, and others (2015). *MODIS VI (MOD13) C5 User's Guide*. University of Arizona. Available at https://lpdaac.usgs.gov/sites/default/files/public/product_documentation/mod13_user_guide.pdf. Accessed 7 May, 2016.

ECSECC (2012). *Eastern Cape Socio-Economic Atlas*. Eastern Cape Socio Economic Consultative Council. Available at https://www.ecsecc.org/documentrepository/informationcentre/ECSECC_Socio_Economic_Atlas.pdf. Accessed 1 January, 2018.

ECSECC Database (2016). *Eastern Cape Socioeconomic Database 2016*. Eastern Cape Socio Economic Consultative Council. Available at https://www.ecsecc.org/information-centre/item/eastern-cape-socio-economic-database-2016. Accessed 1 June, 2018.

Esri, DeLorme Publishing Company, Inc. (2001). Major Cities. TechCenterJefferson. Available at http://techcenter.jefferson.kctcs.edu/data/. Accessed 26 July, 2018.

Esri, DeLorme Publishing Company, Inc. (2017). *World Countries*. Available at https://www.arcgis.com/home/item.html?id=ac80670eb213440ea5899bbf92a04998. Accessed 25 July, 2018.

Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community (2018). *World Imagery*. Available at http://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9. Accessed 25 July, 2018.

Fileccia, Turi, and others (2014). *Ukraine: Soil Fertility to Strengthen Climate Resilience*. World Bank. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/20678/918500WP0UKRAI0E0Box385344B00OUO090.pdf?sequence=1&isAllowed=y

Frayer, Oleksiy (2011). *Agricultural Production Intensification in Ukraine: Decision Support of Agricultural Policies Based On the Assessment of Ecological and Social Impacts in Rural Areas: Interim Report*. International Institute for Applied Systems Analysis. Available at https://core.ac.uk/download/pdf/52951623.pdf

GADM (2018). *Global administrative boundaries*. Global Administrative Boundaries. Available at https://gadm.org/data.html. Accessed 25 July, 2018.

Hayes, Michael, and others (2012). Drought Monitoring: Historical and Current Perspectives. In *Remote sensing of drought: Innovative monitoring approaches*, Brian Wardlow, and others, eds. Boca Raton, FL, CRC Press, pp. 1–19. Available at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1095&context=droughtfacpub

IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. IPCC. Available at http://www.ipcc.ch/report/ar5/wg2/. Accessed 11 May, 2018.

Jordaan, Andries, ed (2017a). *Vulnerability, adaptation to and coping with drought: The case of commercial and subsistence rain fed farming in Eastern Cape: Volume I*. WRC. Available at http://www.wrc.org.za/Knowledge%20Hub%20Documents/Research%20Reports/TT%20716-17.pdf. Accessed 5 December, 2017.

Jordaan, Andries, ed (2017b). *Vulnerability, adaptation to and coping with drought: The case of commercial and subsistence rain fed farming in Eastern Cape: Volume II*. WRC. Available at http://www.wrc.org.za/Knowledge%20Hub%20Documents/Research%20Reports/TT%20716-2-17.pdf. Accessed 29 January, 2018.

Keyzer, Michiel, and others (2012). *Farming and rural development in Ukraine: making dualisation work*. European Commission, Joint Research Centre. Available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC80164/jrc%2080164.pdf

Kogan, Felix (2001). Operational Space Technology for Global Vegetation Assessment. In *Bulletin of the American Meteorological Society*, Vol. 82, No. 9, pp. 1949–1964. Available at https://journals.ametsoc.org/doi/abs/10.1175/1520-0477%282001%29082%3C1949%3AOSTFGV%3E2.3.CO%3B2

Kogan, Felix, and others (2013). Global and regional drought dynamics in the climate warming era. In *Remote Sensing Letters*, Vol. 4, No. 4, pp. 364−372. Available at https://www.tandfonline.com/doi/abs/10.1080/2150704X.2012.736033

Kozlovska, Nadiya (2015). Kyiv region agricultural development in the context of the capital city impact. In *Ukrainian Geographical Journal*, Vol. 2015, No. 1, pp. 50–57.

KSE (2014-2015). *Land Governance Monitoring: Data base 2014-2015*. Kyiv School of Economics. Available at http://www.kse.org.ua/en/research-policy/land/governance-monitoring/database-2014-2015/. Accessed 18 July, 2018.

Lioubimtseva, Elena, and others (2013). Grain Production Trends in Russia, Ukraine and Kazakhstan in the Context of the Global Climate Variability and Change. In *Climate Change and Water Resources*, Younos, T. and Grady, C. A. (eds). Berlin Heidelberg, Springer, pp. 121–141. Available at https://link.springer.com/chapter/10.1007%2F698_2013_225

Lioubimtseva, Elena, and others (2015). Grain Production Trends in the Russian Federation, Ukraine and Kazakhstan in the Context of Climate Change and International Trade. In *Climate change and food systems: global assessments and implications for food security and trade*, Aziz Elbehri (ed). Rome: FAO, pp. 212–237. Available at http://www.fao.org/3/a-i4332e.pdf

Liu, William, and Kogan, Felix (1996). Monitoring regional drought using the Vegetation Condition Index. In *International Journal of Remote Sensing*, Vol. 17, No. 14, pp. 2761−2782. Available at https://www.tandfonline.com/action/showCitFormats?doi=10.1080%2F01431169608949106

Malherbe, Johann, and others (2016). South African droughts and decadal variability. In *Natural Hazards*, Vol. 80, No. 1, pp. 657−681.

Mens, Marjolein, and others (2015). Developing system robustness analysis for drought risk management: An application on a water supply reservoir. In *Natural Hazards and Earth System Science*, Vol. 15, No. 8, pp. 1933−1940. Available at https://www.nat-hazards-earth-syst-sci.net/15/1933/2015/nhess-15-1933-2015.pdf

Moroz, Serhiy (2015). Employment in rural areas of Ukraine: Tendencies and opportunities. In *Studia Obszarów Wiejskich*, Vol. 38, pp. 39−54.

NASU-SSAU (2013-2016). *Crop rotation violation maps*. Space Research Institute.

NASU-SSAU (2015). Land cover and crop map. Space Research Institute.

OSM (2018). *OSM Data Extracts for Nature Conservation*. Open Street Map. Available at http://opengeo.intetics.com.ua/osm/pa/. Accessed 18 July, 2018.

Shelestov, Andrii, and others (2017). Exploring Google Earth Engine Platform for Big Data Processing: Classification of Multi-Temporal Satellite Imagery for Crop Mapping. In *Frontiers in Earth Science*, Vol. 5, p. 4225. Available at https://www.frontiersin.org/articles/10.3389/feart.2017.00017/full

Skryzhevska, Yelizaveta, and David Karácsonyi (2012). Rural population in Ukraine: Assessing reality, looking for revitalization. In *Hungarian Geographical Bulletin*, Vol. 61, No. 1, pp. 49–78. Available at https://www.researchgate.net/publication/287112056_Rural_population_in_Ukraine_Assessing_reality_looking_for_revitalization

Ssemmens_hmhs (2015). *ZA Population Centers.* Available at http://www.arcgis.com/home/item.html?id=923437746e464105b36305787a629506. Accessed 25 July, 2018.

StatSA (2007). *Census of commercial agriculture, 2007, Eastern Cape: Provincial statistics for selected products. Statistics South Africa*. Available at http://www.instepp.umn.edu/sites/default/files/product/downloadable/RSA_2007_03_EC.pdf. Accessed 11 July, 2018.

StatSA (2011a). *Agricultural households municipal data per province*. Statistics South Africa. Available at http://www.statssa.gov.za/agricultural_household_provinces/Eastern%20Cape.xlsx. Accessed 11 July, 2018.

StatSA (2011b). Agricultural statistics. Statistics South Africa. Available at http://www.statssa.gov.za/?page_id=735&id=4. Accessed 10 July, 2018.

StatSA (2014). *Gender Series Volume I: Economic Empowerment, 2001-2014*. Statistics South Africa. Available at http://www.statssa.gov.za/publications/Report-03-10-04/Report-03-10-042014.pdf. Accessed 1 June, 2018.

ThematicMapping.org (2009). *World borders dataset.* Available at http://thematicmapping.org/downloads/. Accessed 26 July, 2018.

UCT (2000). *National Review of Land Degradation in South Africa*. University of Cape Town. Available at http://www.pcu.uct.ac.za/pcu/resources/databases/landdegrade/studydata. Accessed 1 June, 2018.

UHMC (2012). Agrometeorology. Ukrainian Hydrometeorological Centre. Available at http://meteo.gov.ua/en/. Accessed 10 May, 2018.

UkrStat. Use of fertilizers for agricultural crops. Ukrainian State Statistics.

UkrStat (2015a). Statistical yearbook of Kiev oblast. Ukrainian State Statistics.

UkrStat (2015b). The number of the existing population of the Kiev region as of January 1, 2015. Ukrainian State Statistics. Available at http://oblstat.kiev.ukrstat.gov.ua/content/Docs/ZB_chis_nayav_ta_post_nas.pdf. Accessed 10 October, 2017.

UkrStat (2018). Gross domestic product by production method and gross value added by type of economic activity. Ukrainian State Statistics. Available at https://ukrstat.org/en/operativ/operativ2008/vvp/vvp_ric/vtr_e.htm. Accessed 10 May, 2018.

UNISDR (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction*. United Nations Office for Disaster Risk Reduction. Available at https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf. Accessed 10 May, 2018.

UNOCHA (2018). *Ukraine administrative level 0, 1, 2, 3 and 4 boundaries*. United Nations Office for the Coordination of Humanitarian Affairs. Available at https://data.humdata.org/dataset/ukraine-administrative-boundaries-as-of-q2-2017. Accessed 26 July, 2018.

van Leeuwen, Myrna, and others (2012). *The agri-food sector in Ukraine: Current situation and market outlook until 2025: Extension of the AGMEMOD model towards Ukraine*. JRC Scientific and Policy Reports. Available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC71776/lfna25444enn.pdf

# Annex 1

| Indicator | Measure | Author(s) | Data Source (Eastern Cape) | Data source (Kiev region) |
|---|---|---|---|---|
| **Unemployment** | Unemployment rate in % (+) | Borodina, 2009;<br>Borodina and<br>Borodina, 2007;<br>Frayer, 2011;<br>Keyzer, and others, 2012; Moroz, 2015;<br>Skryzhevska and Karácsonyi, 2012<br>Jordaan, 2017b<br>Jordaan, 2017a | StatSA, 2011b | UkrStat, 2015a |
| **Social dependency** | Rate of population at the age of 0-14 and >65 in % (+) | Keyzer, and others, 2012 | StatSA, 2011b | UkrStat, 2015a |
| **Outmigration** | Outmigration 2011-2015 in % (2011=100) (+) | Frayer, 2011 | - | Bespyatov, 1970-2018 |
| **Government support** | Subsidies/capita in UAH (+) | Acs, and others, 2013; Borodina, 2009; Borodina and Borodina, 2007; Frayer, 2011;<br>Lioubimtseva, and others, 2013; Lioubimtseva, and others, 2015; Moroz, 2015 | - | KSE, 2014-2015; UkrStat, 2015a |
| **Income** | Average monthly wage (UAH) (-) | Borodina and Borodina, 2007; Chreneková, and others, 2016; Fileccia, and others, 2014; Frayer, 2011; Keyzer, and others, 2012; Moroz, 2015; Skryzhevska and Karácsonyi, 2012 | - | UkrStat, 2015a |
| | Share of HH living from less than R9600/year (+) | Jordaan, 2017b | StatSA, 2011b | - |
| **Fertilizer use** | 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) |
|---|---|---|---|---|
| **Soil quality** | 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 | |
| **Crop rotation violation** | Area of crop rotation violation from 2013-2016 (+) (%) | Fileccia, and others, 2014; Frayer, 2011; Keyzer, and others, 2012 | - | NASU-SSAU, 2013-2016 |
| **Conservation areas** | Conservation area in % (-) | Keyzer, and others, 2012 | - | OSM, 2018 |
| **Surface water supply** | Surface water in % (-) | Mens, and others, 2015 | - | KSE, 2014-2015 |
| | Surface water/agricultural land ratio (+) | Jordaan, 2017b | DEA, 2015 | |
| **Forest area** | Ratio of forest area and agricultural land (-) | Keyzer, and others, 2012 | - | KSE, 2014-2015 |
| **Education** | % of HH without formal education (+) | Jordaan, 2017b | StatSA, 2011a | |
| **Stock theft** | Number of stock thefts per 1000 HH (+) | Jordaan, 2017b | ECSECC Database, 2016 | |
| **Age** | % of HH between the age of 15 and 55 (-) | Jordaan, 2017b | StatSA, 2011a | |
| **Gender** | Gender parity (% unemployment female/% unemployment male) (+) | Jordaan, 2017b | StatSA, 2014 | |
| **Access to infrastructure** | Infrastructure index (+) | Jordaan, 2017b | ECSECC, 2012 | |
| **Access to information** | % of HH with access to internet (+) | Jordaan, 2017b | StatSA, 2011b | |
| **Alternative on-farm income** | % of agricultural HH in other agricultural activities (+) | Jordaan, 2017b | StatSA, 2011a | |
| **Soil fertility** | Clay content and base status of the soil index (+) | Jordaan, 2017b | UCT, 2000 | |
| **Legend** | (+) the higher the value, the higher the vulnerability<br>(–) the lower the value, the higher the vulnerability | | | |

# Imprint

United Nations University
Institute for Environment and Human Security (UNU-EHS)

UN Campus, Hermann-Ehlers-Str. 10, 53113 Bonn, Germany

Tel.: + 49-228-815-0200, Fax: + 49-228-815-0299

e-mail: info@ehs.unu.edu



Layout: Aileen Orate
Proofreading: Stephen Boyle, Zita Sebesvari, Nadine Hoffmann



e-ISSN: 2075-0501

e-ISBN: 978-3-944535-59-3



For further information: www.ehs.unu.edu

# About UNU-EHS

The United Nations University (UNU) is a global think tank and the academic arm of the United Nations. The mission of the Institute for Environment and Human Security (UNU-EHS) is to carry out cutting edge research on risks and adaptation related to environmental hazards and global change. The institute's research promotes policies and programmes to reduce these risks, while taking into account the interplay between environmental and societal factors.

→ www.ehs.unu.edu