Article

A study on drought and wet conditions in different basins and climates

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Abstract: The Surface Water Supply Index (SWSI) may be considered for studying hydrologic conditions and agricultural water management. By using this indicator, water resources conditions of Colorado and Oregon basins were investigated from extremely wet to extreme drought. The SWSI values can also be plotted as a time series graph while critical years were specified. This allows the user to graphically visualize the values from year to year and to see how the current year's values change from year to year. Managers can then refer to records from critical years in determining strategies for dealing with the current years' water supply. Also evident is whether the streamflow component or the reservoir component is the predominant driving force at any given time. SWSI's can be an excellent water management tool in determining overall risk and management strategies. It gives the water user and manager more information than simply streamflow or reservoir level alone. According to the results, obtained categories based of SWSI values are indicated hydrologic conditions for Colorado and Oregon States with two different climates. Although decisions only based on geographic and climatic information due to the insufficient and sometimes contradictory results than the SWSI can cause water loss or increase the risk of drought.

Keywords: Colorado; Oregon; water

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1. Introduction

Scrutiny of hydrologic parameters especially SWSI for water resources management and estimating of flood and drought periods for prevent of their damages has always been concern of hydrologists. Garen [1] revised SWSI for Western United States. He suggested that indexes for individual hydrologic components be developed to provide supporting information to the SWSI. Shafer and Dezman [3] developed SWSI to assess the severity of drought conditions in snowpack runoff areas. Hoekema and Sridhar [2] using surface water supply and soil moisture indices related climatic attributes and water resources allocation in the Snake River basin, Idaho. The results indicates that the decline in midseason and late season diversions is mostly caused by decreasing supply in the study period, while a comparison of diversions to Palmer index and the standardized precipitation index indicates that early season diversions are highly correlated to early season moisture anomalies. Unfortunately, much research has not been done on SWSI and role of surface water supply index has not been considered in other studies about water resources management [4-16]. Therefore, necessity of this study is specified.

2. Materials and Methods

The surface water supply index (SWSI) is a predictive indicator of total surface water availability within a watershed for the spring and summer water use seasons as follows:

$$SWSI= (aPNsnow+bPNprec+cPNstrm+dPNresv-50)/12 \qquad (1)$$

Where a, b, c, and d are weights for each component and must meet the condition a+b+c+d=1. Each basin has a unique a, b, c, and. PN shows probability of non-exceedance (%) and snow, prec, strm, and resv refer to snowpack, precipitation, streamflow, and reservoir componens, respectively. The revised formulation of the SWSI as follows:

$$SWSI= (PNfcst+resv-50)/12 \qquad (2)$$

Where fcst refer to streamflow forecast.

SWSI values are scaled from +4.2 (abundant supply) to -4.2 (extremely dry) with a value of zero (0) indicating media water supply as compared to historical analysis. SWSI used especially where palmer drought index does not adequately reflect conditions in snow-dominated regions.

Colorado is the U.S. state that encompasses most of the Mountains as well as the northeastern portion of the Colorado Plateau and the western edge of the Great Plains. Abundant sunshine and low humidity typify Colorado's highland continental climate. Winters are generally cold and snowy, especially in the higher elevations of the Rocky Mountains. Summers are characterized by warm, dry days and cool nights. The climate of Colorado is more complex than states outside of the Mountain States region. Unlike most other states, southern Colorado is not always warmer than northern Colorado. Most of Colorado is made up of mountains, foothills, high plains, and desert lands. Mountains and surrounding valleys greatly affect local climate.

Oregon is a state in the Pacific Northwest region of the United States. It is located on the Pacific coast, with Washington to the north, California to the south, Nevada on the southeast and Idaho to the east. Oregon’s climate can mostly be classified as mild. Two major geographic features dominate the climate in the state: the Pacific Ocean and the Cascade Range.

Figure 1 shows Colorado and Oregon States with their basins.

3. Results and Discussion

In order to study the hydrologic condition of Colorado and Oregon basins, the SWSI values were divided into the 11 different categories (Table 1). The average SWSI values of Colorado states shows that this state is wet, of hydrologic conditions (only one basin has the SWSI less than zero). Unlike this state, the Oregon state hydrologic conditions can be evaluated as dry according to the average SWSI values (only one basin has the SWSI more than zero). Due to the mild climate of Oregon, extremely wet and extreme drought hydrologic conditions not observed in any of this state’s basins. Even percent of very wet and severe drought hydrologic conditions were very lower than other hydrologic conditions. But in Colorado state due to the continental climate role of very wet and severe drought categories were significant. To better assess of the hydrologic conditions can be used from Figures 2 and 3.

In Gunnison basin, mild drought condition is dominant. In Colorado, Arkansas, San Juan, Animas, Dolores, and San Miguel basins hydrologic condition is near normal. Hydrologic condition in Yampa, White, and North Platte is moderate drought. This basin has the lowest average SWSI among Colorado basins (Table 1). Thus, Gunnison, Yampa, White, and North Platte basins due to the more probability of drought exceedance should be in priority of water resource allocation, terms of the management. Finally, in South Platte and Rio Grande basins hydrologic condition is very wet and slightly wet, respectively. So, preventive measures are necessary to prevent flooding in South Platte basin. In particular, it has the largest catchment area among of Colorado basins along Arkansas basin (Figure 1). It is noteworthy amount of average SWSI in South Platte basin is maximum (Table 1) whereas climate of the eastern Colorado (South Platte and Arkansas basins) is semi-arid with low humidity and moderate precipitation, usually from 380 to 630 mm annually. Therefore, the climate alone cannot reveal the hydrologic conditions. As geographic information alone is not a criterion for hydrologic judgment:

Northeast, east, and southeast Colorado (South Platte and Arkansas basins) are mostly the high plains, while northern Colorado (North Platte basin) is a mix of high plains, foothills, and mountains. Northwest and west Colorado (Yampa, White, and Colorado basins) are predominantly mountainous, with some desert lands mixed in. Southwest and southern Colorado (Gunnison, Rio

Grande, San Juan, Animas, Dolores, and San Miguel) are a complex mixture of desert and mountain areas.

According to the Figure 3 in North Coast, South Coast, Willamette, Lower Deschutes, Umatilla, Upper John Day, Harney, Grande Ronde, Rogue, and Umpqua basins hydrologic condition is near normal. In Klamath, Lake, Owyhee, Malheur basins hydrologic condition is mild drought. These basins have the lowest average SWSI among Oregon basins (Table 1). Thus, these basins due to the more probability of drought exceedance should be in priority of water resource allocation, terms of the management. Finally, in Upper Deschutes basin hydrologic condition is slightly wet. It is noteworthy amount of average SWSI in this basin is maximum among Oregon basins (Table 1).

The effect of geographic condition on climate is very more than hydrology in this state. The mountains of the Cascade Range act as a divide between the western and eastern sides of the state. The Cascade Range separates the state into two broad climatic zones: the western third (North coast, Willamette, South Coast, Rogue, and Umpqua basins), with relatively heavy precipitation and moderate temperatures, and the eastern two thirds (Other basins), with relatively little precipitation and more extreme temperatures. Within these general regions, climate depends largely on elevation and land configuration. West of the Cascade Range, winters are relatively mild and wet, with precipitation usually falling as rain in the lower elevations. The area's proximity to the Pacific Ocean means that temperatures are moderated and significant moisture comes from the Ocean. Areas along the coast and in the Coast Range can receive upwards of 500 cm of rain annually, most of which falls from October to March. The Willamette Valley, home to about 70% of the state's population, receives about 100-130 cm of precipitation annually. East of the Cascade Range, temperature is less moderated by the Pacific Ocean. Central Oregon is kept dry year-round by the rain shadow created by the Cascade Range, though most of the light precipitation that it does receive also falls between October and March. Temperatures vary more substantially in the central and eastern side of the state. The abundance of clear and calm nights allows the temperature to drop significantly at night, but temperatures can climb to well over 40 °C in the daytime.

According to the mentioned cases, obtained categories based of SWSI values are indicated hydrologic conditions for Colorado and Oregon States with two different climates. Although decisions only based on geographic and climatic information due to the insufficient and sometimes contradictory results than the SWSI can cause water loss or increase the risk of drought.

Conflicts of Interest: The authors declare no conflict of interest.

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Table 1. Average SWSI values and role of each category (percent) in Colorado and Oregon basins

Colorado Basins	Average	Extremely Wet	Very Wet	Moderately Wet	Slightly Wet	Incipient Wet	Near Normal	Incipient Dray Spell	Mild Drought	Moderate	Severe Drought	reme
		SWSI	3<S	2<SW	1<S	0.5<S	-0.5<SW	-1<SWS	-2<SW	-3<SW	-4<SW	S
Gunnison	0.4	0.0	11.7	14.4	15.0	9.4	11.9	6.9	18.3	9.7	2.5	0
Colorado	0.4	0.0	11.7	15.8	14.2	5.6	17.2	7.8	13.9	11.1	1.7	0
South Platte	1.5	0.0	23.9	21.4	21.1	9.4	11.1	6.7	5.0	0.8	0.6	0
Yampa, White, and rth Platte	-0.1	1.1	12.5	11.1	8.3	6.4	13.3	6.4	14.4	16.4	9.7	0
Arkansas	0.5	0.3	9.4	17.2	13.1	8.9	21.4	8.3	15.0	6.1	0.3	0
Rio Grande	0.4	0.3	9.4	15.6	18.9	8.9	16.7	6.7	10.3	6.7	6.7	0
San n, Animas, Dolores, San Miguel	0.3	0.0	10.3	15.0	15.8	7.2	17.5	6.1	14.4	8.9	3.6	1
Oregon Basins												
North Coast	-0.2	0.0	0.0	1.7	16.4	9.7	31.1	15.6	18.1	6.7	0.8	0
South Coast	-0.1	0.0	0.0	4.2	18.6	9.4	27.5	16.1	16.9	6.4	0.8	0
Willamette	-0.1	0.0	0.0	4.7	18.9	14.2	26.4	10.6	16.1	9.2	0.0	0
Rogue and Umpqua	0.0	0.0	0.0	5.3	22.8	11.9	26.4	8.6	14.4	6.1	4.4	0
Lower Deschutes	-0.1	0.0	0.8	1.9	19.7	15.8	23.3	8.9	18.1	9.7	1.7	0
Upper Deschutes	0.1	0.0	0.0	9.2	19.4	15.6	19.2	8.6	19.2	8.6	0.3	0
Klamath	-0.4	0.0	1.1	6.7	15.8	9.7	15.3	8.1	25.3	15.6	2.5	0
Lake	-0.2	0.0	0.0	5.8	20.3	11.1	17.5	10.6	22.2	11.7	0.8	0
Umatilla	-0.3	0.0	0.0	3.9	16.9	11.1	25.6	11.4	16.1	14.7	0.3	0
Upper John Day	-0.1	0.0	0.0	2.5	21.4	12.8	24.7	11.1	20.6	6.7	0.3	0
Harney	-0.2	0.0	0.0	7.2	17.2	8.1	22.8	12.8	22.2	9.2	0.6	0
Grande Ronde	-0.3	0.0	0.0	6.1	17.5	9.4	20.6	11.9	18.3	15.3	0.8	0
Owyhee	-0.4	0.0	0.0	2.5	17.5	12.5	16.9	10.6	27.8	10.3	1.9	0
Malheur	-0.4	0.0	0.0	3.3	17.8	11.7	20.8	7.2	23.6	14.7	0.8	0

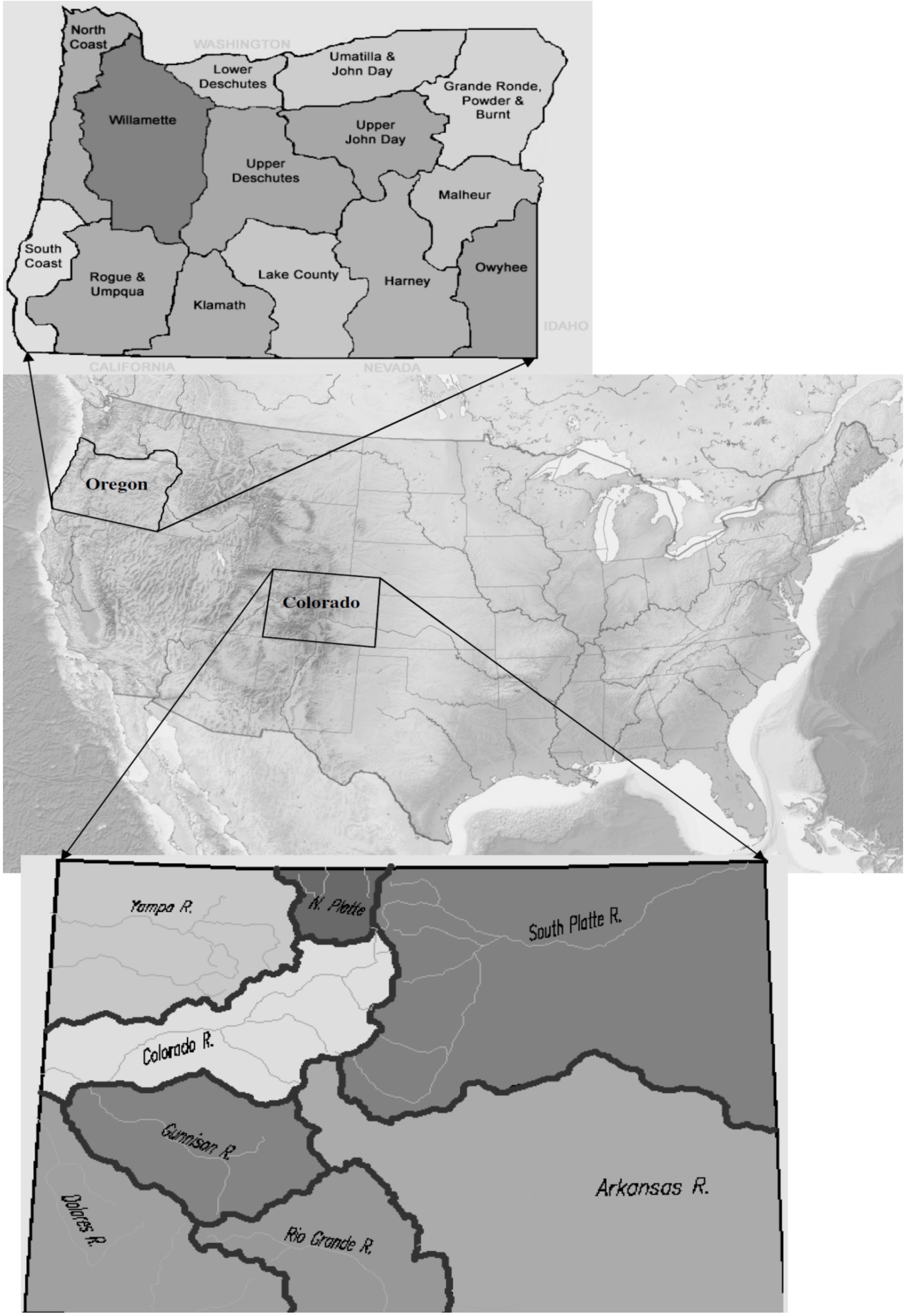

Figure 1. Location of Colorado and Oregon states and their basins in United States

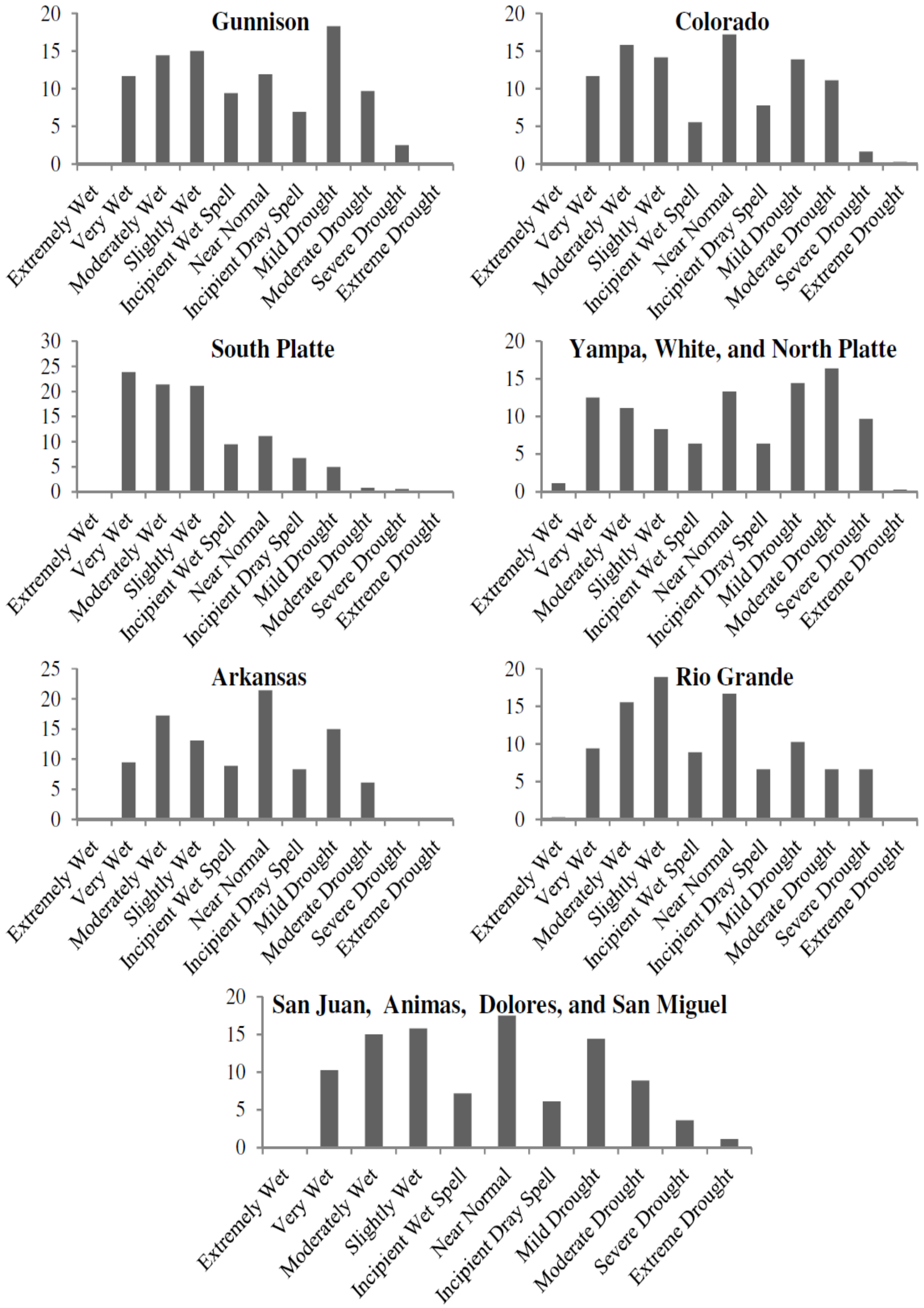

Figure 2. Hydrologic conditions of Colorado basins based on contribution of each category (percent) calculated by dividing number of the SWSI in each category to all data

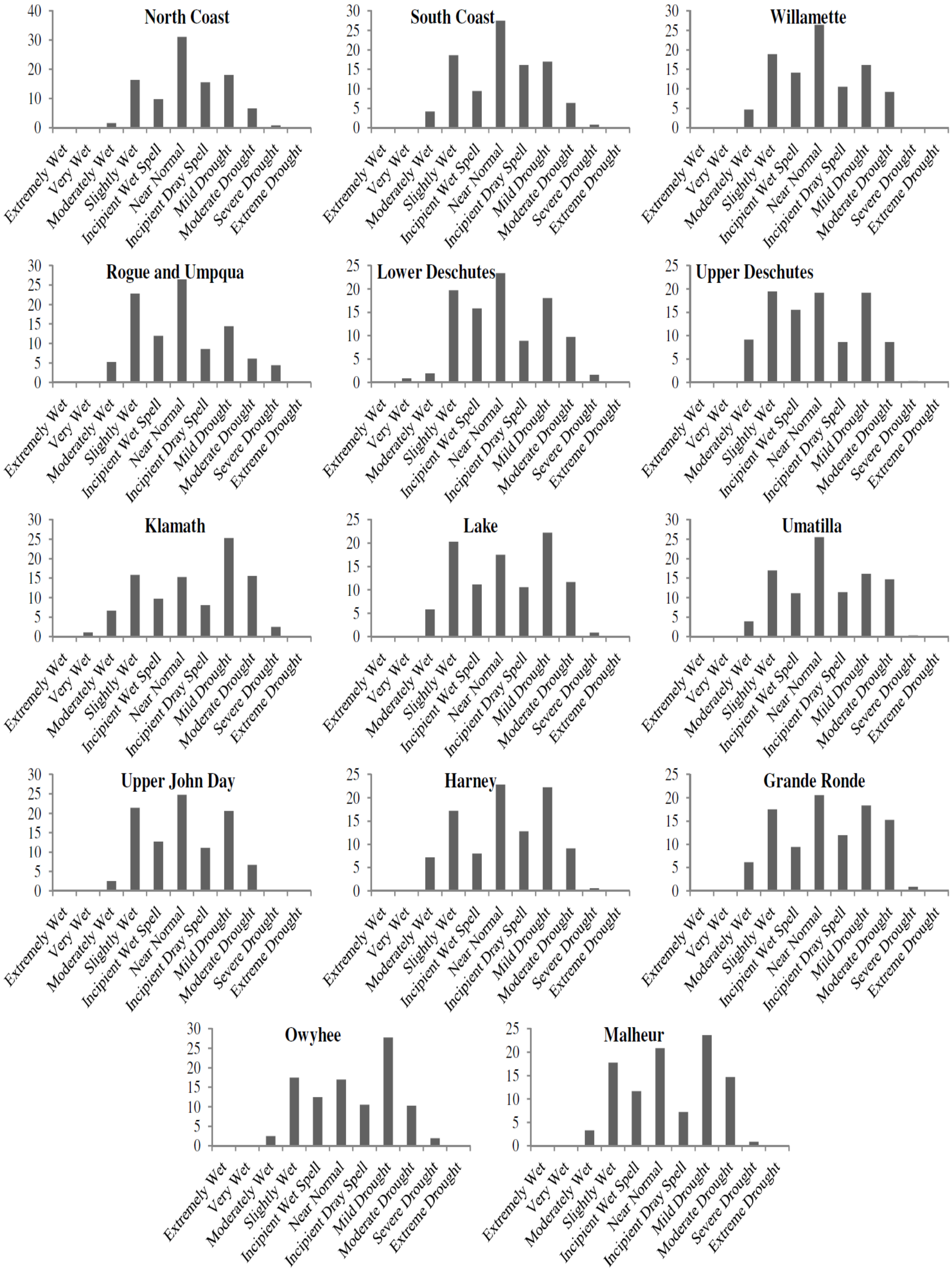

Figure 3. Hydrologic conditions of Oregon basins based on contribution of each category (percent) calculated by dividing number of the SWSI in each category to all data