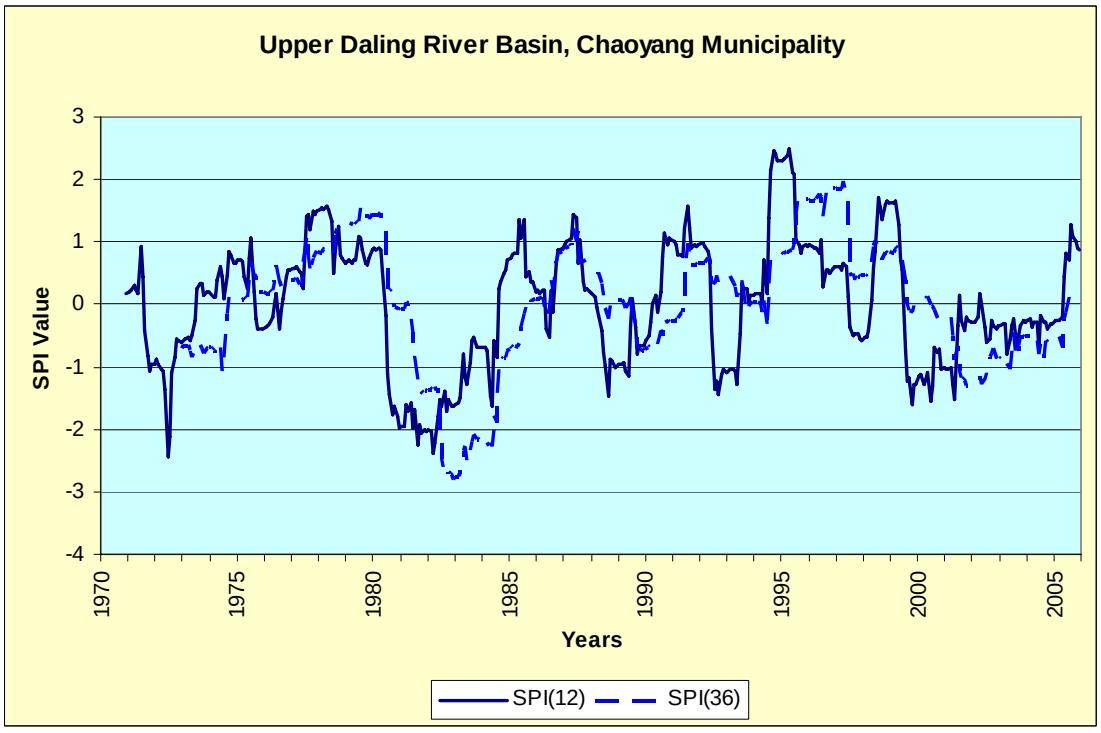
China – UK, WRDMAP
Integrated Water Resources Management Document Series

2. IWRM

Manual 2.5: Using the Standardised Precipitation Index (SPI) to Assess Drought Condition

May 2010



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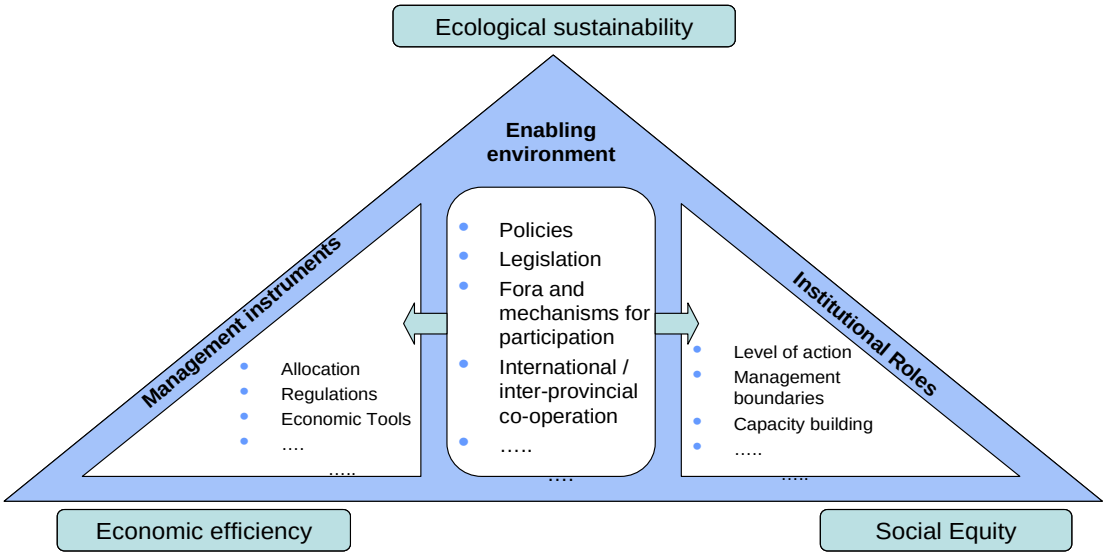
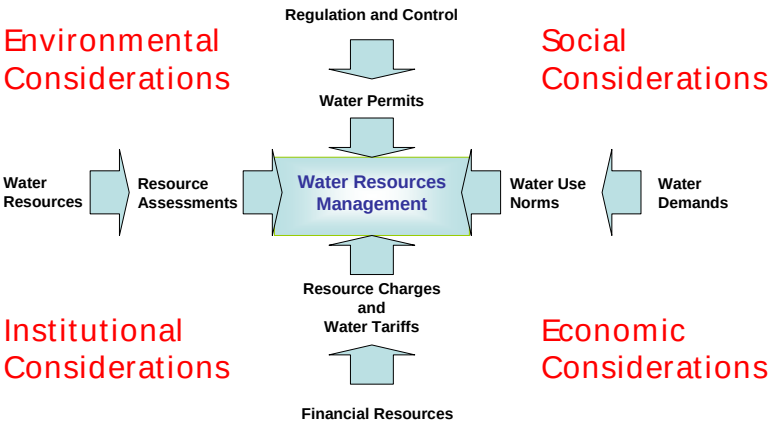
(Basics after Global Water Partnership)



Driving Elements of Integrated Water Resources Management



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Summary: This Manual describes how to use the Standardised Precipitation Index (SPI) method to assess the seriousness of drought conditions. The manual describes how to set up data files and makes suggestions on the presentation of results to inform drought managers. It utilises free software from the National Drought Mitigation Center in the USA.

The document includes sections on:

- SPI and role of indicators in drought management
- Software requirements
- Necessary data
- Input structure
- Running the program
- Presenting results

Examples in this Manual use data from the Upper Daling River Basin in Liaoning Province.

This document is one of a series covering topics on sustainable water resources planning and water allocation. In should be read in conjunction with Thematic Paper 2.5 'Drought Management for Water Resources Managers', Advisory Note 2.5 'Developing a Drought Management Plan – Guidance for Water Resources Managers' and Example 2.5 'Preparation of a Drought management Plan for Chaoyang Municipality, Liaoning Province'.

The Ministry of Water Resources have supported the Water Resources Demand Management Assistance Project (WRDMAP) to develop this series to support WRD/WAB at provincial, municipal and county levels in their efforts to achieve sustainable water use.

1 Introduction

1.1 Role of indicators for operational drought management

Drought is an insidious hazard of nature which originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector.

Operational definitions of drought help people identify the beginning, end, and degree of severity of a drought. The threshold value of an indicator marking the boundary between one drought condition and the next more serious state is often referred to as a 'trigger' because it triggers or initiates actions. Depending on the operational procedures the trigger might initiate an early warning procedure, bring in rotational cuts in supply to conserve water, or take emergency actions to alleviate the consequences of drought.

Operational definitions usually specify the degree of departure from the average of precipitation over some time period. This is usually done by comparing the current situation to the historical average, often based on a 30-year period of record.

The China Meteorological Centre has developed a drought warning system based on three indicators as shown in Figure 1.

1.2 Standardised Precipitation Index (SPI)

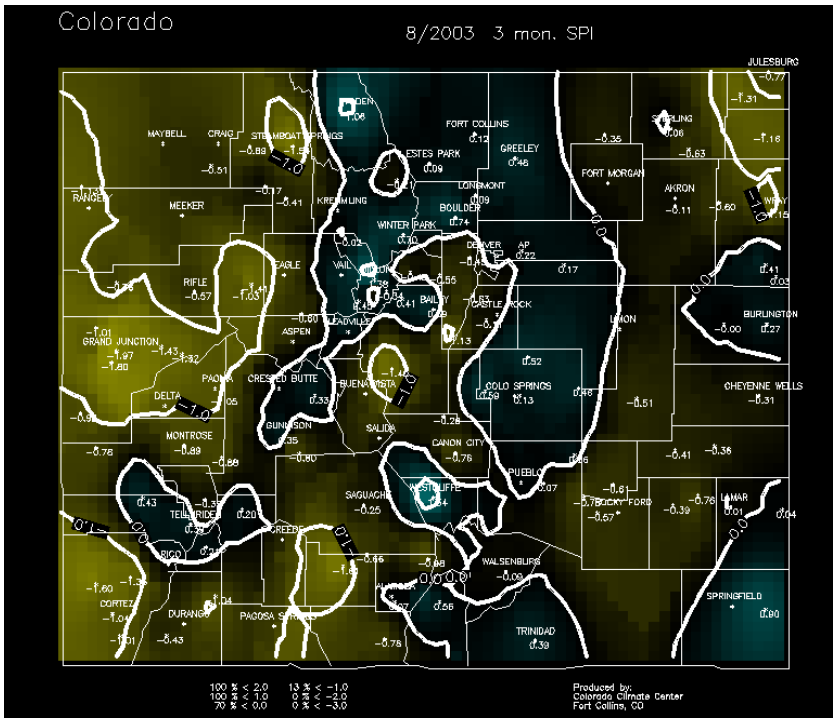
The Standardized Precipitation Index (SPI) was developed in the USA to quantify the precipitation deficit for multiple time scales. These time scales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow, and reservoir storage reflect the longer-term rainfall anomalies.

The SPI calculation for any location is based on the long-term precipitation record for a desired period, eg SPI(24) for 24-months, SPI(18) for 18-months etc.

The authors of the SPI procedure have suggested its use to categorise wet and dry periods as follows:

SPI value for chosen period	
2.0 and above	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and below	extremely dry

The SPI index is widely used for drought monitoring internationally, either on its own or as part of a combined assessment approach. Drought categories may be differently defined in terms of SPI (see Figure 1 for application in China).



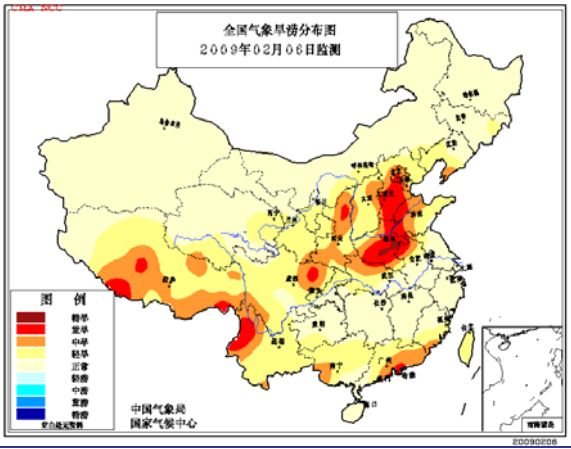
3 month SPI in Colorado state, USA, during May 2003

Figure 1 China drought and flood monitoring

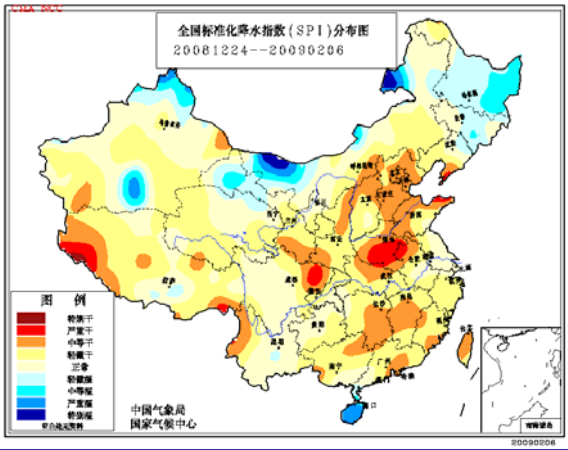
Drought Class	China Index	SPI	Percentage of Precipitation Anomalies (%)
Extreme Drought	CI≤-2.4	-2 and less	< -80
Severe Drought	-2.4 ~ -1.8	-1.5 to -1.99	-80~ -50
Moderate Drought	-1.8 ~ -1.2	-1.0 to -1.49	-50 ~ -25
Slight Drought	-1.2 ~ -0.6	-0.5 to -0.99	-25 ~ 0
No drought	-0.6+	-0.49+	0 +

Example (6th-Feb-2009)

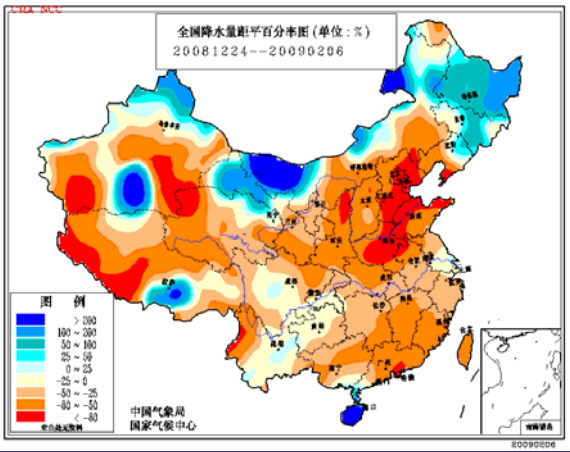
CI



SPI



Percentage of Precipitation Anomalies (%)



Source: China Meteorological Centre http://ncc.cma.gov.cn

2 Requirements

2.1 Software

SPI is available to download from the internet at no cost from the following site:

http://drought.unl.edu/monitor/spi/program/spi_program.htm

The program is already compiled (it was compiled in C++ for PC) so all the user has to do is run the SPI_SL_6.exe file and follow the instructions on the pop up screen.

The fact that this is a compiled program means that the input and output formats cannot be changed by the user. It is necessary to follow the requirements precisely for the program to run successfully.

2.2 Rainfall data

The SPI is usually calculated for monthly periods and therefore uses monthly data. The meteorological station(s) to be analysed should be chosen to be representative of the area being assessed for drought risk.

The quality of the monthly data should be checked for reliability and suitability prior to its use for an SPI analysis.

Long records are desirable because SPI is a statistical approach and long records provide more reliable statistics.

It is recommended that any gaps in individual station records are infilled prior to use in SPI analysis (by using correlation methods for example).

When, as in the Upper Daling example, a number of stations are being used to produce a composite rainfall value for analysis it is important to have an identified procedure for infilling gaps that arise during on-going monitoring of the drought index. Inevitably some rain gauges will not maintain 100% records, or there may be a delay in receiving the latest records from some sites. If a different infilling procedure is used every time the SPI analysis is repeated there is a considerable danger that the analysis will become meaningless.

Box 1 Representative rainfall

In developing drought thresholds or triggers for the Upper Daling River Basin in Chaoyang the hydrologists examined the records of 55 rain gauges and decided upon 30 representative sites with good quality records to use in SPI analysis. The records of these 30 gauges were combined to develop a single monthly series representing the historical rainfall pattern over the whole upper basin.

2.3 Input File Structure

Once approved for use the monthly data must be prepared in a specific format to run with the SPI software.

All input files must follow 3-column format: Year, Month, and Monthly Precipitation Value (see sample input files). The precipitation total must NOT include decimals.

Special attention must be paid to ensure ease of use and avoidance of unnecessary troubleshooting. Pay attention to column spacing and missing data issues. A missing data flag of -9900 will be read in but will introduce errors in the analysis.

3 Running the SPI Program

The input data file name must have the last 4 characters as ".COR" – the SPI program will not recognise any other file extension. The length of file name is not restricted, but the name must not contain any spaces, use of underscore (_) is also not allowed.

Acceptable file names could be "UpperDaling1970-2005.COR" or "Chaoyang.COR".

When using the program to assess thresholds an input file name like "UpperDaling1970-2005.COR" shows the period used to define the statistics. However, when using the SPI program as part of routine drought monitoring each successive month analysed has new data added to the data set and therefore the input file name might be chosen to show which month is the most recently added eg "UpperDaling1970-2009Feb.COR" as the data file for a program run completed in March 2009.

Care is needed when carrying out series of calculations for routine monitoring that file names are well organised or else different sub-directories are used for different sets of calculations.

The data files should be edited using either Notepad or Wordpad. The easiest way to set up a new data file is usually to select an existing data file, edit it, and then save under a new name.

Set up a directory with the SPI executable program file and at least one ".COR" file in it:

From Windows Explorer select the SPI_SL_6.exe file and click OPEN to start the program running.

The program runs in a separate window. Firstly, the program prompts the user for the number of n-month calculations wanted. If the answer is '2' the program will request the period 'n' of the first n-month period eg 3 for a SPI(3) analysis, and then the second 'n'.

The program then prompts the user for the name of the input data file. Type in the name and press Enter.

The program then prompts the user for the output file name to be used. As with input data file naming conventions spaces and underscore symbol should be avoided. One way to organise output files is to use the same name as the input file BUT with a different 4 character extension such as ".OUT". (The extension must not exceed 4 characters including the full stop or period symbol). It is recommended that the user keeps to an organised structure for files and sub-directories when keeping the results of routine monitoring runs.

Once the user has given the output file name the program automatically opens an output file with this name. The screen will clear almost instantly as the program takes only seconds to run.

The ".OUT" file can be opened with Notepad or Wordpad and printed (if required, note that the output can often take many pages to print).

A point to note is that the SPI program output is rather unhelpful: no record is included to show what n-periods the user chose for the run, and the information is presented without column headings. This makes keeping good notes and having a well organised file naming and sub-directory structure all the more important.

Examples of Input File and Run Time Screen

Figure 2 Layout for SPI input data file (Opened with Notepad)

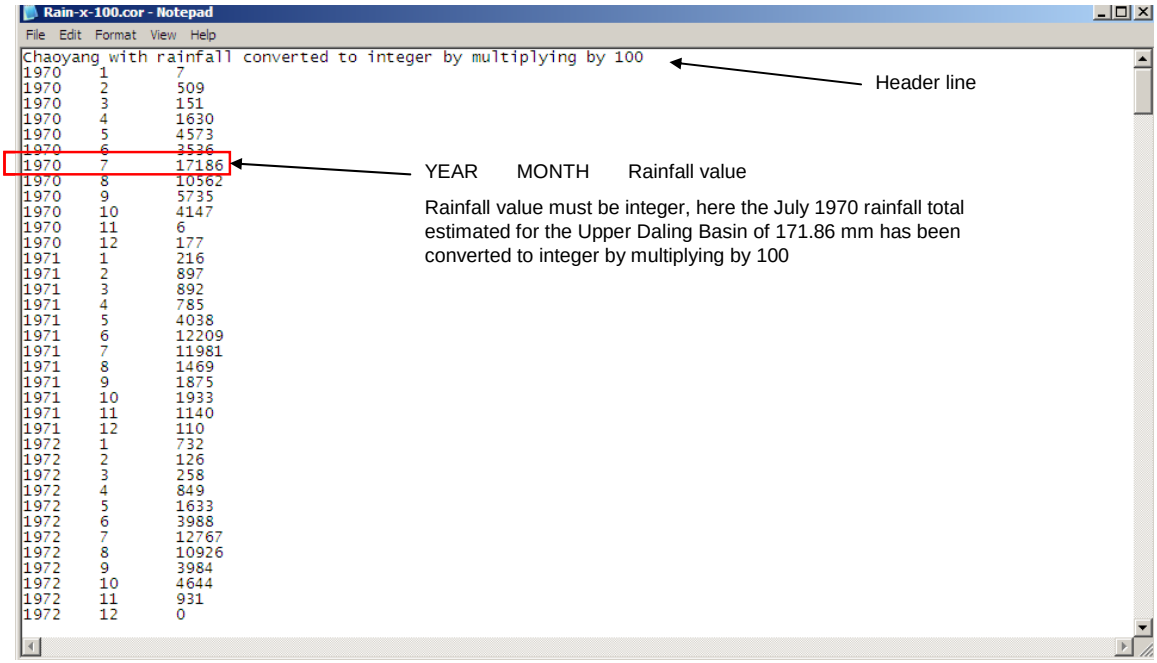
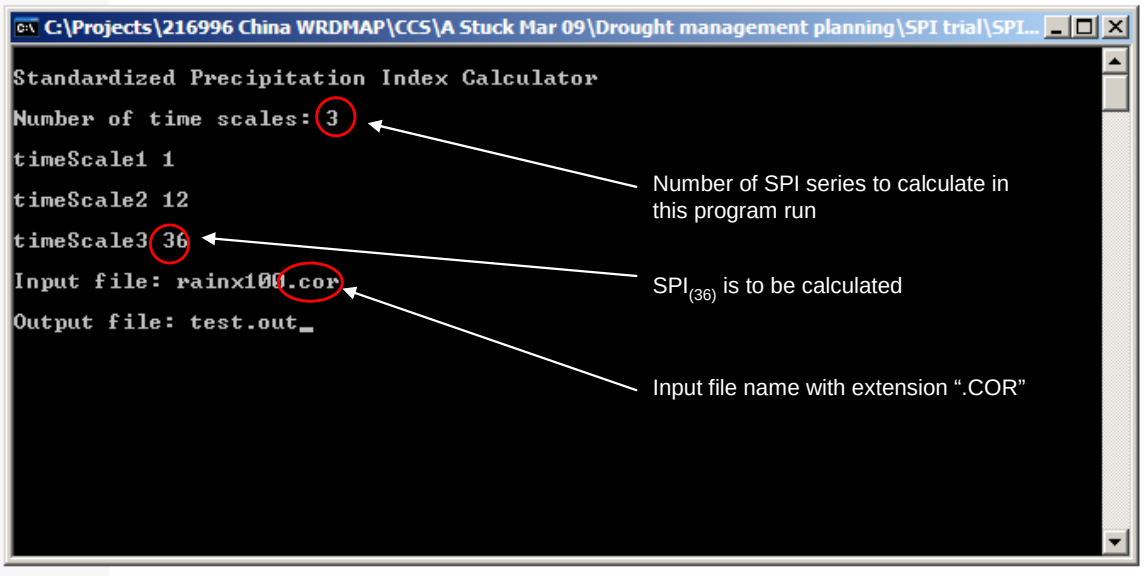


Figure 3 SPI screen view at run time



4 Presentation and Use of SPI Series

As noted above the standard output from the SPI program is not very helpful and there is usually a need to undertake some further procedures in order to provide the results in a format which can be presented to drought managers.

To obtain a graph of the variability of SPI values over time, or to use the SPI values in a further calculation – for example to create a composite index based on more than on SPI series, the user may wish to transfer the results into Excel. To do this, open Excel. Then using the File Open command select the ".OUT" file (remember to look for "All file types"). Excel will then open the file import wizard.

The following examples demonstrate possible ways of presenting the results of SPI analysis.

Examples of Possible Output Presentation

Figure 4 Layout of standard SPI output (Opened with Notepad)

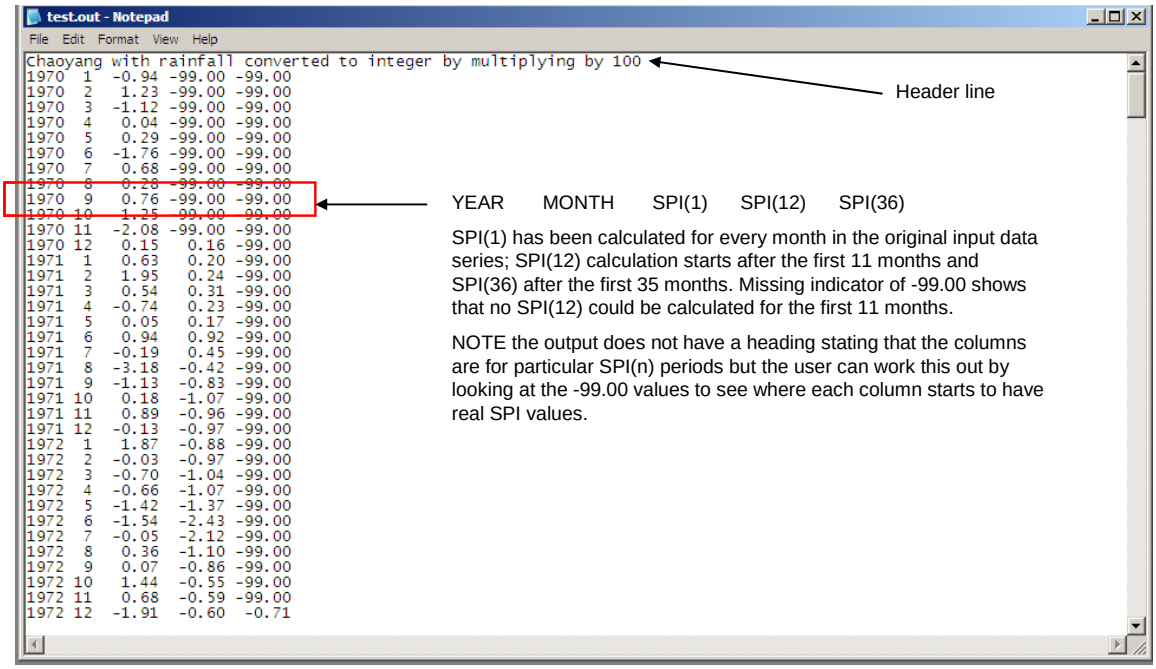


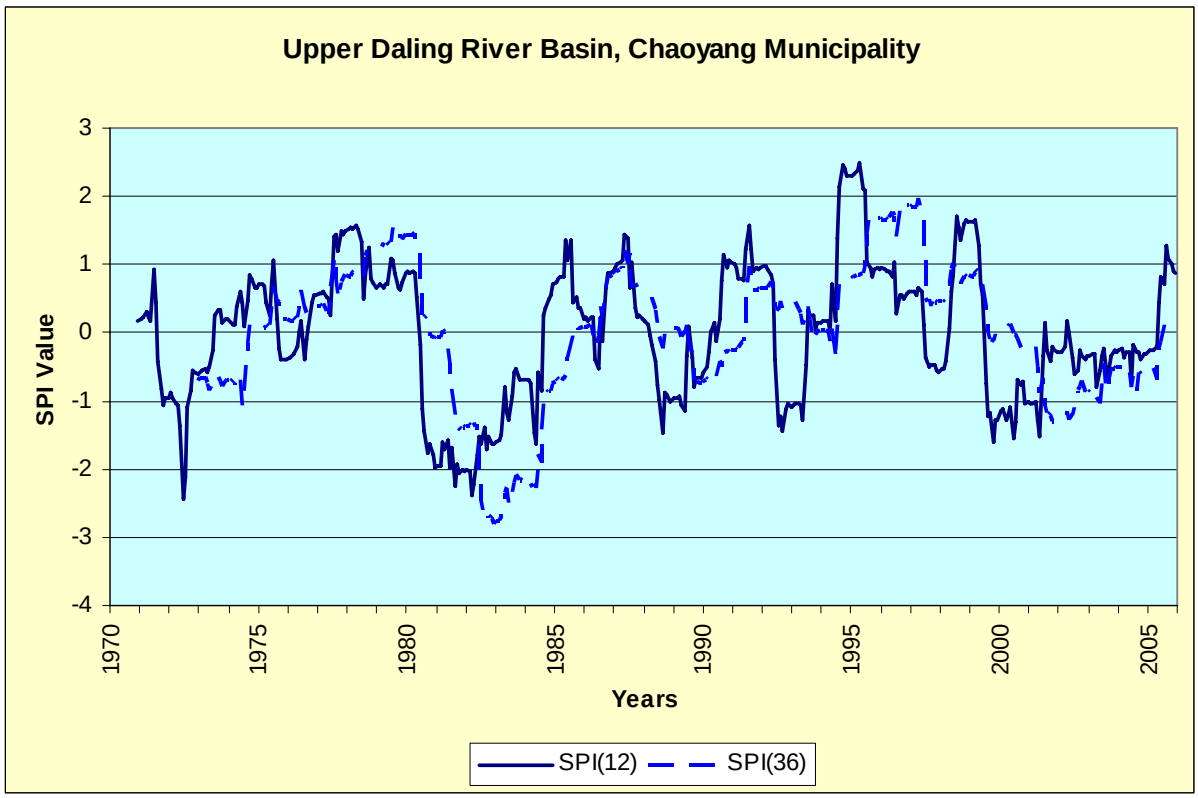
Figure 5 Example of Composite SPI Index for Routine Drought Assessment to Trigger Action based on Drought Management Plan (Prepared using Excel)

Drought Classification by the SPI Method

Year	1980											
Month	1	2	3	4	5	6	7	8	9	10	11	12
Rainfall (mm)	1.8	2.4	4.2	10.0	13.3	63.7	87.4	75.6	12.0	20.8	0.6	3.4
SPI - This Month	0.56	0.43	-0.19	-0.57	-1.70	-0.64	-0.82	-0.47	-1.71	0.26	-1.22	0.61
$SPI_{(3)}$ - 3 Months	1.76	2.06	-0.13	-0.70	-1.85	-1.59	-1.38	-1.25	-1.34	-1.07	-1.64	-0.17
$SPI_{(6)}$ - 6 Months	-0.02	0.25	0.53	0.47	-0.93	-1.67	-1.58	-1.63	-1.88	-1.75	-1.65	-1.38
$SPI_{(12)}$ - 12 Months	0.87	0.85	0.88	0.86	0.54	-0.16	-1.12	-1.35	-1.74	-1.64	-1.80	-1.96
$SPI_{(24)}$ - 24 Months	0.92	0.92	0.90	0.93	0.73	0.57	0.01	-0.30	-0.62	-0.59	-0.59	-0.55
$SPI_{(36)}$ - 36 Months	1.47	1.47	1.45	1.51	1.32	1.15	0.24	0.21	0.19	-0.07	-0.10	-0.14
Combined SPI = $SPI_{(12)}$*0.6+$SPI_{(24)}$*0.3+$SPI_{(36)}$*0.1	0.95	0.93	0.94	0.95	0.68	0.19	-0.65	-0.88	-1.21	-1.17	-1.27	-1.36
Drought Severity Class					IV	III	II	II	I	I	I	I

Description of Conditions:
Severe drought occurred in Chaoyang during this year, particular in Chaoyang City and Beiping with extreme drought.
The annual rainfall was only 333 mm in Chaoyang, which was less 153 mm than normal year.
There were more than 7.00 million mu of cropping field irrigated by manually water collection, including 2.51 million mu of cropping field was cropped two times and 510,000 mu of field was cropped three times. The cropping field of 1.30 million mu had no harvest, and 2.50 million mu with little yield.
The work of planting was not end until July 15.
Most of rivers and streams, lakes, reservoirs and wells were in dry. There was no water available to the population of 200,000.

Figure 6 SPI for Upper Daling River Basin (Prepared using Excel)



Document Reference Sheet

Glossary:

SPI	Standardised Precipitation Index

Bibliography:

SPI Program Files. National Drought Mitigation Center at the University of Nebraska–Lincoln. http://drought.unl.edu/monitor/spi/program/spi_program.htm

Colorado Climate Center. Fort Collins, Colorado, USA

Related materials from the MWR IWRM Document Series:

Thematic Paper 2.5	Drought Management for Water Resources Managers
Advisory Note 2.5	Developing a Drought Management Plan – Guidance for Water Resources Managers
Example 2.5	Preparation of a Drought Management Plan for Chaoyang Municipality, Liaoning Province, Focused on Water Resources

Where to find more information on IWRM – recommended websites:

Ministry of Water Resources: www.mwr.gov.cn

Global Water Partnership: www.gwpforum.org

WRDMAP Project Website: www.wrdmap.com

China – UK, WRDMAP

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