A. Global Drought Hazard and Risk Models

Platforms

A1 Standardized Precipitation Index - IRI data library

This platform can be used to obtain information of meteorological drought hazards on a monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SP1-1, SPI-3, SPI-6, SPI-9, SPI-12			
Countries where available:	Global			
Period available:	From:	01/01/1979	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: This map shows the Standardized Precipitation Index (SPI) for multiple monthly accumulation periods for the globe.				

Contact information	
Link to online tools:	https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/SPI.html#tabs-2
Organization:	IRI (International Research Institute for climate and society)
Contact person:	N/A
Contact details:	help@iri.columbia.edu
Resource:	N/A

Data and links	
Data used:	CAMS_OPI monthly precipitation on a 2.5° lat/lon grid
Data format:	Multiple including OPeNDAP, NETCDF, 2-Dimentional ascii file, GeoTIFF Image, Binary, Text
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	2.5°			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90

Temporal scale:	Monthly
Aggregation period:	1, 3, 6, 9, 12 months
Latency:	near real-time

Quality, remarks, and references
References / supplementary information: Guttman, N. B., 1999: Accepting the Standardized Precipitation Index: A calculation algorithm. J. Amer. Water Resour. Assoc.., 35(2), 311-322. McKee, T. B., N. J. Doesken, and J. Kliest, 1993: The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, CA. American Meteorological Society, Boston, MA. 179-184.
Strengths: Near real-time dataset in a variety of formats
Weaknesses: N/A
Final remarks: Extreme values of the SPI based on this version of the CAMS_OPI dataset should be interpreted with caution

A2 Global Drought Observatory

This platform can be used to obtain near real-time information of meteorological, hydrological, and agricultural drought hazards on a weekly basis for the world, as well as the likelihood of drought impact per country.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard, Mapping likelihood of drought impact			
Indicator(s) included: Likelihood of drought impact (LDI), Daily Soil Moisture, Daily Soil Moisture Anomaly, SPI, Snowpack Indicator, Vegetation Productivity, Vegetation Productivity Anomaly (VPA).				
Countries where available:	Global			
Period available:	From:	1975	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Portal that presents near real-time information on multiple drought indicators: Likelihood of drought impact (LDI), Daily Soil Moisture, Daily Soil Moisture Anomaly, SPI at SYNOP stations from the MARS database, SPI at SYNOP stations interpolated to 0.25dd grid, Snowpack Indicator, Spatial average of SPI at SYNOP stations, interpolated SPI for Eurostat NUTS3 regions, Vegetation Productivity, Vegetation Productivity Anomaly. Different drought indicators have a different temporal and spatial resolution and a different length of time-period				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/gdo
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	N/A

Data and links	
Data used:	Different data-sources per indicator
Data format:	PNG images
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			

Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Weekly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This platform can be used to obtain information and data of meteorological, hydrological, and agricultural drought hazards.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included: hydrological variables (precip, (potential) evap, runoff, discharge, soil moisture, snow pack, snowfall), drought indicators: SPI, SPEI, SRI, SSFI, SSMI				
Countries where available:	Global			
Period available:	From:	1979	To:	2012
Costs involved in obtaining the tool:	none			
Concise model description: Earth2Observe project provides a repository of hydrological variables and drought indicators (upcoming). Tier 1 data is available from 1979 - 2012, Tier 2 will be provided over a period of 1980-2014				

Contact information	
Link to online tools:	https://wci.earth2observe.eu/
Organization:	Earth2Observe project - lead Deltares
Contact person:	Deltares
Contact details:	contact form: http://www.earth2observe.eu/?page_id=86
Resource:	N/A

Data and links	
Data used:	WFDEI functions as forcing data. Multiple hydrological models are run with this input dataset
Data format:	netcdf
Data requirements:	netcdf reader

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5, 0.25			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	daily, monthly			
Aggregation period:	drought indicators: 1, 3, 6, 12, 24, 36 months			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: Verification results: http://earth2observe.github.io/water-resource-reanalysis-v1/results/ilamb.html Jaap Schellekens, Emanuel Dutra, Gianpaolo Balsamo, Albert van Dijk, Frederiek Sperna Weiland, Marie Minvielle, Jean-Christophe Calvet, Bertrand Decharme, Stephanie Eisner, Gabriel Fink, Martina Flörke, Stefanie Peßenteiner, Rens van Beek, Jan Polcher, Hylke Beck, Alberto Martínez-de la Torre, René Orth, Ben Calton, Sophia Burke, Wouter Dorigo and Graham P. Weedon (in press in ESSD). A global water resources ensemble of hydrological models: the eartH2Observe Tier-1 dataset
Strengths: repository of datasets covering multiple global hydrological models, multiple spatial and temporal scales.
Weaknesses: Not all data available online yet.
Final remarks: peer reviewed (models)

A4 NOAA Global Drought Map

This platform can be used to obtain near real-time information of meteorological drought hazards on a monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-1,SPI-2,SPI-3,SPI-6,SPI-9,SPI-12,SPI-24			
Countries where available:	Global - stations			
Period available:	From:	2007	To:	near real-time
Costs involved in obtaining the tool:	none			
Concise model description: Provides station based SPI from 2007 onward. Provides also gridded SPI but not over time. Data can only be downloaded as point data.				

Contact information	
Link to online tools:	https://gis.ncdc.noaa.gov/maps/ncei/drought/global
Organization:	NOAA
Contact person:	N/A
Contact details:	ncei.orders@noaa.gov
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	stations			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	monthly			
Aggregation period:	1, 2, 3, 6, 9, 12, 24 months			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A

Strengths: Provides station based SPI
Weaknesses: No timeseries of gridded SPI available for download
Final remarks: N/A

A5 SPEI global drought monitor

This platform can be used to obtain near real-time information of meteorological drought hazards on a monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPEI-1, SPEI-3, SPEI-6, SPEI-9, SPEI-12, SPEI-24, SPEI-36, SPEI-48			
Countries where available:	Global			
Period available:	From:	1955	To:	near real-time
Costs involved in obtaining the tool:	None. See Licensing at http://spei.csic.es/map			
Concise model description: The SPEI Global Drought Monitor offers near real-time information about drought conditions at the global scale, with a 0.5 degrees spatial resolution and a monthly time resolution. SPEI time-scales between 1 and 48 months are provided. The calibration period for the SPEI is January 1950 to December 2010. The dataset is updated during the first days of the following month based on the most reliable and updated sources of climatic data.				

Contact information	
Link to online tools:	http://spei.csic.es/map/maps.html#months=1#month=4#year=2017
Organization:	Consejo Superior de Investigaciones Científicas (CSIC)
Contact person:	Santiago Beguería, Borja Latorre, Fergus Reig, Sergio M. Vicente-Serrano
Contact details:	Santiago Beguería: (0034) 976 716 158, Sergio M. Vicente-Serrano: (0034) 976 716 141, Or send a question from the 'Contact' tab
Resource:	The SPEI R library allows computing the SPEI and includes a set of additional functionalities and options. It can be obtained from the Comprehensive R Archive Network, CRAN.

Data and links	
Data used: Mean temperature data are obtained from the NOAA NCEP CPC GHCN_CAMS gridded dataset. Monthly precipitation sums data are obtained from the Global Precipitation Climatology Centre (GPCC). Data from the 'first guess' GPCC product, with an original resolution of 1º, are interpolated to the resolution of 0.5º. Currently, the SPEI Global Drought Monitor is based on the Thortnthwaite equation for estimating potential evapotranspiration, PET.	
Data format:	netcdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5°			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Monthly			
Aggregation period:	1, 3, 6, 9, 12, 24, 36, 48 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: Vicente-Serrano S.M., Santiago Beguería, Juan I. López-Moreno, (2010) A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index - SPEI. Journal of Climate 23: 1696-1718. Beguería, S., Vicente-Serrano, S.M. y Angulo, M., (2010): A multi-scalar global drought data set: the SPEIbase: A new gridded product for the analysis of drought variability and impacts. Bulletin of the American Meteorological Society. 91, 1351-1354 Vicente-Serrano, S.M., Beguería, S., López-Moreno, J.I., Angulo, M., El Kenawy, A. (2010): A new global 0.5° gridded dataset (1901-2006) of a multiscalar drought index: comparison with current drought index datasets based on the Palmer Drought Severity Index. Journal of Hydrometeorology. 11: 1033-1043
Strengths: The main advantage of the SPEI Global Drought Monitor is its near real-time character, a characteristic best suited for drought monitoring and early warning purposes
Weaknesses: For long-term analysis, other datasets are to be preferred that rely on more robust methods of PET estimation. Use of the SPEIbase dataset (covers the period between January 1901 and December 2015), which is based on the FAO-56 Penman-Monteith model, is thus recommended for climatological studies of drought.
Final remarks: N/A

A6 Global Drought Information System / National Integrated Drought Information System

This platform can be used to obtain recent information (current conditions) of meteorological drought hazards on a monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-1, SPI-2, SPI-3, (station-based), vegetation health index			
Countries where available:	Global			
Period available:	From:	near real-time	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: N/A				

Contact information	
Link to online tools:	https://www.drought.gov/gdm/current-conditions
Organization:	NOAA
Contact person:	N/A
Contact details:	ncei.orders@noaa.gov tel:1-828-271-4800
Resource:	N/A

Data and links	
Data used:	NOAA NCEP CPC CAMS_OPIv0208 USGS LandDAAC MODIS 250m
Data format:	Image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Monthly			
Aggregation period:	1, 2, 3 months			
Latency:	near real-time			

Quality, remarks, and references

References / supplementary information: N/A
Strengths: Current drought situation for stations
Weaknesses: The platform provide the current drought situation as images, but the data cannot be downloaded
Final remarks: N/A

This platform can be used to obtain near real-time information of meteorological and agricultural drought hazards on a monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	SPI-1,SPI-6,SSI-1,SSI-6,MSDI-1,MSDI-6			
Countries where available:	Global			
Period available:	From:	1980	To:	2016
Costs involved in obtaining the tool:	none			
Concise model description: The Global Integrated Drought Monitoring and Prediction System (GIDMaPS) is a drought monitoring and prediction system that provides near real-time drought information based on multiple drought indicators and input data sets.				

Contact information	
Link to online tools:	http://drought.eng.uci.edu/
Organization:	University of California - Irvine
Contact person:	Amir Aghakouchak
Contact details:	amir.a@uci.edu
Resource:	N/A

Data and links	
Data used: MERRA - NASA Modern-Era Retrospective analysis for Research and Applications-Land (Reichle et al., 2011) NLDAS - NASA North AmericanLand Data Assimilation System (Kumar et al., 2006) GLDAS - NASA Global Land Data Assimilation System (Peters-Lidard et al., 2007) GDCDR - Global Drought Climate Data Record (AghaKouchak and Nakhjiri, 2012) - Combination of GPCP (Adler et al., 2001) and PERSIANN (Sorooshian et al., 2000; Hsu et al., 1997)	
Data format:	png image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	varying from 2/3 (lon) up to 1/8 (lat/lon)			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	monthly			

Aggregation period:	varying: SPI, SSI, MSDI: 1 and 6 month
Latency:	N/A

Quality, remarks, and references
References / supplementary information: Hao Z., AghaKouchak A., 2013a, Multivariate Standardized Drought Index: A Parametric Multi-Index Model, Advances in Water Resources, 57, 12-18, doi: 10.1016/j.advwatres.2013.03.009. (pdf) Hao Z., AghaKouchak A., 2013b, A Nonparametric Multivariate Multi-Index Drought Monitoring Framework, Journal of Hydrometeorology, in revision. AghaKouchak A., and Nakhjiri N., 2012, A Near Real-Time Satellite-Based Global Drought Climate Data Record, Environmental Research Letters, 7(4), 044037, doi:10.1088/1748-9326/7/4/044037. (pdf)
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

A8 IWMI water data portal

This platform can be used to obtain information of socio-economic drought hazards for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Socio-economic			
Applications:	mapping socio-economic drought hazard, drought risk mapping			
Indicator(s) included: SDVI, drought risk index with respect to monthly precipitation, drought risk index with respect to monthly river discharge, mean drought run duration (months), storage-drought duration (length) index, storage-drought deficit index				
Countries where available:	Global (focus on Africa, South-America and Asia)			
Period available:	From:	Static	To:	Static
Costs involved in obtaining the tool:	none			
Concise model description: Refers to various baseline data-sets: Gridded population of the world, World Water Development report database, World Development Indicators, Global Assessment of Human-induced Soil Degradation, Global Land Use Dataset, FAO Digital media Series, AQUASTAT, ProdSTAT, World register of dams, Earthtrends searchable database, World's water database, state of water database (static layers, no time-series)				

Contact information	
Link to online tools:	http://waterdata.iwmi.org/Applications/Drought_Patterns_Map/
Organization:	IWMI
Contact person:	Nishadi Eriyagama
Contact details:	n.eriyagama@cgiar.org
Resource:	N/A

Data and links
Data used: Gridded Population of the World, version 3 (GPWv3) World Water Development Report II (WWDRII) database World Development Indicators (WDI) Global Assessment of Human-induced Soil Degradation (GLASOD) Global Land Use Dataset FAO Digital Media Series AQUASTAT ProdSTAT World Register of Dams compiled by the International Commission on Large Dams (ICOLD) Earthtrends Searchable Database World's Water database State of Water database

Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	shapefiles - administrative boundaries for some indices for gridded indices			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	static (1 layer per topic)			
Aggregation period:	Static data			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: Eriyagama, N., Smakhtin, V., Gamage, N. (2009) Mapping Drought Patterns and Impacts: A Global Perspective. IWMI research report 133. http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB133/RR133.pdf
Strengths: A good variety of drought impact indices is presented.
Weaknesses: Webviewer does not show the full global extend, but has its focus on Africa, South America and Asia. Data cannot be downloaded, only visualized
Final remarks: N/A

A9 Aqueduct Water Risk Atlas

This platform can be used to obtain static, global information of meteorological, hydrological, agricultural, socio-economic drought hazards as well as drought risk to the overall economy.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Socio-economic			
Applications:	Mapping drought risk to the overall economy, Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard, mapping socio-economic drought hazard			
Indicator(s) included: Overall water risk, baseline water stress, inter-annual variability, seasonal variability, flood occurrence, drought severity, upstream storage, groundwater stress, return flow ration upstream protected land, media coverage, access to water, threatened amphibians.				
Countries where available:	Global			
Period available:	From:	Static	To:	Static
Costs involved in obtaining the tool:	none			
Concise model description: Aqueduct Global Maps 2.1 Data include indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. The Aqueduct Water Risk Atlas makes use of a framework of 12 global indicators grouped into three categories of risk and one overall score. Aqueduct Global Maps 2.1 include indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. This data updates the previous version with more recent data from the Global Land Data Assimilation System Version 2.				

Contact information	
Link to online tools:	http://www.wri.org/resources/maps/aqueduct-water-risk-atlas
Organization:	Aqueduct
Contact person:	Andrew Maddocks
Contact details:	amaddocks@wri.org
Resource:	N/A

Data and links
Data used: Basin delineations; freshwater withdrawal by country; gridded population; irrigated agricultural areas; nighttime lights; area equipped for irrigation; global irrigation areas; gdp, population, agricultural land, urban population, CO2 emissions; electricity, total net generation, refinery processing gain, coal production; withdrawals, precipitation, total renewable water supply, irrigated area; consumptive use ratios; runoff; large flood events; drought severity; major dams and reservoirs; groundwater footprint;

protected areas; media coverage; access to water; threatened amphibians.	
Data format:	ESRI geodatabase files, shapefiles
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	shapefiles - administrative boundaries: countries and river basins			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	static (1 layer per topic)			
Aggregation period:	static - 1 layer per topic			
Latency:	2015			

Quality, remarks, and references
References / supplementary information: Paul Reig, Tien Shiao, and Francis Gassert, "Aqueduct Water Risk Framework," Working Paper (World Resources Institute, Washington, DC: January 2013), http://www.wri.org/publication/aqueduct-water-risk-framework. Gassert, F., M. Landis, M. Luck, P. Reig, and T. Shiao, "Aqueduct Global Maps 2.1: Constructing Decision-Relevant Global Water Risk Indicators," Working Paper (World Resources Institute: Washington, DC: 2014), http://www.wri.org/publication/constructing-decision-relevant-global-water-riskindicators. Gassert, F., M. Landis, M. Luck, P. Reig, and T. Shiao, "Aqueduct Global Maps 2.1: Aqueduct metadata document," Working Paper (World Resources Institute: Washington, DC: 2015), http://www.wri.org/sites/default/files/Aqueduct_Global_Maps_2.1.pdf.
Strengths: easy to download
Weaknesses: provides only static layers of water risks
Final remarks: N/A

A10 Global Agricultural Drought Monitoring and Forecasting System

This dataset can be used to obtain data of agricultural drought hazard and drought impact to agriculture and livestock.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock, Mapping agricultural drought hazard			
Indicator(s) included:	Drought, VCI, NDVI			
Countries where available:	Global			
Period available:	From:	2000	To:	near real-time
Costs involved in obtaining the tool:	none			
Concise model description: Global Agricultural Drought Monitoring and Forecasting System (GADMFS) developed by the Center for Spatial Information Science and Systems (CSISS), at George Mason University, is a Web-based GIS system that provides global NDVI, VCI and Drought datasets derived using tile-based MODIS datasets and implements Web Map Service (WMS) and Web Coverage Service (WCS) to support visualization and acquisition of the global data. The system currently provides datasets spanning from 2000 to near real-time and is a contributing component of Global Earth Observation System of Systems (GEOSS) societal benefit areas of agriculture and disaster in its Architecture Implementation Pilot 5 (AIP5). The processing and analyzing services of GADMFS are developed in a Service Oriented Architecture (SOA), using AJAX web applications and BPEL workflow technology. Aiming to overcome the limitations of the current systems in agricultural drought monitoring and forecasting, the GADMFS supports better decision-making with improved monitoring, prediction, and analysis of agricultural drought.				

Contact information	
Link to online tools:	http://gis.csiss.gmu.edu/GADMFS/
Organization:	Center for Spatial Information Science and Systems/ George Mason University (CSISS-GMU)
Contact person:	Dr. Ziheng Sun
Contact details:	zsun@gmu.edu
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	.tiff
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326

Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	180	180	90	-90
Temporal scale:	16 days			
Aggregation period:	16 days, daily, weekly			
Latency:	25 may 2017			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: The advantages of GADMFS compared to other drought systems, are (1) compliant with open standards, (2) interoperable with GEOSS, (3) refined spatial and resolution, and global coverage at near real-time, (4) providing drought information dissemination including maps, data customization and download, and drought information analysis, (5) 14 years of historic drought data analysis, and (6) offering integrated and on-demand services (to analyze and estimate drought severities)
Weaknesses: N/A
Final remarks: Forecasting data seems not to be available yet. There is very little information on the platform regarding definition of indices and source data, references to publications, etc.

A11 Famine Early Warning Systems Network

This platform can used to obtain various types of information and data of agricultural drought hazard, drought risk to population, and drought risk to agriculture and livestock for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought risk to population, Mapping drought risk to agriculture and livestock, Mapping agricultural drought hazard			
Indicator(s) included: Rainfall anomaly/percentile, NDVI, soil moisture percentile, soil water index, actual evapotranspiration, land surface temperature, water availability				
Countries where available:	Mainly focused over FEWS NET regions (Africa, Central Asia and Central America) however some datasets are available globally.			
Period available:	From:	Generally since 1981 or 2000	To:	near real-time
Costs involved in obtaining the tool:	none			
Concise model description: The FEWS NET products include datasets and drought indicators to monitor meteorological, agricultural and hydrological drought. The datasets are based on satellite, station observations, climate and hydrologic models, and reanalysis. The products vary in spatial and temporal resolution, The datasets range from precipitation to vegetation, and surface water monitoring. Reliance on satellite based data allows monitoring in the regions where in-situ data are limited and sparse.				

Contact information	
Link to online tools:	https://www.fews.net/
Organization:	USGS (https://earlywarning.usgs.gov/fews)
Contact person:	(https://earlywarning.usgs.gov/fews/contact)
Contact details:	chris@geog.ucsb.edu, shrad@geog.ucsb.edu
Resource:	N/A

Data and links	
Data used:	Satellite based infrared and vegetation dataset, hydrologic model or crop water balance simulations, station observations, reanalysis.
Data format:	mainly .tiff but data can be provided in .bil and .netcdf
Data requirements:	Almost all graphics are publicly available to download. In several cases underline data can be downloaded easily. If not email requests can be

	made to get access to underline data.

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Administrative unit, country, crop zones.			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	180	180	90	-90
Temporal scale:	N/A			
Aggregation period:	decadal, monthly, seasonal			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: (1) Funk, C., and Coauthors, 2015: The climate hazards infrared precipitation with stationsÑa new environmental record for monitoring extremes. Scientific Data, 2, 150066, doi:10.1038/sdata.2015.66. http://dx.doi.org/10.1038/sdata.2015.66., (2) McNally, A., and Coauthors, 2017: A land data assimilation system for sub-Saharan Africa food and water security applications. Sci Data, 4, 170012, doi:10.1038/sdata.2017.12. http://dx.doi.org/10.1038/sdata.2017.12., (3) Brown, M. E., C. C. Funk, G. Galu, and R. Choularton, 2007: Earlier famine warning possible using remote sensing and models. Eos Trans. Amer. Geophys. Union, 88, 381–382, doi:10.1029/2007eo390001. http://dx.doi.org/10.1029/2007eo390001 (4) Jenkerson, C.B., Maiersperger, T.K., Schmidt, G.L., 2010. eMODIS: A User-friendly Data Source. U.S. Geological Survey Open-File Report, Reston, VA, USA 2010-1055. (5) Senay, G. B., J. P. Verdin, and J. Rowland, 2011: Developing an operational rangeland water requirement satisfaction index. Int. J. Remote Sens., 32, 6047–6053, doi:10.1080/01431161.2010.516028.
Strengths: The primary strength are: (1) Reliance on both satellite and station data (2) Availability of multiple diverse datasets to allow for convergence of evidence (iii) near real-time availability (iv) ground truth validation in near real-time. (v) freely and publically available output (vi) website based interface provides easy access.
Weaknesses: (1) Data quality can be an issue in regions with sparse station data reports. (2) Satellite data can be influences by cloud interference and also lack of long-term continuous sensors.
Final remarks: Main products (such as precipitation dataset, hydrologic model and crop model output, emodis NDVI) are peer-reviewed.

A12 Agricultural Stress Index and precipitation anomalies (FAO)

This platform can be used to obtain near real-time information of agricultural drought hazards and drought impact to agriculture and livestock on a decadal basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock, Mapping agricultural drought hazard			
Indicator(s) included:	NDVI, Agricultural Stress Index, Vegetation Health Index, Vegetation Condition Index			
Countries where available:	Global			
Period available:	From:	1984	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The seasonal indicators are designed to allow easy identification of areas of cropped land with a high likelihood of water stress (drought). The indices are based on remote sensing data of vegetation and land surface temperature combined with information on agricultural cropping cycles derived from historical data, and a global crop mask. The final maps highlight anomalous vegetation growth, and potential drought, in crop zones during the growing season.				

Contact information	
Link to online tools:	http://www.fao.org/giews/earthobservation/asis/index_1.jsp?lang=en
Organization:	FAO
Contact person:	N/A
Contact details:	FAO-HQ@fao.org
Resource:	The satellite data used in the calculation of the mean VHI and the ASI is the 10-day (decadal) vegetation data from the METOP-AVHRR sensor at 1 km resolution (2007 and after). Data at 1 km resolution for the period 1984-2006 was derived from the NOAA-AVHRR dataset at 16 km resolution. The crop mask is a modified version of an EC-JRC data set that compiles several different sources of land cover data, including GlobCover V2.2, Corine-2000, AfriCover, SADC data set and USGS Cropland Use Intensity Data Set. Vegetation indices are based on 10-day (decadal) vegetation data from the METOP-AVHRR sensor at 1 km resolution (2007 and after). Data at 1 km resolution for the period 1984-2006 was derived from the NOAA-AVHRR dataset at 16 km resolution. Precipitation estimates for all African countries (except Cabo Verde and Mauritius) are taken from NOAA/FEWSNet, while for the remaining countries data is obtained from ECMWF.

Data and links				
Data used: ECMWF: http://mars.jrc.ec.europa.eu/mars/About-us/FOODSEC/Data-Distribution RFE: http://earlywarning.usgs.gov/fews/downloads/index.php?regionID=af&productID=3&periodID=6 METOP: http://www.metops10.vito.be/ NOAA-AVHRR: http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php Maps Boundary maps : GAUL 2008 plus South Sudan (Disclaimer). More information on GAUL: http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691 Crop mask : JRC				
Data format:	PNG image			
Data requirements:	No requirements			

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	decadal			
Aggregation period:	decadal, annual			
Latency:	decade previous to current			

Quality, remarks, and references
References / supplementary information: O. Rojas, A. Vrieling b, F. Rembold: Assessing drought probability for agricultural areas in Africa with coarse resolution remote sensing imagery O. Rojas, Shukri Ahmed: Feasibility of using the FAO-Agricultural Stress Index System (ASIS) as a Remote Sensing based Index for Crop Insurance. O. Rojas, Y. Li, R.Cumani: Understanding the drought impact of El Niño on the global agricultural areas: An assessment using FAO's Agricultural Stress Index (ASI) O. Rojas: Protocol for Country-Level ASIS, Calibration and national adaptation processes M. Cumani, O. Rojas: Characterization of the Agricultural Drought Prone Areas on a Global Scale, using the FAO Agricultural Stress Index System (ASIS) to enhance the understanding of, and boost resilience to, water stress conditions in drought-prone areas
Strengths: N/A
Weaknesses: Data cannot be downloaded
Final remarks: N/A

A13 Earth Observation for crop monitoring - Global Information and Early Warning System on Food and Agriculture (GIEWS)

This platform can be used to obtain near real-time information of meteorological and agricultural drought hazards on a decadal basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural, Meteorological			
Applications:	Mapping agricultural drought hazard, Mapping meteorological drought hazard			
Indicator(s) included: Agricultural stress Index, Mean Vegetation Health Index, NDVI anomaly, Vegetation Condition Index, Vegetation Health index, Estimated precipitation, Precipitation Anomaly				
Countries where available:	Global & every country			
Period available:	From:	1984	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: GIEWS monitors the condition of major foodcrops across the globe to assess production prospects. To support the analysis and supplement ground based information, GIEWS utilizes remote sensing data that can provide a valuable insight on water availability and vegetation health during cropping seasons. In addition to rainfall estimates and the Normalized Difference Vegetation Index (NDVI), GIEWS and FAO NRC Division have developed the Agricultural Stress Index (ASI), a quick-look indicator for early identification of agricultural areas probably affected by dry spells, or drought in extreme cases.				

Contact information	
Link to online tools:	http://www.fao.org/giews/earthobservation/
Organization:	FAO
Contact person:	N/A
Contact details:	FAO-HQ@fao.org
Resource:	N/A

Data and links	
Data used:	METOP-AVHRR, NOAA/FEWSNet, ECMWF
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90

Temporal scale:	decadal
Aggregation period:	decadal, seasonal, annual
Latency:	near real-time

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: Data cannot be downloaded
Final remarks: N/A

A14 GEOGLAM Crop Monitor

This platform can be used to obtain near real-time information of drought impact to agriculture and livestock on a daily to monthly basis for the world.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock			
Indicator(s) included:	NDVI, temperature, precipitation, soil moisture, evapotranspiration, crop information on maize, rice, soybeans, wheat			
Countries where available:	global coverage - selected countries			
Period available:	From:	2015	To:	near real-time
Costs involved in obtaining the tool:	none			
Concise model description: During the final ten days of each month, a crop condition assessment is completed for both the Crop Monitor for AMIS and Crop Monitor for Early Warning areas of interest. Prior to the assessment period, the Crop Monitor plays a role in EO data coordination by consistently acquiring data sets relevant to agricultural monitoring, processing the data sets to ensure continuity, and providing access to the data for partner organizations via a web based crop assessment interface. In addition to (constantly updated) sources of EO data (NDVI, Temp, Precip, Soil Moisture, Evapotranspiration), two key baseline data sets have been developed under the GEOGLAM Crop Monitor initiative: “best available” crop-specific masks and crop stage calendars, which reflect the average areal (spatial) extent and crop growth stage (temporal), respectively, at sub-national resolution. Crops taken into account are maize, rice, soybeans and wheat.				

Contact information	
Link to online tools:	https://cropmonitor.org/
Organization:	GEOGLAM, GEO, coordination by University of Maryland
Contact person:	Inbal Becker-Reshef, Christopher Justice
Contact details:	ireshef@umd.edu, cjustice@umd.edu
Resource:	N/A

Data and links	
Data used: NDVI: NASA-UMD, MODIS; Temp: NOAA (NCEP-DOE reanalysis 2 project); Precip: NAOO (NCEP-DOE Reanalysis 2 project); Soil Moisture: NASA-USDA-FAS (SMOS); Evaporative stress index (USDA-NOAA), GOES/MODIS	
Data format:	N/A
Data requirements:	Log-in required

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	EO products: 0.5 to 0.05 degree Crop data: country and county scale			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	cropdata: monthly, EO data: daily			
Aggregation period:	1 day (EO data) or 1 month (cropdata)			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: Data cannot be downloaded, GEOCLAM crop monitor provides bulletins.
Final remarks: Peer-reviewed

A15 Standardized Precipitation Index (SPI)

This index can be used to determine and characterize meteorological drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: Uses historical precipitation records for any location to develop a probability of precipitation that can be computed at any number of timescales, from 1 month to 48 months or longer. As with other climatic indicators, the time series of data used to calculate SPI does not need to be of a specific length. Guttman (1998, 1999) noted that if additional data are present in a long time series, the results of the probability distribution will be more robust because more samples of extreme wet and extreme dry events are included. SPI can be calculated on as little as 20 years' worth of data, but ideally the time series should have a minimum of 30 years of data, even when missing data are accounted for	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The SPI program can be run on Windows-based personal computers, http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx.

Quality, remarks, and references
References / supplementary information: Guttman, N.B., 1998: Comparing the Palmer Drought Index and the Standardized Precipitation Index. Journal of the American Water Resources Association, 34:113–121, doi:10.1111/j.1752-1688.1998. tb05964. Guttman, N.B., 1999: Accepting the Standardized Precipitation Index: a calculation algorithm. Journal of the American Water Resources Association, 35:311–322, doi:10.1111/j.1752-1688.1999. tb03592.x. Hayes, M., M. Svoboda, N. Wall and M. Widhalm, 2011: The Lincoln Declaration on Drought Indices: universal meteorological drought index recommended. Bulletin of the American Meteorological Society, 92(4):485–488. McKee, T.B., N.J. Doesken and J. Kleist, 1993: The Relationship of Drought Frequency and Duration to Time Scales. Proceedings of the 8th Conference on Applied Climatology, 17–22 January 1993, Anaheim, CA. Boston, MA, American Meteorological Society. World Meteorological Organization, 2012: Standardized Precipitation Index User Guide (WMO-No. 1090), Geneva. Wu, H., M.J. Hayes, D.A. Wilhite and M.D. Svoboda, 2005: The effect of the length of record on the Standardized Precipitation Index calculation. International Journal of Climatology, 25(4):505–520.
Strengths: Using precipitation data only is the greatest strength of SPI, as it makes it very easy to use and calculate.

SPI is applicable in all climate regimes, and SPI values for very different climates can be compared. The ability of SPI to be computed for short periods of record that contain missing data is also valuable for those regions that may be data poor or lacking long-term, cohesive datasets. The program used to calculate SPI is easy to use and readily available. NDMC provides a program for use on personal computers that has been distributed to more than 200 countries around the world. The ability to be calculated over multiple timescales also allows SPI to have a wide breadth of application. Many articles relating to SPI are available in the science literature, giving novice users a multitude of resources to rely on for assistance.
Weaknesses: With precipitation as the only input, SPI is deficient when accounting for the temperature component, which is important to the overall water balance and water use of a region. This drawback can make it more difficult to compare events of similar SPI values but different temperature scenarios. The flexibility of SPI to be calculated for short periods of record, or on data that contain many missing values, can also lead to misuse of the output, as the program will provide output for whatever input is provided. SPI assumes a prior distribution, which may not be appropriate in all environments, particularly when examining short-duration events or entry into, or exit out of, drought. There are many versions of SPI available, implemented within various computing software packages other than that found in the source code distributed by NDMC. It is important to check the integrity of these algorithms and the consistency of output with the published versions.
Final remarks: Peer-reviewed

This index can be used to determine and characterize groundwater drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Estimator of groundwater trend	

Contact information	
Organization:	WRI; Deltares
Contact person:	Rutger Hofste (WRI); Marta Faneca (Deltares)
Contact details:	RHofste@wri.org; marta.faneca@deltares.nl
Resource:	Not yet published, but later here: http://www.wri.org/our-work/project/aqueduct

Quality, remarks, and references
References / supplementary information: Gleeson, T., Wada, Y., Bierkens, M. F. P., and van Beek, L. P. H. 2012. Water balance of global aquifers revealed by groundwater footprint, Nature, 488, 197–200, doi:10.1038/nature11295. Faneca, M., Sutanudjaja, E., Kuijper, M., and Bierkens, M. 2016. Aqueduct Water Risk Atlas - Pilot project Groundwater Risk Indicators. Report 1220593-000-BGS-0001-Ik. Galvis Rodríguez, S., E. Sutanudjaja, M. Faneca Sànchez (2017) Update on the groundwater risk indicators.
Strengths: The index provides an indication of change: the level of aquifer depletion, rather that static information.
Weaknesses: Independent declining trends studies vary considerably between authors for same aquifers or spatial units. This is caused by the different estimation methodologies and limitations on the independent data. Differences arise also from the different analyzed periods of the trends.
Final remarks: N/A

A17 Standardized Groundwater Index (SGI)

This index can be used to determine and characterize groundwater drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The SGI builds on the Standardized Precipitation Index (SPI) to account for differences in the form and characteristics of groundwater level and precipitation time series. The SGI is estimated using a non-parametric normal scores transform of groundwater level data for each calendar month. These monthly estimates are then merged to form a continuous index.	

Contact information	
Organization:	N/A
Contact person:	J.P. Bloomfield
Contact details:	jpb@bgs.ac.uk
Resource:	The following package requires Matlab and a MathWorks Account: https://nl.mathworks.com/matlabcentral/fileexchange/51081-standardized-drought-analysis-toolbox--sdat- http://www.hydrol-earth-syst-sci.net/17/4769/2013/

Quality, remarks, and references
References / supplementary information: Bloomfield, J. P. and Marchant, B. P.: Analysis of groundwater drought building on the standardised precipitation index approach, Hydrol. Earth Syst. Sci., 17, 4769-4787, https://doi.org/10.5194/hess-17-4769-2013, 2013. Bloomfield, J. P., Marchant, B. P., Bricker, S. H., and Morgan, R. B.: Regional analysis of groundwater droughts using hydrograph classification, Hydrol. Earth Syst. Sci., 19, 4327-4344, https://doi.org/10.5194/hess-19-4327-2015, 2015. Haas, J. C., & Birk, S. (2015, December). Identifying Groundwater Droughts using standardized Water Levels. In AGU Fall Meeting Abstracts.
Strengths: N/A
Weaknesses: Weaknesses are largely similar to that of SPI: dependent on length of available timeseries, assumed distribution of groundwater levels. Additionally dependent on local recharge patterns. Low groundwater levels do not necessarily indicate serious drought. Additionally, the indicator has no real history of use.
Final remarks: N/A

This index can be used to determine and characterize groundwater drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The GRI is derived from a simple distributed water balance model, and has been tested in a Mediterranean region, characterized by different geo-lithological conditions mainly affecting the summer hydrologic response of the catchments to winter precipitation. The analysis of the GRI characteristics shows a high spatial variability and, compared to the SPI through spectral analysis, a significant sensitivity to the lithological characterization of the analyzed region. The index assumes normality of groundwater levels over time.	

Contact information	
Organization:	N/A
Contact person:	Giuseppe Mendicino
Contact details:	menjoe@dds.unical.it
Resource:	http://www.sciencedirect.com/science/article/pii/S0022169408002321

Quality, remarks, and references
References / supplementary information: Mendicino, G., Senatore, A., & Versace, P. (2008). A Groundwater Resource Index (GRI) for drought monitoring and forecasting in a Mediterranean climate. Journal of Hydrology, 357(3), 282-302.
Strengths: N/A
Weaknesses: High complexity, large data requirements. Index assumes a normal distribution of groundwater detection in the model (skewed distributions change the index behavior), which may hold in Mediterranean countries according to the authors. Additionally, citing: "[the index] involves a great amount of reliable meteorological, hydrological and geo-lithological data, together with several calibration phases necessary for the spatially distributed estimate of the parameters of the water balance model. In this modeling both the surface and the groundwater components have to be calibrated: in the first case considering the largest number of observed runoff data while, for the groundwater, much care has to be used to define the three lithological categories and the associated groundwater reservoir constant values β."
Final remarks: N/A

A19 Groundwater Drought Index (GWI)

This index can be used to determine and characterize groundwater drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: A groundwater drought index derived from monthly groundwater storage output from the Catchment Land Surface Model (CLSM). Essentially an application of the Standardized Groundwater Index, but to groundwater storage rather than groundwater levels.	

Contact information	
Organization:	N/A
Contact person:	Bailing Li
Contact details:	bailing.li@nasa.gov
Resource:	http://www.sciencedirect.com/science/article/pii/S0022169414007094

Quality, remarks, and references
References / supplementary information: Li, B., & Rodell, M. (2015). Evaluation of a model-based groundwater drought indicator in the conterminous US. Journal of Hydrology, 526, 78-88.
Strengths: N/A
Weaknesses: Not evaluated in an arid climate
Final remarks: N/A

A20 Drought deficit volume

This index can be used to determine and characterize drought risk to population and drought risk to municipal and industrial water needs.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping drought risk to population, Mapping drought risk to municipal and industrial water needs
Concise model description: Uses the WaterGAP model output in the paper; deficit as (cumulative) volume below a threshold per grid cell. Threshold is defined as monthly median value of discharges	

Contact information	
Organization:	N/A
Contact person:	Bernhard Lehner
Contact details:	bernhard.lehner@wwfus.org
Resource:	http://www.arno.autoritadibacino.it/rep/biblio/flood_drought.pdf

Quality, remarks, and references
References / supplementary information: Lehner, B., Döll, P., Alcamo, J. et al. Climatic Change (2006) 75: 273. https://doi.org/10.1007/s10584-006-6338-4
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A21 Threshold Level Indicators (Deficit Indices)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Derived from time series of observed or simulated hydrometeorological variables using a pre-defined threshold level. When the variable is below this level, the site is in drought. Drought duration, severity, and frequency can easily be calculated. Thresholds are often derived from percentiles of the flow duration curve, commonly ranging between the 70th and 95th percentile for perennial rivers.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Van Loon, A.F. 2015 Hydrological drought explained. Wiley Interdsciplinary Reviews: Water, 2, 359-392
Strengths: The categories of drought (meteorological, soil moisture, and hydrological drought) can be analyzed with the threshold level method. This makes comparison between variables possible, which is required when studying drought propagation. Another advantage of the threshold level method is that it stays as close to the original time series as possible. It does not need to fit a distribution to the data (like SPI) or use water balance computations and calibration (like PDSI).
Weaknesses: No standard drought classes are calculated, so that in global drought studies standardization is needed to prevent large differences between climate types and to enable comparison. Subjective choices cannot be avoided, for example on the threshold level to use.
Final remarks: N/A

This index can be used to determine and characterize meteorological drought hazards on a monthly basis.

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: Calculated using monthly temperature and precipitation data along with information on the water-holding capacity of soils. It takes into account moisture received (precipitation) as well as moisture stored in the soil, accounting for the potential loss of moisture due to temperature influences.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://hydrology.princeton.edu/data.pdsi.php

Quality, remarks, and references
References / supplementary information: Alley, W.M., 1984: The Palmer Drought Severity Index: limitations and assumptions. Journal of Applied Meteorology, 23: 1100–1109. Palmer, W.C., 1965: Meteorological Drought. Research Paper No. 45, US Weather Bureau, Washington, DC.
Strengths: Used around the world, and the code and output are widely available. Scientific literature contains numerous papers related to PSDI. The use of soil data and a total water balance methodology makes it quite robust for identifying drought
Weaknesses: The need for serially complete data may cause problems. PDSI has a timescale of approximately nine months, which leads to a lag in identifying drought conditions based upon simplification of the soil moisture component within the calculations. This lag may be up to several months, which is a drawback when trying to identify a rapidly emerging drought situation. Seasonal issues also exist, as the PDSI does not handle frozen precipitation or frozen soils well.
Final remarks: N/A

A23 Aridity Anomaly Index (AAI)

This index can be used to determine and characterize meteorological drought hazards on a weekly or two-weekly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: A real-time drought index in which water balance is considered. The Aridity Index (AI) is computed for weekly or two-weekly periods. For each period, the actual aridity for the period is compared to the normal aridity for that period. Negative values indicate a surplus of moisture while positive values indicate moisture stress.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://imdpune.gov.in/hydrology/methodology.html

Quality, remarks, and references
References / supplementary information: http://www.wamis.org/agm/gamp/GAMP_Chap06.pdf
Strengths: Specific to agriculture, calculations are simple, and descriptions of drought (mild, moderate or severe) are based on departure from normal. Responds quickly with a weekly time step.
Weaknesses: Not applicable to long-term or multiseasonal events.
Final remarks: N/A

A24 Deciles

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard
Concise model description: Using the entire period of record of precipitation data for a location, the frequency and distribution of precipitation are ranked. The first decile is composed of the rainfall amounts in which the lowest 10% of the values are not exceeded, and the fifth decile is the median. A wet scale is also available. Daily, weekly, monthly, seasonal and annual values can all be considered in the methodology, as it is flexible when current data are compared to the historical record for any given period.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Gibbs, W.J. and J.V. Maher, 1967: Rainfall Deciles as Drought Indicators. Bureau of Meteorology Bulletin No. 48, Melbourne, Australia.
Strengths: With a single variable being considered, the methodology is simple and flexible for many situations. Using clearly defined thresholds, the current data are put into a historical context and drought status can be recognized. Useful in both wet and dry situations.
Weaknesses: As with other indicators that use only precipitation, the impacts of temperatures and other variables are not considered during the development of drought. A long record period provides the best results because many wet and dry periods will be included in the distribution.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazards on a daily basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Developed to identify drought in the early stages using a uniform method specific to the climate of the region. It is the net effect of evapotranspiration and precipitation in producing a moisture deficiency in the upper layers of the soil and also gives an indication of how much precipitation is needed for saturation of the soil and eliminating drought stress. Drought index specifically for fire potential assessment. It is a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper soil layers. It is a continuous index, relating to the flammability of organic material in the ground.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://www.wfas.net/index.php/keetch-byram-index-moisture–drought-49

Quality, remarks, and references
References / supplementary information: Keetch, J.J. and G.M. Byram, 1968: A Drought Index for Forest Fire Control. United States Department of Agriculture Forest Service Research Paper SE-38, Southeastern Forest Experiment Station, Asheville, NC.
Strengths: Expresses moisture deficiency for an area and can be scaled to indicate the characteristics of each particular location. Calculations are simple and the method is easy to use.
Weaknesses: Assumes a limit of available moisture and the necessity of certain climatic conditions for drought to develop, which may or may not be true for every location.
Final remarks: N/A

A26 Percent of Normal Precipitation

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard
Concise model description: Simple calculation that can be used to compare any time period for any location. Can be computed on daily, weekly, monthly, seasonal and annual timescales, which will suit many users needs. Calculated by dividing actual precipitation by normal precipitation for the time being considered and multiplying by 100.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Hayes, M.J., 2006: Drought Indices. Van Nostrand's Scientific Encyclopedia John Wiley & Sons, Inc., doi: 10.1002/0471743984.vse8593.
Strengths: A popular method that is quick and easy to calculate with basic mathematics.
Weaknesses: Establishing the normal for an area is a calculation that some users could confuse with mean or average precipitation. It is hard to compare different climate regimes with each other, especially those with defined wet and dry seasons.
Final remarks: N/A

A27 Weighted Anomaly Standardized Precipitation Index (WASP)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard
Concise model description: Used mainly in wet tropical regions to monitor developing drought, taking into account the defined wet and dry periods in the climate regime. Can be used to monitor droughts that affect agriculture and other sectors. Uses gridded monthly precipitation data on a 0.5° by 0.5° resolution, and is based on 12-month overlapping sums of weighted, standardized monthly precipitation anomalies.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/WASP_Indices.html

Quality, remarks, and references
References / supplementary information: Lyon, B., 2004: The strength of El Niño and the spatial extent of tropical drought. Geophysical Research Letters, 31: L21204, doi:10.1029/2004GL020901.
Strengths: Using precipitation as a single input allows for simpler computations.
Weaknesses: Does not work so well in desert regions. Gridded precipitation data may be a challenge to obtain in an operational capacity.
Final remarks: N/A

A28 Aridity Index (AI)

This index can be used to determine and characterize meteorological drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: Can be used to classify the climates of various regions, because the ratio of precipitation to temperature provides a method for determining an area's climate regime. Monthly calculation of AI can be used to determine the onset of drought, as the index takes into account temperature impacts as well as precipitation.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Baltas, E., 2007: Spatial distribution of climatic indices in northern Greece, Meteorological Applications, 14: 69–78. De Martonne, E., 1925: Traité de Géographie Physique. 11. Paris, Colin.
Strengths: Easy to compute with just two inputs. Flexible in that various time steps can be analyzed.
Weaknesses: Does not take into account carry-over of dryness from year to year. May be slow to react in certain climates.
Final remarks: N/A

A29 China Z Index (CZI)

This index can be used to determine and characterize meteorological drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: CZI is similar to SPI because precipitation is used to determine wet and dry periods, assuming that the precipitation obeys a Pearson type III distribution. It uses monthly time steps from 1 to 72 months, giving it the ability to identify droughts of various durations.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://onlinelibrary.wiley.com/doi/10.1002/joc.658/pdf.

Quality, remarks, and references
References / supplementary information: Edwards, D.C. and T.B. McKee, 1997: Characteristics of 20th Century Drought in the United States at Multiple Time Scales. Atmospheric Science 634: 1–30. Wu, H., M.J. Hayes, A. Weiss and Q. Hu, 2001: An evaluation of the Standardized Precipitation Index, the China-Z Index and the statistical Z-score. International Journal of Climatology, 21: 745–758.
Strengths: Simple calculations, which can be computed for several time steps. Can be used for both wet and dry events. Allows for missing data, similar to SPI.
Weaknesses: The Z-score data do not require adjustment by fitting them to gamma or Pearson type II distributions, and it is speculated that because of this, shorter timescales may be less well represented compared with SPI.
Final remarks: N/A

A30 Crop Moisture Index (CMI)

This index can be used to determine and characterize agricultural drought hazards on a weekly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: As some of the drawbacks associated with PDSI became apparent, Palmer responded to them with the development of CMI. It is intended to be a drought index especially suited to drought impacts on agriculture, in that it responds quickly to rapidly changing conditions. It is calculated by subtracting the difference between potential evapotranspiration and moisture, to determine any deficit.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	https://www.drought.gov/drought/content/products-current-drought-and-monitoring-drought-indicators/crop-moisture-index

Quality, remarks, and references
References / supplementary information: Palmer, W.C., 1968: Keeping track of crop moisture conditions, nationwide: the Crop Moisture Index. Weatherwise, 21: 156–161.
Strengths: The output is weighted, so it is possible to compare different climate regimes. Responds quickly to rapidly changing conditions.
Weaknesses: As it was developed specifically for the grain-producing regions in the United States, CMI may show a false sense of recovery from long-term drought events, as improvements in the short term may be insufficient to offset long-term issues.
Final remarks: N/A

A31 Drought Area Index (DAI)

This index can be used to determine and characterize meteorological and hydrological drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard
Concise model description: Developed as a method to improve understanding of monsoon rainfall in India, determining both flood and drought episodes using monthly precipitation. By comparing monthly precipitation during the critical monsoon period, the intensities of wet and dry periods are obtained, and the significance of the dryness can be derived based upon the contribution of each month's precipitation to the total monsoon season.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://moeseprints.incois.gov.in/1351/1/large%20scale.pdf

Quality, remarks, and references
References / supplementary information: Bhalme, H.N. and D.A. Mooley, 1980: Large-scale droughts/floods and monsoon circulation. Monthly Weather Review, 108: 1197–1211.
Strengths: Very focused on Indian monsoon seasons in the tropics.
Weaknesses: Lack of applicability to other areas or climate regimes.
Final remarks: N/A

A32 Drought Reconnaissance Index (DRI)

This index can be used to determine and characterize meteorological drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological
Applications:	Mapping meteorological drought hazard
Concise model description: Consists of a drought index that contains a simplified water balance equation considering precipitation and potential evapotranspiration. It has three outputs: the initial value, the normalized value and the standardized value. The standardized DRI value is similar in nature to SPI and can be compared to it directly. DRI is more representative than SPI however, as it considers the full water balance instead of precipitation alone.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://drinc.ewra.net/

Quality, remarks, and references
References / supplementary information: Tsakiris, G. and H. Vangelis, 2005: Establishing a drought index incorporating evapotranspiration. European Water, 9/10: 3–11.
Strengths: The use of potential evapotranspiration gives a better representation of the full water balance of the region than SPI provides, which will give a better indication of the drought severity. Can be calculated for many time steps, as with SPI. All the required mathematics are available in the literature.
Weaknesses: Potential evapotranspiration calculations can be subject to errors when using temperature alone to create the estimate. Monthly timescales may not react quickly enough for rapidly developing droughts.
Final remarks: N/A

A33 Effective Drought Index (EDI)

This index can be used to determine and characterize meteorological, hydrological, and agricultural drought hazards on a daily basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Uses daily precipitation data to develop and compute several parameters: effective precipitation (EP), daily mean EP, deviation of EP (DEP) and the standardized value of DEP. These parameters can identify the onset and end of water deficit periods. Using the input parameters, EDI calculations can be performed for any location in the world in which the results are standardized for comparison, giving a clear definition of the onset, ending and duration of drought. At the time of EDI's development, most drought indices were being calculated using monthly data, so the switch to daily data was unique and important to the utility of the index.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The authors state that the code is available by contacting them directly. The calculations are available and described in the original paper referenced below. EDI calculations are part of a suite of indices calculated as part of the Spatial and Time Series Informational Modeling (SPATSIM) software package, http://www.preventionweb.net/files/1869_VL102136.pdf

Quality, remarks, and references
References / supplementary information: Byun, H.R. and D.A. Wilhite, 1996: Daily quantification of drought severity and duration. Journal of Climate 5: 1181–1201.
Strengths: With a single input required for calculations, it is possible to calculate EDI for any location where precipitation is recorded. Supporting documents explaining the processes are available for the program. EDI is standardized so that outputs from all climate regimes can be compared. It is effective in identifying the beginning, ending and duration of drought events.
Weaknesses: With precipitation alone accounted for, the impact of temperature on drought situations is not directly integrated. Using daily data may make it difficult to use EDI in an operational situation, as daily updates

to input data may not be possible.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: A precipitation-based index in which the actual precipitation measured is compared with normal values during the growing season. Mean precipitation for each week is calculated and a running eight-week average of measured average precipitation is summed and compared. If the actual precipitation is greater than 60% of the normal precipitation for the eight-week period, then the current week is assumed to have little or no water stress. If stress is detected, it remains until the actual precipitation is at 60% or more of normal.	

Contact information	
Organization:	NOAA
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Strommen, N.D. and R.P. Motha, 1987: An operational early warning agricultural weather system. In: Planning For Drought: Toward a Reduction of Societal Vulnerability (D.A. Wilhite, W.E. Easterling and D.A. Wood, eds.). Boulder, CO, Westview Press.
Strengths: The only input is precipitation, in a monthly time step. The calculations and explanation of use are simple.
Weaknesses: At least 30 years' worth of data are required to compute normalized monthly values that are used in the computation of the weekly values. It has very specific applications related to agriculture and crop progression and development.
Final remarks: N/A

A35 Palmer Z Index

This index can be used to determine and characterize meteorological and agricultural drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard
Concise model description: Sometimes referred to as the 'Moisture Anomaly Index', and the derived values provide a comparable measure of the relative anomalies of a region for both dryness and wetness when compared to the entire record for that location.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://drought.unl.edu/

Quality, remarks, and references
References / supplementary information: Palmer, W.C., 1965: Meteorological Drought. Research Paper No. 45, US Weather Bureau, Washington, DC.
Strengths: The scientific literature contains a number of relevant papers. The use of soil data and a total water balance methodology makes the Palmer Z Index quite robust for identifying drought.
Weaknesses: Same as for PDSI, with the need for serially complete data possibly causing problems. It has a timescale of approximately nine months, which leads to a lag in identifying drought conditions based upon simplification of the soil moisture component within the calculations. This lag may be up to several months, which is a drawback when trying to identify a rapidly emerging drought situation. Seasonal issues also exist, as the Palmer Z Index does not handle frozen precipitation or frozen soils well.
Final remarks: N/A

A36 Rainfall Anomaly Index (RAI)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards on a monthly, seasonal and annual basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Uses normalized precipitation values based upon the station history of a particular location. Comparison to the current period puts the output into a historical perspective.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Kraus, E.B., 1977: Subtropical droughts and cross-equatorial energy transports. Monthly Weather Review, 105(8): 1009-1018. van Rooy, M.P., 1965: A Rainfall Anomaly Index independent of time and space. Notos, 14: 43–48.
Strengths: Easy to calculate, with a single input (precipitation) that can be analyzed on monthly, seasonal and annual timescales.
Weaknesses: Requires a serially complete dataset with estimates of missing values. Variations within the year need to be small compared to temporal variations.
Final remarks: N/A

A37 Self-Calibrated Palmer Drought Severity Index (sc-PDSI)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Accounts for all the constants contained in the PDSI and includes a methodology in which the constants are calculated dynamically based upon the characteristics present at each station location. The self-calibrating nature of sc-PDSI is developed for each station and changes based upon the climate regime of the location. It has wet and dry scales.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The Code can be obtained from http://drought.unl.edu/ and https://climatedataguide.ucar.edu/climate-data/cru-sc-pdsi-self-calibrating-pdsi-over-europe-north-america

Quality, remarks, and references
References / supplementary information: Wells, N., S. Goddard and M.J. Hayes, 2004: A self-calibrating Palmer Drought Severity Index. Journal of Climate, 17: 2335–2351.
Strengths: With the calculations for sc-PDSI accounting for each individual location, the index reflects what is happening at each site and allows for more accurate comparisons between regions. Different time steps can be calculated.
Weaknesses: As the methodology is not significantly different from PDSI, it has the same issues in terms of time lag and frozen precipitation and frozen soils.
Final remarks: N/A

A38 Standardized Anomaly Index (SAI)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards on a monthly, seasonal and annual basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Based upon the results of RAI, and was developed to help identify droughts in susceptible regions, such as the West African Sahel and north-east Brazil. RAI accounts for station-based precipitation in a region and standardizes annual amounts. Deviations are then averaged over all stations in the region to obtain a single SAI value.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Equations for the calculations are provided in the literature.

Quality, remarks, and references
References / supplementary information: Katz, R.W. and M.H. Glantz, 1986: Anatomy of a rainfall index. Monthly Weather Review, 114: 764–771. Kraus, E.B., 1977: Subtropical droughts and cross-equatorial energy transports. Monthly Weather Review, 105(8): 1009–1018.
Strengths: Single input, which can be calculated for any defined period.
Weaknesses: Only uses precipitation, and calculations are dependent on quality data.
Final remarks: N/A

A39 Standardized Precipitation Evapotranspiration Index (SPEI)

This index can be used to determine and characterize meteorological, hydrological and agricultural drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, Agricultural, Hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: As a relatively new drought index, SPEI uses the basis of SPI but includes a temperature component, allowing the index to account for the effect of temperature on drought development through a basic water balance calculation. SPEI has an intensity scale in which both positive and negative values are calculated, identifying wet and dry events. It can be calculated for time steps of as little as 1 month up to 48 months or more. Monthly updates allow it to be used operationally, and the longer the time series of data available, the more robust the results will be.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://sac.csic.es/spei/.

Quality, remarks, and references
References / supplementary information: Vicente-Serrano, S.M., S. Begueria and J.I. Lopez-Moreno, 2010: A multi-scalar drought index sensitive to global warming: the Standardized Precipitation Evapotranspiration Index. Journal of Climate, 23: 1696–1718.
Strengths: The inclusion of temperature along with precipitation data allows SPEI to account for the impact of temperature on a drought situation. The output is applicable for all climate regimes, with the results being comparable because they are standardized. With the use of temperature data, SPEI is an ideal index when looking at the impact of climate change in model output under various future scenarios.
Weaknesses: The requirement for a serially complete dataset for both temperature and precipitation may limit its use due to insufficient data being available. Being a monthly index, rapidly developing drought situations may not be identified quickly.
Final remarks: N/A

A40 Agricultural Reference Index for Drought (ARID)

This index can be used to determine and characterize agricultural drought hazards on a daily basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Predicts the status of moisture availability in the soil. It uses a combination of water stress approximations and crop models to identify the impact of water stress on plant growth, development and yield for specific crops.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The equations used and the methodology are well explained in the referenced article below. No source code is publicly available.

Quality, remarks, and references
References / supplementary information: Woli, P., J.W. Jones, K.T. Ingram and C.W. Fraisse, 2012: Agricultural Reference Index for Drought (ARID). Agronomy Journal, 104: 287–300.
Strengths: Crop models and water balance methods prove to be useful in predicting soil moisture and subsequent stress to crops. Can be computed daily so reaction times to drought will be quick.
Weaknesses: Designed and tested in the south-east United States for only a few cropping systems. Not easily transferable.
Final remarks: N/A

A41 Crop Specific Drought Index (CSDI)

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock on a daily basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping drought impact to agriculture and livestock, Mapping agricultural drought hazard
Concise model description: By calculating a basic soil water balance, it takes into account the impact of drought, but identifies when the drought stress occurred within the development of the crop and what the overall impact to the final yield will be. PDSI and CMI can identify drought conditions affecting a crop, but do not indicate the likely impact on yields.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The methodology and calculations are all described thoroughly in the literature.

Quality, remarks, and references
References / supplementary information: Meyer, S.J., K.G. Hubbard and D.A. Wilhite, 1993: A Crop-specific Drought Index for corn. I. Model development and validation. Agronomy Journal, 85: 388–395. Meyer, S.J., K.G. Hubbard and D.A. Wilhite, 1993: A Crop-specific Drought Index for corn. II. Model development and validation. Agronomy Journal, 85: 396–399.
Strengths: Very specific to a particular crop and based upon the development of the plant. The model takes into account when the drought stress occurred during plant growth and estimates the overall impact on yield.
Weaknesses: The inputs are quite complex and many locations will lack the required instruments or period of record needed to properly assess conditions.
Final remarks: N/A

A42 Reclamation Drought Index (RDI)

This index can be used to determine and characterize hydrological drought hazards on a monthly basis at river basin scale. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Developed to define drought severity as well as duration and can also be used to predict the onset and end of drought periods. It has both wet and dry scales and is calculated at the river basin level, in a similar way to the Surface Water Supply Index (SWSI). RDI has water-demand and temperature components, which allow for the inclusion of evaporation into the index.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The characteristics and mathematics are provided in the reference.

Quality, remarks, and references
References / supplementary information: Weghorst, K., 1996: The Reclamation Drought Index: Guidelines and Practical Applications. Bureau of Reclamation, Denver, CO, USA.
Strengths: Very specific to each basin. Unlike SWSI, it accounts for temperature effects on climate. Wet and dry scales allow for monitoring of wet and dry conditions.
Weaknesses: Calculations are made for individual basins, so comparisons are hard to make. Having all the inputs in an operational setting may cause delays in the production of data.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazards on a weekly and monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Can use weekly or monthly precipitation and potential evapotranspiration values in a simple water balance equation. It is intended to reflect the degree of dryness or saturation of the soil compared with normal conditions and to show how soil moisture stress influences crop production around the world.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The inputs and calculations are described thoroughly in the literature.

Quality, remarks, and references
References / supplementary information: Bergman, K.H., P. Sabol and D. Miskus, 1988: Experimental Indices for Monitoring Global Drought Conditions. Proceedings of 13th Annual Climate Diagnostics Workshop, United States Department of Commerce, Cambridge, MA.
Strengths: By taking into account the effects of both temperature and precipitation, the water balance aspects that make PDSI so popular are included with the ability to change constants with site-specific data. It considers moisture at different layers of the soil and is more adaptable than PDSI to different locations.
Weaknesses: The data requirements make it challenging to calculate. Potential evapotranspiration estimates can vary quite substantially by region.
Final remarks: N/A

A44 Evapotranspiration Deficit Index (ETDI)

This index can be used to determine and characterize agricultural drought hazards on a weekly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: A weekly product that is helpful for identifying water stress for crops. ETDI is calculated along with the Soil Moisture Deficit Index (SMDI), in which a water stress ratio is calculated that compares actual evapotranspiration with reference crop evapotranspiration. The water stress ratio is then compared with the median calculated over a long-term period.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Calculations are provided and explained thoroughly in the reference below, along with correlation studies to other drought indices. Information on the SWAT model can be found at http://swat.tamu.edu/software/swat-executables/.

Quality, remarks, and references
References / supplementary information: Narasimhan, B. and R. Srinivasan, 2005: Development and evaluation of Soil Moisture Deficit Index (SMDI) and Evapotranspiration Deficit Index (ETDI) for agricultural drought monitoring. Agricultural and Forest Meteorology, 133(1): 69–88.
Strengths: Analyses both actual and potential evapotranspiration and can identify wet and dry periods.
Weaknesses: The spatial variability of ETDI increases in the summer months during the period of greatest evapotranspiration and highly variable precipitation.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazards on a weekly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: A weekly soil moisture product calculated at four different soil depths (SWAT model), including the total soil column, at 0.61, 1.23 and 1.83 m, and can be used as in indicator of short-term drought, especially using the results from the 0.61m layer.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The calculations are provided and explained thoroughly in the reference below. Information on the SWAT model can be found at http://swat.tamu.edu/software/swat-executables/

Quality, remarks, and references
References / supplementary information: Narasimhan, B. and R. Srinivasan, 2005: Development and evaluation of Soil Moisture Deficit Index (SMDI) and Evapotranspiration Deficit Index (ETDI) for agricultural drought monitoring. Agricultural and Forest Meteorology, 133(1): 69–88.
Strengths: Takes into account the full profile as well as different depths, which makes it adaptable to different crop types.
Weaknesses: There are auto-correlation concerns when all the depths are being used.
Final remarks: N/A

A46 Palmer Hydrological Drought Index (PHDI)

This index can be used to determine and characterize hydrological drought hazards on a weekly and monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Based on the original PDSI and modified to take into account longer-term dryness that will affect water storage, streamflow and groundwater. PHDI has the ability to calculate when a drought will end based on precipitation needed by using a ratio of moisture received to moisture required to end a drought. There are four drought categories: near normal, which occurs approximately 28%–50% percent of the time; mild to moderate, which occurs approximately 11%–27% percent of the time; severe, which occurs approximately 5%–10% percent of the time; and extreme, which will occur approximately 4% of the time.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Palmer, W.C., 1965: Meteorological Drought. Research Paper No. 45. United States Weather Bureau, Washington, DC.
Strengths: Its water balance approach allows the total water system to be considered.
Weaknesses: Frequencies will vary by region and time of year, where extreme drought may not be a rare event during some months of the year. The impact of human influences, such as management decisions and irrigation, are not considered in the calculations.
Final remarks: N/A

A47 Standardized Reservoir Supply Index (SRSI)

This index can be used to determine and characterize drought impact to municipal and industrial water needs and drought impact to hydropower on a monthly basis at river basin scale. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping drought impact to municipal and industrial water needs , Mapping drought impact to hydropower
Concise model description: Similar to SPI in that monthly data are used to compute a probability distribution function of reservoir storage data, to provide information on water supply for a region or basin within a range of -3 (extremely dry) to +3 (extremely wet).	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The International Centre for Water Hazard and Risk Management has applied the SRSI methodology to several Asian river basins, http://www.icharm.pwri.go.jp/

Quality, remarks, and references
References / supplementary information: Gusyev, M.A., A. Hasegawa, J. Magome, D. Kuribayashi, H. Sawano and S. Lee, 2015: Drought Assessment in the Pampanga River Basin, the Philippines. Part 1: A Role of Dam Infrastructure in Historical Droughts. Proceedings of the 21st International Congress on Modelling and Simulation (MODSIM 2015), Broadbeach, Queensland, Australia.
Strengths: Easy to compute, as it mimics SPI calculations using a standard gamma distribution of the probability distribution function.
Weaknesses: Does not take into account changes due to management of the reservoir and losses due to evaporation.
Final remarks: N/A

This index can be used to determine and characterize hydrological drought hazards on a daily and monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Developed using monthly streamflow values and the methods of normalization associated with SPI. Can be calculated for both observed and forecasted data, providing a perspective on high and low flow periods associated with drought and flood.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	It is described well in the literature, with mathematics and case studies available.

Quality, remarks, and references
References / supplementary information: Modarres, R., 2007: Streamflow drought time series forecasting. Stochastic Environmental Research and Risk Assessment, 21: 223–233. Telesca, L., M. Lovallo, I. Lopez-Moreno and S. Vicente-Serrano, 2012: Investigation of scaling properties in monthly streamflow and Standardized Streamflow Index time series in the Ebro basin (Spain). Physica A: Statistical Mechanics and its Applications, 391(4): 1662–1678.
Strengths: Easy to calculate using the SPI program. A single variable input that allows for missing data makes it easy to use.
Weaknesses: Only accounts for the streamflow in the context of monitoring drought, with no other influences being investigated.
Final remarks: N/A

A49 Standardized Water-Level Index (SWI)

This index can be used to determine and characterize hydrological drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: As a hydrology-based drought indicator, it uses data from wells to investigate the impact of drought on groundwater recharge. Results can be interpolated between points.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Bhuiyan, C., 2004: Various Drought Indices for Monitoring Drought Condition in Aravalli Terrain of India. Proceedings of the XXth ISPRS Conference. International Society for Photogrammetry and Remote Sensing, Istanbul, Turkey, http://www.isprs.org/proceedings/XXXV/congress/comm7/papers/243.pdf.
Strengths: The impact of drought on groundwater is a key component in agricultural and municipal water supplies.
Weaknesses: Only takes groundwater into account, and interpolation between points may not be representative of the region or climate regime.
Final remarks: N/A

A50 Streamflow Drought Index (SDI)

This index can be used to determine and characterize hydrological drought hazards on a monthly basis. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Uses monthly streamflow values and the methods of normalization associated with SPI for developing a drought index based upon streamflow data. With an output similar to that of SPI, both wet and dry periods can be investigated, as well as the severity of these occurrences.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	It is described in the literature with mathematical examples provided. The SPI code is available at http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx. See http://drinc.ewra.net/ for information on SDI.

Quality, remarks, and references
References / supplementary information: Nalbantis, I. and G. Tsakiris, 2008: Assessment of hydrological drought revisited. Water Resources Management, 23(5): 881–897.
Strengths: The program is widely available and easy to use. Missing data are allowed, and the longer the streamflow record, the more accurate the results. As with SPI, various timescales can be examined.
Weaknesses: A single input (streamflow) does not take into account management decisions, and periods of no flow can skew the results.
Final remarks: N/A

This index can be used to determine and characterize hydrological drought hazards on a monthly basis at river basin scale. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Takes into account the work done by Palmer with PDSI but adds additional information including water supply data (snow accumulation, snowmelt and runoff, and reservoir data), and is calculated at the basin level. SWSI identifies the approximate frequency of mild drought occurrence at 26%–50%, moderate drought occurrence at 14%–26%, and severe drought occurrence at 2%–14%. Extreme drought occurs approximately less than 2% of the time.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Calculations and an explanation of the methodology are provided in the references.

Quality, remarks, and references
References / supplementary information: Doesken, N.J. and D. Garen, 1991: Drought Monitoring in the Western United States using a Surface Water Supply Index. Preprints, Seventh Conference on Applied Climatology, Salt Lake City, UT. American Meteorology Society, 266–269. Doesken, N.J., T.B. McKee and J. Kleist, 1991: Development of a Surface Water Supply Index for the Western United States. Climatology Report 91-3, Colorado Climate Center, http://climate.colostate.edu/pdfs/climo_rpt_91-3.pdf. Shafer, B.A. and L.E. Dezman, 1982: Development of a Surface Water Supply Index (SWSI) to Assess the Severity of Drought Conditions in Snowpack Runoff Areas. Proceedings of the Western Snow Conference, Colorado State University, Fort Collins, CO, 164–175.
Strengths: Taking into account the full water resources of a basin provides a good indication of the overall hydrological health of a particular basin or region.
Weaknesses: As data sources change or additional data are included, the entire index has to undergo a recalculation to account for these changes in the inputs, making it difficult to construct a homogeneous time series. Since calculations may vary between basins, it is difficult to compare basins or homogeneous regions.
Final remarks: N/A

A52 Aggregate Dryness Index (ADI)

This index can be used to determine and characterize drought impact to population, drought impact to municipal and industrial water needs , and drought impact to agriculture and livestock at the regional scale. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, agricultural and hydrological
Applications:	Mapping drought impact to population, Mapping drought impact to municipal and industrial water needs , Mapping drought impact to agriculture and livestock
Concise model description: A multivariate regional drought index that looks at all water resources across many timescales and impacts. It was developed to be used across uniform climate regimes.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The methodology and mathematics are explained in the literature, with examples provided.

Quality, remarks, and references
References / supplementary information: Keyantash, J.A. and J.A. Dracup, 2004: An aggregate drought index: assessing drought severity based on fluctuations in the hydrologic cycle and surface water storage. Water Resources Research, 40:W09304, doi:10.1029/2003WR002610, http://www.geo.oregonstate.edu/classes/ecosys_info/readings/2003WR002610.pdf
Strengths: Takes into account water stored as well as moisture that comes from precipitation.
Weaknesses: Does not take into account temperatures or groundwater, which are accounted for in the description of the ADI.
Final remarks: N/A

A53 Standardized Snowmelt and Rain Index (SMRI)

This index can be used to determine and characterize hydrological drought hazards related to snow melt. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: With methods similar to SPI, SMRI takes into account both rain and snow deficits and the associated impact to streamflow, including precipitation stored as snow. SMRI is most widely used as a complement to SPI.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Background to the methods and calculations is provided in the literature.

Quality, remarks, and references
References / supplementary information: Staudinger, M., K. Stahl and J. Seibert, 2014: A drought index accounting for snow. Water Resources Research, 50:7861–7872, doi:10.1002/2013WR015143.
Strengths: Accounting for snow and future contributions to streamflow, the index is capturing all the inputs into a basin. With the ability to use temperature and precipitation to model snow, actual snow amounts are not needed.
Weaknesses: The use of gridded data and the fact that the data used go back only to 1971 is a drawback when investigating performance using point data and longer periods of record. Not using actual snow depths and associated snow water equivalency can lead to errors in runoff projections.
Final remarks: N/A

A54 Enhanced Vegetation Index (EVI)

This index can be used to determine and characterize agricultural drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Originated from work done by Huete and a team from Brazil and the University of Arizona, United States, who developed a Moderate Resolution Imaging Spectroradiometer (MODIS)-based tool for assessing vegetation conditions.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Methodology and calculations are provided in the literature, and online resources of products exist, http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php.

Quality, remarks, and references
References / supplementary information: Huete, A., K. Didan, T. Miura, E.P. Rodriguez, X. Gao and L.G. Ferreira, 2002: Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment, 83(1):195–213.
Strengths: High resolution and good spatial coverage over all terrains.
Weaknesses: Stress to plant canopies could be caused by impacts other than drought, and it is difficult to discern them using only EVI. The period of record for satellite data is short, with climatic studies being difficult.
Final remarks: N/A

A55 Evaporative Stress Index (ESI)

This index can be used to determine and characterize hydrological and agricultural drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural, Hydrological
Applications:	Mapping agricultural drought hazard, Mapping hydrological drought hazard
Concise model description: Established as a new drought index in which evapotranspiration is compared to potential evapotranspiration using geostationary satellites. Analyses suggest that it performs similarly to short-term precipitation-based indices, but can be produced at a much higher resolution and without the need for precipitation data.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	Calculations of the index are provided in the literature, http://hrsl.arsusda.gov/drought/.

Quality, remarks, and references
References / supplementary information: Anderson, M.C., C. Hain, B. Wardlow, A. Pimstein, J.R. Mecikalski and W.P. Kustas, 2011: Evaluation of drought indices based on thermal remote sensing of evapotranspiration over the continental United States. Journal of Climate, 24(8):2025–2044.
Strengths: Very high resolution with a spatial coverage of any area.
Weaknesses: Cloud cover can contaminate and affect results. There is not a long period of record for climatological studies.
Final remarks: N/A

A56 Normalized Difference Vegetation Index (NDVI)

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard, Mapping drought impact to agriculture and livestock
Concise model description: Uses the global vegetation index data, which are produced by mapping 4 km daily radiance. Radiance values measured in both the visible and near-infrared channels are used to calculate NDVI. It measures greenness and vigour of vegetation over a seven-day period as a way of reducing cloud contamination and can identify drought-related stress to vegetation.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The literature describes the methodology and calculations. NDVI products are available online, http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php.

Quality, remarks, and references
References / supplementary information: Kogan, F.N., 1995: Droughts of the late 1980s in the United States as derived from NOAA polar-orbiting satellite data. Bulletin of the American Meteorology Society, 76(5):655–668. Tarpley, J.D., S.R. Schneider and R.L. Money, 1984: Global vegetation indices from the NOAA-7 meteorological satellite. Journal of Climate and Applied Meteorology, 23:491–494.
Strengths: Innovative in the use of satellite data to monitor the health of vegetation in relation to drought episodes. Very high resolution and great spatial coverage.
Weaknesses: Data processing is vital to NDVI, and a robust system is needed for this step. Satellite data do not have a long history.
Final remarks: N/A

A57 Temperature Condition Index (TCI)

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard, Mapping drought impact to agriculture and livestock
Concise model description: Using AVHRR thermal bands, TCI is used to determine stress on vegetation caused by temperatures and excessive wetness. Conditions are estimated relative to the maximum and minimum temperatures and modified to reflect different vegetation responses to temperature.	

Contact information	
Organization:	NOAA
Contact person:	N/A
Contact details:	N/A
Resource:	Methodology and calculations are provided in the literature, and online resources of products exist, http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php.

Quality, remarks, and references
References / supplementary information: Kogan, F.N., 1995: Application of vegetation index and brightness temperature for drought detection. Advances in Space Research, 15(11):91–100.
Strengths: High resolution and good spatial coverage.
Weaknesses: Potential for cloud contamination as well as a short period of record.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard, Mapping drought impact to agriculture and livestock
Concise model description: Using AVHRR thermal bands, VCI is used to identify drought situations and determine the onset, especially in areas where drought episodes are localized and ill defined. It focuses on the impact of drought on vegetation and can provide information on the onset, duration and severity of drought by noting vegetation changes and comparing them with historical values.	

Contact information	
Organization:	NOAA
Contact person:	N/A
Contact details:	N/A
Resource:	Methodology and calculations are provided in the literature, and online resources of products exist, http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php.

Quality, remarks, and references
References / supplementary information: Kogan, F.N., 1995: Application of vegetation index and brightness temperature for drought detection. Advances in Space Research, 15(11):91–100. Liu, W.T. and F.N. Kogan, 1996: Monitoring regional drought using the Vegetation Condition Index. International Journal of Remote Sensing, 17(14):2761–2782.
Strengths: High resolution and good spatial coverage.
Weaknesses: Potential for cloud contamination as well as a short period of record.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazard. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Developed as a drought index that was intended to monitor drought-induced vegetation stress using a combination of remote sensing, climate-based indicators, and other biophysical information and land-use data.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The methods used and a description of the calculations can be found in the reference. See also http://vegdri.unl.edu/.

Quality, remarks, and references
References / supplementary information: Brown, J.F., B.D. Wardlow, T. Tadesse, M.J. Hayes and B.C. Reed, 2008: The Vegetation Drought Response Index (VegDRI): a new integrated approach for monitoring drought stress in vegetation. GIScience & Remote Sensing, 45:16–46.
Strengths: An innovative and integrated technique using both surface and remotely sensed data and technological advances in data mining.
Weaknesses: Short period of record due to remotely sensed data. Not useful out of season or during periods of little or no vegetation.
Final remarks: N/A

A60 Vegetation Health Index (VHI)

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard, Mapping drought impact to agriculture and livestock
Concise model description: One of the first attempts to monitor and identify drought-related agricultural impacts using remotely sensed data. AVHRR data in the visible, infrared and near-infrared channels are all used to identify and classify stress to vegetation due to drought.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The calculations and sample case studies are given in the literature. VHI maps can be found online at http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php.

Quality, remarks, and references
References / supplementary information: Kogan, F.N., 1990: Remote sensing of weather impacts on vegetation in non-homogeneous areas. International Journal of Remote Sensing, 11:1405–1419. Kogan, F.N., 1997: Global drought watch from space. Bulletin of the American Meteorological Society, 78:621–636. Kogan, F.N., 2001: Operational space technology for global vegetation assessments. Bulletin of the American Meteorological Society, 82(9):1949–1964.
Strengths: Coverage over the entire globe at a high resolution.
Weaknesses: The period of record for satellite data is short.
Final remarks: N/A

A61 Water Requirement Satisfaction Index (WRSI) and Geo WRSI

This index can be used to determine and characterize agricultural drought hazard and drought impact to agriculture and livestock. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping drought impact to agriculture and livestock, Mapping agricultural drought hazard
Concise model description: Used to monitor crop performance during the growing season and based upon how much water is available for the crop. It is a ratio of actual to potential evapotranspiration. These ratios are crop specific, and are based upon crop development and known relationships between yields and drought stress.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://chg.geog.ucsb.edu/tools/geowrsi/index.html http://iridl.ldeo.columbia.edu/documentation/usgs/adds/wrsi/WRSI_readme.pdf

Quality, remarks, and references
References / supplementary information: Verdin, J. and R. Klaver, 2002: Grid ‐ cell ‐ based crop water accounting for the famine early warning system. Hydrological Processes, 16(8):1617 – 1630.
Strengths: High resolution and good spatial coverage over all terrains.
Weaknesses: Stress related to factors other than available water can affect the results. Satellite-based rainfall estimates have a degree of error that will affect the results of the crop models used and the balance of evapotranspiration.
Final remarks: N/A

A62 Normalized Difference Water Index (NDWI)

This index can be used to determine and characterize agricultural drought hazard. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Very similar to the NDVI methodology, but uses the near-infrared channel to monitor the water content of the vegetation canopy. Changes in the vegetation canopy are used to identify periods of drought stress.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The methodology is described in the literature as are the calculations based on the MODIS data being used, http://www.eomf.ou.edu/modis/visualization/.

Quality, remarks, and references
References / supplementary information: Chandrasekar, K., M.V.R. Sesha Sai, P.S. Roy and R.S. Dwevedi, 2010: Land Surface Water index (LSWI) response to rainfall and NDVI using the MODIS vegetation index product. International Journal of Remote Sensing, 31:3987–4005. Gao, B.C., 1996: NDWI—a Normalized Difference Water Index for remote sensing of vegetation liquid water from space. Remote Sensing of Environment, 58(3):257–266. Note: The NDWI concept and calculations are very similar to those of the Land Surface Water Index (LSWI).
Strengths: High resolution and good spatial coverage over all terrains. Different to NDVI, as the two indices look at different signals.
Weaknesses: Stress to plant canopies can be caused by impacts other than drought, and it is difficult to discern them using only NDWI. The period of record for satellite data is short, with climatic studies being difficult.
Final remarks: N/A

This index can be used to determine and characterize agricultural drought hazard. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: SAVI is similar to NDVI – spectral indices may be calibrated in such a way that the variations of soils are normalized and do not influence measurements of the vegetation canopy. These enhancements to NDVI are useful because SAVI accounts for variations in soils.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The methodology and associated calculations are explained well in the literature.

Quality, remarks, and references
References / supplementary information: Huete, A.R., 1988: A Soil-adjusted Vegetation Index (SAVI). Remote Sensing of Environment, 25(3):295–309.
Strengths: High-resolution and high-density data associated with remotely sensed data allow for very good spatial coverage.
Weaknesses: Calculations are complex, as is obtaining data to run operationally. A short period of record associated with the satellite data can hamper climate analyses.
Final remarks: N/A

This index can be used to determine and characterize meteorological, hydrological, and agricultural drought hazards. (source WMO and GWP, 2016)

General Characteristics	
Type:	Indices
Type of drought:	Meteorological, agricultural and hydrological
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard
Concise model description: Uses information on both precipitation and soil moisture to identify and classify drought episodes by investigating precipitation and soil moisture deficits. It is helpful for identifying drought episodes where typical precipitation-based indicators or soil-moisture-based indicators may not indicate the presence of drought.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	The literature explains the process well, and online resources and maps are readily available, http://drought.eng.uci.edu/.

Quality, remarks, and references
References / supplementary information: Hao, Z. and A. AghaKouchak, 2013: Multivariate Standardized Drought Index: a multi-index parametric approach for drought analysis. Advances in Water Resources, 57:12–18.
Strengths: The gridded and global data represent all areas well. With both a wet and a dry scale, it can be used to monitor more than just drought. It is excellent for areas lacking good surface observations with long periods of record. It is relatively easy to use in that it is computed without the need for input from users. Individual indices can be obtained from MSDI output.
Weaknesses: Grid size may not represent all areas and climate regimes equally. A period of record going back to 1980 is very short when considering climatic applications. To modify, the code and inputs would need to be obtained. Not all timescales are produced for SPI and Standardized Soil Moisture Index outputs.
Final remarks: N/A

A65 Multivariate Standardized Reliability and Resilience Index (MSRRI)

This index can be used to determine and characterize drought impact to population, drought impact to municipal and industrial water needs, and drought impact to hydropower.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	Mapping drought impact to population, Mapping drought impact to municipal and industrial water needs , Mapping drought impact to hydropower
Concise model description: A hybrid index consisting of IDR and WSR to provide information on the overall condition of the system (hydrological and socio-economic drought). MSRRI evaluates the supply and storage relative to the demand in reservoirs resulting in a measure of socioeconomic drought. The values of MSRRI and the corresponding socioeconomic drought severity can be interpreted similar to the SPI —i.e., a negative value indicates socioeconomic drought, while a positive value represents a wet period. MSRRI does not require projections of the water supply. The approach includes an inflow versus water demand reliability indicator that is dominated by climatic and meteorological conditions (top-down) and a water storage resilience index that considers the man-made infrastructure to cope with climate variability (bottom-up).	

Contact information	
Organization:	N/A
Contact person:	A. AghaKouchak
Contact details:	amir.a@uci.edu
Resource:	Methodology and calculations are provided in the literature

Quality, remarks, and references
References / supplementary information: Mehran, A., O. Mazdiyasni, and A. AghaKouchak (2015), A hybrid framework for assessing socioeconomic drought: Linking climate variability, local resilience, and demand, J. Geophys. Res. Atmos., 120, doi:10.1002/2015JD023147.
Strengths: Indicates the onset of the stress based on the onset of the hydrologic drought (IDR) and recovery of the system from a socioeconomic perspective (WSR). Provides an assessment of the overall stress on the system including the system resilience.
Weaknesses: The uncertainty in the assessment of demands and water resources values may result in incorrect values of the indicator.
Final remarks: N/A

A66 Inflow-Demand Reliability (IDR)

This index can be used to determine and characterize hydrological and socio-economic drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard, mapping socio-economic drought hazard
Concise model description: Shows whether the available water (inflow to the system) is sufficient to satisfy water demand regardless of the storage in the reservoir. It is derived by computing the sum of the percent change of inflow with respect to water demand during the projected time frame.	

Contact information	
Organization:	N/A
Contact person:	A. AghaKouchak
Contact details:	amir.a@uci.edu
Resource:	Methodology and calculations are provided in the literature

Quality, remarks, and references
References / supplementary information: Mehran, A., O. Mazdiyasni, and A. AghaKouchak (2015), A hybrid framework for assessing socioeconomic drought: Linking climate variability, local resilience, and demand, J. Geophys. Res. Atmos., 120, doi:10.1002/2015JD023147.
Strengths: The indicator is able to reveal the onset of the hydrological drought based on input to reservoirs.
Weaknesses: The index cannot clearly reveal the severity of water stress, i.e. the index does not detect when the hydrological drought has a socio-economic impact.
Final remarks: N/A

This index can be used to determine and characterize socio-economic drought hazard.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	mapping socio-economic drought hazard
Concise model description: Water storage resilience (WSR) indicator is computed on a monthly basis and shows whether the reservoir storage is sufficient to satisfy water demand for a defined time period. This indicator is defined based on monthly inflow, monthly water demand, monthly storage, and total water demand during the time frame.	

Contact information	
Organization:	N/A
Contact person:	A. AghaKouchak
Contact details:	amir.a@uci.edu
Resource:	Methodology and calculations are provided in the literature

Quality, remarks, and references
References / supplementary information: Mehran, A., O. Mazdiyasni, and A. AghaKouchak (2015), A hybrid framework for assessing socioeconomic drought: Linking climate variability, local resilience, and demand, J. Geophys. Res. Atmos., 120, doi:10.1002/2015JD023147.
Strengths: Detects the onset and persistence of the socioeconomic drought.
Weaknesses: The index cannot clearly reveal the severity of water stress, i.e. it does not detect the onset of the hydrological drought, failing to provide early warning before the onset of the socio-econic drought.
Final remarks: N/A

This index can be used to determine and characterize socio-economic drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	socio-economic
Applications:	Mapping socio-economic drought
Concise model description: The Falkenmark Water Stress Index, which was developed by the Swedish water expert Falkenmark in 1989, consists of the sum of the total yearly local runoff per country compared to estimates of population density. Water availability of more than 1,700m³/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m³/capita/year water stress appears regularly, below 1,000m³/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m³/capita/year water availability is a main constraint to life.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://environ.chemeng.ntua.gr/WSM/Newsletters/Issue4/Indicators_Appendix.htm

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: Despite its global acceptance, this indicator has numerous shortcomings. First of all, only the renewable surface and groundwater flows in a country are considered. Moreover, the water availability per person is calculated as an average with regard to both the temporal and the spatial scale and thereby neglects water shortages in dry seasons or in certain regions within a country.

A69 Standardized Runoff Index (SRI)

This index can be used to determine and characterize hydrological drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: Developed using monthly streamflow values and the methods of normalization associated with SPI. Can be calculated for both observed and forecasted data, providing a perspective on high and low flow periods associated with drought and flood.	

Contact information	
Organization:	Department of Civil and Environmental Engineering, University of Washington, USA
Contact person:	Shraddhanand Shukla, Andrew W. Wood
Contact details:	aww@u.washington.edu
Resource:	It is described well in the literature, with mathematics and case studies available. http://onlinelibrary.wiley.com/doi/10.1029/2007GL032487/full

Quality, remarks, and references
References / supplementary information: Shukla, S., and A. W. Wood (2008), Use of a standardized runoff index for characterizing hydrologic drought, Geophys. Res. Lett., 35, L02405, doi:10.1029/2007GL032487. A. W. Wood and S. Shukla. The value of a standardized runoff index for characterizing hydrologic aspects of drought (http://www.hydro.washington.edu/pub/shrad/imp_stuff/drought%20paper/SRI.dft.pdf)
Strengths: Easy to calculate using the SPI program.
Weaknesses: Only accounts for the streamflow in the context of monitoring drought, with no other influences being investigated.
Final remarks: N/A

This index can be used for socio-economic drought hazard.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	Mapping socio-economic drought
Concise model description: The Watergap is defined as the water demand minus the water availability, where water demand is the sum of industrial, domestic, livestock and irrigation demand, and water availability is the sum of the internal renewable resources (groundwater and surface water) and external inflow minus external outflow.	

Contact information	
Organization:	Deltares
Contact person:	Marta Faneca, Dimmie Hendriks
Contact details:	marta.faneca@deltares.nl, dimmie.hendriks@deltares.nl
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Faneca Sànchez, M., M. van Aalst, S. Vermooten, D. Hendriks, H. van Duijne, O.P. Quintero, D. Rivera (2017) Assessing water related risks to the industry and other stakeholders in 2 basins in Colombia; Focusing on water scarcity. Deltares report 1230409-002.
Strengths: Includes all water sources, also groundwater, and most important demand terms at a sub-watershed scale
Weaknesses: Not yet peer-reviewed; requires a lot of effort to collect all necessary data
Final remarks: N/A

A71 Socioeconomic Drought Vulnerability Index (SDVI)

This index measures the vulnerability of individual countries to socioeconomic drought.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	Mapping socio-economic drought vulnerability
Concise model description: This index measures the vulnerability of individual countries to socioeconomic drought. It is formulated on the consideration that higher GDP contributions from non-agricultural sectors, lower percentage employment in the agricultural sector and higher crops diversity will collectively lower a country's chances of developing socioeconomic drought when meteorological drought occurs. Three sub-indices, namely, the Income Diversity Index (IDI), Employment Diversity Index (EDI) and the Crop Range Index (CDI), make up the composite Socioeconomic Drought Vulnerability Index.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Eriyagama, N., Smakhtin, V., Gamage, N. (2009) Mapping Drought Patterns and Impacts: A Global Perspective. IWMI research report 133. http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB133/RR133.pdf
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A72 Agricultural Stress Index (ASI)

This index is an FAO indicator that highlights anomalous vegetation growth and potential drought in arable land during a given cropping season. It can be used to determine and characterize agricultural drought hazards.

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The Agricultural Stress Index (ASI) is an index based on the integration of the Vegetation Health Index (VHI) in two dimensions that are critical in the assessment of a drought event in agriculture: temporal and spatial. The first step of the ASI calculation is a temporal averaging of the VHI, assessing the intensity and duration of dry periods occurring during the crop cycle at pixel level. The second step determines the spatial extent of drought events by calculating the percentage of pixels in arable areas with a VHI value below 35 percent (this value was identified as a critical threshold in assessing the extent of drought in previous research by Kogan, 1995). Finally, each administrative area is classified according to its percentage of affected area to facilitate the quick interpretation of results by analysts.	

Contact information	
Organization:	FAO
Contact person:	Oscar Rojas
Contact details:	oscar.rojas@fao.org
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Oscar Rojas, Yanyun Li, Renato Cumani, NRL (2014). Understanding the drought impact of El Niño on the global agricultural areas: An assessment using FAO's Agricultural Stress Index (ASI). FAO. ISSN 2071-0992. http://www.fao.org/3/a-i4251e.pdf
Strengths: N/A
Weaknesses: The current version of ASI has the following limitations: • The index detects extreme events of drought, which means that agricultural areas affected by moderate drought (referring to temporal intensity at pixel level) would be neglected. • It defines two cropping seasons around the globe. This works properly for most areas; however, there are regions such as Central America where there are four crop seasons in a calendar year. In ASI the first crop season does not necessarily represent the main crop season, but rather the first crop season in a calendar year. • The current version gives equal weight to all phenological phases when calculating the temporal integration without regard to the crop water requirements and their implications on crop yield reduction.
Final remarks: N/A

A73 Seasonal Small Integral Deviation (SSID) index

This index can be used for agricultural drought hazard.

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The SSID is an index describing the expected seasonal vegetation productivity, considering both agricultural production and available biomass in pastoral areas. The timely detection of critical conditions in vegetation health and productivity, during a vegetation growing season and before its end, helps to identify agricultural areas where crop failures are likely to occur. It is calculated as a simple percent deviation from the historical average value of the vegetation Seasonal Small Integral parameter (i.e. the baseline). An updated SSID value is added to the historical series every sixteen days, thus each time a new MODIS MOD13C1 becomes available. The SSID is supplied together with a reliability coefficient (RC) which is related to the temporal position of the current observation with respect to the total length of the examined season (i.e., RC reaches 100% once the vegetation growing season has ended). During the descending phase of the vegetation growing season (i.e., once the NDVI curve reach its maximum), the values of the SSID are normally subjected to minimal changes.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	http://drought.ithacaweb.org/historical/

Quality, remarks, and references
References / supplementary information: http://meetingorganizer.copernicus.org/EGU2017/EGU2017-14294.pdf http://drought.ithacaweb.org/
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A74 Drought Warning Index (DWI)

This index can be used for agricultural drought hazard.

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The DWI is a drought aggregated index based on vegetation and precipitation anomalies. The best SSID-correlated SPI cumulating interval (1 or 3 months) is selected for each pixel. A meteorological drought warning is provided for those pixels presenting negative SPI and for which no vegetative growing season is yet detected (for these pixels, a blue palette are used in the map). Once the vegetative growing season begins, the interested pixels will be assigned to a different warning value if the calculated SSID, SPI, or both, are negative (amber to brown palette is used in the map). Where the vegetative growing season is ongoing and the SSID is negative, a negative SPI value entails an agricultural drought warning, while a positive SPI implies a vegetation stress warning. A negative SPI value during the vegetation season, with no detectable vegetation stress effects (i.e. positive SSID), produces a meteorological drought warning.	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: http://meetingorganizer.copernicus.org/EGU2017/EGU2017-14294.pdf http://drought.ithacaweb.org/
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This index can be used for agricultural drought hazard.

General Characteristics	
Type:	Indices
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Anomaly of fAPAR (fraction of Absorbed Photosynthetically Active Radiation): 10-day time composite, 1 Km spatial resolution, derived from the Moderate resolution imaging spectroradiometer (MODIS) global coverage satellite products. MODIS-derived 10-day maps are produced in-house starting from the standard MOD15A2 product. Low quality data are masked according to the quality flag in the MOD15A2 product (Myneni et al. 2000), 8-day values are interpolated at 10-day time step using a weighted average (inverse distance in time) of the two closest images, and a temporal smoothing is performed by means of an exponential filter (α=0.5) of the 10-day data (Brown and Meyer, 1961). The anomalies are calculated using a MODIS-consistent baseline with the data available from January 2001 to December 2014. The fAPAR MODIS absorption values are retrieved from the web source https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd15a2, courtesy of the NASA EOSDIS Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, United States of America	

Contact information	
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This index measures the vulnerability to socioeconomic drought.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	Mapping socio-economic drought vulnerability
Concise model description: The Drought Vulnerability Index (DVI) can be applied locally or spatially and with different aggregation levels of the input data. The intermediate components can be evaluated independently, allowing comprehensive interpretation of the strengths and weaknesses of each system. The sequential steps taken for the quantification of the DVI are: (a) select variables that are relevant; (b) normalize the variable values with respect to some common baseline; (c) combine the sub-component variables within each category by weighted averages; and (d) quantify DVI as the weighted average of the components. The scores of the DVI range on a scale of 0 to 1, with the total being generated as the average of each component. Each component of the DVI can be viewed as a dimension. Before calculating the overall DVI, an indicator for each of the dimensions needs to be computed. The four dimensions were named as Renewable Natural Capital, Economic Capacity, Human and Civic Recourses and Infrastructure and Technology. All of these categories contain multiple indicators and were aggregated using equal weights.	

Contact information	
Organization:	JRC
Contact person:	Gustavo Naumann
Contact details:	gustavo.naumann@jrc.ec.europa.eu
Resource:	N/A

Quality, remarks, and references
References / supplementary information: https://www.hydrol-earth-syst-sci-discuss.net/10/12217/2013/hessd-10-12217-2013-print.pdf
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A77 Drought Risk Index (DRI)

This index measures drought risk to the overall population.

General Characteristics	
Type:	Indices
Type of drought:	Socio-economic
Applications:	Mapping drought risk to population, Socio-economic
Concise model description: Risk is defined as R = DHI x DVI, where DHI is the Drought Hazard Index (probability of a drought event happening in a certain period of time, taking into account different drought severities and durations for different aggregating periods) and DVI is the Drought Vulnerability Index. Risk maps are elaborated using the average hazard for each sub-basin.	

Contact information	
Organization:	JRC
Contact person:	Hugo Carrão, Gustavo Naumann, Paulo Barbosa
Contact details:	hugo.carrao@gmail.com
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Hugo Carrão, Gustavo Naumann, Paulo Barbosa, Mapping global patterns of drought risk: An empirical framework based on sub-national estimates of hazard, exposure and vulnerability, Global Environmental Change, Volume 39, July 2016, Pages 108-124, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2016.04.012.
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A78 Standardized Precipitation Index (SPI) for Global Land Surface (1949-2012)

This index can be used to determine and characterize meteorological drought hazards.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-3, SPI-6, SPI-12			
Countries where available:	Global			
Period available:	From:	1949	To:	2012
Costs involved in obtaining the tool:	None			
Concise model description: This dataset includes the Standardized Precipitation Index (SPI) at three-, six-, and 12-month scales for global land surfaces. The precipitation data (1949-2012) are resampled from the original University of East Anglia Climate Research Unit (CRU) global time series, TS3.21, monthly 0.5 degree by 0.5 degree grids to the study unit of analysis, 1.0 degree by 1.0 degree grids, thereby facilitating regression with environmental and socioeconomic variables.				

Contact information	
Link to online tools:	https://rda.ucar.edu/datasets/ds298.0/#!access
Organization:	NCAR UCAR
Contact person:	Arlene Laing, Andrew Gettelman, Jimy Dudhia
Contact details:	Arlene Laing (laing@ucar.edu), Andrew Gettelman (andrew@ucar.edu), Jimy Dudhia (dudhia@ucar.edu)
Resource:	Colorado Climate Center, SPI maps and software, http://ccc.atmos.colostate.edu/standardizedprecipitation.php Monthly Precipitation Data from the CRU TS 3.21, http://badc.nerc.ac.uk/data/cru/

Data and links	
Data used: Precipitation data resampled from the original University of East Anglia Climate Research Unit (CRU) global time series, TS3.21, monthly 0.5° by 0.5° grids to the study unit of analysis, 1.0° by 1.0° grids	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1°			
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	-180	180	90	-90
Temporal scale:	Monthly			
Aggregation period:	3, 6, 12 months			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: McKee, T.B., N.J. Doesken, and J. Kleist, 1993. The relationship of drought frequency and duration to time scales. Proc. Eighth Conference on Applied Climatology, Amer. Meteor. Soc., Jan 17-23, 1993, Anaheim CA, 179-186. McKee, T. B., N. J. Doesken, and J. Kleist, 1993. Drought monitoring with multiple time scales. Proc. Ninth Conference on Applied Climatology, Amer. Meteor. Soc., Dallas, TX, 233-236. O' Loughlin, J., A. Linke, F. Witmer, A. Laing, A. Gettelmann, J. Dudhia, 2012: Climate variability and conflict risk in East Africa: 1990-2009. Proc. Natl. Acad. Sci. Nov 6;109(45):18344-9. doi: 10.1073/pnas.1205130109. Epub 2012 Oct 22. [http://www.pnas.org/content/early/2012/10/17/1205130109
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This dataset can be used to obtain data of large scale groundwater drought hazards.

General Characteristics				
Type:	Dataset			
Type of drought:	Hydrological			
Applications:	Mapping hydrological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Global			
Period available:	From:	2002	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Uses microwave ranging system to measure distance between the two satellites due to gravitational acceleration.				

Contact information	
Link to online tools:	https://grace.jpl.nasa.gov/
Organization:	NASA
Contact person:	User forum is available for questions: https://podaac.jpl.nasa.gov/forum/
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	ASCII, GEOTIFF, NETCDF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5°			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	monthly			

Quality, remarks, and references
References / supplementary information: S.C. Swenson. 2012. GRACE monthly land water mass grids NETCDF RELEASE 5.0. Ver. 5.0. PO.DAAC, CA,

USA. Dataset accessed [YYYY-MM-DD] at http://dx.doi.org/10.5067/TELND-NC005. Landerer F.W. and S. C. Swenson, Accuracy of scaled GRACE terrestrial water storage estimates. Water Resources Research, Vol 48, W04531, 11 PP, doi:10.1029/2011WR011453, 2012. Swenson, S. C. and J. Wahr, Post-processing removal of correlated errors in GRACE data, Geophys. Res. Lett., 33, L08402, doi:10.1029/2005GL025285, 2006. Van Loon, A. F., Kumar, R., & Mishra, V. (2017). Testing the use of standardised indices and GRACE satellite data to estimate the European 2015 groundwater drought in near real-time. Hydrology and Earth System Sciences, 21(4), 1947.
Strengths: Relies on robust relationship between gravity and surface mass, rather than empirical parameterizations and calibrations with in-situ measurements. Used to track volume and movement of water through reservoirs of the hydrologic cycle (taken from: https://climatedataguide.ucar.edu/climate-data/grace-gravity-recovery-and-climate-experiment-surface-mass-total-water-storage-and)
Weaknesses: Coarse spatial and temporal resolutions. The raw data require filtering to be interpretable, and the nature and effects of the various filtering strategies can be difficult to trace (taken from: https://climatedataguide.ucar.edu/climate-data/grace-gravity-recovery-and-climate-experiment-surface-mass-total-water-storage-and)
Final remarks: N/A

This dataset can be used to obtain data on impacts of socio-economic droughts to the overall economy for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	Socio-economic			
Applications:	Mapping drought impact to the overall economy, Mapping drought impact to the population			
Indicator(s) included:	Total deaths, Total affected people, Total damage (US$)			
Countries where available:	Global			
Period available:	From:	1900	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: EM-DAT is a global database on natural and technological disasters, containing essential core data on the occurrence and effects of more than 21,000 disasters in the world, from 1900 to present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain located in Brussels, Belgium.				

Contact information	
Link to online tools:	http://www.emdat.be/database
Organization:	CRED (Centre for Research on the Epidemiology of Disasters)
Contact person:	Via contact form: http://emdat.be/contact
Contact details:	contact@emdat.be.
Resource:	A password is required to enter the database. Can be obtained through registration or via contact details.

Data and links	
Data used: UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Priority is given to data from UN agencies, governments, and the International Federation of Red Cross and Red Crescent Societies.	
Data format:	CSV
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Country			

Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Year			
Aggregation period:	Year			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: http://www.emdat.be/publications
Strengths: It provides impacts for a wide variety of natural hazards.
Weaknesses: Impacts are only provided on a yearly basis, so it might not be easy to match the impacts to an event. For some countries the database is quite sparse.
Final remarks: Drought event overviews reported by national sources often indicate more drought events than EM-DAT. Advised is to combine EM-DAT with national sources.

A81 The Early Warning eXplorer (EWX)

This dataset can be used to obtain data on meteorological and agricultural drought hazards on a decadal to monthly basis for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Agricultural			
Applications:	Drought forecasting , Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	CHIRPS, MODIS LST			
Countries where available:	Global			
Period available:	From:	1981	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Early Warning eXplorer (EWX) software is an interactive web-based mapping tool that allows users to visualize continental-scale rainfall estimate (RFE), land surface temperature (LST) and normalized difference vegetation index (NDVI) data and anomalies at varied time steps and review time series analyses.				

Contact information	
Link to online tools:	https://earlywarning.usgs.gov/fews/ewx/index.html?region=gb
Organization:	USGS
Contact person:	N/A
Contact details:	https://earlywarning.usgs.gov/fews/contact
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	Geotiff, TIFF, PNG
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5, 0.05			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	Monthly, decadal			
Aggregation period:	1,2,3 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A82 Global Precipitation Climatology Centre Drought Database

This dataset can be used to obtain near real-time data of meteorological drought hazards.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	combined drought indicator consisting of SPI and SPEI			
Countries where available:	global			
Period available:	From:	1952	To:	near real-time
Costs involved in obtaining the tool:	none			
Concise model description: The GPCC drought index is a standardized anomaly of precipitation and potential evapotranspiration regarding to long term means. Precipitation data are taken from GPCC's "First Guess" product and temperature data from "NOAA's Climate Prediction Center (CPC) Monthly Global Surface Air Temperature Data Set". Aggregation periods of 1, 3, 6, 9, 12, 24 and 48 months are calculated. The drought index is available from 2013 until near real-time. The retrospective GPCC drought index is a standardized anomaly of precipitation and potential evapotranspiration regarding long term means for the period 1952 to 2013. Precipitation data are taken from GPCC's "Full Data Monthly" product and temperature data from "NOAA's Climate Prediction Center (CPC) Monthly Global Surface Air Temperature Data Set". Aggregation periods of 1, 3, 6, 9, 12, 24 and 48 months are calculated. The retrospective GPCC drought index is available from 1952 - 2013.				

Contact information	
Link to online tools:	http://www.dwd.de/EN/ourservices/gpcc/gpcc.html ftp://ftp-anon.dwd.de/pub/data/gpcc/html/download_gate.html
Organization:	The Global Precipitation Climatology Centre (GPCC): operated by DWD under the auspices of the World Meteorological Organization (WMO)
Contact person:	Dr. Andreas Becker
Contact details:	gpcc@dwd.de
Resource:	N/A

Data and links	
Data used:	GPCC precipitation, NOAA global surface air temperature
Data format:	netcdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1.0			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	monthly			
Aggregation period:	1, 3, 6, 9, 12, 24, 48 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: Ziese, Markus; Becker, Andreas; Finger, Peter; Meyer-Christoffer, Anja; Rudolf, Bruno; Schneider, Udo (2013): GPCC Drought Index Product (GPCC_DI) at 1.0°. DOI: 10.5676/DWD_GPCC/DI_M_100; ftp://ftp.dwd.de/pub/data/gpcc/html/gpcc_di_v_1-1_doi_download.html
Strengths: N/A
Weaknesses: N/A
Final remarks: peer-reviewed

This dataset can be used to obtain data of meteorological and hydrological drought hazards on a daily to monthly basis for the world (includes snow and future scenario's).

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	no drought indicators applied yet			
Countries where available:	Global			
Period available:	From:	1971	To:	2099
Costs involved in obtaining the tool:	none			
Concise model description: Compilation of hydrological datasets: no direct drought indicators available but information on hydrological variables such as precipitation, (potential) evapotranspiration, runoff, discharge, soil moisture, snowpack, snowfall				

Contact information	
Link to online tools:	www.isimip.org
Organization:	PIK Potsdam
Contact person:	info@isimip.org
Contact details:	info@isimip.org
Resource:	N/A

Data and links	
Data used:	multiple global climate models or reanalysis datasets, multiple global hydrological models
Data format:	netcdf
Data requirements:	matlab/python/r-like program required to recalculate data

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	daily, monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: big repository of hydrological data, consistent in set-up, and temporal and spatial resolution
Weaknesses: drought hazard calculations have to be made yet by user.
Final remarks: Peer-reviewed

A84 MODIS Global Terrestrial Drought Severity Index

This dataset can be used to obtain data of meteorological, agricultural and hydrological drought hazards on a weekly to annual basis for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Drought severity index			
Countries where available:	Global			
Period available:	From:	2000	To:	2011
Costs involved in obtaining the tool:	None			
Concise model description: The remotely-sensed DSI uses operational global land products derived from NASA satellite observations, namely the MODIS terrestrial evapotranspiration (ET) and vegetation greenness products. ET is a metric of ecosystem functional status and is directly related to the water, carbon and energy cycles of the land surface. The ratio of ET to potential ET (PET) is commonly used as an indicator of terrestrial water availability and associated wetness or drought. Satellite vegetation greenness indices (VIs), especially the Normalized Difference VI (NDVI), can potentially link climate changes (e.g. increasing frequency and severity of drought) and vegetation responses with land-atmosphere water, carbon and energy fluxes, and associated climate feedbacks (Atkinson et al., 2011). The DSI incorporates NDVI and the ratio of ET to PET into a single index theoretically ranging from unlimited negative values (drier than normal) to unlimited positive values (wetter than normal). More detailed information on the DSI can be found in Mu et al. (2013).				

Contact information	
Link to online tools:	http://www.ntsg.umt.edu/project/modis/dsi.php
Organization:	University of Montana
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used: Evapotranspiration and potential evapotranspiration from the MODIS MOD16 evapotranspiration data product Normalized Difference Vegetation Index from the MODIS MOD13 vegetation indices product	
Data format:	.hdf
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	annual, 8-day interval			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: Mu et al. (2013)
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

A85 Global map of drought risk

This dataset can be used to obtain static data of socio-economic drought hazards and drought risk to the population for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	Socio-economic			
Applications:	Mapping drought risk to population, Socio-economic			
Indicator(s) included:	N/A			
Countries where available:	Global			
Period available:	From:	N/A	To:	N/A
Costs involved in obtaining the tool:	N/A			
Concise model description: A global map of drought risk has been elaborated at the sub-national administrative level. Drought risk is assessed for the period 2000–2014 and is based on the product of three independent determinants: hazard, exposure and vulnerability. Drought hazard is derived from a non-parametric analysis of historical precipitation deficits at the 0.5°; drought exposure is based on a non-parametric aggregation of gridded indicators of population and livestock densities, crop cover and water stress; and drought vulnerability is computed as the arithmetic composite of high level factors of social, economic and infrastructural indicators, collected at both the national and sub-national levels.				

Contact information	
Link to online tools:	N/A
Organization:	JRC
Contact person:	Hugo Carrão, Gustavo Naumann, Paulo Barbosa
Contact details:	hugo.carrao@gmail.com
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: Hugo Carrão, Gustavo Naumann, Paulo Barbosa, Mapping global patterns of drought risk: An empirical framework based on sub-national estimates of hazard, exposure and vulnerability, Global Environmental Change, Volume 39, July 2016, Pages 108-124, ISSN 0959-3780, https://doi.org/10.1016/j.gloenvcha.2016.04.012.
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

This dataset can be used to obtain data for calculations of meteorological drought hazards at various temporal scales for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Global			
Period available:	From:	Variable	To:	Variable
Costs involved in obtaining the tool:	None			
Concise model description: Provides free access to NCDC's archive of global historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals.				

Contact information	
Link to online tools:	https://www.ncdc.noaa.gov/cdo-web/datatools/selectlocation
Organization:	NOAA
Contact person:	N/A
Contact details:	ncei.orders@noaa.gov
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references

References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

A87 E2O drought indicators

This dataset can be used to obtain data for calculations of meteorological drought hazards at monthly basis for the world.

General Characteristics				
Type:	Dataset			
Type of drought:	hydrological , meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI, SPEI, SRI, SSFI, SSMI			
Countries where available:	global			
Period available:	From:	1983	To:	2012
Costs involved in obtaining the tool:	None			
Concise model description: Global-scale drought indicators developed as part of the E2O project. Estimated drought values are based on the inputs of different global (hydrological) models: W3RA (CSIRO/ANU), HTESSEL (ECMWF), LISFLOOD (JRC), WaterGAP (university Kassel), PCR-GLOBWB (Utrecht University), SURFEX-TRIP (meteo France). Eacht of these models was forced with WFD-EI. Time-series that was used to estimate the drought values was 1980-2012. Due to differences in accumulation time-period, actual drought values between 1983-2012 were provided only. Drought values are calculated for: SPI, SPEI, SRI, SSFI, and SSMI. Each with accumulation times of 1, 3, 6, 12, 24, and 36 months.				

Contact information	
Link to online tools:	https://wci.earth2observe.eu/portal/?
Organization:	IVM-VU
Contact person:	Ted Veldkamp
Contact details:	ted.veldkamp@vu.nl
Resource:	N/A

Data and links	
Data used:	Forcing: WFDEI; Models: W3RA, HTESSEL, LISFLOOD, WaterGAP, PCR-GLOBWB, SURFEX-TRIP
Data format:	netcdf
Data requirements:	matlab/python/r-like program required to post-process the data

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5 and 0.25			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	monthly			
Aggregation period:	1, 3, 6, 12, 24, 36 months			

Latency:	N/A

Quality, remarks, and references
References / supplementary information: Upcoming
Strengths: N/A
Weaknesses: N/A
Final remarks: Underlying hydrological data-sets have been evaluated and described by Beck, H. E., van Dijk, A. I. J. M., de Roo, A., Dutra, E., Fink, G., Orth, R., and Schellekens, J.: Global evaluation of runoff from 10 state-of-the-art hydrological models, Hydrol. Earth Syst. Sci., 21, 2881-2903, https://doi.org/10.5194/hess-21-2881-2017, 2017. Performance of drought indicators is being tested by a Kolmogorov-Smirnov test. A paper describing the results of this evaluation is currently in preparation., See Beck et al. 2017.

A88 PCR-GLOBWB

This tool can be used to simulate and obtain information of (future scenarios of) hydrological drought hazards.

General Characteristics				
Type:	Tools			
Type of drought:	Hydrological			
Applications:	Mapping hydrological drought hazard			
Indicator(s) included:	water demands, groundwater and surface water withdrawal, water consumption, return flows, river discharge.			
Countries where available:	Global			
Period available:	From:	1958	To:	2017
Costs involved in obtaining the tool:	None			
Concise model description: PCR-GLOBWB is a large-scale process-based hydrological model intended for global to regional studies. It provides a grid-based representation of terrestrial hydrology with a typical spatial resolution of less than 50×50 km (currently 0.5° globally) on a daily basis. For each grid cell, PCR-GLOBWB uses process-based equations to compute moisture storage in two vertically stacked soil layers as well as the water exchange between the soil and the atmosphere and the underlying groundwater reservoir. Exchange to the atmosphere comprises precipitation, evapotranspiration and snow accumulation and melt, which are all modified by the presence of the canopy and snow cover.				

Contact information	
Link to online tools:	http://pcraster.geo.uu.nl/projects/applications/pcrglobwb/; https://github.com/UU-Hydro/PCR-GLOBWB_model
Organization:	Dept. of Physical Geography, Utrecht University (Netherlands)
Contact person:	Rens van Beek, Marc Bierkens
Contact details:	r.vanbeek at geo.uu.nl, m.f.p.bierkens@uu.nl, E.H.Sutanudjaja@uu.nl,
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	daily, monthly			
Aggregation period:	monthly, daily			
Latency:	historic or future simulation periods			

Quality, remarks, and references
References / supplementary information: Bierkens, M.F.P. and L.P.H. van Beek (2009): Seasonal predictability of European Discharge: NAO and Hydrological Response Time. J. Hydrometeor, 10, 953–968. Loos, S., H. Middelkoop, M. van der Perk and R. van Beek (2009). Large scale nutrient modelling using globally available datasets: A test for the Rhine basin. Journal of Hydrology. Volume 369, Issues 3-4, 15 May 2009, Pages 403-415. Sperna Weiland, F.C., L. P. H. van Beek, J. C. J. Kwadijk, and M. F. P. Bierkens (2010). Hydrol. Earth Syst. Sci., 14, 1595-1621. Petrescu, A. M. R., L. P. H. van Beek, J. van Huissteden, C. Prigent, T. Sachs, C. A. R. Corradi, F. J. W. Parmentier, and A. J. Dolman (2010), Modeling regional to global CH_4 emissions of boreal and arctic wetlands, Global Biogeochem. Cycles, 24, GB4009, doi:10.1029/2009GB003610. Wada, Y., L. P. H. van Beek, C. M. van Kempen, J. W. T. M. Reckman, S. Vasak, and M. F. P. Bierkens (2010), Global depletion of groundwater resources, Geophys. Res. Lett., 37, L20402, doi:10.1029/2010GL044571.
Strengths: The model has a water use scheme that is integrated at each time step, i.e. at every time step sector specific water demands are calculated, resulting in groundwater and surface water withdrawal, water consumption and return flows. The model computes several hydrological variables that can be used to compute different drought indices. Results from the global model are available for the period 1979 to 2012 at https://wci.earth2observe.eu/portal/?
Weaknesses: The global model has quite a low resolution (0.5°), and setting up a higher resolution model for a specific region is not easy; The model does not solve full surface energy balance (e.g. as done by VIC). The current version of PCR-GLOBWB uses Penman-Monteith;The model does not have a user interface.
Final remarks: Peer-reviewed

A89 Global Groundwater Model (UU, Deltares)

This tool can be used to simulate and obtain information of (future scenario's of) groundwater drought hazards.

General Characteristics				
Type:	Tools			
Type of drought:	Hydrological			
Applications:	Mapping hydrological drought hazard			
Indicator(s) included:	groundwater level			
Countries where available:	Global			
Period available:	From:	1958	To:	2017
Costs involved in obtaining the tool:	None			
Concise model description: Global-scale groundwater model (run at 6' resolution) using MODFLOW to construct an equilibrium water table at its natural state as the result of long-term climatic forcing. The used aquifer schematization and properties are based on available global data sets of lithology and transmissivities combined with the estimated thickness of an upper, unconfined aquifer. The model is forced with outputs from the land-surface PCRaster Global Water Balance (PCR-GLOBWB) model, specifically net recharge and surface water levels.				

Contact information	
Link to online tools:	n/a
Organization:	Dept. of Physical Geography, Utrecht University (Netherlands) and Deltares
Contact person:	Marc Bierkens, Edwin Sutanudjaja, Marta Faneca, Dimmie Hendriks
Contact details:	m.f.p.bierkens@uu.nl, E.H.Sutanudjaja@uu.nl, marta.faneca@deltares.nl, dimmie.hendriks@deltares.nl
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-180	180	90	-90
Temporal scale:	daily, monthly			
Aggregation period:	monthly, daily			
Latency:	historic or future simulation periods			

Quality, remarks, and references
References / supplementary information:

De Graaf, I. E. M., van Beek, L. P. H., Wada, Y., and Bierkens, M. F. P.: Dynamic attribution of global water demand to surface water and groundwater resources: effects of abstractions and return flows on river discharges, Adv. Water Resour., 64, 21–33, doi:10.1016/j.advwatres.2013.12.002, 2013. 10 de Graaf, I. E. M., van Beek, L. P. H., Sutanudjaja, S. H., and Bierkens, M. F. P.: A high-resolution global-scale groundwater model, HESS, 2, 823–837, 2015.
Strengths: The Global MODFLOW model enables simulating groundwater head dynamics such that it can be used to analyze/quantify/predict groundwater drought (and groundwater flood) under different climate conditions. Commonly available drought indices hardly incorporate groundwater head dynamics and have limited applicability in characterizing groundwater drought. This models enables applying groundwater-related drought indices. Relatively high resolution for groundwater model for the global extent (5 arcmin (~10 km).
Weaknesses: The model does not have a user interface.
Final remarks: Peer-reviewed

A90 Global RIBASIM Model (Deltares)

This tool can be used to simulate and obtain information of (future scenarios of) drought hazards and effects of interventions and water use(rs).

General Characteristics				
Type:	Tools (upcoming)			
Type of drought:	Hydrological, Socio-economic			
Applications:	Mapping hydrological drought hazard, mapping socio-economic drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Global			
Period available:	From:	N/A	To:	N/A
Costs involved in obtaining the tool:	N/A			
Concise model description: Global RIBASIM is an water allocation model based on water balances approach intended for global to regional to local studies. It provides a network representation of water availability, demand, infrastructure, distribution and priority rules for water allocation.				

Contact information	
Link to online tools:	N/A
Organization:	N/A
Contact person:	Judith ter Maat, Karen Meijer, Frederiek Sperna Weiland
Contact details:	N/A
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	water provinces	N/A	N/A	N/A
Temporal scale:	daily, monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Modelling Software

A91 RIBASIM

This modelling software can be used to simulate drought risk to population, drought risk to municipal and industrial water needs, drought risk to agriculture and livestock, drought risk to hydropower.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological, socio-economic
Applications:	Mapping drought risk to population, Mapping drought risk to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower
Concise model description: RIBASIM (River Basin Simulation Model) is a generic model package for analyzing the behavior of river basins under various hydrological conditions. The model package is a comprehensive and flexible tool which links the hydrological water inputs at various locations with the specific water-users in the basin.	

Contact information	
Link to online tools:	https://www.deltares.nl/en/software/ribasim/
Organization:	Deltares
Contact person:	Wil van der Krogt
Contact details:	wil.vanderkrogt@deltares.nl
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Van der Krogt, W. 2010. Technical report: RIBASIM 7.01. Deltares, Delft.

This modelling software can be used to simulate drought impact to agriculture and livestock on a daily and monthly basis.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping drought impact to agriculture and livestock
Concise model description: CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.	

Contact information	
Link to online tools:	http://www.fao.org/land-water/databases-and-software/cropwat/en/
Organization:	Food and Agriculture organization
Contact person:	No information
Contact details:	No information
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Smith, M., Kivumbi, D., & Heng, L. K. (2002). Use of the FAO CROPWAT model in deficit irrigation studies. In Deficit irrigation practices.Smith, M. (1992). CROPWAT: A computer program for irrigation planning and management (No. 46). Food & Agriculture Org..

A93 Aquacrop

This modelling software can be used to simulate drought impact to agriculture and livestock on a daily and monthly basis.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping drought impact to agriculture and livestock
Concise model description: AquaCrop simulates the yield response of herbaceous crops to water and is particularly well suited to conditions in which water is a key limiting factor in crop production. AquaCrop balances accuracy, simplicity and robustness. To ensure its wide applicability, it uses only a small number of explicit parameters and mostly intuitive input variables that can be determined using simple methods.	

Contact information	
Link to online tools:	http://www.fao.org/land-water/databases-and-software/aquacrop/en/
Organization:	Food and Agriculture organization
Contact person:	No information
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Raes, D., Steduto, P., Hsiao, T.C., and Fereres, E. 2015. AquaCrop Reference manual. http://www.fao.org/nr/water/aquacrop.html Saxton, K. E., Rawls, W. J. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J. 70, 1569–1578. URL web page (for downloading the hydraulic properties calculator): http://hydrolab.arsusda.gov/soilwater/Index.htm

A94 HBV

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The HBV model is a rainfall-runoff model, which includes conceptual numerical descriptions of hydrological processes at the catchment scale. It is available as a module for many scripting languages, and is part of several rainfall-runoff modelling suites.	

Contact information	
Link to online tools:	http://rsminerve.hydro10.org/software/ http://hypecode.smhi.se/open-source/tools-2/ https://www.deltares.nl/en/software/module/sobek-d-rainfall-runoff-open-water/
Organization:	Swedish Meteorological and Hydrological Institute
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Bergström, S., 1976. Development and application of a conceptual runoff model for Scandinavian catchments, SMHI Report RHO 7, Norrköping, 134 pp. Bergström, S. 1995. The HBV model. In: Singh, V.P. (Ed.) Computer Models of Watershed Hydrology. Water Resources Publications, Highlands Ranch, CO., pp. 443-476.

A95 TOPMODEL

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: TOPMODEL is a physically based, distributed watershed model that simulates hydrologic fluxes of water (infiltration-excess overland flow, saturation overland flow, infiltration, exfiltration, subsurface flow, evapotranspiration, and channel routing) through a watershed. The model simulates explicit groundwater/surface- water interactions by predicting the movement of the water table, which determines where saturated land-surface areas develop and have the potential to produce saturation overland flow.	

Contact information	
Link to online tools:	https://cran.r-project.org/web/packages/topmodel/index.html
Organization:	Lancaster University, Department of Environmental Science, Institute of Environmental and Natural Sciences
Contact person:	Keith Beven
Contact details:	K.Beven@lancaster.ac.uk
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Beven, K. and Freer, J. (2001), "A dynamic TOPMODEL" ,Hydrol. Process., Vol. 15(10), pp. 1993-2011.

A96 WFLOW

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The WFlow hydrological model is a distributed hydrological model that requires little calibration effort and maximizes the use of available spatial data. The model is programmed in a dynamic GIS language called PCRaster. As such, the structure of the model is transparent (and can be changed by other modelers easily) and the system allows for rapid application in 'new' model areas. The PCRaster version used here is a beta version that comes with bindings to the Python programming language.	

Contact information	
Link to online tools:	https://www.deltares.nl/en/software/module/sobek-d-rainfall-runoff-open-water/ https://publicwiki.deltares.nl/display/OpenS/WFlow+rainfall-runoff+model
Organization:	Deltares
Contact person:	Jaap Schellekens
Contact details:	Jaap.Schellekens@deltares.nl
Resource:	N/A

Quality, remarks, and references
References / supplementary information:

Kohler, L., Mulligan M., Schellekens J., Schmid S., and Tobon C. (2006). Final Technical Report DFID-FRP Project no. R7991 Hydrological impacts of converting tropical montane cloud forest to pasture, with initial reference to northern Costa Rica.
Beck, C., J. Grieser, & B. Rudolf (2004), A new monthly precipitation climatology for the global land areas for the period 1951 to 2000. Climate Status Report 2004, German Weather Service, Offenbach, Germany, pp. 181–190.
Deursen van, W. P. A. (1995). Geographical Information Systems and Dynamic Models. Ph.d., Utrecht University, NGS Publication 190, 198 pp., 1995. URL, http://www.carthago.nl.
Dunne, T., and L.B. Leopold (1978). Water in Environmental Planning. W.H. Freeman Co. Soan Francisco, CA.
Fekete, B. M., C. J. Vörösmarty, J. O. Roads & C. J. Willmott (2004), Uncertainties in precipitation and their impacts on runoff Estimates. Journal of Climate 17, pp. 294–304.
Fiedler, K. & P. Döll (2007), Global modelling continental water storage changes – sensitivity to different climate data sets. Advances in Geosciences 11, pp. 63–68.
Gash, J. H. C. (1979). An analytical model of rainfall interception by forests. Quarterly Journal of the Royal Meteorological Society, 105:43–55, 1979.

Gash, J. H. C., Lloyd, C. R., and Lachaud, G. (1995) Estimating sparse forest rainfall interceptionwith an analytical model. Journal of Hydrology, 170:79–86, 1995.
Leopold, L.B. and Maddock, T. (1959), The Hydraulic Geometry of stream channels and some physiographic implications, geological survey professional paper 252. United states department of the interior.
Leopold, L.B. (1994). A view of the River. Harvard University Press, Cambridge, Masachusetts.
New, M., M. Hulme & P. Jones (1999), Representing Twentieth-Century space-time climate variability. Part 1: Development of a 1961–90 mean monthly terrestrial climatology. Journal of Climate 12(3), pp. 829–856.
New, M., M. Hulme, M. & P. Jones (2000), Representing Twentieth-Century space–time climate variability. Part II: Development of 1901–96 monthly grids of terrestrial surface climate. Journal of Climate 13, pp. 2217–2238.
Noah J. Finnegan et al. (2005). Controls on the channel width of rivers: Implications for modeling fluvial incision of bedrock, Quaternary Research Center and Department of Earth and Space Sciences, University of Washington, Washington, March 2005
Sperna Weiland, F. C., van Beek, L. P. H., Kwadijk, J. C. J. and Bierkens, M. F. P. (2010). The ability of a GCM-forced hydrological model to reproduce global discharge variability, Hydrol. Earth Syst. Sci., 14(8), 1595-1621, 2010.
Troccoli, A. & P. Kållberg (2004), Precipitation correction in the ERA-40 reanalysis. ERA-40 Project Rep. Series 13, 6 pp., ECMWF, Reading, UK.
Uppala, S. M., Kallberg, P. W., Simmons, A. J., Andrae, U., Bechtold, V. D. C., Fiorino, M., Gibson, J. K., Haseler, J., Hernandez, A., Kelly, G. A., Li, X. et al. (2005). The ERA-40 re-analysis, Quart. J. Roy. Meteor. Soc., 131, 2961-3012, doi:10.1256/qj.04.176.
Uppala, S. M. et al. (2006), The ERA-40 re-analysis. Quarterly Journal of the Royal Meteorological Society 131, pp. 2961–3012.
Schellekens, J. (2011) WFlow , a flexible hydrological model, July 9, 2011.
Snell, J. and Sivapalan, M. (1995). Application of the metachannel concept: construction of the meta-channel hydraulic geometry for a natural channel. Hydrol. Processes, 9, 485-505.

A97 Sacramento Model

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The Sacramento Model is a catchment water balance model that relates runoff to rainfall with daily data. The model contains five stores and has sixteen parameters. It is available as a module for many scripting languages, and is part of several rainfall-runoff modelling suites.	

Contact information	
Link to online tools:	http://rsminerve.hydro10.org/software/
Organization:	United States National Weather Service and State of California, Department of Water Resources
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Anderson, E. (2002) Calibration of conceptual hydrological models for use in river forecasting. NOAA Technical Report, NWS 45, Hydrology Laboratory, August 2002. Burnash, R.J.C, Ferral, R.L. & McGuire, R.A. (1973) A generalized streamflow simulation system: conceptual modeling for digital computers, Technical Report, Joint Federal and State River Forecast Center, US National Weather Service and California Department of Water Resources, Sacramento, CA.

A98 GR4J

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: The GR4J model is a catchment water balance model that relates runoff to rainfall and evapotranspiration using daily data. The model contains two stores and has four parameters. It is available as a module for many scripting languages, and is part of several rainfall-runoff modelling suites.	

Contact information	
Link to online tools:	http://rsminerve.hydro10.org/software/
Organization:	N/A
Contact person:	N/A
Contact details:	contact form in http://rsminerve.hydro10.org/contact/
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Andréassian, V., C. Perrin, L. Berthet, N. Le Moine, J. Lerat, C. Loumagne, L. Oudin, T. Mathevet, M. H. Ramos, and A. Valéry (2009), Crash tests for a standardized evaluation of hydrological models, Hydrol. Earth. Syst. Sci., 13, 1757-1764. Edijatno (1991), Mise au point d'un modèle élémentaire pluie-débit au pas de temps journalier, Thèse de Doctorat thesis, 242 pp, Université Louis Pasteur/ENGEES, Strasbourg. Edijatno, and C. Michel (1989), Un modèle pluie-débit journalier à trois paramètres, La Houille Blanche, 113-121. Edijatno, N. O. Nascimento, X. Yang, Z. Makhlouf, and C. Michel (1999), GR3J: a daily watershed model with three free parameters, Hydrol. Sci. J., 44, 263-277. Le Moine, N. (2008), Le bassin versant de surface vu par le souterrain : une voie d'amélioration des performances et du réalisme des modèles pluie-débit ?, Thèse de Doctorat thesis, 324 pp, Université Pierre et Marie Curie, Paris. Michel, C., Perrin, C., Andréassian, V., Oudin, L. and Mathevet, T.(2006) Has basin-scale modelling advanced beyond empiricism? In: Andréassian, V., Hall, A., Chahinian, N. and Schaake, J. (eds) Large sample basin experiments for hydrological model parameterization: results of the model parameter experiment (MOPEX) 2006 pp. 108-116. IAHS Publication 307. Nascimento, N. O. (1995), Appréciation à l'aide d'un modèle empirique des effets d'action anthropiques sur la relation pluie-débit à l'échelle du bassin versant, Thèse de Doctorat thesis, 550 pp, CERGRENE/ENPC, Paris. Perrin, C. (2000), Vers une amélioration d'un modèle global pluie-débit au travers d'une approche

comparative, Thèse de Doctorat thesis, 530 pp, INPG (Grenoble) / Cemagref (Antony).
Perrin, C. (2002), Vers une amélioration d'un modèle global pluie-débit au travers d'une approche comparative, La Houille Blanche, 84-91.
Perrin, C., C. Michel, and V. Andréassian (2001), Does a large number of parameters enhance model performance? Comparative assessment of common catchment model structures on 429 catchments, J. Hydrol., 242(3-4), 275-301.
Vaze, J., Chiew, F. H. S., Perraud, JM., Viney, N., Post, D. A., Teng, J., Wang, B., Lerat, J., Goswami, M., 2011. Rainfall-runoff modelling across southeast Australia: datasets, models and results. Australian Journal of Water Resources, Vol 14, No 2, pp. 101-116.

This modelling software can be used to simulate rainfall and runoff to estimate streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: SIMHYD is a conceptual rainfall-runoff model that estimates daily stream flow from daily rainfall and areal potential evapotranspiration data. The model contains three stores for interception loss, soil moisture and groundwater. The model has seven parameters. It is available as modules for scripting languages.	

Contact information	
Link to online tools:	https://github.com/hydrogo/LHMP
Organization:	N/A
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Rainfall Runoff Library v1.0.5, June 25, 2004 (http://www.toolkit.net.au/Tools/RRL). Chiew, F. H. S., M. J. Stewardson and T. A. Mc Mahon (1993). "Comparison of six rainfall-runoff modelling approaches." Journal of Hydrology 147: 1-36. Chiew, F. H. S. and T. A. McMahon (1994). "Application of the daily-runoff model MODHYDROLOG to 28 Australian catchments." Journal of Hydrology 153: 383-416. Chiew, FHS, Peel, MC & Western, AW 2002, 'Application and testing of the simple rainfall-runoff model SIMHYD', in VP Singh & DK Frevert (eds), Mathematical models of small watershed hydrology and Applications, Water Resources Publication, Colorado, pp.335-367. Chiew FHS, Vaze J, Viney NR, Jordan PW, Perraud J-M, Zhang L, Teng J, Young WJ, Penaarancibia J, Morden RA, Freebairn A, Austin J, Hill PI, Wiesenfeld CR and Murphy R (2008) Rainfall-runoff modelling across the Murray-Darling Basin. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. 62pp Peel, M. C., F. H. S. Chiew, A. W. Western and T. A. McMahon (2000). Extension of Unimpaired Monthly Streamflow Data and Regionalisation of Parameter Values to Estimate Streamflow in Ungauged Catchments. Canberra, National Land and Water Resources Audit. Vaze, J., J.-M. Perraud, N. R. Viney, D. A. Post, J. Teng, B. Wang, J. Lerat and M. Goswami (2010). "Rainfall-runoff modelling across southeast Australia: Datasets, models and results." Australian Journal of Water Resources 14(2): 101-116.

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: SIMGRO is a modelling framework that can facilitate the investigation of various kinds of regional water management problems. The framework connects to diverse hydrologic model codes like MODFLOW for groundwater and SOBEK-CF for surface water simulation. A number of 'in-house' codes make SIMGRO especially suitable for modelling situations with shallow groundwater levels in relatively flat areas, like in delta regions	

Contact information	
Link to online tools:	http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Software-en-modellen/SIMGRO.htm
Organization:	Alterra
Contact person:	AA Veldhuizen
Contact details:	ab.veldhuizen@wur.nl
Resource:	N/A

Quality, remarks, and references
References / supplementary information: http://www.wur.nl/nl/Expertises-Dienstverlening/Onderzoeksinstituten/Environmental-Research/Faciliteiten-Producten/Software-en-modellen/SIMGRO/References-SIMGRO.htm

A101 DRAINMOD

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The model simulates the hydrology of poorly drained, high water table soils on an hour-by-hour, day-by-day basis for long periods of climatological record (e.g. 50 years). The model predicts the effects of drainage and associated water management practices on water table depths, the soil water regime and crop yields.	

Contact information	
Link to online tools:	https://www.bae.ncsu.edu/agricultural-water-management/drainmod/
Organization:	NC State University
Contact person:	Brian Phillips, Chad Poole, R. Wayne Skaggs, Shiyang Tian, Mohamed A Youssef, Chip Chescheir
Contact details:	https://www.bae.ncsu.edu/agricultural-water-management/contact-people/
Resource:	N/A

Quality, remarks, and references
References / supplementary information: https://www.bae.ncsu.edu/agricultural-water-management/publications-2/

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: SWAP (Soil, Water, Atmosphere and Plant) simulates transport of water, solutes and heat in unsaturated/saturated soils. The model is designed to simulate flow and transport processes at field scale level, during growing seasons and for long term time series. It offers a wide range of possibilities to address both research and practical questions in the field of agriculture, water management and environmental protection.	

Contact information	
Link to online tools:	http://www.swap.alterra.nl/
Organization:	Alterra
Contact person:	Joop Kroes, Jos van Dam
Contact details:	http://www.swap.alterra.nl/Contact.htm
Resource:	N/A

Quality, remarks, and references
References / supplementary information: http://www.swap.alterra.nl/

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The program numerically solves the Richards' equation for saturated-unsaturated water flow and Fickian-based advection dispersion equations for heat and solute transport. The Flow equation incorporates a sink term to account for water uptake by plant roots. The Heat transport equation considers conduction as well as convection with flowing water. The Solute transport equations consider advective-dispersive transport in the liquid phase, and diffusion in the gaseous phase.	

Contact information	
Link to online tools:	https://www.pc-progress.com/en/Default.aspx?H1D-description#k1
Organization:	PC-Progress and University of California, Riverside, USA
Contact person:	N/A
Contact details:	https://www.pc-progress.com/en/Default.aspx?contact
Resource:	N/A

Quality, remarks, and references
References / supplementary information: https://www.pc-progress.com/en/Default.aspx?h1d-references

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: The Decision Support System for Agrotechnology Transfer (DSSAT) Version is a software application program that comprises crop simulation models for over 42 crops (as of Version 4.6). For DSSAT to be functional it is supported by data base management programs for soil, weather, and crop management and experimental data, and by utilities and application programs. The crop simulation models simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics. DSSAT and its crop simulation models have been used for many applications ranging from on-farm and precision management to regional assessments of the impact of climate variability and climate change.	

Contact information	
Link to online tools:	http://dssat.net/
Organization:	Collaboration among University of Florida, the University of Georgia, University of Guelph, University of Hawaii, the International Center for Soil Fertility and Agricultural Development, USDA-Agricultural Research Service, Universidad Politecnica de Madrid, Washington State University, and other scientists associated with ICASA.
Contact person:	N/A
Contact details:	http://dssat.net/contact-us
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, K.J. Boote, L.A. Hunt, U. Singh, J.I. Lizaso, J.W. White, O. Uryasev, R. Ogoshi, J. Koo, V. Shelia, and G.Y. Tsuji. 2015. Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.6 (http://dssat.net). DSSAT Foundation, Prosser, Washington. Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003. DSSAT Cropping System Model. European Journal of Agronomy 18:235‐265.

A105 CROPSYST

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: CropSyst is a is a user-friendly, conceptually simple but sound multi-year multi-crop daily time step simulation model. The model has been developed to serve as an analytic tool to study the effect of cropping systems management on productivity and the environment. The model simulates the soil water budget, soil-plant nitrogen budget, crop canopy and root growth, dry matter production, yield, residue production and decomposition, and erosion. Management options include: cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, tillage operations (over 80 options), and residue management.	

Contact information	
Link to online tools:	http://modeling.bsyse.wsu.edu/CS_Suite/CropSyst/index.html
Organization:	Washington State University
Contact person:	Claudio O. Stöckle, Roger L. Nelson
Contact details:	Phone: (509)335-1578, FAX: (509)335-2722.
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Donatelli, M., C. O. Stockle , E. Ceotto, and M. Rinaldi. 1996. CropSyst validation for cropping systems at two locations of Northern and Southern Italy. European Journal of Agronomy (in press). Ferrer-Alegre, F. 1995. A model for assessing crop response and water management in saline conditions. MS Thesis, Washington State University, Pullman, WA, USA. Monteith, J.L. 1977. Climate and crop efficiency of crop production in Britain. Phil. Trans. Res. Soc. London Ser. B, 281:277-329. Pala, M., C.O. Stockle , and H.C. Harris. 1996. Simulation of durum wheat (triticum durum) growth under differential water and nitrogen regimes in a mediterranean type of environment using CropSyst. Agricultural Systems (in press). Stockle, C. O. 1996. GIS and simulation technologies for assessing cropping systems management in dry environments. American Journal of Alternative Agriculture (in press). Stockle, C. O. and R. L. Nelson. 1996. Cropsyst User's manual (Version 2.0). Biological Systems Engineering Dept., Washington State

University, Pullman, WA, USA (In preparation).
Stockle, C. O. , M. Cabelguenne, and P. Debaeke. 1996.
Validation of CropSyst for water management at a site in southwestern France. Proc. 4th European Society of Agronomy Congress, Wageningen (In press)
Stockle, C. O. and P. Debaeke. 1996.
Modeling crop N requirement: A critical analysis. Proc. 4th European Society of Agronomy Congress, Wageningen (In press)
Stockle, C. O. , S. Martin and G. S. Campbell. 1994.
CropSyst, a cropping systems model: water/nitrogen budgets and crop yield. Agricultural Systems 46:335-359.
Stockle, C. O. and R. L. Nelson. 1994.
Cropsyst User's manual (Version 1.0). Biological Systems Engineering Dept., Washington State University, Pullman, WA, USA.
Tanner, C.B. and T.R. Sinclair. 1983.
Efficient water use in crop production: Research or Research? In Limitations to Efficient Water Use in Crop Production. H.M. Taylor, W.R. Jordan and T.R Sinclair (eds.). Amer. Soc. Agron, Madison, WI, USA.
Willmott, C.J. 1982.
Some comments on the evaluation of model performance. Bull. Amer. Meteor. Soc. 63:1309-1313.

A106 SWAT

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture and hydrology.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural, Hydrological
Applications:	Mapping agricultural and hydrological drought hazard
Concise model description: SWAT (Soil & Water Assessment Tool) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. SWAT is a public domain software enabled model actively supported by the USDA Agricultural Research Service at the Blackland Research & Extension Center in Temple, Texas, USA. It is a hydrology model with the following components: weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer. SWAT can be considered a watershed hydrological transport model. This model is used worldwide and is continuously under development.	

Contact information	
Link to online tools:	http://swat.tamu.edu/
Organization:	USDA
Contact person:	Jeff Arnold, Nancy Sammons
Contact details:	http://swat.tamu.edu/contact
Resource:	N/A

Quality, remarks, and references
References / supplementary information: http://swat.tamu.edu/publications/peer-reviewed-publications/

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: STICS, an interdisciplinary simulator for standard crops, models crop development at plot level across all agronomic criteria: climate, soil, and agricultural practices. It is also able to model intercropping systems and crop rotation cycles.	

Contact information	
Link to online tools:	http://www.inra.fr/en/Scientists-Students/Agricultural-systems/All-reports/Modelling-and-agrosystems/STICS-an-agronomy-dynamo
Organization:	Institut national de la recherche agronomique (INRA)
Contact person:	Marie Launay, Françoise Ruget
Contact details:	marie.launay@avignon.inra.fr, francoise.ruget@avignon.inra.fr
Resource:	N/A

Quality, remarks, and references
References / supplementary information: N. Brisson, M. Launay, B. Mary, N. Beaudoin, 2012, Conceptual Basis, Formalisations and Parameterization of the Stics Crop Model

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: Root Zone Water Quality Model 2 (RZWQM2) simulates major physical, chemical, and biological processes in an agricultural crop production system. RZWQM2 is a one-dimensional (vertical in the soil profile) process-based model that simulates the growth of the plant and the movement of water, nutrients and pesticides over, within and below the crop root zone of a unit area. It has a quasi-two-dimensional macropore/lateral flow. It responds to agricultural management practices including planting and harvest practices, tillage, pesticide, manure and chemical nutrient applications, and irrigation events. The model includes simulation of a tile drainage system.	

Contact information	
Link to online tools:	https://www.ars.usda.gov/plains-area/fort-collins-co/center-for-agricultural-resources-research/rangeland-resources-systems-research/docs/system/rzwqm/#Support
Organization:	USDA
Contact person:	N/A
Contact details:	RZWQMsupport@ars.usda.gov
Resource:	N/A

Quality, remarks, and references
References / supplementary information: https://www.ars.usda.gov/ARSUserFiles/30122000/RZWQM/rzwqmpub.pdf

A109 WOFOST

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: WOFOST (WOrld FOod STudies) is a simulation model for the quantitative analysis of the growth and production of annual field crops. It is a mechanistic model that explains crop growth on the basis of the underlying processes, such as photosynthesis, respiration and how these processes are influenced by environmental conditions.	

Contact information	
Link to online tools:	http://www.wur.nl/en/Expertise-Services/Research-Institutes/Environmental-Research/Facilities-Products/Software-and-models/WOFOST.htm
Organization:	Alterra
Contact person:	dr. AJW de Wit
Contact details:	allard.dewit@wur.nl
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Boogaard, H.L., van Diepen, C.A., Roetter, R.P., Cabrera, J.M.C.A. and Laar, H.H.v., 1998. WOFOST 7.1 : user's guide for the WOFOST 7.1 crop growth simulation model and WOFOST Control Center 1.5. Technical document / DLO Winand Staring Centre;52. DLO Winand Staring Centre, Wageningen. Supit, I., Hooijer, A.A. and Diepen van, C.A., 1994. System Description of the WOFOST 6.0 Crop Simulation Model Implemented in CGMS, Volume 1: Theory and Algorithms. EUR 15956 EN, Joint Research Center, Commission of the European Communities, Luxembourg. Diepen, C.A., van, Wolf, J. and Keulen, H., van, 1989. WOFOST: a simulation model of crop production. Soil Use and Management, 5: 16-24 Keulen, H. van ; Wolf, J. 1986. Modelling of agricultural production : weather, soils and crops. http://edepot.wur.nl/168025

This modelling software can be used to simulate soil moisture conditions and/or crop growth, and drought impacts on agriculture.

General Characteristics	
Type:	Modelling Software
Type of drought:	Agricultural
Applications:	Mapping agricultural drought hazard
Concise model description: WARM 1 is a Windows desktop application providing users with a powerful environment for rice simulations. The application implement the version 1 of WARM (Water Accounting Rice Model) model, simulating rice growth and development, paddy soil hydrology, blast disease, floodwater effect on vertical thermal profile, cold-induced spikelet sterility.	

Contact information	
Link to online tools:	http://www.cassandralab.com/applications/1#tab-general
Organization:	Universita Degli Studi di Milano
Contact person:	Roberto Confalonieri
Contact details:	roberto.confalonieri@unimi.it
Resource:	N/A

Quality, remarks, and references
References / supplementary information: http://www.cassandralab.com/applications/1#tab-papers

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: MODFLOW is the USGS's modular hydrologic model. MODFLOW is considered an international standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions. Originally developed and released solely as a groundwater-flow simulation code when first published in 1984, MODFLOW's modular structure has provided a robust framework for integration of additional simulation capabilities that build on and enhance its original scope. The family of MODFLOW-related programs now includes capabilities to simulate coupled groundwater/surface-water systems, solute transport, variable-density flow (including saltwater), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management.	

Contact information	
Link to online tools:	https://water.usgs.gov/ogw/modflow/
Organization:	USGC
Contact person:	Chris Langevin, Edward Banta, Richard Winston
Contact details:	Chris Langevin (langevin@usgs.gov), Edward Banta (erbanta@usgs.gov), or Richard Winston (rbwinst@usgs.gov)
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Harbaugh, A.W., Langevin, C.D., Hughes, J.D., Niswonger, R.N., and Konikow, L. F., 2017, MODFLOW-2005 version 1.12.00, the U.S. Geological Survey modular groundwater model: U.S. Geological Survey Software Release, 03 February 2017, http://dx.doi.org/10.5066/F7RF5S7G; Harbaugh, A.W., 2005, MODFLOW-2005, the U.S. Geological Survey modular ground-water model -- the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: SutraSuite contains the SUTRA ground-water simulation code and a number of utilities for both pre- and post-processing for simulations in both two spatial dimensions (2D) and three spatial dimensions (3D). SUTRA simulates saturated and/or unsaturated, constant-density or density-dependent groundwater flow and either single-species reactive solute transport or thermal energy transport.	

Contact information	
Link to online tools:	https://water.usgs.gov/nrp/gwsoftware/sutra.html
Organization:	USGC
Contact person:	Clifford I. Voss and Alden M. Provost
Contact details:	Clifford I. Voss (cvoss@usgs.gov) and Alden M. Provost (aprovost@usgs.gov)
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Voss, C. I., and Provost, A.M., 2002 (Version of September 22, 2010) SUTRA, A model for saturated-unsaturated variable-density ground-water flow with solute or energy transport, U.S. Geological Survey Water-Resources Investigations Report 02-4231, 270 p.

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: FEFLOW (Finite Element subsurface FLOW system) is a computer program for simulating groundwater flow, mass transfer and heat transfer in porous media and fractured media. The program uses finite element analysis to solve the groundwater flow equation of both saturated and unsaturated conditions as well as mass and heat transport, including fluid density effects and chemical kinetics for multi-component reaction systems.	

Contact information	
Link to online tools:	https://www.mikepoweredbydhi.com/products/feflow
Organization:	DHI-WASY
Contact person:	Fabien Cornaton
Contact details:	fjc@dhigroup.com
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Trefry, M.G.; Muffels, C. (2007). "FEFLOW: a finite-element ground water flow and transport modeling tool". Ground Water. 45 (5): 525–528. doi:10.1111/j.1745-6584.2007.00358.x.

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: IGW is a software environment for real-time 2D and 3D groundwater modeling. The software functions as a ‘‘numerical laboratory’’ in which the modeler can freely explore: visually creating an aquifer of desired configurations and then immediately investigating and visualizing the groundwater system. IGW allows the modeler’s thought processes to progress naturally and intuitively with the information visualized, overlaid, and compared at the instant it is required for analysis, providing a real sense of continuous active exploration and engaged problem solving.	

Contact information	
Link to online tools:	http://www.egr.msu.edu/~lishug/research%20web/NSF-CRCD-IGW.htm
Organization:	Michigan State University
Contact person:	Shu-Guang Li
Contact details:	lishug@egr.msu.edu
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Li, S.G. and Q. Liu, "A real-time, computational steering environment for integrated groundwater modeling". Recommended for publication, under revision, Ground Water. Li, S.G., Q. Liu, and S. Afshari, "An Object-Oriented Hierarchical Patch Dynamics Paradigm (HPDP) for Groundwater Modeling". Recommended for publication, under revision, Environmental Modeling and Software. Ni, C.F. and S.G. Li, "Simple Closed-Form Formulas for Predicting Groundwater Flow Model Uncertainty in Complex, Heterogeneous Trending Media". Recommended for publication, under revision. Water Resources and Research. S.G. Li and Q. Liu, "Interactive Ground Water (IGW)", Environmental Modeling and Software. Vol. 20, No. 12. S.G. Li, Q. Liu, Interactive Ground Water (IGW): An Innovative Digital Laboratory For Groundwater Education and Research, COMPUTER APPLICATIONS IN ENGINEERING EDUCATION. Vol. 11(4):179~202, 2003.

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: ParFlow is an open-source, object-oriented, parallel watershed flow model. It includes fully-integrated overland flow, the ability to simulate complex topography, geology and heterogeneity and coupled land-surface processes including the land-energy budget, biogeochemistry and snow (via CLM).	

Contact information	
Link to online tools:	http://inside.mines.edu/~rmaxwell/maxwell_software.shtml
Organization:	Integrated GroundWater Modeling Center
Contact person:	Reed M. Maxwell
Contact details:	rmaxwell@mines.edu
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Maxwell, R.M., S.J. Kollet, S.G. Smith, C.S. Woodward, R.D. Falgout, I.M. Ferguson, N. Engdahl, L.E. Condon, B. Hector, S.R. Lopez, J. Gilbert, L. Bearup, J. Jefferson, C. Collins, I. de Graaf, C. Prubilick, C. Baldwin, W.J. Bosl, R. Hornung, S. Ashby, ParFlow User's Manual. Integrated GroundWater Modeling Center Report GWMI 2016-01, 167p

A116 IWFM: Integrated Water Flow Model

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: IWFM is a water resources management and planning model that simulates groundwater, surface water, stream-groundwater interaction, and other components of the hydrologic system. A unique feature of IWFM is the land use based approach of calculating water demand. IWFM simulates stream flow, soil moisture accounting in the root zone, flow in the vadose zone, groundwater flow, and stream-aquifer interaction. Agricultural and urban water demands can be pre-specified, or calculated internally based on different land use types. Water re-use is also modeled as well as tile drains and lakes or open water areas. Another notable feature of IWFM is a “zone budget” that includes subsurface flow computations across element faces.	

Contact information	
Link to online tools:	http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/index.cfm
Organization:	California Department of Water Resources
Contact person:	N/A
Contact details:	IWFMtechsupport@water.ca.gov
Resource:	N/A

Quality, remarks, and references
References / supplementary information: IWFM is a water resources management and planning model that simulates groundwater, surface water, stream-groundwater interaction, and other components of the hydrologic system. A unique feature of IWFM is the land use based approach of calculating water demand. IWFM simulates stream flow, soil moisture accounting in the root zone, flow in the vadose zone, groundwater flow, and stream-aquifer interaction. Agricultural and urban water demands can be pre-specified, or calculated internally based on different land use types. Water re-use is also modeled as well as tile drains and lakes or open water areas. Another notable feature of IWFM is a “zone budget” that includes subsurface flow computations across element faces.

A117 HydroGeoSphere (HGS)

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: HydroGeoSphere (HGS) is a three-dimensional control-volume finite element simulator which is designed to simulate the entire terrestrial portion of the hydrologic cycle. HGS also dynamically integrates key components of the hydrologic cycle such as evaporation from bare soil and water bodies, vegetation-dependent transpiration with root uptake, snowmelt and soil freeze/thaw. Features such as macro pores, fractures, and tile drains can either be incorporated discretely or by using a dual-porosity, dual permeability formulation	

Contact information	
Link to online tools:	https://www.aquanty.com/hydrogeosphere/
Organization:	Aquanty Inc., a hydrological science and research spin-off company from the University of Waterloo, was founded in 2012 by the key developers of HydroGeoSphere™ (HGS).
Contact person:	N/A
Contact details:	sales@aquanty.com
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Brunner, P., & Simmons, C. T. (2012). HydroGeoSphere: a fully integrated, physically based hydrological model. Groundwater, 50(2), 170-176.

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: MIKE SHE is an integrated hydrological modelling system for building and simulating surface water flow and groundwater flow. It can simulate the entire land phase of the hydrologic cycle and allows components to be used independently and customized to local needs. MIKE SHE can be used for the analysis, planning and management of a wide range of water resources and environmental problems related to surface water and groundwater, especially surface-water impact from groundwater withdrawal, conjunctive use of groundwater and surface water, wetland management and restoration, river basin management and planning, impact studies for changes in land use and climate.	

Contact information	
Link to online tools:	https://www.mikepoweredbydhi.com/products/mike-she
Organization:	DHI-WASY
Contact person:	Torben Strange Jensen
Contact details:	tsj@dhigroup.com
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Abbott, M.B.; Bathurst, J.C.; Cunge, J.A.; O'Connell, P.E.; Rasmussen, J. (1986). "An introduction to the European Hydrological System — Systeme Hydrologique Europeen, "SHE", 1: History and philosophy of a physically-based, distributed modelling system". Journal of Hydrology. 87 (1–2): 45–59. doi:10.1016/0022-1694(86)90114-9.

This modelling software can be used to simulate groundwater flow and estimate groundwater supplies.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping hydrological drought hazard
Concise model description: River basin Decision Support System and network flow model designed specifically for developing improved basin wide and regional strategies for short-term water management, long-term operational planning, drought contingency planning, water rights analysis and resolving conflicts between urban, agricultural, and environmental concerns.	

Contact information	
Link to online tools:	http://modsim.engr.colostate.edu/
Organization:	Colorado State University
Contact person:	John Labadie
Contact details:	labadie@engr.colostate.edu
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Labadie, J. 2010. MODSIM 8.1: River Basin Management Decision Support System User Manual and Documentation. Colorado State University, Fort Collins, Colorado, 130 pages.

This modelling software can be used to simulate drought risk to population, drought risk to municipal and industrial water needs , drought risk to agriculture and livestock, drought risk to hydropower.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping drought risk to population, Mapping drought risk to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower
Concise model description: River basin and catchment modeling platform with three primary modes of execution: catchment, planning, and "river operations". Across these modes of implementation is a wide range of choices for component model (for example, choice of rainfall-runoff model, nutrient and sediment generation and transport model, groundwater interaction model and crop water use model) and water management rules (including water sharing rules, resource allocation and environmental flow requirements).	

Contact information	
Link to online tools:	http://ewater.org.au/products/ewater-source/
Organization:	eWater Limited
Contact person:	N/A
Contact details:	Contact form at http://ewater.org.au/contact-us/
Resource:	N/A

Quality, remarks, and references
References / supplementary information: N/A

A121 Water Evaluation And Planning system (WEAP)

This modelling software can be used to simulate drought risk to population, drought risk to municipal and industrial water needs , drought risk to agriculture and livestock, drought risk to hydropower.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping drought risk to population, Mapping drought risk to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower
Concise model description: WEAP is a software tool for integrated water resources planning. Operates on the basic principle of a water balance model that can be applied to municipal and agricultural systems, a single watershed, or complex transboundary river basin systems. WEAP simulates a broad range of natural and engineered components within these systems, including rainfall runoff, base flow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities; reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements.	

Contact information	
Link to online tools:	http://www.weap21.org/index.asp?action=205
Organization:	Stockholm Environment Institute.
Contact person:	N/A
Contact details:	info@weap21.org
Resource:	N/A

Quality, remarks, and references
References / supplementary information: William Johnson, Quentin Williams and Paul Kirshen, "WEAP: A Comprehensive and Integrated Model of Supply and Demand," Proceedings of the 1995 Georgia Water Resources Conference, Athens, Georgia, USA, April 11-12, 1995. Paul Kirshen, Paul Raskin and Evan Hansen, "WEAP: A Tool for Sustainable Water Resources Planning in the Border Region," Proceedings of the 22nd Annual Water Resources Planning and Management Division Conference, ASCE, Integrated Water Resources Planning for the 21st Century, Cambridge, MA, USA, May 7-11, 1995. David Yates, Jack Sieber, David R. Purkey and Annette Huber-Lee, "WEAP21--A Demand-, Priority-, and Preference-Driven Water Planning Model: Part 1, Model Characteristics," Water International, 30 (2005), pp. 487-500.

A122 GSFLOW

This modelling software can be used to estimate surface water and groundwater supplies, and streamflows.

General Characteristics	
Type:	Modelling Software
Type of drought:	Hydrological
Applications:	Mapping drought risk to population, Mapping drought risk to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower
Concise model description: An integrated hydrologic model called GSFLOW (Ground-water and Surface-water FLOW) was developed to simulate coupled ground-water and surface-water resources. GSFLOW simulates coupled groundwater/surface-water flow in watersheds by simultaneously computing flow across the land surface and within streams and lakes as well as within subsurface saturated and unsaturated materials. Climate data consisting of measured or estimated precipitation, air temperature, and solar radiation, as well as groundwater stresses (such as withdrawals) and boundary conditions are the driving factors for a GSFLOW simulation. The model is appropriate for evaluating effects of land-use change, climate variability, and groundwater withdrawals on surface and subsurface flow for watersheds.	

Contact information	
Link to online tools:	https://water.usgs.gov/ogw/gsflow/index.html
Organization:	USGS
Contact person:	N/A
Contact details:	Contact form at https://answers.usgs.gov/
Resource:	N/A

Quality, remarks, and references
References / supplementary information: Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008, GSFLOW-Coupled Ground-water and Surface-water FLOW model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240 p. This is the initial report that describes the theory and use of GSFLOW.

B. Drought Hazard and Risk Models for Africa

Platforms

B123 African Flood and Drought Monitor

This platform can be used to obtain information of meteorological, hydrological, and agricultural drought hazards on a real-time and forecast basis for Africa.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Drought forecasting , Mapping hydrological drought hazard, Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included: Meteorology: Precipitation, max temperature, min temperature, wind; Hydrology: soil Moisture, soil moisture anomaly (from remote sensing), evaporation, surface runoff, baseflow, streamflow; Drought indices: SPI-1, SPI-3, SPI-6, SPI-12, NDVI (from remote sensing), Streamflow percentiles, and Drought index. The Drought index is calculated by determining the percentile of the daily average of relative soil moisture at each grid cell with respect to its empirical cumulative probability distribution function provided by the historical simulations (1950 – 2008)				
Countries where available:	Africa			
Period available:	From:	01/02/1950	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Based on macro scale hydrologic modeling, the system ingests available data to provide a real-time assessment of the water cycle and drought conditions, and puts this in the context of the long-term record back to 1950. The data is made available online for drought research and operational use to augment on-the ground assessments of drought. The monitoring system comprises two parts: i) First, a historic reconstruction (1950 – 2008) of the water cycle forced by a merged reanalysis/ observational meteorological data set; this forms the climatology against which current conditions are compared. ii) Second, a real-time monitoring system (2009 – present) driven by remote sensing precipitation and atmospheric analysis data that tracks drought conditions in near real-time.				

Contact information	
Link to online tools:	http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en
Organization:	Princeton University
Contact person:	Julio Herrera, Nate Chaney, Colby Fisher, Justin Sheffield, Eric Wood
Contact details:	No info available, but contact is possible by filling the form in the top-right tab 'Feedback'
Resource:	N/A

Data and links	
Data used: For the historic reconstruction, the model is forced by meteorological data derived from a blending of reanalysis (NCEP/NCAR) and gridded observation-based datasets including: the CRU TS3.1 monthly precipitation and temperature data set, the NASA TRMM, the monthly gridded precipitation and temperature data set of Willmott and Matsura, and the GPCP monthly data set (Sheffield et al., 2006). For the real-time monitor, the VIC model is forced by a mixture of observations and modeled/remotely sensed meteorology to produce updates of water cycle variables. Daily mean wind speed and daily maximum and minimum temperatures are taken from NOAA's GFS analysis fields, which ingest data from multiple sources including remote sensing and in-situ observations in real-time (Parrish and Derber, 1992); this is a reliable source for real-time data over large-scales. Daily precipitation comes from the NASA TRMM Multi-satellite Precipitation Analysis (TMPA) data set (Huffman et al., 2007) when available, otherwise from GFS. Both TMPA and GFS are bias-corrected to ensure consistency with the historical meteorological data set.	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.25°			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-20	52	38	-35
Temporal scale:	Daily, Monthly			
Aggregation period:	1, 3, 6, 12 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: https://collaboration.worldbank.org/events/2619 http://www.gwadi.org/tools/hydrologic_monitoring/africa_monitor
Strengths: N/A
Weaknesses: N/A
Final remarks: The VIC model was validated against discharge observations (GRDC, 1950-2010). The quality is quite poor for most of the gauges., The tool provides, in some cases, indicators based on different models or datasets, which can be used to quantify uncertainty.

B124 African Drought Observatory

This platform can be used to obtain information of meteorological, hydrological, and agricultural drought hazards as well as drought impact to the overall economy on a near real-time and forecast basis for Africa.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Drought forecasting, Mapping drought impact to agriculture and livestock, Mapping drought impact to the overall economy, Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included: Precipitation and derived indicators, such as the precipitation anomalies (% of normal) and the Standardized Precipitation Index (SPI), Vegetation productivity anomaly, drought hazard index, drought vulnerability index, drought risk				
Countries where available:	Africa			
Period available:	From:	01/01/1979	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The main monitoring products are the precipitation and their derived indicators, such as the precipitation anomalies (% of normal) and the Standardized Precipitation Index (SPI). Drought vulnerability and risk are assessed at country and basin level following a socio-economic approach (Naumann et al., 2013b). Regarding the seasonal forecast, the two main outputs are the forecasted SPI following a probabilistic or a deterministic approach. A number of geographic background data sets are also available such as climate classifications (Aridity Index and Köppen-Geiger Classification), land cover and soil maps (Land cover, Agricultural Management Factor, Soil Fertility Index), water resources (Irrigation cropping pattern zones, Surface water bodies and River Basins), and population indicators (Population Density and Infant Mortality Rate)				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/ado/
Organization:	Joint Research Centre (JRC)
Contact person:	Alfred de Jager, Jürgen Vogt, Paulo Barbosa
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	N/A

Data and links
Data used: The GPCC and the ECMWF atmospheric reanalysis ERA-Interim precipitation datasets are used as the main sources of precipitation. ERA-Interim monthly temperature and soil moisture including their

anomalies are also displayed. The vegetation conditions are assessed through the anomaly of fAPAR (fraction of Absorbed Photosynthetically Active Radiation; Gobron et al., 2007) 10-day time composite derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument. The meteorological seasonal forecast relies in the ECMWF dynamical ocean-atmosphere coupled system 4 (S4)	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Precipitation anomalies and SPI-3: 1° Hazard, Vulnerability and Risk indices: country and sub-basin scales			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-20	52	38	-35
Temporal scale:	Monthly			
Aggregation period:	3, 6, 12 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: Naumann, G., Dutra, E., Barbosa, P., Pappenberger, F., Wetterhall, F., & Vogt, J. (2013). Establishing the dominant source of uncertainty in drought indicators. Hydrology and Earth System Sciences Discussions, 10, 13407-13440. Naumann missing Dutra, E., Di Giuseppe, F., Wetterhall, F., & Pappenberger, F. (2013). Seasonal forecasts of droughts in African basins using the Standardized Precipitation Index. Hydrology and Earth System Sciences, 17(6), 2359-2373.
Strengths: N/A
Weaknesses: N/A
Final remarks: The indicators and datasets were selected after having been tested at regional and continental scale (Dutra et al., 2013 and Naumann et al., 2013a).

B125 IGAD Climate Prediction and Applications Centre

This platform can be used to obtain meteorological drought hazard information on a near real-time monthly basis for Ethiopia, Kenya, South Sudan, Sudan, Uganda, Somalia, Eritrea, Tanzania.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	Standardized Precipitation Index (SPI), NDVI anomaly			
Countries where available:	Ethiopia, Kenya, South Sudan, Sudan, Uganda, Somalia, Eritrea, Tanzania			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Knowledge management products including databases, Geoportals and Geospatial applications are developed at IGAD Climate Predictions and Applications Centre in order to organize, document, visualize and share (some of) data to member states and partners. This point station data is blended with the satellite data to enhance the quality of the products for the region Due to sparse station networks, the blending of data with satellite improve the spatial representativeness of the areas . The station data are also useful to verify, calibrate and validate some of the climate parameters generated by ICPAC scientists. The website has applications for decision makers such as: Food security integrated phase classification (IPC)				

Contact information	
Link to online tools:	http://www.icpac.net/index.php/applications/agriculture-livestock-application.html
Organization:	IGAD Climate Prediction and Applications Centre
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used: The monitoring products for the IGAD region are: - NDVI anomaly (updated for the last two months), Vegetation Anomaly, SPI (updated for the last two months), The long term average rainfall is presented (1981-2015) , Rainfall deviation from long-term dataset	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale

Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Updated to the last month			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

B126 Seasonal Monitor for Southern Africa, Horn of Africa, West Africa Sahel and Eastern Regions

This platform can be used to obtain information of meteorological and agricultural drought hazards on a near real-time seasonal basis for countries within Southern Africa, Horn of Africa, West Africa Sahel and Eastern Regions.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	Rainfall, NDVI			
Countries where available:	Countries within Southern Africa, Horn of Africa, West Africa Sahel and Eastern Regions			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Animations showing how cumulative rainfall, vegetation index, 30-day rainfall and start of season evolved during the current season compared to average trends for the alst 20 years. Reports are also provided.				

Contact information	
Link to online tools:	http://vam.wfp.org/sites/seasonal_monitor/afs/
Organization:	World food program (WFP)
Contact person:	Rogerio Bonifacio
Contact details:	rogerio.bonifacio@wfp.org +390665133917
Resource:	N/A

Data and links	
Data used:	NDVI, rainfall,
Data format:	.pdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Seasonal			
Aggregation period:	N/A			
Latency:	updated by season			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

B127 FLDAS - Eastern Africa

This platform can be used to obtain information of meteorological agricultural, and hydrological drought hazards for Burundi, D.R. Congo, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania, Uganda.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	GeoWRSI, NOAA Daily Rainfall, CHIRPS Precipitation			
Countries where available:	Burundi, D.R. Congo, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan, Tanzania, Uganda			
Period available:	From:	1981	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: (1) FLDAS outputs are based on multiple hydrologic models hence they better represent the uncertainty in simulated hydrologic variables. (2) FLDAS provides simulation of soil moisture and runoff/streamflow (observations of which are sparse at best) hence it allows monitoring of agricultural and hydrological drought.				

Contact information	
Link to online tools:	http://lis.gsfc.nasa.gov/projects/fewsnet-east-africa
Organization:	NASA
Contact person:	Amy McNally
Contact details:	amy.l.mcnally@nasa.gov
Resource:	FEWS NET

Data and links	
Data used:	CHIRPS, MERRA, GDAS, RFE2
Data format:	NetCDF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.25 and 0.1 degree (~25, 10km)			
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	22.05	51.35	22.95	-11.75
Temporal scale:	30 minute time steps (Noah), 1 hr (VIC), 3-hourly output fields; decade (WRSI)			
Aggregation period:	Pentad to seasonal			
Latency:	Every Five Days			

Quality, remarks, and references
References / supplementary information: McNally, A., and Coauthors, 2017: A land data assimilation system for sub-Saharan Africa food and water security applications. Sci Data, 4, 170012, doi:10.1038/sdata.2017.12
Strengths: Provides detailed hydrologic information
Weaknesses: Long Latency
Final remarks: Peer-reviewed

This platform can be used to obtain real-time information on meteorological, hydrological, and agricultural drought hazards for Angola, Botswana, Burundi, Congo-Brazzavile, Congo-Kinshasa, Equatorial Guinea, Gabon, Kenya, Lesotho, Madagascar, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	GeoWRSI, NOAA Daily Rainfall, CHIRPS Precipitation			
Countries where available:	Angola, Botswana, Burundi, Congo-Brazzavile, Congo-Kinshasa, Equatorial Guinea, Gabon, Kenya, Lesotho, Madagascar, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe			
Period available:	From:	1981	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: (1) FLDAS outputs are based on multiple hydrologic models hence they better represent the uncertainty in simulated hydrologic variables. (2) FLDAS provides simulation of soil moisture and runoff/streamflow (observations of which are sparse at best) hence it allows monitoring of agricultural and hydrological drought.				

Contact information	
Link to online tools:	http://lis.gsfc.nasa.gov/projects/fewsnet-southern-africa
Organization:	NASA
Contact person:	Amy McNally
Contact details:	amy.l.mcnally@nasa.gov
Resource:	FEWS NET

Data and links	
Data used:	CHIRPS, MERRA, GDAS, RFE2
Data format:	NetCDF
Data requirements:	No requirements

Spatial and temporal scale

Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.25 and 0.1 degree (~25, 10km)			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	6.05	54.55	6.35	-37.85
Temporal scale:	30 minute time steps (Noah), 1 hr (VIC), 3-hourly output fields; decade (WRSI)			
Aggregation period:	Pentad to seasonal			
Latency:	Every Five Days			

Quality, remarks, and references
References / supplementary information: McNally, A., and Coauthors, 2017: A land data assimilation system for sub-Saharan Africa food and water security applications. Sci Data, 4, 170012, doi:10.1038/sdata.2017.12
Strengths: Provides detailed hydrologic information
Weaknesses: Long Latency
Final remarks: Peer-reviewed

This platform can be used to obtain real-time information on meteorological, hydrological, and agricultural drought hazards for Benin, Burkina Faso, Cameroon, Chad, Cote D'Ivoire, The Gambia, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	GeoWRSI, NOAA Daily Rainfall, CHIRPS Precipitation			
Countries where available:	Benin, Burkina Faso, Cameroon, Chad, Cote D'Ivoire, The Gambia, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo			
Period available:	From:	1981	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: (1) FLDAS outputs are based on multiple hydrologic models hence they better represent the uncertainty in simulated hydrologic variables. (2) FLDAS provides simulation of soil moisture and runoff/streamflow (observations of which are sparse at best) hence it allows monitoring of agricultural and hydrological drought.				

Contact information	
Link to online tools:	http://lis.gsfc.nasa.gov/projects/fewsnet-west-africa
Organization:	NASA
Contact person:	Amy McNally
Contact details:	amy.l.mcnally@nasa.gov
Resource:	FEWS NET

Data and links	
Data used:	CHIRPS, MERRA, GDAS, RFE2
Data format:	NetCDF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.25 and 0.1 degree (~25, 10km)			
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	-18.65	25.85	17.65	5.35
Temporal scale:	30 minute time steps (Noah), 1 hr (VIC), 3-hourly output fields; decade (WRSI)			
Aggregation period:	Pentad to seasonal			
Latency:	Every Five Days			

Quality, remarks, and references
References / supplementary information: McNally, A., and Coauthors, 2017: A land data assimilation system for sub-Saharan Africa food and water security applications. Sci Data, 4, 170012, doi:10.1038/sdata.2017.12
Strengths: Provides detailed hydrologic information
Weaknesses: Long Latency
Final remarks: Peer-reviewed

B130 Famine Early Warning Systems Network - Africa

This platform can be used to obtain near real-time information on meteorological, hydrological, and agricultural drought hazards for Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	CHIRPS precipitation, NOAA Rainfall Estimate, SSEBop Evapotranspiration, eMODIS NDVI, Water Requirement Satisfaction Index			
Countries where available:	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Chad, Comoros, Congo, Congo (Dem. Rep.), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe			
Period available:	From:	Varies (CHIRPS - 1981, TRMM - 2000, eMODIS - 2010)	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The primary strength are: (1) Reliance on both satellite and station data (2) Availability of multiple diverse datasets to allow for convergence of evidence (iii) near real-time availability (iv) ground truth validation in near-real time. (v) freely and publically available output (vi) website based interface provides easy access.				

Contact information	
Link to online tools:	https://earlywarning.usgs.gov/fews/search/africa
Organization:	USGS

Contact person:	N/A
Contact details:	Contact form in website
Resource:	FEWS NET

Data and links	
Data used:	Geostationary IR, MODIS IR/visible
Data format:	GeoTIFF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	500m to 5 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-17	51	37	-35
Temporal scale:	Monthly			
Aggregation period:	Pentad to seasonal			
Latency:	Every Five Days			

Quality, remarks, and references
References / supplementary information: Help pages at earlywarning.usgs.gov Funk et al. (2015) Scientific Data; Xie and Arkin (1997) Verdin and Klaver (2002) Hydrologic Processes; Xie and Arkin (1997) BAMS; Senay et al. (2011) Agricultural Water Management
Strengths: Routinely updated, high resolution
Weaknesses: Often lacking in situ station support
Final remarks: Peer-reviewed

B131 NOAA CPC

This platform can be used to obtain real-time information on meteorological, hydrological, and agricultural drought hazards for Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Chad, Comoros, Congo, Congo (Dem. Rep.), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	CPC-U SPI, CMORF SPI, Soil Moisture Percentile, Runoff Percentile, Temperature Percentile, Precipitation, Temperature			
Countries where available:	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Chad, Comoros, Congo, Congo (Dem. Rep.), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe			
Period available:	From:	2000 (RFE2) 1983 (ARC2)	To:	2017
Costs involved in obtaining the tool:	None			
Concise model description: Routinely updated				

Contact information	
Link to online tools:	http://www.cpc.ncep.noaa.gov/products/international/africa/africa.shtml
Organization:	NOAA CPC
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	GRIB
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	.1 degree			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-20	55	40	-40
Temporal scale:	Daily			
Aggregation period:	0.5, 1, 6 months			
Latency:	Daily			

Quality, remarks, and references
References / supplementary information: http://www.cpc.noaa.gov/products/fews/RFE2.0_tech.pdf https://data.noaa.gov/dataset/climate-prediction-center-cpc-africa-rainfall-climatology-version-2-0-arc2
Strengths: rapid update
Weaknesses: systematic bias, non-stationarity
Final remarks: Good platform.

B132 ITHACA Drought Monitoring

This platform can be used to obtain information of drought risk to the vegetation for Africa on a monthly basis.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping drought risk to agriculture and livestock, Mapping drought risk to population			
Indicator(s) included:	SPI-3, SSID, DWI			
Countries where available:	Africa			
Period available:	From:	2001	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: In the broad context of drought Early Warning, ITHACA's efforts are oriented towards the development of an automated system (Drought Monitoring), able to monitor relevant environmental variables thus enabling the detection and characterization of vegetation stress conditions. Different parameters are integrated into a simplified drought risk model which considers environmental data related to vegetation production and rainfall. In particular, the near real-time monitoring of satellite derived vegetation indexes allows the early detection of water stress conditions of vegetation, and the monitoring of derived phenological parameters. The latter, coupled with the evaluation of precipitation conditions, leads to a near real-time assessment of the vegetation productivity expected at the end of the considered growing season. The timely detection of critical conditions in vegetation health and productivity allows to spot agricultural areas with increased potential of crop failure or food crisis risk.				

Contact information	
Link to online tools:	http://drought.ithacaweb.org/
Organization:	Information Technology for Humanitarian Assistance, Cooperation and Action (ITHACA)
Contact person:	N/A
Contact details:	info@ithacaweb.org
Resource:	N/A

Data and links	
Data used:	MODIS MOD13C1 Terra CMG dataset, TRMM 3B42 daily data
Data format:	PNG
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326

Spatial scale:	5.6 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-20	55	40	-40
Temporal scale:	15 days			
Aggregation period:	3 months			
Latency:	Previous month			

Quality, remarks, and references
References / supplementary information: Angeluccetti, I., et al. (2017) An approach to drought data web-dissemination. Geophysical Research Abstracts, Vol. 19, EGU2017-14294, 2017. http://meetingorganizer.copernicus.org/EGU2017/EGU2017-14294.pdf
Strengths: N/A
Weaknesses: N/A
Final remarks: Not (yet) peer-reviewed

Datasets

B133 African drought monitor and continental seasonal climate forecast service

This data set can be used to obtain information and data of meteorological, hydrological, and socio-economic drought hazards on a near real-time basis for Africa.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Socio-economic drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Africa			
Period available:	From:	Varies	To:	Varies
Costs involved in obtaining the tool:	None			
Concise model description: - Monthly and seasonal precipitation in percent of average for meteorological drought - Monthly soil moisture anomaly data for agricultural/ hydrological drought - The NDVI data is used to measure agricultural drought - Lakes and rivers levels data for hydrological drought expected soon with sentinel suite of satellites				

Contact information	
Link to online tools:	http://www.acmad.net/rcc/
Organization:	ACMAD
Contact person:	N/A
Contact details:	dgacmad@acmad.ne/dgacmad@acmad.org Tel: +227 20 73 49 92
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			

Latency:	near real-time

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

B134 SARCOF SADC seasonal climate outlook

This newsletter can be used to obtain information of seasonal meteorological drought forecasts for Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	N/A			
Countries where available:	Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Every season the SADC issues a newsletter with the expected climate conditions for the SARCOF region in Southern Africa for the following season. This includes the probabilities of normal, above-normal, and below-normal rainfall in 10 distinct regions in Southern Africa				

Contact information	
Link to online tools:	http://www.sadc.int/news-events/newsletters/climate-outlook/
Organization:	SADC
Contact person:	N/A
Contact details:	registry@sadc.int. Tel: +267 3951 863
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	No relevant			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Seasonal			
Aggregation period:	N/A			
Latency:	Updated every season			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This newsletter can be used to obtain information of seasonal drought forecasting , drought impact to agriculture and livestock, and drought impact to population for Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Uganda, Burundi, Rwanda and Tanzania.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Socio-economic			
Applications:	Drought forecasting , Mapping drought impact to agriculture and livestock, Mapping drought impact to population			
Indicator(s) included:	N/A			
Countries where available:	Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Uganda, Burundi, Rwanda and Tanzania			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Every season ICPAC issues a bulletin with the expected climate conditions for the GHACOF region in the Horn of Africa for the following season. This includes the probabilities of normal, above-normal, and below-normal rainfall in 4 distinct regions. Information on the forecast of the onset (start) of the rainy season, number of dry spells forecasted for the season and cessation (end) of the rains is also available. The bulletin also includes a description of possible impacts and recommendations (mitigation measures) for different stakeholders together with an analysis of Drought risk and vulnerability for the region.				

Contact information	
Link to online tools:	http://www.icpac.net/
Organization:	ICPAC
Contact person:	N/A
Contact details:	info@icpac.net
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Seasonal			
Aggregation period:	N/A			
Latency:	Updated every season			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This newsletter can be used to obtain information of meteorological, hydrological, and agricultural drought hazards on a real-time and forecast basis for Kenya.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Drought forecasting			
Indicator(s) included:	Rainfall, VCI			
Countries where available:	Kenya			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Drought early warning bulletins per province in Kenya including crop stages, livestock body condition, household water access.				

Contact information	
Link to online tools:	http://www.ndma.go.ke/
Organization:	National Drought Management Authority (NDMA)
Contact person:	N/A
Contact details:	info@ndma.go.ke
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Monthly - last month			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Tools

B137 Veg-Out Ethiopia

This tool can be used to monitor and predict meteorological, hydrological, and agricultural drought hazards for Ethiopia.

General Characteristics				
Type:	Tools			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Drought forecasting , Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	Standardized NDVI, WHC, SPI_3 month, PDO, AMO, NAO, PNA, MEI, Land cover, Ecoregion type,			
Countries where available:	Ethiopia			
Period available:	From:	N/A	To:	N/A
Costs involved in obtaining the tool:	None			
Concise model description: A drought monitoring tool has been developed that predicts the vegetation condition (Vegetation Outlook) using a regression-tree technique at a monthly time step during the growing season in Eastern Africa. This prediction tool (VegOut-Ethiopia) is demonstrated for Ethiopia as a case study. VegOut-Ethiopia predicts the standardized values of the Normalized Difference Vegetation Index (NDVI) at multiple time steps (weeks to months into the future) based on analysis of ''historical patterns'' of satellite, climate, and oceanic data over historical records.				

Contact information	
Link to online tools:	Not available
Organization:	National Drought Mitigation Center, University of Nebraska-Lincoln, Lincoln, Nebraska, USA
Contact person:	T. Tadesse
Contact details:	Ttadesse2@unl.edu
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	33	48	14	3
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	Monthly			

Quality, remarks, and references
References / supplementary information: Tadesse, T., G. B. Demisse, B. Zaitchik, and T. Dinku (2014), Satellite-based hybrid drought monitoring tool for prediction of vegetation condition in Eastern Africa: A case study for Ethiopia, Water Resour. Res., 50, 2176–2190, doi:10.1002/2013WR014281.
Strengths: Generally, since VegOut-Ethiopia maps and products integrate climate, satellite, and oceanic data as well as incorporate the environmental characteristics of the local areas to predict the vegetation condition with a reasonable accuracy, they can be used by agricultural producers, extension agents, early warning institutes, policy makers, and other stakeholders to make more informed decisions at the local levels
Weaknesses: The VegOut-Ethiopia model should be further evaluated and compared to and integrated with other suites of drought and vegetation monitoring tools to help in foodsecurity decision making
Final remarks: Although the example shown in this paper, using the 2011 drought year, illustrates the potential value of VegOut-Ethiopia for predicting large-area vegetation conditions, additional validation work is needed to fully understand this new predictive tool's performance.

C. Drought Hazard and Risk Models for Asia

Platforms

C138 Drought Monitoring - Bangladesh

This platform can be used to obtain information of meteorological hazards on a monthly basis for Bangladesh.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-1, SPI-3, Temperature Anomalies (Max, Mean and Min)			
Countries where available:	Bangladesh			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Monthly update; Maps of SPI-1 and SPI-3 and deviations of max, mean and min temperatures of a month; covering entire Bangladesh.				

Contact information	
Link to online tools:	http://bmd.gov.bd/?/p/=Service-10
Organization:	Bangladesh Meteorological Department
Contact person:	N/A
Contact details:	info@bmd.gov.bd
Resource:	N/A

Data and links	
Data used:	Precipitation data from the Bangladesh Meteorological Department
Data format:	PNG Maps
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Monthly			
Aggregation period:	1 Month and 3 Months			

Latency:	Every month

Quality, remarks, and references
References / supplementary information: N/A
Strengths: Operational; BMD is a reliable source for Bangladesh
Weaknesses: Only maps are available
Final remarks: N/A

C139 India Agromet Advisory Bulletins

This platform can be used to obtain information of meteorological and agricultural drought forecasts on a weekly basis for India.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Drought forecasting			
Indicator(s) included:	Rainfall, temperature anomalies, Soil Moisture, SPI, NDVI.			
Countries where available:	India			
Period available:	From:	29/06/2006	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Weekly Bulletin consisting of various products, such as monsoon watch, temperature anomaly, SPI, NDVI, etc.				

Contact information	
Link to online tools:	http://www.wamis.org/countries/india.php
Organization:	Links through: World Agrometeorological Information Service
Contact person:	N/A
Contact details:	http://www.wamis.org/contact.php
Resource:	N/A

Data and links	
Data used:	Mostly from Indian Meteorological Department
Data format:	PDF file
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Weekly			
Aggregation period:	Not known			
Latency:	Every week			

Quality, remarks, and references

References / supplementary information: Brief description available: http://www.wamis.org/countries/india.php.
Strengths: Operational; Focused for agriculture
Weaknesses: Only available in pdf file
Final remarks: N/A

C140 Famine Early Warning Systems Network - Middle East

This platform can be used to obtain information of meteorological, hydrological, and Mapping agricultural drought hazards on a near real-time basis for Yemen, Iraq, Turkey, Syria, Iran, Azerbajan.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	NOAA Rainfall Estimate, SSEBop Evapotranspiration, eMODIS NDVI, Temperature			
Countries where available:	Yemen, Iraq, Turkey, Syria, Iran, Azerbaijan			
Period available:	From:	Varies (2001/2003)	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Routinely updated, high resolution				

Contact information	
Link to online tools:	https://earlywarning.usgs.gov/fews/search/Asia/Middle%20East
Organization:	USGS
Contact person:	N/A
Contact details:	Contact form in https://earlywarning.usgs.gov/fews/contact
Resource:	N/A

Data and links	
Data used:	Geostationary IR, MODIS IR/visible
Data format:	GeoTIFF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	500m to 5 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	32	52	40	12
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Every 5 Days			

Quality, remarks, and references

References / supplementary information: Help pages at earlywarning.usgs.gov Funk et al. (2015) Scientific Data; Xie and Arkin (1997) Verdin and Klaver (2002) Hydrologic Processes; Xie and Arkin (1997) BAMS; Senay et al. (2011) Agricultural Water Management
Strengths: Routinely updated, high resolution
Weaknesses: Often lacking in situ station support
Final remarks: N/A

C141 Famine Early Warning Systems Network - Central Asia

This platform can be used to obtain information of meteorological, hydrological, and Mapping agricultural drought hazards on a near real-time basis for Afghanistan, Kazakhstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan, Kyrgyzstan.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	NOAA Rainfall Estimate, SSEBop Evapotranspiration, eMODIS NDVI			
Countries where available:	Afghanistan, Kazakhstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan, Kyrgyzstan			
Period available:	From:	Varies (1981/ 2000/ 2010)	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Routinely updated, high resolution				

Contact information	
Link to online tools:	https://earlywarning.usgs.gov/fews/search/Asia/Central20%Asia
Organization:	USGS
Contact person:	N/A
Contact details:	Contact form in https://earlywarning.usgs.gov/fews/contact
Resource:	N/A

Data and links	
Data used:	Geostationary IR, MODIS IR/visible
Data format:	GeoTIFF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	500m to 5 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	40	80	55	25
Temporal scale:	Monthly			
Aggregation period:	N/A			

Latency:	Every 5 Days

Quality, remarks, and references
References / supplementary information: Help pages at earlywarning.usgs.gov Funk et al. (2015) Scientific Data; Xie and Arkin (1997) Verdin and Klaver (2002) Hydrologic Processes; Xie and Arkin (1997) BAMS; Senay et al. (2011) Agricultural Water Management
Strengths: Routinely updated, high resolution
Weaknesses: Often lacking in situ station support
Final remarks: N/A

C142 FLDAS - Central Asia Snow Modeling

This platform can be used to obtain information of Mapping meteorological drought hazards on a near real-time basis for Afghanistan and Pakistan (including snow).

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	Snow Water Equivalent (SWE)			
Countries where available:	Afghanistan, Pakistan			
Period available:	From:	2001	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Routinely updated, high resolution				

Contact information	
Link to online tools:	http://lis.gsfc.nasa.gov/projects/fewsnet-central-asia
Organization:	NASA
Contact person:	Amy McNally
Contact details:	amy.l.mcnally@nasa.gov
Resource:	N/A

Data and links	
Data used:	CHIRPS, MERRA, GDAS, RFE2
Data format:	NetCDF and GeoTIFF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1km x 1km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	30	100	56	21
Temporal scale:	1 hr time step			
Aggregation period:	N/A			
Latency:	Every 5 Days			

Quality, remarks, and references
References / supplementary information: https://www.nature.com/articles/sdata201712

McNally et al. (2017) A land data assimilation system for sub-Saharan Africa food and water security applications, Scientific Data.
Strengths: Provides detailed hydrologic information
Weaknesses: Long Latency
Final remarks: N/A

C143 IMWI South Asia drought monitoring system

This platform can be used to obtain information of weekly to monthly meteorological drought forecasts for South Asia.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	SPI			
Countries where available:	N/A			
Period available:	From:	2001	To:	2014
Costs involved in obtaining the tool:	N/A			
Concise model description: Provides SPI index values and eight-day and monthly drought extents				

Contact information	
Link to online tools:	http://dms.iwmi.org/app/
Organization:	IWMI
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	60	99	39	5
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A

Weaknesses: The data cannot be downloaded, only visualized.
Final remarks: N/A

This platform can be used to obtain information of Mapping meteorological drought hazards for China.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Hazard mapping			
Indicator(s) included:	N/A			
Countries where available:	China			
Period available:	From:	01/01/2014	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: N/A				

Contact information	
Link to online tools:	http://bcc.ncc-cma.net/channel.php?channelId=22
Organization:	Beijing Climate Centre
Contact person:	N/A
Contact details:	Beijing Climate Centre, China Meteorological Administration; Email: bcc@cma.gov.cn
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	Maps
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths:

N/A
Weaknesses: N/A
Final remarks: N/A

C145 India Agromet Advisory Bulletins

This platform can be used to obtain information of meteorological drought forecasts for India.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Drought forecasting			
Indicator(s) included:	N/A			
Countries where available:	India			
Period available:	From:	29/06/2006	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: Weekly Bulletin consisting of various products, such as monsoon watch, temperature anomaly, SPI, NDVI, etc.				

Contact information	
Link to online tools:	http://www.wamis.org/countries/india.php
Organization:	Links through: World Agrometeorological Information Service
Contact person:	N/A
Contact details:	http://www.wamis.org/contact.php
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	PDF file
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A

Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Datasets

C146 NWP (Numerical Weather Prediction) Products - Bangladesh

This dataset can be used to obtain data of meteorological monthly drought forecasts for Bangladesh.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	Forecasts of Monthly and 3-monthly Precipitation Anomaly, Temperature Anomaly, Precipitation and Temperature			
Countries where available:	Bangladesh			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: One month and three month forecasts of Monthly Rainfall, Monthly Temperature and Monthly P and T anomaly; Covers entire Bangladesh.				

Contact information	
Link to online tools:	http://bmd.gov.bd/?/nwp-products/&/one-month-forecast/
Organization:	Bangladesh Meteorological Department
Contact person:	N/A
Contact details:	info@bmd.gov.bd
Resource:	N/A

Data and links	
Data used:	Numerical Model Result from the Tokyo Climate Centre (TCC) of the Japan Meteorological Agency (JMA)
Data format:	PNG Maps
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	80	100	30	19
Temporal scale:	Monthly			
Aggregation period:	Forecast lead time: 1 Month and 3 Months			

Latency:	Every month

Quality, remarks, and references
References / supplementary information: N/A
Strengths: Operational; Reliable data source (TCC, JMA)
Weaknesses: Only maps are available
Final remarks: N/A

C147 Climate System Monitoring (CSMD) - China

This data set and newsletter can be used to obtain information of Mapping meteorological drought hazards on a monthly basis for China.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	Monthly precipitation and temperature and anomalies.			
Countries where available:	China			
Period available:	From:	01/01/2003	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Monthly bulletin consisting of monthly temperature, and temperature anomaly; monthly precipitation and precipitation anomaly; and unusual monthly mean temperature and precipitation over China.				

Contact information	
Link to online tools:	http://bcc.ncc-cma.net/channel.php?channelId=25
Organization:	Beijing Climate Centre
Contact person:	N/A
Contact details:	Beijing Climate Centre, China Meteorological Administration; Email: bcc@cma.gov.cn
Resource:	N/A

Data and links	
Data used:	Several global data sources
Data format:	Maps
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Monthly			
Aggregation period:	1 Month			
Latency:	Every month			

Quality, remarks, and references

References / supplementary information: Instruction document available: http://cmdp.ncc-cma.net/Monitoring/Bulletin/201706/monitoringc/data-e.pdf
Strengths: Operational
Weaknesses: Only maps are available
Final remarks: N/A

C148 Agromet Products (India) - Agricultural Meteorology Division

This data set can be used to obtain data of meteorological and agricultural daily to seasonal drought forecasts India.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Agricultural			
Applications:	Drought forecasting			
Indicator(s) included:	Rainfall distribution, Soil Moisture, SPI, NDVI.			
Countries where available:	India			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Various products, such as weekly rainfall distribution, NDVI, SPI etc.				

Contact information	
Link to online tools:	http://www.imdagrimet.gov.in/
Organization:	AGRIMET
Contact person:	Dr.N.Chattopadhyay
Contact details:	nabansu_c@yahoo.co.in; agrimet_information@yahoo.com
Resource:	N/A

Data and links	
Data used:	Mostly from Indian Meteorological Department
Data format:	Maps in PDF file
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Daily, Monthly, Seasonal			
Aggregation period:	Not known			
Latency:	Every week			

Quality, remarks, and references
References / supplementary information: N/A

Strengths: Operational; Includes Soil Moisture
Weaknesses: Only maps are available
Final remarks: N/A

Newsletters & Bulletins

C149 Weekly Agromet Forecast - Bangladesh

This newsletter can be used to obtain information of meteorological and Mapping agricultural drought hazards on a weekly basis for Bangladesh.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	Precipitation and temperature forecast for one week.			
Countries where available:	Bangladesh			
Period available:	From:	08/08/2009	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Weekly Bulletin consisting of weekly rainfall, weekly rainfall forecast, and monthly rainfall forecast, and rainfall/temperature analysis per divisions of Bangladesh.				

Contact information	
Link to online tools:	http://www.wamis.org/countries/bangladesh.php
Organization:	Links through: World Agrometeorological Information Service
Contact person:	N/A
Contact details:	http://www.wamis.org/contact.php; info@bmd.gov.bd
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Weekly			
Aggregation period:	One week			
Latency:	Every week			

Quality, remarks, and references

References / supplementary information: N/A
Strengths: Operational; Includes analysis for various divisions of Bangladesh
Weaknesses: N/A
Final remarks: N/A

D. Drought Hazard and Risk Models for Europe

Platforms

D150 European Drought Centre Impact Report Inventory

This platform can be used to obtain information of drought impact to the overall economy related observed meteorological droughts in Europe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping drought impact to the overall economy			
Indicator(s) included:	Observed drought events			
Countries where available:	Europe			
Period available:	From:	01/01/1904	To:	31/12/2014
Costs involved in obtaining the tool:	None			
Concise model description: Collection of drought impact reports over Europe. Mainly .pdf and .doc documents. Information can be downloaded.				

Contact information	
Link to online tools:	http://www.geo.uio.no/edc/droughtdb/edr/impactdatabase.php
Organization:	European Drought Centre
Contact person:	Lena Tallaksen, Henny van Lanen
Contact details:	Contact field on website - no e-mail provided
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	.doc and .pdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	Not known			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

This platform can be used to obtain information on meteorological droughts on a daily basis for Europe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-6			
Countries where available:	Europe			
Period available:	From:	01/01/1958	To:	01/12/2009
Costs involved in obtaining the tool:	None			
Concise model description: Standardized Precipitation Index with a 6-month scale for Europe over the time-period 1959-2009. Data cannot be downloaded				

Contact information	
Link to online tools:	http://www.geo.uio.no/edc/droughtdb/edr/spidates.php
Organization:	European Drought Centre
Contact person:	Lena Tallaksen, Henny van Lanen
Contact details:	Contact field on website - no e-mail provided
Resource:	N/A

Data and links	
Data used:	Not presented
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Not given			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	Not given	Not given	Not given	Not given
Temporal scale:	Daily			
Aggregation period:	6 months			
Latency:	Not known			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A

Weaknesses: N/A
Final remarks: Peer-reviewed

D152 European Drought Observatory

This platform can be used to obtain near-real time information on meteorological and agricultural drought hazards for Europe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included: Combined Drought Indicator, Daily Soil Moisture, Daily Soil Moisture Anomaly, SPI, Snowpack Indicator, Vegetation Productivity, Vegetation Productivity Anomaly.				
Countries where available:	Europe			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Portal that presents near real-time information on multiple drought indicators: Combined Drought Indicator, Daily Soil Moisture, Daily Soil Moisture Anomaly, SPI at SYNOP stations from the MARS database, SPI at SYNOP stations interpolated to 0.25dd grid, Snowpack Indicator, Spatial average of SPI at SYNOP stations, interpolated SPI for Eurostat NUTS3 regions, Vegetation Productivity, Vegetation Productivity Anomaly. Different drought indicators have a different temporal and spatial resolution and a different length of time-period				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	N/A

Data and links	
Data used:	Different data-sources per indicator
Data format:	Part of the data can be downloaded in .gtiff
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	N/A			

Aggregation period:	N/A
Latency:	near-realtime

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

D153 German Drought Monitor

This platform can be used to obtain near real-time information on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping agricultural drought hazard			
Indicator(s) included:	SMI			
Countries where available:	Germany			
Period available:	From:	1950	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The mesoscale hydrologic model (mHM) to create an ensemble of daily soil moisture fields over Germany at the spatial resolution of 4 × 4 km2 . The drought monitor is updated daily. Due to data availability of the meteorological input data, the drought monitor has a lag time of four days. The underlying soil moisture index SMI is based on the frequency distribution of the soil moisture for 65 years starting in 1951. An actual value of 0.3 (Abnormally Dry) means that the actual soil moisture is as low as in 30% of the cases in the timeframe 1951-2015. A value of 0.02 (Exceptional Drought) means that the soil moisture only fell below the actual value in 2% of the cases in 1951-2015.				

Contact information	
Link to online tools:	http://www.ufz.de/index.php?en=37937
Organization:	UFZ
Contact person:	Dr. Andreas Marx
Contact details:	klima@ufz.de, andreas.marx@ufz.de
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	.netcdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	4 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	6	16	55	47
Temporal scale:	Daily			
Aggregation period:	N/A			
Latency:	near real-time (4 days lag)			

Quality, remarks, and references
References / supplementary information: http://iopscience.iop.org/article/10.1088/1748-9326/11/7/074002/meta
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

This platform can be used to obtain near real-time information on meteorological drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI-1,SPI-3,SPI-6,SPI-12,WBA-60			
Countries where available:	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, FYROM, Greece, Hungary, Moldova, Romania, Slovenia, Turkey, Montenegro, Serbia			
Period available:	From:	1951	To:	near real-time
Costs involved in obtaining the tool:	None			

Concise model description:
Basic information on drought in the current season are summarized in drought bulletin for SE Europe. Drought bulletin is being published since spring 2010.
Drought Bulletin for SE Europe. Using GPCC data, some preliminary maps of the SPI, Percentiles and Precipitation for the region were prepared. For making maps monthly precipitation data from GPCC were used. This data are land-only in latitude/longitude format in resolution 1 degree x 1 degree. For calculating monthly percentiles (5, 10, 15, 20 and 25 - with R) data from VASClimO (resolution 0.5 degree x 0.5 degree) for all period (1951-2000) were used.
Data were imported into GRASS GIS and interpolated to 100x (50x) better resolution (0.01 degree). For reprojecting maps into Lambert Conformal Conic Projection (lcc) nearest interpolation method was used. Maps are updated twice per month. Final data maps with two months delay are available after 20th day of the current month. First-guess maps are available after 5th day of the next month. Final data are available from January 1986, first-guess from August 2004. For period 1951-2000 maps are available here.

Contact information	
Link to online tools:	http://www.dmcsee.org/en/drought_monitor/
Organization:	Drought Management Centre for Southeastern Europe
Contact person:	Gregor Gregorič
Contact details:	gregor.gregoric@gov.si
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	.tiff
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.01 degree			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	10	48	32	50
Temporal scale:	Monthly			
Aggregation period:	1, 3, 6, 12 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Datasets

D155 European Drought Centre Reference Database

This dataset can be used to obtain data of drought hazards, drought impact to municipal and industrial water needs, drought impact to agriculture and livestock, drought impact to hydropower, and drought impact to the overall economy for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Hazard mapping, Mapping drought impact to population, Mapping drought impact to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower, Mapping drought impact to the overall economy			
Indicator(s) included:	N/A			
Countries where available:	N/A			
Period available:	From:	N/A	To:	N/A
Costs involved in obtaining the tool:	N/A			
Concise model description: Toolbox that brings together Impact reports and historical drought hazard maps over Europe for the period 1959 - 2009				

Contact information	
Link to online tools:	http://www.geo.uio.no/edc/droughtdb/index.php
Organization:	European Drought Centre
Contact person:	Lena Tallaksen, Henny van Lanen
Contact details:	Contact field on website - no e-mail provided
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			

Aggregation period:	N/A
Latency:	Not known

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This dataset can be used to obtain near-real time data on meteorological, hydrological, and agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, agricultural and hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	SPI, soil moisture, Fraction of Absorbed Photosynthetically Active Radiation (fAPAR)			
Countries where available:	Europe			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The indicator is based in five levels; “Watch” when a relevant precipitation shortage is observed, “Warning” when this precipitation shortage translates into a soil moisture anomaly, “Alert” when these two conditions are accompanied by a negative anomaly in the vegetation condition, “Partial recovery” when the meteorological conditions are recovered to normal but not the vegetation - 3 - conditions, “Full recovery” when meteorological and vegetation normal conditions are recovered after a drought episode.				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_combinedDroughtIndicator.pdf

Data and links	
Data used:	N/A
Data format:	.gtiff
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	1/24 decimal degrees			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			

Aggregation period:	1 SPI, 10 days for soil moisture and fAPAR anomalies
Latency:	near-realtime

Quality, remarks, and references
References / supplementary information: G. Sepulcre-Cantó, S. Horion, A. Singleton, H. Carrão, J. Vogt (2012). Development of a Combined Drought Indicator to detect agricultural drought in Europe. Natural Hazards and Earth System Sciences, 12, 3519–3531.
Strengths: [+] Generally the drought assessment is done using individual indices, based or in meteorological data or in remote sensing images. The development of a combined index integrating meteorological and remote sensing indicators can help to reduce false alarms, for example in the case of the vegetation indices where a biomass reduction can be generated by other reasons different than water stress. [+] An integrated approach, showing a convergence of indicators and therefore an evidence of drought can also help to policy makers, for an effective risk management and decision making.
Weaknesses: [-] The alarm impact should be considered only for the growing period. The mean growing period of Europe can considered from April to October, however the southern countries of Europe have longer growing periods and advanced respected to the mean. Future research will be done to include the use of phonological information per area, like spatial phenological indicators. [-] fAPAR is an index obtained from the optical spectra, therefore is susceptible to clouds. These clouds are generally masked but sometimes low clouds are not detected resulting in erroneous values, especially in the northern countries. To solve this problem, future developments will include the use of more than one indicator related to vegetation condition.
Final remarks: Peer-reviewed

This dataset can be used to obtain near-real time data and forecasts on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Agricultural			
Applications:	Drought forecasting , Mapping agricultural drought hazard			
Indicator(s) included:	soil water potential: output of LISFLOOD model			
Countries where available:	Europe			
Period available:	From:	N/A	To:	7-day forecasts (near real-time)
Costs involved in obtaining the tool:	None			
Concise model description: The soil moisture map and the anomaly, as well as, the forecast maps provide information on spatial distribution of the soil water content and its evolution along the time. Each day the EDO mapserver automatically update the soil moisture values over the last ground observation available and the weather forecast .The soil moisture map as well as the Anomaly map could provide a “proxy” information on the possible presence of drought conditions in case of pF values bigger than 4.2÷4.4 or/and in case of large deviations from the long term average conditions. Of course, the presence of real water stressing conditions depends on the specific plant resistance and capacity to water extraction from the soil matrix. At the same time pF values lower than 2 could be consider as indicator of soil water excess.				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_soilmoisture.pdf

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	5 km			

Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			
Aggregation period:	daily			
Latency:	near-realtime			

Quality, remarks, and references
References / supplementary information: De Roo, A., Wesseling ,C., Van Deursen, W. ‘Physically based river basin modelling within a GIS: the LISFLOOD model’. Hydrol. Process . 14, 1981- 1992 (2000) Laguardia, G., Niemeyer S. (2007) Towards a soil moisture-based drought index. Geophysical Research Abstracts, Vol. 9, 06714, 2007. Laguardia, G., Niemeyer S. (2008) On the comparison between the LISFLOOD modelled and the ERS/SCAT derived soil moisture estimates. Hydrol. Earth Syst. Sci. Discuss., 5, 1227–1265, 2008 Mo, Xingguo , Pappenberger, Florian , Beven, Keith , Liu, Suxia , De Roo, Ad and Lin, Zhonghui(2006) 'Parameter conditioning and prediction uncertainties of the LISFLOOD-WB distributed hydrological model', Hydrological Sciences Journal, 51: 1, 45 — 65 Van Der Knijff, J. M. , Younis, J. and De Roo, A. P. J.(2010) 'LISFLOOD: a GIS-based distributed model for river basin scale water balance and flood simulation', International Journal of Geographical Information Science, 24: 2, 189 — 212, First published on: 24 November 2008 Van Der Knijff, and De Roo, A. P. J.(2008) LISFLOOD Distributed Water Balance and Flood Simulation Model : Revised User Manual. JRC Scientific and Technical report
Strengths: [+] The daily update and the use of weather forecast give continuous information on the simulated status of the soil moisture and the spatial extension of the area affected by drought or under risk. Moreover, the analysis of the time series allows to estimate the duration and the severity of drought.
Weaknesses: [-] The generalizations and the scientific assumption (soil physic, land use, canopy cover, meteo data interpolation, etc.) embedded in the soil water balance model, and at the same time, the calibration of the model could produce in some case large approximation of the real soil moisture and progressive divergence with the real conditions
Final remarks: Peer-reviewed

This dataset can be used to obtain near-real time data and forecasts on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Agricultural			
Applications:	Drought forecasting , Mapping agricultural drought hazard			
Indicator(s) included:	soil water potential: output of LISFLOOD model			
Countries where available:	Europe			
Period available:	From:	N/A	To:	7-day forecasts (near-realtime)
Costs involved in obtaining the tool:	None			
Concise model description: The soil moisture map and the anomaly, as well as, the forecast maps provide information on spatial distribution of the soil water content and its evolution along the time. Each day the EDO mapserver automatically update the soil moisture values over the last ground observation available and the weather forecast The soil moisture map as well as the Anomaly map could provide a “proxy” information on the possible presence of drought conditions in case of pF values bigger than 4.2÷4.4 or/and in case of large deviations from the long term average conditions. Of course, the presence of real water stressing conditions depends on the specific plant resistance and capacity to water extraction from the soil matrix. At the same time pF values lower than 2 could be consider as indicator of soil water excess.				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_soilmoisture.pdf

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	5 km			

Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			
Aggregation period:	daily			
Latency:	near-realtime			

Quality, remarks, and references
References / supplementary information: De Roo, A., Wesseling ,C., Van Deursen, W. ‘Physically based river basin modelling within a GIS: the LISFLOOD model’. Hydrol. Process . 14, 1981- 1992 (2000) Laguardia, G., Niemeyer S. (2007) Towards a soil moisture-based drought index. Geophysical Research Abstracts, Vol. 9, 06714, 2007. Laguardia, G., Niemeyer S. (2008) On the comparison between the LISFLOOD modelled and the ERS/SCAT derived soil moisture estimates. Hydrol. Earth Syst. Sci. Discuss., 5, 1227–1265, 2008 Mo, Xingguo , Pappenberger, Florian , Beven, Keith , Liu, Suxia , De Roo, Ad and Lin, Zhonghui(2006) 'Parameter conditioning and prediction uncertainties of the LISFLOOD-WB distributed hydrological model', Hydrological Sciences Journal, 51: 1, 45 — 65 Van Der Knijff, J. M. , Younis, J. and De Roo, A. P. J.(2010) 'LISFLOOD: a GIS-based distributed model for river basin scale water balance and flood simulation', International Journal of Geographical Information Science, 24: 2, 189 — 212, First published on: 24 November 2008 Van Der Knijff, and De Roo, A. P. J.(2008) LISFLOOD Distributed Water Balance and Flood Simulation Model : Revised User Manual. JRC Scientific and Technical report
Strengths: [+] The daily update and the use of weather forecast give continuous information on the simulated status of the soil moisture and the spatial extension of the area affected by drought or under risk. Moreover, the analysis of the time series allows to estimate the duration and the severity of drought.
Weaknesses: [-] The generalizations and the scientific assumption (soil physic, land use, canopy cover, meteo data interpolation, etc.) embedded in the soil water balance model, and at the same time, the calibration of the model could produce in some case large approximation of the real soil moisture and progressive divergence with the real conditions
Final remarks: Peer-reviewed

This dataset can be used to obtain near-real time data and forecasts on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Agricultural			
Applications:	Drought forecasting , Mapping agricultural drought hazard			
Indicator(s) included:	soil water potential: output of LISFLOOD model			
Countries where available:	Europe			
Period available:	From:	N/A	To:	7-day forecasts (near-realtime)
Costs involved in obtaining the tool:	None			
Concise model description: The soil moisture map and the anomaly, as well as, the forecast maps provide information on spatial distribution of the soil water content and its evolution along the time. Each day the EDO mapserver automatically update the soil moisture values over the last ground observation available and the weather forecast The soil moisture map as well as the Anomaly map could provide a “proxy” information on the possible presence of drought conditions in case of pF values bigger than 4.2÷4.4 or/and in case of large deviations from the long term average conditions. Of course, the presence of real water stressing conditions depends on the specific plant resistance and capacity to water extraction from the soil matrix. At the same time pF values lower than 2 could be consider as indicator of soil water excess.				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_soilmoisture.pdf

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	5 km			

Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			
Aggregation period:	daily			
Latency:	near-realtime			

Quality, remarks, and references
References / supplementary information: De Roo, A., Wesseling ,C., Van Deursen, W. 'Physically based river basin modelling within a GIS: the LISFLOOD model'. Hydrol. Process . 14, 1981- 1992 (2000) Laguardia, G., Niemeyer S. (2007) Towards a soil moisture-based drought index. Geophysical Research Abstracts, Vol. 9, 06714, 2007. Laguardia, G., Niemeyer S. (2008) On the comparison between the LISFLOOD modelled and the ERS/SCAT derived soil moisture estimates. Hydrol. Earth Syst. Sci. Discuss., 5, 1227–1265, 2008 Mo, Xingguo , Pappenberger, Florian , Beven, Keith , Liu, Suxia , De Roo, Ad and Lin, Zhonghui(2006) 'Parameter conditioning and prediction uncertainties of the LISFLOOD-WB distributed hydrological model', Hydrological Sciences Journal, 51: 1, 45 — 65 Van Der Knijff, J. M. , Younis, J. and De Roo, A. P. J.(2010) 'LISFLOOD: a GIS-based distributed model for river basin scale water balance and flood simulation', International Journal of Geographical Information Science, 24: 2, 189 — 212, First published on: 24 November 2008 Van Der Knijff, and De Roo, A. P. J.(2008) LISFLOOD Distributed Water Balance and Flood Simulation Model : Revised User Manual. JRC Scientific and Technical report
Strengths: [+] The daily update and the use of weather forecast give continuous information on the simulated status of the soil moisture and the spatial extension of the area affected by drought or under risk. Moreover, the analysis of the time series allows to estimate the duration and the severity of drought.
Weaknesses: [-] The generalizations and the scientific assumption (soil physic, land use, canopy cover, meteo data interpolation, etc.) embedded in the soil water balance model, and at the same time, the calibration of the model could produce in some case large approximation of the real soil moisture and progressive divergence with the real conditions
Final remarks: Peer-reviewed

D160 European Drought Observatory -Standardized Precipitation Index

This dataset can be used to obtain near-real time data on meteorological and hydrological drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Europe			
Period available:	From:	1901/1950/2005 (dependent on source)	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Computation of the SPI involves fitting a probability density function to a given frequency distribution of precipitation totals for a station or grid point and for an accumulation period. For EDO we use the gamma probability density function. The statistics for the frequency distribution are calculated on the basis of a reference period of at least 30 years (see point 2.b). - 4 - DESERT Action – LMNH Unit SPI Factsheet The parameters of the probability density function are then used to find the cumulative probability of the observed precipitation for the required month and temporal scale. This cumulative probability is then transformed to the standardized normal distribution with mean zero and variance one, which results in the value of the SPI. The procedure of transforming the observed rainfall via the cumulative distribution functions (CDF) of the Gamma distribution and the standardized normal variable to the SPI is illustrated in Figure 1:				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_spi.pdf

Data and links	
Data used:	SYNOP, GPCC, E-OBS precipitation estimates/observations
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326

Spatial scale:	5 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			
Aggregation period:	1, 3, 6, 12, 24, 48 months			
Latency:	near-realtime			

Quality, remarks, and references
References / supplementary information: Guttman, N. B., 1999: Accepting the standardized precipitation index: A calculation algorithm. J. Amer. Water Resour. Assoc., 35, 311-322. Haylock, M. R., N. Hofstra, A. M. G. Klein Tank, E. J. Klok, P. D. Jones and M. New, 2008: A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res. (Atmospheres), 113, D20119, doi:10.1029/2008JD10201 McKee, T. B., J. Nolan, and J. Kleist, 1993: The relationship of drought frequency and duration to time scales. Preprints, Eighth Conf. on Applied Climatology, Anaheim, CA, Amer. Meteor, Soc., 179- 184. McKee, T. B., J. Nolan, and J. Kleist, 1995: Drought monitoring with multiple time scales. Preprints, Ninth Conf. on Applied Climatology, Dallas, TX, Amer. Meteor. Soc., 233-236.
Strengths: [+] SPI gives a measure of the rainfall deficit (or surplus) at a location that is unambiguously comparable with other locations and periods in time [+] SPI is easy to interpret with boundaries set to describe the severity of the rainfall deficit (or surplus) [+] Because the SPI can be computed for a range of accumulation periods it can be made use of by a whole range of user groups, from agriculture to water management
Weaknesses: [-] Fitting a distribution to the data is an approximation. If the fit is not good, the SPI value may not be representative [-] For SPI computed at station level, depending on the station density, the spatial representativeness of interpolated SPI will vary. [-] Since the gamma distribution is bounded on the left at zero, it is not defined for zero precipitation. If the data includes observations of zero precipitation a mixed distribution is used that takes account of the probability of zero precipitation and the cumulative probability H(x) becomes H(x) = q + (1-q)G(x), - 6 - DESERT Action – LMNH Unit SPI Factsheet where q is the probability of zero, calculated from the frequency of zero precipitation observations in the time series, and G(x) is the cumulative probability calculated from the gamma distribution for non-zero observations.
Final remarks: Peer-reviewed

This dataset can be used to obtain near-real time data on meteorological and hydrological drought hazards related to snow on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Snowpack indicator only applies in those regions where snowpack accumulation is regular annually. These regions in the EU are mainly the Nordic countries, the Alps, the Pyrenees and the Carpathian Mountains. Nevertheless, the impact of snowpack to the hydrology is not limited only to these regions. Several large Central Europe rivers' flow, e.g. the Rhein, partly depends on the melting snowpack of the Alps			
Period available:	From:	1979	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The SSPI is computed the same way as the SPI (Standardized Precipitation Index), except for being based on the daily snowpack water equivalent (=kg/m2 of snow) time series. The SSPI provides information of the relative volume of the snowpack in the catchment on a ten-daily and monthly basis compared to the period of reference. The indicator can be used for awareness raising, evaluation of occurred droughts, forecasting future drought risks and management purposes.				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_sspi.pdf

Data and links	
Data used: European Space Agency's (ESA) GlobSnow project led by the Finnish Meteorological Institute (FMI) has developed and provides snowpack water equivalent (SWE) values for the whole Northern Hemisphere. The SWE data is based on passive microwave radiometer data combined with ground-based synoptic snow observations. The SSPI is calculated based on SWE values by the FMI for the whole EU.	
Data format:	N/A

Data requirements:	

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	25 km (soon 10km)			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	Daily			
Aggregation period:	1 month			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: Pulliainen, J, 2006. Mapping of snow water equivalent and snow depth in boreal and sub-arctic zones by assimilating space-borne microwave radiometer data and ground-based observations. Remote Sensing of Environment, vol. 101, pp. 257-269. Takala, M., Pulliainen, J.,Metsämäki, S. and Koskinen, J., 2009. Detection of Snowmelt Using Spaceborne Microwave Radiometer Data in Eurasia from 1979 to 2007. IEEE Transactions on Geoscience and Remote Sensing, vol. 47, no. 9, pp. 2996-3007. Takala, M., Luojus, K., Pulliainen, J., Derksen, C., Lemmetyinen, J., Kärnä, J.-P., Koskinen, J. and Bojkov, B., 2011. Estimating northern hemisphere snow water equivalent for climate research through assimilation of space-borne radiometer data and ground-based measurements. Remote Sensing of Environment, doi:10.1016/j.rse.2011.08.014.
Strengths: Strength of the data is that it presents only natural variation since there is now human abstraction from the snowpack. It is also strength that the data is congruent throughout the Europe since the data is collected through same methodology.
Weaknesses: The weakness of the data is that there are still some difficulties to estimate the snowpack in the mountains. Improvements regarding this issue are being made to the product (e.g. going from 25 km grids to 5 km grids). Testing of the data together with the Swiss snowpack data (done together with the WSL Institute for Snow and Avalanche Research SLF) shows that the GlobSnow data underestimates the actual snowpack in the mountains during high snowpack occurrence. Otherwise the data has consistent behavior and it is suitable for detection of anomalies. The data is suitable for the calculation of the SSPI indicator since the indicator is calculated as anomalies from the time series (probabilities) and not as specific values of snowpack (cp. SPI).
Final remarks: Peer-reviewed

D162 European Drought Observatory -Fraction of absorbed photosynthetically active radiation (fAPAR)

This dataset can be used to obtain near-real time data on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Agricultural			
Applications:	Mapping agricultural drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Europe			
Period available:	From:	2013	To:	near real-time
Costs involved in obtaining the tool:	None			

Concise model description:
fAPAR is difficult to measure directly but can be inferred from models describing the transfer of solar radiation in plant canopies, using Earth Observation information as input data. fAPAR estimates are retrieved using EO information by numerically inverting physically-based models. The fAPAR estimates used within the DESERT Action were operationally produced by the European Space Agency (ESA) till 2011. They were derived from the multispectral images acquired by the Medium Resolution Imaging Spectrometer (MERIS) onboard ENVISAT by means of the MERIS Global Vegetation Index (MGVI) algorithm, developed at the JRC (Gobron et al. 2004). From 2012, fAPAR images used are the result of applying the same algorithm to the images acquired by the VEGETATION sensor onboard SPOT. These images are produced by the Flemish institute for technological research (VITO). MGVI is a physically based index which transforms the calibrated multispectral directional reflectance into a single numerical value while minimizing possible disturbing factors. It is constrained by means of an optimization procedure to provide an estimate of the fAPAR of a plant canopy. The objective of the algorithm is to reach the maximum sensitivity to the presence and changes in healthy live green vegetation while at the same time minimizing the sensitivity to atmospheric scattering and absorption effects, to soil color and brightness effects, and to temporal and spatial variations in the geometry of illumination and observation. The MGVI level-3 aggregation processor has been developed and is maintained by the European Commission Joint Research Centre (JRC). More information on the algorithm can be found in Pinty B. et al. (2002) and Gobron N. et al. (2004).

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_fapar.pdf

Data and links

Data used: The MERIS Global Vegetation Index (MGVI) is a remote sensing derived index estimating fAPAR at canopy level. Till 2011, the index was derived from ENVISAT-MERIS images. From 2012, the fAPAR estimations are the result of applying the MGVI algorithm to SPOT-VEGETATION images	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	up to 1 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	10-daily			
Aggregation period:	10 days			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: Aussedat O., Taberner M., Gobron N., and Pinty B. (2007). MERIS Level 3 Land Surface Aggregated Products Description. Institute for Environment and Sustainability, EUR Report No. 22643 EN, 16pp. Gobron, N., Pinty, B., Verstraete, M.M., and Widlowski, J.-L. (2000). Advanced Vegetation Indices Optimized for Up-Coming Sensors: Design, Performance and Applications. IEEE Transactions on Geoscience and Remote Sensing, 38: 2489-2505. Gobron N., Pinty B., Mélin F., Taberner M., and Verstraete M. M. (2002). Sea Wide Field-ofView Sensor (SeaWiFS) - Level 2 Land Surface Products - Algorithm Theoretical Basis Document. Institute for Environment and Sustainability, EUR Report No. 20144 EN, 23 p. Gobron N., Aussedat O., Pinty B., Taberner M., and Verstraete M. M. (2004). Medium Resolution Imaging Spectrometer (MERIS) - An optimized FAPAR Algorithm - Theoretical Basis Document. Revision 3.0. Institute for Environment and Sustainability, EUR Report No. 21386 EN, 20 p. http://fapar.jrc.ec.europa.eu/WWW/Data/Pages/FAPAR_Home/FAPAR_Home_Publications/atbd_meris_v4_gen.pdf Gobron N., Pinty B., Mélin F., Taberner M., Verstraete M.M., Belward A., Lavergne T., and Widlowski J.-L. (2005). The state vegetation in Europe following the 2003 drought. International Journal Remote Sensing Letters, 26 (9): 2013-2020. Gobron, N., Aussedat, O., Pinty, B., Robustelli, M., Taberner, M., Lavergne, T. (2006a). Technical Assistance for the Validation the ENVISAT MGVI Geophysical Product. Final Report. EUR Report 22246 EN, European Commission - DG Joint Research Centre, Institute for Environment and Sustainability, 103pp. Gobron, N., Pinty, B., Aussedat, O., Chen, J. M., Cohen, W. B., Fensholt, R., Gond, V., Lavergne, T., Mélin, F., Privette, J. L., Sandholt, I., Taberner, M., Turner, D. P., Verstraete, M. M., Widlowski, J.-L. (2006b). Evaluation of Fraction of Absorbed Photosynthetically Active Radiation Products for Different Canopy Radiation Transfer Regimes: Methodology and Results Using Joint Research Center Products Derived from SeaWiFS Against GroundBased Estimations. Journal of Geophysical Research – Atmospheres, 111(13), D13110. Gobron, N., Pinty, B., Mélin, F., Taberner, M., Verstraete, M.M., Robustelli, M., Widlowski, J.-L. (2007).

Evaluation of the MERIS/ENVISAT fAPAR Product. Advances in Space Research 39: 105-115. Pinty B., Gobron N., Mélin F., and Verstraete M.M. (2002). Time Composite Algorithm Theoretical Basis Document. Institute for Environment and Sustainability, EUR Report No. 20150 EN, 8 pp. http://fapar.jrc.ec.europa.eu/WWW/Data/Pages/FAPAR_Home/FAPAR_Home_Publications/pinty_etal_ies_2002.pdf Rossi, S., Weissteiner, C., Laguardia, G., Kurnik, B., Robustelli, M., Niemeyer, S., and Gobron, N. 2008. “Potential of MERIS fAPAR for drought detection”, in Lacoste, H., and Ouwehand, L. (eds.), Proceedings of the 2nd MERIS/(A)ATSR User Workshop, 22–26 September 2008, Frascati Italy (ESA SP-666), ESA Communication Production Office, November 2008. http://envisat.esa.int/pub/ESA_DOC/meris_workshop_2008/papers%20/p63_rossi.pdf
Strengths: [+] Every ten days, the MGVI gives a spatially continuous picture of the vegetation status/health at a high spatial resolution (~1km) for the entire Europe.
Weaknesses: [-] Drought and water stress are not the only factors that can cause a decrease of MGVI values/anomalies. Change in land covers or pests and diseases can also be responsible for such - 5 - variation of the signal. Therefore this indicator must be used jointly with other indicators giving information on the deficit of rainfall /soil moisture in order to determine if the variation in the vegetation response (signal) is linked with a drought event or not. [-] Anomalies are dependent of the time series available to calculate the mean values and the standard deviations. This period should be long enough to characterize the area where the index is calculated.
Final remarks: Peer-reviewed

D163 European Drought Observatory -Fraction of absorbed photosynthetically active radiation (fAPAR) anomaly

This dataset can be used to obtain near-real time data on agricultural drought hazards on a daily basis for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Agricultural			
Applications:	Mapping agricultural drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Europe			
Period available:	From:	2002	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: fAPAR is difficult to measure directly but can be inferred from models describing the transfer of solar radiation in plant canopies, using Earth Observation information as input data. fAPAR estimates are retrieved using EO information by numerically inverting physically-based models. The fAPAR estimates used within the DESERT Action were operationally produced by the European Space Agency (ESA) till 2011. They were derived from the multispectral images acquired by the Medium Resolution Imaging Spectrometer (MERIS) onboard ENVISAT by means of the MERIS Global Vegetation Index (MGVI) algorithm, developed at the JRC (Gobron et al. 2004). From 2012, fAPAR images used are the result of applying the same algorithm to the images acquired by the VEGETATION sensor onboard SPOT. These images are produced by the Flemish institute for technological research (VITO). MGVI is a physically based index which transforms the calibrated multispectral directional reflectance into a single numerical value while minimizing possible disturbing factors. It is constrained by means of an optimization procedure to provide an estimate of the fAPAR of a plant canopy. The objective of the algorithm is to reach the maximum sensitivity to the presence and changes in healthy live green vegetation while at the same time minimizing the sensitivity to atmospheric scattering and absorption effects, to soil color and brightness effects, and to temporal and spatial variations in the geometry of illumination and observation. The MGVI level-3 aggregation processor has been developed and is maintained by the European Commission Joint Research Centre (JRC). More information on the algorithm can be found in Pinty B. et al. (2002) and Gobron N. et al. (2004).				

Contact information	
Link to online tools:	http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111
Organization:	European Drought Observatory
Contact person:	Alfred de Jager, JRC
Contact details:	alfred.de-jager@ec.europa.eu
Resource:	http://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_fapar.pdf

Data and links
Data used:

The MERIS Global Vegetation Index (MGVI) is a remote sensing derived index estimating fAPAR at canopy level. Till 2011, the index was derived from ENVISAT-MERIS images. From 2012, the fAPAR estimations are the result of applying the MGVI algorithm to SPOT-VEGETATION images	
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	up to 1 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	35	52	71	35
Temporal scale:	10-daily			
Aggregation period:	10 days			
Latency:	near real-time			

Quality, remarks, and references

References / supplementary information:

Aussedat O., Taberner M., Gobron N., and Pinty B. (2007). MERIS Level 3 Land Surface Aggregated Products Description. Institute for Environment and Sustainability, EUR Report No. 22643 EN, 16pp.

Gobron, N., Pinty, B., Verstraete, M.M., and Widlowski, J.-L. (2000). Advanced Vegetation Indices Optimized for Up-Coming Sensors: Design, Performance and Applications. IEEE Transactions on Geoscience and Remote Sensing, 38: 2489-2505.

Gobron N., Pinty B., Mélin F., Taberner M., and Verstraete M. M. (2002). Sea Wide Field-ofView Sensor (SeaWiFS) - Level 2 Land Surface Products - Algorithm Theoretical Basis Document. Institute for Environment and Sustainability, EUR Report No. 20144 EN, 23 p.

Gobron N., Aussedat O., Pinty B., Taberner M., and Verstraete M. M. (2004). Medium Resolution Imaging Spectrometer (MERIS) - An optimized FAPAR Algorithm - Theoretical Basis Document. Revision 3.0. Institute for Environment and Sustainability, EUR Report No. 21386 EN, 20 p. http://fapar.jrc.ec.europa.eu/WWW/Data/Pages/FAPAR_Home/FAPAR_Home_Publications/atbd_meris_v4_gen.pdf

Gobron N., Pinty B., Mélin F., Taberner M., Verstraete M.M., Belward A., Lavergne T., and Widlowski J.-L. (2005). The state vegetation in Europe following the 2003 drought. International Journal Remote Sensing Letters, 26 (9): 2013-2020.

Gobron, N., Aussedat, O., Pinty, B., Robustelli, M., Taberner, M., Lavergne, T. (2006a). Technical Assistance for the Validation the ENVISAT MGVI Geophysical Product. Final Report. EUR Report 22246 EN, European Commission - DG Joint Research Centre, Institute for Environment and Sustainability, 103pp.

Gobron, N., Pinty, B., Aussedat, O., Chen, J. M., Cohen, W. B., Fensholt, R., Gond, V., Lavergne, T., Mélin, F., Privette, J. L., Sandholt, I., Taberner, M., Turner, D. P., Verstraete, M. M., Widlowski, J.-L. (2006b). Evaluation of Fraction of Absorbed Photosynthetically Active Radiation Products for Different Canopy Radiation Transfer Regimes: Methodology and Results Using Joint Research Center Products Derived from SeaWiFS Against GroundBased Estimations. Journal of Geophysical Research – Atmospheres, 111(13), D13110.

Gobron, N., Pinty, B., Mélin, F., Taberner, M., Verstraete, M.M., Robustelli, M., Widlowski, J.-L. (2007). Evaluation of the MERIS/ENVISAT fAPAR Product. Advances in Space Research 39: 105-115.

Pinty B., Gobron N., Mélin F., and Verstraete M.M. (2002). Time Composite Algorithm Theoretical Basis Document. Institute for Environment and Sustainability, EUR Report No. 20150 EN, 8 pp. http://fapar.jrc.ec.europa.eu/WWW/Data/Pages/FAPAR_Home/FAPAR_Home_Publications/pinty_etal_ies_2002.pdf Rossi, S., Weissteiner, C., Laguardia, G., Kurnik, B., Robustelli, M., Niemeyer, S., and Gobron, N. 2008. "Potential of MERIS fAPAR for drought detection", in Lacoste, H., and Ouwehand, L. (eds.), Proceedings of the 2nd MERIS/(A)ATSR User Workshop, 22–26 September 2008, Frascati Italy (ESA SP-666), ESA Communication Production Office, November 2008. http://envisat.esa.int/pub/ESA_DOC/meris_workshop_2008/papers%20/p63_rossi.pdf
Strengths: [+] Every ten days, the MGVI gives a spatially continuous picture of the vegetation status/health at a high spatial resolution (~1km) for the entire Europe.
Weaknesses: [-] Drought and water stress are not the only factors that can cause a decrease of MGVI values/anomalies. Change in land covers or pests and diseases can also be responsible for such - 5 - variation of the signal. Therefore this indicator must be used jointly with other indicators giving information on the deficit of rainfall /soil moisture in order to determine if the variation in the vegetation response (signal) is linked with a drought event or not. [-] Anomalies are dependent of the time series available to calculate the mean values and the standard deviations. This period should be long enough to characterize the area where the index is calculated.
Final remarks: Peer-reviewed

This dataset can be used to obtain data on historical meteorological drought hazards on for Europe.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	PDSI, tree-ring reconstructions			
Countries where available:	Europe			
Period available:	From:	0001BC	To:	01/01/2012
Costs involved in obtaining the tool:	None			
Concise model description: Reconstructed PDSI for Europe-Mediterranean Region				

Contact information	
Link to online tools:	http://kage.ldeo.columbia.edu/TRL/OWDA/
Organization:	LDEO TreeRingLab
Contact person:	N/A
Contact details:	naomi@ldeo.columbia.edu
Resource:	N/A

Data and links	
Data used:	tree-ring reconstructions
Data format:	.netcdf
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	0.5 degree			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-11.75	44.75	70.75	27.25
Temporal scale:	yearly			
Aggregation period:	yearly			
Latency:	created 2015/updated june 2017			

Quality, remarks, and references
References / supplementary information: Cook, E. R., R. Seager, Y. Kushnir, K. Briffa, U. Buentgen, D. Frank, P. Krusic, W. Tegel, G. van der Schrier, L. Andreu-Hayles, M. Baillie, C. Baitttinger, A. Billamboz, N. Bleicher, N. Bonde, D. Brown, M. Carrer, R. Cooper, K. Cufar, C. Dittmar, J. Esper, C. Giggs, B. Gunnarson, B. Gunther, E. Gutierrez, K. Haneca, S. Helema, F. Herzig, K.-U. Heussner, J. Hofman, P. Janda, R. Kontic, N. Kose, T. Kyncl, T. Levanic, H.

Linderholm, S. Manning, T. Melvin, D. Miles, B. Neuwirth, K. Nicolussi, P. Nola, M. Panayotov, I. Popa, A. Rothe, K. Seftigen, A. Seim, H. Svarva, M. Svoboda, T. Thun, M. Timonen, R. Touchan, V. Trotsiuk, V. Truet, F. Walder, T. Wazny, R. Wilson, C. Zang, 2015: Old World megadroughts and pluvials during the Common Era. Science Advances, in press.
Strengths: N/A
Weaknesses: N/A
Final remarks: Peer-reviewed

E. Drought Hazard and Risk Models for North America

Platforms

E165 Famine Early Warning Systems Network - C. America/Caribbean/Mexico

This platform can be used to obtain information of meteorological, hydrological, and agricultural drought hazards on a five day basis for Mexico, Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Haiti, Dominican Republic.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	CHIRPS Precipitation, TRIMM Rainfall, eMODIS NDVI, Water Requirement Satisfaction Index			
Countries where available:	Mexico, Guatemala, Belize, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Haiti, Dominican Republic			
Period available:	From:	Varies (1981/2000/ 2010)	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Routinely updated, high resolution				

Contact information	
Link to online tools:	https://earlywarning.usgs.gov/fews/search/LAC
Organization:	USGS
Contact person:	N/A
Contact details:	Contact form in https://earlywarning.usgs.gov/fews/contact
Resource:	N/A

Data and links	
Data used:	Geostationary IR, MODIS IR/visible
Data format:	GeoTIFF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326

Spatial scale:	500m to 5 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-117	-68	32	7
Temporal scale:	Monthly			
Aggregation period:	Pentad to seasonal			
Latency:	Every Five Days			

Quality, remarks, and references
References / supplementary information: Help pages at earlywarning.usgs.gov Funk et al. (2015) Scientific Data; Verdin and Klaver (2002) Hydrologic Processes
Strengths: Routinely updated, high resolution
Weaknesses: Often lacking in situ station support
Final remarks: N/A

This platform can be used to obtain information about drought impact to agriculture and livestock on a daily basis for North America including United States of America, Canada, and Mexico.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock			
Indicator(s) included:	GOES land surface temperature (LST), satellite-based vegetation information and solar insolation observations.			
Countries where available:	North America including United States of America, Canada, and Mexico.			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: GOES Evapotranspiration and Drought (GET-D) products are derived from the Atmosphere-Land Exchange Inversion model (ALEXI). ALEXI computes principle surface energy fluxes, including Evapotranspiration (ET), which is a critical boundary condition to weather and hydrologic modeling, and a quantity required for regional water resource management. ALEXI ET estimates have been rigorously evaluated in comparison with ground-based data, and perform well over a range in climatic and vegetation conditions.				

Contact information	
Link to online tools:	http://www.ospo.noaa.gov/Products/land/getd/
Organization:	NASA/ NOAA/ USDA
Contact person:	Christopher Hain and Martha Anderson
Contact details:	christopher.hain@nasa.gov; Martha.Anderson@ars.usda.gov
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:				
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	-130	-50	60	5
Temporal scale:	Daily			
Aggregation period:	2 to 12 weeks			
Latency:	2 days			

Quality, remarks, and references
References / supplementary information: Anderson, M.C., Hain, C., Wardlow, B., Pimstein, A., Mecikalski, J.R. and Kustas, W.P., 2011. Evaluation of drought indices based on thermal remote sensing of evapotranspiration over the continental United States. Journal of Climate, 24(8), pp.2025-2044. Hain, C., Anderson, M.C., Fang, L., Zhan, X. and Otkin, J., 2016, February. Transition of the GOES Evapotranspiration and Drought Product System (GET-D) into Operations at NOAA/NESDIS. In AGU Fall Meeting Abstracts.
Strengths: The ALEXI surface energy balance model was specifically designed to minimize the need for ancillary meteorological data while maintaining a physically realistic representation of land-atmosphere exchange of energy and water over a wide range of vegetation cover conditions.
Weaknesses: N/A
Final remarks: N/A

E167 North American Drought Monitor (NADM)

This platform can be used to gather information about the current assessment of meteorological drought on a monthly basis for North America.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, agricultural and hydrological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included: Precipitation, Temperature, SPI, PDSI, streamflow, reservoir levels, satellite inputs for PET and vegetation health, soil moisture and other indicators that vary by country.				
Countries where available:	Canada, Mexico and the United States of America.			
Period available:	From:	01/01/2002	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Drought Monitor concept was developed (jointly by the National Weather Service, the National Drought Mitigation Center and the US Department of Agriculture's Joint Agricultural Weather Facility in the late 1990s) as a "hybrid" combined indicator process that synthesizes multiple indicators, indices, and local impacts into an assessment that best represents current drought conditions (Svoboda et al., 2002). The final outcome of each Drought Monitor is a consensus of federal, state, academic scientists and local experts.				

Contact information	
Link to online tools:	https://www.ncdc.noaa.gov/temp-and-precip/drought/nadm/maps
Organization:	NOAA-NCEI
Contact person:	Deke Arnt, Richard Heim
Contact details:	derek.arndt@noaa.gov, richard.heim@noaa.gov
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:				
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-150	-50	90	15
Temporal scale:	Monthly			

Aggregation period:	1 month to seasonal
Latency:	Approximately 2 weeks

Quality, remarks, and references
References / supplementary information: Svoboda, M., et al., 2002. The Drought Monitor. Bulletin of the American Meteorological Society, 83, 1181-1190. Heim, Jr., R. R., 2002. A review of Twentieth-Century drought indices used in the United States. Bulletin of the American Meteorological Society, 83, 1149-1165. Lawrimore, J., et al., 2002. Beginning a new era of drought monitoring across North America. Bulletin of the American Meteorological Society, 83, 1191-1192.
Strengths: The NADM is a cooperative effort between drought experts in Canada, Mexico and the United States to monitor drought across the continent operationally.
Weaknesses: Consistency and availability of real-time data in each country is a challenge
Final remarks: N/A

E168 Vegetation Drought Response Index (VegDRI)

This platform can be used to obtain information of drought impacts to agriculture and livestock on a weekly basis for the United Sates of America and Canada.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock			
Indicator(s) included:	SPI, PDSI, Seasonal Greenness (NDVI-based), Land cover, Percent Irrigation, Soil Available water capacity, and elevation (DEM)			
Countries where available:	United States of America and Canada			
Period available:	From:	01/01/2000	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: The Vegetation Drought Response Index, or VegDRI, is a weekly depiction of vegetation stress across the contiguous United States. VegDRI is a fine resolution (1-km2) index based on remote sensing data, but unlike other satellite-based measurements, VegDRI also incorporates climate and biophysical data to determine the cause of vegetation stress.				

Contact information	
Link to online tools:	http://drought.unl.edu/MonitoringTools/VegDRI.aspx
Organization:	N/A
Contact person:	Tsegaye Tadesse, Brian Wardlow, and Jess Brown
Contact details:	ttadesse2@unl.edu, bwardlow2@unl.edu, jfbrown@usgs.gov
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:				
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-150	-50	90	25
Temporal scale:	Weekly			
Aggregation period:	1 Week to seasonal			

Latency:	4 days

Quality, remarks, and references
References / supplementary information: Tadesse, T., B.D. Wardlow, J. Brown, M. Hayes, M. Svoboda, B. Fuchs, and D. Gutzmer, 2015. Assessing the vegetation condition impacts of the 2011 drought across the U.S. Southern Great Plains using the Vegetation Drought Response Index (VegDRI), Journal of Applied Meteorology and Climatology, 54 (1):153-169. Tadesse, T., Champagne, C., Wardlow, B.D., Hadwen, T.A., Brown, J.F., Demisse, G.B., Bayissa, Y.A. and Davidson, A.M., 2017. Building the vegetation drought response index for Canada (VegDRI-Canada) to monitor agricultural drought: first results. GIScience & Remote Sensing, 54(2), pp.230-257. Brown, J.F., B.D. Wardlow, T. Tadesse, M.J. Hayes, and B.C. Reed, 2008. The vegetation drought response index (VegDRI): A new integrated approach for monitoring drought stress in vegetation, GIScience and Remote Sensing, 45(1):16-46.
Strengths: VegDRI provides continuous geographic coverage over large areas, and have inherently finer spatial detail (1 km resolution) than other commonly available drought indicators. The VegDRI maps deliver regional to sub-county scale information about drought's effects on vegetation.
Weaknesses: Requires high level of computation to build the model.
Final remarks: N/A

E169 US Drought Impact Reporter (DIR)

This platform can be used to obtain data on drought impacts on people, municipal and industrial water needs , agriculture and livestock, hydropower (energy), and to the overall economy on a weekly basis for the United Sates of America.

General Characteristics				
Type:	Platform			
Type of drought:	Socio-economic			
Applications:	Mapping drought impact to population, Mapping drought impact to municipal and industrial water needs , Mapping drought impact to agriculture and livestock, Mapping drought impact to hydropower, Mapping drought impact to the overall economy			
Indicator(s) included: Incorporates reports from many sources including the media, citizens, state/federal agency and academic reports, and other observing networks such as CoCoRaHS				
Countries where available:	United States of America			
Period available:	From:	2007	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Collects and displays more types of information, providing researchers and interested members of the public with more context and detail, as well as more readily summarized information. All information comes into the Drought Impact Reporter as a report. Some reports contain information that meets our definition of a drought impact: An observable loss or change that occurred at a specific place and time because of drought. All impacts are made from one or more reports.				

Contact information	
Link to online tools:	http://droughtreporter.unl.edu/map/
Organization:	National Drought Mitigation Center (part of the University of Nebraska-Lincoln)
Contact person:	NDMC
Contact details:	DIRinfo@unl.edu
Resource:	N/A

Data and links	
Data used:	Reports from the media, citizens, state/federal agency and academic reports, and other observing networks such as CoCoRaHS
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:				
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-150	-50	90	25
Temporal scale:	Weekly as moderated			
Aggregation period:	Varies: user defined from weekly to monthly, seasonally or annually			
Latency:	1 week			

Quality, remarks, and references
References / supplementary information: Wilhite, Donald A., Mark D. Svoboda, and Michael J. Hayes. "Understanding the complex impacts of drought: a key to enhancing drought mitigation and preparedness." Water resources management 21.5 (2007): 763-774. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1042&context=droughtfacpub
Strengths: Provides a comprehensive database of drought impacts of the United States.
Weaknesses: Primarily culled from media reports
Final remarks: N/A

E170 Canadian agroclimate impact reporter

This platform can be used to obtain information on drought impact to agriculture on a weekly basis for Canada.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural			
Applications:	Mapping drought impact to agriculture and livestock			
Indicator(s) included:	Incorporates reports from many sources			
Countries where available:	Canada			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The AIR application is an online tool for the collection, compilation, and integration of agro-climate impact information across Canada. It offers the public, media, and decision-makers a useful tool with which to support the agricultural industry. Reports are provided through anonymous and media input, and a network of registered users. Impact reports from network participants play a significant and valuable role in evaluating emerging weather and climate related risks to Canadian agriculture. The Agro-climate Impact Reporting network currently consists of approximately 300 producers across the three Prairie Provinces and the Peace River region of B.C. Discussions to expand the existing network across Canada are ongoing.				

Contact information	
Link to online tools:	http://www.agr.gc.ca/atlas/air
Organization:	Government of Canada
Contact person:	National Agroclimate Information Service (NAIS)
Contact details:	nais-snia@agr.gc.ca
Resource:	N/A

Data and links	
Data used:	N/A
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-150	-50	90	40
Temporal scale:	Weekly			

Aggregation period:	1 week to seasonal
Latency:	1 week

Quality, remarks, and references
References / supplementary information: Agriculture and Agri-Food Canada (AAFC), Agroclimate Imp[act Reporter, http://www.agr.gc.ca/atlas/air
Strengths: Provides a comprehensive database of drought impacts of Canada.
Weaknesses: Accessible only indirectly through a web portal (?)
Final remarks: N/A

This platform can be used to obtain information on Early warning of agricultural drought, hydrologic drought, and fire-weather risk a daily basis for the United States of America.

General Characteristics				
Type:	Platform			
Type of drought:	Agricultural, Hydrologic			
Applications:	Drought forecasting , Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	Temperature, humidity, wind speed, and incoming solar radiation from the North American Land Data Assimilation System (NLDAS-2) dataset			
Countries where available:	United States of America			
Period available:	From:	01/01/1980	To:	near real-time
Costs involved in obtaining the tool:	None			

Concise model description:
Reference evapotranspiration (ET0) is calculated using the Penman Monteith FAO56 reference ET formulation driven by temperature, humidity, wind speed, and incoming solar radiation. For a particular time-window, EDDI is estimated by standardizing the E0 anomalies relative to the whole period of the record (1979-present), using a non-parametric method (see Hobbins et al., 2016). For plotting purposes, EDDI values are binned into different percentile categories analogous to the US Drought Monitor plots. However, in case of EDDI plots, both drought and anomalously wet categories are shown.

Contact information	
Link to online tools:	https://www.esrl.noaa.gov/psd/eddi/realtime_maps/
Organization:	NOAA
Contact person:	Mike Hobbins
Contact details:	Mike.Hobbins@noaa.gov
Resource:	N/A

Data and links	
Data used:	North American Land Data Assimilation System (NLDAS-2)
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	~ 12 km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	-125	-67	50	25
Temporal scale:	Daily			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: Michael Hobbins, Andrew Wood, Daniel McEvoy, Justin Huntington, Charles Morton, James Verdin, Martha Anderson, and Christopher Hain (June 2016): The Evaporative Demand Drought index: Part I – Linking Drought Evolution to Variations in Evaporative Demand. J. Hydrometeor., 17(6),1745-1761. doi:10.1175/JHM-D-15-0121.1. Daniel J. McEvoy, Justin L. Huntington, Michael T. Hobbins, Andrew Wood, Charles Morton, James Verdin, Martha Anderson, and Christopher Hain (June 2016) The Evaporative Demand Drought index: Part II – CONUS-wide Assessment Against Common Drought Indicators. J. Hydrometeor., 17(6), 1763-1779. doi:10.1175/JHM-D-15-0121.1.
Strengths: Calculates evaporative demand without rainfall parameter
Weaknesses: A new drought index that should be evaluated
Final remarks: N/A

F. Drought Hazard and Risk Models for Pacific, Australia, New Zealand

Platforms

F172 Drought - Australia

This platform can be used to obtain near real-time information of meteorological and agricultural drought hazards at a monthly basis for Australia.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	Soil moisture and rainfall deficiency			
Countries where available:	Australia			
Period available:	From:	2000	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Includes 3-months rainfall deficiency and soil moisture				

Contact information	
Link to online tools:	http://www.bom.gov.au/climate/drought/
Organization:	Bureau of Meteorology, Australian Government
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used: Soil moisture data is from the Bureau's Australian Water Resources Assessment Landscape (AWRA-L) model, developed through the Water Information Research and Development Alliance between the Bureau and CSIRO.	
Data format:	GIF file
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Country maps			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	110	160	-10	-45
Temporal scale:	Monthly			

Aggregation period:	N/A
Latency:	Monthly

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This platform can be used to obtain near real-time information of meteorological and hydrological drought hazards at a monthly basis for Australia.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Daily rainfall and temperature			
Countries where available:	Australia			
Period available:	From:	2013	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Monthly Weather Review provides a concise but informative overview of the temperatures, rainfall and significant weather events for the month. It is published towards the end of the following month.				

Contact information	
Link to online tools:	http://www.bom.gov.au/climate/mwr/
Organization:	Bureau of Meteorology, Australian Government
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	Daily rainfall and temperature records over Australia
Data format:	pdf
Data requirements:	No reuirments

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Country maps			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	110	160	-10	-45
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Monthly			

Quality, remarks, and references

References / supplementary information: N/A
Strengths: The climatological averages shown in the text and tables are generally long-term means based on observations from the years 1961–1990. They are not shown for sites with less than 25 years of record in that time, as they cannot then be calculated reliably. Climatological extremes are generally taken from all available years of record; the number of years can vary markedly from site to site.
Weaknesses: N/A
Final remarks: N/A

F174 Australian Groundwater Insight

This platform can be used to obtain information of hydrological drought hazards (groundwater) at a yearly basis for Australia.

General Characteristics				
Type:	Platform			
Type of drought:	Hydrological			
Applications:	Mapping hydrological drought hazard			
Indicator(s) included:	Groundwater level status, groundwater level trend, Groundwater salinity			
Countries where available:	Australia			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			

Concise model description:
The Australian Groundwater Insight integrates physical information on aquifers and groundwater salinity with management data providing background to the groundwater level and trend analysis presented.
The Insight provides broad scale, nationally consistent information on groundwater for non-technical users. Data used in the Insight is current to the 2015–16 financial year, and is updated annually. Where it exists data is also available for the 2013–14 and 2014–15 financial years.

Contact information	
Link to online tools:	http://www.bom.gov.au/water/groundwater/insight/#/gwtrend/20yeartrend/upper_2014
Organization:	Bureau of Meteorology, Australian Government
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	Groundwater level status, groundwater level trend, Groundwater salinity
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	110	160	-10	-45
Temporal scale:	N/A			

Aggregation period:	N/A
Latency:	Yearly

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

This platform can be used to obtain predictions of meteorological and hydrological drought hazards at a monthly basis for Cook Islands, Fiji, Kiribati, Marshall Islands, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Hydrological			
Applications:	Drought forecasting			
Indicator(s) included:	SST, monthly rainfall, rainfall anomaly			
Countries where available:	Cook Islands, Fiji, Kiribati, Marshall Islands, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu			
Period available:	From:	2013	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The statistical model (SCOPIC) uses discriminant analysis (multiple linear regression) and the relationships of sea surface temperatures (SST) or the Southern Oscillation Index (predictors) and monthly rainfall (predictors) to predict rainfall at various lead times.				

Contact information	
Link to online tools:	https://www.pacificmet.net/products-and-services/climate-bulletin
Organization:	Bureau of Meteorology - Australia
Contact person:	Simon McGree, Grant Smith, Roan Plotz
Contact details:	COSPPac_Support@bom.gov.au
Resource:	N/A

Data and links	
Data used: Sea Surface temperatures (SST), Southern Oscillation Index (predictors) and monthly rainfall (predictands) to predict rainfall at various lead times.	
Data format:	N/A
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	Not given	Not given	Not given	Not given
Temporal scale:	Monthly			

Aggregation period:	N/A
Latency:	Updated by every user

Quality, remarks, and references
References / supplementary information: N/A
Strengths: The forecast skill is high in the Pacific region due to its proximity to the tropical ocean, where the El Niño-Southern Oscillation (ENSO) provides the main source of tropical climate variability and predictability on seasonal time scales. SCOPIC has good skill where local orography is important on rainfall i.e. Papua New Guinea and parts of Fiji (Cottrill et al., 2013).
Weaknesses: Low skills for neutral years
Final remarks: N/A

F176 New Zealand Drought Monitor

This platform can be used to obtain near real-time information of meteorological drought hazards at a daily and monthly basis for New Zealand.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	New Zealand			
Period available:	From:	2007	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: It is a climate data-based indicator of drought based on four commonly-used climatological drought indicators: The Standardized Precipitation Index, the Soil Moisture Deficit, the Soil Moisture Deficit Anomaly, and the Potential Evapotranspiration Deficit. Only the ‘dry’ part of the SPI and SMD Anomaly are used, while the PED and SMD only indicate dry conditions and not wet conditions. Furthermore we transform the SMD, SMDA and PED to a non-linear scale, similar to the SPI scale, so that 1 mm of water during very dry conditions has a lot more impact than 1 mm of water during less-dry conditions.				

Contact information	
Link to online tools:	https://www.niwa.co.nz/climate/information-and-resources/drought-monitor
Organization:	NIWA
Contact person:	N/A
Contact details:	climate-enquiries@niwa.co.nz
Resource:	N/A

Data and links	
Data used:	The Standardized Precipitation Index, the Soil Moisture Deficit, the Soil Moisture Deficit Anomaly, and the Potential Evapotranspiration Deficit.
Data format:	PNG image
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:

	166	180	-34	-48
Temporal scale:	Daily, Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Datasets

F177 Climate data online - BOM

This dataset can be used to obtain near real-time data of meteorological and hydrological drought hazards at a daily basis for Australia.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Daily rainfall and temperature			
Countries where available:	Australia			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Available data in cvs format of daily and monthly time scales of rainfall, temperature and solar exposure.				

Contact information	
Link to online tools:	http://www.bom.gov.au/climate/data/
Organization:	Bureau of Meteorology, Australian Government
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	Daily rainfall and temperature records over Australia
Data format:	csv
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	110	160	-10	-45
Temporal scale:	Monthly, Daily			
Aggregation period:	N/A			
Latency:	Daily			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: The climatological averages shown in the text and tables are generally long-term means based on observations from the years 1961–1990. They are not shown for sites with less than 25 years of record in that time, as they cannot then be calculated reliably. Climatological extremes are generally taken from all available years of record; the number of years can vary markedly from site to site.
Weaknesses: N/A
Final remarks: N/A

This dataset can be used to obtain near real-time data of hydrological drought hazards at a monthly basis for Australia.

General Characteristics				
Type:	Dataset			
Type of drought:	Hydrological			
Applications:	Mapping hydrological drought hazard			
Indicator(s) included:	Soil moisture, deep drainage, actual evapotranspiration, potential evapotranspiration, runoff, precipitation			
Countries where available:	Australia			
Period available:	From:	2005	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Bureau of Meteorology has developed an interactive mapping tool called 'Australian Landscape Water Balance' that provides graphical data about Soil Moisture (Root Zone, Upper, Lower, and Deep soil moisture), Evapotranspiration, Run-off and Precipitation.				

Contact information	
Link to online tools:	http://www.bom.gov.au/water/landscape/#/sm_pct/Relative/Day/-40.07/129.55/4/Point/Separate/-25.75/124.35/2017/7/11
Organization:	Bureau of Meteorology, Australian Government
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Data and links	
Data used:	Soil Moisture (Root Zone, Upper, Lower, and Deep soil moisture), Evapotranspiration, Run-off and Precipitation.
Data format:	netcdf4, ASCII
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	110	160	-10	-45
Temporal scale:	Daily, Monthly			
Aggregation period:	N/A			

Latency:	Monthly

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: The estimated water balance information for urban and irrigation areas, and open water storages, needs to be used with caution due to lack of impervious surface, irrigated crops and waterbodies in the AWRA-L model.
Final remarks: N/A

F179 NIWA - South Pacific

This newsletter can be used to obtain near real-time information of meteorological and hydrological drought hazards at a monthly basis for Cook Islands, Fiji, Kiribati, Marshall Islands, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Cook Islands, Fiji, Kiribati, Marshall Islands, Niue, PNG, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Every month NIWA issues a newsletter with the expected climate conditions for the Pacific region. This includes the rainfall outlook and the potential water stress.				

Contact information	
Link to online tools:	https://www.niwa.co.nz/climate/icu/island-climate-update-202-july-2017
Organization:	NIWA
Contact person:	N/A
Contact details:	enquiries@niwa.co.nz
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	135	-120	24	`
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Last month			

Quality, remarks, and references
References / supplementary information:

N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Tools

F180 Predictive Ocean-Atmosphere Model for Australia (POAMA)

This tool can be used to predict meteorological and hydrological droughts at a daily basis for Australia.

General Characteristics				
Type:	Tools			
Type of drought:	Meteorological, Hydrological			
Applications:	Drought forecasting			
Indicator(s) included:	N/A			
Countries where available:	Australia			
Period available:	From:	N/A	To:	real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: Uses the current state of the climate (initial ocean and atmospheric conditions) and model physics to predict forecasts of many climate variables at all locations across the globe and also at various lead times. The initial focus of POAMA is the prediction of El Nino				

Contact information	
Link to online tools:	http://poama.bom.gov.au/
Organization:	Bureau of Meteorology - Australia
Contact person:	N/A
Contact details:	poama@bom.gov.au
Resource:	http://www.bom.gov.au/climate/poama2.4/about-POAMA-outlooks.shtml

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Daily			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses:

These trial products are made available for a fixed trial period for user feedback.
Final remarks: POAMA has good skill across most of the equatorial Pacific and parts of the southwest Pacific, especially in the austral summer, which is the wet season in the southwest Pacific (Cottrill et al., 2013)

G. Drought Hazard and Risk Models for South America

Platforms

G181 Regional Hydroclimate Variability and Land Surface Processes

This platform can be used to obtain information on meteorological, hydrological, and agricultural drought hazards at a monthly basis for South America.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard, Drought forecasting			
Indicator(s) included:	Precipitation, Anomalies (%)			
Countries where available:	South America			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Maps showing several meteorological, hydrological and soil moisture variables. Both historical over last 30, 60 and 90 days are shown. Averages/Accumulations over these periods as well as anomalies				

Contact information	
Link to online tools:	http://www.atmos.umd.edu/~berbery/research/
Organization:	Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, USA
Contact person:	Hugo Berbery
Contact details:	berbery@essic.umd.edu
Resource:	N/A

Data and links	
Data used:	WRF Model run over the domain of South America. Resolution 45x45km
Data format:	Images
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	45km			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-95	-25	15	-60

Temporal scale:	Monthly
Aggregation period:	Weeks
Latency:	near real-time

Quality, remarks, and references
References / supplementary information: Guttman, N. B., 1999: Accepting the Standardized Precipitation Index: A calculation algorithm. J. Amer. Water Resour. Assoc.., 35(2), 311-322. McKee, T. B., N. J. Doesken, and J. Kliest, 1993: The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, CA. American Meteorological Society, Boston, MA. 179-184.
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Platform that can be used to obtain information on meteorological drought hazards at a monthly basis for Argentina, Brazil (Rio Grande do Sul), Chile, Paraguay, Uruguay (, Bolivia).

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	Deciles, Percentage of Normal, SPEI, SPEI. 1, 2, 3, 6. 9, 12, 18, 24, 36, 48 months.			
Countries where available:	Argentina, Chile, Paraguay, Uruguay, Brazil (Rio Grande do Sul), Bolivia also included but no data available			
Period available:	From:	01/01/1961	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Maps showing stations with colour indicating the status of the selected climate index. Wide range of indices available. Data can be downloaded per station in CSV formatted files.				

Contact information	
Link to online tools:	http://www.crc-sas.org/pt/monitoreo_sequias.php
Organization:	Centro Regional Climático para el Sur de América del Sur (CRC-SAS)
Contact person:	N/A
Contact details:	crc-sas@crc-sas.org
Resource:	N/A

Data and links	
Data used:	Station baed data
Data format:	CSV
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-84	-32	-10	-60
Temporal scale:	Monthly			
Aggregation period:	1, 2, 3, 6, 9, 12, 18, 24, 36, 48 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Platform that can be used to obtain information on meteorological drought hazards at a monthly basis for Argentina.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	Precipiation, Daily Mean,Max,Min Temperature			
Countries where available:	Argentina			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Maps providing access to station data across Argentina, showing actuals as well as anomalies for temperature (min, max, mean) and precipitation				

Contact information	
Link to online tools:	http://climar.cima.fcen.uba.ar/index.php
Organization:	Centro de Investigaciones del Mar y la Atmósfera, Universidad de Buenos Aires, Argentina
Contact person:	Dra. Claudia Simionato
Contact details:	webmaster@cima.fcen.uba.ar
Resource:	N/A

Data and links	
Data used:	Station Based Data
Data format:	Images
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-71	-53	-20	-60
Temporal scale:	Daily			
Aggregation period:	N/A			
Latency:	near real-time			

Quality, remarks, and references

References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Platform that can be used to obtain information on meteorological drought hazards at a monthly basis for Peru.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI1, 3, 6, 9, 12; NDVI, Percentage of normal precipitation			
Countries where available:	Peru			
Period available:	From:	01/01/1981	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Drought Observatory is a collection of maps and other figures that monitor drought at present, near future and in the recent past. The maps and figures can be manipulated and are linked to the original data.				

Contact information	
Link to online tools:	http://ons.snirh.gob.pe
Organization:	ANA & SENHAMI
Contact person:	N/A
Contact details:	snirh@ana.gob.pe
Resource:	N/A

Data and links	
Data used:	Appears to be developed primarily using station based data, as well as CPC Unified precipitation 0.5 degrees resolution
Data format:	N/A
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-82	-68	0	-19
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Platform that can be used to obtain information on meteorological and hydrological drought hazards at a daily and monthly basis for South and Central America.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	SPI1, 3, 6, 9, 12; NDVI, Streamflow % normal, Soil Moisture			
Countries where available:	South and Central America			
Period available:	From:	01/01/1950	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: The Drought Monitor provides an interactive set of maps of indicators across the LAC region. Users can select indicators to display based on historical data, primarily from satellite based rainfall (TRMM-3B42RT) that is used to force a VIC model of the region. Data can also be downloaded through an Email request. Station data can also be uploaded to the platform for verification analysis.				

Contact information	
Link to online tools:	http://stream.princeton.edu/LAFDM/WEBPAGE/interface.php?locale=sp
Organization:	Princeton University
Contact person:	Professor Eric Wood, Princeton Univerity, USA
Contact details:	No info available, but contact is possible by filling the form in the top-right tab 'Feedback'
Resource:	N/A

Data and links	
Data used:	VIC Hydrological model; TRMM 3B42 RT; GFS
Data format:	NetCDF; ESRI ASCII
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-118	-32	33	-60
Temporal scale:	Daily, Monthly			
Aggregation period:	1, 3, 6, 12 months			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

N/A

General Characteristics				
Type:	Platform			
Type of drought:	N/A			
Applications:	N/A			
Indicator(s) included:	No info available/Under Development			
Countries where available:	Argentina, Bolivia, Brasil, Chile, México, and Perú			
Period available:	From:	N/A	To:	N/A
Costs involved in obtaining the tool:	N/A			
Concise model description: A drought monitor is in the stages of being established. Currently there is a link to the Princeton Latin American & Caribbean Drought Monitor				

Contact information	
Link to online tools:	http://www.cazalac.org
Organization:	Regional Water Center for Arid and Semi-Arid Zones in Latin America and the Caribbean (CAZALAC)
Contact person:	N/A
Contact details:	cazalac@cazalac.org
Resource:	N/A

Data and links	
Data used:	It is not fully clear what the information system provides
Data format:	N/A
Data requirements:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	N/A			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information:

N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Platform that can be used to obtain information on meteorological drought hazards related to El Niño for South and Central America.

General Characteristics				
Type:	Platform			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard			
Indicator(s) included:	SPI			
Countries where available:	South America			
Period available:	From:	01/01/2014	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Data provided include a bulletin with a range of data and information, focusing on information on the ENSO phenomenon. Also includes maps showing indicators across South America, including SPI1 and a wide range of other parameters.				

Contact information	
Link to online tools:	http://www.ciifen.org/
Organization:	Centro Internacional para la Investigación del Fenómeno de El Niño
Contact person:	N/A
Contact details:	http://www.ciifen.org
Resource:	N/A

Data and links	
Data used:	Bulletin primarily based on data from CPC, BoM and other global data sources, with some additional processing done at CIIFEN
Data format:	PDF
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-118	-32	33	-60
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Datasets

G188 CPTEC-INPE

Dataset that can be used to obtain data for daily and seasonal meteorological drought predictions for Brazil and South America.

General Characteristics				
Type:	Dataset			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	All basin meteorological parameters			
Countries where available:	Brazil, South America			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: CPTEC is one of the global meteorological centers and runs several short, medium and seasonal forecast models. Data and information can be accessed through the web portal but also downloaded through FTP.				

Contact information	
Link to online tools:	http://www.cptec.inpe.br/
Organization:	CPTEC
Contact person:	N/A
Contact details:	clima@cptec.inpe.br
Resource:	N/A

Data and links	
Data used:	NWP models, including ETA and BRAHMS (developed in Brazil)
Data format:	GRIB
Data requirements:	No requirements

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-100	-20	15	-60
Temporal scale:	Daily, Seasonal			
Aggregation period:	N/A			
Latency:	near real-time			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Newsletters & Bulletins

G189 SIRCSAN - Sistema de Información sobre Riesgo Climático y Seguridad Alimentaria y Nutricional

Newsletter that can be used to obtain information and predictions of meteorological drought hazards on a monthly basis for Panamá, El Salvador, Nicaragua, Costa Rica, Honduras, Belize and Guatamala.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological			
Applications:	Drought forecasting , Mapping meteorological drought hazard			
Indicator(s) included:	Protected portal			
Countries where available:	Panamá, El Salvador, Nicaragua, Costa Rica, Honduras, Belize and Guatamala.			
Period available:	From:	01/07/2007	To:	01/11/2016
Costs involved in obtaining the tool:	N/A			
Concise model description: Bulletin issued as a part of climate outlook forum. Shows probabilities of rainfall in next trimester falling in lower, middle or upper terciles of the distribution. Bulletins are open access. It is expected that additional information can be found through a log-in protected link.				

Contact information	
Link to online tools:	http://fc.geotrk.us/sircsan/login.php
Organization:	Comité Regional de Recursos Hídricos, San José, Costa Rica
Contact person:	N/A
Contact details:	http://recursoshidricos.org
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-93	-76	19	7
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A

Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

G190 Monitor de Sequía en México (MSM)

Newsletter that can be used to obtain information of meteorological, hydrological, and agricultural drought hazards on a monthly basis for Mexico.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard, Mapping agricultural drought hazard			
Indicator(s) included:	SPI 1,3,6,12; Percent Normal Precipiation; Vegetation Health Index (VHI); Soil Moisture; NDVI; Drought Intensity Indices (DO, D1, D2, D3 ,D4, D5)			
Countries where available:	Mexico			
Period available:	From:	01/01/2002	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Web site based bulletin that shows the areas affected by drought of different category. A graph showing the percentage of national territory under drought conditions can also be shown				

Contact information	
Link to online tools:	http://smn.cna.gob.mx/es/climatologia/monitor-de-sequia/monitor-de-sequia-en-mexico
Organization:	Servicio Meteorológico Nacional (SMN)
Contact person:	N/A
Contact details:	sequia_smn@conagua.gob.mx
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-117	-86	33	14
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths:

N/A
Weaknesses: N/A
Final remarks: N/A

G191 CEMADEN - Brazil

Newsletter that can be used to obtain information of meteorological and hydrological drought hazards on a daily and monthly basis for Brazil.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	N/A			
Countries where available:	Brazil			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Web passed tool for the provision of alerts. Station based raw data can also be downloaded through a data portal.				

Contact information	
Link to online tools:	http://www.cemaden.gov.br/
Organization:	CEMADEN
Contact person:	N/A
Contact details:	contato@cemaden.gov.br
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	N/A	N/A	N/A	N/A
Temporal scale:	Daily, Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Newsletter that can be used to obtain information of monthly and seasonal predictions of meteorological droughts for Argentina.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	Probability of precipitation / temperature falling in tercile			
Countries where available:	Argentina			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Bulletin issued on monthly basis (assumed frequency) with 3-monthly climate outlook. Predictions include probability of rainfall and temperature being in lower, middle or upper tercile				

Contact information	
Link to online tools:	http://www.smn.gov.ar/serviciosclimaticos/?mod=clima&id=3
Organization:	Servicío Nacional Meteorológico, Argentina
Contact person:	N/A
Contact details:	smn@smn.gov.ar
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	N/A			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-75	-30	6	-35
Temporal scale:	Monthly, Seasonal			
Aggregation period:	N/A			
Latency:	Every month			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

G193 Boletín Agrometeorológico Mensual - Paraguay

Newsletter that can be used to obtain information of meteorological, hydrological, and agricultural drought hazards at a monthly basis for Paraguay.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Precipitation, Actual Evaporation, Absolute anomalies, SPI1, 3, 6 & 12			
Countries where available:	Paraguay			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Bulletin issued monthly, providing maps with the indicators over Paraguay. Data appears to be an interpolated analysis from station data. Station data also provided. Network appears to comprise some 19 stations across the country				

Contact information	
Link to online tools:	http://www.meteorologia.gov.py/adm/uploads/boletin_agrometeorologico.pdf
Organization:	Dirección de Meteorología e Hidrología, Paraguay
Contact person:	Lic.Julián Báez, Director de Meteorologia y Hidrología
Contact details:	Julian.Baez@meteorologia.gov.py
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-63	-53	-19	-27
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Every month (assumed)			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

G194 Boletín de Recursos Hidricos y Agricultura- Uruguay

Newsletter that can be used to obtain information of meteorological, hydrological, and agricultural drought hazards at a monthly basis for Uruguay.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Precipitation, Actual Evaporation, Absolute anomalies, SPI1, 3, 6 & 12			
Countries where available:	Uruguay			
Period available:	From:	01/01/2009	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Bulletin issued monthly, providing maps with the indicators over Uruguay. Data appears to be an interpolated analysis from station data. Extensive network of conventional and automatic stations				

Contact information	
Link to online tools:	http://meteorologia.gub.uy/
Organization:	Dirección Nacional de Meteorología, Uruguay
Contact person:	N/A
Contact details:	contacto@meteorologia.gub.uy
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-59	-53	-30	-35
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Every month (assumed)			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Newsletter that can be used to obtain information of monthly predictions of meteorological droughts for Bolovia.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological			
Applications:	Drought forecasting			
Indicator(s) included:	Precipiation, Temperature, Wind			
Countries where available:	Bolivia			
Period available:	From:	01/01/2009	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Monthly outlook bulletin based on ENSO indices. Two bulletins available; a monthly product and a three monthly product				

Contact information	
Link to online tools:	http://www.senamhi.gob.bo/meteorologia/enso
Organization:	Servicio Nacional de Meteorología e Hidrología, Bolivia
Contact person:	N/A
Contact details:	No info available, but contact is possible by filling form at: http://www.senamhi.gob.bo/formulario.php
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-70	-57	-9	-23
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	Every month			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses: N/A
Final remarks: N/A

Newsletter that can be used to obtain information of monthly predictions of meteorological droughts for Chile.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological			
Applications:	Mapping meteorological drought hazard, Drought forecasting			
Indicator(s) included:	Percentage Normal Precipitation, SPI3, 6,12,18,24,36,48			
Countries where available:	Chile			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	None			
Concise model description: Monthly Bulletin, containing various maps of precipitation and temperature anomalies over the whole country				

Contact information	
Link to online tools:	http://www.meteochile.gob.cl
Organization:	Dirección Meteorológica de Chile, Chile
Contact person:	N/A
Contact details:	No info available, but contact is possible by filling form at: http://www.meteochile.gob.cl/PortalDMC-web/index.xhtml
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-73	-67	-15	-60
Temporal scale:	Monthly			
Aggregation period:	1, 3, 6, 12, 24, 36, 48 months			
Latency:	Every month (assumed)			

Quality, remarks, and references
References / supplementary information: N/A
Strengths:

N/A
Weaknesses: N/A
Final remarks: N/A

G197 Boletín de Recursos Hidricos y Agricultura- INAMHI, Ecuador

Newsletter that can be used to obtain information of meteorological, hydrological, and agricultural drought hazards at a monthly basis for Ecuador.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	SPI, Precipitation, Temperature, Soil moisture			
Countries where available:	Ecuador			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: Monthly Bulletin, containing various maps of precipitation and temperature anomalies over the whole country				

Contact information	
Link to online tools:	http://www.serviciometeorologico.gob.ec/
Organization:	Insituto Nacional de Meteorología y Hidrología, Ecuador
Contact person:	N/A
Contact details:	servicio@inamhi.gob.ec
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-81	-75	2	-5
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A
Strengths: N/A
Weaknesses:

N/A
Final remarks: N/A

G198 Boletín de Recursos Hidricos y Agricultura- IDEAM, Colombia

Newsletter that can be used to obtain information of meteorological, hydrological, and agricultural drought hazards at a monthly basis for Colombia.

General Characteristics				
Type:	Newsletter/Bulletin			
Type of drought:	Meteorological, Agricultural, Hydrological			
Applications:	Mapping meteorological drought hazard, Mapping agricultural drought hazard, Mapping hydrological drought hazard			
Indicator(s) included:	Precipitation, Actual Evaporation, Absolute anomalies, SPI1, 3, 6 & 12; Forecast Precipitation Anomalies			
Countries where available:	Colombia			
Period available:	From:	N/A	To:	near real-time
Costs involved in obtaining the tool:	N/A			
Concise model description: Monthly Bulletin, containing various maps of precipitation and temperature anomalies over the whole country. There are also links from IDEAM to the Sistema de Información de Recursos Hídrico.				

Contact information	
Link to online tools:	http://www.ideam.gov.co/web/tiempo-y-clima/meteorologia-agricola
Organization:	Instituto de Hidrología, Meteorología y Estudios Ambientales, Colombia
Contact person:	N/A
Contact details:	N/A
Resource:	N/A

Spatial and temporal scale				
Spatial reference:	WGS84		EPSG:	4326
Spatial scale:	Station Based			
Spatial extent:	West lon:	East lon:	North lat:	South lat:
	-79	-66	13	-5
Temporal scale:	Monthly			
Aggregation period:	N/A			
Latency:	N/A			

Quality, remarks, and references
References / supplementary information: N/A

Strengths: N/A
Weaknesses: N/A
Final remarks: N/A