

# Earth observation contributions to flood and drought risk assessment

Dr. Stefan Voigt, DLR

Expert Meeting Space-Based Information for  
Flood and Drought Risk Reduction

5-6 June 2014

Bonn, Germany








Knowledge for Tomorrow

# EO potential to describe “Risk” components for floods and droughts






$$\text{Risk} = f \{ \text{Hazard, Exposure, Vulnerability} \}$$




## Potentially damaging process

- Likelihood 
- Magnitude 
- Duration 
- Speed 
- Spatial extent 
- ...

## Objects/goods potentially adversely affected

- People 
- Property 
- Infrastructure 
- ...

## Attributes that describes possible future harm

- Physical 
- Social 
- Economic 
- ...

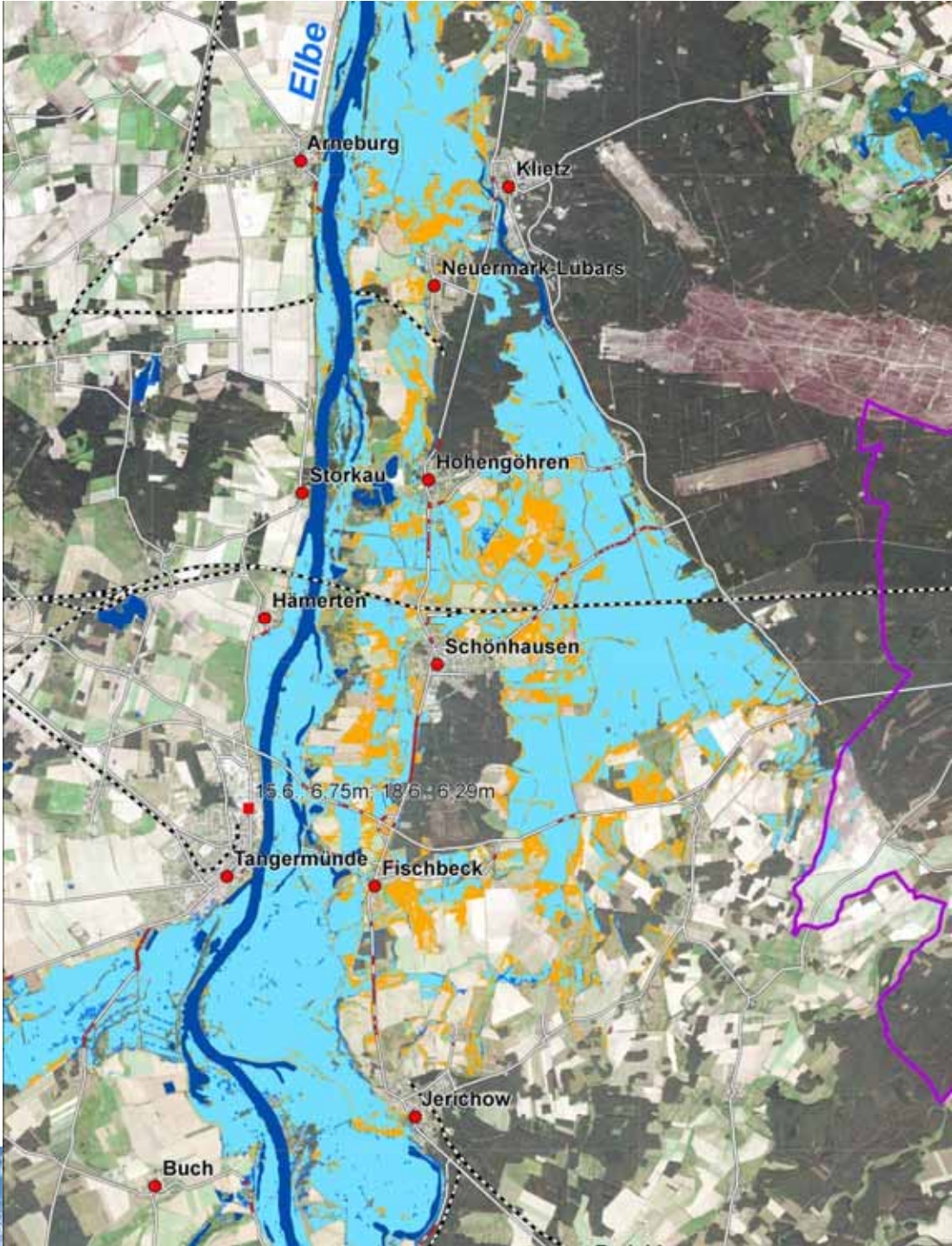
EO potential:

-  high
-  medium
-  low



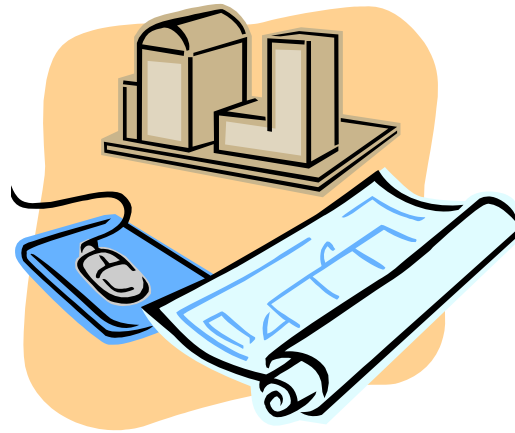
Satellite based flood map  
June 15, 2013

Elbe-River, Germany

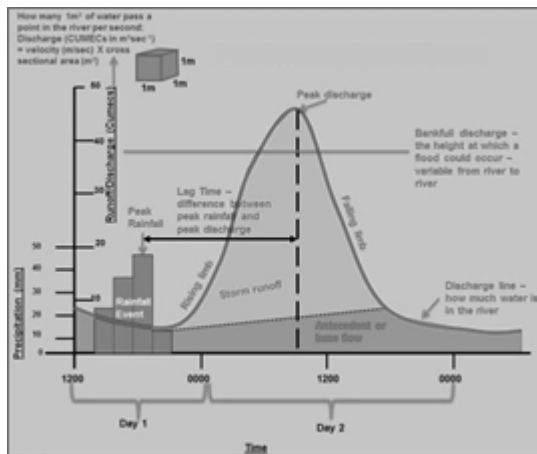


# Combination of satellite observations and modelling!

## Model








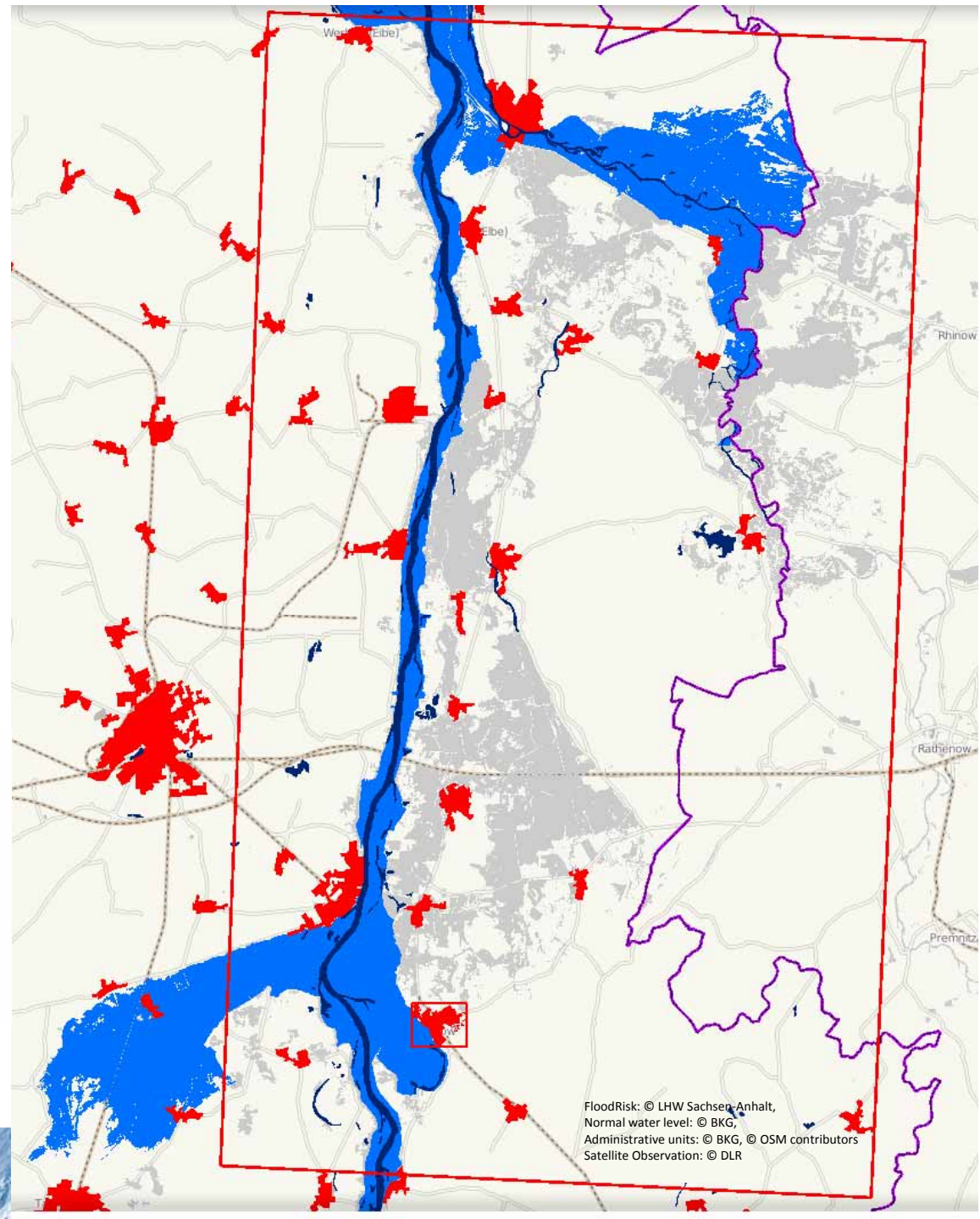
## Satellite



# Flood Risk Modelling and Satellite Observations






## Elbe-River, Germany

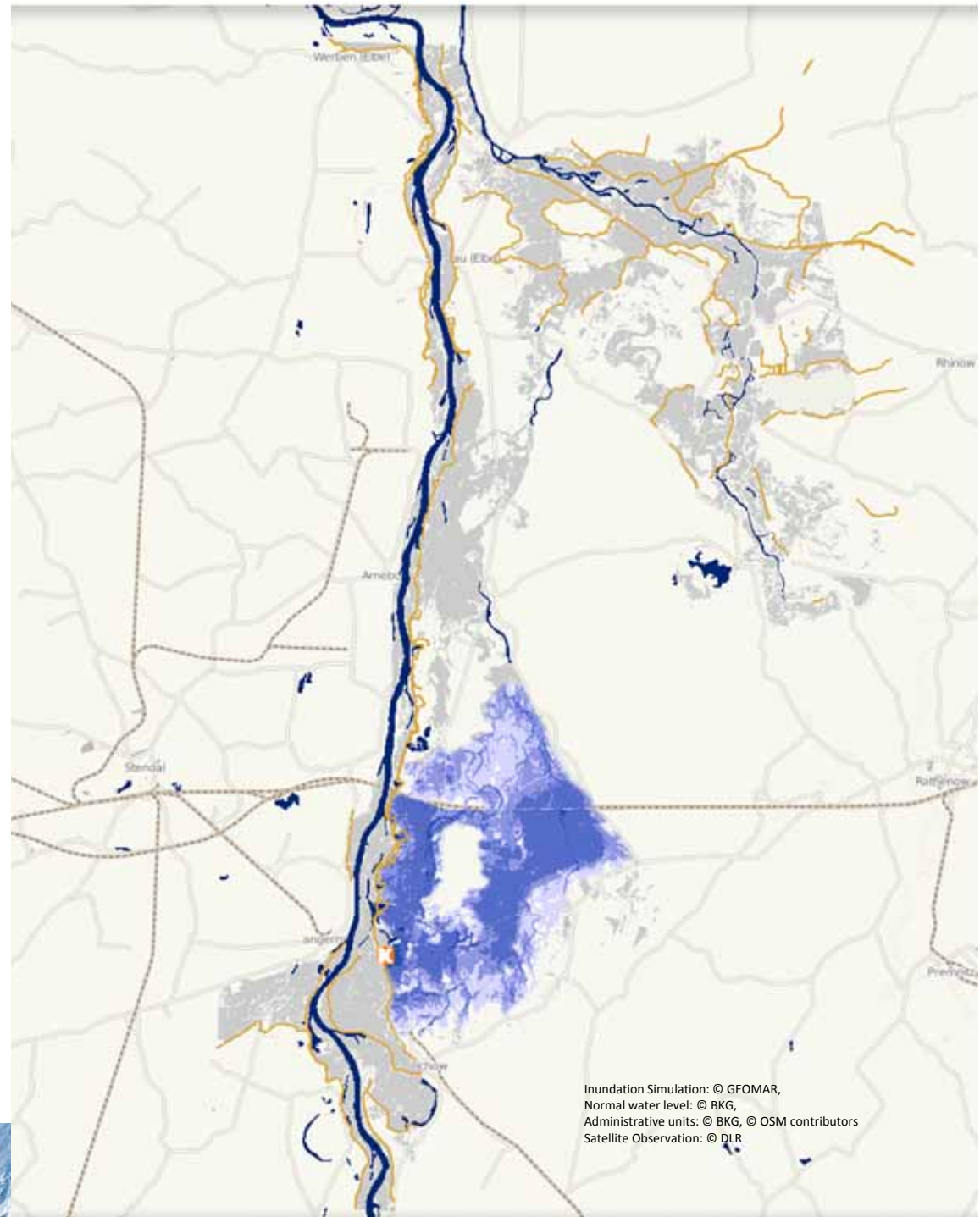
-  Build-up area
-  Normal water level
-  HQ 100
-  HQ 200
-  Satellite June 15, 2013



Improved flood risk assessment by fusion of hydrological modelling and satellite observation

Elbe-River, Germany

-  Build-up area
-  Normal water level
-  Failure of dike
-  Flood Simulation
-  Satellite June 15, 2013



# Improved Risk Assessment through synergistic use of Earth Observation and Modelling

Synergy	Hydrological Model	Earth Observation
<b>Interpolation</b>	Initialise by observation	Fill the gap between observations
<b>Extrapolation</b>	Now casting / Forecasting	Fit scenarios/ Plan future acquisitions
<b>Validation</b>	Validate Model	Validate Retrieval/Mapping
<b>Confirmation</b>	“Second Opinion”	“Second Opinion”
<b>Assimilation</b>	Force/drive by observation	Support for Modelling
<b>Calibration</b>	Model set up / building	Support for Modelling / Optimisation of Retrieval/ Mapping



# Earth Observation and Drought risk

## - Water Stress:

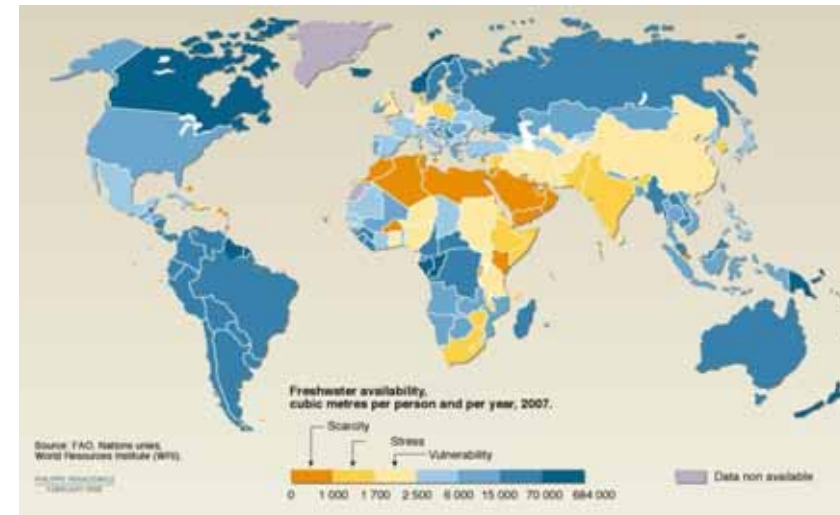
- Physical water stress
- Economic water stress

- here considered as **critical lack of available water for livelihoods**

The use of Satellite Data...

## - Existing indices:

- Water indices (some incl. land cover)
- Drought, desertification, land degradation indices (are not focus of this work).



Falkenmark Water Stress Index (Freshwater availability per m<sup>3</sup>, per person, per year): © Rekacewicz, 2008; accessed at UN, Aug 2012:

<http://www.un.org/waterforlifedecade/scarcity.shtm>



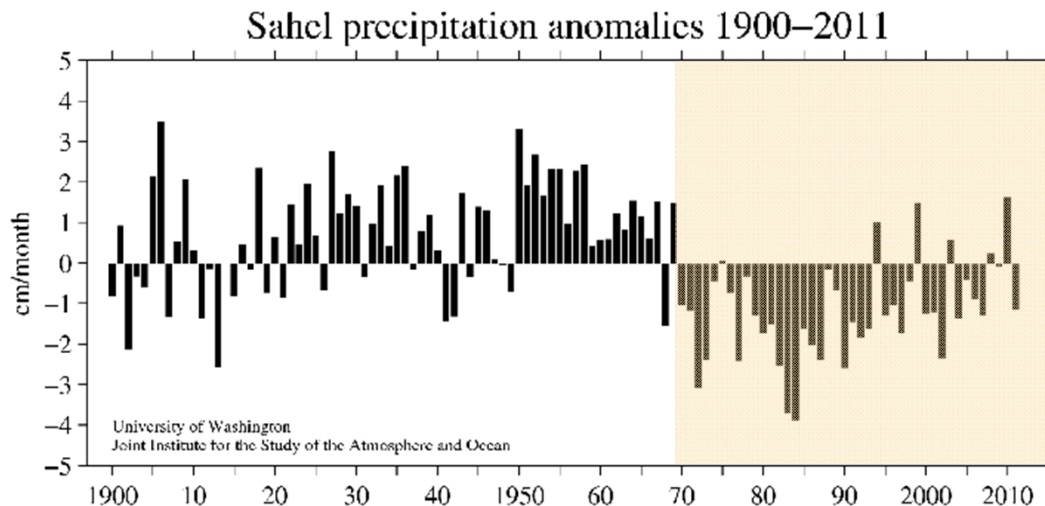
Water Poverty Index 2002: © FAO, Aug 2012, UNEP/GRID-Arendal :

[http://www.grida.no/graphicslib/detail/water-poverty-index-by-country-in-2002\\_d6db](http://www.grida.no/graphicslib/detail/water-poverty-index-by-country-in-2002_d6db)





# Example: Droughts in Sahel



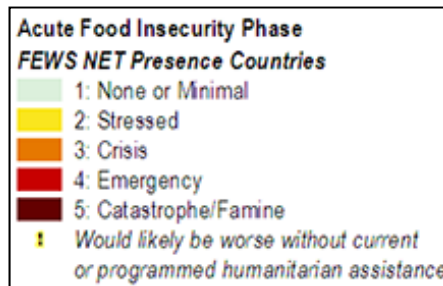
Mean Sahel precipitation anomaly during the rain season (June–October). Averages over 20-10N, 20W-10E, 1900–2010 climatology. NOAA NCDC Global Historical Climatology Network data. © Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington, USA. <http://jisao.washington.edu/data/sahel/#analyses>.

## Drought history:

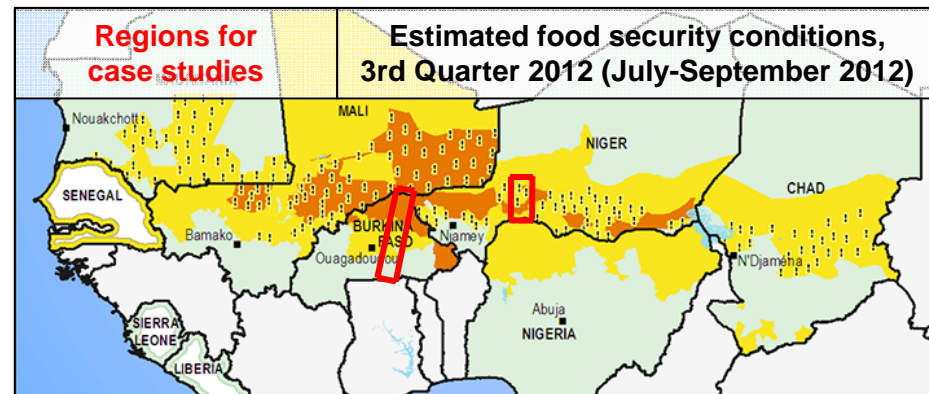
- **Mid-1970s** (e.g. 72-73)
- **Mid-1980s** (e.g. 84-85)
- 20-year dry period (1970-89)
- Then increase of annual rainfall, never reached pre-drought conditions.

## Droughts in the last decade:

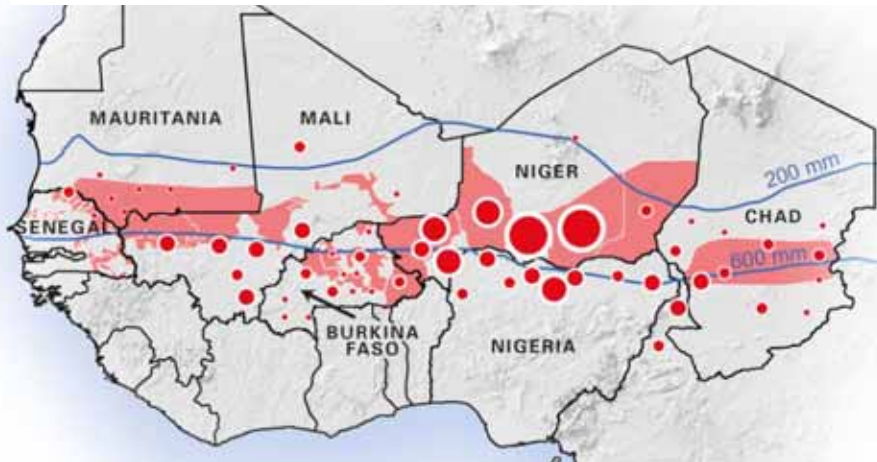
- **2005, 2008, 2010, 2012**



© Famine Early Warning Systems Network (FEWSNET), July 2012: <http://www.fews.net/>

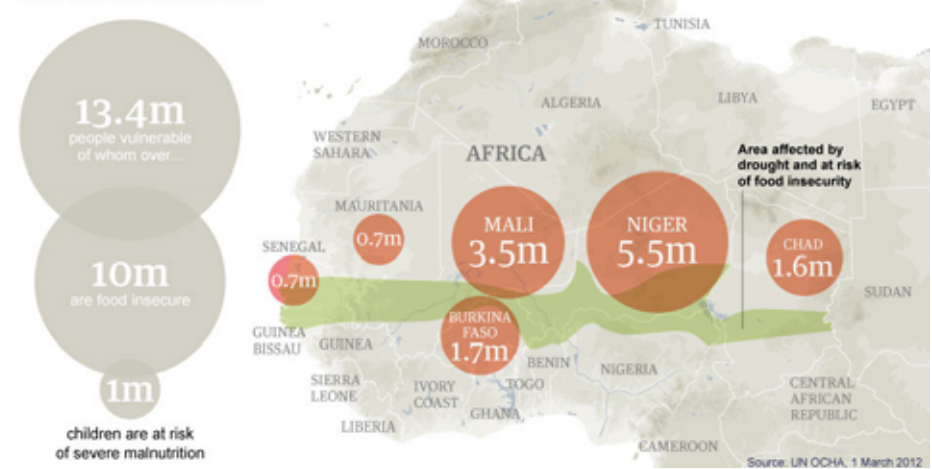


# General Drought Info Sahel

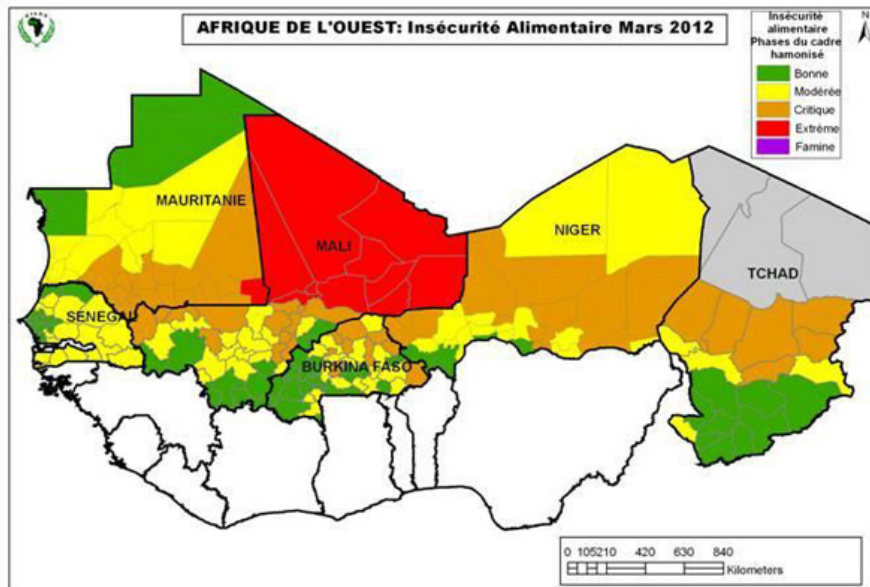


© Humanitarian Aid and Relief, May 2012: <http://humanitarian.worldconcern.org/2012/04/03/crisis-is-brewing-in-the-sahel/>

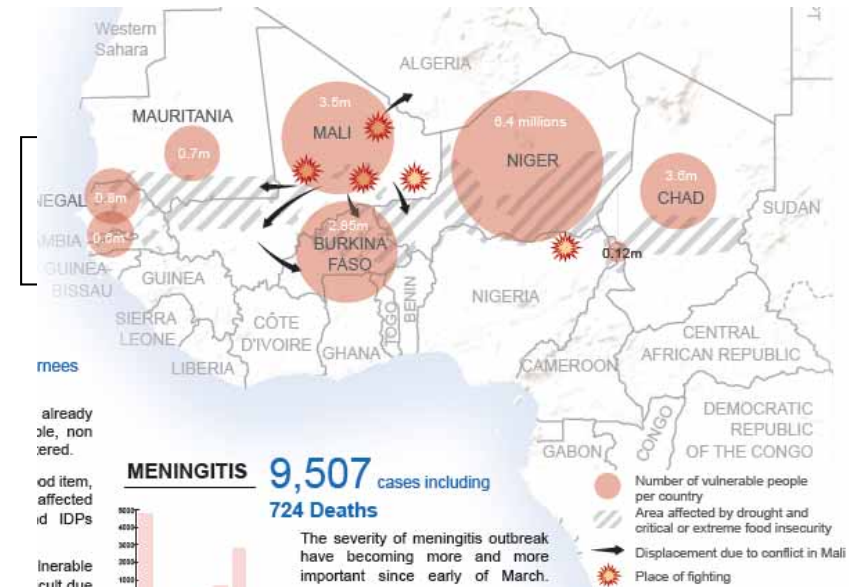
## Sahel: food and nutrition crisis



© UN OCHA, 2012, accessed May 2012: [http://static.guim.co.uk/sys-images/Guardian/Pix/maps\\_and\\_graphs/2012/3/9/1331299647277/Map---Sahel-food-crisis-001.jpg](http://static.guim.co.uk/sys-images/Guardian/Pix/maps_and_graphs/2012/3/9/1331299647277/Map---Sahel-food-crisis-001.jpg)



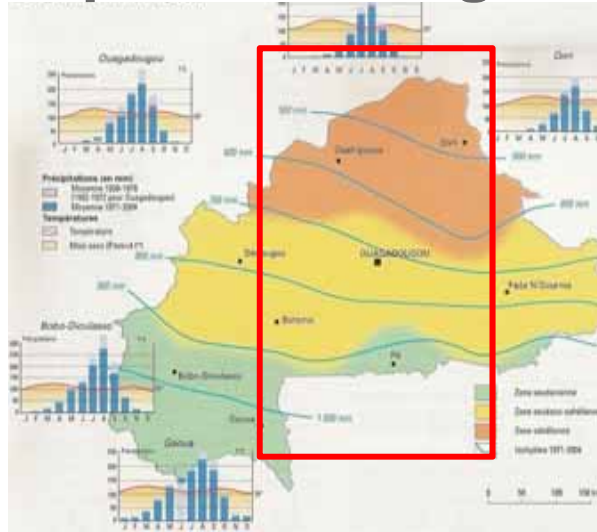
© FAO, May 2012: <http://www.fao.org/crisis/sahel/the-sahel-crisis/ar/>



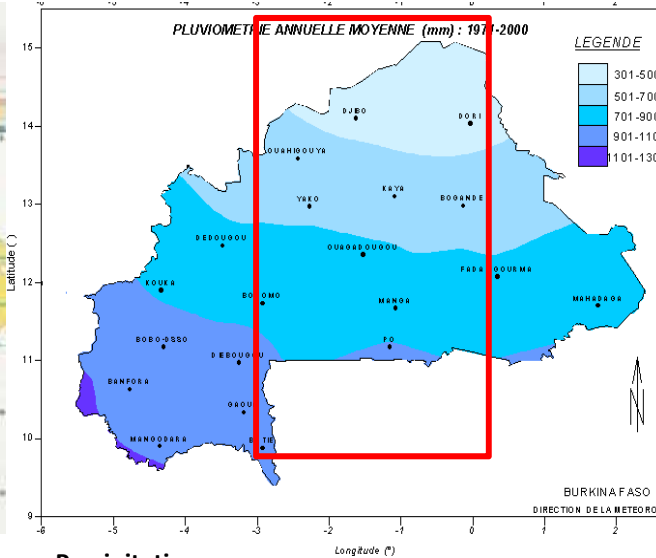
© Reliefweb, May 2012: [http://reliefweb.int/sites/reliefweb.int/files/resources/map\\_2079.pdf](http://reliefweb.int/sites/reliefweb.int/files/resources/map_2079.pdf)



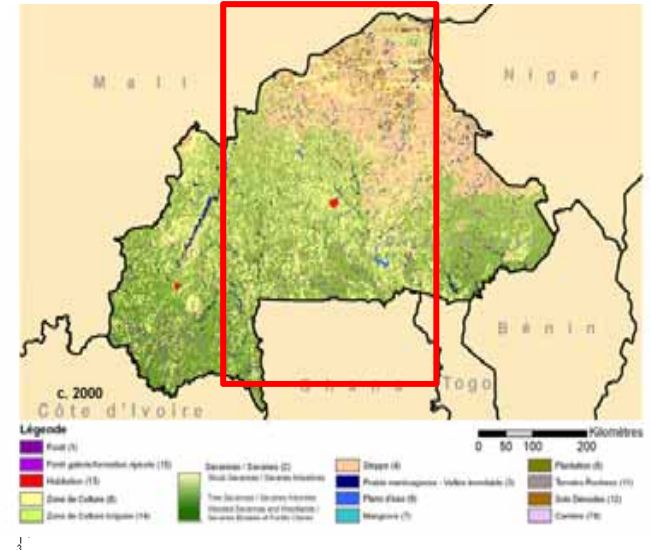
# Specific Background Info Burkina Faso



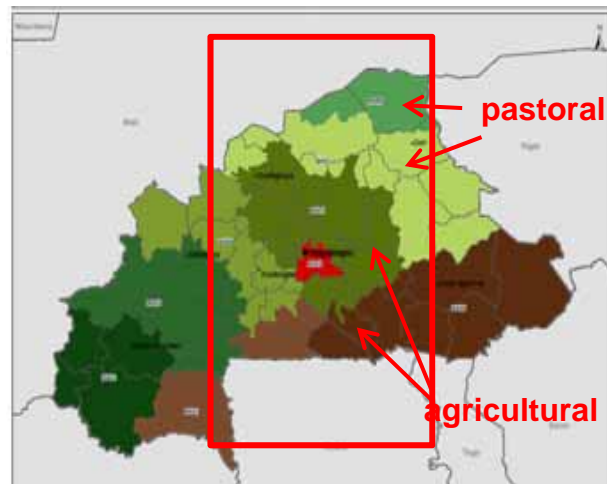
**Climatic Zones / Precipitation**  
 © Atlas de l'Afrique – Burkina Faso, 2005



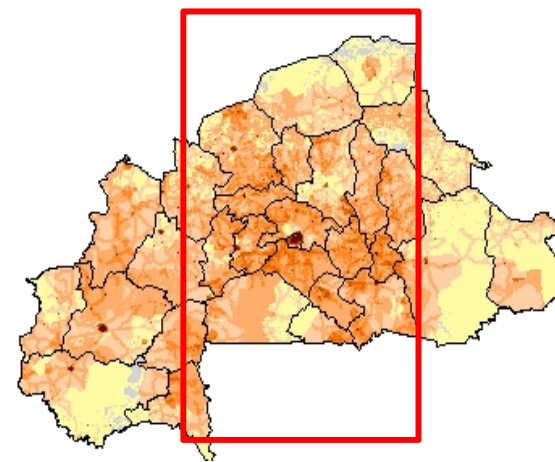
**Precipitation**  
 May, 2012: © [http://www.planete-burkina.com/geographie\\_burkina.php](http://www.planete-burkina.com/geographie_burkina.php)



**LULC Classification**  
 © West Africa Land Use and Land Cover Trends Project, May, 2012: <http://lca.usgs.gov/lca/afrialulc/results.php>



**Livelihood Zones**  
 © FEWSNET, May 2012:  
[http://www.fews.net/docs/Publications/BF\\_Livelihoods.pdf](http://www.fews.net/docs/Publications/BF_Livelihoods.pdf)



**Population Density**  
 May 2012: © [http://www.catsg.org/cheetah/07\\_map-centre/7\\_4\\_North-African-region/thematic-maps/thematic-maps.htm](http://www.catsg.org/cheetah/07_map-centre/7_4_North-African-region/thematic-maps/thematic-maps.htm)



# Observable Parameters – EO potential

**Traffic light system:**  
**Green = feasible**  
**Yellow = challenging**  
**Red = not feasible**

ID	Spatial Category	Indicators			Spatial requirements vs. possibilities						Time scale requirements vs. possibilities																			
		Category	Significance of	Feature	Useful Resolution	Spectral range	Sensor	Observable coverage by remote sensing	Required time scale for analysis	Observable time scale by remote sensing	Relevance of remote sensing (coverage, time, technical)	Relevance of remote sensing observations																		
1	Wetland indicators	Wetland water change	TS	Flooding regime, seasonality	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)		
				Wetland surrounding change	Mad / Change	irrigated agriculture / garden around	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)
				State	State	fence, restricted access	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)
				Med / Change	Med / Change	village, population around lake	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)
		Vegetation indicator change	TS / Mad	increase / decrease (big picture)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)		
				pattern, patcher (big picture)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)		
				area expansion (big picture) w. partial pattern, patcher (big picture) w. partial	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)		
				Mad	Mad	number	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)
2	LULC indicators	Change / Mad	LULC modification and transformation	Change	farmland to cropland	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	cropland to cropland	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	farmland to cropland	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	vegetation to bare	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	bare to vegetation	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	land to water (dammed lake)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Change	anything to urban	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)	
				Mad	Mad	farmland	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)
3	Distance relationships (to non-wetland or land use)	State	to road / path (recent)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)			
			to village (recent)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)			
			to wetland, lake, water area (recent)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)			
			to water point / water infrastructure (recent)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)			
			to animal corridor (recent)	HR1 (0.5-1m)	HR2 (2-4m)	HR3 (5-10m)	HR4 (15-30m)	HR5 (40-100m)	HR6 (150-300m)	HR7 (0.5-1m)	HR8 (2-4m)	HR9 (5-10m)	HR10 (15-30m)	HR11 (40-100m)	HR12 (150-300m)	HR13 (0.5-1m)	HR14 (2-4m)	HR15 (5-10m)	HR16 (15-30m)	HR17 (40-100m)	HR18 (150-300m)	HR19 (0.5-1m)	HR20 (2-4m)	HR21 (5-10m)	HR22 (15-30m)	HR23 (40-100m)	HR24 (150-300m)			

spatial resolution

spatial coverage

temporal resolution

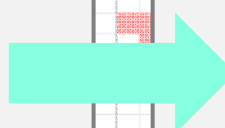
EO feasibility & relevance




# Observable Parameters – EO potential

**Traffic light system:**  
**Green = feasible**  
**Yellow = challenging**  
**Red = not feasible**

Feature:	Example:	Example:
Spatial Category:	<b>Wetlands</b> water area change <b>High Resolution (HR)</b>	<b>Wetlands</b> water area change <b>Medium Resolution (MR)</b>
Useful spatial resolution:	HR1 (4-10m), HR2 (10-30m)	MR (30-500m)
Spectral range:	VNIR, SWIR, TIR, SAR	VNIR, SWIR
Required coverage:	communal - regional	national - regional
Observable coverage:	<b>communal - regional</b>	<b>national - regional</b>
Required time scale:	monthly - yearly	weekly - monthly
Observable time scale:	<b>monthly - yearly</b>	<b>weekly - monthly</b>
Seasonal Component?:	Seasonal (S)	Seasonal (S)
Scale of monitoring:	Change Detection (CD)	Time Series Analysis (TS)
Remote sensing potential:	***	****
Relevance of EO analysis:	*****	*****
Overall scale:	4	4,5



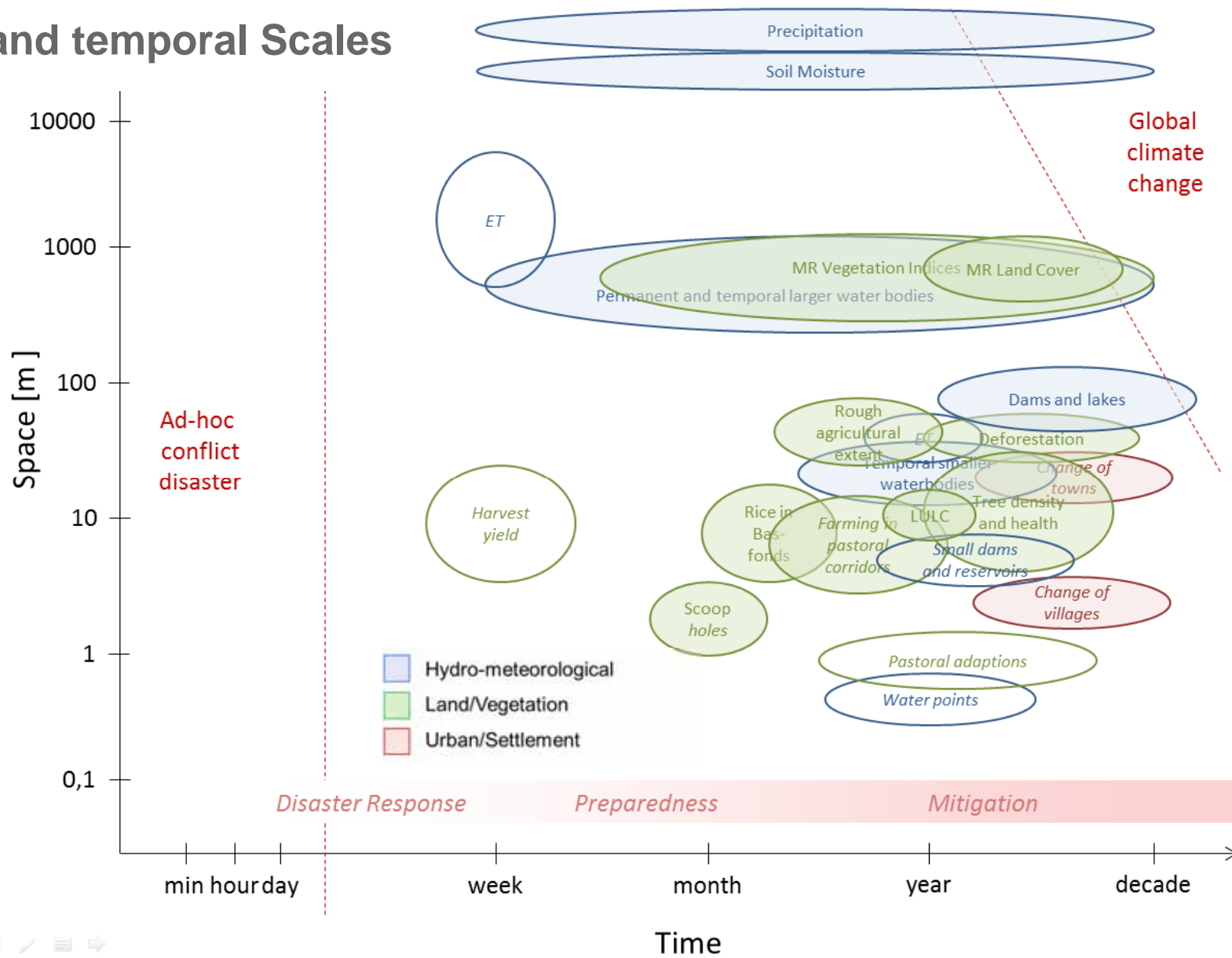


Observable parameters: spatial resolution, spatial coverage, temporal coverage, and relevance



# Observable Parameters

## Spatial and temporal Scales



# Observable Parameters – EO potential

**Traffic light system:**  
**Green = feasible**  
**Yellow = challenging**  
**Red = not feasible**

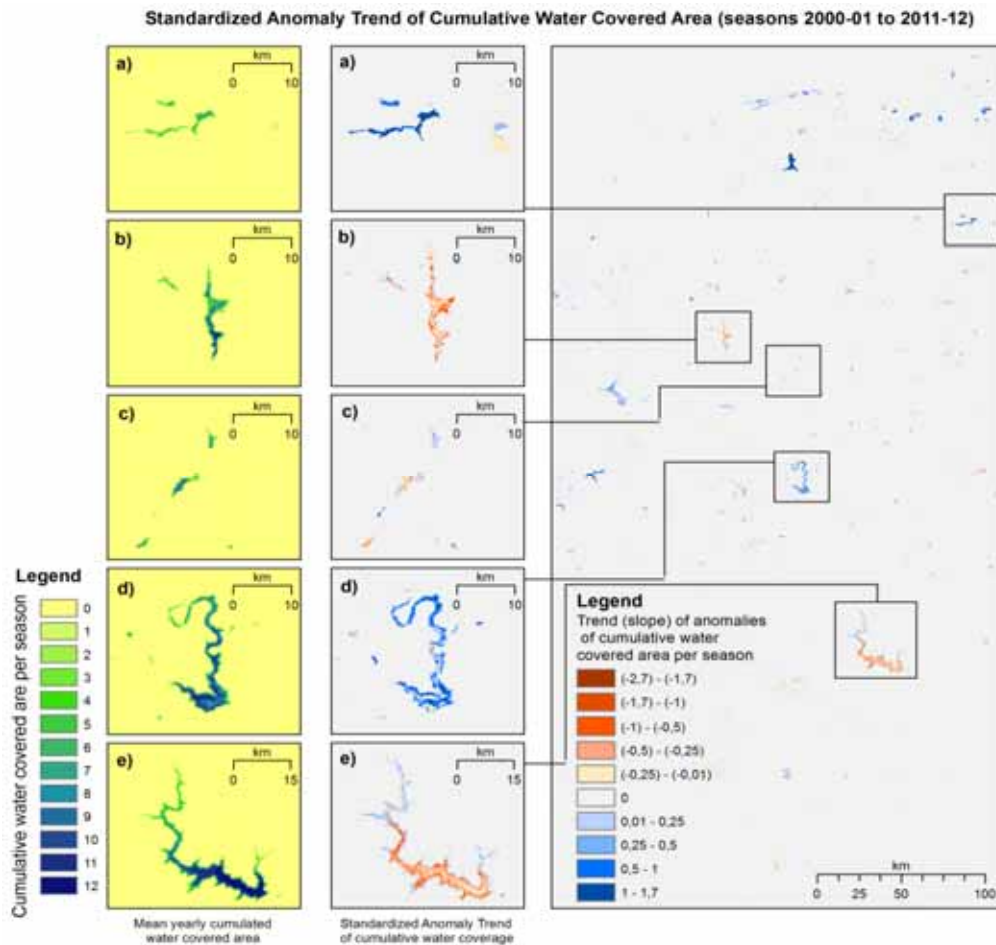
a) Waterbody and Wetland Dynamics

b) Land Use Indicators

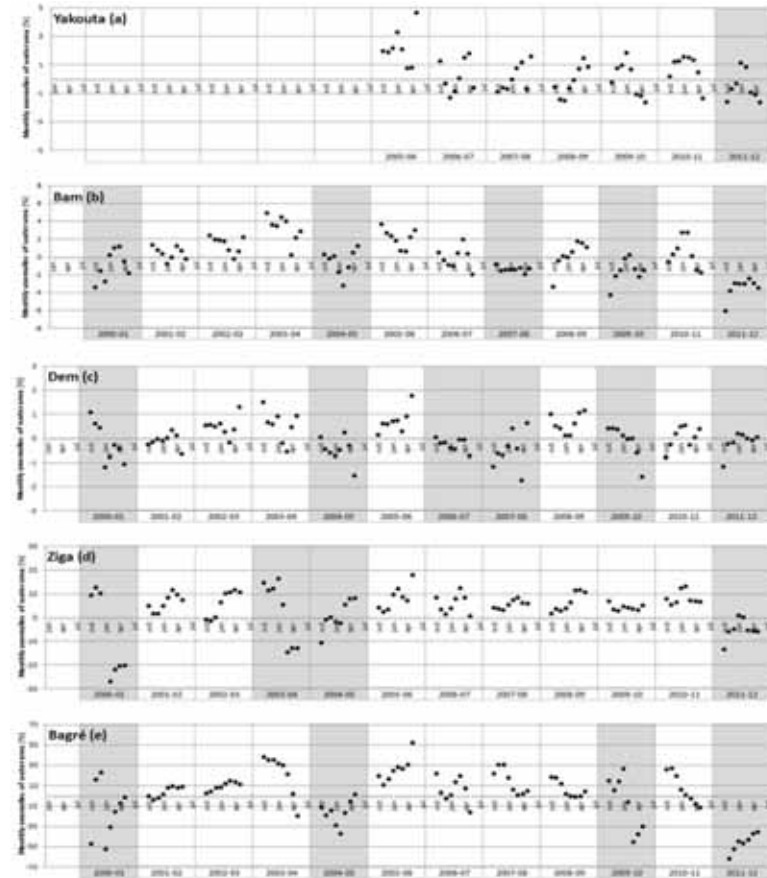
	spatial coverage		temporal resolution		EO feasibility & relevance	
Water (river)	Grey	Green	Grey	Green	*****	*****
Wetland (regime and dam)	Grey	Yellow	Grey	Red	**	*****
Water (lake)	Grey	Green	Grey	Yellow	**	*****
Culture/gardens around	Grey	Green	Grey	Yellow	*****	*****
Access, restricted access	Grey	Green	Grey	Red	*	*****
Villages, population around lakes	Grey	Green	Grey	Red	*	*****
Urban area	Grey	Green	Grey	Green	*****	*****
Patterns, patches	Grey	Green	Grey	Green	*****	*****
Area expansion	Grey	Green	Grey	Yellow	**	*****
Fields	Grey	Green	Grey	Yellow	**	**
Fields	Grey	Green	Grey	Yellow	**	*****



# Satellite based monitoring of water bodies and wetlands as indicator for critical water shortage and drought risk in the Sahel



Monthly anomalies of water body size, with respect to the 13-year mean displayed for the dry season (October – May) 2000-2012



Moser et al. 2014





# Concluding Remarks

- **Earth Observation can contribute in multiple ways to risk mapping and assessment.** Flood, drought and beyond.
- The **combination/synergy of Earth Observation and Modelling** of risks (all components) still bares great potential, not fully developed yet. Especially for flood risk assessment / hydrological risks.
- **Temporal and spatial scales**, as well as observational limitations, have to be respected when incorporating EO for any kind of risk assessment.
- EO provides time series of observations up to 30years. We can start to work on **satellite climatology for “coarse” risk phenomena** and assess statistical parameters of natural hazards for risk assessment - even though satellites.
- Can we start thinking of ways **use EO for documentation of avoided or mitigated disasters?**

stefan.voigt@dlr.de

