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On the use of Standardized Drought Indices under decadal climate variability: Critical assessment and drought policy implications

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SUMMARY

Since the recent High Level Meeting on National Drought Policy held in Geneva in 2013, a greater concern about the creation and adaptation of national drought monitoring systems is expected. Consequently, backed by international recommendations, the use of Standardized Drought Indices (SDI), such as the Standardized Precipitation Index (SPI), as an operational basis of drought monitoring systems has been increasing in many parts of the world. Recommendations for the use of the SPI, and consequently, those indices that share its properties, do not take into account the limitations that this type of index can exhibit under the influence of multidecadal climate variability. These limitations are fundamentally related to the lack of consistency among the operational definition expressed by this type of index, the conceptual definition with which it is associated and the political definition it supports. Furthermore, the limitations found are not overcome by the recommendations for their application. This conclusion is supported by the long-term study of the Standardized Streamflow Index (SSI) in the arid north-central region of Chile, under the influence of multidecadal climate variability. The implications of the findings of the study are discussed with regard to their link to aspects of drought policy in the cases of Australia, the United States and Chile.

1. Introduction and study objective

Drought is one of the most widespread natural hazards in the world which, in conjunction with the societal vulnerability of the affected regions, has become the most significant natural disaster in terms of famines, human death and worldwide economic loss (Speranza et al., 2008; Sheffield and Wood, 2011). Thus, for the first time in history, a major international effort has recently been made to reach a political consensus that will allow this global scourge to be addressed (UNCCD-FAO-WMO, 2012a). Scientific knowledge, meanwhile, has advanced significantly in recent decades in the characterization, quantification, monitoring and economic assessment of droughts, as well as in the development of models for managing and adapting to it which are incorporated into public policies to combat it. However, in spite of these scientific advances and the social, economic and environmental impact of drought on a global level, only one country, Australia, has made systematic efforts to create, apply, and constantly reevaluate a National Drought Policy (White and Karssies, 1999; Botterill and Hayes, 2012; Kiem and Austin, 2013).

It is expected that the international effort already underway will spur a global push for the creation of national drought policies, along with a strengthening of scientific knowledge for designing and evaluating drought monitoring and early alert systems that provide operational support to these policies. With respect to these systems, drought monitoring and early warning systems have in large part have been based on the creation of Drought Indices (DI), of which the Standardized Precipitation Index (SPI) – a member of the Standardized Drought Indices (SDI) family – is the most important representative at the international level. Its purpose, as with the rest of the DI, is to provide an early alert of the occurrence of this silent, progressive, and pervasive disaster (Redmond, 2002;

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Sheffield and Wood, 2011). In this context, climate change and especially natural multidecadal climatic variability impose a great challenge to the creation, evaluation, selection and adoption of SDI. A particular challenge is assuring the existence of consistency, understood as the ability to be asserted together without contradiction (Merriam-Webster, 2013), among the conceptual definition that sustains SDI, the operational definition that they express and the political definition that they support (Smakhtin and Schipper, 2008; Botterill and Hayes, 2012). In this sense, the conceptual definition is understood as that which is expressed in general terms while the operational definition is that which allows to measure – by means of the selected Drought Index – the beginning, end and severity of the drought to be identified (Smakhtin and Schipper, 2008; WMO, 2005). Meanwhile the political definition is understood in terms of an explicitly stated declaration in a regulation that establishes when the event exists for the State and is linked to a public response, which is consistent with the term "legal definition" of drought suggested by López-Barrero and Iglesias (2009, p. 22) or the "legal concept" noted by the La Calle (2009, p. 48). Consistency among these definitions is considered to be of the utmost relevance in this work since the very ambiguity of the concept of drought constitutes one of the main obstacles to the creation of drought policies (Smakhtin and Schipper, 2008; La Calle, 2009; Whitney, 2013).

Thus, this work aims to analyze the applicability of the Standardized Streamflow Index (SSI), (Vicente-Serrano et al., 2012) as a natural extension of the SPI, to hydrological droughts, in the context of multidecadal climate variability and its relationship with international recommendations for the appropriate use of SDI. Thus, the work is structured in the following way: In Section 1, a background of drought in the world and international initiatives to fight it is given, DI are presented with an emphasis on SDI, and the properties, advantages and limits of SPI are reviewed. It concludes with the role of multidecadal climate variability in drought occurrence and the potential effects of the appropriate use of SDI. In Section 2, a case study that supports this work is presented and justified, and the analysis methods used are detailed. In Section 3, the results related to the effect of record length and reference period on the distributional properties and recurrence of drought events estimated by the SSI are presented. The work concludes with Section 4, with a discussion of the results and an analysis of their implications in drought policy in representative cases at the international level.

1.1. Drought and international initiatives to fight it

Drought has been, is and will very likely continue to be one of the most significant natural disasters affecting society and the environment in a large part of the world. In spite of the controversy that exists as to the occurrence and projections of drought frequency at the global level (Dai, 2012; Sheffield et al., 2012), an objective fact is that this hydrometeorological phemonenon caused more than half of the deaths associated with natural disasters in the twentieth century and was, after floods, the natural disaster that affected the greatest number of people, with a direct global cost of more than 80 billion dollars (Below et al., 2007; Sheffield and Wood, 2011). Although it is recognized that drought affects virtually every climate regime (Wilhite and Buchanan-Smith, 2005), the drylands of the earth, which cover 41% of the surface of the planet and sustain the lives of 35% of the global population, with one of the highest poverty rates (45%), are the most seriously affected (Toni and Holanda, 2008; Speranza et al., 2008; Sheffield and Wood, 2011; FAO et al., 2011). The impact of drought in the arid and semiarid regions of the world, within the drylands, is precisely what has motivated the primary international efforts against it. For example, the droughts that occurred in sub-Saharan Africa spurred the creation of the United Nations Sudano-Sahelian Office (UNSO) in 1973 (Stringer, 2008). In 1991–92, UNSO assisted countries under its jurisdiction in the Sudano-Sahelian region to prepare for the United Nations Conference on Environment and Development (UNCED). This was an intermediate step that contributed to the subsequent creation in 1994 of the United Nations Convention to Combat Desertification (UNCCD) which, although it has focused on desertification as a fundamental global problem, has also included drought as a relevant component (UNDP, 2013). At present and again making reference to the droughts that are significantly impacting in the Horn of Africa and the Sahel, an international effort to cope with the global impacts of drought has been organized. This effort is the High Level Meeting on National Drought Policy (HMNDP), coordinated by the United Nations Convention to Combat Desertification (UNCCD), the Food and Agriculture Organization (FAO) and the World Meteorological Organization (WMO) (UNCCD-FAO-WMO, 2012a) and held in Geneva in March, 2013.

The HMNDP has been convened to initiate a dialogue for the creation and adoption of national drought policies at the global level. The scientific purpose of this initiative comprises 39 elements, associated with the following five spheres of activity, (UNCCD-FAO-WMO, 2012b):

(a) Promoting standard approaches to vulnerability and impact assessment.
(b) Implementing effective drought monitoring and early warning systems.
(c) Enhancing preparedness and mitigation actions.
(d) Implementing emergency response and recovery measures that reinforce national drought management policy goals.
(e) Understanding the cost of inaction.

Along with the proposal, a ten-step planning process which has been a key tool in providing guidance in the development of drought preparedness and mitigation plans is presented. Step 7 of the planning process refers explicitly to "*Integrating science and policy aspects of drought management*", a topic directly related to the present work (UNCCD-FAO-WMO, 2012b, p. 11).

1.2. Drought indices as a tool for supporting drought policies

As mentioned in Section 1.1, using effective monitoring and early warning systems is a fundamental component in a drought policy, since these systems allow responses to and management of drought to be improved (Botterill and Hayes, 2012). As of the Declaration of the Heads of State and Government, drafted during the HMNDP, an increase can be expected in the global dissemination and adoption of national drought monitoring systems and, especially, the adoption of Drought Indices and drought triggers, which are the basis of drought management plans (Steinemann and Cavalcanti, 2006; Zargar et al., 2011; Botterill and Hayes, 2012). In this context, there have been great advances in the last two decades in the creation and design of DI for drought monitoring in their various forms of expression (Keyantash and Dracup, 2002; Heim, 2002; Quiring, 2009; Zargar et al., 2011). From the wide range of available DI, the SPI has been recognized as one of the most appropriate for drought monitoring, and is the most globally widespread DI at both the research and operative levels, even though it is surpassed in its attributes by the rainfall deciles method, which is widely used in Australia. The SPI belongs to the probability-based SDI family, all of which are sensitive to factors and assumptions that govern probabilistic hydrology (Hosking and Wallis, 1997). This family includes, in addition to the SPI, the Standardized Precipitation Evapotranspiration Index (SPEI) for meteorological drought, the Standardized Runoff Index (SRI) and