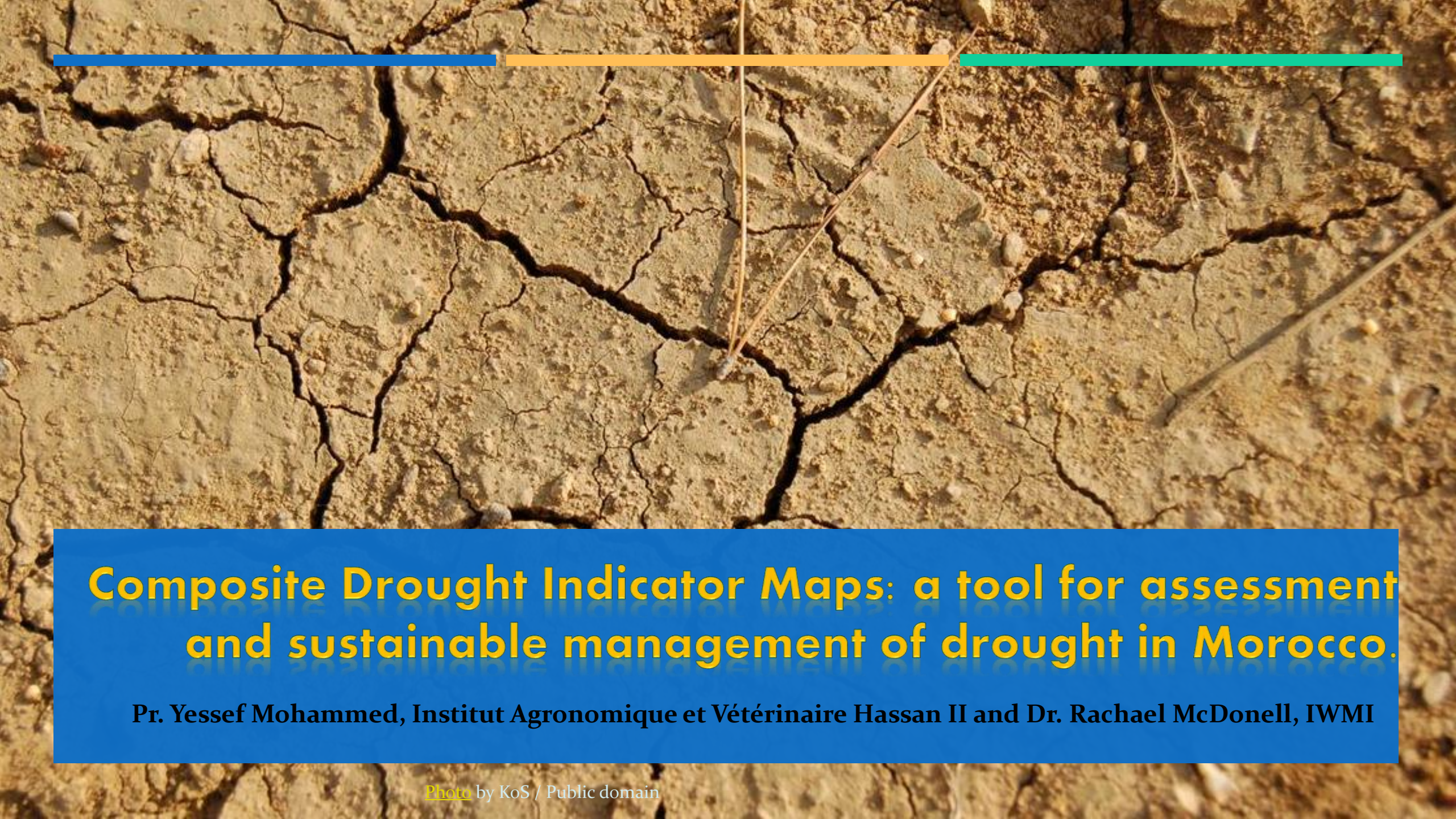


Composite Drought Indicator Maps: a tool for assessment and sustainable management of drought in Morocco.

Pr. Yessef Mohammed, Institut Agronomique et Vétérinaire Hassan II and Dr. Rachael McDonell, IWMI

Moroccan Drought Context

Only 15 percent of the country's lands are irrigated, while the rest are rain-fed crops.

Morocco's 1.4 million hectares of irrigated crops consume, on average, 85% of available water resources ; while 12% and 3% of resources are used for public water supply and industry, respectively.

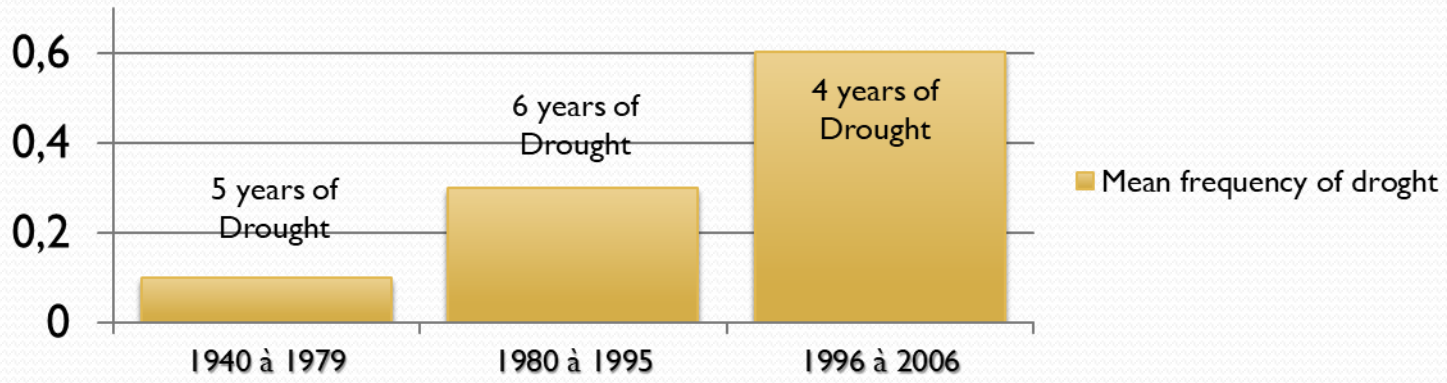
Agricultural sector in Morocco accounts for :

- 15 percent of the GDP ;
- 40 percent of all employment 70% farmers have no more than 2.1 ha. of land and struggle with frequent drought,.

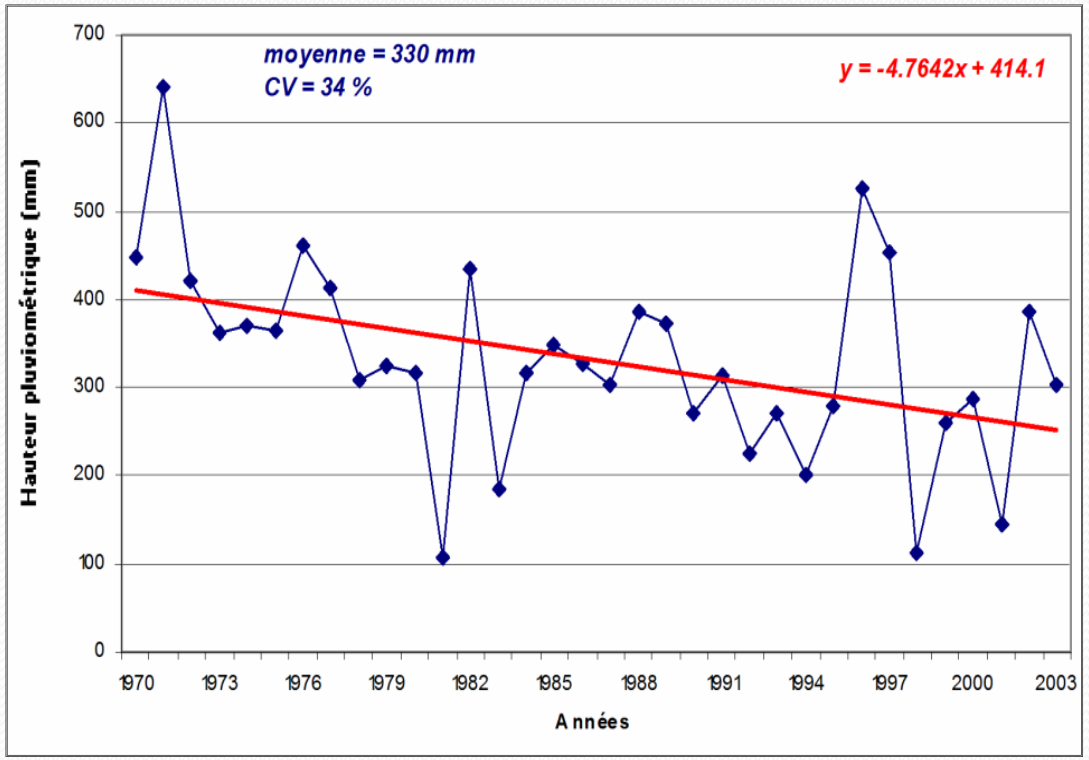
Climatological history of droughts in Morocco

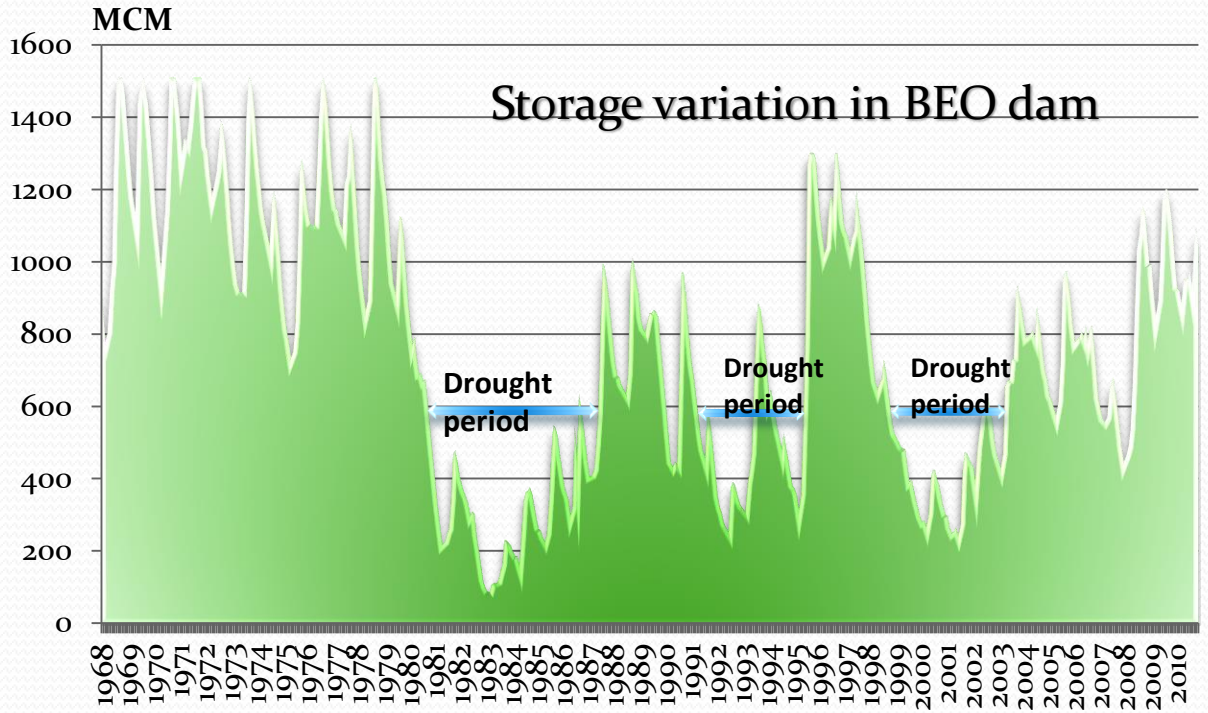
Drought Frequency :

- During the last 40 years, more than 20 dry episodes were recorded;
- Some episodes are generalized for all the country, and exceed 5 years;
- Drought become a chronic phenomenon in Morocco, and it duration increase:



Climatological history of droughts in Morocco

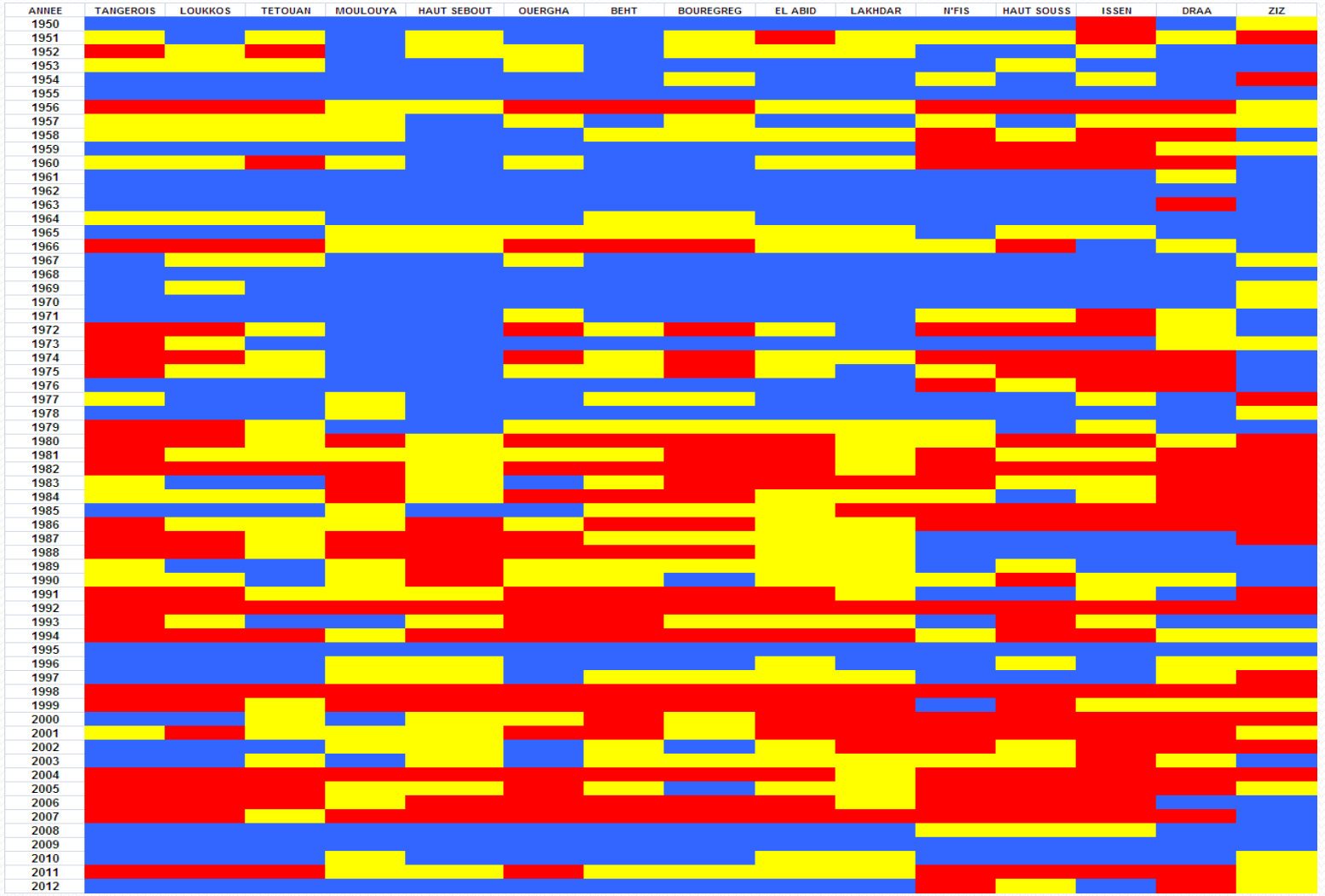




HYDROLOGICAL DROUGHT CHARACTERISTICS

DEFICIT OF WATER FLOWS

- **surplus**
- **Deficit < 50%**
- **Deficit > 50%**



1. Increase in the drought frequency from the end of the seventies;

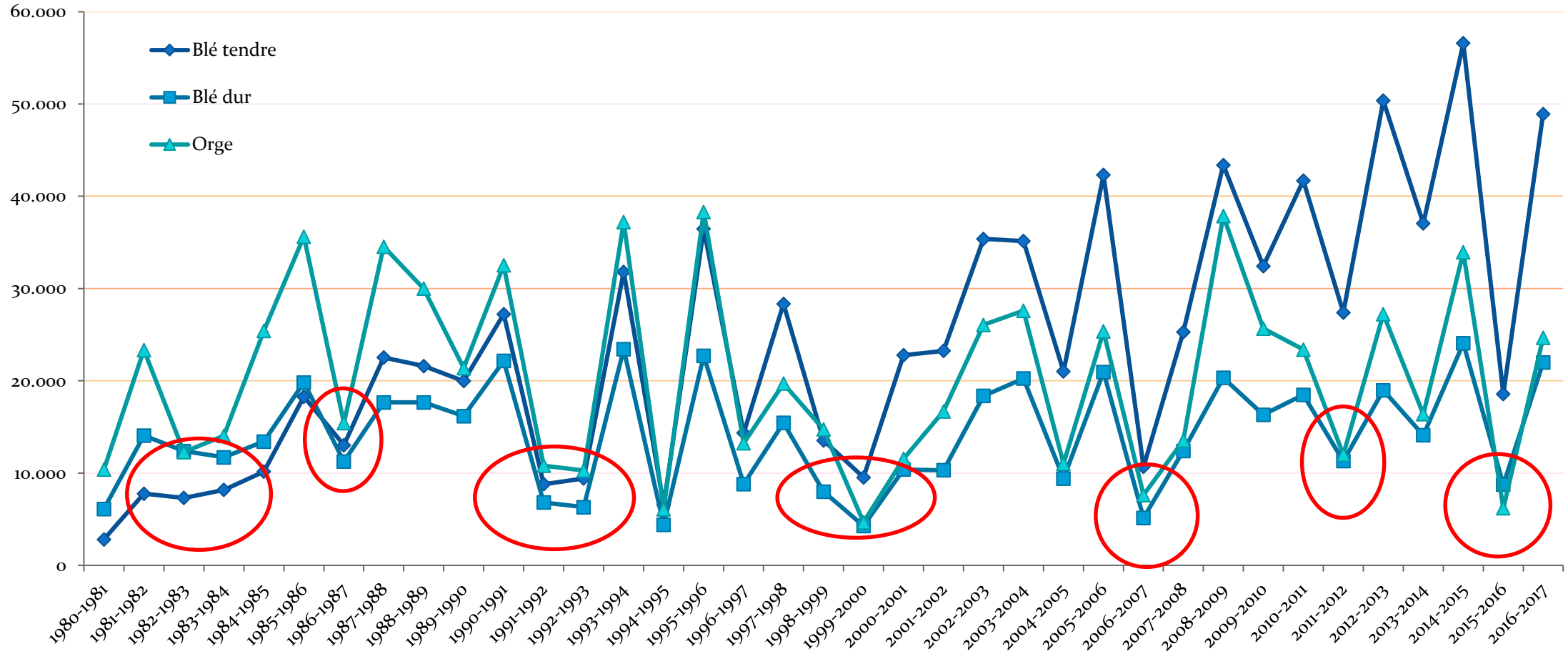
2. Drought is a structural rather than an exceptional phenomenon.

These climate changes have negative effects on natural resources and the sustainability of our agriculture.

Thus drought history could also be addressed through the evolution of crops production

Drought periods reported in the literature 1981-1984, 1991-1993, 1994-1995 and 1999-2001.

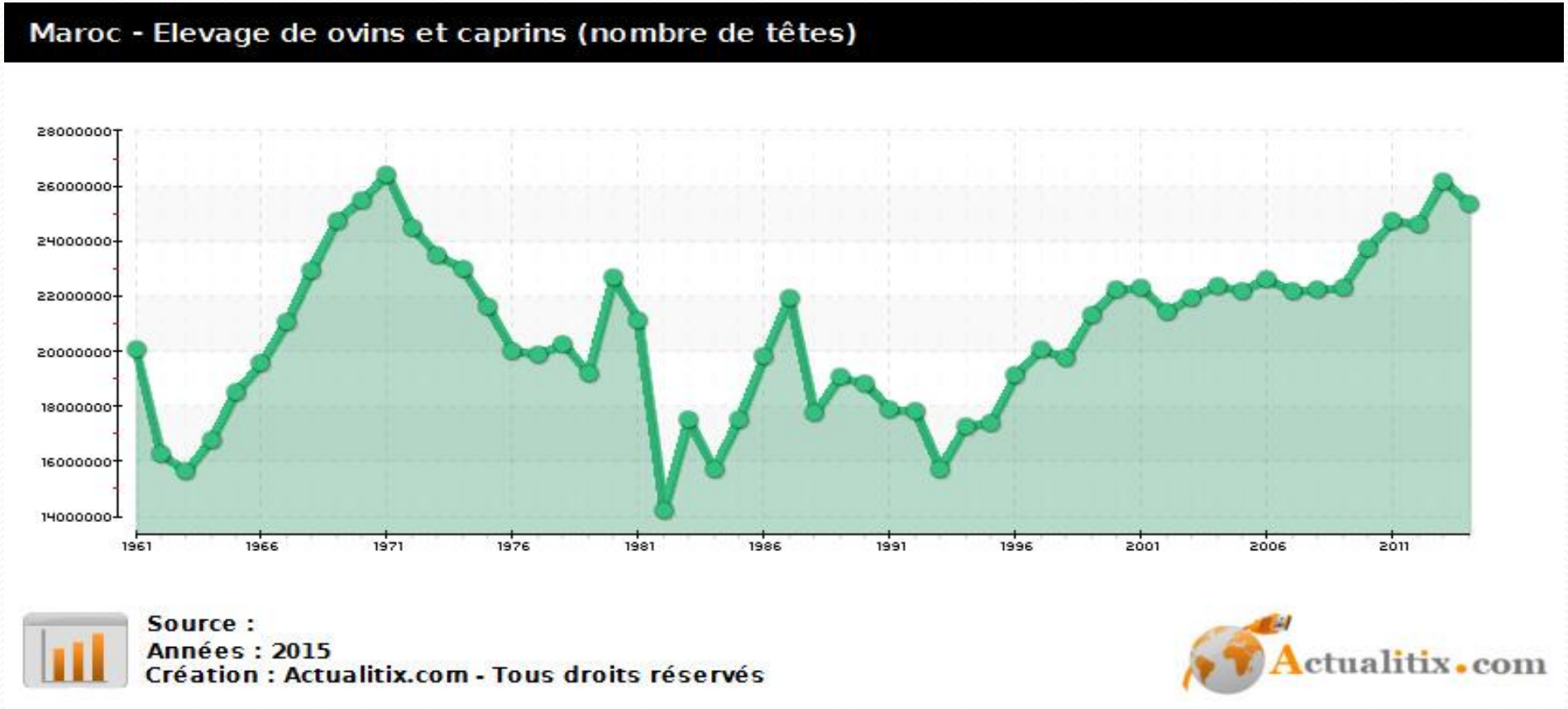
Past Droughts in MOROCCO



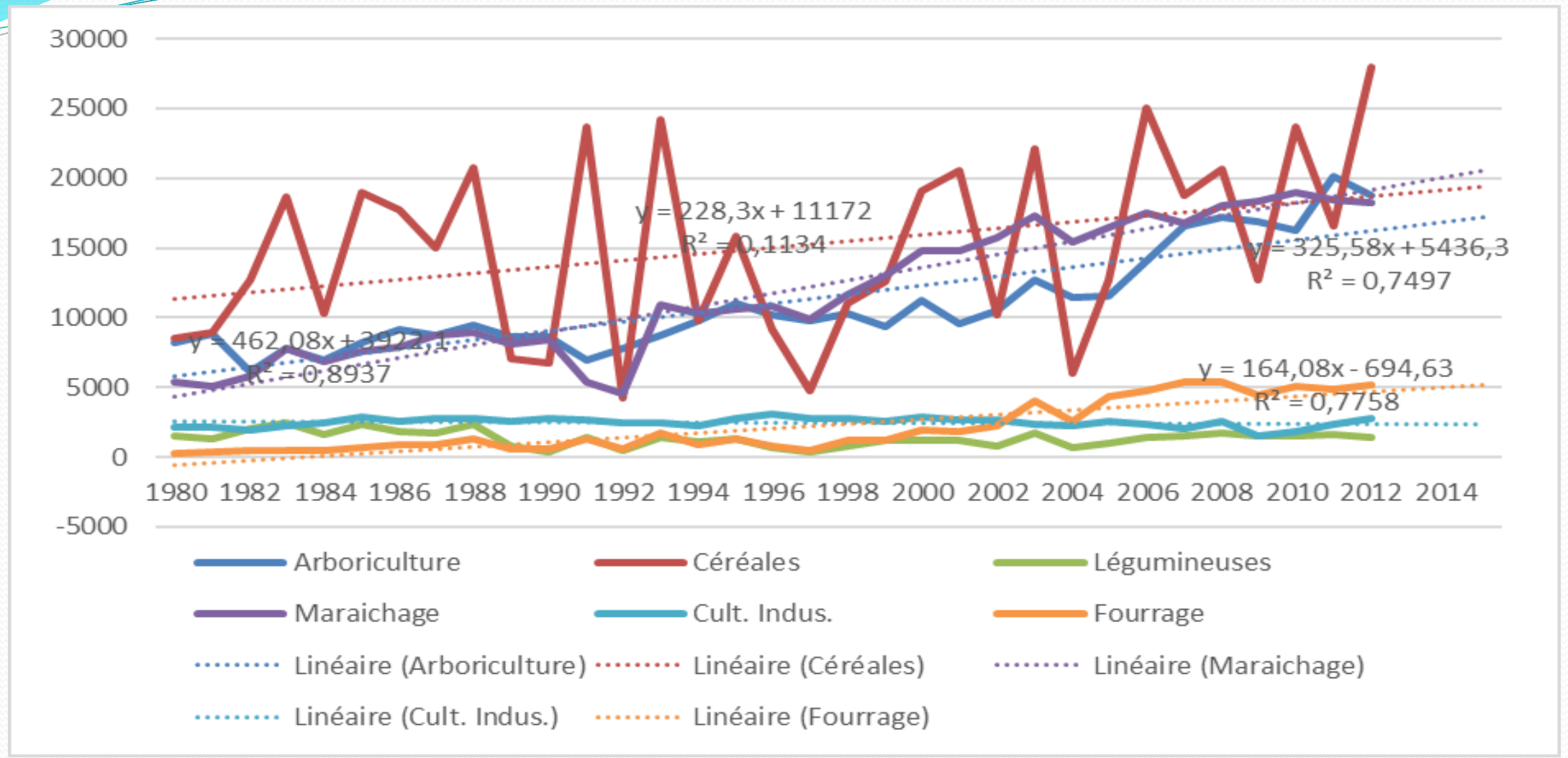
HISTORICAL EVOLUTION OF DROUGHT AS REFLECTED BY CEREAL PRODUCTION

Past Droughts in MOROCCO

climatological history of droughts in Morocco



Value of [illegible] (constant prices Base 2000)



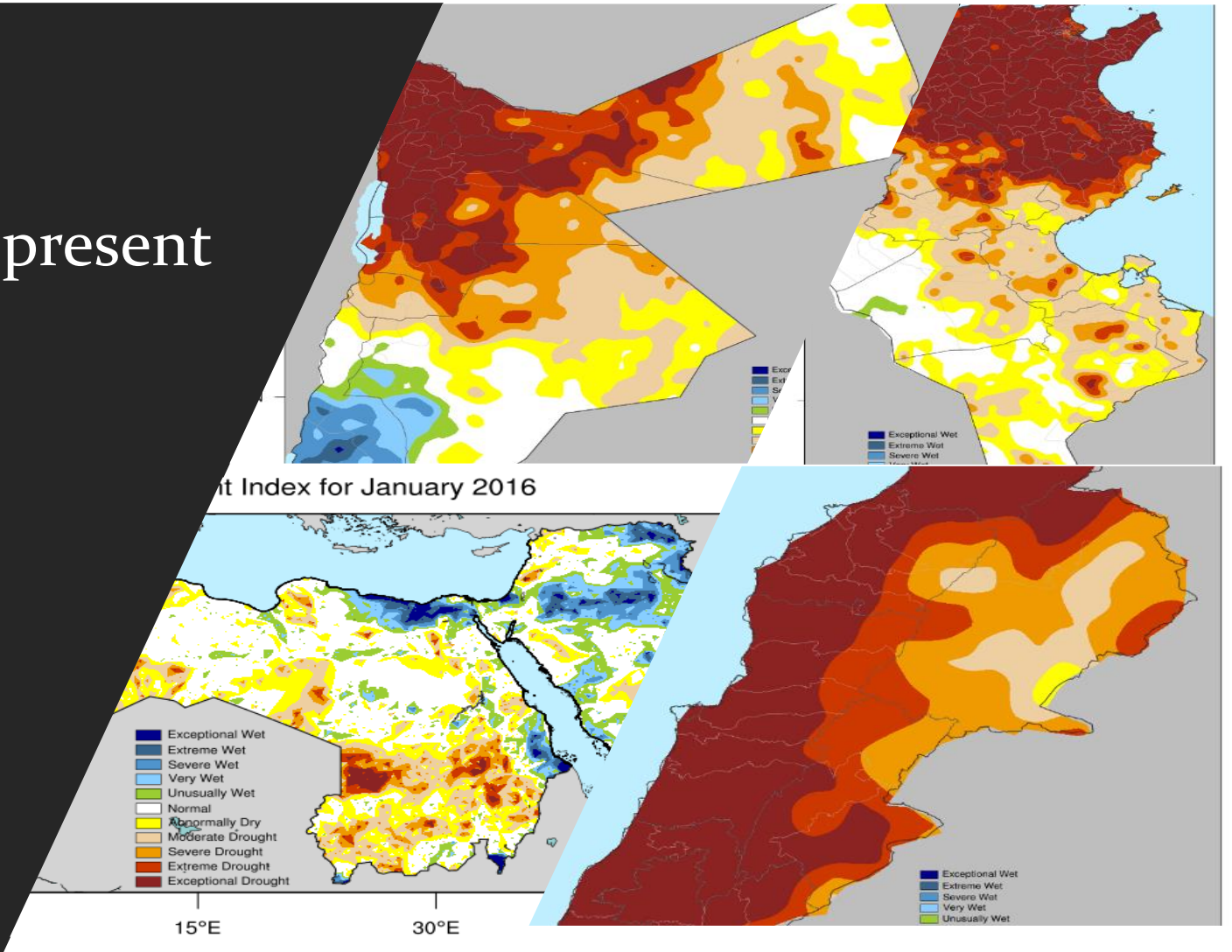
Decision-makers needs

to <u>empower</u> decision-makers to plan for and manage the impacts of droughts on food and water security under current and future climate conditions

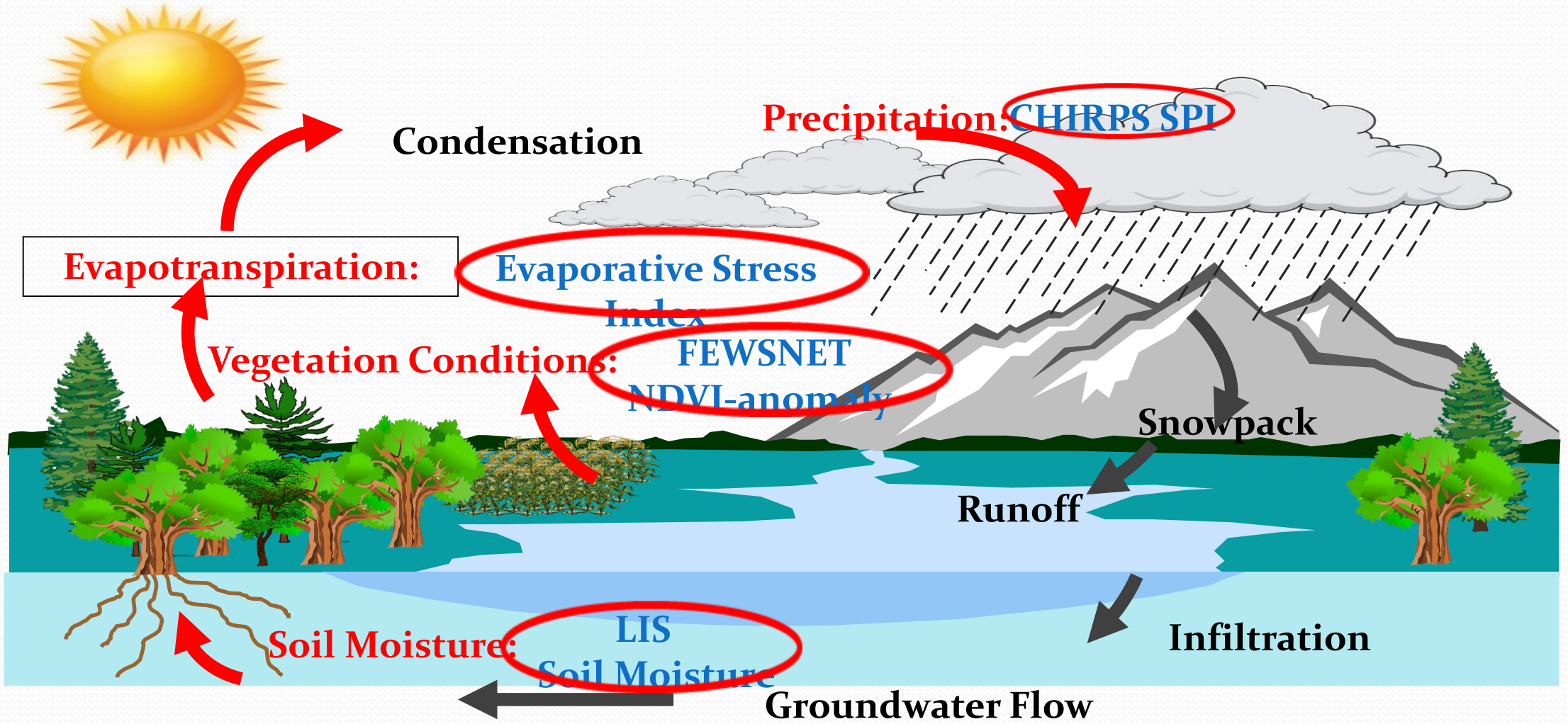
Composite **D**rought **I**ndex **(CDI)**

Maps of drought
grid cell anomalies for past, present and future

- Precipitation
- Evapotranspiration
- Soil Moisture
- Vegetation stress



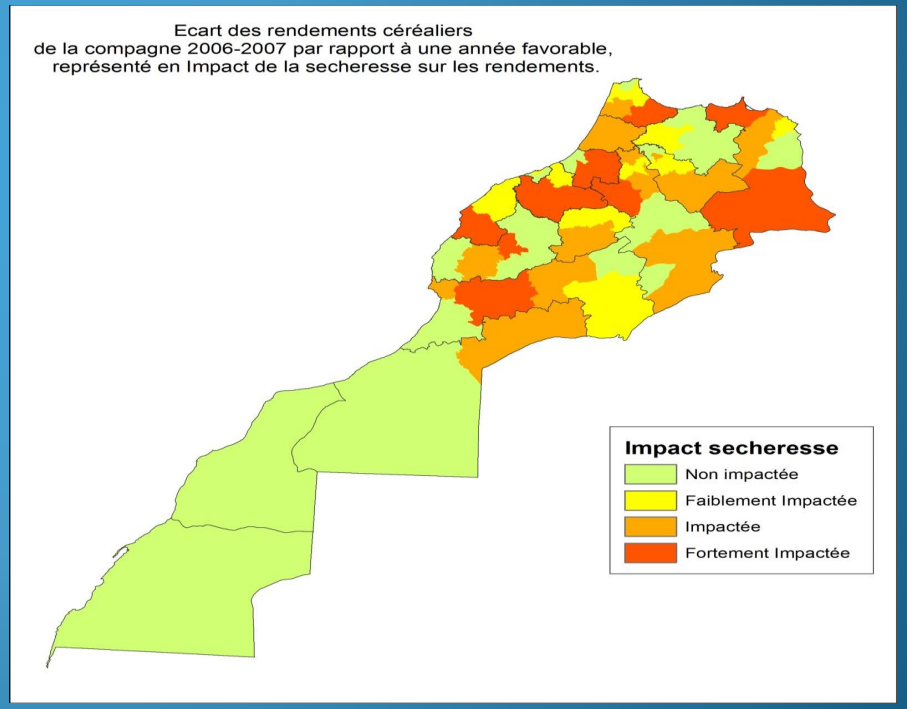
The Hydrologic Cycle and the CDI



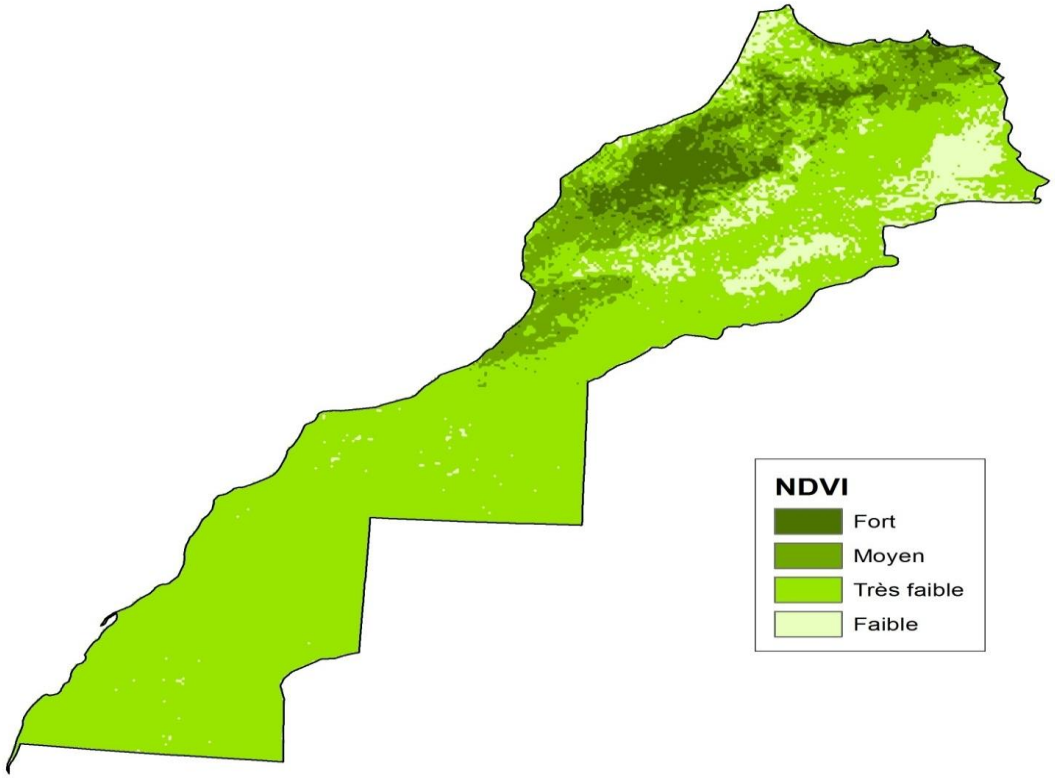
Weight of the CDI components

Classification of agricultural campaign (years) in term of drought conditions based on crop parameters drought.

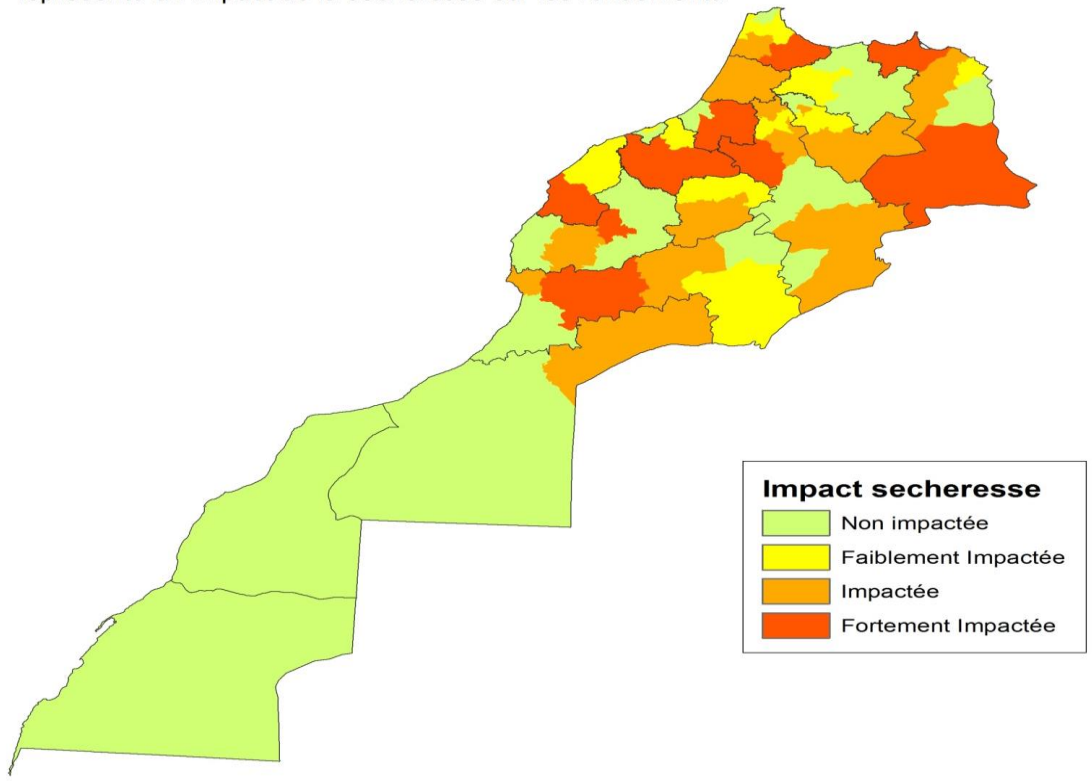
These classes were used for the comparison /confrontation/overlapping with the different CDI parameters.

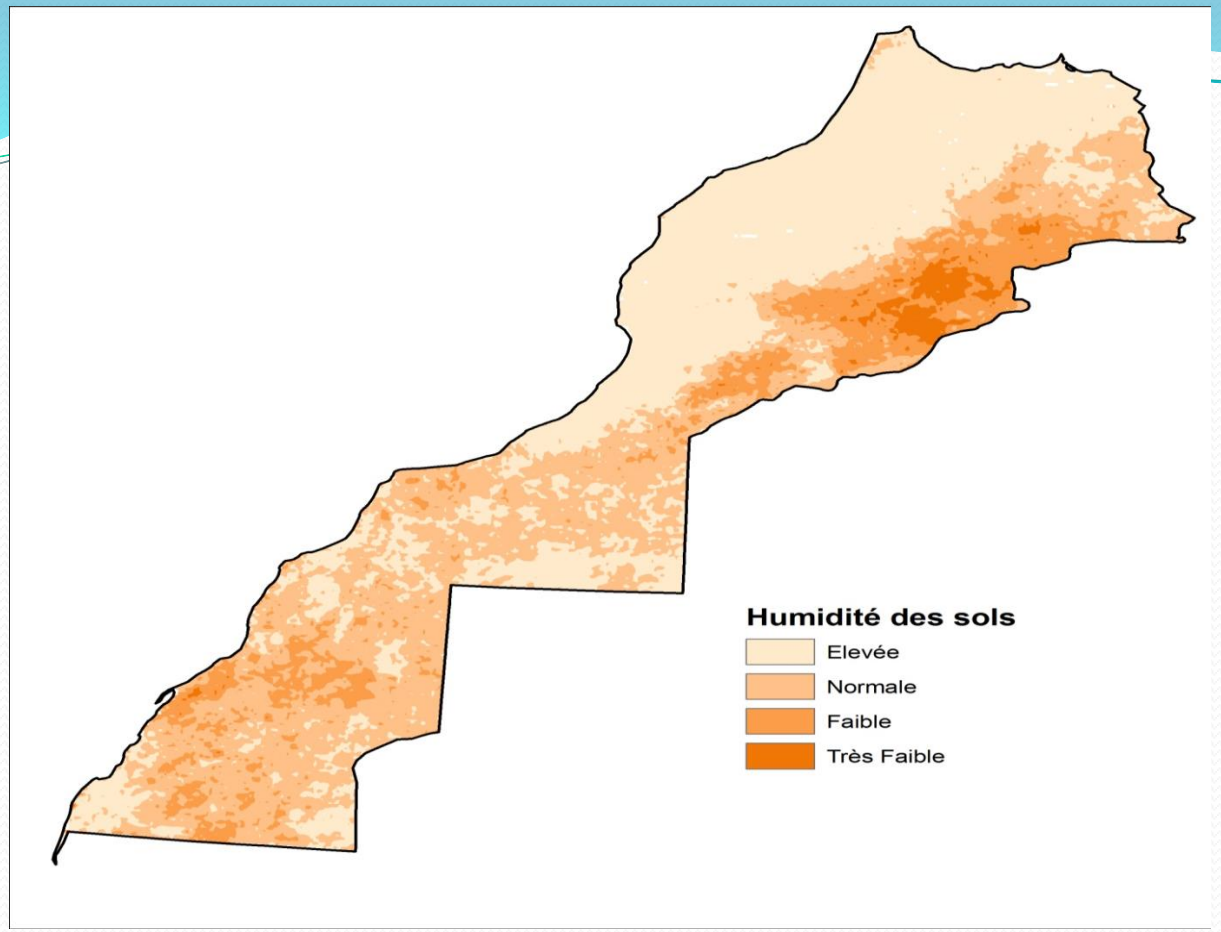


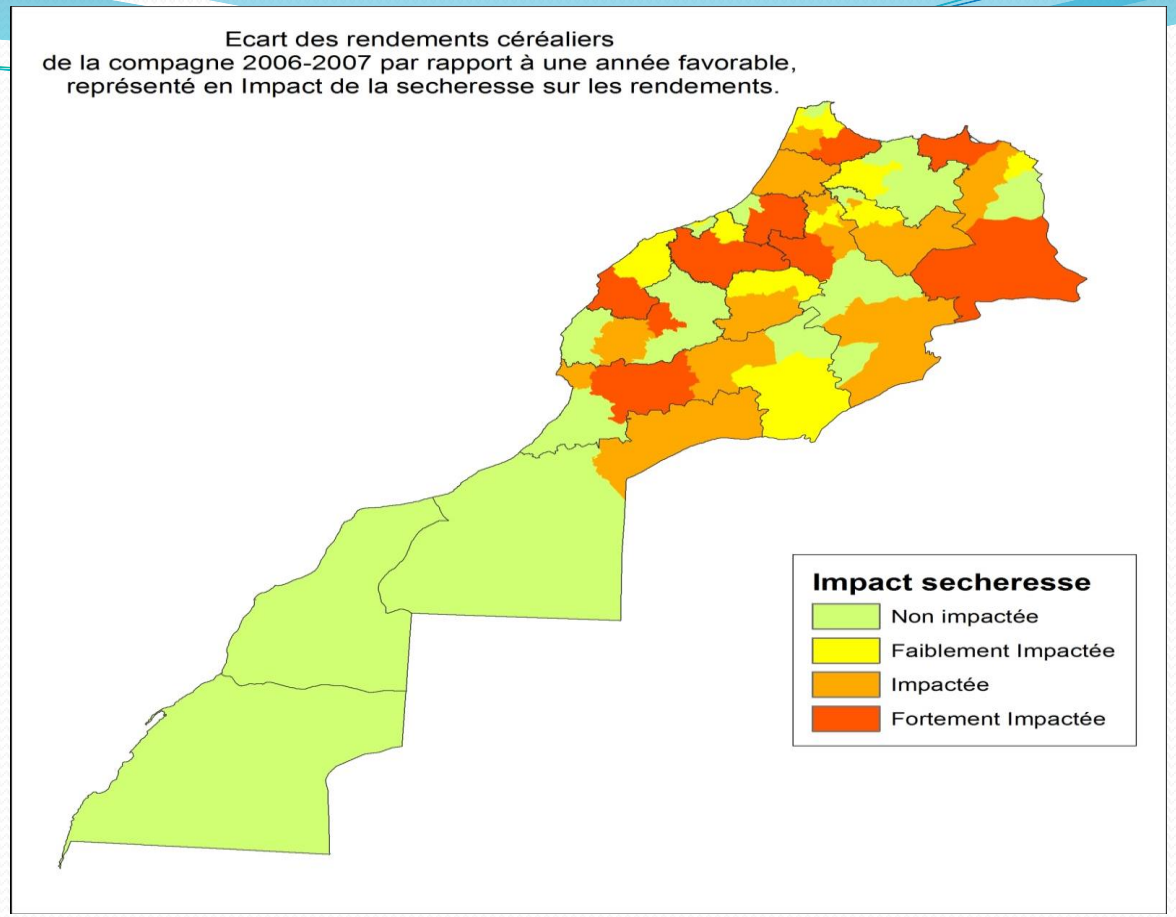
NDVI de la compagne agricole 2006-2007 (7 mois)

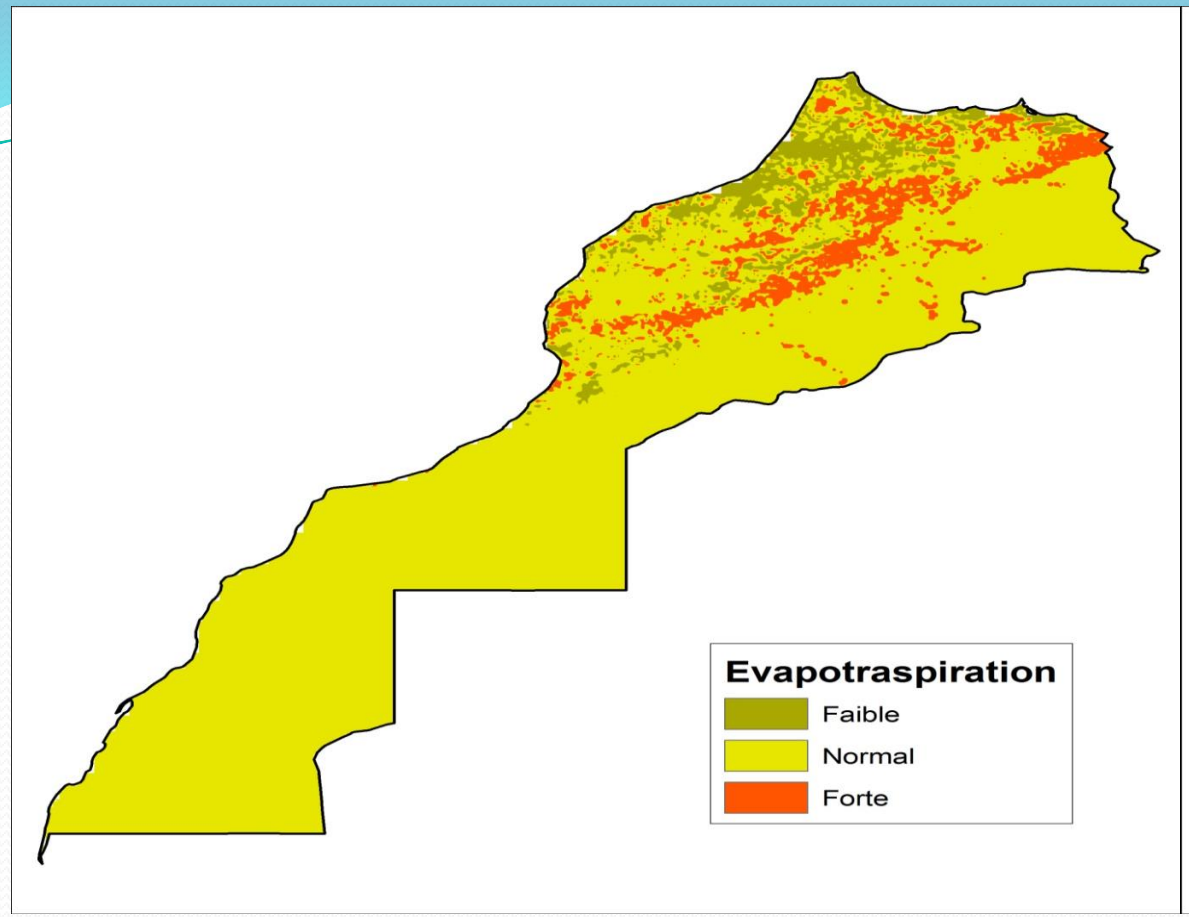


Ecart des rendements céréaliers
de la compagne 2006-2007 par rapport à une année favorable,
représenté en Impact de la secheresse sur les rendements.

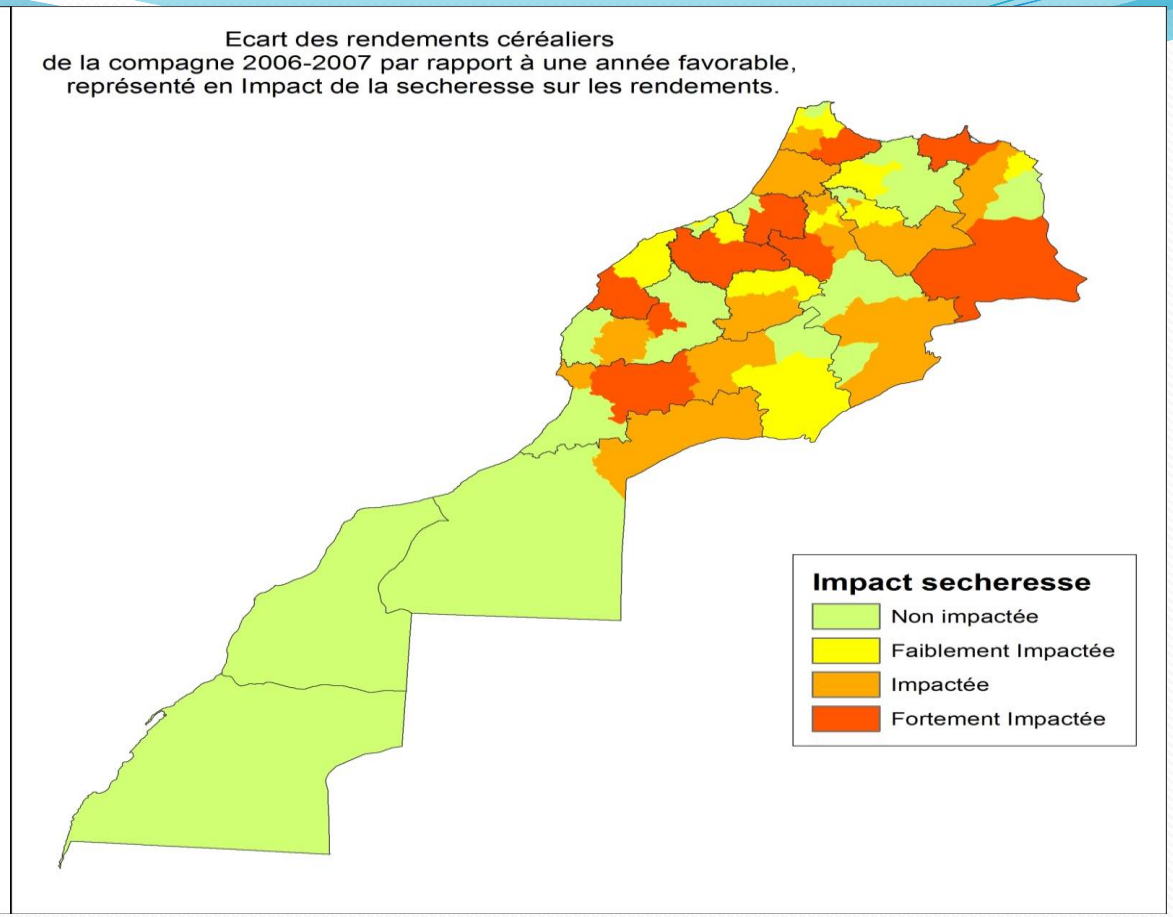


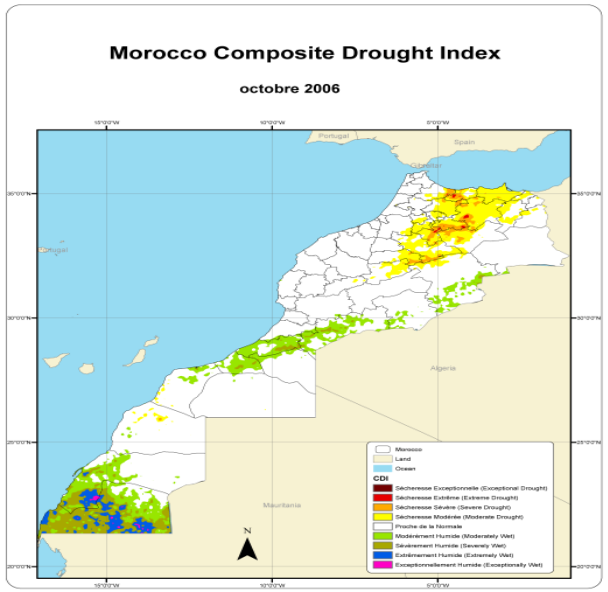

Humidité des sols
Elevée
Normale
Faible
Très Faible

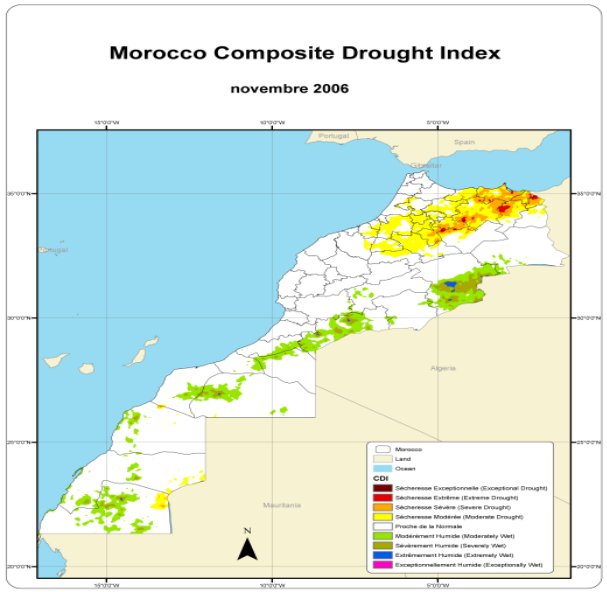

Ecart des rendements céréaliers
de la compagne 2006-2007 par rapport à une année favorable,
représenté en Impact de la secheresse sur les rendements.
Impact secheresse
Non impactée
Faiblement Impactée
Impactée
Fortement Impactée

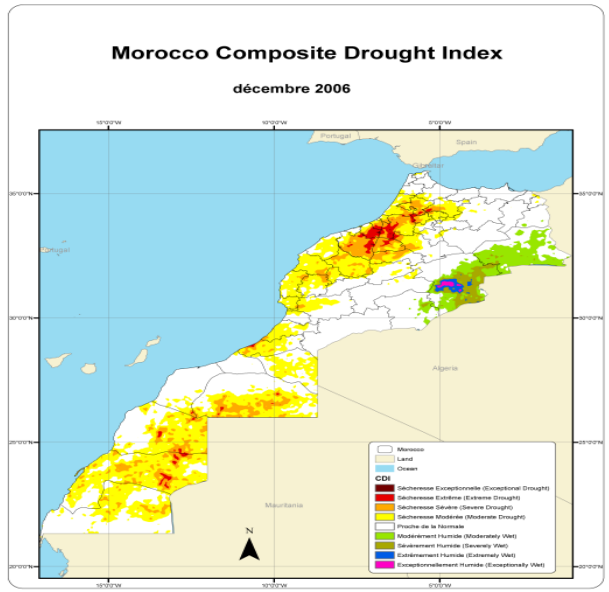


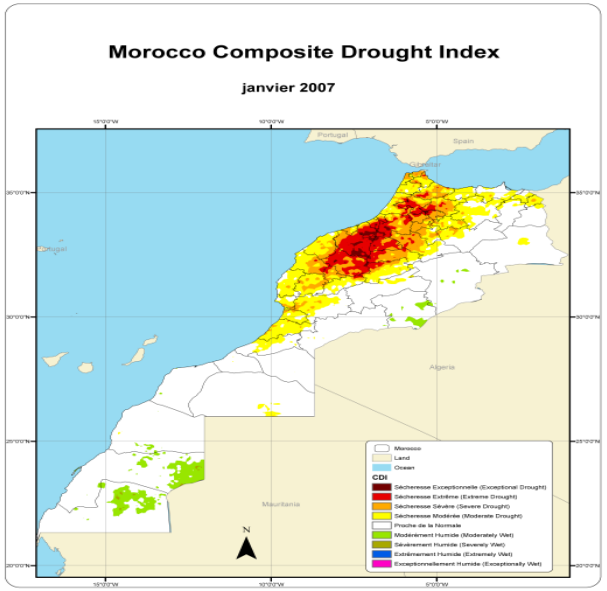
Ecart des rendements céréaliers
de la compagne 2006-2007 par rapport à une année favorable,
représenté en Impact de la secheresse sur les rendements.

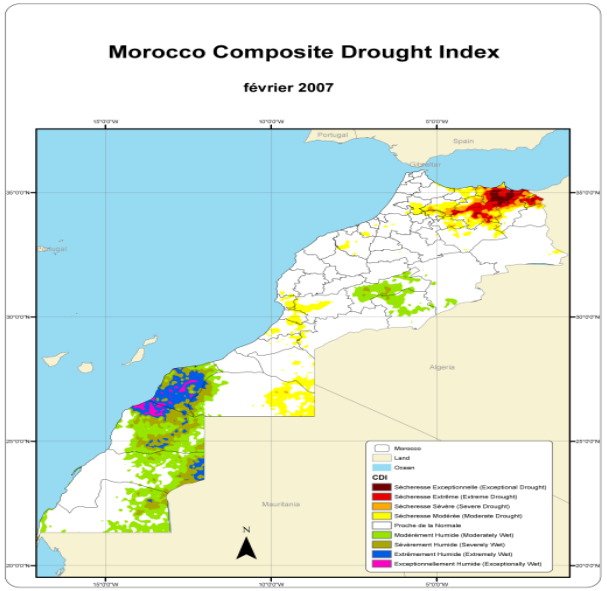


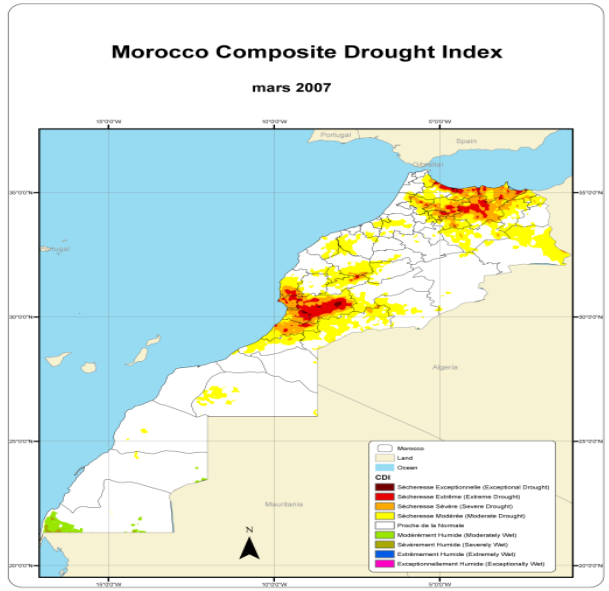

Morocco Composite Drought Index
octobre 2006
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N

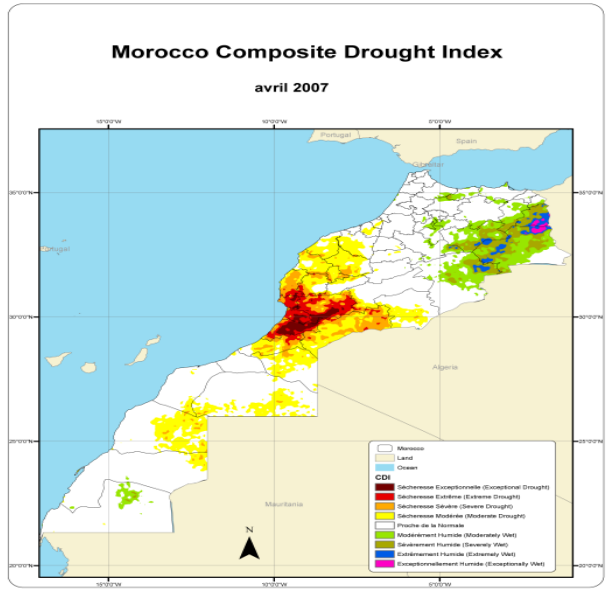

Morocco Composite Drought Index
novembre 2006
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N


Morocco Composite Drought Index
décembre 2006
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N


Morocco Composite Drought Index
janvier 2007
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N

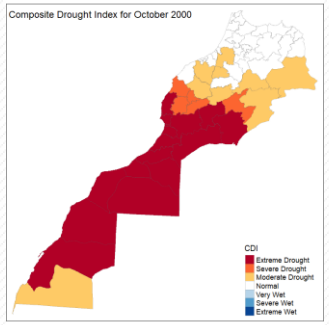

Morocco Composite Drought Index
février 2007
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N

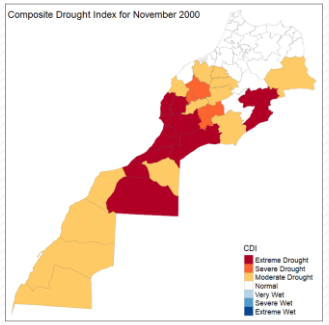

Morocco Composite Drought Index
mars 2007
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N

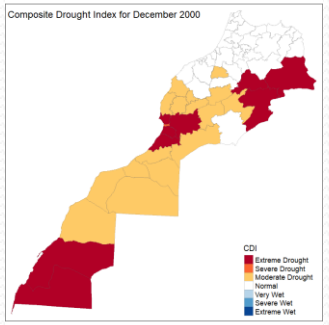

Morocco Composite Drought Index
avril 2007
Portugal
Spain
Gibraltar
Algeria
Mauritania
Maroc
Land
Ocean
CDI
Sécheresse Exceptionnelle (Exceptional Drought)
Sécheresse Extrême (Extreme Drought)
Sécheresse Sévère (Severe Drought)
Sécheresse Modérée (Moderate Drought)
Proche de la Normale
Modérément Humide (Moderately Wet)
Sévèrement Humide (Severely Wet)
Extrêmement Humide (Extremely Wet)
Exceptionnellement Humide (Exceptionally Wet)
N

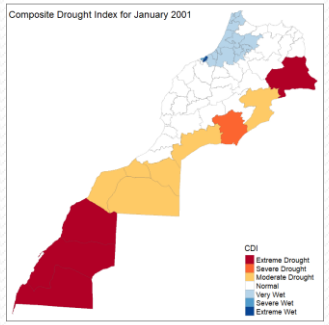
Validating CDI drought maps : Results

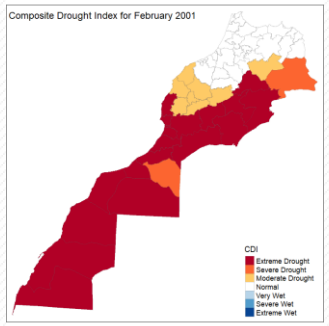
2000-2001

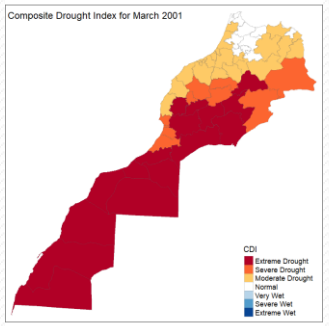


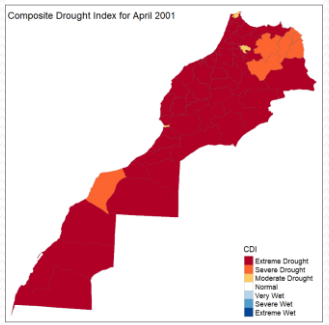


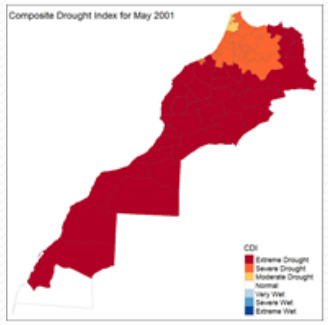


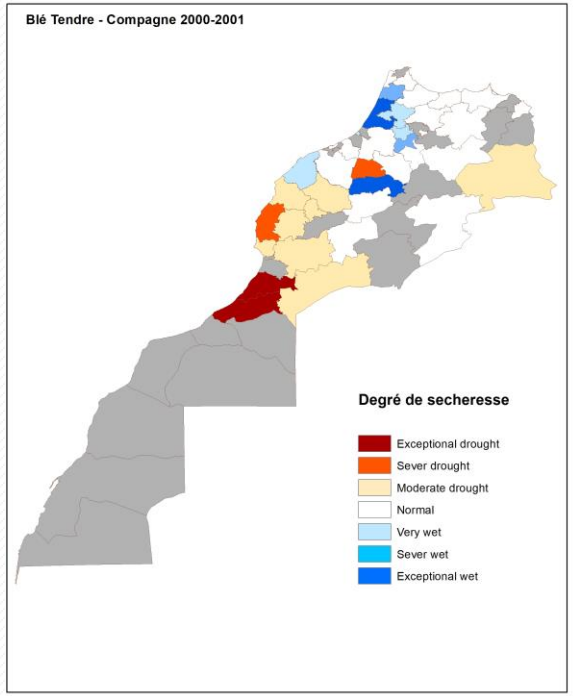


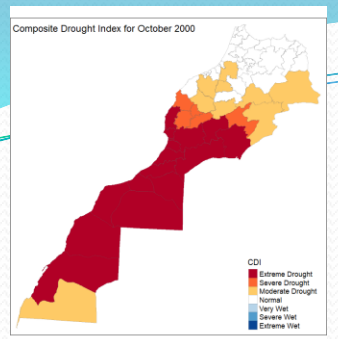


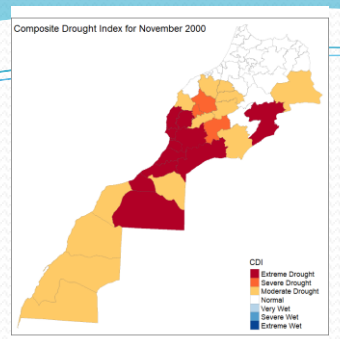


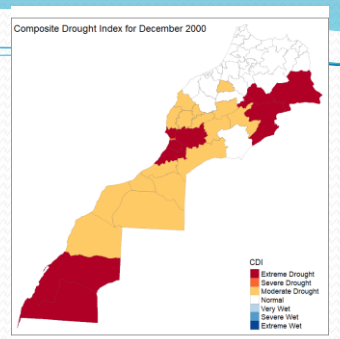


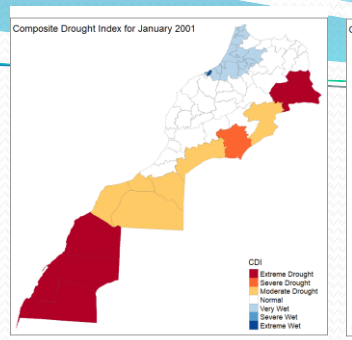


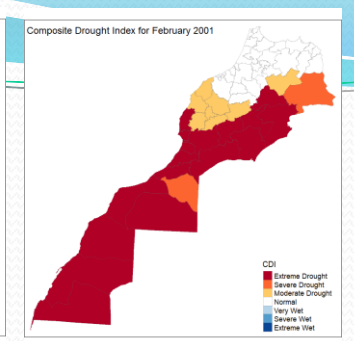


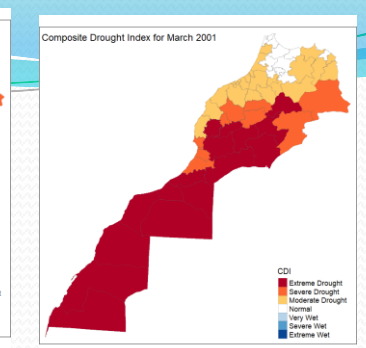

Composite Drought Index for October 2000
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet

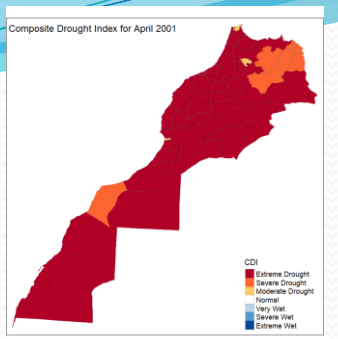

Composite Drought Index for November 2000
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet

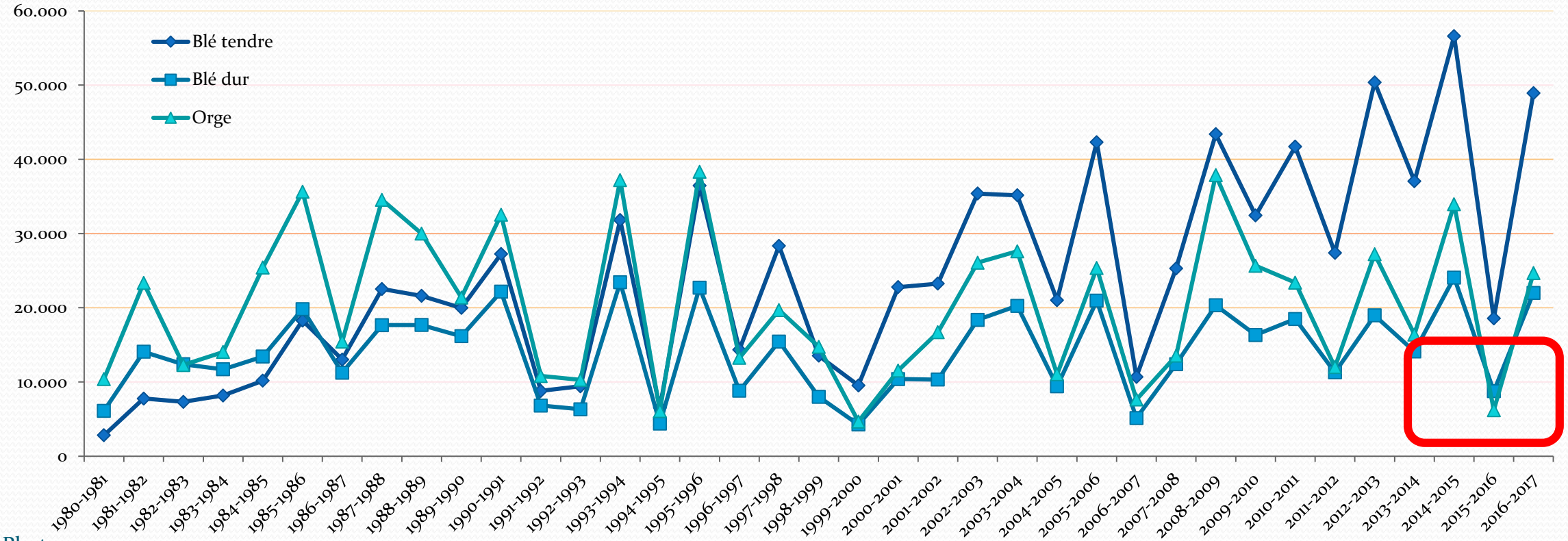

Composite Drought Index for December 2000
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet


Composite Drought Index for January 2001
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet


Composite Drought Index for February 2001
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet


Composite Drought Index for March 2001
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet


Composite Drought Index for April 2001
CDI
Extreme Drought
Severe Drought
Moderate Drought
Normal
Very Wet
Severe Wet
Extreme Wet


60.000
50.000
40.000
30.000
20.000
10.000
0
Blé tendre
Blé dur
Orge
1980-1981
1981-1982
1982-1983
1983-1984
1984-1985
1985-1986
1986-1987
1987-1988
1988-1989
1989-1990
1990-1991
1991-1992
1992-1993
1993-1994
1994-1995
1995-1996
1996-1997
1997-1998
1998-1999
1999-2000
2000-2001
2001-2002
2002-2003
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
2015-2016
2016-2017

Phot

- The CDI is relatively accurate to asses drought condition on a monthly bases;

- The Accuracy of the CDI varies according to agro-climatic zones;

Value and uses of CDI maps

This system of monitoring (mapping) on a monthly basis will allow early warning to be prepared for food shortage (wheat and barley for livestock)

as well as for natural disasters (on the other extreme of drought during very rainy seasons causing flooding).

This type of monitoring will allow also to take into consideration both spatial and temporal dimension of the occurrence of this phenomena (drought and flooding)

Indeed drought may take place in one area (ecosystem) but its impact occurs elsewhere.

This is the case for example for transhumance when drought occur in southern areas,

herds will move north toward wet areas in the search for forage and water, leading to overgrazing in these areas.

Moroccan Government is looking for support to implement the new pastoral law for the regulation of transhumance.

The CDI approach offer a promising way for such objective.

Pastoral CDI

Other uses of CDI maps

- When heavy rainfall occurs in a particular watershed,

- areas downstream are threatened by floods particularly in the plains and cities near rivers;

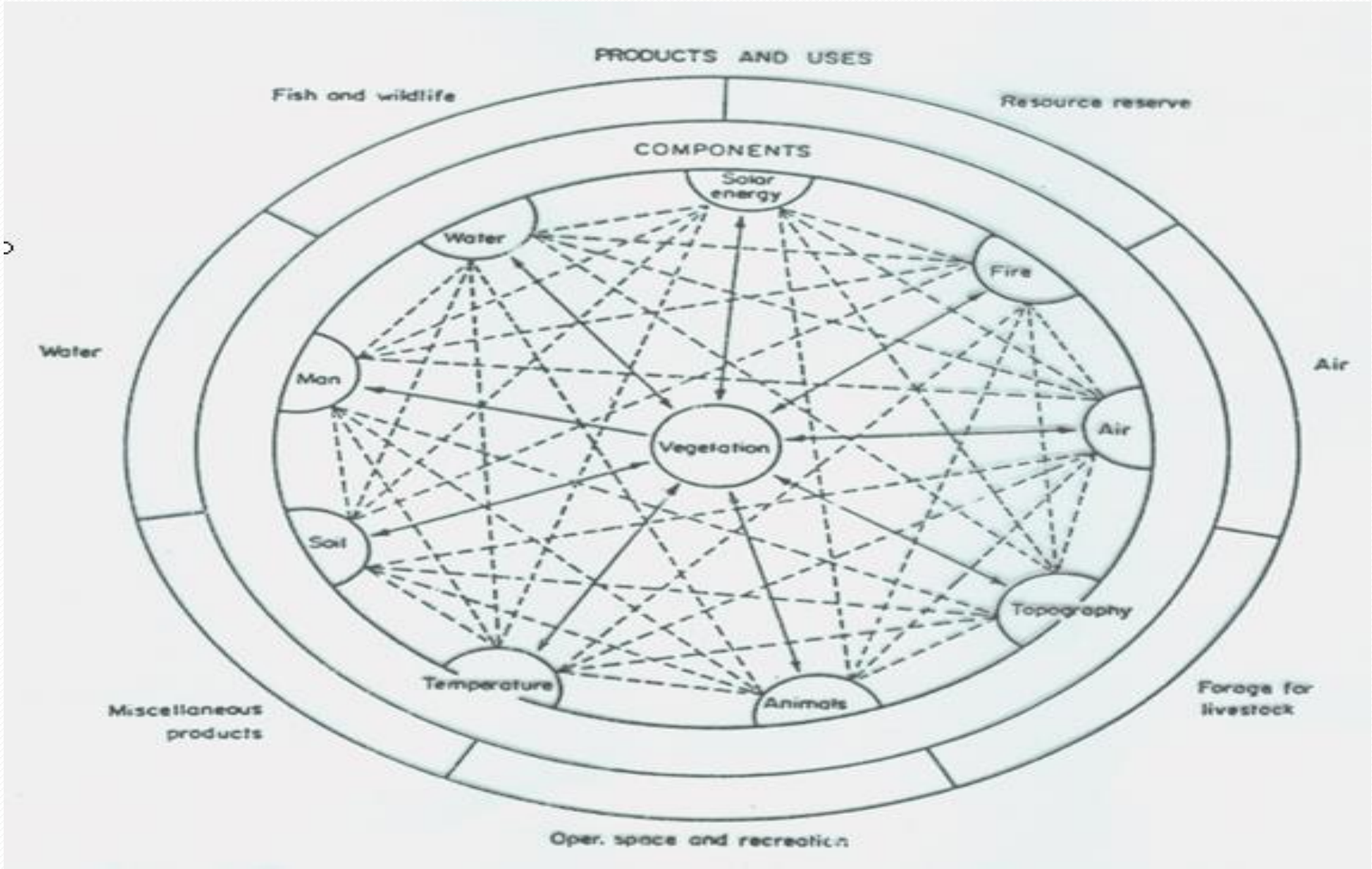
- In the opposite situation, drought occurring in mountains and watersheds will affect the filling of dams and natural lakes and the underground water.

Finally accumulation of the information issued from these maps over a long period of time (10 to 20 years at least) and their overlapping

will also help to detect particular zones where drought and/or floods are frequent and structural rather the conjectural (decisions about review land uses/suitability

agroforestery instead unsustainable agriculture for example).

All these considerations urge for the adoption of ecosystemic approach to deal with natural resources issues



the "ecosystem" approach identifies problems at the local level, as well as at different spatial and temporal scales.

develop a system of representation which makes it possible to apprehend complex situations in an appropriate manner.

IN TERM OF METHODS

DPSIR Model a good method to address environmental issues

Drivers

Pressure

State

Impact

Response

DPSIR is an approach for environment/ecosystem assessment.

It identifies five different classes of indicators, which can be mapped to the needs of environmental management/ evaluation.

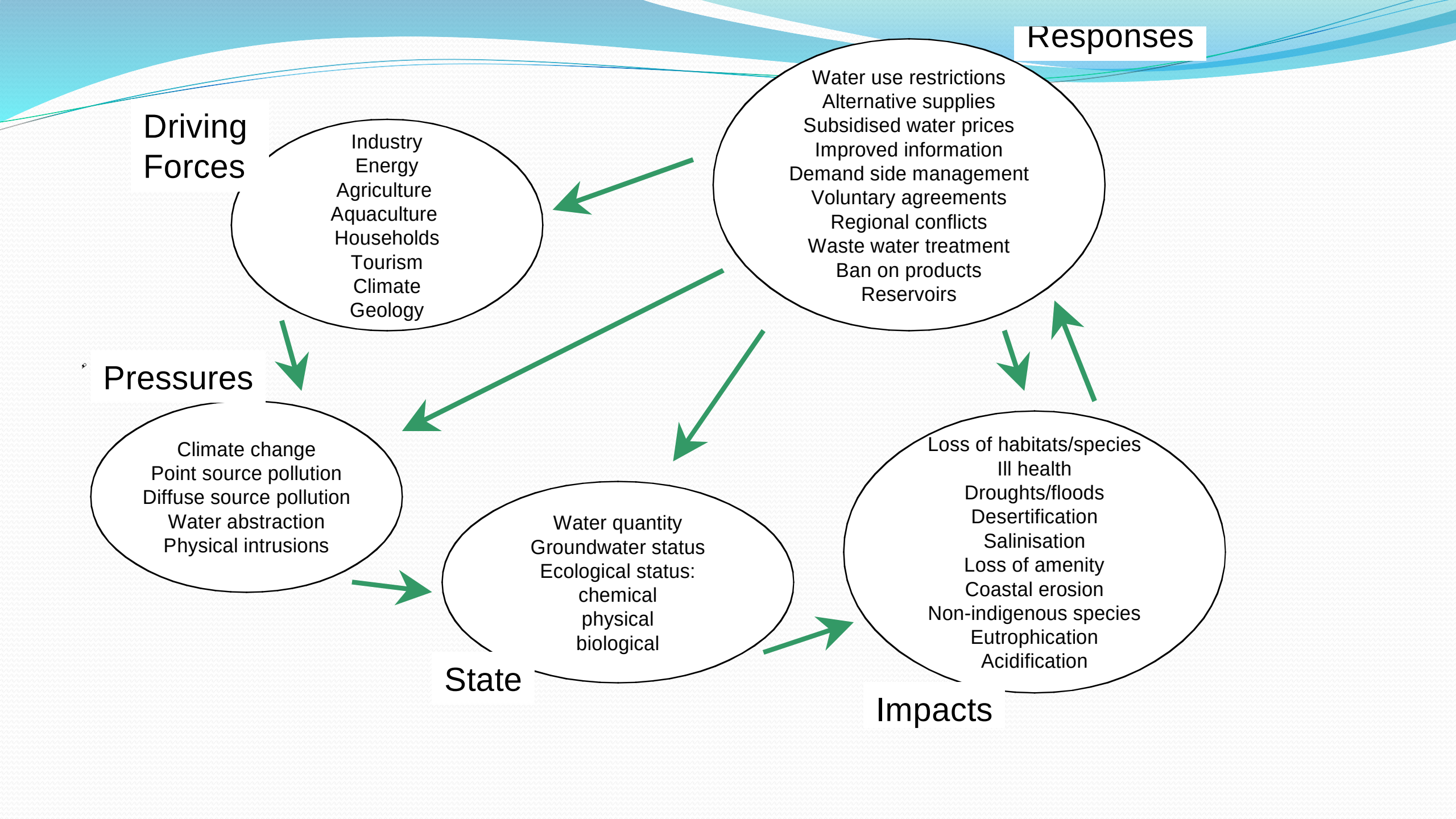
According to this model, social and economic developments act as Driving forces

that exert **Pressure** on the environment,

as a consequence, the **State** of the environment changes, such as the provision of adequate conditions for health, resources availability and biodiversity.

this leads to **Impacts** on human health, ecosystems and materials

that may elicit a societal **Response** that feeds back on the Driving forces, or on the state or impacts directly, through adaptation or curative action.


Responses
Water use restrictions
Alternative supplies
Subsidised water prices
Improved information
Demand side management
Voluntary agreements
Regional conflicts
Waste water treatment
Ban on products
Reservoirs
Driving Forces
Industry
Energy
Agriculture
Aquaculture
Households
Tourism
Climate
Geology
Pressures
Climate change
Point source pollution
Diffuse source pollution
Water abstraction
Physical intrusions
Water quantity
Groundwater status
Ecological status:
chemical
physical
biological
State
Loss of habitats/species
Ill health
Droughts/floods
Desertification
Salinisation
Loss of amenity
Coastal erosion
Non-indigenous species
Eutrophication
Acidification
Impacts

Thank you