REGIONAL COORDINATION ON IMPROVED WATER RESOURCES MANAGEMENT AND CAPACITY BUILDING PROGRAM

Moving From Drought Monitoring to Modeling and Mapping Drought Risk in Arab Region

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1. Drought Hazard, definition, indices and Key Massages

1.1. Definition of Drought

Drought is undoubtedly one of the human being's worst natural enemies (WMO,1975[1] , 1986[2]). Among the extreme meteorological events, drought is possibly themost slowly developing and long existing event (extensive hazard), and probably is the leastpredictable among the atmospheric hazards. Due to these characteristics,particularly their temporal character, drought cannot be compared with othernatural hazards such as flood, hurricane, tornado, lightening, hailstorm, frost, orplague of locust, which also significantly can contribute to a nation's annual loss due to disadvantageous natural circumstances, Dunkel (2009)[3] .

The definition of drought is itself complex; although themajority of people may consider extreme precipitation shortageas drought, how to objectively characterize it for planningand management is a challenging issue.

Drought used to begenerally defined as "the extreme persistence of precipitationdeficit", González and Valdés (2006) [4] , over a specific regionfor a specific period of time (Beran and Rodier 1985;Correia et al. 1994). In addition to the elements of 'persistence'of 'substantial precipitation deficit', 'bounded by timeand space', definitions have expanded to include impacts onenvironment and society (Tsakiris and Vangelis 2004).

In all these approaches the same parameters and methods of drought identificationcan be used (Budyko, 1952[5] ; Eitzinger et al., 2008[6] ; Ivanov, 1948[7] ; Koshelenko andVolevakha, 1971[8] ; Ped, 1975[9] ; Sun and Ward, 2007[10] ; Theophilou, 2006[11] ; Tsiros etal., 2006[12] ; Wilhite, 2005[13]),which can also be based on the same definition.

Drought has been defined verycommonly and frequently as a period of precipitation deficiency (Wilhite, 1983)[14] .It seems to be a nice definition, but nobody speaks about drought in case of Sahara, where the weather is generally dry. But when wemention drought, we somehow involve the agricultural product into ourconsideration, or, more simply, the vegetation production or plant life cycle, Dunkel (2009).

Drought was defined byWMO (1992)[15] as, "prolonged absence or marked deficiency of precipitation, period of abnormally dry weather sufficiently prolongedfor the lack of precipitation to cause a serious hydrologicalimbalance", but that should be differentiated from the term "Dry Seasons: period of year characterizes by almost complete absence ofrainfall", the term is mainly used for low latitude regions", and from the term "Dry Spell: period of abnormally dry weather", Use of them should beconfined to conditions less severe those of a drought.

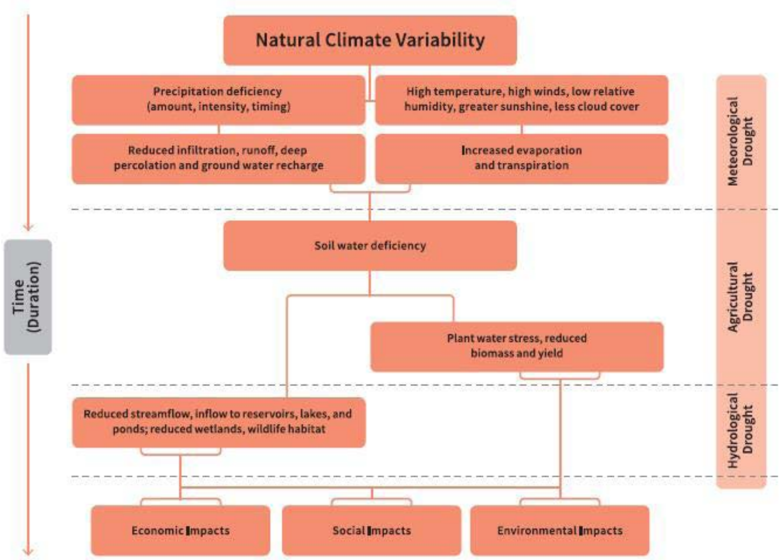
That could be understood by the explanation of the different types of drought explained by Dunkel (2008[16] and 2009) , "Atmospheric Drought:too high saturation deficit", "Meteorological Drought:a longer period of time with considerably less thanaverage precipitation amounts", "Agricultural Drought:available soil moisture is inadequate and yield is considerablyless than the average because of water shortage", "Hydrological Drought: refers to a period of below-normal stream- flow", "Physiological Drought:plant is unable to take up water in spite of the presentsufficient soil moisture", and finally "Socioeconomic Drought:from as supply and demand of some economic good with elements ofmet, hydrological, and agricultural drought".

Zargar et al (2011)[17] , defined drought as "a stochastic natural hazard that is instigated by intense andpersistent shortage of precipitation",followingan initial meteorological phenomenon, subsequent impacts are realized on agriculture and hydrology.

Among the naturalhazards, droughts possess certain unique features; in addition to delayed effects, droughts vary by multiple dynamic dimensionsincluding severity and duration, which in addition to causing a pervasive and subjective network of impacts makesthem difficult to characterize, (Wilhite 1993)[18] .

A broad definition of drought is a deficiency ofprecipitation over an extended period of time, usuallya season or more, which results in a water shortagefor some activity, group, or environmental sectors.However, in terms of typologies, droughts arecommonly classified as meteorological, agricultural,hydrological, and socio-economic.

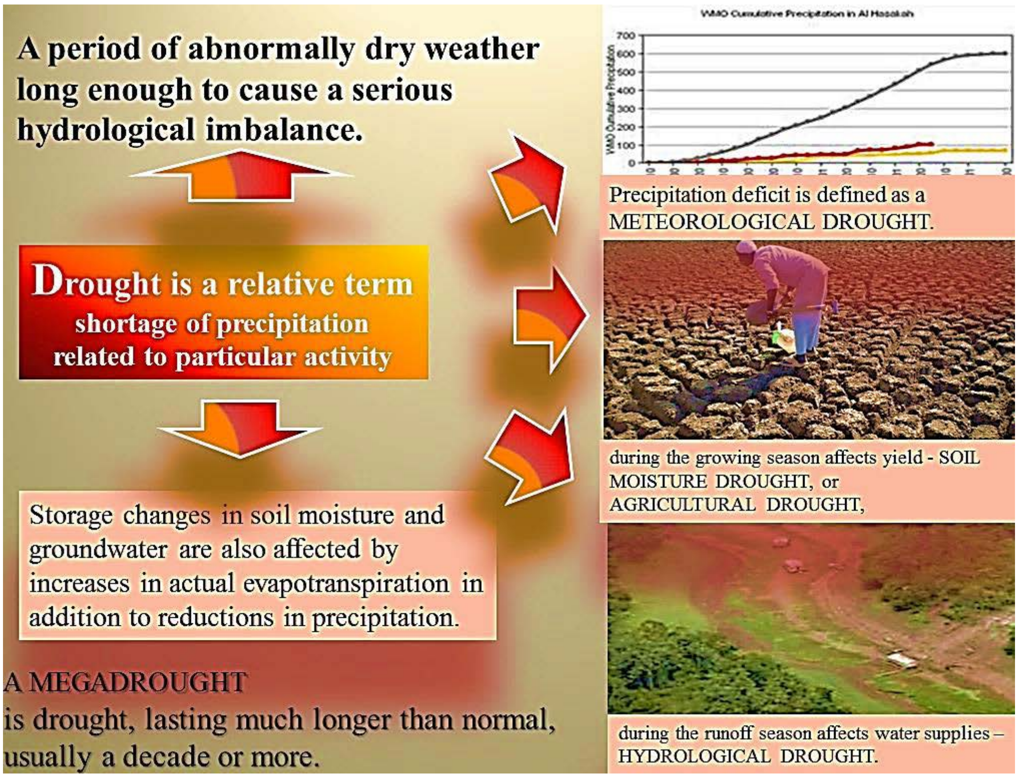
Meteorological drought is a natural event that resultsfrom climatic causes, which differ from region toregion. Agricultural, hydrological, and socioeconomicdrought, however, place greater emphasison the human or social aspects of drought. Theyhighlight the interaction between the naturalcharacteristics of meteorological drought and humanactivities that depend on precipitation to provideadequate water supplies to meet societal andenvironmental demands.Relationships between meteorological, agricultural, hydrological, and socio-economic drought, is shown in (figure 1).



Most recently, the Glossary, (IPCC 2012) [19], defines drought as follows:

> "A period of abnormally dry weather long enough to cause a serious hydrological imbalance.Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-relatedactivity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production orecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolationseason primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected byincreases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit isdefined as a meteorological drought. Amega-drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.",figure (2), after (Erian 2012)[20]

In addition to type, droughts are fundamentally characterized in three dimensions: severity, duration, and spatial distribution. Additional characteristics include: frequency, magnitude (cumulated deficit), predictability, rate of onset, and timing. Unfortunately, usage of the terms severity, intensity, and magnitude is not universal, and sometimes their meanings are switched. For example, Yevjevich (1967) [21] uses the vocabulary of run-sum, run-length, and runintensity for the associated terms of severity, duration, and magnitude used by (Dracup et al. 1980) [22] . Here, we use the widely adopted terminology of Salas (1993) [23] :



Duration:

Depending on the region, drought's duration can vary between a week up to a few years. Because of drought's dynamic nature, a region can experience wet and dry spells simultaneously when considering various timescales. As such, in shorter durations the region experiences dryness or wetness, while in longer-term, it experiences the opposite (NCDC 2010). Magnitude: The accumulated deficit of water (e.g., precipitation, soil moisture, or runoff) below some threshold during a drought period.

Intensity:

The ratio of drought magnitude to its duration.

Severity:

Two usages are provided for drought severity: the degree of the precipitation deficit (i.e., magnitude), or the degree of impacts resultant from the deficit (Wilhite 2004).

Geographic extent:

The areal coverage of the drought which is variable during the event. This area can cover one or several pixels (cells), watersheds or regions.

Frequency (return period):

The frequency or return period of a drought is defined as the average time between drought events that have a severity that is equal to or greater than a threshold.

Weather and climate phenomena reflect the interaction of dynamic and thermodynamic processes over a very wide range of space and temporal scales. This complexity results in highly variable atmospheric conditions, including temperatures, motions, and precipitation, a component of which is referred to as 'extreme events.' Extreme events include the passage of an intense tornado lasting minutes and the persistence of drought conditions over decades, (IPCC 2001) [24] . The absence of precipitation as well as excess evapo-transpiration from the soil can be climate extremes, and lead to drought, (McKee et al., 1993) [25] .

Soil moisture drought often called agricultural drought, which refers to a deficit of (mostly root zone) soil moisture. IPCC uses the term 'soil moisture drought' instead of 'agricultural drought,' despite the widespread use of the latter term (e.g., Heim Jr., 2002 [26] ; Wang, 2005 [27]), because soil moisture deficits have several additional effects beside those on agro-ecosystems, most importantly on other natural or managed ecosystems (including both forests and pastures).

Drought should not be confused with aridity, which describes the general characteristic of an arid climate (e.g., desert). Indeed, drought is considered a recurring feature of climate occurring in any region and is defined with respect to the average climate of the given region (e.g., Heim Jr., 2002; Dai, 2011 [28]) . Nonetheless, the effects of droughts are not affecting different regions equally (e.g.,a short-term lack of precipitation in a very humid region may not be critical for agriculture because of the ample soil moisture supply).

In fact for soil moisture or hydrological droughts, the main drivers as in the definition are reduced precipitation and/or increased evapo- transpiration as shown in figure (3), concerning vegetation cover point (nature or cultivated) , the changes in simulated soil moisture drought are mostly driven by changes in precipitation, with increased evapo-transpiration from higher vapor pressure deficit which often linked to increased temperature and available radiation modulating some of the changes (e.g., Burke and Brown, 2008 [29] ; Sheffield and Wood, 2008 [30] ; Orlowsky and Seneviratne, 2011 [31]).

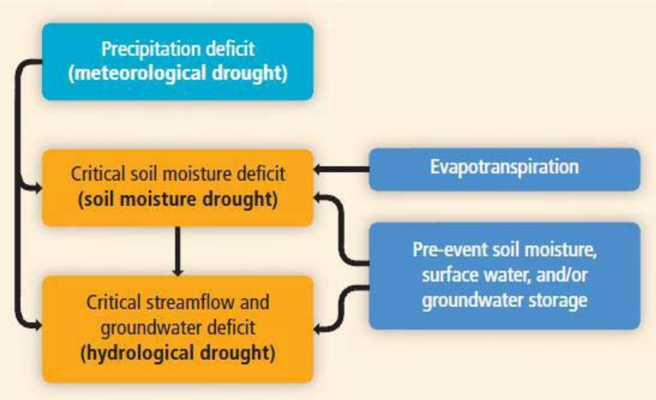


Figure 3. Simplified sketch, of processes and drivers relevant for meteorological,

1.2. Drought Indices

Drought characterization is essential for drought managementoperations. Using drought indices is a pragmatic wayto assimilate large amounts of data into quantitative informationthat can be used in applications such as drought forecasting, declaring drought levels, contingency planning andimpact assessment.

Along with precipitation deficit, additional variables suchas evapotranspiration and stream flow are also used to morecomprehensively characterize drought. Using different models(e.g., water balance/hydrological models), such variablesor indicators are used in combination to derive a drought index.Such indicators can be meteorological, agriculture, hydrological, orwater supply-and-demand in nature. Inpractice, however, some indicators such as precipitation, potentialevapotranspiration, and soil- and vegetation-covercharacteristics have had wider applications and influence(Tsakiris and Vangelis 2005) [32] .

Drought indices are calculated from assimilatingdrought indicators. A droughtindex provides a comprehensive picture for drought analysisand decision-making that is more readily useable comparedwith raw data from indicators (Hayes 2006) [33] . More than 150drought indices have been developed (Niemeyer 2008) [34] andadditional indices have recently been proposed (Cai et al.2011 [35] ; Karamouz et al. 2009 [36] ; Rhee et al. 2010 [37] ; Vasiliades etal. 2011 [38] ; Vicente-Serrano et al. 2010 [39]).

Operationally, using an index for drought characterizationserves the following purposes:

- drought detection and real-time monitoring (Niemeyer 2008)
- declaring the beginning or end of a drought period (Tsakiris et al. 2007) [40]
- allowing drought managers to declare drought levels and instigate drought responses measures;
- drought evaluation (Niemeyer 2008)

Commonly, drought indices are categorized based on thetype of impacts they relate to. The taxonomy of drought indices can also bebased on the variables they relate to (Steinemann et al. 2005) [41] or use of disciplinary data (Niemeyer 2008). Niemeyer (2008) adds three categories tothe three popularcategories meteorological, agricultural and hydrologicaldrought indices this are comprehensive, combined and remote-sensing-baseddrought indices. Comprehensive drought indices use a varietyof meteorological, agricultural and hydrological variables todraw a comprehensive picture of drought. The PalmerDrought Severity Index (PDSI) and Slandered Precipitation Evapotranspiration Index (SPEI),are two examples of this approach.Remote-sensing-based drought indices use informationfrom remote-sensing sensors to map the condition of theland, e.g., the Normalized Difference Vegetation Index,NDVI, Tucker (1979) [42] . Combined (also termed hybrid andaggregate) drought indices are derived by incorporating existingdrought indicators and indices into a single measure. TheUS Drought Monitor (Svoboda et al. 2002) [43] is an example.

Because of the complex definition of droughts, and the lack of soil moisture observations, several indices have been developed to characterize (meteorological, soil moisture, and hydrological) drought (see, e.g., Heim Jr., 2002 [44] ; Dai, 2011 [45]). Some indices are based solely on precipitation data, these include:

The Standard Precipitation Index (SPI) is a widely used index (McKee et al., 1993[46] Lloyd-Hughes and Saunders, 2002[47]), is a popular meteorological drought index that is also solely based on precipitation data. Similar to the percentof normal, SPI compares precipitation with its multiyear average.SPI overcomes the discrepancies resulting from using a non-standardized distribution by transforming the distributionof the precipitation record to a normal distribution. For this, the precipitation record is first fitted to a gamma distribution that is then transformed into a normal distribution using an equal-probability transformation.

The mean is then set to zero and as such, values above zero indicate wet periods and values below zero indicate dry periods. For any given drought, its score in SPI represents how many standard deviations its cumulative precipitation deficit deviates from the normalized average (Drought Watch 2010)[48].SPI values of -0.5 to -1 correspond to mild droughts, -1 to -1.5 to moderate droughts, -1.5 to -2 to severe droughts, and below -2 to extreme droughts. Similarly, values from 0 to 2 correspond to mildly wet to severely wet conditions, and values above 2 to extremely wet conditions (Lloyd-Hughes and Saunders, 2002).

SPI can be computed over several time scales (e.g., 3, 6, 12, or more months) and thus indirectly considers effects of accumulating precipitation deficits, which are critical for soil moisture and hydrological droughts.

The disadvantages of SPI is uses only precipitation, loosely connected to ground conditions. Potential evapotranspiration is a valuable additional indicator (Hu and Willson 2000; Tsakiris and Vangelis 2005; Vicente-Serrano et al. 2010). Limitations of the precipitation data including accuracy of measurements, the number of gauging stations and length of the record Lacks the ability to identify regions with greater tendency to droughts;Requires knowledge of the local climatology.

The Consecutive Dry Days (CDD) index is Another index commonly used in the analysis of climate model simulations, which considers the maximum consecutive number of days without rain (i.e., below a given threshold, typically 1 mm day-1) within a considered period (i.e., year in general; Frich et al., 2002 [49] ; Alexander et al., 2006 [50] ; Tebaldi et al., 2006 [51]). For seasonal time frames, the CDD periods can either be considered to be bound to the respective seasons or considered in their entirety (across seasons) but assigned to a specific season.

Other indices reflect both precipitation and estimates of actual or potential evapotranspiration, in some cases also accounting for some temporal accumulation of the persistence of the drought anomalies, these include:

The Palmer Drought Severity Index (PDSI) (Palmer, 1965 [52]), which measures the departure of moisture balance from normal conditions using a simple water balance model (e.g., Dai, 2011 [53]). There are still large uncertainties regarding observed global-scale trends in droughts. The AR4 reported based on analyses using PDSI that very dry areas had more than doubled in extent since 1970 at the global scale (Trenberth et al., 2007) [54] . This assessment was, however, largely based on the study by Dai et al. (2004) [55] only. These trends in the PDSI proxy were found to be largely affected by changes in temperature, not precipitation (Dai et al., 2004).

The advantage of PDSI are, the index is more comprehensive than precipitation only indices as evapotranspiration and soil moisture are also considered, can use basic data for calculation: precipitation and air temperature for which records for a long time back exist, and Most effective where impacts sensitiveto soil moisture

The disadvantage of PDSI, that it uses arbitrary selection of beginning and end intensity values and algorithmsLess transparency because of more sophisticated computation,calibrated for US Great Plains' conditions; limited applicability in locationswith climatic extremes, mountainous terrain, or snow-packunless calibrated, Variable performance across regions and time periods, Applicability to regions with extreme climate (e.g., highly variablerainfall or runoff, mountainous areas), Handling of snow and soil freeze, Neglecting the lag between rainfall and runoff Lag. PDSI uses the Thornthwaite method to estimate potential evapotranspiration.Although this index has had wide acceptance, it is stillconsidered an approximation (NDMC 2006) [56].

All Palmer Indices are hardly appropriate for droughts within withwater management systemsas they exclude water storage, snowfall,and other supplies. They also do not take human water balance impactssuch as irrigation into account (Steinemannet al. 2005) [57] .

On the other hand, based on soil moisture simulations with an observation-driven land surface model for the time period 1950-2000, Sheffield and Wood (2008) [58] have inferred trends in drought duration, intensity, and severity predominantly decreasing, but with strong regional variation and including increases in some regions. They concluded that there was an overall moistening trend over the considered time period, but also a switch since the 1970s to a drying trend, globally and in many regions, especially in high Northern latitudes. Some regional studies are consistent with the results from Sheffield and Wood (2008), regarding, for example, less widespread increase (or statistically insignificant changes or decreases) in some regions compared to the study of Dai et al. (2004).

More recently, Dai (2011) by extending the record did, however, find widespread increases in drought both based on various versions of PDSI (for 1950-2008) and soil moisture output from a land surface model (for 1948-2004). Hence there are still large uncertainties with respect to global assessments of past changes in droughts. Nonetheless, there is some agreement between studies over the different time frames (i.e., since 1950 versus 1970) and using different drought indicators regarding increasing drought occurrence in some regions, although other regions also indicate opposite trends.

The Precipitation Potential Evaporation Anomaly (PPEA), based on the cumulative difference between precipitation and potential evapotranspiration used in Burke and Brown (2008) [59].

The Standardized Precipitation Evapotranspiration Index (SPEI), which considers cumulated anomalies of precipitation and potential evapotranspiration and described in (Vicente-Serrano et al. 2010) [60] . The SPEI allows comparison of drought severity through time and space, since it can be calculated over a wide range of climates, Keyantash and Dracup (2002) [61] indicated that drought indices must be statistically robust and easily calculated, and have a clear and comprehensible calculation procedure. All these requirements are met by the SPEI. However, a crucial advantage of the SPEI over other widely used drought indices that consider the effect of PET on drought severity is that its multi-scalar characteristics enable identification of different drought types and impacts in the context of global warming. The SPEI index is a standardized monthly climatic balance computed as the difference between the cumulative precipitation and the potential evapotranspiration. This method is recommended when the required parameters to apply the Penman-Monteith equation are not available (Droogers& Allen 2002) [62].

In addition, some experimental studies have showed similar PET estimations by means of the Penman-Monteith and Hargreaves methods in Spain (Martínez-Cob 2002 [63] , López-Urrea et al. 2006 [64] , Gavilán et al. 2008 [65] , Van der linden et al. 2008[66] , López-Moreno et al. 2009 [67]). The SPEI can be calculated at the monthly scale with time Interval = 1, or accumulated at more than one month with time Interval > 1. Typical values are 1, 3, 6, 12 and 24 months. If the accumulated index is calculated, the starting date of the resulting SPEI series will be lagged a number of months equal to time Interval – 1.

NDVI (multiple) Visible red band and near infrared bands: While resolution is high (1 km) (compared to weather stations) AVHRR covers a large land area (Ji and Peters 2003) [68] .The disadvantage of NDVI is corresponding with

- Resolution: The resolution of NDVI datasets extracted from MODIS sensor is 250 m and lacks accuracy for some applications. These include monitoring change in riparian buffer zones and urban areas (Nagler et al. 2005) [69] ,
- Soil conditions effects: NDVI is sensitive to darker and wet soil background (Huete

et al. 1985)[70] . In wet conditions, the reflectance may not be equal in two bands and as such, the NDVI may vary with soil moisture variations.

- Nonlinearity: Similar to other ratio-based standardized vegetation indices (SVI), NDVI suffers from scaling and nonlinearity Saturation: In dense vegetation and (or) multilayered canopy, where large biomass is present NDVI tends to saturate.
- Vegetation stress and moisture correlation: Vegetation stress is influenced by more factors than moisture conditions alone. These include regional rainfall patterns and soil type as well events such as floods, insect infestation, wildfire, etc. (Ji and Peters 2003).

At the meantime the different drought indices could be classified as meteorological, agricultural, and hydrological drought indices, after, (Zargar et al 2011) [71] :

♦ **Meteorological drought indices:**

The development and implementation of a drought index depends on data availability (Steinemann et al. 2005). Earlier drought indices used meteorological data readily available from synoptic meteorological stations (Niemeyer 2008) [72] . These include precipitation-only indices such as RAI (Van-Rooy 1965) [73] , BMDI (Bhalme and Mooley 1980) [74] , DSI (Bryant et al. 1992) [75] , NRI (Gommes and Petrassi 1994) [76], EDI (Byun and Wilhite 1999) [77] , and DFI (González and Valdés 2006) [78] .

For reasons such as better correlation with drought impacts and accounting for temporal trends in temperature, additional meteorological variables have been considered. These include modifications to SPI (McKee et al. 1993) [79] , to develop the more comprehensive RDI (Tsakiris and Vangelis 2005) [80] that incorporates evapotranspiration resulting in better association with impacts from agricultural and hydrological droughts. Vicente-Serrano et al.(2010) developed SPEI, which is sensitive to long-term trends in temperature and water balance change. SPEI performs similarly to SPI as Meteorological drought indices.

In addition to temperature and evapotranspiration, PDSI (Palmer 1965) [81] similar to SPEI areconsider stream flow and soil moisture to give a more complete picture of the water balance. Improvements in such indices include self-calibration capacity (Wells et al. 2004) [82] and modifications to the evapotranspiration estimation methods replacing the original Thornthwaite method (Thornthwaite 1948) [83] with other formulations.

♦ **Agricultural drought indices:**

Approaches to characterize agricultural drought mainly evolve around monitoring soil water balance and the subsequent deficit in the event of a drought.

RSM (Thornthwaite and Mather 1955) [84], CMI (Palmer 1968), which is similar to PDSI however models short-term agricultural by considering moisture deficit only in the top of soil column (Byun and Wilhite 1999 [85]; Narasimhan and Srinivasan 2005 [86]), and CSDI (Meyer et al. 1993) [87] originally designed for corn and its variant for soybean (Meyer and Hubbard 1995) [88] .

DTx (Matera et al. 2007) [89] calculates the daily transpiration deficit (DT) for x days. DTx uses the soil moisture balance model (Zinoni and Marletto 2003) [90] with inputs including soil, crop, and weather conditions in addition to temperature anomalies, which affect evapotranspiration. Increased spatial and temporal resolutions were sought in developing SMDI and ETDI (Narasimhan and Srinivasan 2005) [91] .

Remote-sensing-based vegetation indices such as NDVI(Tucker 1979) [92] , EVI (Liu and Huete 1995) [93] , VegDRI (Brownet al. 2008) [94] , TCI (Kogan 1995) [95] , and NDWI (Gao 1996) [96] arealso used to monitor general vegetation state and health (Sivakumaret al. 2011) [97] .

- **Hydrological drought indices:**

This group of indices aimsat providing a comprehensive characterization of delayed hydrologicimpacts of drought. Earlier, the sophisticated PHDI(Palmer 1965) model considered precipitation, evapotranspiration,runoff, recharge, and soil moisture. The PDSI family ofindices show ever lacked the snow component accumulation,which led to the development of SWSI (Shafer and Dezman 1982) [98] , probably the most popular of this group. Later, RDI (Weghorst 1996) [99] improved SWSI by incorporating temperature and hence calculated a variable water demand as input.

RSDI (Stahl 2001) [100] bases its model on homogeneous drought-stricken regions that comprise several neighboring low-flow gauging stations. RSDI first calculates the deficiency in stream flow compared with historic values and then uses cluster analysis to delineate the drought-stricken regions. Two later indices consider a water balance model: GRI (Mendicino et al. 2008) [101] and Water Balance Derived Drought Index (Vasiliades et al. 2011) [102] . The formerfocuses on groundwater resources and uses geo-lithological conditions information in a distributed water balance model, while the latter uses a model that artificially simulates runoff for ungagged and low-data watersheds.

- **Expanding the remote-sensing capacity:**

New sensors and algorithms have constantly enabled the incorporation of improved remotely sensed information in drought characterization. New sensors have higher spatial resolution, a current shortcoming in drought indices products (Niemeyer 2008)[103] .

Novel noise reduction algorithms and other atmosphere correction algorithms improve the thematic accuracy of remote-sensing datasets. Remote-sensing indices are diverse and new indices are frequently proposed. While NDVI has remained popular, other indices such as VegDRI, VCI (Kogan 1990) [104] , TCI, and VHI (Kogan 1995)[105] are currently operationally used (NDMC 2011 [106] ; NOAA 2011 [107]).

Traditionally used bands include near infrared (NIR), red and short-wavelength infrared (SWIR). The Land Surface Temperature (LST) has been used as additional source along with NDVI to improve drought characterization accuracy (Cai et al. 2011[108] Lambin and Ehrlich 1995 [109] ; Prihodko and Goward 1997 [110] ; Rhee et al. 2010[111] ; Wan et al.2004 [112] ; Wang et al. 2001 [113]) .

1.3. Drought in Arab region and Mediterranean

The main key massages concerning drought in Near East and North Africa could be presented as follows:

- In presently dry regions, drought frequency will likely increase by the end of the 21st century under RCP8.5, (medium confidence), IPCC (2014) [114] .
- Compounded stress on water resources facing significant strain from overexploitation and degradation at present and increased demand in the future, with drought stress exacerbated in drought-prone regions of Africa (high confidence) , IPCC (2014).
- A number of studies project large increases in water stress, groundwater supplies, and drought in a number of regions with greater than 4°C warming, and decreases in others, generally placing already arid regions at greater water stress, IPCC (2014).
- There is no evidence that surface water and groundwater drought frequency has changed over the last few decades, although impacts of drought have increased mostly due to increased water demand, IPCC (2014).
- River discharge also influences the response of river temperatures to increases of air temperature, Globally averaged, air temperature increases of 2°C, 4°C, and 6°C are estimated to lead to increases of annual mean river temperatures of 1.3°C, 2.6°C, and 3.8°C, respectively (van Vliet et al., 2011) [115] . Discharge decreases of 20% and 40% are computed to result in additional increases of river water temperature of 0.3° C and 0.8°C on average (van Vliet et al., 2011). rivers will experience drought more frequently in the future, freshwater-dependent biota will suffer not only directly by changed flow conditions but also by drought-induced river temperature increases.
- Regional to global-scale projected decreases in soil moisture and increased risk of agricultural drought are likely in presently dry regions, and are projected with medium confidence by the end of this century under the RCP8.5 scenario. But Low confidence in a global-scale observed trend in drought or dryness (lack of rainfall), IPCC (2014).
- Increased tree mortality and associated forest dieback is projected to occur in many regions over the 21st century, due to increased temperatures and drought (medium confidence), IPCC (2014). Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihood and food security (high confidence)
- In Africa and Near East extreme weather and climate events including droughts have significant impacts on Increased risk of drought-related water and food shortage causing malnutrition (high confidence), IPCC (2014), economic sectors, natural resources, ecosystems, livelihoods, and human health.Median yield changes (%) for major crop types in a 4°C world relative to the 1980–2010 baselines, figure (4), (Rosenzweig et al. 2013) [116] .

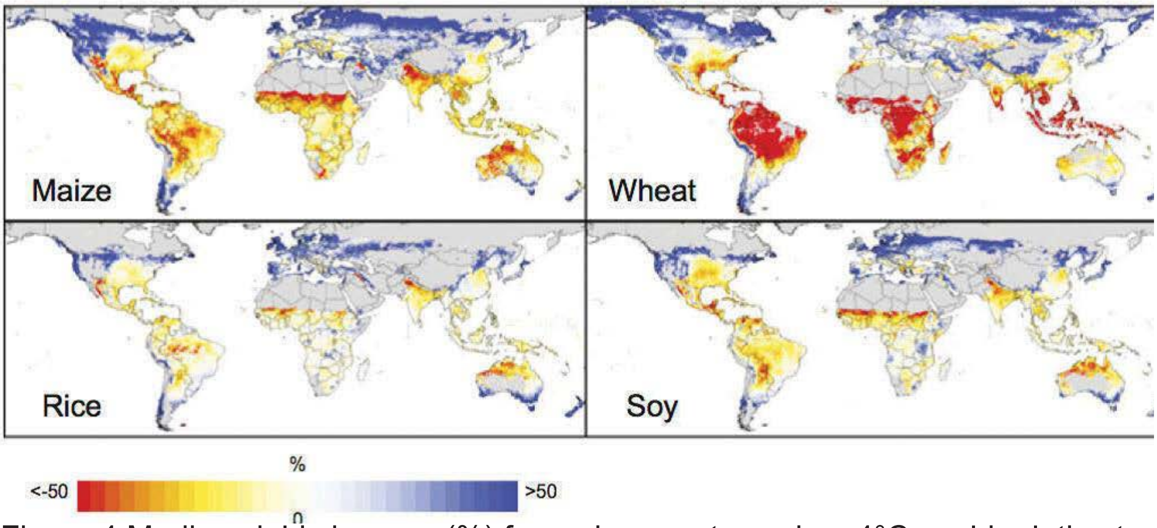


Figure 4.Median yield changes (%) for major crop types in a 4°C world relative to the 1980–2010

- Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings, IPCC (2014).

- In the Mediterranean region, higher fire risk, longer fire season, and more frequent large, severe fires are expected as a result of increasing heat waves in combination with drought (Duguy et al., 2013) [117] .

- The health of human populations is sensitive to shifts in weather patterns and other aspects of climate change (very high confidence). These effects occur directly, due to changes in temperature and precipitation and in the occurrence of heat waves, and droughts. Health may be damaged indirectly by climate change-related ecological disruptions, such as crop failures or shifting patterns of disease vectors, or by social responses to climate change, such as displacement of populations following prolonged drought, IPCC (2014).

- The elderly face disproportional physical harm and death from heat stress and droughts.

- The types of hydrologic changes reported included effects on snow, ice, and frozen ground; the number and size of glacial lakes; increased runoff and earlier spring peak discharge in thermal structure and water quality of rivers and lakes; and more intense drought in some regions, IPCC (2014).

- Historical droughts (last 1000 years) have been more severe than those observed since 1900. Global-scale trends in drought or dryness since 1950 have low confidence due to lack of direct observations, methodological uncertainties, and geographical inconsistencies; hence confidence levels in global drought trends since the 1970s as reported in AR4 are overstated. Regional trends are found: the frequency and intensity of drought has increased in the Mediterranean and West Africa. Decreases in soil moisture with increased risk of agricultural drought are projected in presently dry regions. Regions where droughts are projected to become longer and more frequent include the Mediterranean IPCC (2014).

Coherent shifts in drought regimes are expected with changing global circulation patterns provides regional and continental-scale assessments of observed trends in dryness based on different indices. More details concerned with continent could be reviewed in brief after IPCC (2012), as follows:

- Much more severe and longer droughts occurred in the past centuries with widespread ecological, political, and socioeconomic consequences. Overall, these studies confirm that in the last millennium several extreme droughts have occurred (Breda and Badeau, 2008 [118] ; Kallis, 2008 [119] ; Büntgen et al., 2010 [120]).

- In Mediterranean region, there is medium confidenceregarding increases in dryness based on some indices in the Southern part of the continent, Dai et al. (2004)[121] found an increase in dryness for most of the European continent based on PDSI, Lloyd-Hughes and Saunders (2002) [122] and van der Schrier et al. (2006)[123] concluded, that statistically significant changes were observed in extreme and moderate drought conditions in Mediterranean region. Sheffield and Wood (2008a) also found contrasting dryness trends in Europe, with increases in the Southern and eastern part of the continent. Beniston (2009) [124] reported a strong increase in warm-dry conditions over all central-Southern Europe.

- Trends of decreasing precipitation and discharge are consistent with increasing salinity in the Mediterranean Sea, indicating a trend toward freshwater deficits (Mariotti et al., 2008) , but this could also be partly caused by increased human water use. In France, an analysis based on a variation of the PDSI model also reported a significant increasing trend in drought conditions, in particular from the 1990s onward (Corti et al., 2009) [126] .

- The exceptional 2003 summer heat wave on the European continent was also associated with a major soil moisture drought, as could be inferred from satellite measurements (Andersen etal., 2005) [127], model simulations (Fischer et al., 2007a[128],b [129]), and impacts on ecosystems (Ciais et al., 2005 [130] ; Reichstein etal., 2007) [131].

The variety of drought indicesreflects a fundamental lack of universal definition andconcepts, and different operational requirement. In additionto the variability in the types and applications of droughts

Recent and potential future increases in global temperatures are likely to be associated with impacts on the hydrologic cycle, including changes to precipitation and increases in extreme events such as droughts, (Sheffield and Wood 2008) [132] . Droughts are the world's costliest natural disasters, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster, (Wilhite 2000) [133] . Given the consequences and pervasiveness of drought, it is important to assess drought severity, but the precise quantification of drought is a difficult geophysical endeavor. Numerous specialized indices have been proposed to do this; for an extensive listing of available indices, the reader is referred to WMO (1975) [134] and Heim (2000) [135] .

The study carried out by Sheffield and Wood 2008, to analyze changes in drought occurrence using soil moisture data, under the future projections, showed decreases in soil moisture globally for all scenarios with a corresponding doubling of the spatial extent of severe soil moisture deficits and frequency of droughts from the mid-twentieth century to the end of the twenty-first. Long-term droughts become three times more common. Regionally, the Mediterranean, west African, central Asian and central American regions show large increases most notably for long-term frequencies as do mid-latitude North American regions but with larger variation between scenarios.

The study conducted by Burke and Brown, (2007) [136] using different indices related to moisture (Palmer drought severity index PDSI, and soil moisture anomaly SMA), shows increases in the proportion of the overall increase in areas affected by drought. The study also showed that all indices that include some measure of the atmospheric demand for moisture (PPEA, PDSI, and SMA) show increases in the proportion of the global land surface in drought ranging from an additional 5%–45%. SPI, based solely on precipitation, shows much smaller global changes ranging from 5% less to 10% more of the land surface.

In addition to the overall increase in area affected by drought, the area in more severe drought increases much more than the area in less severe drought. This could have serious consequences as the impact of drought on socioeconomics increases with the severity of drought. They added that regionally, there is a very large range in the sign and magnitude of drought changes. The only regions where there is a consistent increase in drought across all indices and ensembles are those where the annual average precipitation decreases as found for the Mediterranean, Amazonia, and Southern Africa.

In other regions the sign and magnitude of the change in drought is dependent on index definition and ensemble member. The impact of change in drought will be felt at the regional scale. Therefore, in order to perform optimum impact assessments of changes in drought, regional studies are required using locally appropriate drought indices. For example, a soil-moisture-based drought index on a daily basis over the growing season will be most relevant for studying the impacts in agriculture.

Regional climate simulations highlight the Mediterranean region as being affected by more severe droughts, consistent with available global projections; Giorgi, (2006) [137] , calculated the Regional Climate Change Index RCCI using wet season (WS) and dry season (DS) as defined by Giorgi and Bi, (2005) [138] , temperature and precipitation over 26 land regions of the world, as shown in figure (5), and out of 20 global model simulations the RCCI for the different regions showed that the most prominent Hot-Spots emerging from the RCCI analysis are the Mediterranean and North Eastern Europe (NEE) regions, Mediterranean was identified as the most prominent Hot-Spots emerging from the Regional Climate Change Index RCCI analysis, a large decrease in mean precipitation and an increase in precipitation variability during the dry (warm) season, which makes the Mediterranean one of the most responsive regions to global change; (Giorgi 2006).

the analysis presented here identifies the Mediterranean and Northeastern Europe regions as the most prominent climate response Hot-Spots, followed by high latitude Northern hemisphere regions and Central America. The latter appears to be the primary Hot-Spot in the tropics, immediately followed by Southern Equatorial Africa and Southeast Asia. Other prominent mid-latitude Hot-Spot regions are Eastern North America and Central Asia.

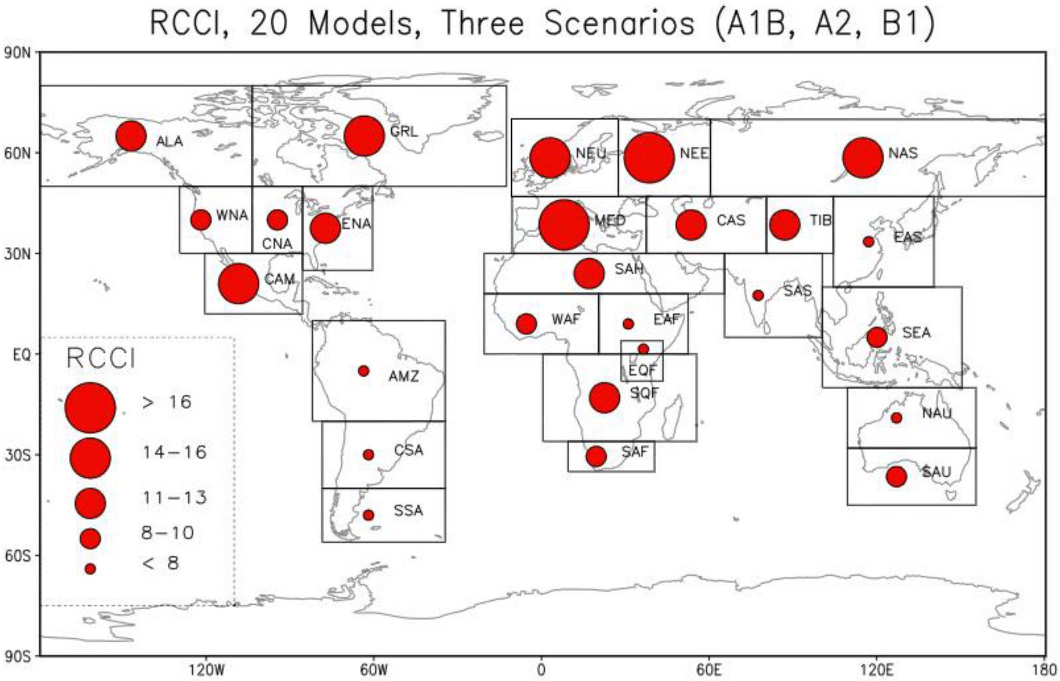


Figure 5. Regional Climate Change Index RCCI

Simulated precipitation regimes depict a globally drier Mediterranean in 2030–2060, with a 10–20% drop in annual rainfall, a drier Mediterranean in 2031– 2060 translates into about 1 week of additional dry days along the coast and in the already dry southeast basin; Over land areas in the Northern part, up to and over 3 weeks of additional dry days; thus, if the effects of ozone are to be included in an assessment of crop yields in the Mediterranean under a future climate scenario, the results are likely to be greater yield reductions; (figure 6), (Giannakopoulos et al, 2009 and Dai, 2010).

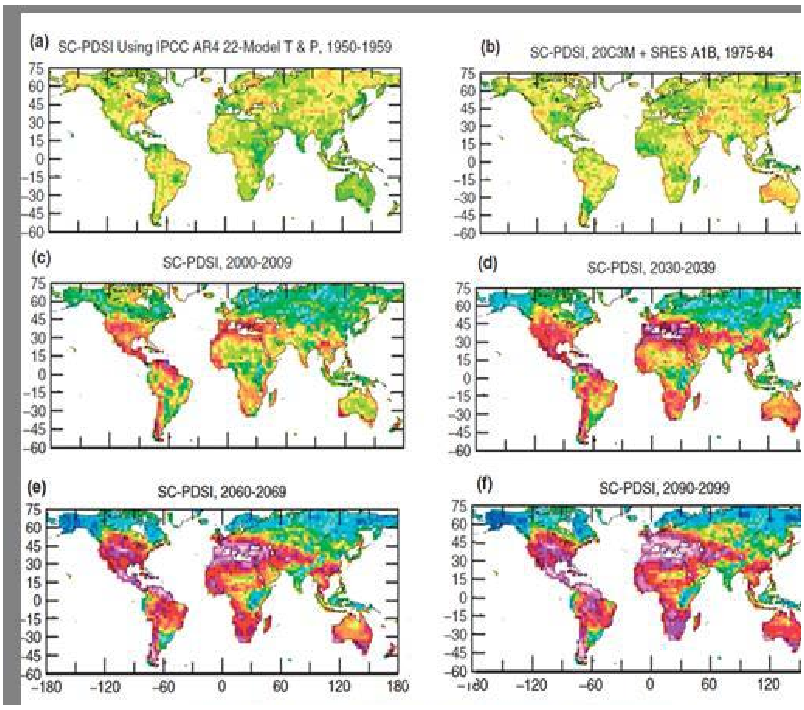


Figure 6. Mean annual sc-PDSI pm for years (a) 1950–1959, (b) 1975–1984, (c) 2000–2009, (d) 2030–2039, (e) 2060–2069, and (f) 2090–2099 calculated using the 22-model ensemble-mean surface air temperature, precipitation, humidity, net radiation, and wind speed used in the IPCC AR4 from the 20th century and SRES A1B 21st century simulations.128 Red to pink areas are extremely dry (severe drought) conditions while blue colors indicate wet areas relative to the 1950–.1979 mean

Mariotti et al., (2008), described the Southern Europe-Mediterranean region as a well-known region for its pleasant climate that has favored the rise of past great civilizations. People have learned to deal with an almost total lack of rainfall during the summer months, but water is still one of the most vulnerable aspects of life in the region, now supporting an increased local population.

Under a suite of global climate change scenarios, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4 hereafter; (IPCC 2007)[139]) projects major changes in the Mediterranean region, in particular as a 'Hot Spot' in hydrological change with significant impacts on both mean precipitation and variability (Gibelin and Deque 2003 [140] , Giorgi 2006 [141] , Ulbrich et al 2006 [142] , Giorgi and Lionello 2008 [143] , Sheffield and Wood 2008 [144]).

In fact Mediterranean countries are experiencing an increased drought frequency, intensity and duration that have resulted in increased drought losses and impacts on agricultural production, rural livelihoods, migration, urban, economic sectors and ecosystem decline. Mariotti et al., (2008) [145] , the CMIP3 model simulations show a progressive decrease in rainfall in the Mediterranean region that has been on-going during the 20th century (−0.007 mm/d per decade; see table 2S (available at stacks.iop.org/ERL/3/044001) for a summary of all trends) and accelerates around the turn of the 21st century, followed by rapid drying from 2020 and onwards (figure 1; −0.02 mm/d per decade).

The projected changes will cause Mediterranean land regions to become gradually more arid, with roughly 15% less precipitation in 2070–2099 compared to 1950–2000, and an 8% decrease already by 2020–2049.

The amplitude of the mean change foreseen by 2020–2049 (about 0.1 mm/d) is comparable to that of the driest spells experienced by the region during the 20th century, (figures 7 a, b). CMIP3 simulations for the 20th century suggest that the Mediterranean region has a tendency toward drier and warmer conditions.

All datasets, winter season precipitation shows a major downward deviation over the period 1960–2004 (−0.09±0.02 mm/d per decade), with inter-decadal variations, a decrease during the period mid-1960s to early-1990s and an increase after that while dry season showed negative trends over the period 1950–2000 have also been observed in relation to a blocking-like pattern deflecting storms away from much of western and Southern Europe (Pal et al 2004).

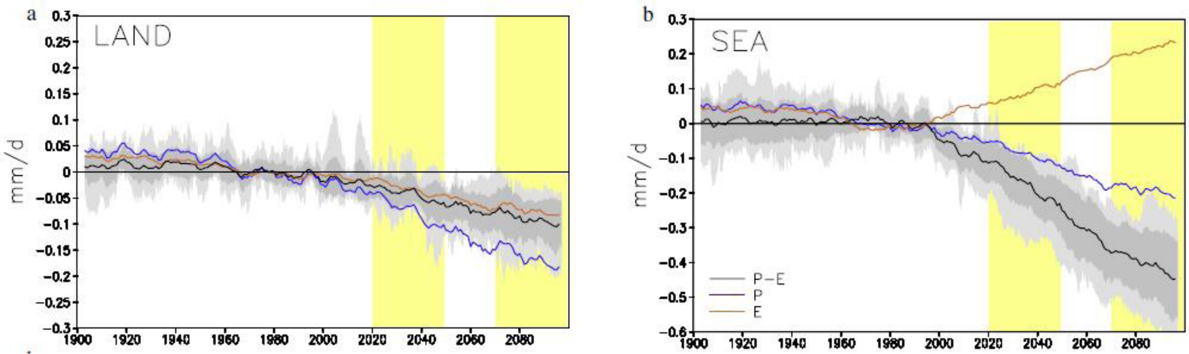


Figure. 7 Mediterranean water cycle anomalies over the period 1900–2100 relative to 1950–2000. Area-averaged evaporation (brown), precipitation (blue) and precipitation minus evaporation (black; P – E) are based on an average of CMIP3 model, after .Mariotti et al., 2008

These tendencies are supported by observational evidence of century-long negative trends in regionally averaged precipitation, PDSI and discharge from numerous rivers; and are consistent with reported increases in Mediterranean sea water salinity, (figure.8).

The study reflected that By 2070–2099, that precipitation is projected to decrease throughout the year and particularly during the dry season about −10% and 23% for the wet and dry seasons, respectively. In contrast, most of the land evaporation decrease occurs during the summer dry season (−12%) when land surface aridity will be greatest.

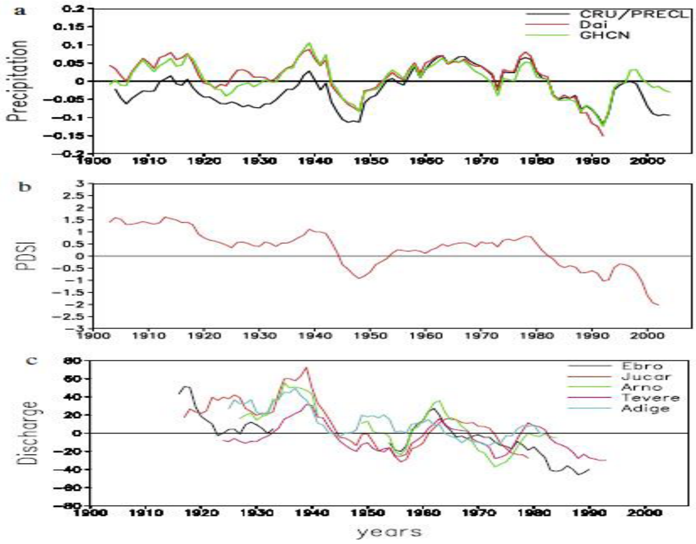


Figure 8 Mediterranean water cycle changes observed during the 20th century relative to the period 1950–2000. Area-averaged annual mean precipitation anomalies (six years running means) from various datasets (panel a; mm/d) and PDSI (panel b; au); discharge anomalies (units are % of climatology) for various Mediterranean rivers (panel c). Due to data availability, discharge anomalies are relative to the 1960–1980 period.

The combination of these changes results in a decrease in effective land precipitation that is similar during the wet and dry seasons (about 20%). Over the sea, freshwater deficit will increase throughout the year and particularly during the wet season (29%) when evaporation increase will be at a maximum (about 7%). The pattern of maximum precipitation changes has a general South to North migration going from winter into summer, following the climatological seasonal cycle of precipitation (figure 9)

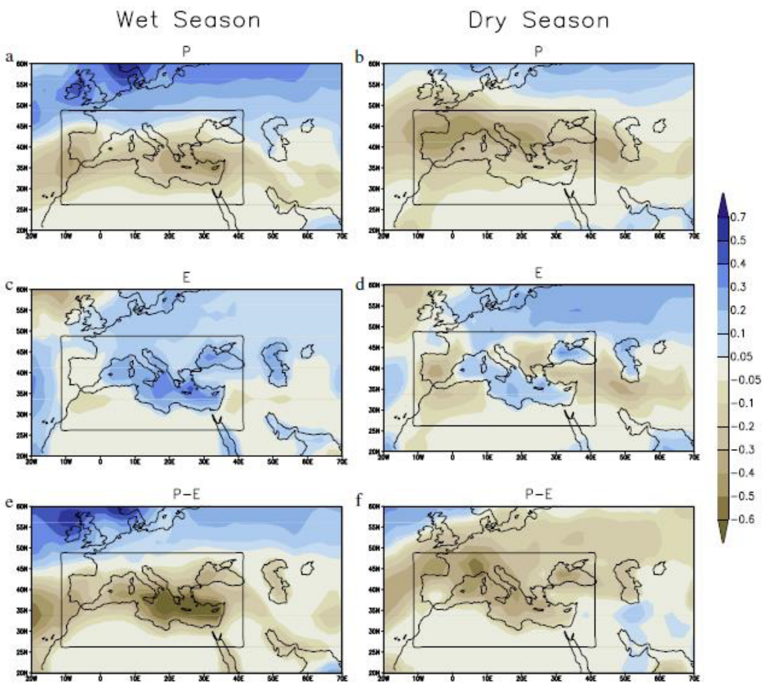


Figure 9. Mediterranean water cycle changes by 2070–2099 compared to 1950–2000 for the 'wet' and 'dry' seasons. Precipitation (a) and (b), evaporation (c) and (d), and precipitation minus evaporation (e) and (f). Anomalies are based on an average of CMIP3 model runs. For all, units are mm/d. The box broadly depicts the Mediterranean region.

2. Drought Monitoring inCAPWATER

Drought is an insidious, slow-onset natural hazard that produces a complex web of impactsthat ripple through many sectors of the economy. These impacts may be experienced welloutside the affected region, extending even to the global scale.

The complexity of impactsis largely caused by the dependence of so many sectors on water for producing goods andproviding services. Another complicatingfactor in characterizing drought impacts is that they vary on both a spatial andtemporal scale.

A drought event today may beof similar intensity and duration as a historical drought event, but the impacts will likelydiffer markedly because of changes in societal characteristics.

Thus, the impacts that occurfrom drought are the result of interplay between a natural event (precipitation deficienciesbecause of natural climatic variability) and the demand placed on water and other naturalresources by human-use systems.

As vulnerability to drought increases because of mounting pressure onwater and other natural resources, it is clear that the scientific community faces a significantchallenge to produce more timely and more comprehensive assessments of impacts.

It is oftensaid that drought is the most complex of all natural hazards, and more people are affectedby it than any other hazard.

Still, few studies have endeavored to identify the complexity ofthese impacts at the local, regional, or national scale, and databases to document impactsand track trends by region or sector are virtually nonexistent.

As nations strive to improvetheir level of drought preparedness through the creation of improved early warning systemsand the adoption of drought policies and response and mitigation plans, it is imperative forscientists and policy makers to document to what degree these investments are diminishingeconomic, social, and environmental losses in order to justify future investments in droughtmitigation and planning.

Drought monitoring is a high priority for Arab states. Preparedness for drought forms an important part of national environmental policies. At present, as all countries of the region, Lebanon, Jordan, Tunisia and Morocco have limited institutional and technical capacity to prepare for a drought and to mitigate its impacts. This is due to insufficient readily available Information on drought onset and development for agencies and for the general public. That is why CAPWATER project aimed at improving countries capabilities.

Theimplementation of a drought monitoring systems in CAPWATER is based on the development of a methodology to calculate, analyze the drought indicators “Concept of Composite Drought Index (CDI)” by using NDVI, Precipitation SPI, Eta, SPEI, Soil Moisture anomaly and other Climate and Environmental Parameters at the national and local level for the prediction and monitoring of drought.

Most of used systems focused on crop stresses by drought, but the question of the efficient and capability of the used systems could be assessed as follows:

2.1. Assessing Drought Monitoring in Lebanon

The recent occurrence of prolonged drought conditions in Lebanon has emphasized the need for adequate monitoring tools of drought events, the used drought indices

- Standard precipitation index (SPI) has been used as conventional drought index based on ground measurements. The SPI point calculation software was used to calculate from metrological stations data, then DCE (drought calculation and evaluation) software was used for Raster calculation and mapping, and

- Satellite drought indices based on remote sensed data (e.g. NDVI, VCI, TCI, VHI).

The main result produced by NCRS is based on remote sensing using MODIS data, the used flow chart is presented as in figure (10), and examples of VCI, TCI and VHI results are shown as in (figures 11, 12,13 and 14).

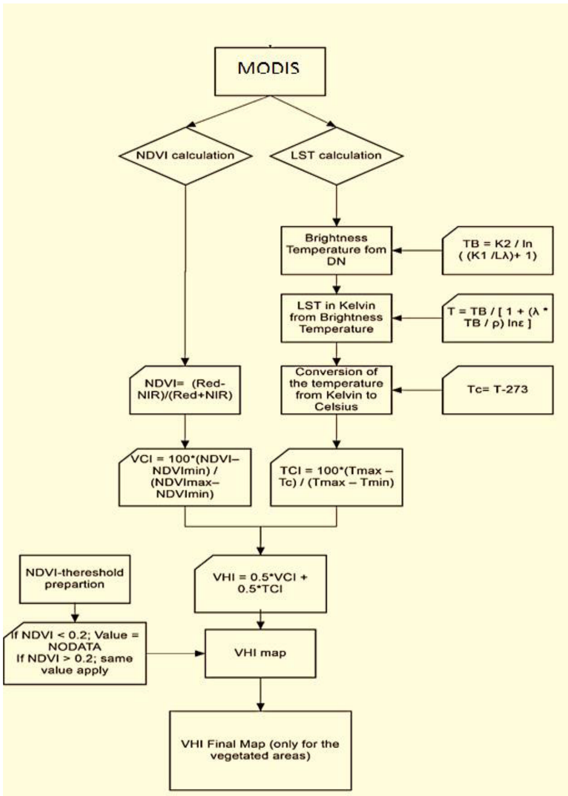


Figure 10.The Flowchart for calculating VHI

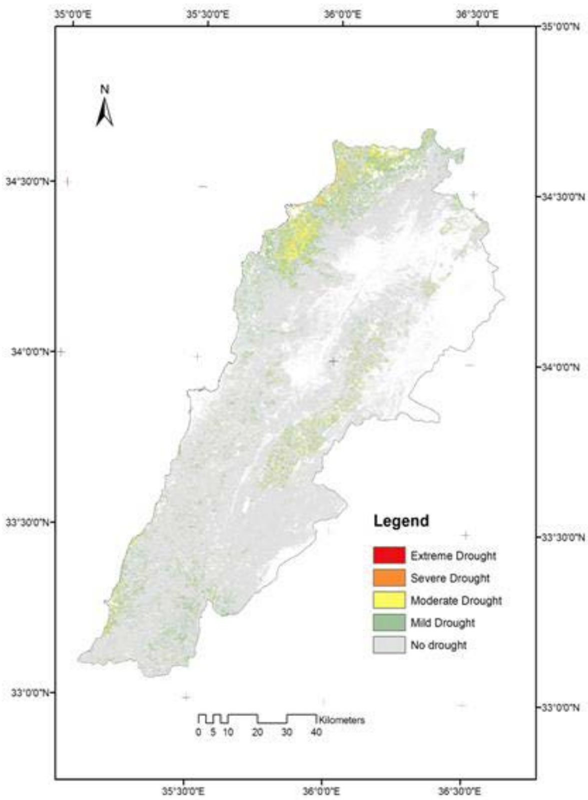


Figure 11. VegetationHealthy Index (VHI) classes in Lebanon, 2014

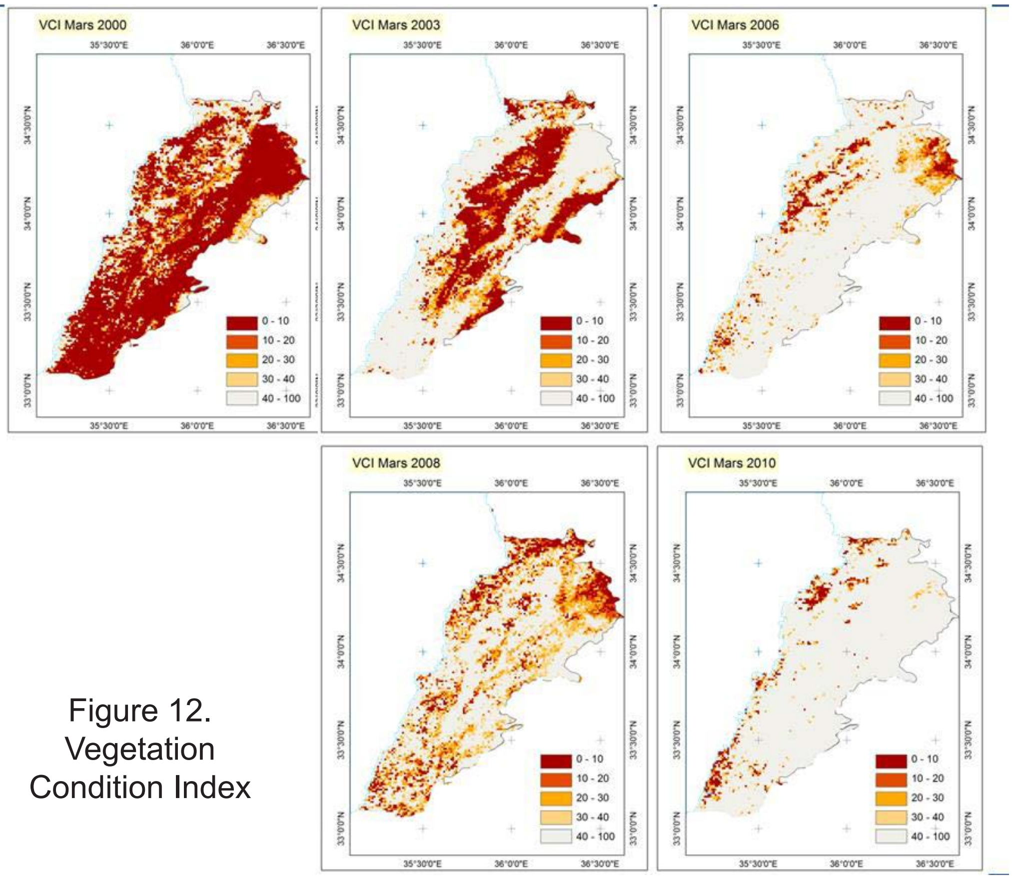


Figure 12. Vegetation Condition Index

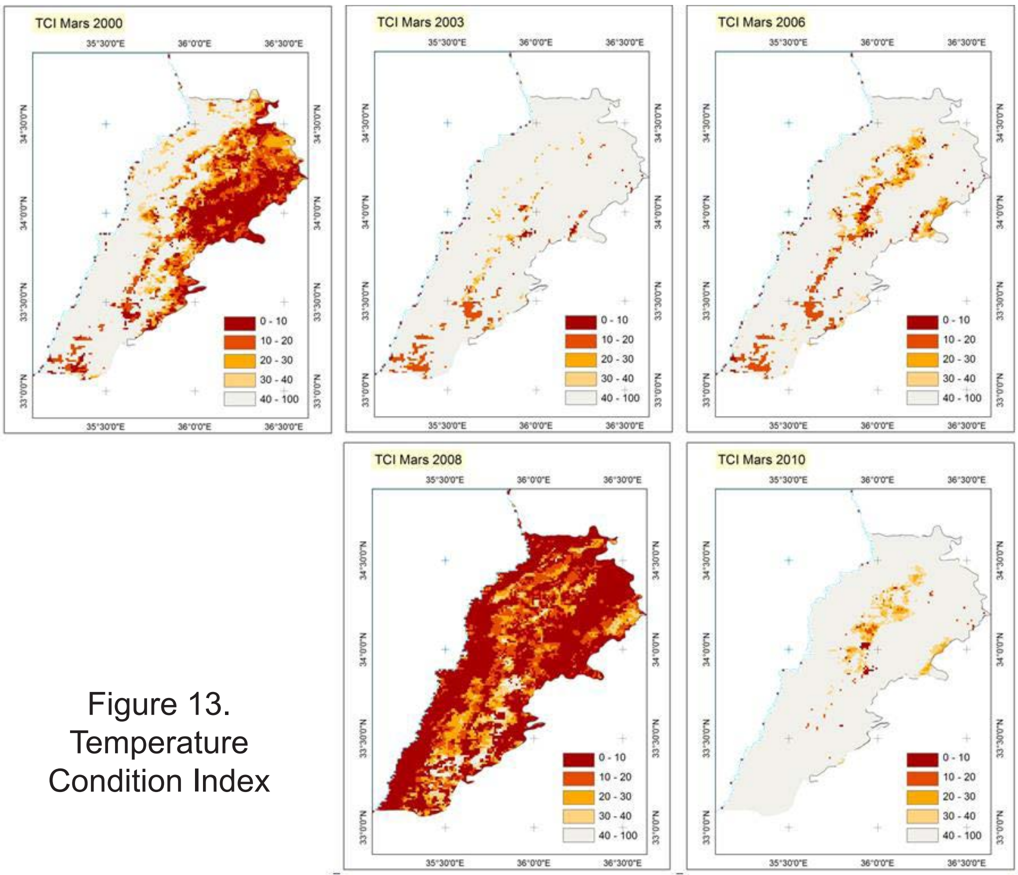


Figure 13. Temperature Condition Index

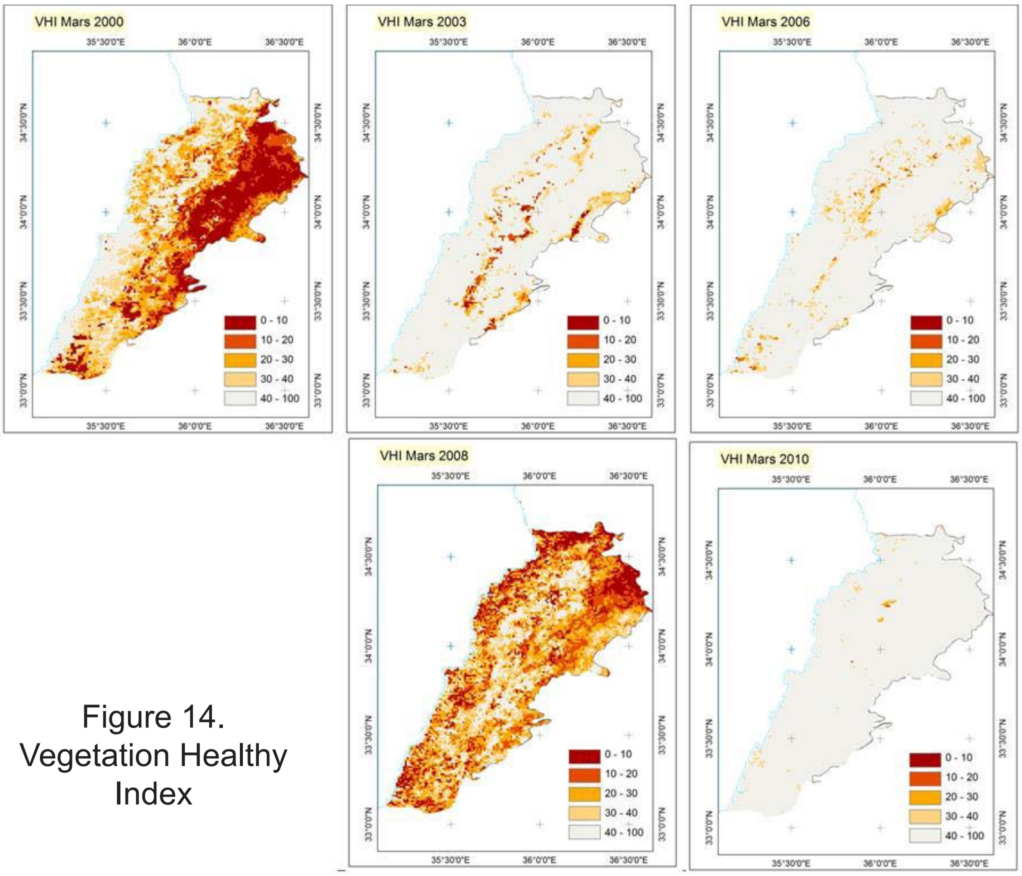


Figure 14.
Vegetation Healthy Index

In assessing NCRS drought monitoring approach we could conclude the following:

- The use of Remote sensing for drought monitoring for early warning is very strong tool, but at the meantime require on-line source for providing daily data,.
- Measuring drought hazard didn’t include its intensity, frequent, and consecutive duration in the different cycles,
- Agriculture depends on agriculture seasons and related to the length of the agriculture season (winter season in case of Lebanon that falls under Mediterranean climate), that was not reflected on the results.
- The study reflected more Soil Moisture (agriculture drought) but didn’t make much in interpreting the outcomes of the study or identify the expose vegetation cover. Accordingly the monthly precipitation distribution during different months of the agriculture seasons in rainfed croplands and rangelands which is important to understand the impact was not considered.
- Identifying the high variability of the region which is part of the complexity of drought was not considered.
- Although by “Definition” drought since the special IPCC extreme events report on 2012, should include “Evapotranspiration” as part of the assessment that was not considered.

2.2. Assessing Drought Monitoring in Jordan

The goal of drought monitoring component was to develop early warning indicators using Global MOD13Q1 data “MODIS/TERRA VEGEGTATION INDICES 16-DAY L3 GLOBAL 250 m SIN GRID V005” are provided every 16 days at 250-meter spatial resolution as a gridded level-3 product in the Sinusoidal projection. The data used covers the season 2013/2014, as vegetation monitoring and the study target was aiming at using several indicators including:

- Standardized vegetation index,
- Vegetation condition index VCI,
- Temperature condition index TCI,
- Vegetation health index VHI,
- Vegetation drought index,
- Water stress vegetation index"
- With the support of daily ALEXI ET maps provided by NASA, as well as the integration of the TRMM satellite precipitation.

NCARE presented its share of the ongoing research in drought monitoring particularly for the Northeast Jordan (Mafraq study area), the location map and the detailed map of cropland area are shown in (figure 15).

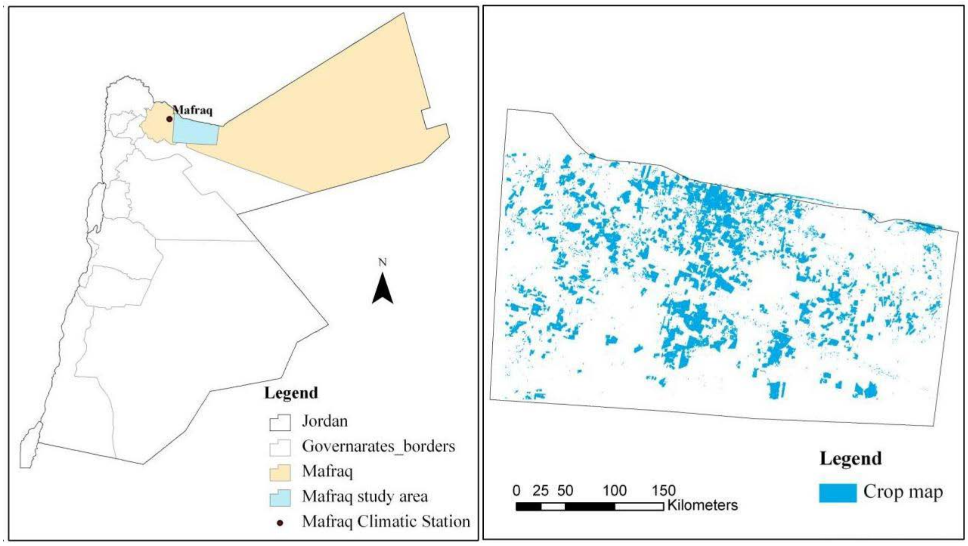


Figure 15 Location map of study area and detailed cropland

Mafraq governorate is located to the north-east of Amman capital of Jordan. The climate is characterized by dry hot summers and cold dry winters. The Mean Annual Maximum air temperature is 23.9 ºC and the Mean Annual Minimum air temperature is 9.3 ºC with an average total annual precipitation of 161.3 mm (Source: Jordan Climatological Handbook 2000 – Meteorological Department).

Overlaying the crop map on NDVI images was used to join information from both sources. The analysis involved two approaches:

- ♦ Grouping crop types into three groups: trees, field crops and vegetables (figure 16).
- ♦ Selecting areas covered by similar group type with minimum area more or equal to 50000 meter square. This resembles at least 90% coverage of same group in one pixel of 250 m.

  - Pixels that match the above characteristics were used as area of interest "AOI".
  - The mean of these sampled pixels were used in NDVI growth profile analysis of different groups.
  - Detailed information about each group, areas, and number of pixels analyzed can be found in (figure 17).

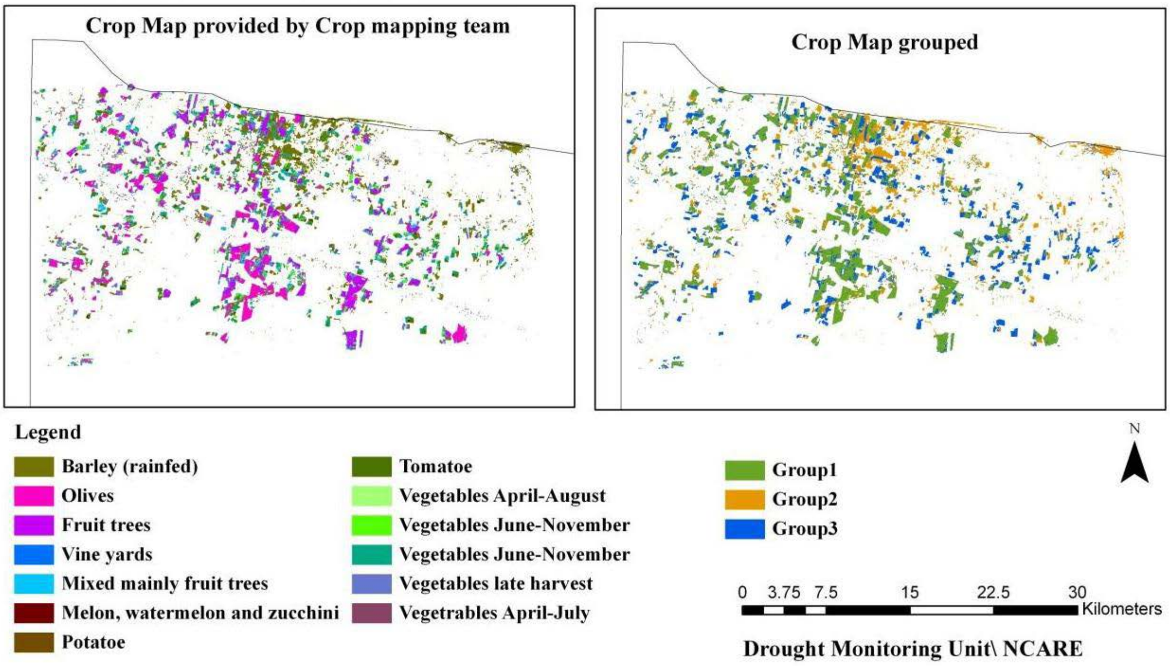


Figure 16CropMapGroupedinto 3 Groups

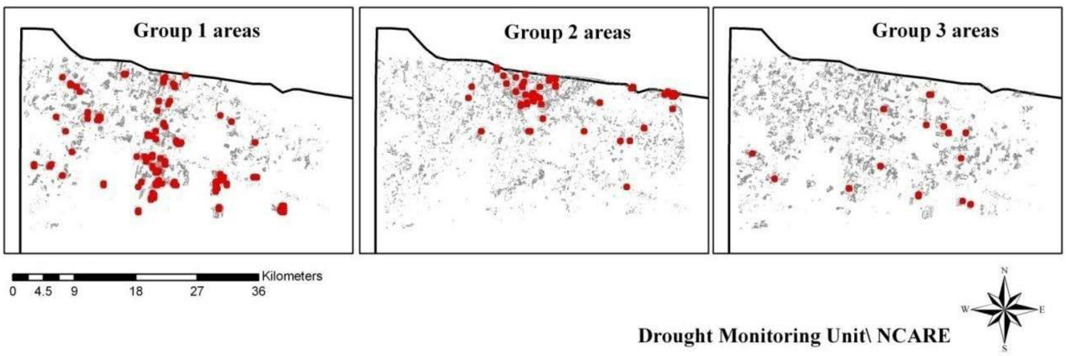


Figure 17: Group Maps and pixels

The long term statistical NDVI show that the study area is characterized by low to medium vegetation were tree areas (group1) showing the highest NDVI values (Olive trees -permanent vegetation).

The long term seasonal growth pattern was studied using the mean 16-day image for the time series 2000-2013. The output show relatively high NDVI values in different areas and in different periods, due to the large cover with olive trees (permanent vegetation) that irrigated during summer time using ground water, and the use of ground water for irrigation for field crops is common especially in summer time, during the period from December to April the NDVI patterns reflect the rainfed agriculture.

Analyses of the season 2013/2014 growth pattern deviation from the mean show the periods were vegetation growth was above or below average, that could be summarized as follows:

- During summer period irrigated areas (using ground water) clearly have deviation values above the mean. Variation of the vegetation cover (plus and minus) during the period from "May to November" could be attributed to irrigation scheduling and agricultural practices,
- During the rainy season the deviation was below average, especially the rainfed areas are affected by rainfall shortages during the period from January to March. The change in vegetation during December is related with the low temperature and snow that affected the country in the second week of December, the high rainfall (snow) amount that came in December had good impact on increasing vegetation during the second half of January but Heavy rainfall received in the second week of March impact is obvious in increasing the NDVI values during the following period of March 22 to April 6th.
- The use of Vegetation Condition Index (VCI), is another simple indicator that shows low VCI values in most of the study area, all over the season indicating drought conditions. More drought conditions are obvious during the period from February to April.
- Detailed investigation show that most of the low values <30 are in the uncultivated "rangeland areas" indicating drought conditions. Meanwhile the cultivated/ irrigated areas were not affected by drought.

In conclusion:

This used method gives simple indicator about crop stress by drought; the drought is not directly measured but indicated by vegetation density in different seasons.

At themeantime the used method showed the importance of the supplementary irrigation using ground water, which eliminated the impact of drought on irrigated vegetation, but was very clearly reflected in rangeland areas.

The study needs in the future toanswerquestions that reflect the drought economic and environment impacts:

- Measuring rainfall, temperature as well as potential evapotranspiration variability and their correlations with the crops water requirements, between and within studied years and seasons, and
- Agriculture sustainability with increased cost of used energy for pumping ground water.
- The level of severity of land degradation in Rangelands.
- The scenarios that are related to social vulnerability under the increased biophysical climate change and drought stress.

2.3. Assessing Drought Monitoring in Tunisia

The Drought Component of LDAS project could be summarized as follows:

- Provide reliable and easily exploitable information characterizing spatial and temporal extension of drought (duration, intensity, scale, etc.) and drought impact Three principal components are to be considered: a surveillance and early warning system, a risk evaluation system and mitigation/adaptation system (Wilhite and Svoboda, 2000).

- Development and calculation of Vegetation monitoring indicators (standardized vegetation index, vegetation condition index, temperature condition index, vegetation health index, vegetation drought index, water stress vegetation index) with the following specifications: 1 km spatial resolution; 10-day synthesis temporal resolution; monthly and 10-day product frequency; raster (Tiff, img) format at national scale; input data: AVHRR data used since 1999 and other sources to be explored: MODIS, Spot VGT.

- Soil moisture prediction using radiometric signal changes of terriestrial surface temperature.

The mean data used for implementing the project drought component were:

a. MODIS Terra and Aqua Normalized Difference Vegetation Index (NDVI) and Land surface temperature (LST) products 250 m and 500 m resolution for the period of 2000–2014,
b. The Tropical Rainfall Measuring Mission (TRMM) monthly rainfall data for the period of 2000–2014, and
c. The global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (GTOPO30)
d. The MODIS Terra and Aqua Land Cover provided every year at 500-meter spatial resolution as a gridded level-3 product (MCD12Q1, collection v051) for the period of 2001- 2012 were acquired from the Land Processes Distributed Active Archive Center (LP DAAC). The International Geosphere Biosphere Programme (IGBP), which identifies 17 land cover classes (11 natural vegetation classes, 3 developed and mosaicked land classes, and 3 non-vegetated land classes).

A time series analysis of the vegetation response using the normalized difference vegetation index (NDVI), in relation with the temporal distribution of precipitation and land surface temperature stratified by land cover classes and elevation levels datasets has been carried out in order to detect the presence of statistically significant trends in time series of different climatic variable and vegetation indices; analyze the temporal dynamic of vegetation in terms of biomass in areas affected by persistent drought phenomena; and analyze the relationship between the vegetation evolution and climatic variables (precipitation, temperature), (Figure 18).

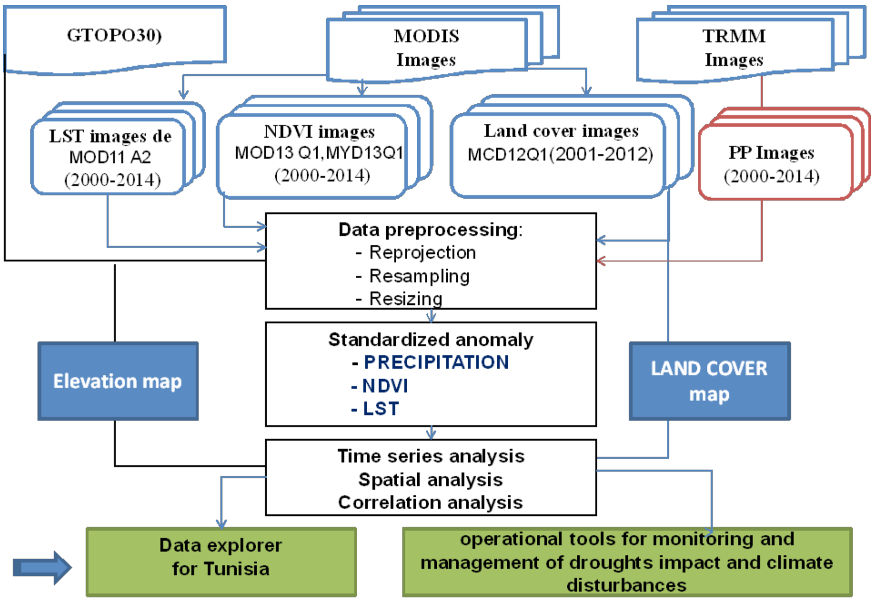


Figure 18 Time series analysis of vegetation response

Correlation analysis: Correlation analysis between NDVI, precipitation and land surface temperature standardized anomaly through using three types of correlations coefficients: Pearson correlation, Kendall rank correlation and Spearman, (Figure 19).

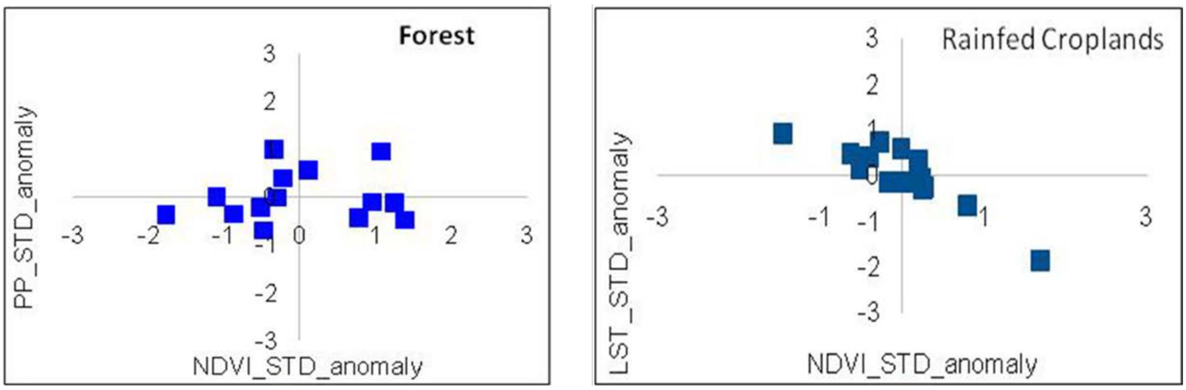


Figure 19 NDVI, ST and Precipitation, ST correlation analysis for different vegetation Land Use

Clustering analysis: Clustered analysis of NDVI standardized anomaly for Medenine department stratified by elevation and land cover, (Figure 20).

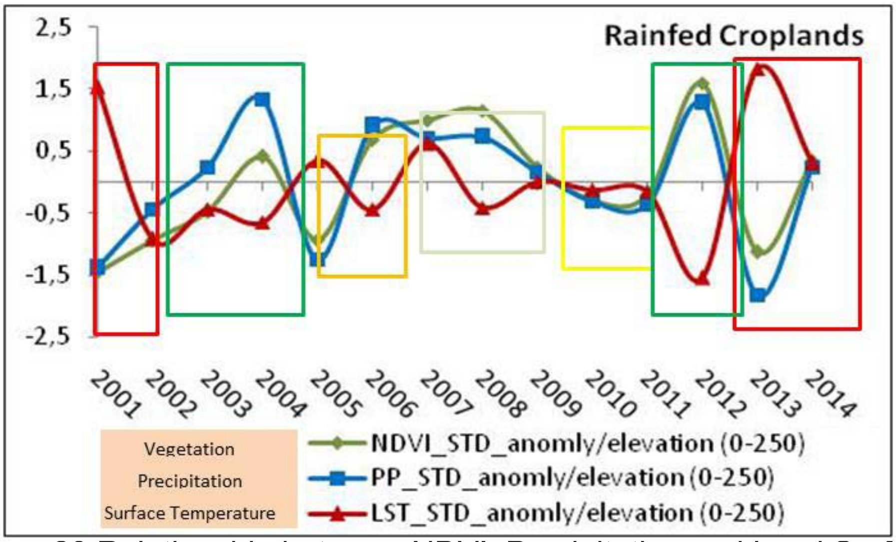


Figure 20 Relationship between NDVI, Precipitation and Land Surface temperature in rainfed croplands

Spatial comparisons: For each year the standardized anomaly values of the NDVI, precipitation and land surface temperature were averaged through crop year (September to August), visually examined and compared the relationship between them particularly in dry and wet condition,(Figure 21).

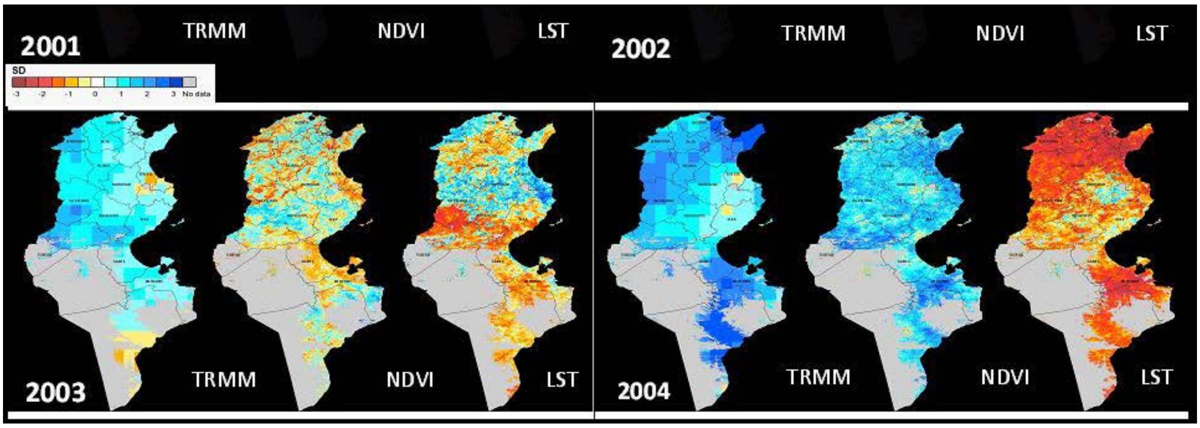


Figure 21 NDVI, precipitation and land surface temperature averaged in two different years (2001- 2004) through crop year (September to August),

The results reflected the following:

- A high variability of rainfall in Tunisia, the response of vegetation to climate variability depending on the type of cover and altitude.

- The period (2001-2002) is the largest deficit during the 2000-2014 observation periods.

- Synchronization between the temporal evolution of NDVI and those of the precipitation particularly during the dry and wet periods, andAn inverse relationship was recorded between NDVI and surface temperature ST expressing both the influence of soil coverage by vegetation and water stress of plants during dry periods, vegetation water stress can justify their use as appropriate indicators for monitoring and management of drought in Tunisia.

- Some aspects require further consideration such as:
    - ♦ Quantification of threshold values of NDVI, Rainfall and ST from remote sensing data likely to announce levels of drought risk to be used for the establishment of a monitoring system to drought.

    - ♦ The identification of most areas vulnerable to drought for better decision support.

- The identification of high potential of the NDVI for the characterization and detection of drought impacts on vegetation particularly in arid and semiarid regions of Tunisia, offers new possibilities to implement a decision support system for long term monitoring of climate change at different spatial and temporal scales.

In conclusion:

- The first defined objectives to develop a prototype remote sensing based platform for monitoring and characterizing the vegetation response to climate variability have been done using NDVI the most direct simple indicator about crop stress by drought, the drought is not directly measured but indicated by vegetation density in different seasons.

  The NDVI correlation with both rainfall and surface temperature is obvious, as explained by The inter-annual fluctuations of rainfall are not uniform throughout the region. In the driest areas the contrast between years in the areas bounded by the 200 mm and 500 mm isohyets. Rainfall threshold exists, above which NDVI is insensitive to rainfall fluctuations; this threshold appears to lie at approx. 1000 to 1100 mm/annually or 200 mm / monthly (Malo and Nicholson, 1990 [146] ; Nicholson and Davenport 1990 [147]). NDVI values are highly correlated with multi-month rainfall as rainfall effects on Vegetation in cumulative, results found that there is a good spatial agreement between NDVI and rainfall (Nicholson, et al. 1990)[148], as the spatial distribution of the vegetation cover is strongly related to climatic conditions (Richard et al.,1998) [149] .

  The correlation coefficients of NDVI-rainfall exhibit a clear structure in terms of spatial distribution in semi-arid area of Great Plain, USA (Wang et al., 2003[150]) and China (Liu et al., 2010[151]). Further, it was reported that change in NDVI values can be affected by the amount and timing of rainfall, (Schultz,et al., 1995)[152] . Nicholson (1990)[153] demonstrates that a linear relationship between NDVI and rainfall as long as the rainfall does not exceed approximately 500 mm/year or 50-100 mm/month. Above these limits a “saturation” response occurs and NDVI increases the amount of rainfall only very slowly.

  The study after Erian et al (2012)[154] , showed the result of five equations were used to describe the relation between the studied variables, namely: a) Straight line passing through the origin, b) Straight line with slope and intercept, c) Exponential passing through the origin, d) Second order polynomial with intercept, and e) Second order polynomial without intercept.The study covered croplands and rangelands.

1. The Straight line passing through the origin equation:

$$NDVI = 0.0009 * Rain \qquad (R2=0.3481)$$

Has the lowest coefficient of determination (R2=0.3481). However, its behavior is correct where NDVI increases linearly with increasing rain, starting from NDVI = 0 ant zero rain.

2. A higher coefficient of determination was obtained (R^2 = 0.6139) in the straight line with slope and intercept equation:

$$NDVI = 0.0006 * Rain + 0.1932 \qquad (R^2 = 0.6139)$$

The equation has the correct behavior where NDVI increases linearly with increasing rain. However, the intercept (0.1932) value at zero rain is not acceptable.

3. The exponential equation:
   NDVI = 0.0151 Rain 0.555 (R² = 0.6155)

Has a higher coefficient of determination ($R^2 = 0.6155$) and correct behavior too

4. The Second order polynomial with intercept has two drawbacks namely the intercept and decreasing NDVI values with increasing the rain in the high rain range. However, the coefficient of determination is high.
   NDVI = -5E-07 Rain 2 + 0.0011 Rain + 0.0878 ($R^2 = 0.6857$)

Good positive correlation was obtained between the two parameters.

The correlation coefficient ranged between 0.59 and 0.83 (determination coefficient between 0.34 and 0.69). The Second order polynomial without intercept has one withdraw only which is the decreasing NDVI values with increasing the rain in the high rain range

The previous analysis of the relation between NDVI and rain puts the exponential equation (Eq. 3) as the best candidate describing the relationship. Equation 3 shows high slope of the curve at low rain and decreasing slope with increasing precipitation by divided the whole range of precipitation in 4 parts, we notice decreasing the slope with increasing the precipitation very clearly.

The decrease of slope of NDVI vs. rain with increasing rain opens suggests the existence of Rainfall threshold, above which NDVI is insensitive to rainfall fluctuations; this threshold appears to lie at rainfall of 691.99 mm which is smaller than the value (approx. 1000 to 1100 mm/annually) suggested by Malo and Nicholson, (1990); Nicholson and, Davenport (1990). The value of the break point was obtained using SegReg program.

- The second objective to identify the vulnerable areas and to develop an early warning toolswas not fulfilled

2.4. Assessing Drought Monitoring in Morocco

The main objectives of the drought studyis to build a system for drought monitoring is to development a methodologythat is based on analysis drought indicators at national scale, the used data are: a) precipitations using Climate Hazards Group InfraRed Precipitation with Station data CHIRPS to calculate SPI, as shown in figure (22);b) Soil moisture calculated from MODIS Day-Night LST Difference, as shown in figure (23); c) Vegetation index after Famine Early Warning System Network FEWSNET, as shown in figure (24); and d)Evapotranspirationafter FEWSNET, as shown in (figure 25). Few examples of used data are shown in (figure 26).

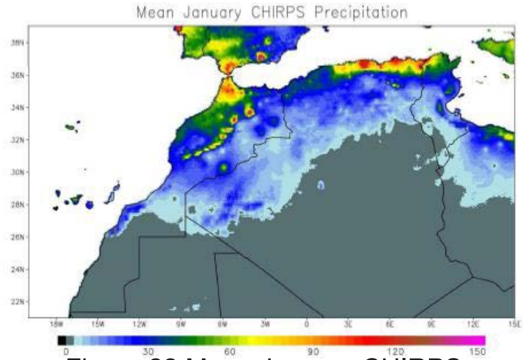


Figure 22 Mean January CHIRPS Precipitations

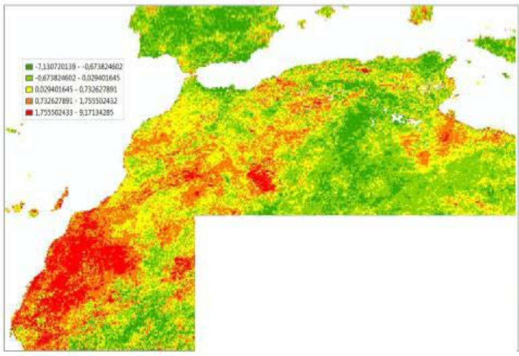


Figure 23 Calculated Soil Moisture SM Proxy

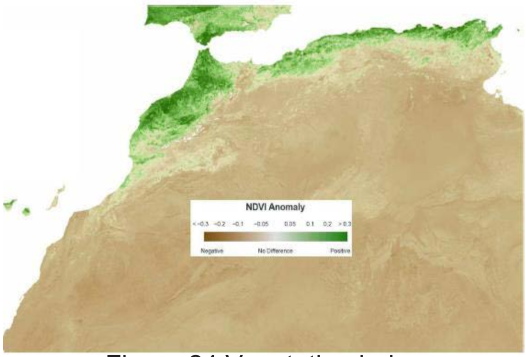


Figure 24 Vegetation index

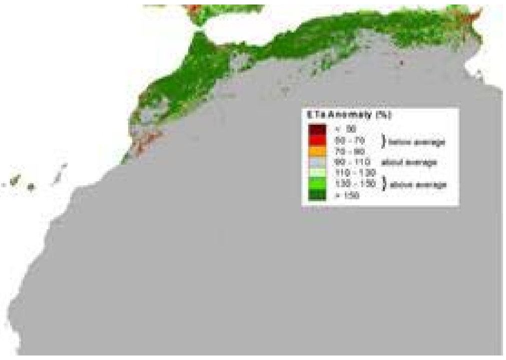


Figure 25 Evapotranspiration

The Composite Drought Index CDI was then created using the flowchart as shown in figure (26), the obtained CDIis presented in (figure 27). The CDI is classified in Percentiles as follows:

D1, Moderate Drought (10%-20% once per 5 to 10 years), D2, Severe Drought: (5%-10%once per 10 to 20 years), D3, Extreme Drought (2%-5%once per 20 to 50 years) and D4, Exceptional Drought (less than 2% once per 50+ years). Examples of the CDI results are shown (figure 28).

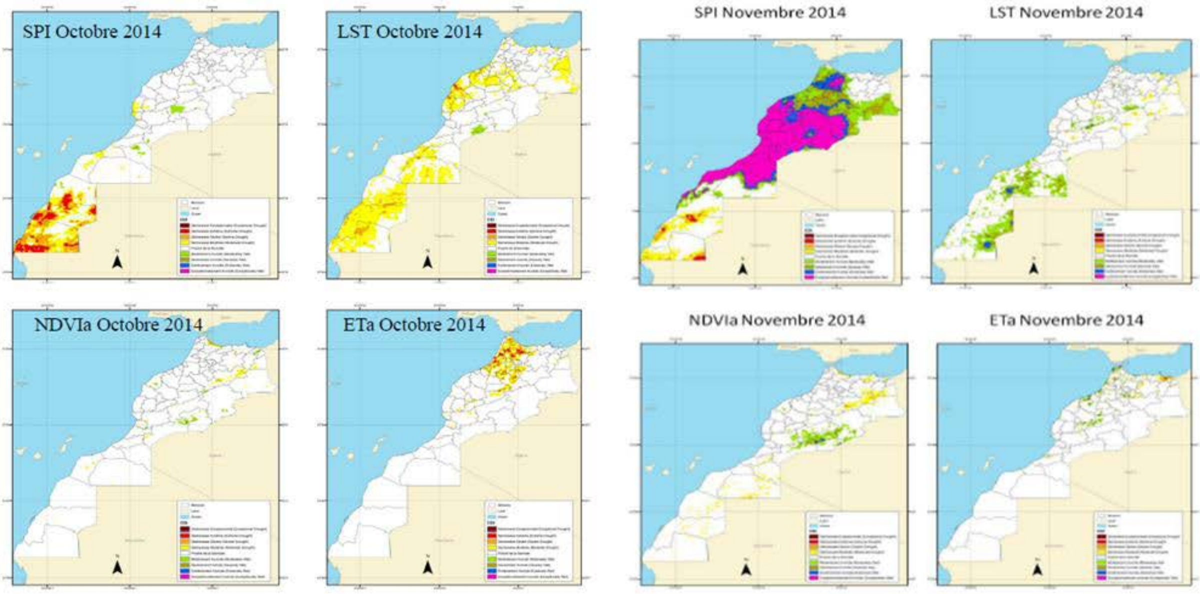


Figure 26 Examples of Used Data

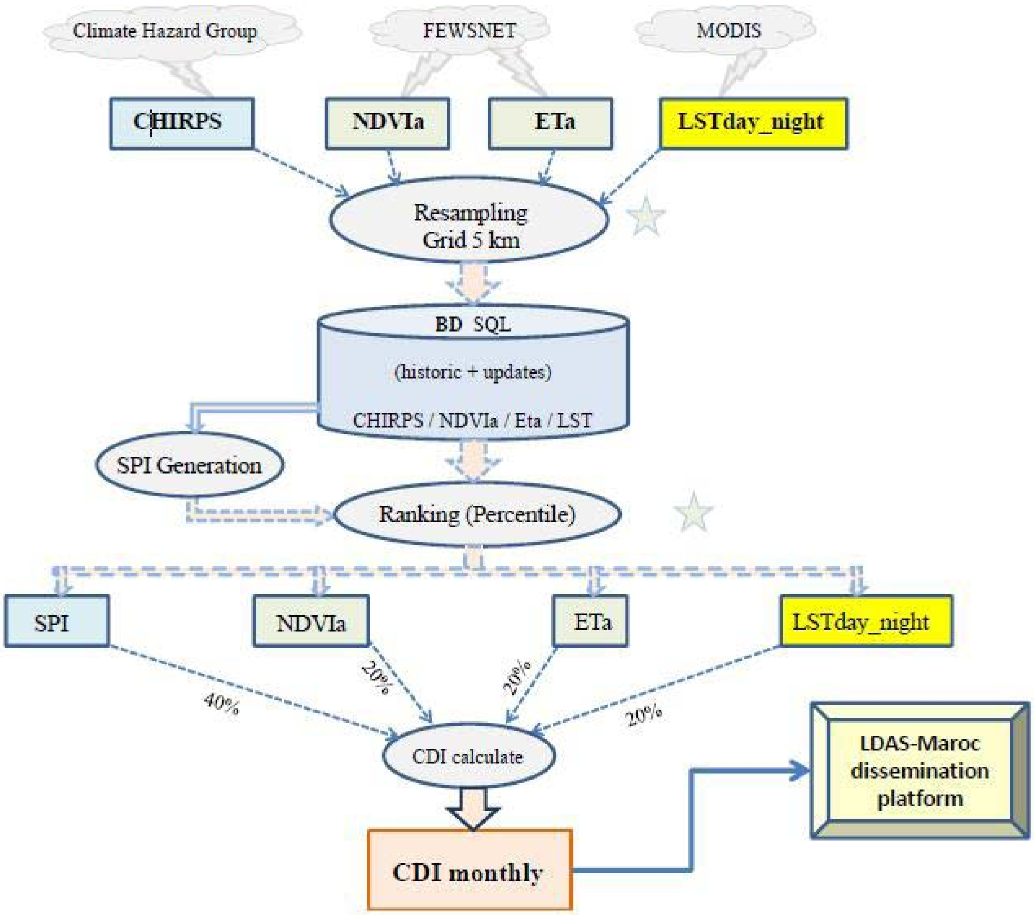


Figure 27.CDI Flowchart

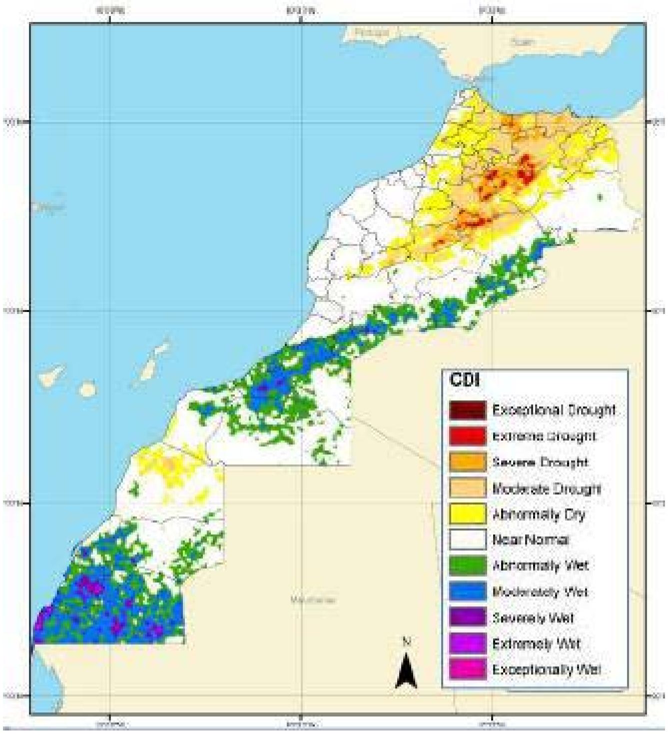


Figure 28 CDI example of study area

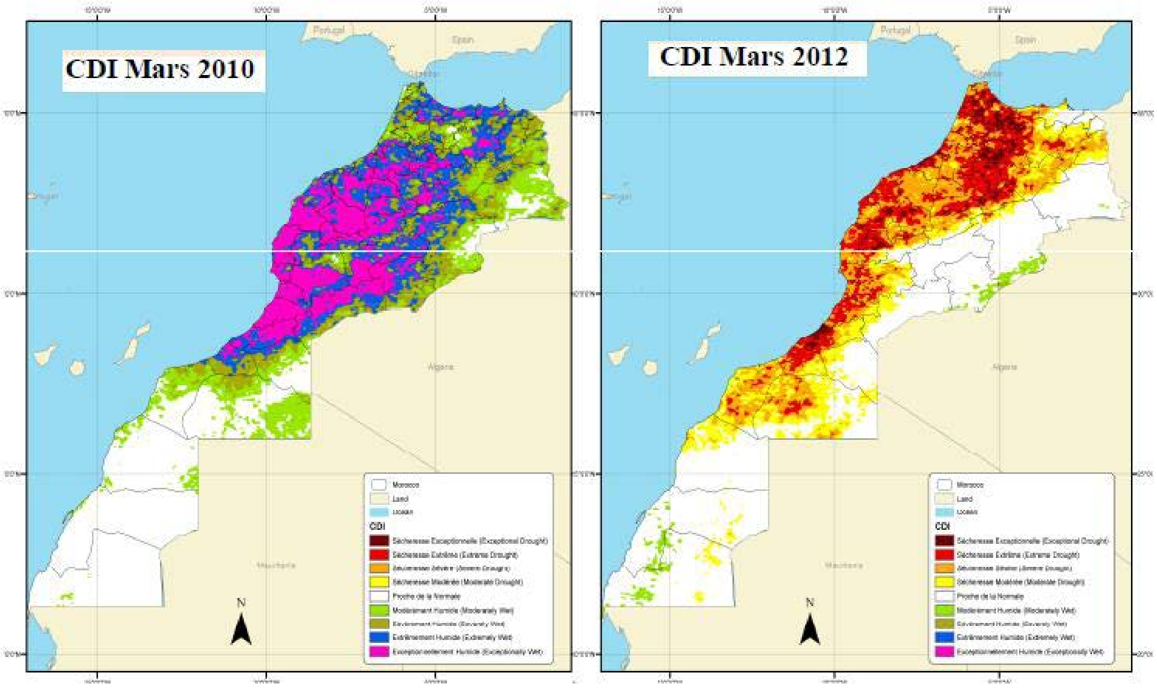


Figure 29 CDI in different seasons

Conclusion

The specific selected data inputs are using several criteria to develop CDI with a flexible framework that can be adapted to include additional or new data inputs, if necessary, as they become available in the future. But at the meantime the CDI is depending on weighting the different data inputs against each other and the weight is based on personal opinions. Modeling the used parameter is the only way to build the CDI system.

At the meantime the system is still in need for development as the balance between used data is not exist,

- The term soil moisture is usually calculated as a water balance between precipitation and potential evapotranspiration, while in the used method the precipitation was calculated as SPI and Evapotranspiration was used as separate elements.
- On the other hand soil moisture was calculated from strange equation that has no reference as it show the daily temperature variability (MODIS Day-Night LST Difference).

2.5. Overall conclusion

The used approaches are summarized as in table (1), and as discussed above the mean common limitations could be as follows:

- The use of metrological data and remote sensing for monitoring drought and for building drought early warning systems is essential and remote sensing could be considered a very strong tool, but at the meantime all discussed approaches still requires butter utilization of the used data and on-line source for providing daily data,
- Monitoring drought hazard included in different waysmonthly droughtintensity but both drought frequencyand drought consecutive duration are anydrought monitored systems and drought seasonal and long term cyclesare not part of all discussed systems, Agriculture depends on agriculture seasons and related to the length of the agriculture season (winter season in all cases as they part of Mediterranean climate),the seasonal drought was not reflected on the results.
- The studiesconcentrated more on vegetation and drought stress (agriculture drought) but didn't make much in interpreting the outcomes or identifying the exposed vegetation cover. Or come with quantitative outcomes.
- Identifying the high variability of the region which is part of the complexity of drought was not considered.
- Accordingly the monthly variability on precipitation and temperature distribution during the different agriculture months in rainfed croplands and rangelands is not clearly discussed, and drought impact on the different vegetation land use types was not clearly disscussed.
- Although by "Definition" drought since the special IPCC extreme events report on 2012 and 2014 should include "Evapotranspiration" as part of the assessment that was not considered in most of the approaches.

Table 1 The Comparison Between used Systems for Monitoring Drought

Lebanon	Veg DRI	VCI	TCI	VHI	SPI	Veg drought Index Brown et al.(2008) drought impacts Kogan 1990/1995) SPI McKee et al. 1993
Jordan	NDVI	VCI	CWSI	PDI/ MPDI Ghulam et al. 2007		Crop Water Stress IndexJackson 1981 CWSI = 1 – AET/PET where AET = actual ET and PET = potential ET Modified Perpendicular Drought Index (MPDI) , For non flat topography with variable soil types and eco-systems , semi-arid regions selected as satellite based
Morocco Tunisia	NDVI	P and ET_a	LST	SPI	CDI	CDI Crop Drought Index Meyer et al1993 P, ET, and T

3. Building Regional Drought Modeling and Monitoring System

This main goal and objectives in building regional drought modeling and monitoring system should:

- Focus on building regional modeling drought assessment risk and moving from crises management to risk management
- Respond to gaps and needs in data – information, _Knowledge required for more effective actions in regional, national and community levels for building resilience,
- Increasing modeling certainty, and enhanced assessment capacities.
- Enhance collaboration between regional and local institutions and empower academia and regional applied studies,
- Building indicators and benchmarks related to the bio-physical climate, environment and social stress, and
- Assess regional profile related to water, food and social vulnerability nexus to meet its role in climate change adaptation and disaster risk management toward sustainable development in the Arab region,

<u>Those objectives could be achieved through under taking the following activities:</u>

- Establish AWC Geographical Information Team,

This subcomponent describes the organizational arrangements to operate and administrate the Project in terms of technical, administrative, financial and training aspects. A service with the name “Geographical Information Technical Team (GITT)” will be established at the Arab Water Council (AWC). It takes advantage of the recent decision of the Arab Water Ministerial Council of LAS in its meeting of May 27, 2015 to establish a Unit of Technical Excellence to act as a regional hub for information and communication at the AWC. This arrangement will have the advantage of (i) integrating the scientific initiatives with focus on information, knowledge and decision support under the umbrella of LAS; and (ii) reducing the transaction cost for operationalizing this initiative/project.

The proposed structure and tentative responsibilities are:

- A full-time core team at AWC with technical, administrative, financial, information technology (IT) and training capabilities will be responsible for implementing the annual plans, establishing data basis, preparing digital mapping, communication with stakeholders and dissemination of information. A team leader will be assigned by AWC and will work closely with the Project Coordinator.
- Technical Team consisting of leading experts on voluntary basis to lead the scientific work, advice on priorities, propose annual plans, prepare TORs, review CVs, select consultants and review project output and outcome of technical activities.
- Part time consultants who will be selected and assigned on the basis of their qualifications and expertise to carry out specific studies, analyses and do reporting as appropriate for the work in question.

- Modeling drought and land degradation Hazards Assessment Risk in the Arab Region,
- Building validation system that includes, office activities and field work for identifying hot spots and socio-economic vulnerability and increase communities awareness by involving national and local decision makers with civil society, academia, national offices of international UN agencies and regional Arab organizations and NGOs in designing policies, measurements and actions to manage risk
- Capacity Building to National Institution,
- Preparing report that assess natural metrological hazards impacts on water, food and social vulnerability nexus
- Design several activities to be implemented in the project second phase as pilot activities to build communities resilience and reduce risk.

The main framework for planned activities should include:

- Project Preparation/ establish AWC Geo-Information Team
- Building ET regional unit:

  - ET Production requires multi resolution (scale) that should be part of the data validation and calibration stage of the ET estimation algorithms that move from science for planning and operational.
  - ET will be used in managing; measures water productivity, improving cropping pattern adjustment, increase upstream storage capacity, increase management measures through improving irrigation by irrigation scheduling.
- Modeling Drought and Land degradation Hazards Assessment Risk in Arab Region
  - Drought Production system still requires a multi scale, using calibrated ET and rainfall for long term drought measurements.
  - The Standardized Precipitation-Evapotranspiration Index “SPEI”, fulfills the requirements of a drought index, Satellite data will be used to produce vegetation healthy index and applying other Drought indices as well for hydrological drought studies in the region.
  - Building better understanding for soil moisture using SMAP, the new NASA satellite will provide measurements of the land surface SOIL MOISTURE and freeze-thaw state with near-global revisit coverage in 2–3 days. These measurements will enable science applications users to understand processes that link the terrestrial water beside develop improved drought monitoring capability.
  - AGIR team will use the trend line analysis for measuring land degradation and understanding vegetation degradation
  - Detailed ground validation in different land utilization types is required for better understanding land degradation causes.

- Mapping Regional/National Land Cover Classification on suitable scale.
  - Land cover using FAO Land Cover Classification system (LCCS) is a proposed method to enable interoperability for land-cover data
- Integrating Multiple Regional Hazards Risk Map by combining drought land degradation maps
- Validation for Identifying Hot Spots and Socio-economic Vulnerability
  - Selecting countries for ground truth and validation
  - Validation by Regional Metrological Authorities Networks
  - Reviewing and collecting available data/information concerned with Hazards in Arab States
  - Executing Field Survey and data collecting that include Vegetation Cover Survey and g social and economic studies in cooperation with National/Local Committees
  - Building Regional /National / Local Community Social Vulnerability Maps
- Finalizing Modeling and Mapping guided by validation results
- Establish Early Warning System EWS
- Capacity Building to National Institution
  - National training workshops: ministries of Agriculture and Water beside National Remote sensing centers, and universities with more focus on "how to do"
  - Forming Academic task force from several national universities to work with experts from different science and technology
- Preparing report the report will explain all outputs of the drought modeling and mapping risk assessment as shown in figure (30) beside assess Hazards Impacts on Water, Food and Social Vulnerability Nexus, to address Sustainable development in Arab Region,

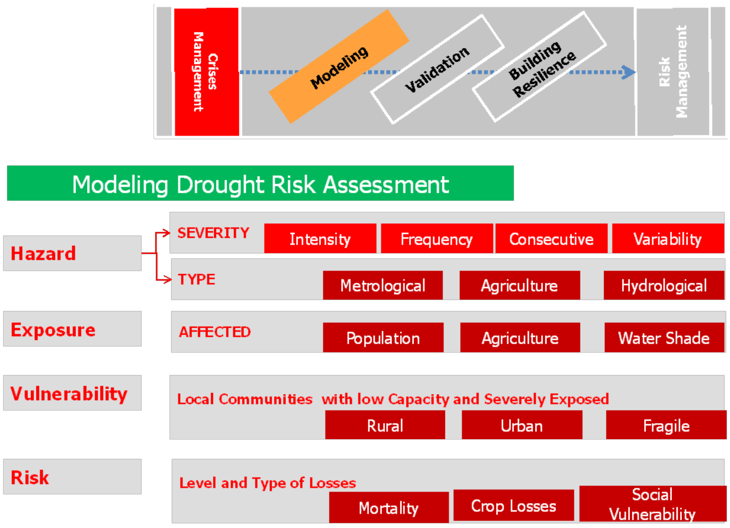


Figure 30.Moving to drought risk management by modeling and mapping drought assessment risk

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