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Review of Methodologies for Analyzing Drought, Its Impact on Economy and Water Resources

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ABSTRACT

Incidence and severity of drought in dry lands of Asia due to recent global climate change are predicted to result increased shortage of water and food and influence on livelihoods, health, and economy. Accordingly, proper drought management requires appropriate assessment of the phenomena. Therefore, assessing drought as a physical phenomenon, identifying causes of economic imbalance, and causes of reducing quality and quantity of water resource, need careful selection of methodologies. Consequently, objective of this study is to analyse present literature pertaining to drought assessment methods applied recently, supporting climatological, economic, and environmental economic aspects of drought management. This study is based on review of literature and methodology followed on conducting thematic analysis.

It is recommended for tropical dry lands to use estimates of SPI calculated using precipitation based periods consisting weekly data. As drought effects are localized, research on empirical level is much needed to understand the economic impact of drought. The notion of a household

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health production function model is widely applied in health and environmental economics to value the welfare effects of environmental quality changes by observing consumer behaviour.

KEY WORDS: *Drought, Dry lands, Sri Lanka, Drought research methods*

1. INTRODUCTION

Incidence and severity of drought in dry lands of Asia are predicted to increase water and food shortage and affect livelihoods, health, and economy due to recent global climate change (IPCC, 2014). Dry zone of Sri Lanka is such a geographic entity, already experiencing droughts, with a long history of planned and spontaneous adaptations to droughts. Further, the government of Sri Lanka in line with global conventions is implementing various programmes to reduce risks posed by droughts. However, preliminary studies confirm that affected people receive only meager of relief during drought and lack any kind of measure for adjusting farming plans for expected droughts. Rural dwellers consisting 94.6% of the North Central Province in the dry zone are mostly affected from the consequences.

Proper management of drought requires appropriate assessment of the phenomena. Moreover, agro-climate, economy, and water resources in Sri Lanka are complicated systems representing tropical monsoonal island with mountain range. This makes difficulties in directly adapting many indicators established for other regions of the world. Therefore, assessing drought as a physical phenomenon, along with causes of economic imbalance and causes of reduced quality and quantity of water resources, needs careful selection of appropriate methodology. Consequently, objective of this study was to analyse present literature relating to drought assessment methods applied recently, which support various aspects of drought management.

2. MATERIALS AND METHODS

This study is based on review of literature relevant to the objective, and followed methodology of conducting thematic analysis (Marchall, 2006). The authors followed subsequent steps in the analysis: organizing available literature, concentration on data, generating themes, coding, interpretations, alternative understanding, and writing. The themes of literature analysis on drought were as follows: assessment of drought occurrence and severity, assessment of economic impact of drought, and assessment of environmental economics on water scarcity.

3. RESULTS AND DISCUSSION

The authors analysed the material separately for three aspects of drought studies: viz. climatic analysis, economic analysis, and environmental economic analysis. Analysis of material related to climatic assessment is presented under drought occurrence and severity. The material related to methodologies of economics is confined to economic impact of drought, whereas environmental economic analysis is restricted to averting expenditure method.

3.1 Drought occurrence and severity studies

Literature analysis involved drought identification component of risk assessment. It revealed that the drought studies involve eight categories of applications such as indicator performance comparison, measurement of types of drought, spatial variations, temporal variations, forecasting and early warning, planning, impact monitoring, and modeling. Comparison of performance among various indices was an objective of studies across all times and was conducted for US and global studies. These studies compared variations of PDSI (Palmer Drought Severity Index), SPI (Standardized Precipitation Index), and their variations resulted by other components such as vegetation, temperature, and evapotranspiration producing another class of indicators. Despite the advancement of

investigations on science of drought, comparing performance of various indices is being continued. The comparison studies comprise global and regional data in US. These comparisons have improved understanding of the relationship of drought with various components of ecosystem and improve potential for applying to some specific purposes such as stream flow. Many studies have made comparisons to test performance of monthly indicators and some compared for sums of weeks such as 12, 24, and 156 weeks (Wu, 2005).

Meteorological, agricultural, and hydrological droughts and relationship with their integral parts of the same such as soil moisture, ground water, and stream flow were among the categories of application in assessing drought. Commonly, the studies base on PDSI (Agwata, 2014;Alley, 1985), and SPI indicators, and recently, multi-sensor data, and new indicators such as GPCC- DI were tested (Ziese, 2014). This is an alternative to established two indicators, which target on assessment of meteorological drought resulting monthly estimates. However, it is worth noting that this indicator is also a modification of SPEI (Standardized Precipitation Evapotranspiration Index).

Obviously, all studies capturing global coverage aim at assessing spatial variations. In addition, some individual countries have evaluated spatial variation within countries (Xie, 2013;Piratheeparajah, 2014). Studies on tropical regions have mostly used SPI monthly and several consecutive monthly values. Moisture Availability Index was another measure used to assess spatial variations with monthly values (Chitranayana, 2008). Some of these studies embrace both spatial and temporal variations (Xie, 2013) and many studies focus mainly on trend analysis (Dai, 2011;Mekuria, 2012). SPI and PDSI have assessed spatial and temporal variation of drought.

Another application of drought is forecasting and early warning of various aspects of drought (Wedisinghe, 2011;Mekuria, 2012), and some of them had specific predictions such as wild fire risk prediction (Bifulco, 2014), prediction of yield (Quiring, 2003), and early warning of seasonal drought (Lyon, 2009). All studies have employed ground-based data calculating SPI and PDSI for forecasting, and exceptions found where other vegetation-based

parameters used to calculate specific indicators (Mekuria, 2012). All tropical regions employed SPI while Canadian Prairies used PDSI.

Several studies have attempted to calculate SPI based on weekly data (Wu, 2005;Orvos, 2014;Wedisinghe, 2011). Drought impact in global scale monitoring was studied using variations of SPI and PDSI. Water supply system planning and drought modeling are some other applications of drought studies (Stagge, 2015;Orvos, 2014;Prudhomme, 2007). SPI and PDSI were the generally applied indicators except (Prudhomme, 2007), where RDI (Regional Deficiency Index) based on parameters of atmospheric circulations was applied.

We found many indices used, among which, ten possesses wide application. They are Palmer Drought Severity Index, Palmer - Z, Palmer Hydrological Drought Index (PHDI), Modified Palmer Drought Severity Index (PMDI), Crop Moisture Index (CMP), Bhelme and Mooley Drought Index (BMDI), Surface Water Supply Index (SWSI), Standardized Precipitation Index (SPI), Standard Precipitation Evapotranspiration Index (SPEI), and Reclamation Drought Index (RDI).

Nevertheless, all indices can classify into three categories: 1) PDSI based indicators, 2) SPI based indicators, and 3) complex indicators for region and sector variations. Almost all indicators were calculated for monthly estimates and several studies estimated drought based on weekly data. PDSI based indicators proved successful in large homogeneous regions where calculating continuous drought periods as cumulative value is not possible, whereas SPI is suitable for all climatic regions and possible to calculate weekly, monthly, or other consecutive longer periods. This advantage provides an opportunity to calculate drought severity for various shorter and longer periods from one to many weeks, even several months.

3.2 Considerations to Assessment of Economic Impact of Drought

Assessments of economic impact of drought have gained interest among economists in the recent past due to the likely impact of drought on economic variables, e.g. economic growth, gross domestic product, budget expenditure, and food imports. These economic

assessments of impact of drought have employed diverse methodologies and hence comparing assessment methodologies is unrealistic. In general, the existing state of knowledge provides several disciplinary areas for the assessments, e.g. impact on crop yield, cultivated area and farm income, employment, savings, investment and consumption, health issues, and education and trainings.

Most studies have cited the potential of severe impact of drought on agricultural yield, cultivated area, and income. It is assumed that by the end of 21st century, the cropland drought disaster will double with rising temperature (Yinpeng, 2009), and crop failure and pasture losses are the primary direct effect of drought within the agricultural sector (Ding, Hayes, & Widhalm, 2010).

Crop failure and pasture losses result in negative supply shocks in agricultural commodities. However, net effect of drought on agricultural income depends on two factors: 1) how much of negative supply shocks are transferred to consumers due to price increase of agricultural commodities, and 2) how much of losses can be safeguarded through any crop insurance programme (Ding, Hayes, & Widhalm, 2010; Ghalavand, Karim, & Hashemi, 2012). There are many country specific studies that explain the adverse impacts of drought on crop yield, cultivated area, and agricultural income (Joshi, Maharjan, & Piya, 2012; Pandey, Bhandari, & Hardy, 2007). According to (Pandey, Bhandari, & Hardy, 2007), the average production losess for rice during a drought year of 44% compared with those of a normal year in Philippine. The severity of drought impact on crop yield is dependent on various factors such as irrigation infrastructure, agroecological conditions, drought resistance crop varieties, crop and land management strategies etc. (Alam, Paris, & Cueno, 2012; Wanninayake, 2011; Pandey, Bhandari, & Hardy, 2007). The studies have paid lesser attention on the economic cost of people's health issues in drought-affected areas. Most scholars have outlined the complexity in decomposing the economic cost of drought related health issues. By conducting a comprehensive literature review, Stanke *et al.* (2013) have identified five types of health issues associated with drought: i.e. nutrition related effects, water related diseases, air-bone and dust related effects, vector borne diseases, and mental

health effects. This study emphasised the need of considering direct and indirect costs of drought related health issues in the economic assessment.

Many studies have identified drought as a factor of employment decline, particularly in the agricultural regions (Alston & Kent, 2004; Travis & Klein, 2012). Specifically, the studies reveal that drought result in downgrading seasonal employment opportunities in the agriculture regions, especially to women. According to a study conducted by (Aslin & Russell, 2008) in the Queensland Central Coast and in the Riverine, drought resulted in declined employment in agriculture by 20.6% and 8.8%, respectively, over a five-year period to 2006.

The existing literature on impact assessment of drought on consumption provides rather blend results. According to (Pandey, Bhandari, & Hardy, 2007), farmers can maintain their consumption level during the drought period since they can earn an off-farm income. However, this depends on healthy growth of off-farm sector. Some scholars argue that people utilise their savings to maintain their consumption levels during drought period, particularly resources poor and low income groups in drought affected regions (Pandey, Bhandari, & Hardy, 2007). In fact, if there is no adequate savings for contingency, those groups are more vulnerable during the drought period in terms of food insecurity, children's education, bussiness investments, etc.

Under Sri Lankan context, researchers have paid little attention on assessment of economic impact of drought. A study conducted by (Manour & Jayamanna, 2014) in a rural community in the central highlands of Sri Lanka found protein energy malnutrition, skin sepsis, poor oral hygiene, and respiratory symptoms as some drought related health issues. The research however, has not attempted to identify the direct and indirect costs of drought related health issues. A study conducted in three villages in Monaragala district in Sri Lanka revealed that households below the poverty line are more vulnerable to drought (Gillespie, 2011). Specifically, annual and perennial crop losses, crop yield reduction, quality deterioration of produce, income loss of farmers, difficulty of obtaining loans, and inadequacy of paddy for consumption are the economic impacts of drought recognized by the study. The

study provided empirical evidence on significance of traditional farming in mitigating adverse impact of drought.

3.3 Water: Values, Scarcity, and Issues

"Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any use-value; but a very great quantity of other goods may frequently be had in exchange for it."

(Adams Smith, Diamond-Water Paradox, Wealth of the Nations, 1776)

Despite the fact that Diamond-Water Paradox has resolved many years ago, the real paradox of lack of access to good quality water supply, when it would be so essential, is still a key challenge especially in draught vulnerable areas around the world. Water is the most precious and vital resource on earth for human well-being, an essential input to economic development, and necessary for ecosystems functioning. Even though 70% of the earth surface is covered by water, 97% of the water is sea or brackish water, and only less than 1% is fresh water available for human requirements.

Ensuring access to clean water supply and adequate sanitation is one of the Millennium Development Goals (MDGs). The target is to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation, relative to 1990. However, 800 million people are still without access to clean water and 2.5 billion lacks improved sanitation (UNICEF/WHO, 2012). It is claimed that water, sanitation, and hygiene related health issues are responsible for the death of over 3.4 million people in the world and nearly 99% of these deaths occur in developing countries (WHO, 2008). It is estimated that approximately 10% of the global diseases could be prevented through improving water supply and sanitation, and managing water resources in a sustainable manner (UN World Water Development Report 3, 2009). The OECD (2006) predicts that by 2025, global water consumption will rise by up to 30% in developing countries and over 10% in developed countries. It is further highlighted that

between 1995-2025, world population living in water-stressed regions will increase by 100%. By 2030, two-third of the world population will face moderate to high water shortage.

Water access, human health, and poverty are closely related. Better health plays a vital role of human well-being and economic development. The Ministerial Declaration of Bonn Freshwater Conference in 2001 highlighted that, "Combating poverty is the main challenge for achieving equitable and sustainable development, and water plays a vital role in relation to human health, livelihood, economic growth, as well as sustaining ecosystems."

3.4 Cost of Access to Good Quality Water Supply

The provision of clean, consistent water supply is considered an essential good, and a requirement for achieving a minimum standard of living and overall economic development of a country. Drought creates the direct and indirect environmental and socio-economic impacts across micro household level to macro national economies.A considerable amount of literature estimates the cost of lack of access to good quality water at regional and global level (Hutton and Haller, 2004; Hutton *et al.*, 2007; WHO, 2008; Hutton, 2012). Hutton (2012) estimates that globally, the annual economic losses associated with inadequate water supply and sanitation are 260 billion USD. According to Hutton *et al.* (2007), investing 1 USD results in a return of 5 USD to 46 USD depending on the intervention and the main contribution to the economic benefit is the value of time saving, which account for around 70% - 90% of the total benefit (Hutton *et al.*, 2007; Hutton, 2012).

3.5 Economic Valuation of Water Service Improvements

Public policies should reflect an understanding of the public values in relation to environmental quality though such values are not correctly reflected by the market system (Champ *et al.*, 2003). Integration of non-market valuation of environmental resources into the decision making process has extensively developed over the past few decades. Quantification of the cost and benefits of public projects are an important aspect of public policy making, and non-market valuation play an important role in this context (Alpizar, 2003). Non-market

valuation is employed to infer monetary values of individual preferences for outcomes of policy proposals or events (Young, 2005). As the existing market system cannot measure the water quality improvements, various non-market valuation techniques have developed to measure the benefits of such improvements.

Environmental Economics have proposed two main types of non-market valuation techniques that can estimate the welfare change of the water service improvements; Stated Preference (SP) and Revealed Preference (RP) approaches. SP is based on choices in hypothetical market while RP on actual choice behaviours of respondents in a real market (Bateman *et al.*, 2002, 2003; Alpizar *et al.*, 2003). Therefore, higher validity of data is one of the main advantage of RP, when compared to SP (Louviere *et al.*, 2000).

3.6 Revealed Preference Approach: Averting Expenditure Method

As a Revealed Preference approach, Averting Expenditure Method (AEM) assumes that in the absence of an explicit market, it is possible to value the change of water quality and service explicitly observing individuals' behaviour to improve water quality. Households practice several coping strategies to reduce the health risk, and the expenditures they incur for such actions implicitly reflect their preferences for water service improvements. Households could refrain from the averting measures if they are provided with improved, reliable, and affordable water supply; hence, the averting activities can measure the value of water service improvements (Pattanayak *et al.*, 2005). Expenditures on averting behaviours of water consumers are considered as one indicator, which reflect the individuals demand, hence willingness to pay for ensuring water access and quality improvement.

4. CONCLUSIONS & RECOMMENDATIONS

Dry lands in the tropical monsoonal region as in the dry zone of Sri Lanka poses highly variable climate in terms of both spatial and temporal context. Climatic seasons in Sri Lanka classification is based on precipitation, and do not coincide exactly with calendar months.

Therefore, it would be appropriate to divide periods coinciding with rainfall seasons rather than based on months. This literature review reveals that the complexity of the hydrological conditions in the dry zone consisting ephemeral streams and numerous small and large *wewas* (water reservoir ecosystems) to be taken into account in successful designing of an indicator for drought assessment and management planning. In this context, it is recommended to use estimates of SPI calculations using precipitation based periods consisting weekly data for the dry zone of Sri Lanka.

This literature review also indicates the absence of sufficient studies undertaken to assess the economic impact of drought on farm households in Sri Lanka. Specifically, drought effects are localized and thus, empirical level research is highly desired. New methodological development in quantifying economic vulnerability is another research niche.

Averting Expenditure Method is grounded in household health production approaches. This model is developed using an individual utility maximizing framework and captures an individual's behaviour in order to prevent reducing environmental quality (Markandya and Richardson, 1992). Grossman (1972) formally developed the notion of a household health production function model with the application to measure health impacts of air pollution. Since then, the method has been widely applied in health and environmental economics to value the welfare effects of environmental quality changes by observing consumer behaviours.

Literature review on drought assessment methodologies reveals the importance of studying environmental conditions of drought, social and economic impact, and water resource value in the dry zone of Sri Lanka, in terms of theoretical and pragmatic approaches. Such a study will contribute to develop climatic, social, economic, and environmental economic indicators and methodologies appropriate to tropical dry lands and associated communities. Further, it is required to focus such studies to develop constructive programmes to manage drought with a disaster management approach. It would also be appropriate to focus on micro-level variations to fine tune community concerns on management of drought in particular areas. Various agro-ecological conditions, river basins, and variation of socio-economic conditions

such as poverty and food insecurity would consider for such establishment of micro-level changes with empirical data.

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