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Historical and future seasonal rainfall variability in Nusa Tenggara Barat Province, Indonesia: Implications for the agriculture and water sectors

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ABSTRACT

Climate change impacts are most likely to be felt by resource-dependent communities, and consequently locally-relevant data are necessary to inform livelihood adaptation planning. This paper presents information for historical and future seasonal rainfall variability in Nusa Tenggara Barat (NTB) Province, Indonesia, where rural livelihoods are highly vulnerable to current climate variability and future change. Historical rainfall variability is investigated using observational data from two stations located on the islands of Lombok and Sumbawa. Future rainfall is examined using an ensemble of six downscaled climate model simulations at a spatial resolution of 14 km for 1971–2100, applying the IPCC SRES-A2 'Business as Usual' emissions scenario, and the six original global climate models (GCMs). Analyses of the observed seasonal rainfall data highlight cyclical variability and long-term declines. The observed periodicities are of about 2–4, 5, 8, 11, and 40–50 years. Furthermore, dry season rainfall is significantly correlated with the El Niño Southern Oscillation (ENSO), while wet season rainfall is weakly correlated with ENSO. The simulated rainfall data reproduce the observed seasonal cycle very well, but overestimate the magnitude of rainfall and underestimate inter-annual rainfall variability. The models also show that the observed rainfall periodicities will continue throughout the 21st century. The models project that rainfall will decline, although with wide ranges of uncertainty, depending on season and location. Crop water demand estimates show that the projected changes will potentially impact the first growing period for rice during November–March. Rainfall may also be insufficient to meet water demand for many crops in the second growing period of March–June, when high value commodities such as chillies and tobacco are produced. The results reinforce the importance to consider all uncertainties when utilizing climate projections in subsequent impact assessments. Recommendations on the effective presentation of these results to inform multi-stakeholder adaptation planning for livelihoods, agriculture and irrigation are given.

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1. Introduction

Climate change impacts are most likely to be felt at the local scale by resource-dependent communities (Füssel, 2007). Hence generating and effectively communicating locally-relevant climate change information is an important prerequisite for informed decision-making and livelihood adaptation planning (Srinivasan et al., 2011; Kirono et al., 2014). At the minimum, information should include climate variability and change which has been experienced historically and may be expected in the future, plus the uncertainties that exist around these estimates. For example, knowledge of rainfall variability on a year-to-year time scale provides useful guidance for the management of the agricultural and water resource sectors, while that on a decade-to-century time scale enables better-informed strategic decision-making for investments in infrastructure such as irrigation and water storage (Srinivasan et al., 2011).

One of the primary challenges is that information about projected climate is usually only available at global and national scales, and is rarely available at the sub-national and local scale, especially in less developed countries (Birkmann and Teichman, 2010). This is also true in Indonesia where little scientific data on current climate change exist (Suroso et al., 2009). Hence there is a gap in research and capacity to monitor and project climate change, particularly at sub-national and local scales (DNPI, 2010, 2011) where adaptation planning and action need to occur (Butler et al., 2016a).

According to the Indonesian National Council on Climate Change (DNPI, 2010), the limited scientific basis for quantifying climate change in Indonesia can be attributed to at least two reasons. Firstly, there is a lack of well-documented, spatially-distributed and long-term observational data for key climate variables. Secondly, existing studies mostly rely on global climate models (GCMs), and do not provide finer spatial resolution required to better understand local scale vulnerabilities in order to formulate and prioritise adaptation actions. The Indonesia Climate Change Sectoral Roadmap (ICCSR) (MoE, 2009) and DNPI (2010) have called for studies which can provide the empirical basis for climate change impacts, and that they should combine observations, data analysis, modeling and projections. These studies are required to achieve one of the primary goals of the ICCSR, namely "risks from climate change impacts on all sectors of development will be considerably reduced in year 2030, through public awareness, strengthened capacity, improved knowledge management, and the application of adaptive technology" (MoE, 2009, p. 10).

This study provides empirical information on historical and future seasonal rainfall variability based on observation and modeling. It focuses on the islands of Lombok and Sumbawa in the province of Nusa Tenggara Barat (NTB), which is one of the poorest regions of Indonesia, and where communities are highly dependent on agriculture and irrigation water infrastructure for their livelihoods (Butler et al., 2014). Specifically, this study aims to: (1) document the historical seasonal rainfall variability and trends in NTB from rainfall station data; (2) describe the likely future seasonal rainfall variability and trends using downscaled climate simulation data (McGregor et al., 2016) and the source GCM data, and (3) assess the potential implications for the agriculture and water sectors in NTB. This information was applied in participatory adaptation planning involving multiple stakeholders (Butler et al., 2015; 2016b), and for modeling the potential impacts on ecosystem services and livelihoods (Skewes et al., 2016). This required the presentation of data and results in a form that was accessible to stakeholders ranging from communities, government officials and other scientists (Butler et al., 2016b).

2. Data

2.1. Observed data

This study uses rainfall station data because gridded observed data are not available for NTB, and the available global gridded rainfall data sets (such as the Climate Research Unit (CRU) (Hulme, 1992) with a $2.5^\circ \times 3.75^\circ$ resolution; and the Aphrodite's Water Resources or (APHRO_MA) (Yatagai et al., 2012) with a 0.5° resolution) are too coarse for use in small island geographies such as NTB. To select the stations, we considered that, as suggested by Alexandersson (1986), the study of historical climate variability and change should utilize reliable data that are free of artificial trends or changes. Artefacts of measurement caused by changes in observation practice, equipment, site exposure, and location can lead to misleading results when used in trend analyses (Karl et al., 1993).

There are currently more than 30 rainfall stations distributed across NTB, with varying lengths of record and degree of completeness. Among these are two stations which have more than 40 years of monthly rainfall records, and have been scrutinized for data quality, consistency, and missing values (Kirono, 2002). These are Ampenan (in west Lombok) and Sumbawa (in west Sumbawa; Fig. 1), and they are among the 526 Indonesian stations in the World Meteorological Organization-National Oceanic and Atmospheric Administration (WMO-NOAA) project on the Global Historical Climatology Network database (Vose et al., 1992). Thus, they are included in the development of many global data sets including the CRU and the APHRO_MA mentioned above.

At the time of the study, Ampenan had monthly rainfall data for 1950–2010, while Sumbawa had data for 1961–2010. The monthly data were aggregated into seasonal data using the definition of the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG, 2013), whereby in NTB the normal dry season period is April–October, and the wet season is November–March.