Hydrological Drought Index Based on Traditional Pasten System

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Abstract

Drought is a natural disaster that threatens life and cause enormous damage. Report of the Intergovernmental Panel on Climate Change states that the world is more vulnerable to drought in the next 25 years, and climate projections indicate that this will get worse in the future. An important component of a national drought strategy is a comprehensive drought monitoring system which can give warning at the beginning and end of the drought, determine the severity, and disseminating information on various sectors, especially agriculture, public water supply, energy, and health. Such a monitoring system needs a drought index, which is a variable for assessing the effect of a drought, and defining different drought parameters, to detect and evaluate occurrence of droughts.

Drought generally classified into meteorological drought, hydrological drought, agricultural drought, and socio-economic drought. Hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. At present no hydrological index has been developed and applied in Indonesia.

This paper describes the development of a hydrological drought index for Indonesia, using indicator of traditional pasten, or its modern derivative Faktor-K indicating the ratio between water supplied available and the corresponding water demand in an irrigation system.

Since long time ago, early in the colonial Dutch era, farmers in Indonesia already cultivate rice in the same way as nowadays. The allocation of irrigation water for sugarcane, rice and palawija is planned and monitored using the pasten system to achieve a fair distribution. At present the farmers still practice the pasten system, and the data on water demand and supply is available on most irrigation diversions. It is expected that a hydrological drought index using the easily available data at the farmer level that have been practiced for centuries in Indonesia, can be developed and applied for drought monitoring and water allocation. Preliminary results using this pasten system with the statistical theory of run, indicate that this index is highly correlated with the occurrence of drought in the northern parts of Central Java.

Keywords: drought, drought index, water allocation, irrigation, indigenous, traditional, pasten,

1 Introduction

1.1 Background

Drought is a natural disaster that threatens life and cause enormous damage. Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) states that the world is more vulnerable to drought in the next 25 years, and climate projections indicate that this will get worse in the future. An important component of a national drought strategy is a comprehensive drought monitoring system which can give warning at the beginning and end of the drought, determine the severity, and disseminating information on various sectors, especially agriculture, public water supply, energy, and health. Such a monitoring system needs a drought index, which is a variable for assessing the effect of a drought, and defining different drought parameters, to detect and evaluate occurrence of droughts.

Drought generally classified into meteorological drought, hydrological drought, agricultural drought, and socio-economic drought. Hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system.

Hydrological drought index is an important tool in water allocation and drought management. At present no hydrological index has been developed and applied in Indonesia.

1.2 Objective

This paper describes the development of a hydrological drought index for Indonesia, using indicator of traditional pasten, or its modern derivative Faktor-K indicating the ratio between water supplied available and the corresponding water demand in an irrigation system.

2 Research problems

2.1 Problem Formulation

Hydrological drought index might consist of several indicators, for examples: rainfall, river discharges, water level in lakes and reservoirs, groundwater level, and other data on water availability and water demands. As hydrological drought is more oriented toward the deficiency of water to supply the demands, a hydrological drought index containing status of demand fulfillment would be an advantage. In Indonesia the water in traditional irrigation system is allocated using factor-k, the ratio between water supply and water demand. It is a challenge to use the traditional factor-k into a hydrological drought index.

2.2 Hypothesis

The hypothesis of the research is that the hydrological drought based on traditional factor-k can represent hydrological drought condition.

2.3 Research Question

This paper discusses the possibility of developing a hydrological index based on traditional pasten system, or factor-k. The research question is: can the index to be used as tools to evaluate different kind of drought?

2.4 Methodology

The new drought index based on traditional pasten system is developed, and tested using k-factor data from the Pemali-Comal river basin territory in Northern part of Central Java. The result is compared with conventional hydrological drought index and the common well known fact on recent drought.

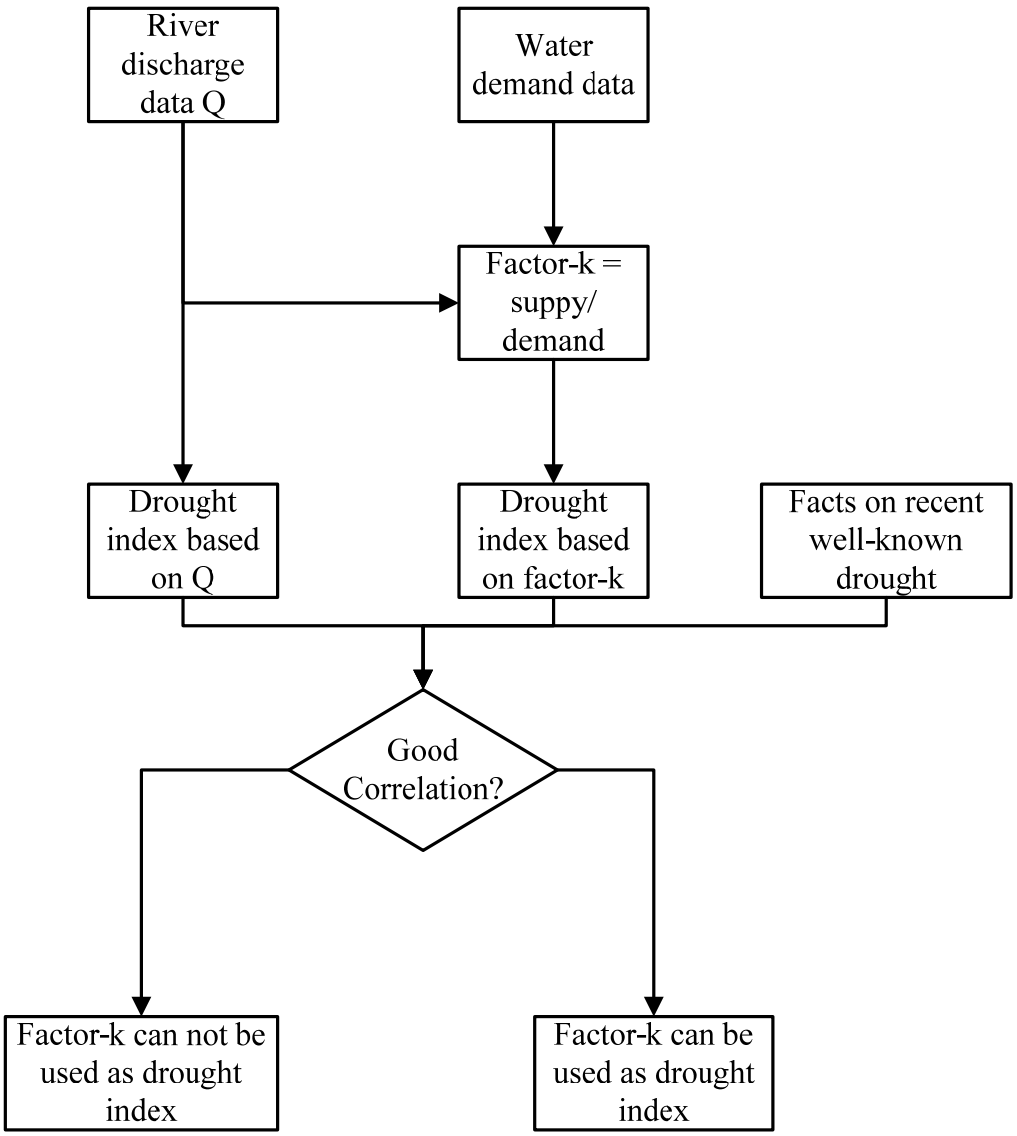

Figure 1 Flow chart of Research Methodology

Preliminary analysis using factor-k data from Notog Weir in Pemali River has been carried out. The location of Notog Weir and the other diversion structures in the study area of Pemali-Comal river basin territory is presented in the next figure.

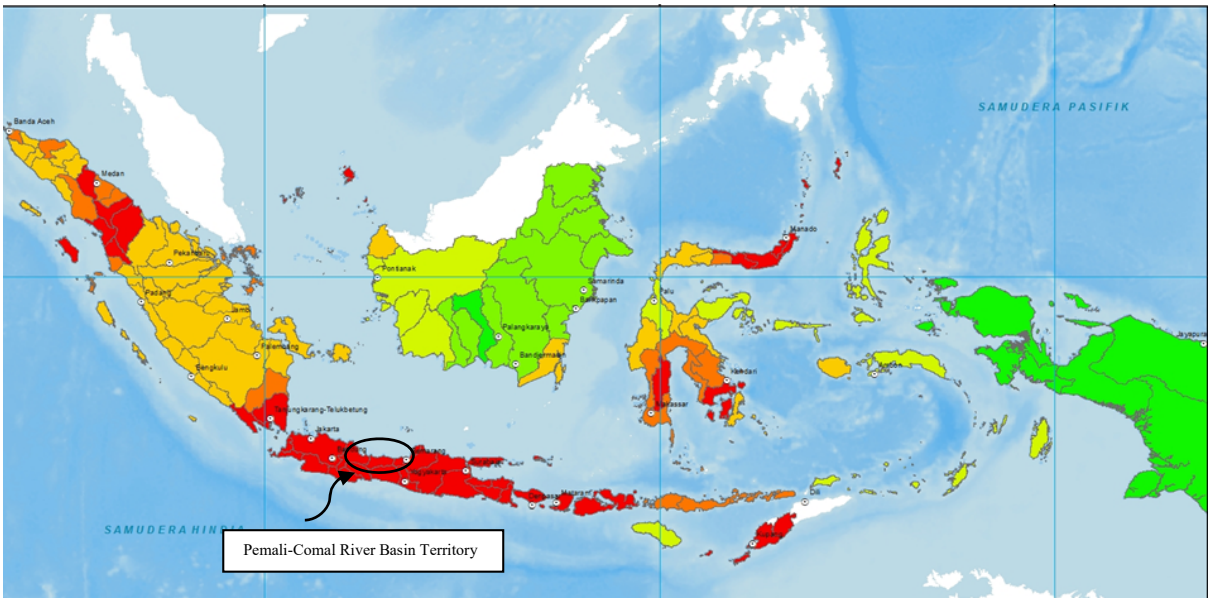

Figure 2 Location of Study Area

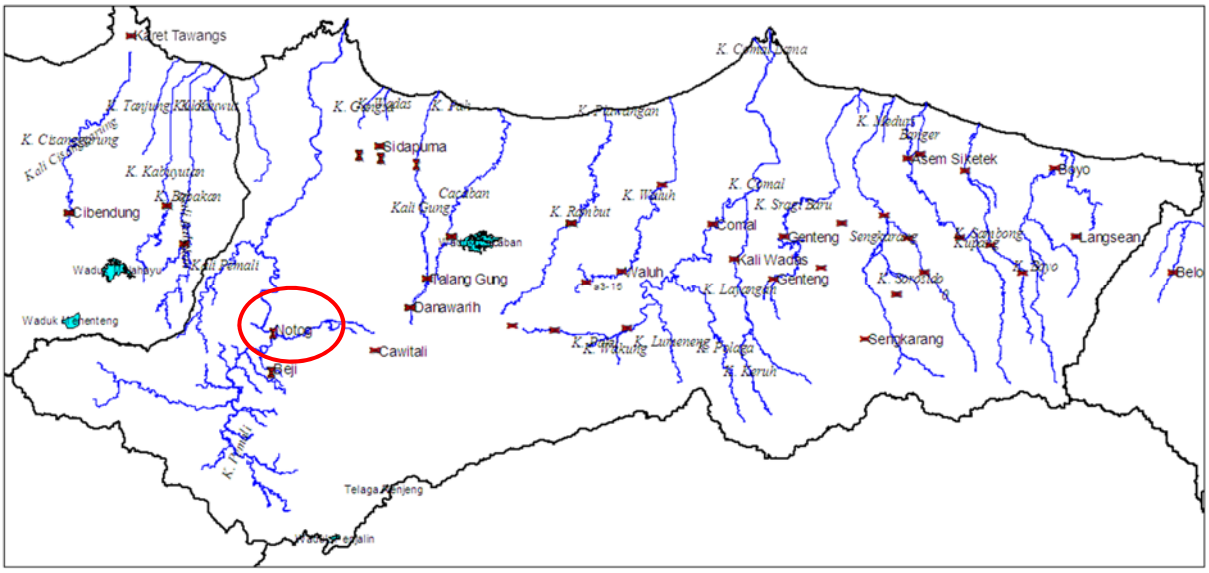

Figure 3 Location of Notog Weir in Pemali-Comal River Basin Territory

3 Discussion

3.1 Pasten System

As reported by Keeley et al. (1989), Dinar et al. (1997), and Pasandaran (2010), since long time ago, early in the colonial Dutch era, farmers in Indonesia already cultivate rice in the same way as nowadays. The allocation of irrigation water for sugarcane, rice and palawija is planned and monitored using the pasten system to achieve a fair distribution. At present the farmers still practice the pasten system, and the data on water demand and supply is available on most irrigation diversions. It is expected that a hydrological drought index using the easily available data at the farmer level that have been practiced for centuries in Indonesia, can be developed and applied for drought monitoring and water allocation.

There are at least three advantages of using Pasten system as an index of hydrological drought are: (1) It is already becoming tradition since long-time ago, makes the research can be traced back to the long previous drought disaster; (2) It is available in almost all weir in Java Island, in a weekly time-step; and (3) It is easily understood by the water manager as well as the farmer.

The disadvantage of using the pasten system directly is that it only can show current condition, it cannot bring the dimension of duration and intensity. To overcome this problem an approach developed by Yevjevich (1967) by applying the Theory of Run to the truncated series of the indicator is applied as shown in the following figure.

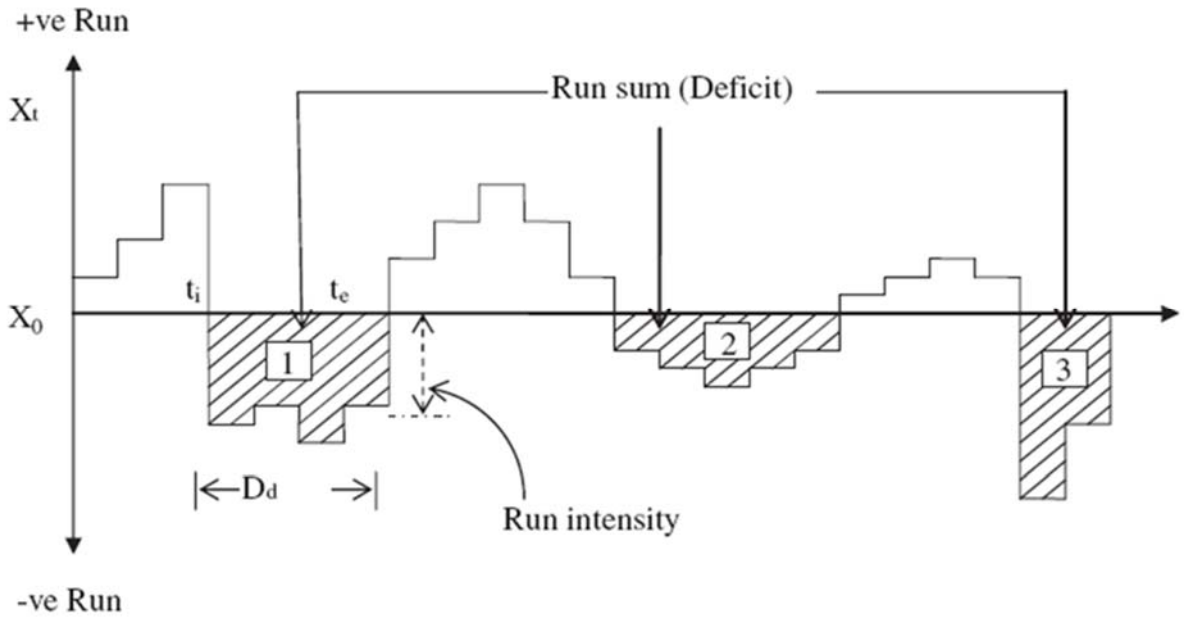

Figure 4 The Theory of Run applied to the truncated series of drought indicator

3.2 Data Analysis

Data on Notog Diversion Weir has been collected from the year of 1990 until 2010. The conventional drought index using river discharge in the weir with truncation level of dependable flow 80% is presented in Figure 5, showing the drought disaster in the year of 1994 as the most severe drought. This figure does not reveal other drought year, while the fact is that drought in Java is happened in the year of 1991, 1994, 1997, and 2003.

The series of index derived from factor-k with truncation level in 70% shown in Figure 6 shows so many drought disasters, while it also shows drought in 1991, 1994, 1997 and 2003 although not distinct to other years. Figure 7 plot the duration of drought in half-month time-step for each year. It distinctively shows that 1991, 1993, 1994, 1997 and 2003 are the drought year.

Finally Figure 8 presents the severity of drought, that defined as multiplication of duration and its intensity. It shows clearly the drought years from the most severe are: 1994, 1997, 2003, 2006, 1991, and 1993. Both results of duration and the severity of drought using traditional pasten system prove to be close to reality than the drought index composed of river discharge alone.

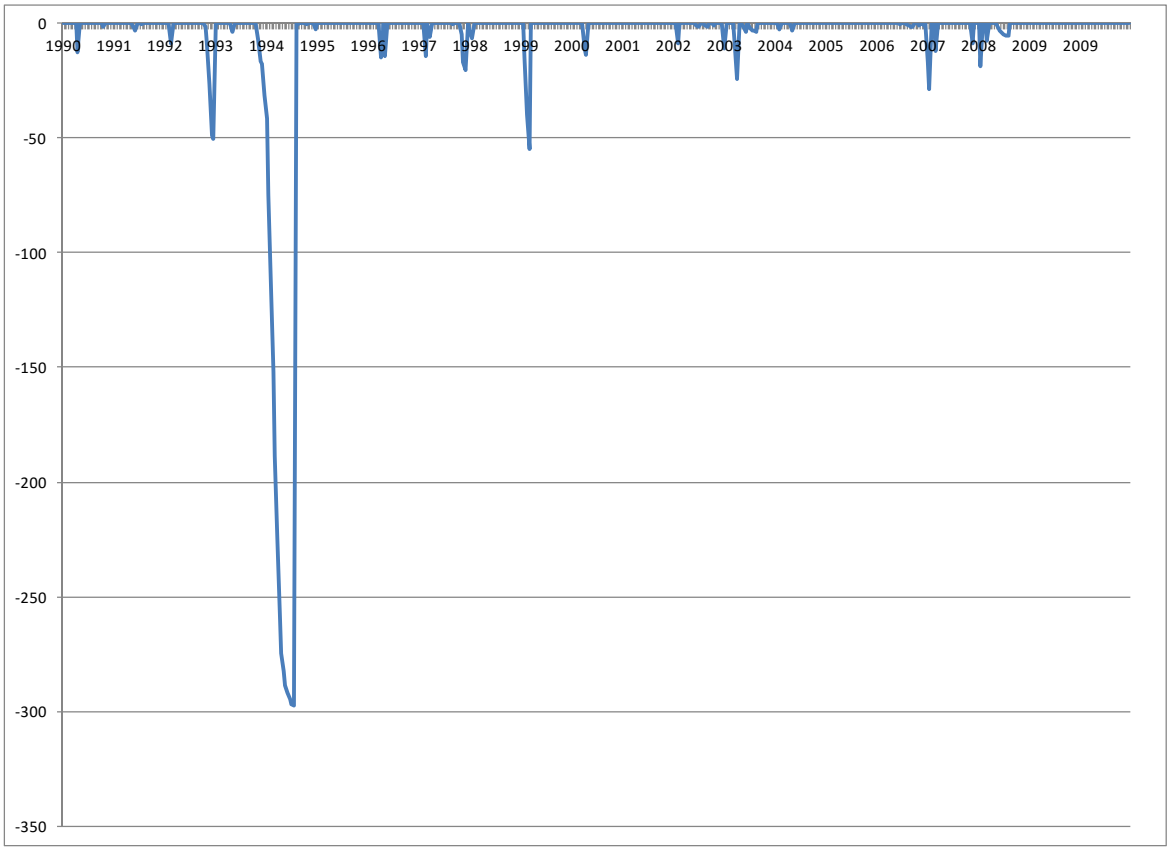

Figure 5 Drought index of river discharge in Notog Weir

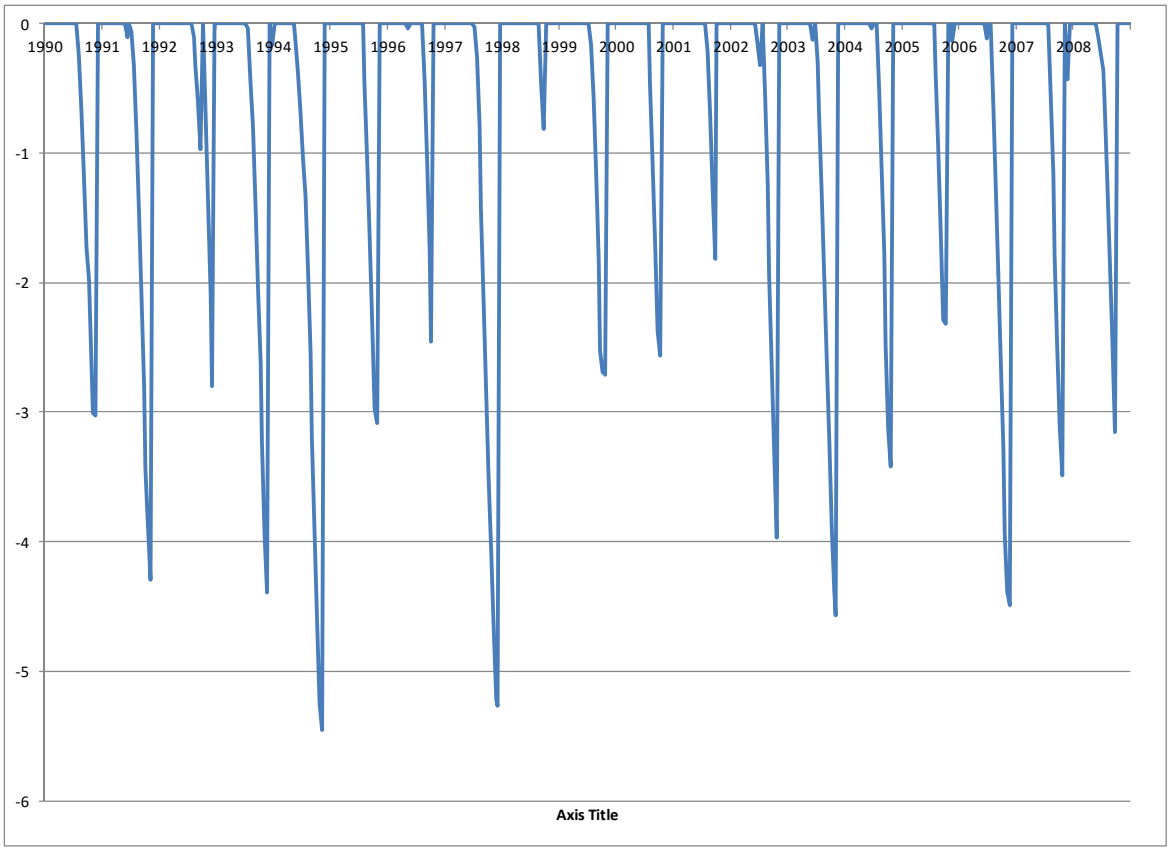

Figure 6 Drought Index of factor-k in Notog Weir

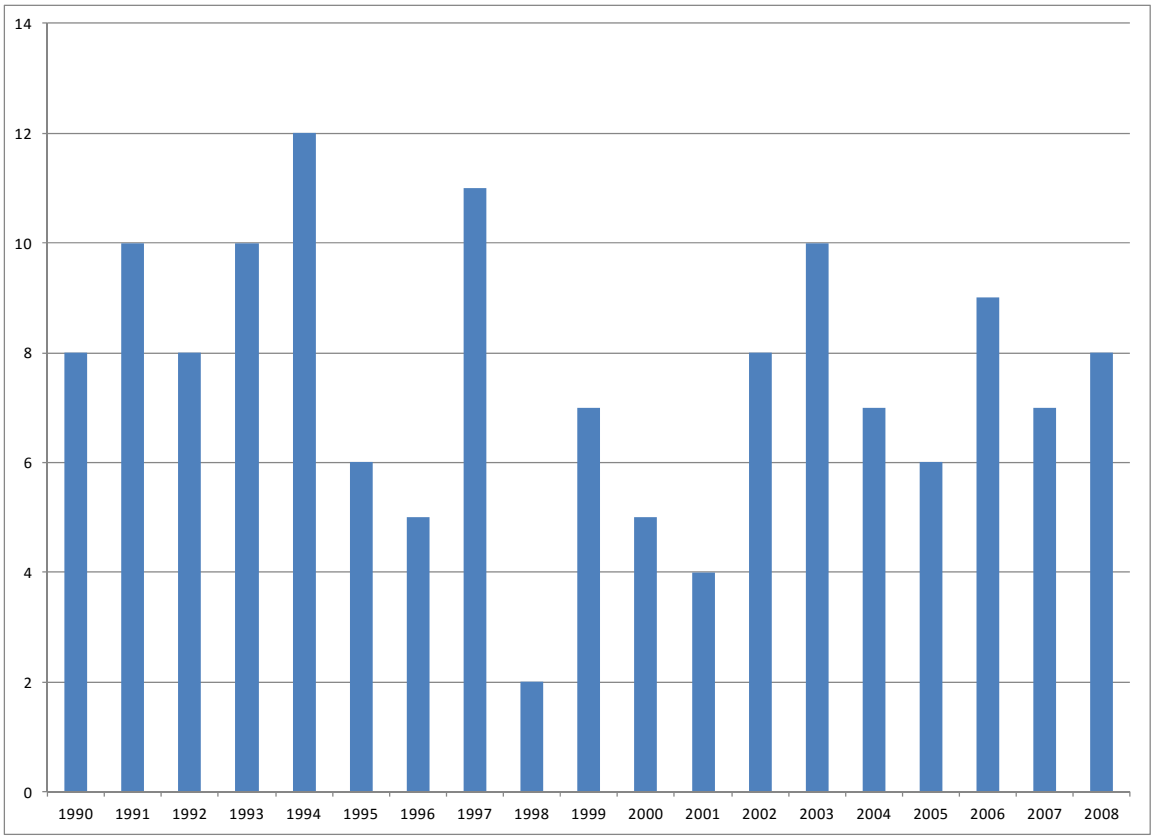

Figure 7 Duration of the drought (in half-month)

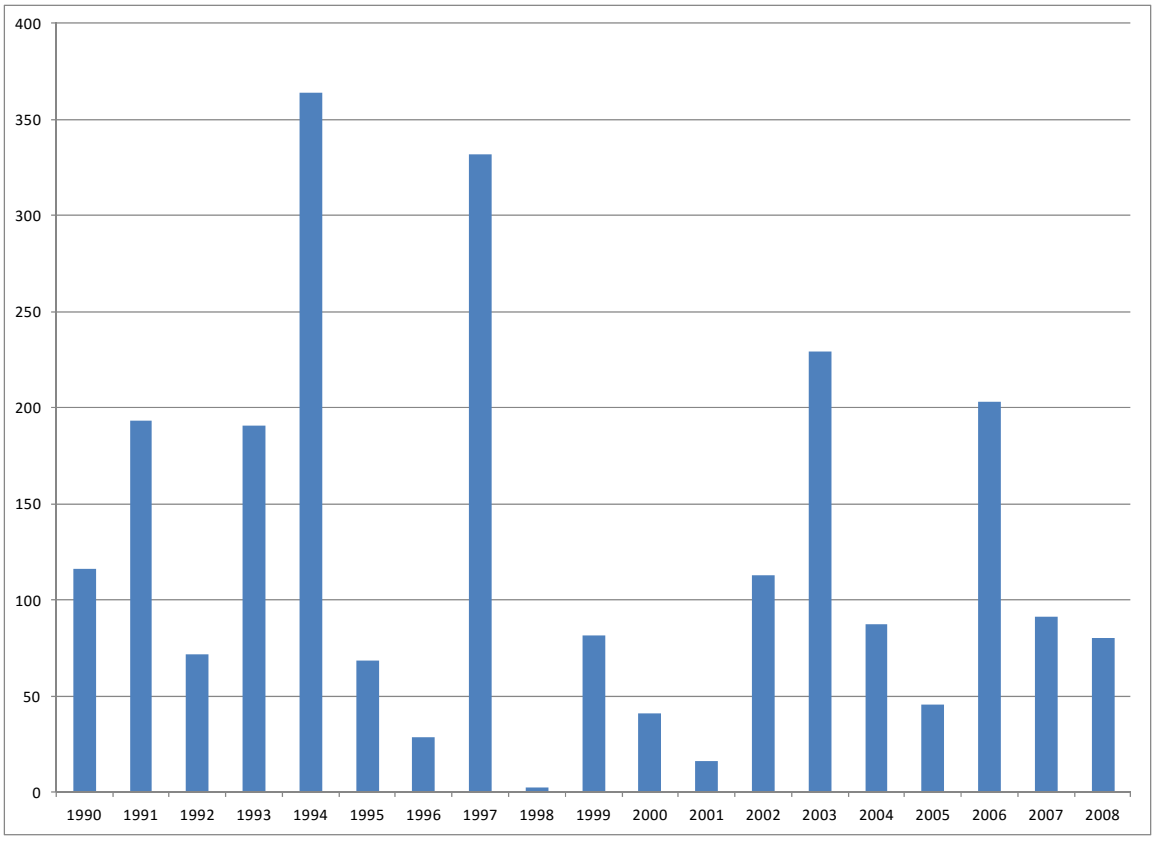

Figure 8 Severity of Drought

4 Conclusion

It is concluded that conceptually the traditional Pasten system of factor-k is a good indicator of hydrological drought. By applying the theory of run to the certain level of truncation of factor-k, then it become an effective hydrological drought index. Preliminary 20 years of half-monthly data from Notog Weir in the Pemali-Comal River Basin Territory shows that factor-k index is much better than conventional river discharge index in revealing the severe drought year. More data collection will be carried out to generalized this preliminary finding.

Acknowledgement

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