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CHAPTER 10

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Extreme Weather Events and Crop Yields: A Case Study with Coconut

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Extreme Weather Events and Crop Yields: A Case Study with Coconut

Abstract

Weather events individually or as averages over time affect critically on biomass and crop yields, making them vital in addressing the effects of climate on agricultural productivity. Potential detrimental effects of extreme weather events related to ambient temperature and rainfall have been a growing concern, especially in view of the global climate change. Drought is the most crucial extreme weather event for coconut in Sri Lanka. Coconut is an economically important palm species and being a perennial plant, it is adversely affected by weather fluctuations throughout its life cycle. Coconut is especially sensitive to drought during the post-fertilization phase of growing bunches. This reduces nut set resulting from a reduction in assimilate production and ultimately affecting quantity as well as the quality of nuts. As per the distribution of coconut by agro-ecological environments, the low country intermediate zone, IL1 and IL1b contributes to approximately 50% of the annual national coconut production. Coconuts grown in the intermediate zone are exposed to supra optimal or high temperatures, especially during the months of drought. Long term precipitation data has provided evidence for the increasing occurrences of drought events in agro-ecological region IL1b. The correlation of drought events with long term yield data has revealed the patterns of adverse effects of drought on coconut yield. The increased frequency of drought events necessitates the implementation of drought preparedness measures for the sustainability of the coconut industry.

Keywords: *Cocos nucifera L., climate change, crop yields, drought, Sri Lanka*

Introduction

The term 'weather' represents the state of the atmosphere, with respect to precipitation temperature, cloudiness, rain etc. at a particular place during a short period of time. In contrast, 'climate' is the weather conditions that prevail in an area, averaged over a long period. Further, the term 'climate change' refers to the average level changes in weather outcomes (e.g. degree of temperature) that occur over a long period of time. A specific feature of climate change is the increasing frequency of

weather shocks which are referred to as extreme weather events. Globally, the extreme weather events are threatening humans in various ways, the reduction in agricultural productivity being one of the major issues. Weather events individually or as averages over time affect critically on biomass and crop yields, making them vital in addressing the effects of climate on agricultural productivity.

Coconut, as a commercial crop, has been cultivated in Sri Lanka since the 17th century. By 2014, the total coconut extent of the country was 443,538 ha, which is about 20% of total extent under agriculture in the Island (Department of Census and Statistics, 2017). Out of this, the total extent of coconut in bearing stage is about 342,662.2 ha producing 2500-3000 million nuts per annum. This production, however, is insufficient to meet the industrial demand and for the sustainability of the coconut industry in the country.

Being a perennial plant, coconut is adversely affected by weather fluctuations throughout its life cycle. Potential detrimental effects of extreme weather events related to ambient temperature and rainfall have been a growing concern in Sri Lanka, especially in view of the global climate change. The information derived from systematic studies on the effect of climate change on coconut production is highly useful in maintaining the production and ensuring the sustainability of coconut cultivations. Such information is especially important with the expansion of coconut plantations into drier areas, where the effects of extreme weather events are expected to be more detrimental than in the areas in the traditional coconut triangle, which are better suited for coconuts. Although the literature provides evidence for the effect of weather parameters on coconut production (Peiris, 1993; Peiris *et al.*, 1993; Peiris and Thattil, 1997; Hansen and Zubair, 2008) the studies on the effect of extreme weather events on coconut production remain comparatively scarce.

Drought is the most important extreme weather event that causes extensive damage in coconut plantations, adversely affecting the production and productivity. The definition of drought itself is complex, but in many textbook examples, drought is considered as a natural stochastic phenomenon that arises from a considerable deficiency in precipitation. There are many quantitative measures of drought that have been widely used depending on the discipline affected, amount of data needed for computation, and the particular application (Svoboda and Fuchs, 2016). Several indices developed by Wayne Palmer (Palmer

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Drought Severity Index, Palmer Z Index) and Standardized Precipitation Index on different time scales are among them for describing the many scales of drought and these are being widely used because of their simplicity. Accordingly, this chapter describes the effect of extreme weather event; drought, on coconut yields in Sri Lanka using the commonly used simple computational methods.

Drought in Sri Lanka

Drought is considered the most crucial natural disaster in Sri Lanka (UNDRR, 2019), causing severe hardships on the livelihoods in terms of water scarcity, resulting in the second-highest agricultural crop damage. In the last few decades, South Asian countries, including Sri Lanka have reported increased drought events as frequently as once in every three years (Aadhar and Mishra, 2017). Over the past 40 years, the country experienced the worst drought in 2016-2017, affecting 20 districts and approximately 1.8 million people (CFE-DM, 2017). Occurrences of drought is inevitable in almost all regions of Sri Lanka due to noticeable changes in major meteorological situations. The changes such as low-level disturbances, depressions and cyclones in the formation of weather systems in the bay of Bengal and the highly variable activity of the Inter-Tropical Convergence Zone are responsible in the formation of different weather systems in different seasons (Chithranayana and Punyawardena, 2008).

Developing a definition to describe drought or an index to measure it are difficult tasks. Many quantitative measures of drought have been developed in the United States, depending on the discipline affected, the region being considered, and the particular application. Several indices developed by Wayne Palmer, as well as the Standardized Precipitation Index, are useful for describing the many scales of drought.

Observing the long-term monthly Moisture Availability Index, Chithranayana and Punyawardena (2008) claim that there is no risk of occurring drought in agro-ecological regions (AERs) in the up-country intermediate zone. However, compared to the wetter part of the island, drought proneness is relatively higher in the intermediate zone. The majority of AERs in the low country intermediate and dry zones are vulnerable to drought during January–March and June-August periods. There is a low chance for the occurrence of frequent droughts in the wet zone except for the period of January–February (Chithranayana and Punyawardena, 2008).

A study conducted by Gunda *et al.*, (2010) revealed a strong association between the Northeast monsoon and *El-Niño* in recent decades. They further suggested that the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI) at a 9-month scale (SPI-9) can appropriately be used as agricultural drought monitoring tools, respectively in the intermediate and the dry zones (Gunda *et al.*, 2016).

Comparing SPIs at different time scales, a recent study revealed that more drought events ($SPI \leq -1$) and a greater increase in the trend occurred during *Yala* (effective during the period from May to end of August) than *Maha* cropping season (from September to March in the following year) (Abeysingha and Rajapaksha, 2020). The authors further revealed more frequent drought occurrence in the dry zone than the wet and intermediate zones at the annual time scale.

Effect of drought on coconut yields

The International Panel on Climate Change (IPCC) claims that the negative impacts on crop production will be more common in future, resulting in decreased crop productivity with an expected local temperature increase of 1-2°C and an increase in the frequency of droughts and floods in countries of low latitude (IPCC, 2014). The ill-effects of drought can be more prominent on plantation crops such as coconut due to their perennial nature making future coconut supply uncertain due to climate change and its unknown impacts (Pathiraja *et al.*, 2015). This uncertainty may create adverse effects on domestic consumers, producers and the coconut processing industries, but, effective application of adaptation measures may minimize the vulnerability depending on the severity of change.

Physiological effects of drought on coconut

Coconut is especially sensitive to drought during the post-fertilization phase of growing bunches, reducing the nut yield (Abeywardena, 1956). Coconut palm takes ~44 months to produce a mature bunch of nuts from the initiation of inflorescence primordia with longer pre-fertilization period (~32 months) than post-fertilization (12 months) period. Therefore, the impact of weather changes beyond the comfort zone at any of the critical stages of the development of inflorescence affects nut yield.

The first few months before and after the opening of the coconut spathe are identified as the most 'sensitive stages' of inflorescence development.

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Of them, ovule and pollen formation take place within the last three months before the opening of the spathe (Perera *et al.*, 2010) and pollination and button nut formation occur within the first month of spathe opening. High temperature and water stress on these sensitive stages decide the fruit set, the main yield determining factor, by negatively affecting the viability of female flowers and pollen. Bai *et al.* (1988) revealed the possibility for radiation above 265 Wm^{-2} , temperature beyond $33 \text{ }^{\circ}\text{C}$ and vapour pressure deficit of 2.6 KPa to cause moisture stress in coconut and the further aggravation by soil water deficit due to rain-free periods exceeding two months (Bai *et al.*, 2003). In addition to reduced fruit set, changing climate is shown to affect the quality of fruits and the rate and duration of assimilate production (Ranasinghe, 2017).

The dry matter (DM) requirement of vegetative organs has the priority over fruits (Navarro *et al.*, 2008) in perennial crops because of the simultaneous growth of vegetative and reproductive organs. It was found out in a recent study (Ranasinghe and Premasiri, 2016) that the total DM requirement of coconuts (fruits) was at the highest during November to February and the lowest in June irrespective of the year to year variations. The authors suggested that these variations are mainly associated with low number of fruit setting in February–March period resulting in a lower number of rapidly growing fruits in June–July and a higher number of fruit setting in May–August resulting in a high number of rapidly growing fruits in September–January (Ranasinghe and Premasiri, 2016). The flowers and young fruits are not able to compete for assimilates with the fast-growing fruits (6–10 months old nuts) when the total DM requirement of the palm is high and hence abort, resulting in low fruit set. In coconuts, female flowers become receptive and ready for pollination in 22 days after spathe opening (Thomas and Josephraj Kumar, 2013) and the climatic conditions during the first three months after inflorescence opening determines the number of set fruits.

Supra-optimal temperatures can affect photosynthesis because the fixation of CO_2 via rubisco enzyme and regeneration of the ribulose-1-5-bisphosphate (RuBP) through the Calvin Cycle is highly influenced by temperature variation, leading to a reduction in the DM production of palms. Moreover, the DM requirement for maintenance respiration of palms also increases at high temperatures (Amthor, 1984). Both imbalances can widen the gap between dry matter requirement and supply to developing fruits leading to the abortion of young fruits and

flowers as there is a high competition for assimilates between vegetative organs and developing fruits. Even though there is a short-term mechanism in coconut (Navarro *et al.*, 2008) to adjust source-sink imbalances by changing the light use efficiency and partly compensating transitory reserves in leaf petioles, long term and frequent occurrences of droughts and high temperature events may be detrimental to the palms.

Drought in major coconut growing areas and coconut yields

There should be a minimum rainfall of 5mm to satisfy the daily water requirement of an adult coconut palm (Peiris and Kularathne, 2008). Regression analyses between coconut productivity and the number of extreme events (number of days with maximum temperature (T_{max}), rainfall exceeding the 90th percentile of the daily distributions, and number of days with rainfall below the 10th percentile of the daily distribution) during the first four months after flowering in three major climatic zones revealed negative influence on productivity on high T_{max} days in the dry zone. The number of high rainfall events and the mean T_{max} of the same period had a negative impact on coconut productivity in the intermediate zone and the number of extreme weather events had no influence yet, on the coconut productivity in the wet zone (Pathmeswaran *et al.*, 2018).

Out of the total extent under coconut cultivation in Sri Lanka, about 69% is concentrated in the districts belonging to the "Coconut Triangle; Kurunegala, Puttalam and Gampaha", while another 9.5 percent is confined to "Southern Coconut Belt" consisting the districts Kalutara, Galle, Matara and Hambantota (Figure 1). Kurunegala district alone claims 38 percent of the country's total coconut extent (Department of Census and Statistics, 2017).

As per the distribution of coconut by agro-ecological environments, the low country intermediate zone (IL1 and IL1b – part of the Puttalam and Kurunegala districts) contributes for approximately 50% of the annual national coconut production. Coconuts grown in the intermediate zone are exposed to supra optimal or high temperatures, especially during the months of drought.

A recent study that analyzed the long-term trends in weather parameters; rainfall and maximum temperature in the low country dry intermediate zone (IL1b) revealed significant climate changes especially

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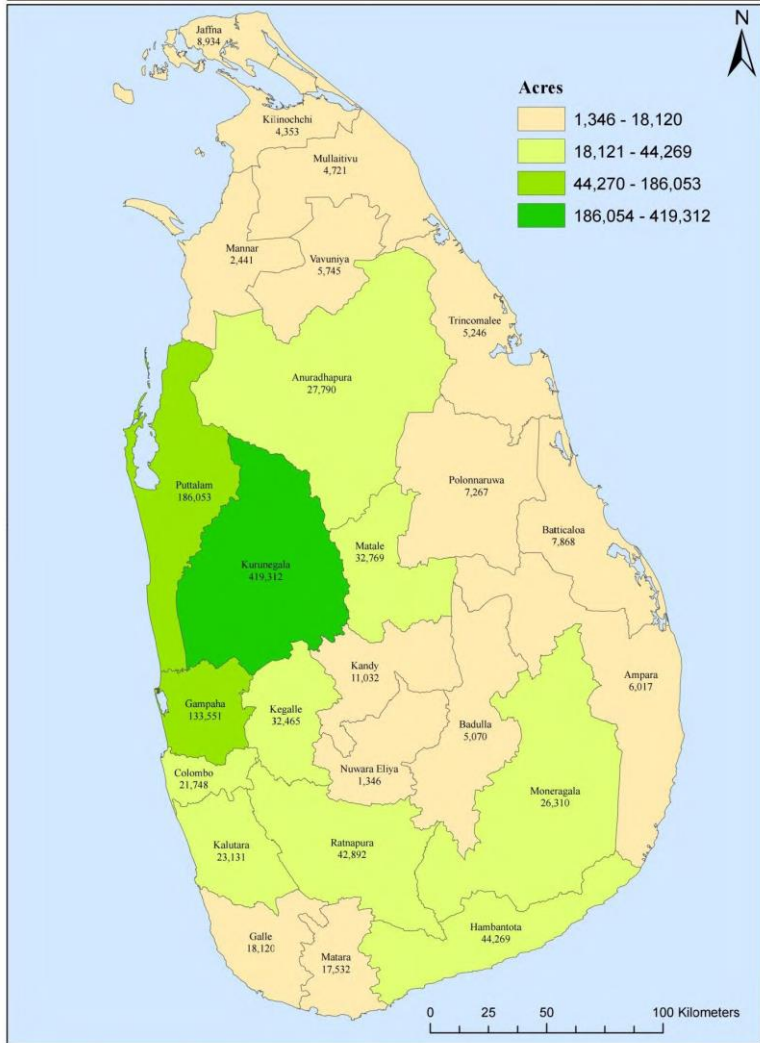


Figure 1: Distribution of coconut cultivation by districts in Sri Lanka.
Source: (Department of Census and Statistics, 2017).

during the South West Monsoon (SWM-May to September) (Waidyarathne *et al.*, 2019). This change has occurred due to the increased severity of drought and heat in the recent decades caused by the increment of maximum temperature and the reduction of the length of rainy spells. The study further revealed the combinatorial effect of high temperature and low rainfall in the First Inter Monsoon (FIM – March and April) and SWM, to negatively influence the coconut production in the area. Accordingly, the changes in the amount and duration of precipitation, dry days, maximum temperature and their cumulative effect causing dryness were revealed to determine 90% of the annual yield variability. However, records on studies to identify the effect of drought on coconut using any quantitative measures of drought remain scarce.

Case study on the effect of drought on coconut in AER IL1b

In addition to the large extent of commercial coconut cultivations, the entirety of the hybrid seednuts and about 60% of the genetically improved tall coconut seednuts are produced in the AER IL1b in Sri Lanka (Waidyarathne *et al.*, 2019). Accordingly, addressing climate change effects on coconut production in IL1b region of Sri Lanka is a priority concern to ensure the coconut production and the improvement of coconut seednut production.

A study conducted on a Sri Lankan Tall (cultivar CRIC60) coconut population revealed the effect of drought on coconut production in the AER, IL1b. The study population consisted of 300 palms, grown in Isolated Coconut Seed Garden (ISG), Ambakelle, Sri Lanka. Secondary bimonthly yield production data of the palms over 25 years, from 1975–2000, beginning from the age of 16 years, were analyzed.

ISG contributes for more than 50% of the hybrid seednut production as it is dedicated for the production of genetically improved coconut cultivars; CRIC60, CRIC65, Kapruwana and Kapsuwaya. The area records a semi-dry climate with a mean annual maximum temperature of 31°C and precipitation of 1250 mm. The soil is well-drained and highly suitable for growing coconuts and the estate is managed following all the standard recommended management practices at the optimum level compared to farmers' coconut holdings.

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The AER IL1b was hit by moderate to severe droughts over a minimum period of 3-months in 1974, 1975, 1983, 1987, 2004, 2008, 2011, 2012, 2016 and 2017 providing evidence for the frequent occurrence of droughts in the most recent decade (Figure 2). The longest and the most severe drought was on for more than 12 months beginning from late 2016.

The drought in the first four months of nut development was found to have a negative influence on the final yield as PDSI and the yield were positively correlated at 95% confidence. The Pearson correlation coefficients of yield were 0.29 with PDSI lag 11-12 and 0.17 with PDSI lag 9-10. In addition, drought was compared at different time scales based on SPI. Short-term SPIs (3 and 6 months) can be considered as

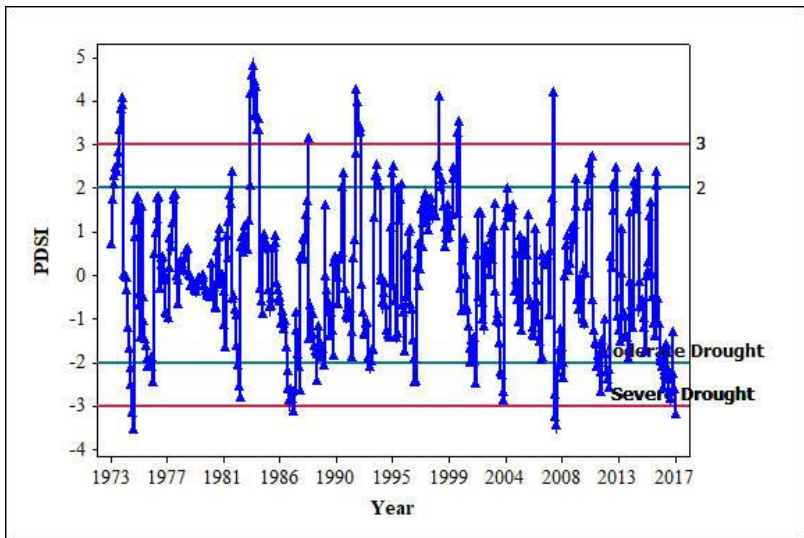


Figure 2: Distribution of PDSI from 1973 to 2017 in ISG, Sri Lanka (PDSI is grouped into 11 categories to define the intensity of the droughts: ≥ 4 – extreme wet, 3.00 – 3.99 – severe wet, 2.00 – 2.99 – moderate wet, 1.00 – 1.99 – mild wet, 0.5 – 0.99 – incipient wet, 0.49 - -0.49 – normal, -0.5 – -0.99 – incipient drought, -1.00 – -1.99 – mild drought, -2.00 – -2.99 – moderate drought, -3.00 – -3.99 – severe drought and ≤ -4 – extreme drought).

Source: (Waidyarathne *et al.*, 2019).

agricultural drought indicators representative of immediate impacts such as soil moisture reduction; hence, short accumulation periods of SPI can be best linked to yield stress. Long-term SPIs (12 months) reflect long-term precipitation patterns in the area and that can also be linked to coconut yield considering the perennial nature of the palm and long development cycle of a coconut bunch. Results revealed that SPIs below -2.00, which are referred to be extreme drought events, in the area were comparatively high in the recent years in all time scales. Further, Sequential Mann Kendall analysis revealed that SPIs in all three-time scales declined after the year 2000, indicating the temporal progress of drought. The coconut yield did not show any significant correlation with SPI in 6- and 12-months scales but was negatively correlated with SPI in 3-months scale. It was hard to explain such relationships using knowledge on crop phenology. However, it appeared that drought might not be the dominant factor affecting the coconut yield during those specific months and/or climate change with respect to drought had no significant variation during the period of yield was concerned.

In summary, the case study provided ample evidence for the increasing occurrences of drought events in AER IL1b, reiterating the need for the adoption of moisture conservation methods in coconut lands to sustain the cultivations.

Conclusion and future directions

The majority of coconut growing areas in Sri Lanka is concentrated in the intermediate zone where the negative effects of climate change on coconut production have already become evident. Being, a perennial palm, coconut will have to face the adverse effects of extreme weather events, especially drought, throughout its long-life cycle. The drought induces the combined abiotic stresses of moisture and heat in coconut, disturbing the physiological functions and reduction in nut set, leading to low yields. Accordingly, in view of the anticipated increased frequency and severity of drought events, it is essential to adopt proper moisture conservation strategies to minimize yield reduction and damage to palms and assure the sustainability of the coconut industry.

References

- Aadhar, S., and Mishra, V. (2017). High-resolution near real-time drought monitoring in South Asia. *Scientific Data*, 4(1): 170145. <https://doi.org/10.1038/sdata.2017.145>.

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Abeyasingha, N.S., and Rajapaksha, U.R.L.N. (2020). SPI-based spatiotemporal drought over Sri Lanka. *Advances in Meteorology*, 2020:9753279. <https://doi.org/10.1155/2020/9753279>.

Amthor, J.S. (1984). The role of maintenance respiration in plant growth. *Plant, Cell and Environment*, 7(8): 561–569.

Bai, K.V.K., Reddy, D.V.S., Ratnambal, M.J. and Laxman, R.H. (2003). Factors contributing to female flower production and button shedding in coconut. *Journal of Plantation Crops*, 31(2): 33–36.

CFE-DM. (2017). *Sri Lanka: Disaster Management Reference Handbook*. Ford Island Center for Excellence in Disaster Management and Humanitarian Assistance.

Chithranayana, R., and Punyawardena, B.V.R. (2008). Identification of drought prone agro-ecological regions in Sri Lanka. *Journal of National Science Foundation of Sri Lanka*, 36(02): 117–123.

Department of Census and Statistics. (2017). Economic Census 2013/14 - Agricultural Activities. Department of Census and Statistics, Sri Lanka.

Gunda, T., Hornberger, G.M. and Gilligan, J.M. (2016). Spatio temporal patterns of agricultural drought in Sri Lanka: 1881-2010. *International Journal of Climatology*. <https://doi.org/10.1002/joc.4365>

IPCC. (2014). IPCC 2014: Summary for policymakers in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: *Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (Christopher B Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, R. C. Genova, (Eds.), Contrib. Work. Gr. II to Fifth Assess. Rep. Intergov. Panel Clim. Chang.

- Kasturibai, K.V, Voleti, S.R. and Rajagopal, V. (1988). Water relations of coconut palms as influenced by environmental variables. *Agricultural and Forest Meteorology*, 43(3-4): 193-199.
- Navarro, M.N.V, Jourdan, C., Sileye, T., Braconnier, S., Mialet-Serra, I., Saint-André, L. and Bonnefond, J.-M. (2008). Fruit development, not GPP, drives seasonal variation in NPP in a tropical palm plantation. *Tree Physiology*, 28(11): 1661-1674.
- Pathiraja, P., Griffith, G.R., Farquharson, R.J. and Faggian, R. (2015). The Sri Lankan coconut Industry: current status and future prospects in a changing climate. *Australasian Agribusiness Perspectives*, 1-23.
- Pathmeswaran, C., Lokupitiya, E., Waidyarathne, K.P., and Lokupitiya, R.S. (2018). Impact of extreme weather events on coconut productivity in three climatic zones of Sri Lanka. *European Journal of Agronomy*, 96: 47-53.
<https://doi.org/https://doi.org/10.1016/j.eja.2018.03.001>.
- Peiris, T.S.G. and Kularathne, J.D.J.S. (2008). Assessment of climate variability for coconut and other crops: A statistical approach. *CORD*, 24(1): 19.
- Perera, P.I.P., Hocher, V., Weerakoon, L.K., Yakandawala, D.M.D., Fernando, S.C. and Verdeil, J.-L. (2010). Early inflorescence and floral development in *Cocos nucifera* L.(Arecaceae: Arecoideae). *South African Journal of Botany*, 76(3): 482-492.
- Ranasinghe, C.S. (2017). Climate change impacts on coconut production and potential adaptation and mitigation measures: a review of current status. In: B. Marambe (Ed.), *The Workshop on Present Status of Research Activities on Climate Change Adaptations Sri Lanka*. Council for Agricultural Research Policy, Colombo, 71-82.
- Ranasinghe, C.S. and Premasiri, R.D.N. (2016). Dry matter requirement for growth and respiration of coconut. *COCOS*, 21:21-31.

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Thomas, R.J. and Josephraj Kumar, A. (2013). Flowering and pollination biology in coconut. *Journal of Plantation Crops*, 41(2):109-117.

UNDRR. (2019). Disaster Risk Reduction in Sri Lanka: Status Report 2019. Bangkok, Thailand. Retrieved from https://www.unisdr.org/files/68230_10srilankadrmstatusreport.pdf.

Waidyaratne, K.P., Dissanayake, H.D.M.A.C., Perera, S.A.C.N. and Chandrathilake, T.H. (2019). Impact of extreme weather events on coconut production in IL1b Agro-ecological region of Sri Lanka. In V.H.L. Rodrigo, B.W. Wijesuriya, D.G. Edirisinghe and N.M.C. Nayanakantha (Eds.), *In: Proceedings of the seventh symposium on plantation crop research*, Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatta, 12200, Sri Lanka. 1-1).

World Meteorological Organization (WMO) and Global Water Partnership (GWP), 2016: Handbook of Drought Indicators and Indices. M. Svoboda and B.A. Fuchs (Eds.), Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva.