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Research Article

Projected Moisture Index (MI) for Tropical Sri Lanka

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Atmospheric moisture loading can cause a great impact on the performance and integrity of building exteriors in a tropical climate. Buildings can be highly impacted due to the changing climate conditions over the world. Therefore, it is important to incorporate the projected changes of moisture loads in structural designs under changing climates. The moisture index (MI) is widely used in many countries as a climate-based indicator to guide the building designs for their durability performance. However, this was hardly considered in structural designs in Sri Lanka, even though the country is one of the most affected countries under climate change. Therefore, this study investigates future climate change impacts on the environmental moisture in terms of MI, which can be used in climate zoning, investigating indoor air quality, understanding thermal comfort and energy consumption, etc. The moisture index was found as a function of the drying index (DI) and wetting index (WI) to the whole country for its four rainfall seasons. The temporal and spatial distributions were plotted as MI maps and showcased under two categories; including historical MI maps (1990–2004) and future projected MI maps (2021–2040, 2041–2070, and 2071–2100). Future projected MI maps were constructed using bias-corrected climatic data for two RCP climatic scenarios (RCP4.5 and RCP8.5). Results showed that the temporal and spatial variations of MIs are justifiable to the country's rainfall patterns and seasons. However, notable increases of MIs can be observed for future projected MIs in two seasons, and thus a careful investigation of their impacts should be assessed in terms of the construction of buildings and various agricultural activities. Therefore, the outcome of this research can be essentially used in policy implementation in adapting to the ongoing climate changes in Sri Lanka.

1. Introduction

Global climate change creates adverse impacts on the environment. Human living conditions are usually deteriorating due to them. Frequent natural disasters, sea-level rise, water, food scarcity, health concerns, biodiversity extinction, and so on are a few of the impacts of ongoing climate change [1, 2]. Recent studies on the global climate model (GCM) projections discuss that the global mean surface temperature would increase about 3.7°C (within a range of 2.6–4.8°C) by the end of the 21st century, in relation to time period of 1986–2005. This is under the "business as usual" high greenhouse gas emission scenario [3]. In addition, the recorded global mean temperature rise from 2006 to 2015 was much higher than that from 1850 to 1900 (which was the preindustrialized time) [4].

Increases in atmospheric temperatures can also be seen in Sri Lanka under the changing climate. The temperature increasing rate of Sri Lanka from 1961 to 1990 is 0.016°C per year, and this rate is higher than the global average rate of 0.013°C [5]. They have also reported that the 100-year warming trend of Sri Lanka from 1896–1996 is 0.003°C per year. However, the trend for 1987–1996 is 0.025°C, thus confirming the faster warming environment in more recent years. Therefore, the annual mean temperature over Sri Lanka by the end of the 21st century would be increased by 0.8–3.2°C [6]. However, this is slightly lower compared to other South Asian counties [7]. Nevertheless, the increase is significant and can cause many adverse impacts. In addition, it is predicted that the number of days with temperatures higher than 35°C from a baseline of 20 days would increase to over 100 days by the 2090s under Representative Concentration Pathway (RCP8.5) climatic scenario [8].

Studies carried out in Sri Lanka show that there is a high tendency for the annual rainfall trends to increase in all four climate zones, which are wet, dry, intermediate, and semiarid zones. Due to the increase of rainfall in both annual and seasonal levels, there is an increased risk of floods in the southern and western provinces in the future and risk of droughts in the eastern and southeastern districts of Sri Lanka [9]. Therefore, the country is at a severe risk under the changing climates. Khaniya et al. [10, 11] and Karunanayake et al. [12] carried out extensive research work on climate change and its relationships to the water resources and other ecosystems in Sri Lanka. However, research on the construction industry under the changing climate is yet to be done in the context of Sri Lanka.

Delaying construction projects is quite frequent in Sri Lanka due to adverse climate conditions [13, 14]. In addition, the construction quality is severely affected by adverse weather conditions [15, 16]. Therefore, building design standards are updated to cope with these weather conditions in different parts of the world [3, 17]. Not only the constructions but also the maintenance and healthiness of the buildings are affected due to changing climates [18]. Walls, decks, floors, exteriors, and so on can be damaged due to the higher moisture content in the environment. This can happen in both exterior and interior of the buildings and can also cause some health risks due to fungus grown inside buildings [19, 20]. In addition, atmospheric moisture can adversely affect the performance and durability of building materials [21]. Therefore, analysis of moisture content in the atmosphere is highly important.

A moisture index (MI) was introduced by the Moisture Management of Exterior Wall Systems (MEWS), Canada, to evaluate the project areas of structural buildings in Canada on moisture-related problems [22]. The moisture index is currently used in the National Building Code of Canada (NBCC) in order to incorporate impact from moisture loading in the designs of wall assemblies to safeguard its performance and durability. The MI is the hypotenuse of normalized values of the wetting index (WI), which represents the annual rainfall recorded, and the drying index (DI), which represents the drying capacity of the air (the ability to take up water vapor) [3]. Moisture indices are known to have a significant contribution towards climate zoning for applications such as agriculture and vegetation [22, 23].

Sri Lanka, being a tropical country, experiences issues relating to warmer and humid environmental conditions. The country had many development projects in the recent past and many are in the pipeline. Colombo, the capital of Sri Lanka, is highly exposed to building construction after ending the country's war (in 2009). As stated in the preceding paragraphs, Sri Lanka is highly vulnerable to the changing climate. Therefore, it is very important to incorporate the moisture index in structural designs to prevent cracking and moisture-related complications in construction and finishing work. However, to the authors' knowledge, this was a grey area in Sri Lanka. Therefore, this research study presents a comprehensive analysis of the moisture index over Sri Lanka and then develops the contour maps to showcase the spatial and temporal variation of MI. The research presents the MI maps for the historical climatic records (1990–2004) and for future climatic conditions (2021–2100). Future climatic conditions were assessed under two climatic scenarios (RCP4.5 and RCP8.5) for three time periods, including near-future period (2021–2040), mid-future period (2041–2070), and far-future period (2071–2100). The importance of the results was discussed along the lines of the construction industry as Sri Lanka showcases a construction boom. In addition, this is the first related study in the Sri Lankan context for future projected moisture content in the atmosphere.

2. Study Area and Data Collection

Sri Lanka is a tropical country in the Indian Ocean with a land extent of 65,610 km^2. Sri Lanka is rich in water resources, and thus it has around 2905 km^2 of inland waters [24]. The country lies in between 5.92°–9.79°N and 79.68°–81.8°E, latitudes and longitudes, respectively; therefore, it has an equatorial climate. Most of the perennial rivers originated from the central highlands of the country, and therefore the highlands are hydrologically significant. The rivers subsequently descend radially to the coast. The river system in the country is nutrified by the higher rainfalls received to the central highlands of Sri Lanka.

Sri Lanka is divided into four climatic zones based on the received annual rainfall. They are the wet zone, dry zone, intermediate zone, and semiarid zone [9]. The wet zone receives more than 2500 mm of rainfall, whereas the semiarid zone receives around 800–1200 mm rainfall per year. Rainfall is not only spatially varied but also temporally varied in seasons. Southwest monsoon (SWM) and northeast monsoon (NEM) are the two major monsoon seasons that bring the majority of rainfall to the country. SWM starts in mid-May of the year and lasts until the end of September. Western, southern, and southwestern slopes of the central hill areas receive the majority of their rainfall during SWM season [25]. Similarly, the NEM season provides rainfall to the northern, eastern, and northeastern slopes of central hills from December to February [26]. However, two intermediate seasons, the first inter-monsoon (FIM) from March to April and the second inter-monsoon (SIM) from October to November bring rainfall to the country. Thus, it is evident that the four rainfall seasons encompass rainfall regimes over the entire country resulting in a high agro-ecological diversity.

However, Sri Lanka experiences a rather homogenous temperature pattern in the lowlands with a mean annual average temperature of 27°C (altitude: 100–150 m), and it decreases to 15°C towards the highlands as the altitude increases to 1800 m [27]. Not only the spatial variation but also the temporal variations for temperature can be seen. In the months of December to February, most of the areas have cooler temperatures, whereas warmer temperatures are experienced from April to August. In addition, the relative humidity (RH) of Sri Lanka is around 70–90% during the morning hours and 55–80% during the late afternoons. Furthermore, the country has a significant evaporation rate which varies from 3 to 8 mm per day depending on geographical region [26].

Daily rainfall data for 35 rainfall measuring stations were purchased from the Department of Meteorology, Sri Lanka. These 35 rainfall stations are well spread over Sri Lanka as shown in Figure 1. In addition, daily temperature and relative humidity data were purchased from the same department for 18 gauging stations. Sri Lanka has many gauging stations to measure daily rainfall (more than 500); however, there are only few of them for all other climatic parameters. Therefore, the available 18 stations were selected for temperature and relative humidity data collection. Depending on all data available for the total number of stations, a common time frame of 15 years from 1990–2004 was selected. The 18 meteorological stations and their spatial variation can be seen from Figure 1, and the total description including the locations and elevations can be found in Table 1.

The daily climate data were extracted for the historical years (from 1990 to 2004) and future years (from 2021 to 2100) from the climate model IS-ENES Climate4Impact. Two datasets under RCP4.5 and RCP8.5 were extracted for future climate data. All these climate data were extracted to the exact coordinates of the observed gauging station. Therefore, a clear comparison can be made between the observed and modeled climate data. RCPs showcase trajectories based on greenhouse gas concentration. RCP4.5 presents an intermediate scenario where the peak of greenhouse gas concentration is in 2040s, whereas RCP8.5 showcases an extreme case where the peak of greenhouse gas concentration goes to 2100.

Climate4Impact is a database, which has modeled regional climate model (RCM) climatic data for research purposes. The Coordinated Regional Downscaling Experiment (CORDEX) climate data can be freely extracted from this European Union-funded database. The database was widely used for many countries and areas [28–33]. The database can be found at https://climate4impact.eu/impactportal/general/index.jsp.

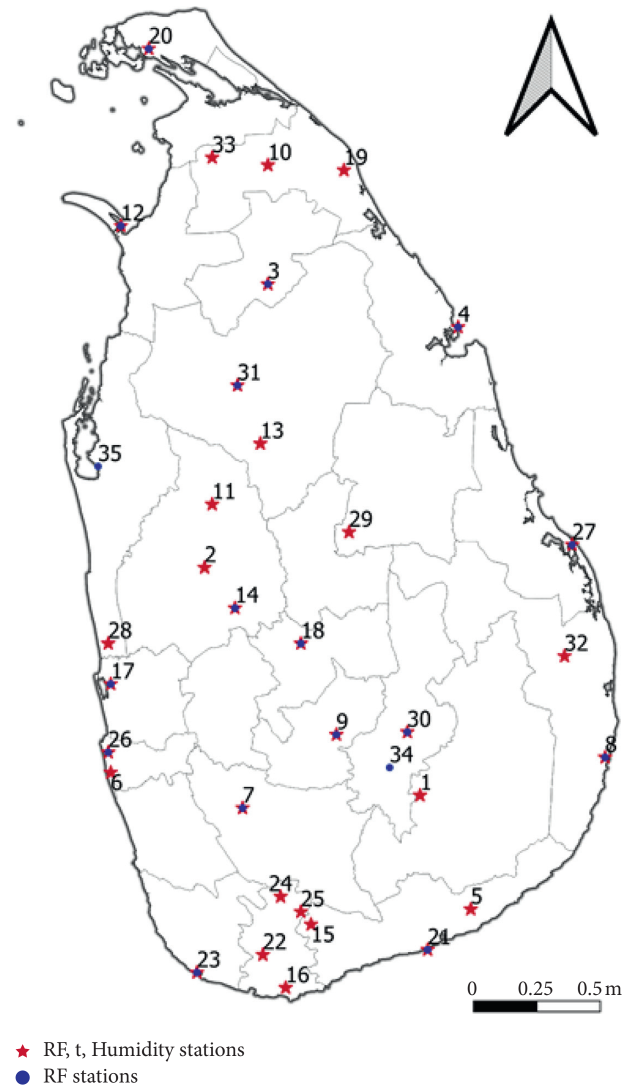


Figure 1: Meteorological stations used for the study.

3. Methodology

3.1. Bias Correction. The linear scaling method was used in order to remove the biases from the rainfall, temperature, and relative humidity data obtained from the climate model. The linear scaling bias correction method is a simple method, but it also performs other complex methods such as power transformation, quantile mapping, and delta change [12]. Measured meteorological data and historical data obtained from the climate model IS-ENES Climat4Impact for 1990–2004 were used to carry out bias corrections for the future projected meteorological data. Additive correction (refer to equation (1)) was used for temperature while multiplicative correction (refer to equation (2)) was used for precipitation and relative humidity data.

$$t^*_{F,d} = t_{F,d} + \left(\left(\mu_{O,t} \times t_{O,d}\right) - \left(\mu_{H,t} \times t_{H,d}\right)\right), \quad (1)$$

where $t^*_{F,d}$, $t_{F,d}$, $t_{O,d}$, and $t_{H,d}$ are the bias-corrected future temperature data, raw RCM temperature data, observed temperature data, and raw RCM temperature data for the observed duration, respectively. The subscript "*d*" stands for the daily basis data. $\mu_{O,t}$ and $\mu_{H,t}$ represent the long-term mean of the monthly temperature based on the observed and RCM temperature data.

$$P^*_{F,d} = P_{F,d} \times \frac{\mu_{O,P} \times P_{O,d}}{\mu_{H,P} \times P_{H,d}}, \quad (2)$$

where $P^*_{F,d}$, $P_{F,d}$, $P_{O,d}$, and $P_{H,d}$ are the bias-corrected future precipitation data, raw RCM precipitation data, observed rainfall data, and raw RCM data for the observed duration, respectively. $\mu_{O,P}$ and $\mu_{H,P}$ represent the long-term mean of the monthly precipitation based on the observed and RCM rainfalls. Some researchers have suggested using climate-

Table 1: List of meteorological stations and their locations.

No.	Station	Station type	Longitude	Latitude	Elevation (m)
1	Wellawaya	RF	81.1	6.73	16
2	Wariyapola	RF	80.25	7.63	16
3	Vavuniya	RF, T, RH	80.5	8.75	98
4	Trincomalee	RF, T, RH	81.25	8.58	24
5	Tissamaharama	RF	81.3	6.28	16
6	Ratmalana	RF	79.88	6.82	5
7	Ratnapura	RF, T, RH	80.4	6.68	86
8	Pottuvil	RF, T, RH	81.83	6.88	4
9	Nuwara Eliya	RF, T, RH	80.77	6.97	1894
10	Mutu Iyankaddu	RF	80.65	9.22	16
11	Mediyawa Wewa	RF	80.28	7.88	16
12	Mannar	RF, T, RH	79.92	8.98	4
13	Maha Illuppallama	RF	80.47	8.12	117
14	Kurunegala	RF, T, RH	80.37	7.47	116
15	Kirama	RF	80.67	6.22	122
16	Kekanadura	RF	80.57	5.97	49
17	Katunayake	RF, T, RH	79.88	7.17	8
18	Katugastota	RF, T, RH	80.63	7.33	417
19	Kannukkeni Tank	RF	80.8	9.2	30
20	Jaffna	RF, T, RH	80.03	9.68	3
21	Hambantota	RF, T, RH	81.13	6.12	16
22	Goluwawatta	RF	80.48	6.1	16
23	Galle	RF, T, RH	80.22	6.03	12
24	Deniyaya	RF	80.55	6.33	16
25	Dampahala	RF	80.63	6.27	176
26	Colombo	RF, T, RH	79.87	6.9	7
27	Batticoloa	RF, T, RH	81.7	7.72	8
28	Bandirippuwa	RF	79.87	7.33	16
29	Bakamuna	RF	80.82	7.77	16
30	Badulla	RF, T, RH	81.05	6.98	670
31	Anuradhapura	RF, T, RH	80.38	8.35	92
32	Amparai Tank	RF	81.67	7.28	27
33	Ambalperumalkulam	RF	80.28	9.25	16
34	Bandarawela	RF, T, RH	80.98	6.83	1220
35	Puttalam	RF, T, RH	79.83	8.03	2

modeled data directly for relative humidity due to difficulties in identifying biases [34]; however, a similar formula given in equation (2) was used to carry out the bias correction for relative humidity in this study.

3.2. The Wetting Index (WI) and Drying Index (DI). The wetting index (WI) indicates the source or the availability of the moisture loading [3]. It can be calculated using the annual total recorded rainfall at a location normalized using 1000 mm. However, the drying index (DI) indicates the drying potential of evaporation or sink of the moisture loading [3]. The DI is calculated using the humidity ratio between saturated and ambient air conditions. The DI values are normalized using the maximum limits of DI to represent normalized *DI* values between zero and one. The drying index is calculated using the following equation:

$$DI = \sum_K \Delta w \times 1000, \tag{3}$$

$$\Delta w = w_{sat} - w_{amb}, \tag{4}$$

$$w_{sat} = 0.622\left(\frac{V_{sat}}{P - V_{sat}}\right) \text{and } w_{amb} = 0.622\left(\frac{V_{amb}}{P - V_{amb}}\right), \tag{5}$$

where P, w, and K are the total pressure (assumed to be 101.1 KPa), humidity, and the number of hours in a year, respectively. The subscripts *sat* and *amb* represent the saturated and ambient levels of the atmosphere. Saturated (w_{sat}) and ambient (w_{amb}) humidity levels as shown in equation (4) are needed to calculate using the change of vapor pressures (shown in equation (5)).

The saturated vapor pressure is calculated according to equation (6) by using the monthly mean temperature values (t) [8], whereas the ambient vapor pressure is calculated according to equation (7) using the results of saturated vapor pressure obtained from the following equation:

$$V_{sat} = 6.112 \cdot \exp\left(\frac{17.62 \times t}{243.12 + t}\right), \tag{6}$$

$$V_{amb} = RH \times V_{sat} \times 100\%. \tag{7}$$

The relative humidity is the ratio of ambient vapor pressure of water (P_w) to the saturation water vapor pressure ($P_{s,w}^{pure}(t)$) and can be seen from the following equation:

$$RH = \frac{P_w}{P_{s,w}^{pure}(t)} \times 100\%. \quad (8)$$

3.3. The Moisture Index (MI). The moisture index (MI) formulates the potential atmospheric moisture loading as a function of wetting index (WI) and the drying index (DI) and then expresses the potential of moisture impacts when exposed to exterior climates [22]. Equation (9) shows the mathematical relationship among the indices.

$$\mathrm{MI} = \sqrt{\mathrm{WI}^2 + (1 - \mathrm{DI})^2}. \quad (9)$$

Ideally, more parameters such as hourly wind speed and direction of wind should be considered for MI calculation; however, the comprehensive form was not used here due to data scarcity. The projected climatic data used in the model are corrected for their biases using linear bias correction technique as stated above. Therefore, the model performance in obtaining MI was kept as a higher level.

3.4. Overall Methodology. The historical wetting index (WI) was calculated using the annual mean rainfall data of 35 rainfall stations spread all across Sri Lanka for the time period 1990–2004. The average monthly mean rainfall was calculated for observed daily rainfall data. In addition, the mean seasonal rainfalls were calculated for each monsoon (NEM, FIM, SWM, and SIM). In order to calculate the drying index, temperature data and relative humidity of 18 stations across the country for the time period of 1990–2004 were used. Finally, the MI was calculated for the time period of 1990–2004 as historical MIs and illustrated in maps. The observed climatic data were interpolated using inverse distance weighting (IDW) in generating these illustrations.

The future projections of the WI were calculated by analyzing projected daily rainfall data for three climatic cycles, including near-future period (2021–2040), mid-future period (2041–2070), and far-future period (2071–2100). Twenty years were considered for the near-future scenario, and 30 years of climate cycles were considered for the mid-future and far-future analysis based on the literature [35–37]. The climatic data were extracted under two Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and RCP8.5), and they were bias-corrected using the linear bias corrections (refer to equations (1) and (2)). These projected climate data were used to analyze the future MIs. Finally, the maps were developed for projected MIs for the three climatic cycles.

4. Results and Discussion

4.1. Historical Indices (1990–2004). Figure 2 presents the historical indices for DI (refer to Figure 2(a)), WI (refer to Figure 2(b)), and MI (refer to Figure 2(c)) for the observed meteorological data in the 1990–2004 period. The results are given for the four seasons. As discussed in the methodology, the DI was normalized by the maximum values obtained for the DI. Therefore, the normalized drying index values ranged from zero to one. However, the WI was normalized using the minimum values obtained for the WI, and thus the normalized range was between one to values greater than one. As a result, MI ranges from 1 to values greater than one.

The literature states that drying potential can be used as the normalization factor to calculate the drying index [38]. However, the drying potential for Sri Lanka is unavailable; therefore, the corresponding minimum and maximum values of the wetting index and drying index were used in normalization. Nevertheless, the results obtained for the MI were greater than 1 [3].

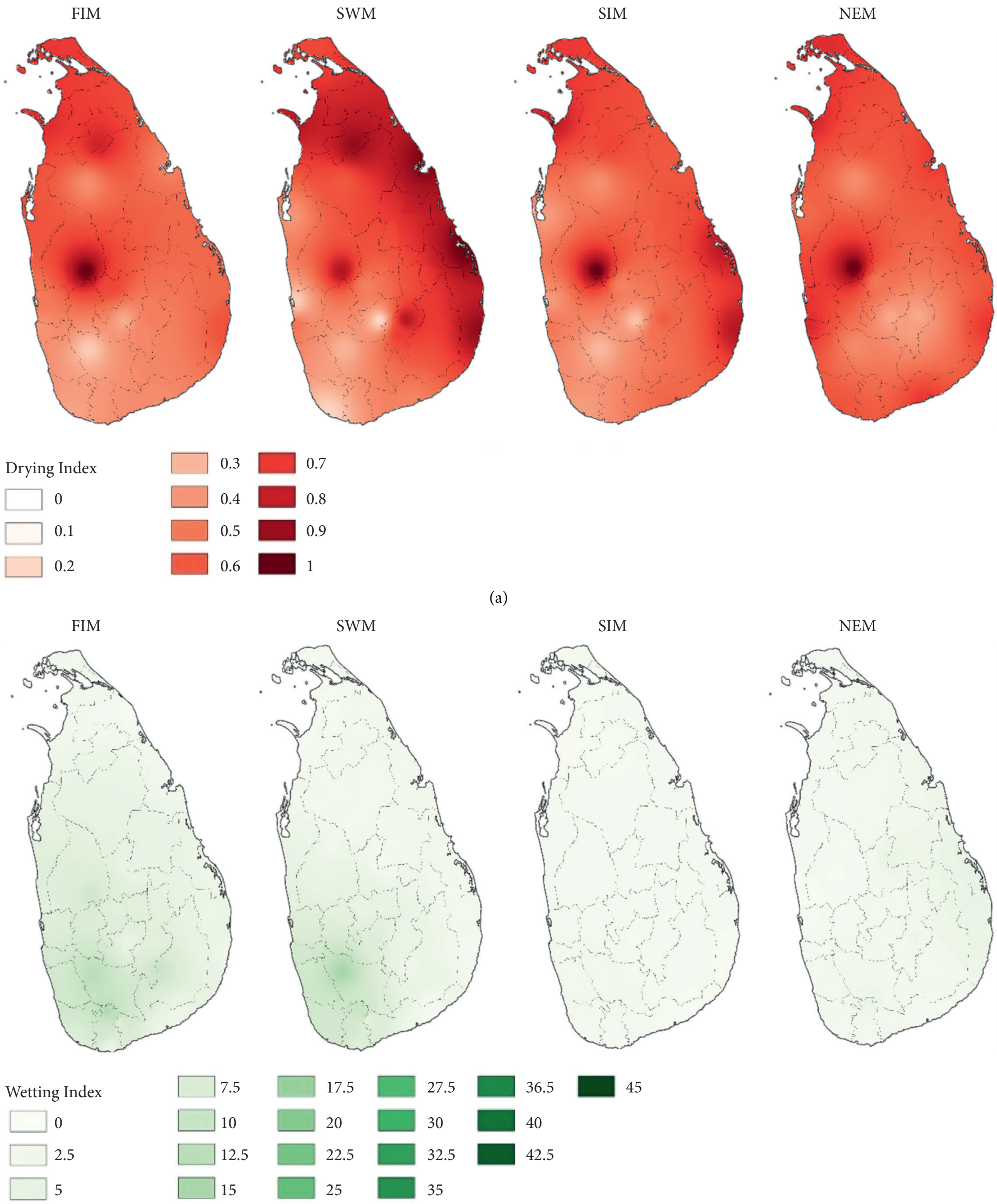
The major drawbacks of using minimum and maximum values are that the normalized index does not represent the value of the index. Thus, the highest normalized WI does not represent the highest WI. The highest normalized wetting index represents the scenario with the largest range of wetting index but not the highest value.

It can be seen that the DI is higher in northwestern and western areas of the country for all four seasons (dark red patches). In addition, the northeastern and eastern regions showcase higher DI during the southwestern monsoon period. The SWM brings rain to southwestern Sri Lanka, and the wind direction is significantly towards the southwestern to northeastern direction. However, the high central hills limit the rainfall to eastern and northeastern Sri Lanka during this period. Therefore, higher DI can be expected in northeastern and eastern areas of Sri Lanka.

However, there are no significant changes in WI for the four seasons. Therefore, the moisture loading does not showcase a big difference from one season to another. Nevertheless, MI is higher in FIM and SWM for the southwestern area of the country. Therefore, the atmospheric moisture content in these two seasons is higher compared to SIM and NEM seasons. Some of the numerical values for indices are given in Table 2 for more information for the variations shown in Figure 2. The maximum MI is limited to 15.25 in SWM as shown in Table 2. In addition, the SWM season has comparably higher DI and WI values. Therefore, the numerical representation of MI can be important in identifying the maximums and minimums.

4.2. Near-Future Indices (2021–2040). Figures 3 and 4 illustrate the DI, WI, and MI obtained for near-future climates from 2021–2040. The indices derived for RCP4.5 climate scenario are presented in Figure 3, whereas the indices for RCP8.5 are given in Figure 4. No significant differences can be identified from the corresponding indices for two RCP scenarios. Higher DI values can be seen in the northwestern region of the country for both historical and future years for all four seasons. In addition, eastern regions showcase higher DI during three seasons other than NEM. The observations are common for both RCPs.

WI and MI are found to be higher in the southwestern region for SWM season for both RCPs. Therefore, the construction industry in highly developing areas of Sri



(a)

(b)

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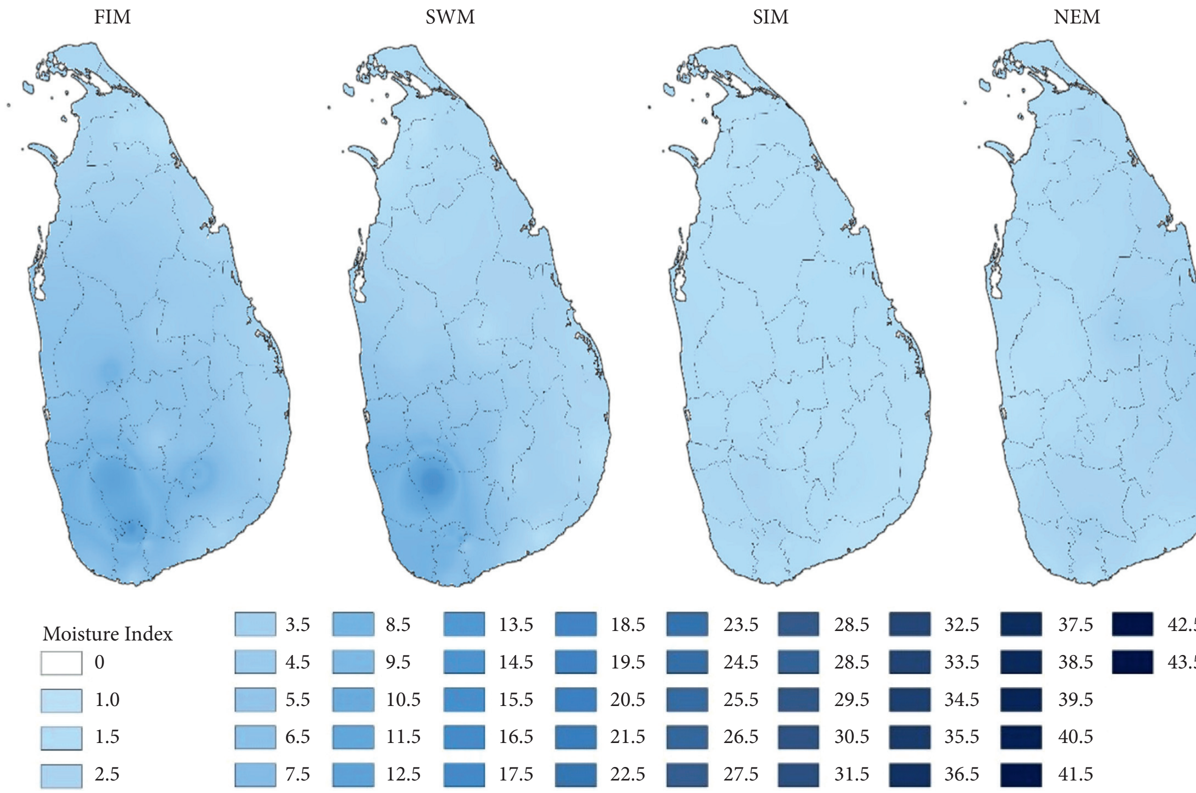


(c)

Figure 2: Historical indices from observed climatic parameters (1990–2004). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

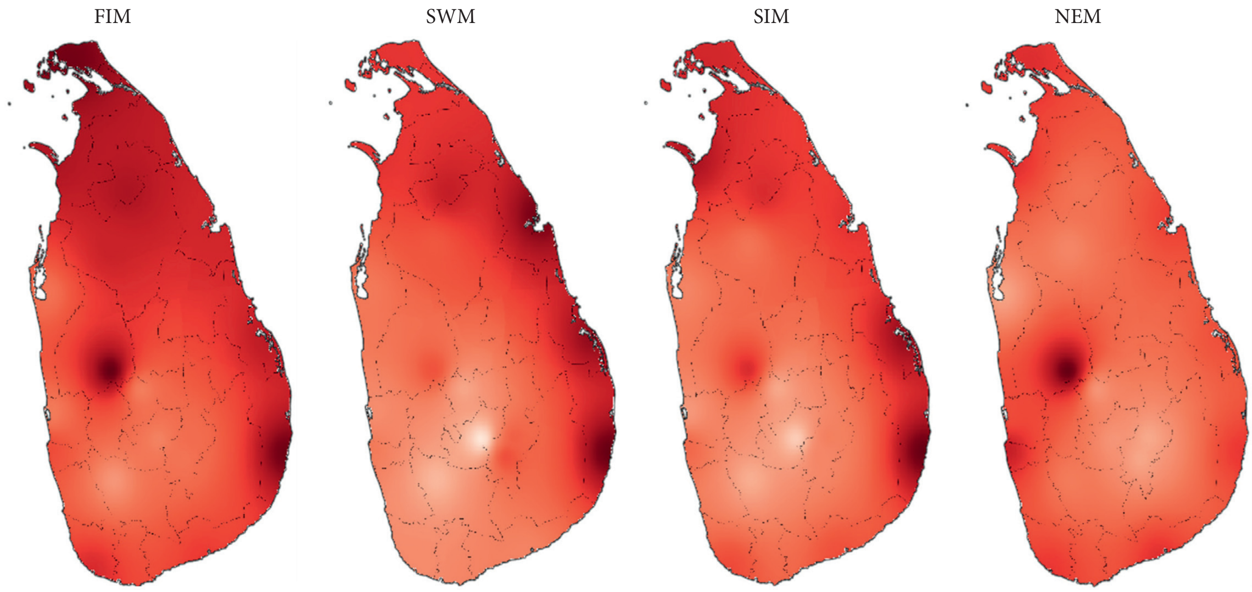
Table 2: Indices for historical meteorological observations.

Season	DI		WI		Moisture index	
	Min	Max	Min	Max	Min	Max
FIM	2.37	10.13	1.55	21.52	1.06	13.87
SWM	1.58	8.15	3.93	59.86	1.03	15.25
SIM	1.46	5.61	11.95	30.81	1.09	2.64
NEM	2.03	5.98	6.48	29.14	1.04	4.52

Lanka would be concerned. In addition, the wetting index has been increased considerably compared to historical indices, owing to the increasing trends of rainfall. Table 3 presents the minimums and maximums for DI, WI, and MI for four seasons under both RCPs. Non-normalized DI and WI do not show a significant difference from RCP4.5 to RCP8.5. This can be seen for the MI too. Therefore, the normalized DI and WI reflect the non-normalized indices. Thus, the spatial variations shown in Figures 3 and 4 are justifiable.

4.3. Mid and Far-Future Indices (2041–2070 and 2071–2100). Table 4 presents the DI, WI, and MI for mid-future and far-future periods under both RCP scenarios. DIs do not show a significant difference from mid-future to far-future periods in both minimum and maximum DIs during the RCP4.5 and RCP8.5 climatic scenarios. However, differences can be observed in WIs from mid-future to far-future periods for RCP4.5. Nevertheless, the differences are not significant for RCP8.5. In addition, minimum MIs are always kept around 1; however, the maximum MIs have significant variations from mid-future to far-future periods in RCP4.5. Interestingly, these significant variations cannot be found for RCP8.5 climatic scenarios. The developed maps for DI, WI, and MI for mid-future and far-future periods for two RCPs are given in Figures 5–8.

The highest drying index is experienced in the southeast regions of the country for the three monsoons—FIM, SWM, and SIM, whereas for the NEM, the highest drying index is observed in the southwestern regions (refer to Figures 5–8). This phenomenon is consistent for both the time periods in both RCPs for the spatial variations of DIs. From the results given in Figures 5–8, it can be derived that the wetting index has a wide range of spatial distribution as a result of the wet regions and the dry regions of the country. Since the wetting



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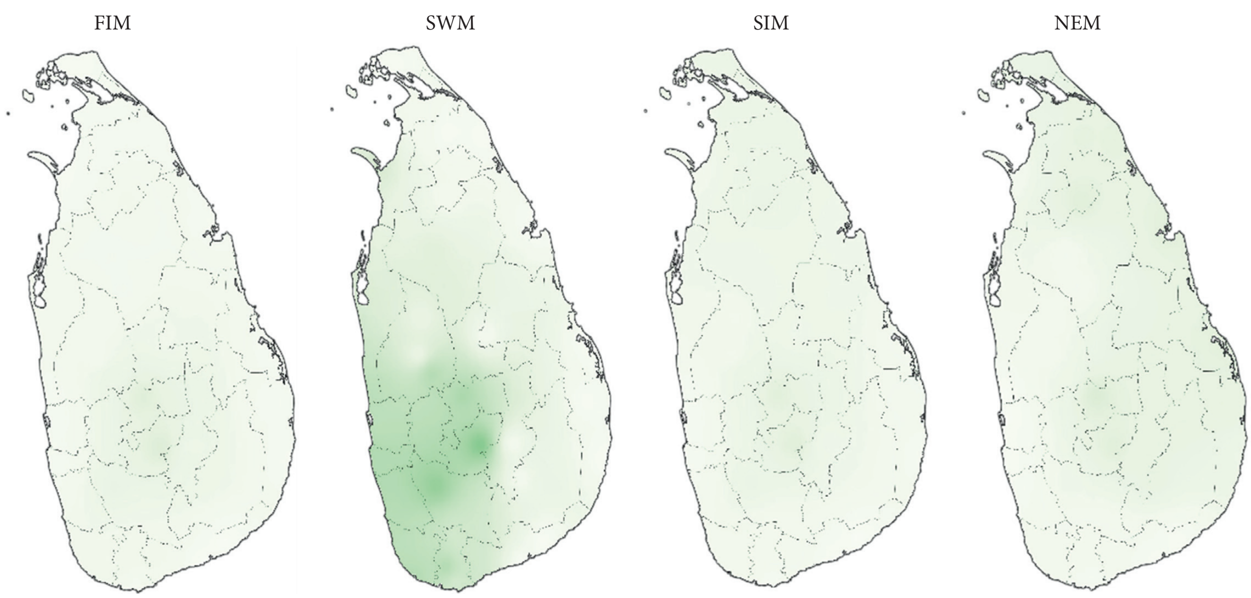

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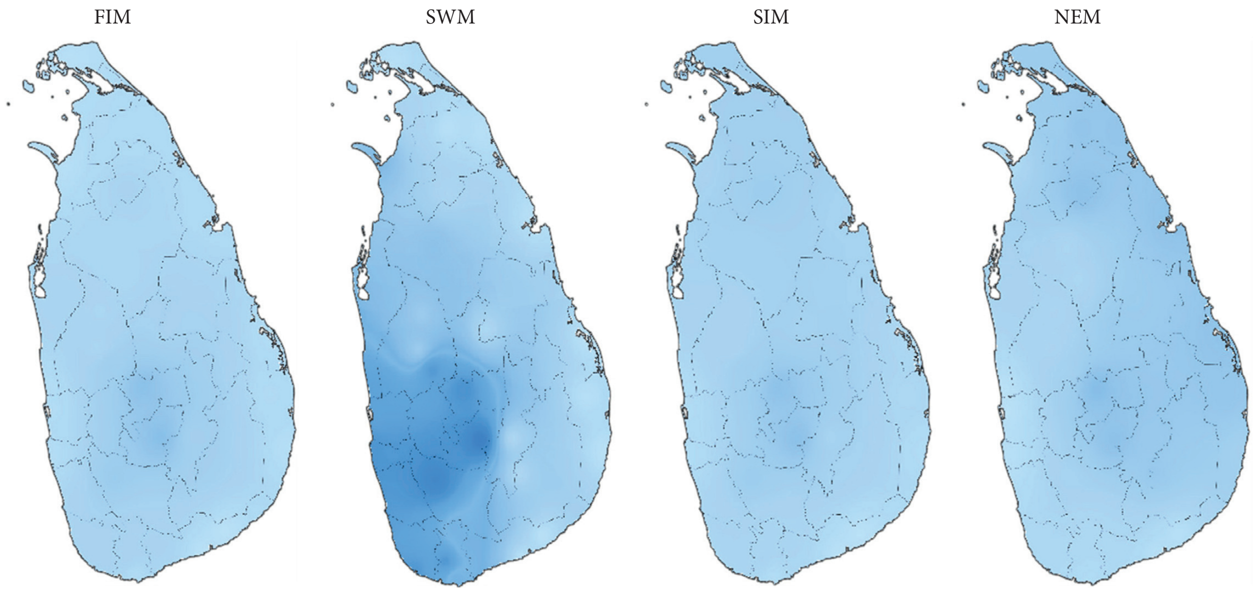
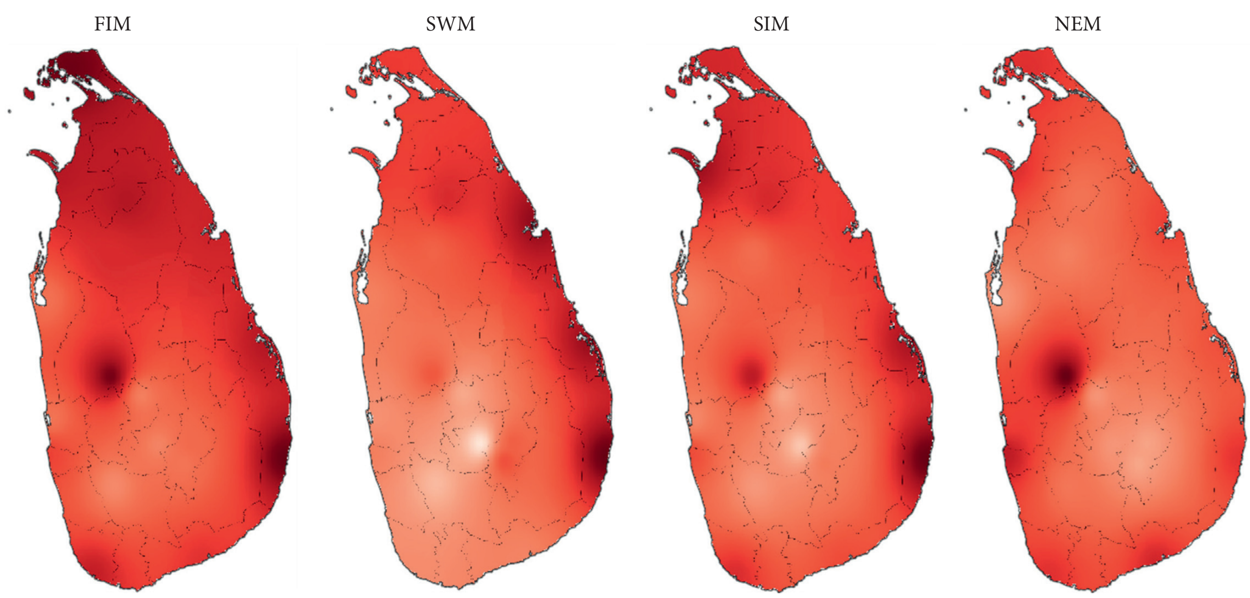
Figure 3: Continued.



(c)

Figure 3: Near-future indices under RCP4.5 (2021–2040). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.



(a)

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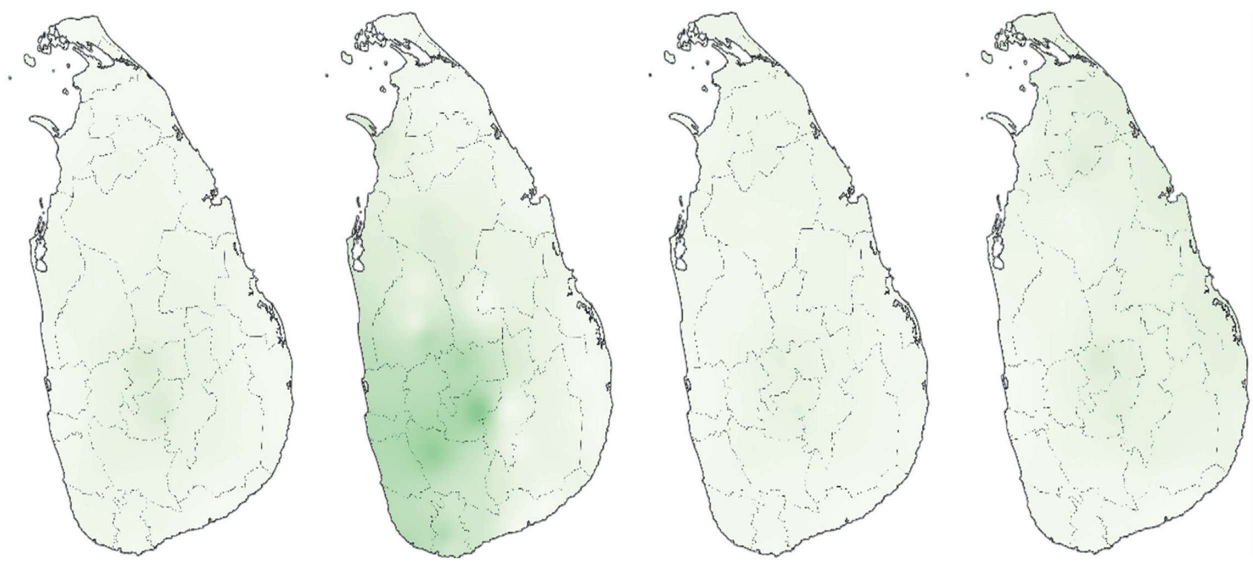

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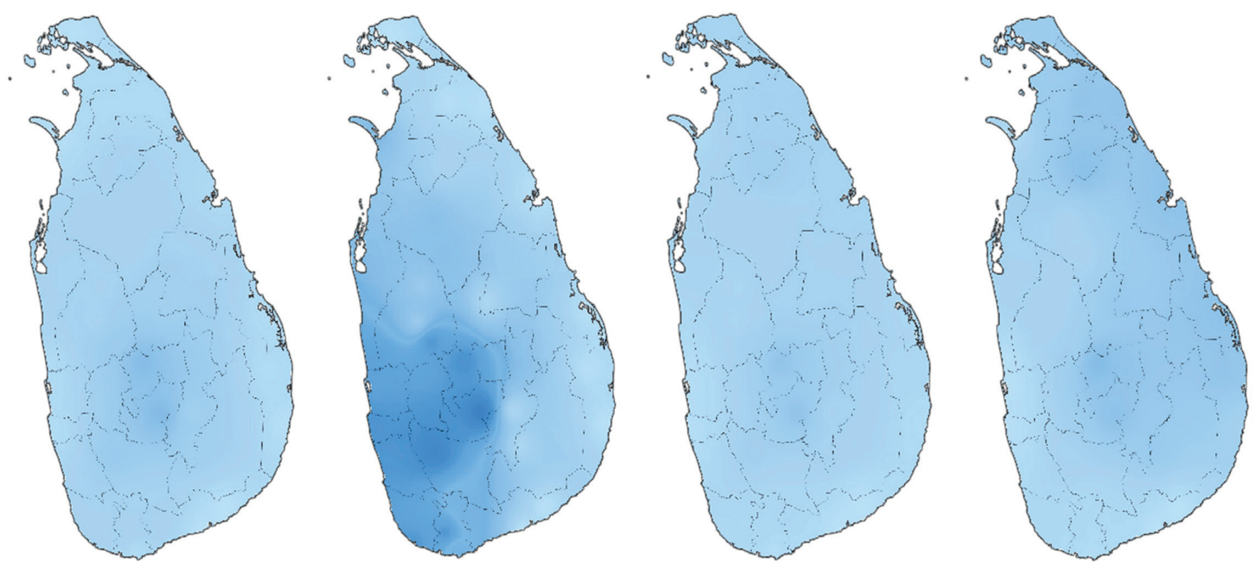


(c)

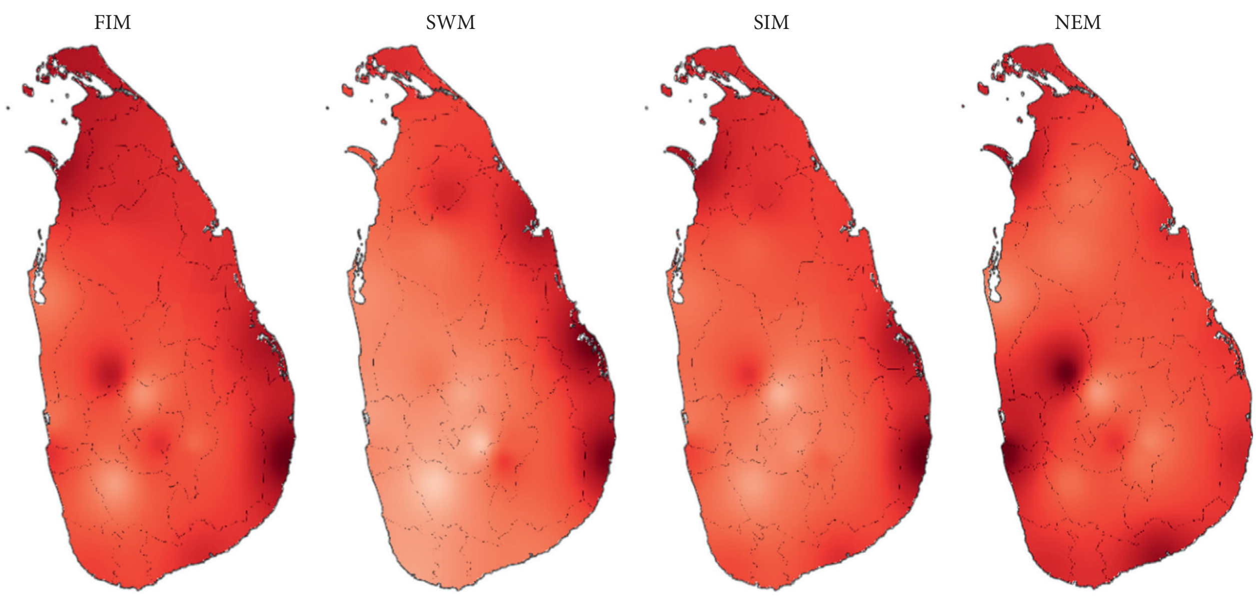
Figure 4: Near-future indices under RCP8.5 (2021–2040). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

Table 3: Minimum and maximum indices for near-future climates.

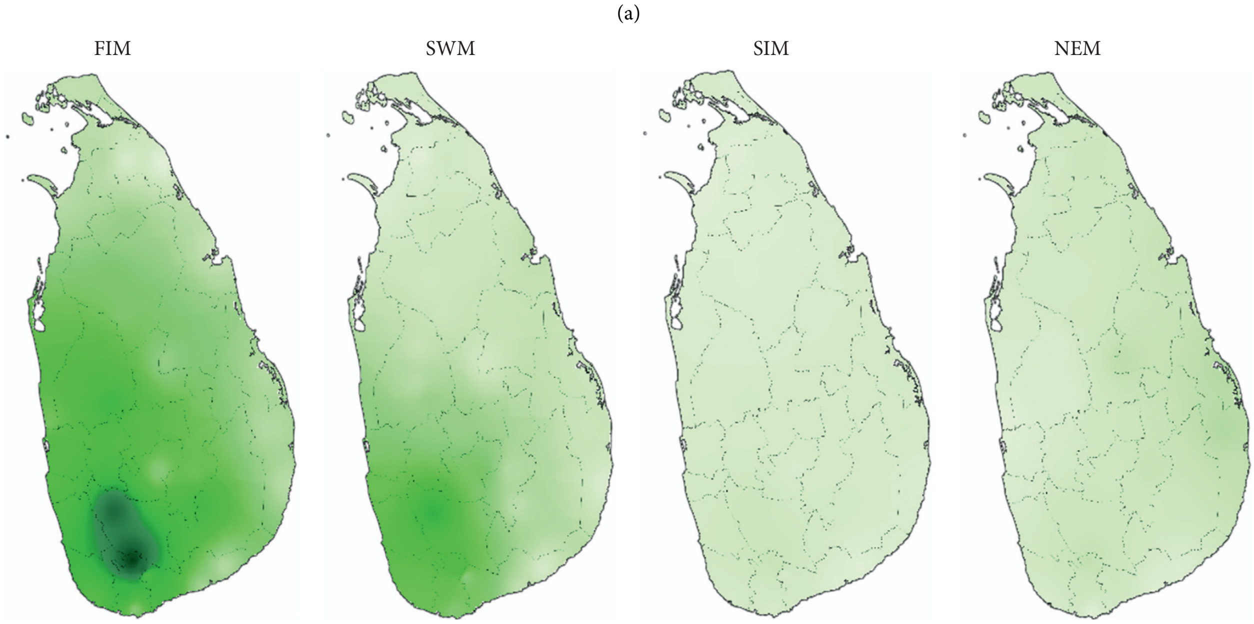
Season	DI		WI		MI	
	Min	Max	Min	Max	Min	Max
RCP4.5 (2021–2040)						
FIM	2.82	7.08	211	1428.31	1.05	6.79
SWM	1.34	8.82	12.14	2412.34	1.04	19.61
SIM	1.25	5.34	150.81	944.15	1.07	6.31
NEM	2.26	6.61	161.12	1153.98	1.06	7.19
RCP8.5 (2021–2040)						
FIM	3.36	7.63	178.82	1359.09	1.04	7.62
SWM	1.37	8.96	126.54	2479.78	1.06	19.62
SIM	1.25	4.95	201.44	1080.84	1.06	5.41
NEM	2.42	6.92	147.98	1090.29	1.03	7.40

Table 4: Mid and far-future indices (2041–2070 and 2071–2100).

Season	DI		WI		MI		DI		WI		MI	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
	RCP4.5 (2041–2070)						RCP4.5 (2071–2100)					
FIM	2.5	6.8	18.1	782	1.0	43.1	2.8	7.2	180.4	1382	1.0	7.7
SWM	2.4	9.9	86.9	2166	1.1	24.9	2.5	10.2	152.9	2260	1.1	14.8
SIM	1.7	5.4	340.4	1206	1.0	3.6	1.8	5.6	554.3	3424	1.1	6.2
NEM	2.4	6.2	154.7	857	1.0	5.6	2.5	6.3	201.4	1702	1.0	8.5
	RCP8.5 (2041–2070)						RCP8.5 (2071–2100)					
FIM	3.5	7.9	192	1534	1.0	8.0	4.7	9.9	200	1499	1.0	7.5
SWM	1.5	9.7	133	2253	1.1	16.9	1.7	11.1	150	2478	1.0	16.6
SIM	1.3	5.1	611	3756	1.1	6.2	1.3	5.2	872	5368	1.1	6.2
NEM	2.4	7.5	180	1789	1.1	9.9	3.2	9.0	173	1810	1.1	10.5



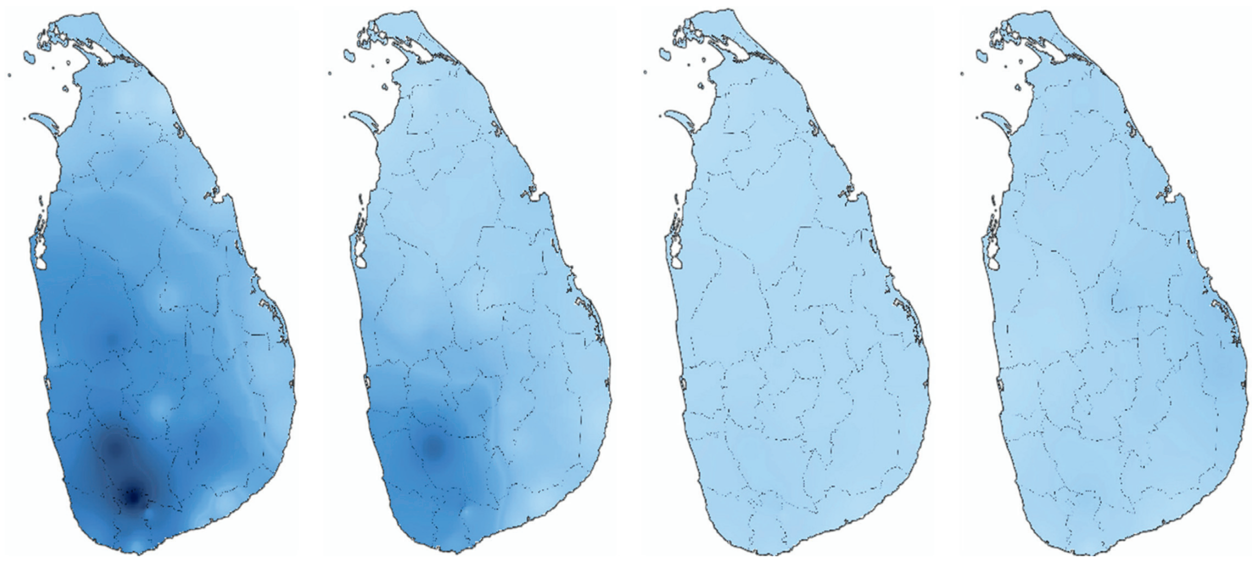
(a)



(b)

Figure 5: Continued.

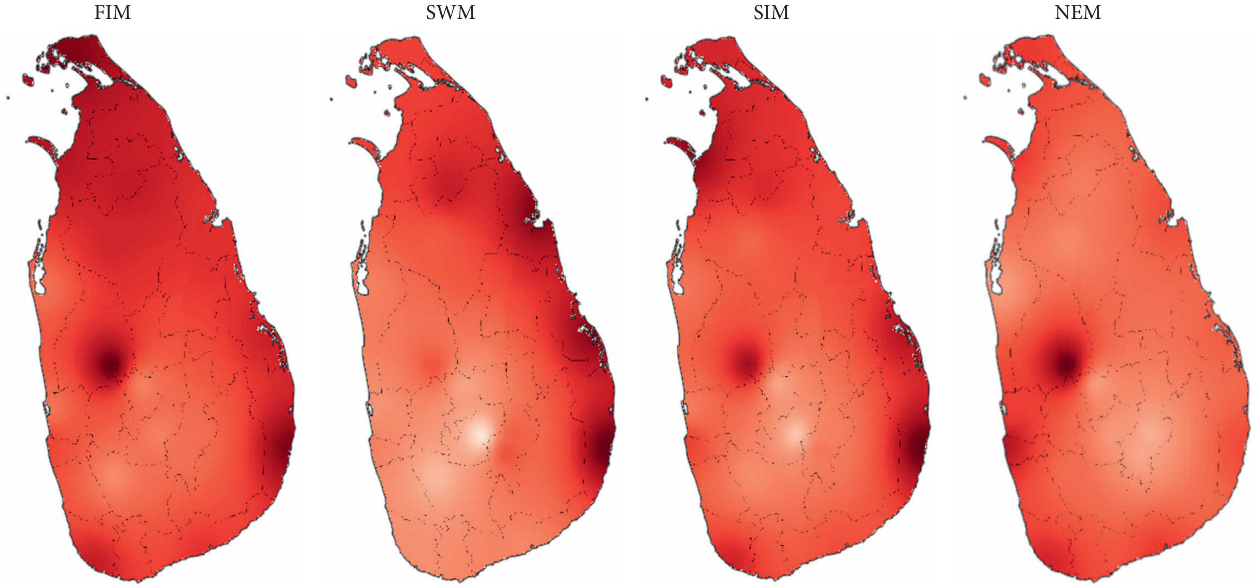
FIM SWM SIM NEM



(c)

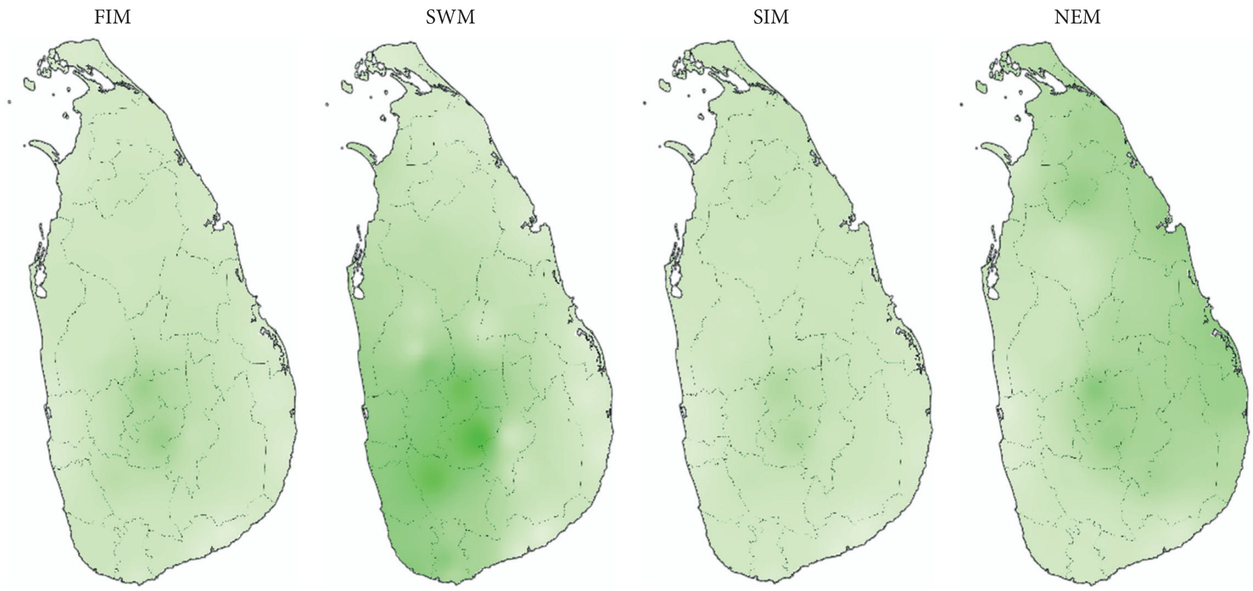
Figure 5: Mid-future indices under RCP4.5 (2041–2070). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

FIM SWM SIM NEM



(a)

Figure 6: Continued.



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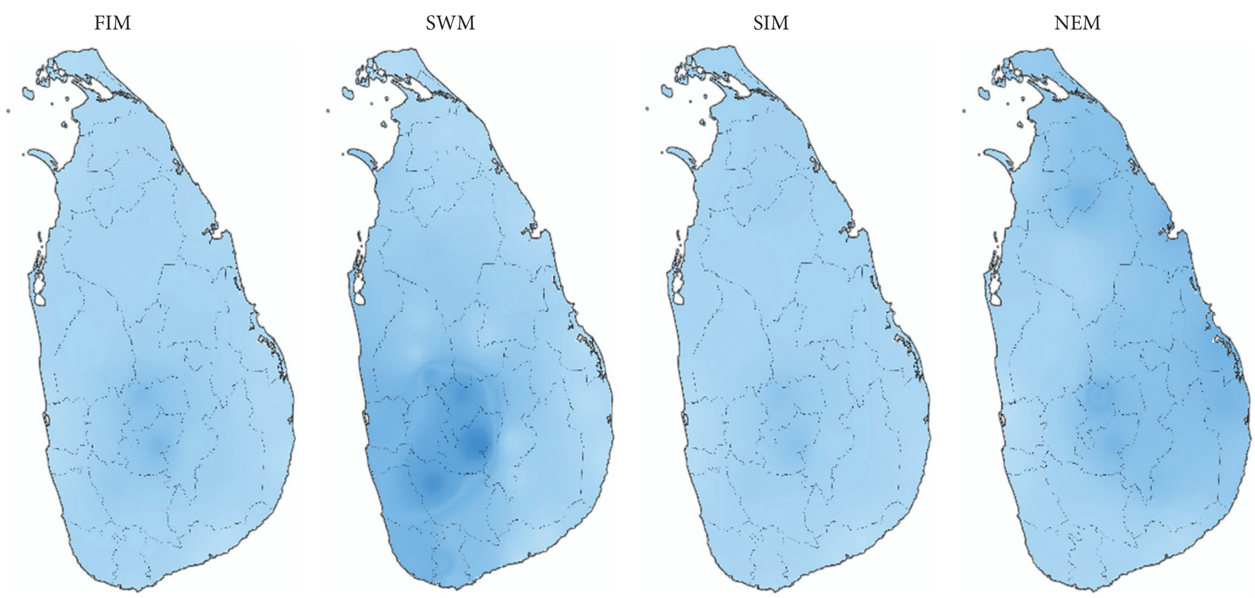
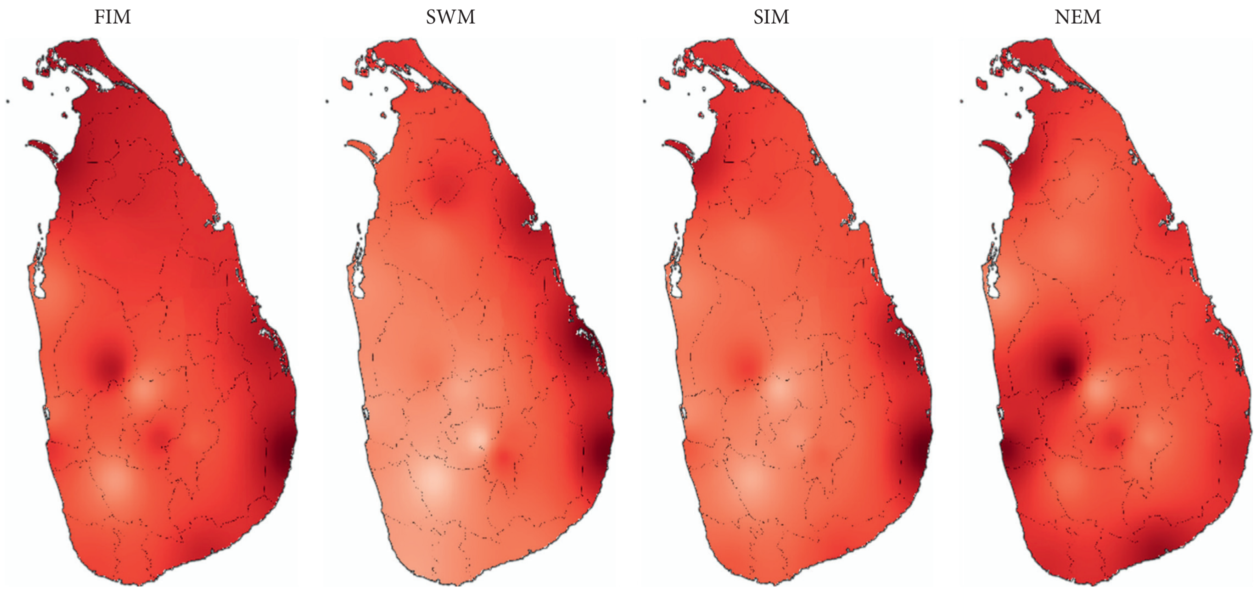


(c)

Figure 6: Mid-future indices under RCP8.5 (2041–2070) (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

index solely depends on the amount of rainfall, the pattern of the wetting index variation is evident. During the FIM and SWM, the southwestern regions experience the highest wetting index, while the northeastern regions experience the highest wetting index during the NEM. These observations clearly showcase the relationship to the rainfall seasons of the country. During the other two inter-monsoons (FIM and SIM), the central highlands of the country experience the highest wetting potential. Unlike the DI, the WI increases at a significant rate for the RCP8.5 when comparing the two-time series.

Figure 9 presents the temporal comparison of minimum and maximum moisture indices over the years for historical climatic observations and projected climatic scenarios. No significant changes can be seen for minimum MIs over the years for four seasons. However, significant variations can be seen for the maximum MIs over the years. Decreases and increases can be seen from historical MIs to near-future MIs in all four seasons. However, notable changes can be observed in FIM and SWM seasons from 2021–2040 to 2041–2070 for RCP4.5 climatic scenario. Nevertheless, SIM and NEM seasons do not show significant changes in MIs.



(a)

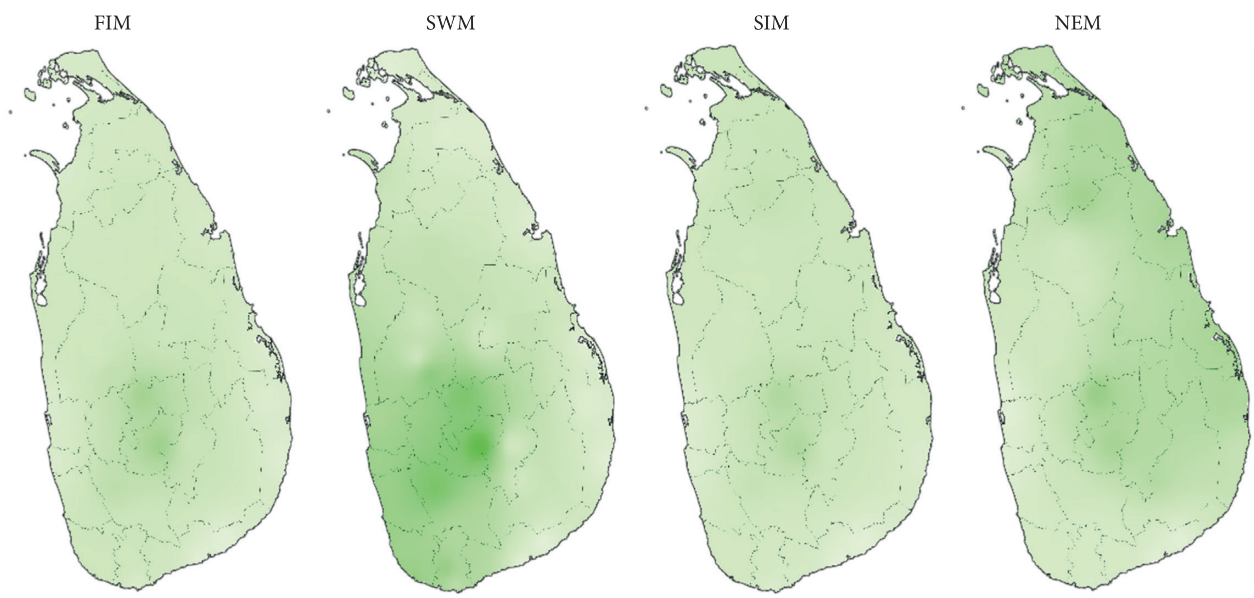


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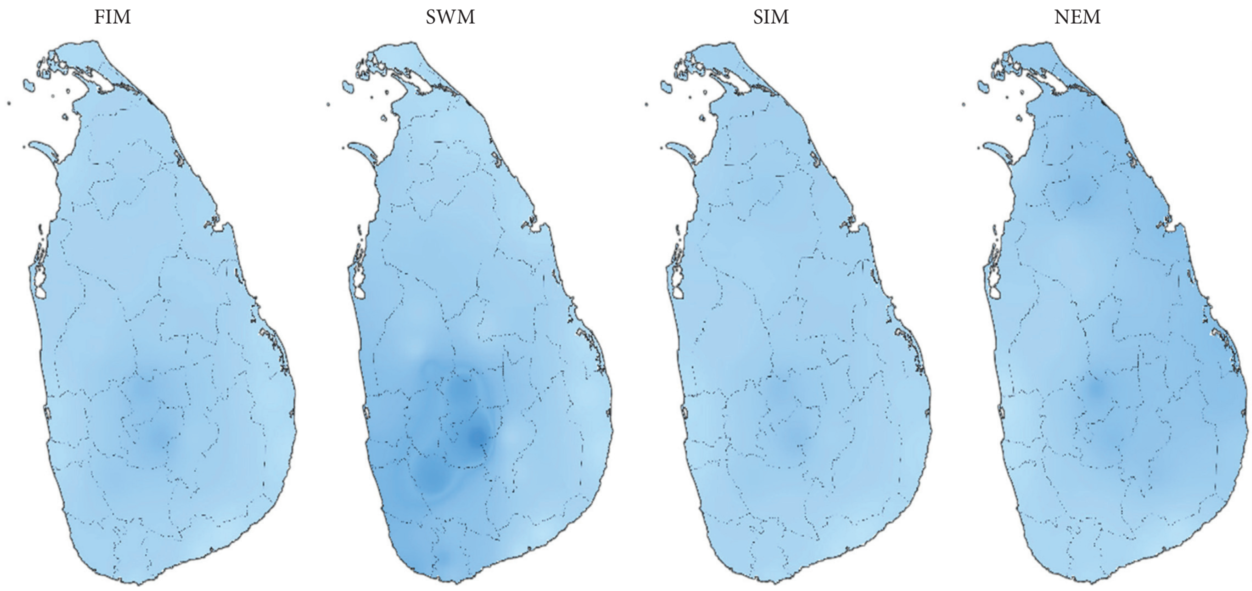
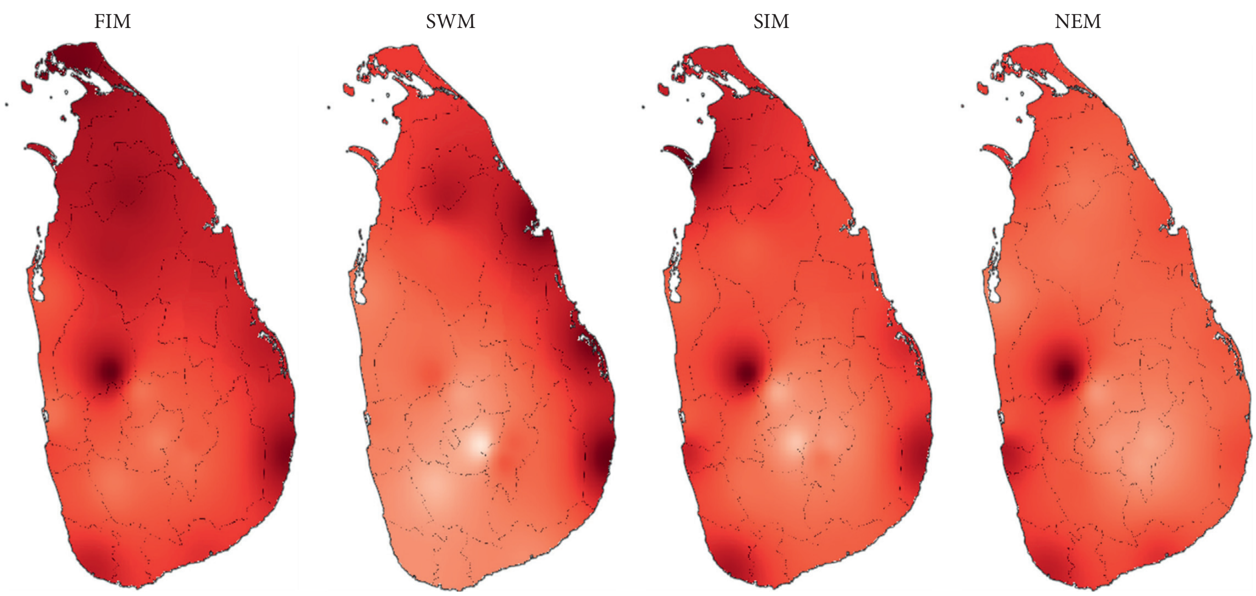
Figure 7: Continued.



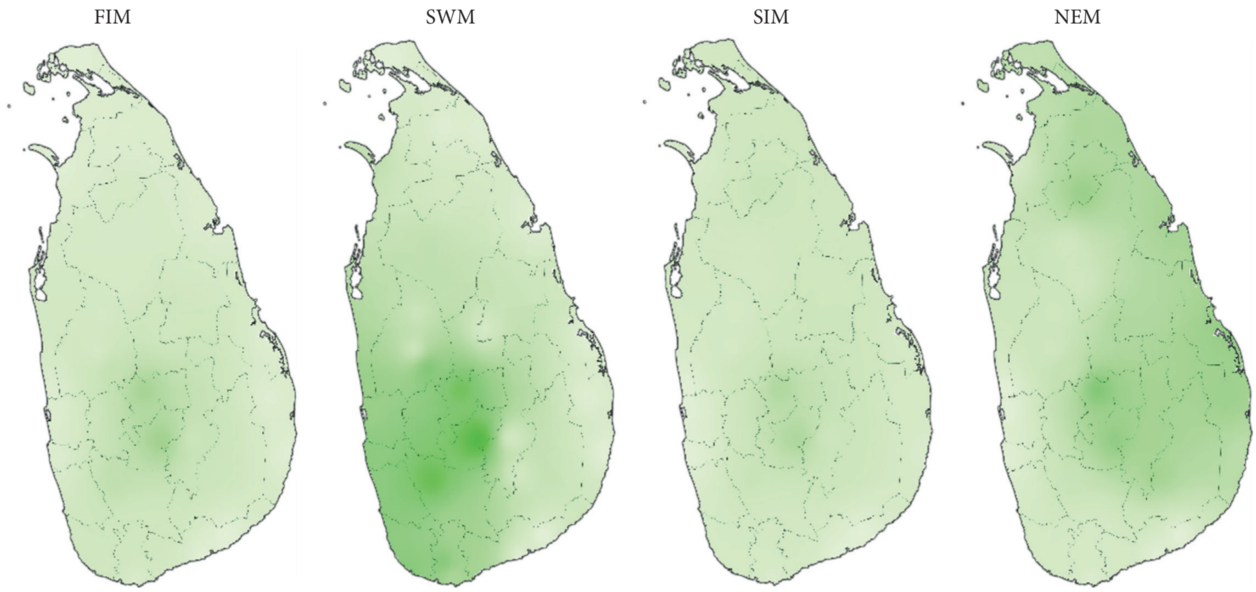
(c)

Figure 7: Far-future indices under RCP4.5 (2071–2100). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

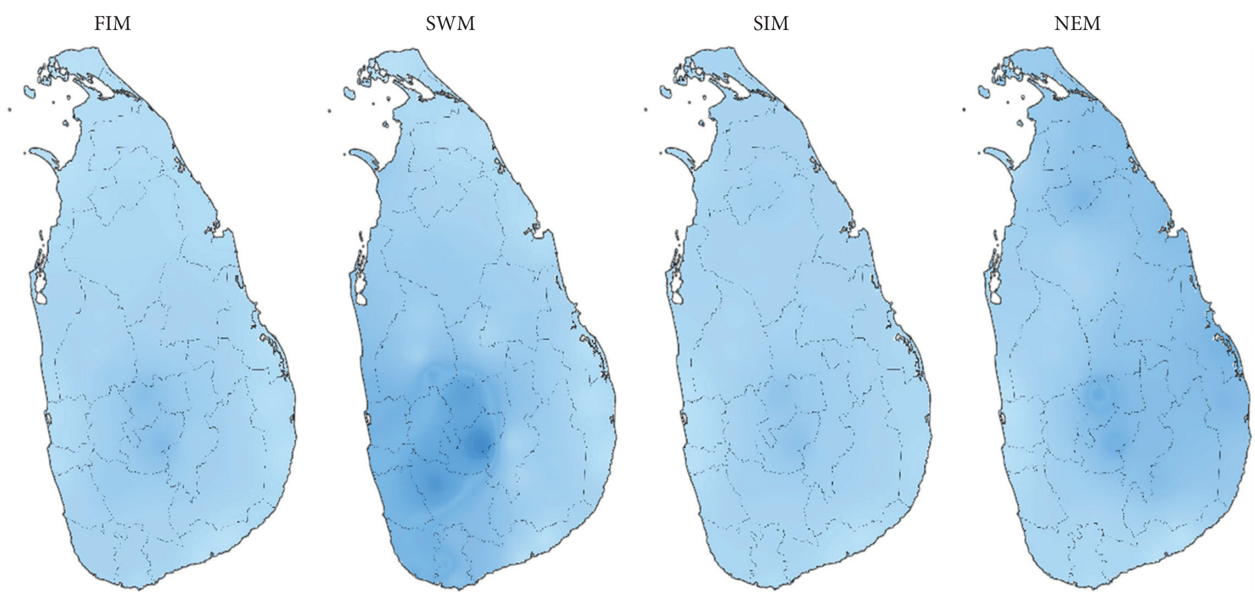


(a)

Figure 8: Continued.



(b)



(c)

Figure 8: Far-future indices under RCP8.5 (2071–2100). (a) For normalized DI. (b) For normalized WI. (c) Moisture index.

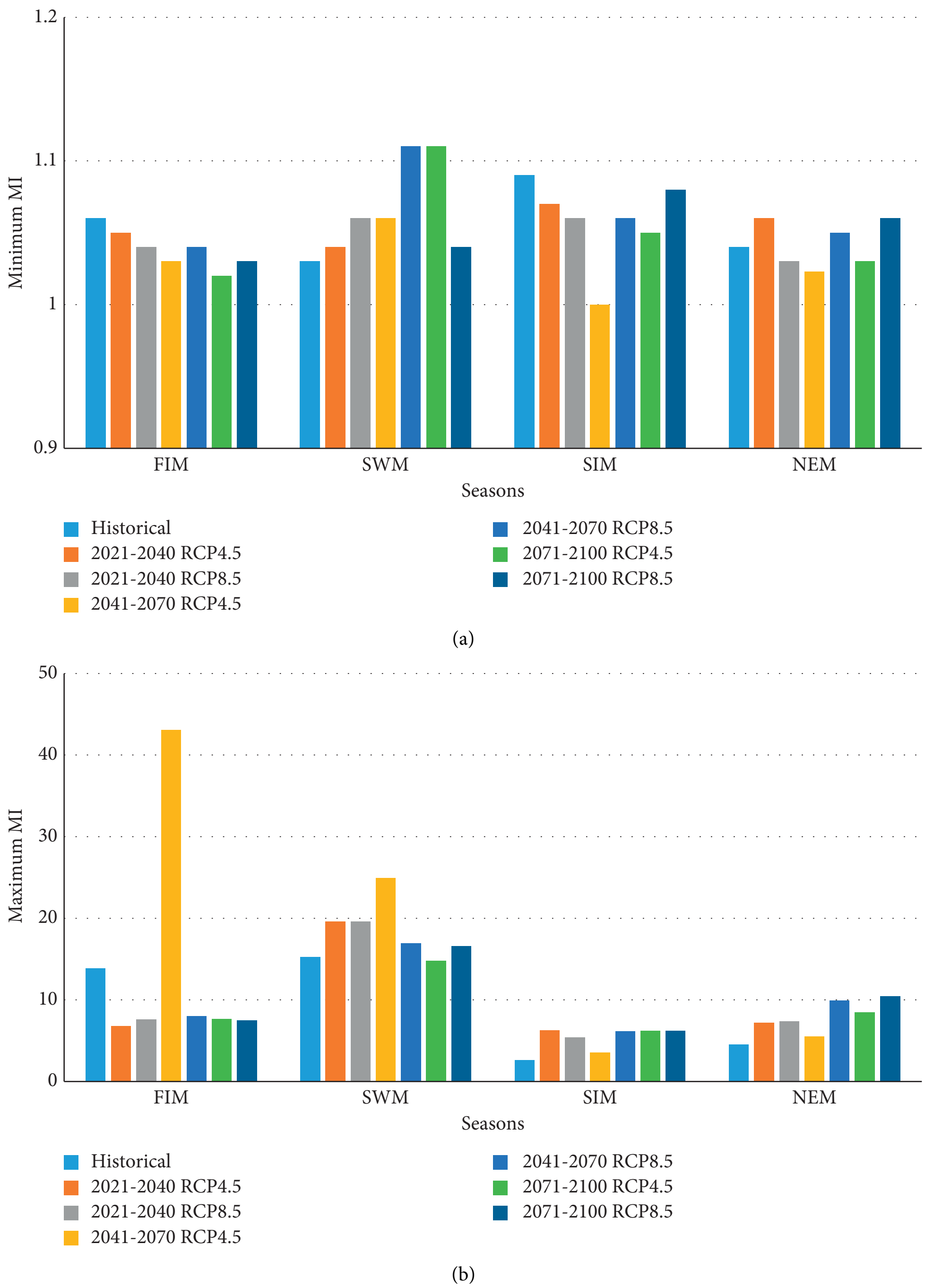


Figure 9: Comparisons of MI. (a) For minimum MI. (b) For maximum MI.

Therefore, this is very important for the construction industry in Sri Lanka in the future. The quality of the constructions can be guided along the lines of the findings of this research.

5. Summary and Conclusions

The moisture variation, in the form of the moisture index, across Sri Lanka for historical climates (1990–2004) and projected future climatic scenarios (2021–2100) was evaluated in this research work. This is the first study in Sri Lanka to conduct such research and to come up with moisture maps for the whole country. In addition, future MI projections are significant in the changing climates. Therefore, this research clearly compiles that research gap for Sri Lanka.

The moisture load in the environment affects the durability of the building exteriors, and therefore the understanding of the moisture index over an island nation is helpful in building construction. Spatial and temporal distribution results are clearly in agreement with the country's spatial and temporal rainfall distribution. Sri Lanka's eastern and northeastern areas have and will have higher dry indices during the SWM season. Higher WI and MI can be seen for western and southwestern areas of the country for both historical and future projected climates during the SWM and FIM seasons. However, notable changes as showcased in the results section for FIM and SWM seasons should be further investigated.

Therefore, not only the building construction but also the agricultural activities may have to be streamlined according to the results of this study. In addition, the results can effectively be used in climate zoning, investigating indoor air quality for respiratory issues, and understanding thermal comfort and energy consumption of buildings. However, a detailed investigation should be carried out related to specific disciplines including building construction and agriculture specifically to the western, southwestern, eastern, and northeastern areas of the country.

In addition, this study was carried out using the most accurate data available, yet this can be further improved by using more sophisticated and more accurate climate models and bias correction techniques. This will ensure a higher level of accuracy and less uncertainty in the results obtained. Furthermore, other climatic parameters such as wind speed, wind direction, and solar radiation which have a high impact on the moisture load in the atmosphere can be used as future improvements to this study. However, the results obtained in this study can effectively be used by decision makers in Sri Lanka and similar countries.

Data Availability

The data used in this study are available from the corresponding author upon request only for research purposes.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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