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Characterization of future drought conditions in the Lower Mekong River Basin

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ABSTRACT

This study evaluates future changes to drought characteristics in the Lower Mekong River Basin using climate model projections. The Lower Mekong Basin (LMB), covering Thailand, Cambodia, Laos and Vietnam, is vulnerable to increasing droughts. Univariate analysis was employed in this study to compare drought characteristics associated with different return periods for the historical period 1964–2005 and future scenarios (RCP 4.5 2016–2057, RCP 4.5 2058–2099, RCP 8.5 2016–2057 and RCP 8.5 2058–2099). Because a single drought event is defined by several correlated characteristics, drought risk assessment by a multivariate analysis was deemed appropriate, and a multivariate analysis of droughts was conducted using copula functions to investigate the differences in the trivariate joint occurrence probabilities of the historical period and future scenarios. The Standardized Precipitation Index (SPI) was selected as the drought index because of its ability to detect and compare metrological droughts across time and space scales. Historical precipitation data from 1964 to 2005 and future precipitation projections from 2016 to 2099 for 15 global circulation models (GCMs) obtained from the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset were employed. In all future scenarios, the Lower LMB and 3S subbasins were expected to experience more severe and intense droughts. The multivariate drought risk assessment revealed an increase in drought risks in the LMB. However, the Chi-Mun subbasin may experience an alleviation of future drought characteristics. Because the basin was expected to experience an increase in average monthly precipitation in most months, the variability in magnitude suggested that the LMB region requires adaptation strategies to address future drought occurrences.

1. Introduction

Drought is a recurrent natural hazard that can occur in any climatic zone on the globe. Generally, droughts are divided into four categories according to their nature and effects as meteorological, hydrological, agricultural and socio-economic droughts (Wilhite and Glantz, 1985). Although drought lacks a universal definition (Mishra and Singh, 2010), the categorization helps in assessing droughts. A drought is described by multiple characteristics such as severity, duration, and intensity and hence is designated a complicated natural hazard (Mishra and Singh, 2010). Furthermore, compared with other natural disasters, droughts affect a wide areal extent (Wilhite et al., 2014). Hence, in a drought analysis, it is important to consider its multivariate nature and spatial variability. Climate change is expected to intensify the global hydrological cycle (Huntington, 2006; Milly et al., 2002), and the consequences can lead to an overall increase in extreme events such as droughts. Despite having relatively higher annual average precipitation, the Lower Mekong Basin (LMB), covering Thailand, Cambodia, Laos, and Vietnam, is vulnerable to increasing droughts, affecting the agricultural economy of the region (Adamson and Bird, 2010; Hung, 2017; MRC, 2005). This study seeks to understand future meteorological drought conditions in the LMB under climatic changes. Such knowledge would help to formulate adaptation strategies.

The LMB is an important area in Southeast Asia in which droughts regularly affect the socio-economic conditions of more than 60 million people (Joy, 2012). Although the LMB receives a high amount of precipitation during monsoon seasons, socio-economic activities are organized and adjusted for expected conditions, rendering such activities vulnerable to deviations from regular precipitation patterns (Adamson and Bird, 2010). The rain-fed agriculture-based rural economy in the region is considered to be a most vulnerable sector (Shimizu et al., 2006). Limited irrigation is practiced for rice farming, particularly in areas in northeastern Thailand and the Mekong Delta at the mouth of the river near the South China Sea, (Adamson and Bird, 2010; Thanopanuwat,

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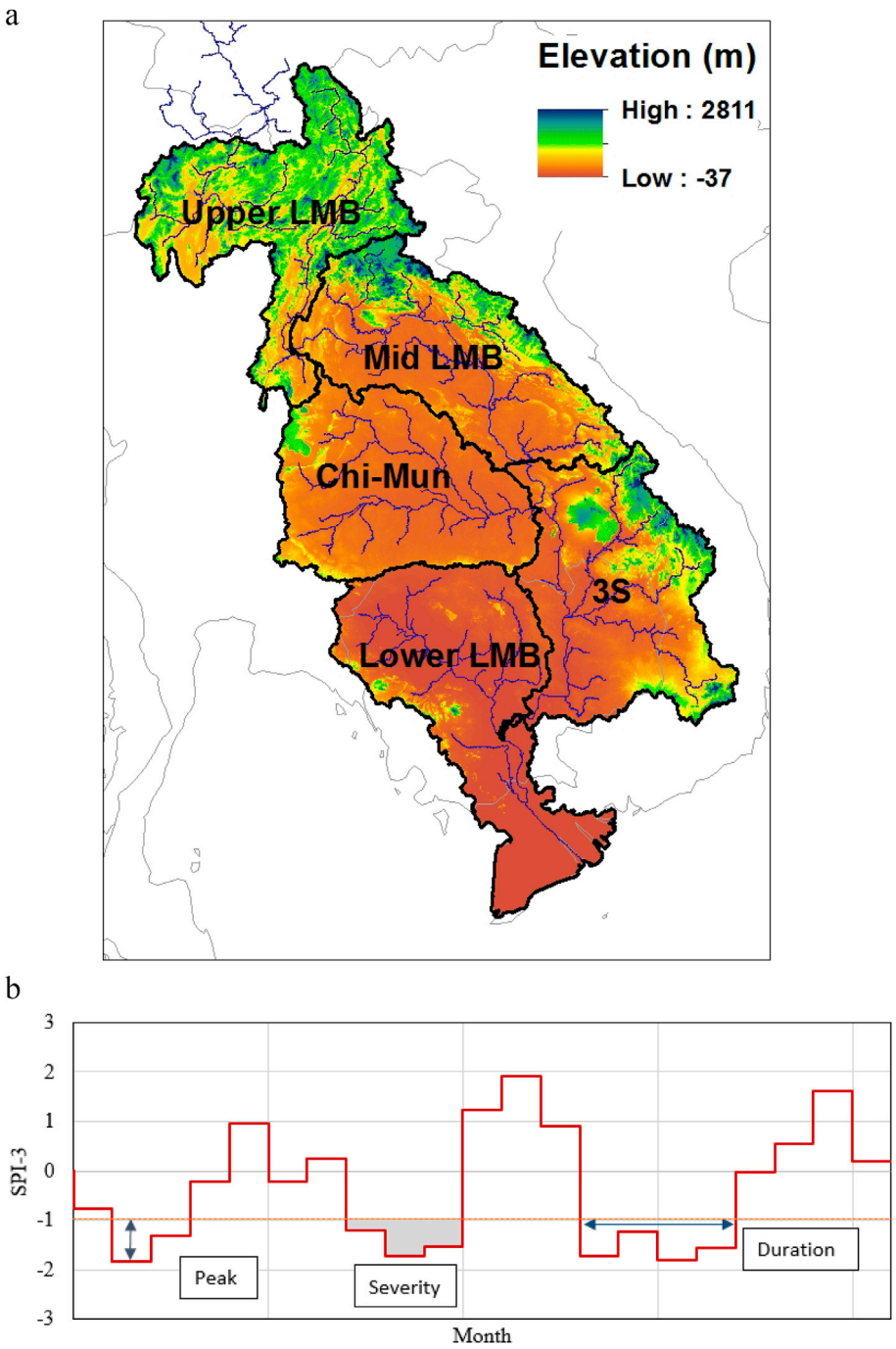

Fig. 1. (a) Map of the Lower Mekong Basin with the subbasins and elevation. (b) Definition of drought events and characteristics using the theory of runs.

2010). The basin-wide extreme drought in 1992 caused 210 million USD in damage in Thailand, and similar extreme drought events occurred in 1997–98 and 2004 (Prapertchob et al., 2007). Widespread drought conditions during 1997–98 in Vietnam affecting 3 million people resulted in an estimated total loss of 400 million USD in agricultural production (Shaw and Nguyen, 2011a). A similar drought during 2002 in Cambodia affected southern provinces, affecting more than 2 million people and destroying 100,000 ha of paddy fields (Shaw and Nguyen, 2011b). Several studies have attributed these drought occurrences primarily to extreme weather events, mentioning concerns that drought effects may be exacerbated by upstream hydrological alterations such as dams (Lu et al., 2014; MRC, 2005). Meteorological droughts may occur with the precipitation shortfall relative to average conditions in the area and can be identified using climatological drought indices. This study identified the historical droughts that occurred in 1992, 1997, 1998, 2002 and 2004 in the LMB using a climatological drought index for further evaluation with a high-resolution historical precipitation dataset. Because the precipitation patterns in the Mekong Basin are expected to change with climatic changes (MRC, 2005; Kiem et al., 2008; Lauri et al., 2012; MRC, 2012; Piman et al., 2013; Tatsumi and Yamashiki, 2015), an assessment of how the future climatic changes may affect meteorological drought conditions is important.

Global climate models (GCMs) are considered to be the most reliable tools with which to obtain global climate projections hundreds of years into the future (Sehgal et al., 2016). Numerous studies have evaluated climate change effects over the Mekong Basin using future projections from a single GCM (Hoanh et al., 2010; Kiem et al., 2008; Västilä et al., 2010). For example, Västilä et al. (2010) reported a 4% increase in the