Review of available drought indices

Indices	Method	Application
Percent of Normal	Percent of Normal is a simple method to detect drought. It is calculated by dividing actual precipitation by normal precipitation –typically a 30-year mean and multiplying it by 100% for each location. Data are not normalized.	**Pros:** Percent of Normal is effective in single region or season. **Cons:** Percent of Normal cannot determine the frequency of the departures from normal or compare with different locations. Also, it cannot identify specific impact of drought or the inhibition factor for drought risk mitigation plans.
Standardized Precipitation Index (SPI)	SPI is a simple index which is calculated from the long term record of precipitation in each location (at least 30 years). The data will be fitted to normal distribution and be normalized to a flexible multiple time scale such as 3-,6-,12-,24- 48- and etc .	SPI is used to identify the meteorological drought or deficit of precipitation. **Pros:** SPI can provide early warning of drought and its severity because it can specify for each location and is well-suited for risk management. **Cons:** The data can be changed from the long term precipitation record. The long time scale up to 24 month is not reliable.
Palmer Drought Severity Index(PDSI)	PDSI complexity is calculated from precipitation, temperature and soil moisture data. Soil moisture data has been calibrated to the homogeneous climate zone. PDSI has an inherent time scale of 9 months. PDSI treats all forms of precipitation as rain.	**Pros:** PDSI has been widely used to trigger agricultural drought. PDSI can be used to identify the abnormality of drought in a region and show the historical aspects of current conditions.. **Cons:** The PDSI may lag in the detection of drought over several months because the data depend on soil moisture and its properties which have been simplified to one value in each climate division. The PDSI will not present accurate results in winter and spring due to the effects of frozen ground and snow. PDSI also tends to underestimate runoff conditions.
Palmer Hydrological Drought Index	PHDI has been derived from the PDSI index to quantify the long term impact from hydrological drought.	**Pros:** The PHDI has been officially used by NCDC to determine the precipitation needed for drought termination and amelioration which has a PHDI equal to -0.5 and -2.0 consecutively. It has been used Indiana for drought monitoring. **Cons:** The PHDI is developed from precipitation, outflow, and storage. PHDI may change more slowly than PDSI and it has sluggish response for drought.
Crop Moisture Index (CMI)	CMI is a derivative of PDSI which was developed from moisture accounting procedures as the function of the evapotranspiration anomaly and the moisture excesses in the soil. It also can be present as	**Pros:** CMI is used to monitor crop condition. It is effective for the detection of short term agricultural drought while the Z index determines drought on a monthly scale. It can detect drought sooner than PDSI and PHDI.

	the monthly moisture anomaly or Z index (ZNDX) as a product from PDSI calculation. CMI looks at the top 5 feet of the soil layer.	**Cons:** CMI is limited to use only in the growing season; it can not determine the long term period of drought.
Surface Water Supply Index(SWSI)	SWSI is used for frequency analysis to normalize long-term data such as precipitation, snow pack, stream flow, and reservoir level.	**Pros:** The SWSI is very useful for indicating snow pack conditions in mountain areas to measure the water supplied for community **Cons:** The index of different basins can not be compared with each other and has been computed seasonally. States such as Colorado, Oregon, Montana, Idaho, and Utah have used SWSI.
Reclamation Drought Index (RDI)	The RDI index is similar to the SWSI index. It combines the functions of supply, demand and duration. RDI also combines temperature features and duration in the index.	**Pros:** The RDI is used as the trigger to evaluate drought reclamation plans and to release drought emergency funds. **Cons:** The disadvantage of RDI is the same as the SWSI index. The state such as Oklahoma has used RDI.
Deciles	Deciles have been developed to use instead of percent of normal. Deciles are calculated from the number of occurrences distributed from 1 to 10. The lowest value indicates conditions drier than normal and the higher value indicates conditions wetter than normal.	**Pros:** The deciles index has been used in Australia; it provides accurate precipitation data for drought response. **Cons:** However, it's use requires a long climatology record to accurately calculate the deciles index.
Experimental Objective Blends of Drought Indicators	Drought Blend Indicators are divided into short-term and long-term blends. The short term blend includes PDSI, Z, SPI 1, 3-month, and soil moisture. The long-term blend includes PHDI, SPI 06 12 24 and 60-month, and soil moisture. The drought blend method has been used for US drought monitoring: http://www.drought.unl.edu/dm/monitor.html	In the short-term blend method, the indicators are weighted to the precipitation and soil moisture which use to identify the impacts of no irrigated agriculture, wildfire dangers, top soil moisture, and pasture conditions. The long blend index indicates the impacts of hydrological drought such as reservoir and well levels and irrigated agriculture. The drought indicator used in Drought Monitor provides the most widely used map for drought conditions across United States (and is suitable for Indiana).

Source: *Drought Indices, Michael J. Hayes, National Drought Mitigation Center (http://www.drought.unl.edu/whatis/indices.htm). With modifications by Dev Niyogi and Umarporn Charusambot, Indiana State Climate Office, Purdue University (http://iclimate.org)*

The Standard Precipitation Index
Agricultural/ Meteorological drought is a result of deficient rainfall (precipitation). The SPI (Standard Precipitation Index) has been used to quantify the deficit of precipitation. It can be computed at different time scales from less than 1 month to 48 months or more. The calculation time period depends on the user's application. Short-term SPI can be used to detect agricultural drought, and long-term SPI can be used for water supply management. The SPI value is derived from the inverse value of the cumulative probability function of the observed precipitation distribution. The negative value from zero shows the severity of dryness. The positive value of SPI shows the degree of wetness. The SPI value normally ranges from (-2) – (+ 2). An index of (+2) indicates extremely wet; (1.5) – (1.99) very wet; (1.0) – (1.49) moderately wet; (0.99) – (- 0.99) near normal; (-1.0) – (1.49) moderately dry; (-1.5) – (-1.99) severely dry; (-2.0) or (less) extremely dry. The drought stage indices for Indiana as per SPI changes are as follows:

Stage	SPI Index
Normal	(- 0.99) – (0.99)
Drought Watch	(- 1.0) – (-1.49)
Drought Warning	(- 1.5) – (-1.99)
Drought Emergency	(- 2.0) – (< -2.0)

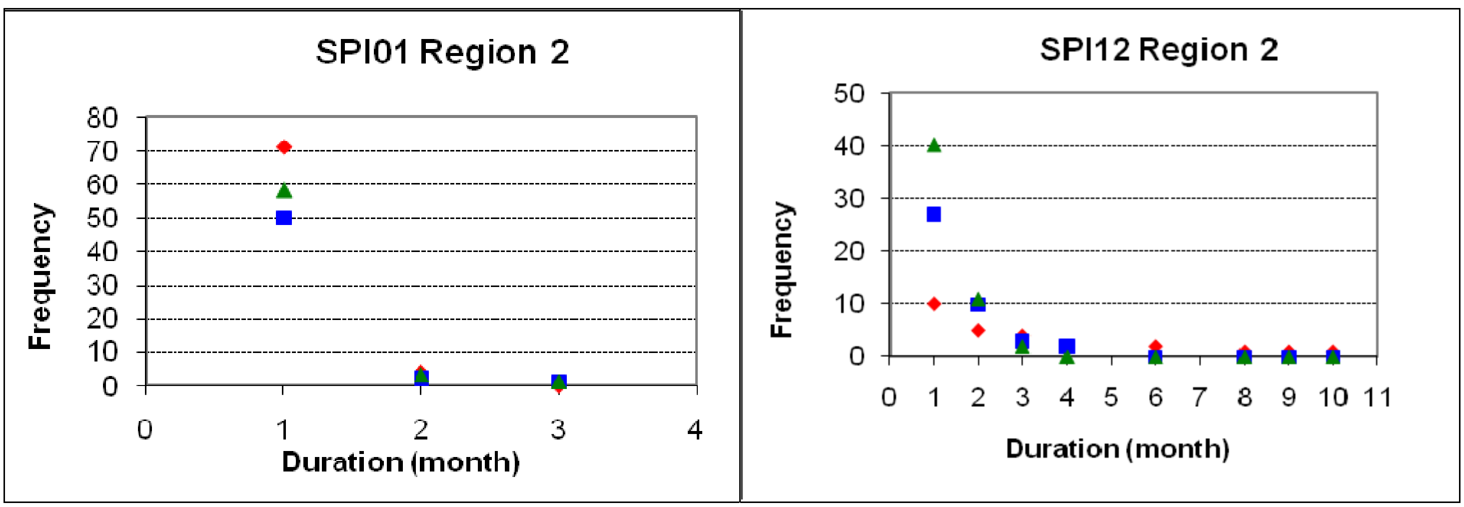
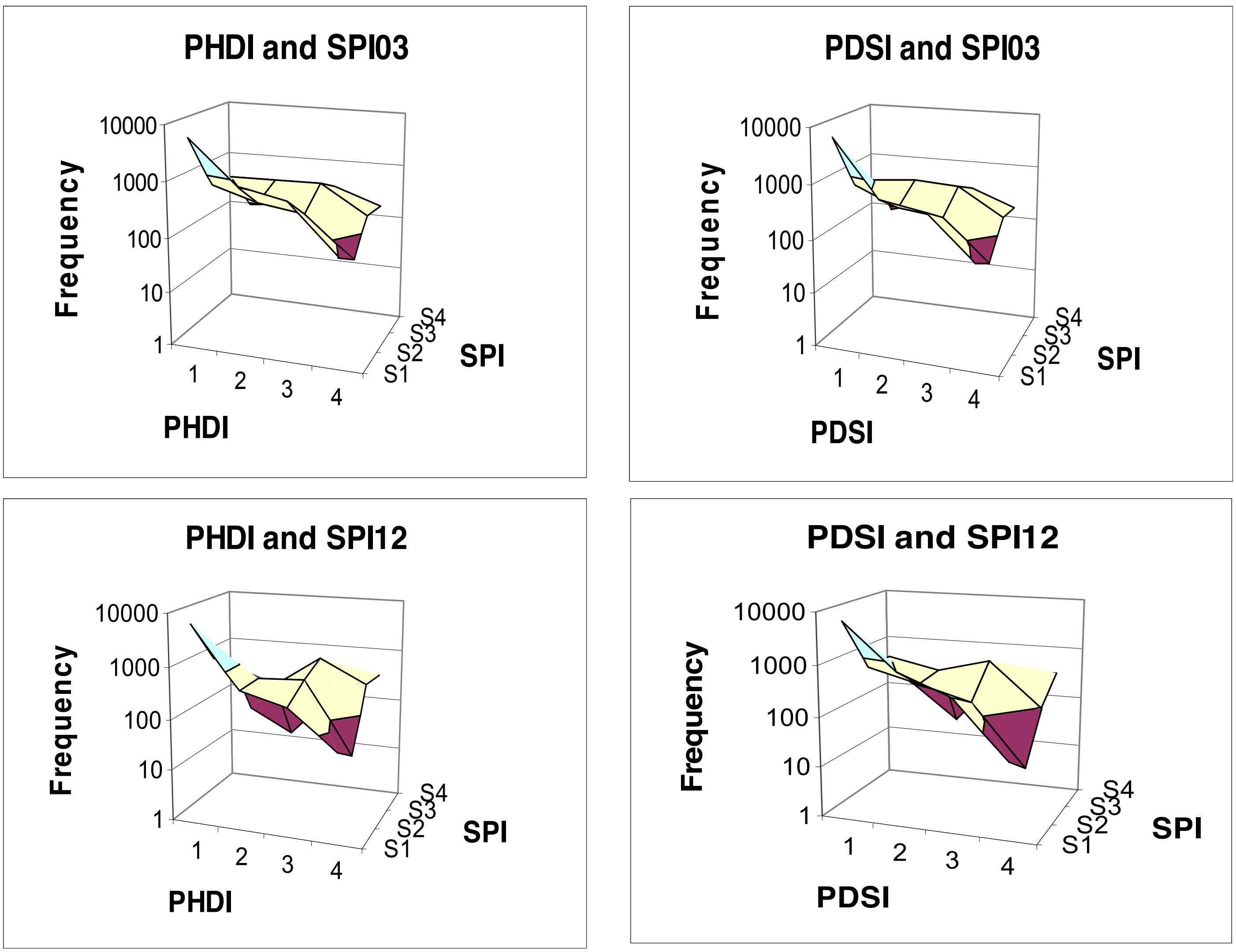


Figure 1 shows the frequency of drought occurrences in Region 2. The figure shows that SPI detects drought emergencies more than the drought watch and/or warning when the time scale of SPI increases; drought warning frequency increases along time period.

The drought indices consider precipitation as the main factor in the drought calculation. Therefore, precipitation monitoring is at the heart of every drought index. All the indices rely on accurate and spatially representative rainfall observations.
Estimation of water loss from evapotranspiration is also useful as it provides the information on effective precipitation available.

Selection of appropriate index
A National Climatic Data Center led study by Guttman (1998) compared the PDSI and SPI indices for drought analysis. The results show that SPI 3 and 6-month lead (phase > 0) and perform better than PDSI. The 12-month SPI shows simultaneously performance as the PDSI. A Indiana drought frequency analysis conducted by the Indiana State Climate Office at Purdue University, summarized in Figure 2 below shows, that 665 events have occurred in which SPI 3-month identifies a drought watch (S2), while PDSI still identifies normal conditions (1) over Indiana. On the other hand, while SPI03 indicates 306 emergency drought events (S4), PDSI still registers this event as a warning drought condition (1). On a 12-month time scale, the slope of consistency between PDSI and PHDI with SPI12 has been increased which means the PDSI and PHDI indices have a higher consistency with SPI when the time scale increases.

Figure 2 shows the PHDI, PDSI and SPI consistency over Indiana



PDSI or PHDI: 1 = Normal, 2 = Watch, 3 = Warning, 4 = Emergency drought condition.
SPI: S1 = Normal, S2 = Watch, S3 = Warning, S4 = Emergency drought condition.

The analysis concludes that over Indiana, SPI 01, 03, and 06 can be used as a trigger for short term droughts (meteorological drought) over PDSI and PHDI. SPI indicates more instances and increased intensity of drought information across all the Indiana climate divisions. In Indiana SPI has been calculated from 32 Cooperative Observer Stations (Figure 3A). Also the SPI can be calculated from the 32km gridded precipitation data as part of the North America Regional Reanalysis (NARR) (Figure 3B).

Figure 3 A: Precipitation stations used to calculate SPI

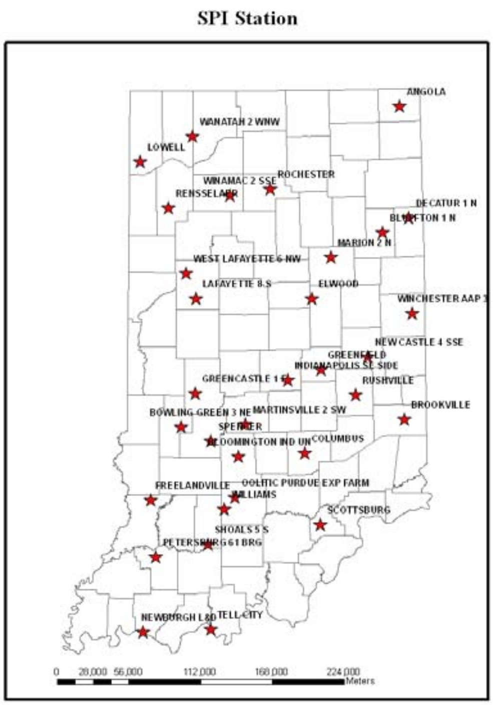
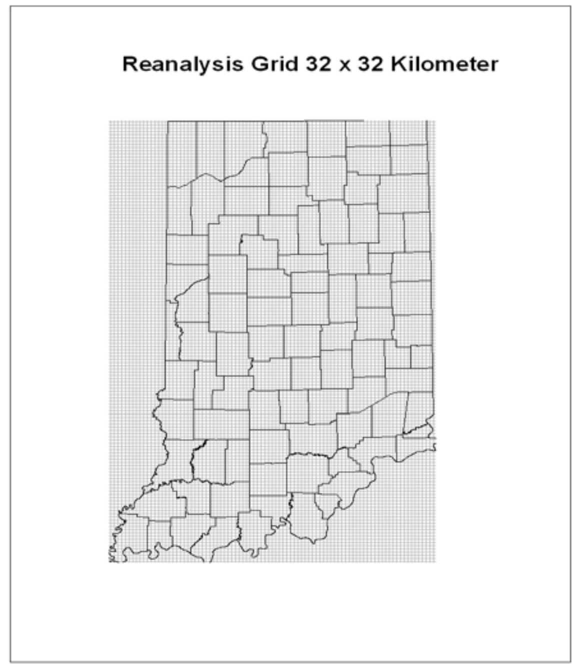


Figure 3B: Precipitation data from Reanalysis grid



Agricultural drought generally considers soil availability to the crop and plant more than the precipitation deficit. The most significant factor for agricultural drought is the soil root zone water holding capacity. Therefore the indicators often used to determine agricultural drought are the CMI and ZNDX indices. However, CMI has limitations due to its calculation consider same soil texture and properties over all climate divisions. In addition, the CMI does not consider the water balance from landuse and landcover. Due to the limitations of CMI, the availability of soil moisture / soil temperature data will assist in using some of the crop indices that may be of interest to agriculture applications. Since SPI is also used in national drought monitoring as well as in neighboring states such as Illinois, the products and assessments made both at the national and regional scales become relevant to the state for determining drought-related actions. Also like any single measure trying to capture the complex nature of drought, SPI will have its limitations. *Therefore SPI is recommended as the drought index for Indiana. This index should be used in addition to the information available from the US drought monitor and input from agencies such as State Climate Office, National Weather Service, United States Geological Services, and other local agencies to accurately assess the threat of drought.*