Journal of Scientific Research & Reports

17(6): 1-11, 2017; Article no.JSRR.39201
ISSN: 2320-0227

Implications of Geographical Factors and Trends of Climatic Factors on Aridity/Humidity Trends

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JSRR/2017/39201
Editor(s):
(1) Francisco Torrens, Institut Universitari de Ciència Molecular, Universitat de València, Edifici d'Instituts de Paterna, València, Spain.
Reviewers:
(1) Philbert Modest Luhunga, Tanzania.
(2) K. E. Ukhurebor, Edo University Iyamho, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/22960

Original Research Article

Received 3rd November 2017
Accepted 25th January 2018
Published 31st January 2018

ABSTRACT

The study aimed to find the implications of geographical factors and trends of climatic factors (precipitation, temperature, relative humidity, wind speed and solar radiation) on aridity index trends at 56 sites in South Korea. Monthly, seasonal, and annual normal aridity index values for the 56 study stations in South Korea were estimated for a 30-year period (1974-2003). The aridity index was estimated as the ratio of precipitation (P) to potential evapotranspiration (PET) (P/PET). Detailed geographical information and multiple linear regression (MLR) analyses were used to assess the implications. The trends of climatic factors had more close implications on aridity index trends than geographical factors. The aridity index changes were driven mainly by changes in precipitation; and the changes in other climatic factors (wind speed, relative humidity, and solar radiation) also showed significant correlations with the aridity index trend. When considering the relative importance of geographical factors (elevation, freshwater area, urbanization, and proximity to the coast) on aridity/humidity trends, the elevation were found to be the most important factor. The changes in precipitation as climatic factor and elevation as geographical factor are turned out to be the most important factors affecting on regional aridity/humidity trends in South Korea.

Keywords: Aridity index; geographical and climatic factors; trend analysis; multiple regression.

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1. INTRODUCTION

Deforestation accompanied by urbanization and industrialization are closely linked to climate change, and the corresponding increases in greenhouse gas emissions are driving global warming trends around the world [1-3]. Global warming can affect precipitation and evapotranspiration directly [4], and the ratio of precipitation to potential evapotranspiration, namely, the aridity index (P/PET, where P represents precipitation and PET represents potential evapotranspiration), has been proposed a useful tool to assess changes in regional moisture conditions; it can also be used as an index to define the usable amount of water resources in a region [5]. Regional moisture conditions are affected not only by climatic factors, but also directly by the geographical characteristics of a region. Therefore, both geographical factors and climatic factors should be considered as controlling factors when determining the aridity or humidity conditions of a region.

In the past, air temperature, net radiation, and specific humidity instead of evapotranspiration were used to calculate the aridity index [6]. However, it was reported that potential evapotranspiration was more applicable than air temperature when estimating the aridity index [7]. This index has been applied by different researchers [8-11] for investigations of aridity/humidity conditions in different regions.

Recently, many researchers have undertaken efforts to analyze the variation of aridity index values under the conditions of climate change at the regional scale [12-21]. [16] showed that the aridity index values in northwestern China are closely affected by several climate factors, whose influence were classed in the order of precipitation, vapor pressure, solar radiation, wind speed, and air temperature. On the basis of study results for the annual aridity/humidity characteristics in Iran [14,18], [14] revealed that both drying and wetting trends occurred. [18] concluded that increasing precipitation trend and decreasing potential evapotranspiration trend are closely related to the increasing aridity index trend.

Kafle and Bruins [12] studied aridity trends by considering precipitation and Thornthwaite potential evapotranspiration in Israel and discovered that the climate of the majority of Israel has become dry except for in the coastal plain area. Based on the aridity trend study in Greece, [15] commented a progressive shift from humid land to sub-humid and semi-arid land. [22] examined the impact of climate aridity on agricultural systems at the regional scale in Italy by using the UNEP aridity index. In this study, the FAO Penman-Monteith (P-M) equation suggested by [23] was used for the estimation of potential evapotranspiration. During the application of the FAO P-M equation, the evaporating powers of different study sites can be compared for specific study periods [23].

When considering previous studies, most previous studies have analyzed the aridity trends using data obtained from limited sites, while other studies have examined aridity trends according to climatic factors in various sites without considering detailed data on geographical characteristics. However, aridity trends have a close relationship not only with climatic factors, but also with geographical characteristics. Therefore, it is important to analyze the implications of geographical and climatic factors on regional aridity/humidity trends by using detailed geographical information. This paper also examine the relative importance of geographical factors and trends of climatic factors on regional aridity/humidity trends by using detailed geographical information from different study sites in South Korea.

2. MATERIALS AND METHODS

2.1 Study Sites and Data

In this study, 56 sites in South Korea were selected based on the usability of the climate data. A climatological station was centrally located in each of the study sites. Most farms in South Korea are situated on the southwestern plain area that covers the western half of South Korea and on the southern plain area along the south coast (Fig. 1, Table 1).

For this study, climate data measured by the Korean Meteorological Administration (KMA) were obtained from 56 stations in South Korea. The collected and analyzed climate data included the monthly average daily precipitation, temperature, wind speed, relative humidity, and sunshine duration. The data used for this study spanned a 30-year period from 1974 to 2003. The solar radiation was calculated by using formulas suggested by [23].

To examine the effects of geographical factors on aridity index trends, the 56 study sites were selected by considering four different geographical conditions (i.e., elevation, urbanization, distance to the coast, and proximity of the observation-station to the sea). Geographical information system (GIS) data analyses were carried out within a 10-km radius for each respective sites (Table 1). The elevations of the study sites were analyzed by using digital elevation model (DEM) data for 2004. Moreover, study site data for 6 years (1975, 1980, 1985, 1990, 1995, and 2000) were selected and classified with land cover maps supplied by the Ministry of Land, Transport, and Maritime Affairs (MLTM).

2.2 Aridity Index Trends

Monthly, seasonal, and annual normal aridity index values for the 56 study stations in South Korea were estimated for a 30-year period (1974-2003). The aridity index (P/PET) was estimated as the ratio of precipitation (P) to potential evapotranspiration (PET). In this study, the FAO P-M potential evapotranspiration equation suggested by [23] was used. The non-parametric Mann-Kendall trend test [24] is used to determine the monthly, seasonal and annual trends (Z-scores) of aridity index values and climatic variables (precipitation, temperature, relative humidity, wind speed, and solar radiation) for the past 30 years (1974-2003). A positive Mann-Kendall Z-score indicates an upward trend and vice versa.

2.3 Multiple Linear Regressions

In this study, multiple linear regression (MLR) analyses were used to analyze the effects of four different geographical factors (elevation, urbanization, freshwater area, proximity to the coast) and trends of five different climate variables (precipitation, air temperature, wind speed, relative humidity, solar radiation) on aridity index trends at 56 measurement stations located in South Korea. The MLR analyses were conducted by using the direct regression method and stepwise regression techniques with the monthly, seasonal, and annual Mann-Kendall Z-scores; specifically, the aridity index (P/PET) trends were set as the dependent variable and the geographical factors and trends of climatic factors were set as the independent variables.

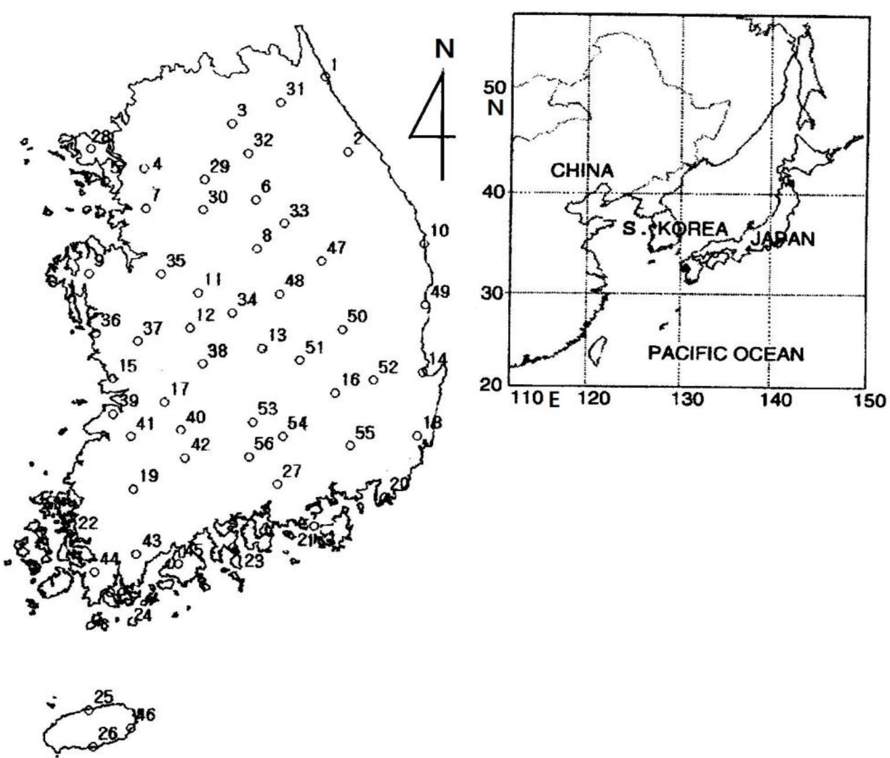

Fig. 1. The 56 climatological stations in the Korean Peninsula. Station numbers refer to Table 1

Table 1. Geographical characteristics of the 56 study stations. Elevation (m): elevation of study station; Inland area (%): ratio of inland area to total area (314km^2); Urbanization (%): ratio of residential area to total area (314km^2); Freshwater area (%): ratio of freshwater area to total area (314km^2)

Station no.	Station name	Latitude (N)	Longitude (E)	Elevation (m)	Inland area(%)	Urbanization (%)	Freshwater area (%)
1	Sokcho	38°15'	128°34'	17.8	53	3.5	0.7
2	Daegwallyeong	37°41'	128°46'	842.5	100	0.3	0.3
3	Chuncheon	37°54'	127°44'	76.8	100	5.6	6.7
4	Seoul	37°34'	126°58'	86.0	100	51.2	6.2
5	Incheon	37°28'	126°38'	68.9	61	36.7	13.7
6	Wonju	37°20'	127°57'	149.8	100	3.1	0.2
7	Suwon	37°16'	126°59'	33.6	100	13.0	1.2
8	Chungju	36°58'	127°57'	114.1	100	3.4	7.0
9	Seosan	36°46'	126°30'	25.9	100	3.7	2.5
10	Uljin	36°59'	129°25'	49.4	51	1.5	0.8
11	Cheongju	36°38'	127°27'	57.4	100	8.3	1.4
12	Daejeon	36°22'	127°22'	68.3	100	15.3	0.6
13	Chupungnyeong	36°13'	128°00'	242.5	100	0.4	0.3
14	Pohang	36°02'	129°23'	1.9	74	8.0	3.0
15	Gunsan	36°00'	126°45'	26.9	80	9.8	7.0
16	Daegu	35°53'	128°37'	57.6	100	17.7	1.3
17	Jeonju	35°49'	127°09'	53.5	100	8.8	1.0
18	Ulsan	35°33'	129°19'	34.7	100	4.7	1.7
19	Gwangju	35°10'	126°54'	70.5	100	13.6	1.3
20	Busan	35°06'	129°02'	69.2	63	32.5	6.3
21	Tongyeong	34°51'	128°26'	31.7	56	2.1	4.1
22	Mokpo	34°49'	126°23'	37.9	56	9.0	14.0
23	Yeosu	34°44'	127°45'	66.1	41	10.3	2.3
24	Wando	34°24'	126°43'	34.9	59	3.2	6.8
25	JeJu	33°31'	126°32'	20.0	53	10.9	0.4
26	Seogwipo	33°15'	126°34'	50.5	52	5.2	0.4
27	Jinju	35°12'	128°07'	21.3	100	3.0	2.2
28	Ganghwa	37°42'	126°27'	45.7	86	4.2	1.5
29	Yangpyeong	37°29'	127°30'	47.0	100	0.8	2.9
30	Icheon	37°16'	127°29'	77.8	100	2.6	0.0
31	Inje	38°03'	128°10'	198.6	100	1.0	2.1
32	Hongcheon	37°41'	127°53'	140.6	100	2.1	0.9
33	Jecheon	37°09'	128°12'	263.2	100	2.9	0.2
34	Boeun	36°29'	127°44'	174.1	100	1.9	0.4
35	Cheonan	36°47'	127°07'	24.9	100	5.6	0.7
36	Boryeong	36°19'	126°34'	15.3	69	5.7	4.3
37	Buyeo	36°16'	126°55'	11.3	100	4.4	2.9
38	Geumsan	36°06'	127°29'	171.3	100	3.0	0.4
39	Buan	35°44'	126°43'	10.7	90	5.1	6.7
40	Imsil	35°37'	127°17'	246.9	100	1.9	0.6
41	Jeongeup	35°34'	126°52'	44.1	100	4.0	0.6
42	Namwon	35°24'	127°20'	89.7	100	3.2	0.6
43	Jangheung	34°41'	126°55'	45.2	100	2.3	0.8
44	Haenam	34°33'	126°34'	13.7	100	2.6	8.4
45	Goheung	34°37'	127°17'	53.3	76	3.6	2.5
46	Seongsanpo	33°23'	126°53'	18.6	54	3.7	0.5
47	Yeongju	36°52'	128°31'	210.2	100	0.5	0.2
48	Mungyeong	36°37'	128°09'	170.4	100	0.9	0.4
49	Yeongdeok	36°32'	129°25'	41.2	63	0.3	0.7
50	Uiseong	36°21'	128°41'	81.1	100	0.4	0.3
51	Gumi	36°08'	128°19'	47.9	100	2.2	1.6
52	Yeongcheon	35°58'	128°57'	94.1	100	0.7	0.9
53	Geochang	35°40'	127°55'	220.9	100	0.3	0.2
54	Hapcheon	35°34'	128°10'	32.7	100	0.2	1.5
55	Miryang	35°29'	128°45'	12.6	100	1.1	1.2
56	Sancheong	35°25'	127°53'	138.6	100	0.2	0.4

The standardized coefficients were compared in order to analyze the effects of independent variables on the dependent variables. The standardized coefficients were in the range of –1.0 to 1.0; here, values closer to 0 indicate that the independent variables had weak effects on the dependent variables, while values closer to 1 are indicative of strong effects. In this study, in order to gauge the statistical significance of the effects of each independent variable on the dependent variables, a significance level of $\alpha = 0.05$ (two-tailed test) was applied. Multicollinearity between independent variables in the MLR models was insignificant.

3. RESULTS AND DISCUSSIONS

3.1 Comparison of Normal Aridity Index Values

Normal monthly, seasonal, and annual aridity index values for 30 years at 56 study stations were compared. The spatial distribution of the aridity index values varied according to the season. South Korea has four distinct seasons with a temperate climate. Spring (March, April, and May) and autumns (September, October, and November) are pleasant and mild. Summers (June, July, and August) are hot and humid, whereas winters (December, January, and February) are cold and dry. Additionally, the seasonal aridity index values were also closely linked with the geographical characteristics of South Korea. The aridity index values in each season showed different patterns reflecting the geographical characteristics of South Korea. [25] also described the spatial and seasonal variation in the aridity index values in China.

The aridity index values for the summer season were in the range of 1.44~3.22 throughout South Korea, and the summer season values were greater than those of the other seasons because precipitation was much greater than evapotranspiration during the summer. Conversely, during the spring season, the aridity index values were in the range of 0.66~1.83. The aridity index values for the autumn and winter seasons were in the range of 0.52~2.68. (Fig. 2).

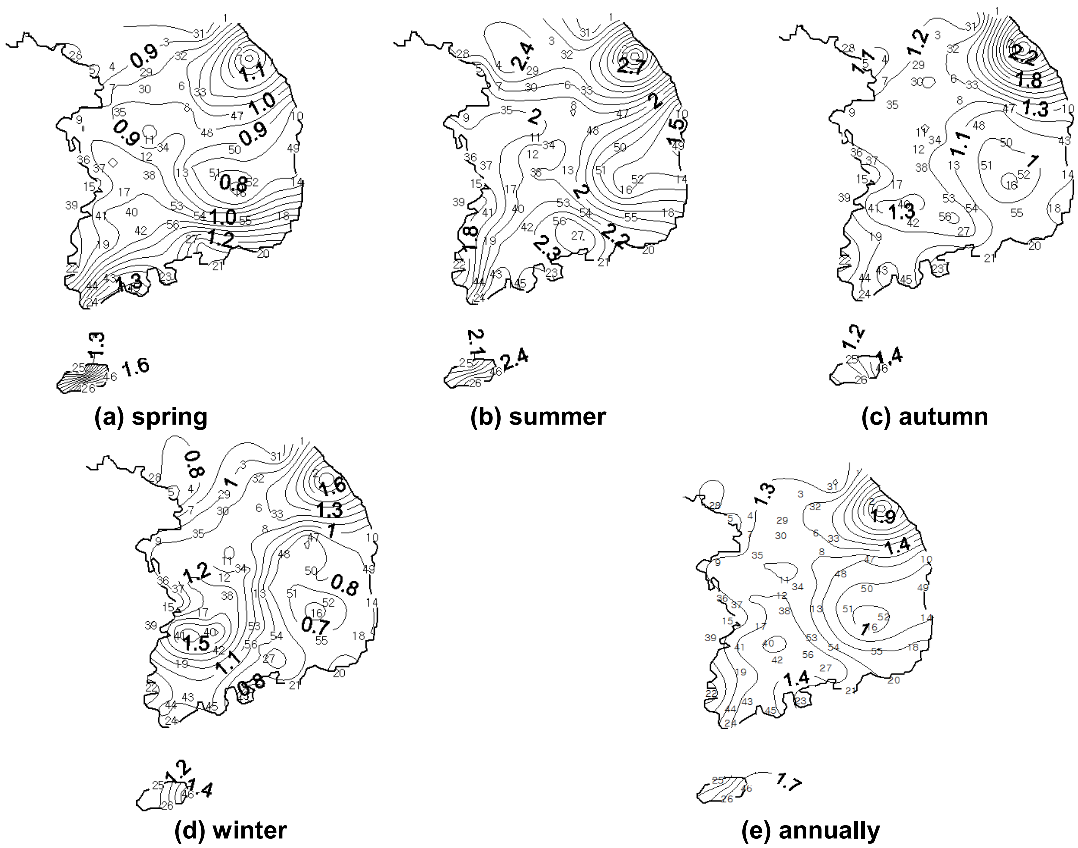

Fig. 2. Geographical distribution of average aridity/humidity index for (a) spring, (b) summer, (c) autumn, (d) winter, and (e) annually

Based on the classification used by [26,5], the spring and autumn seasons in South Korea were found to be the humid or dry period throughout the country. Winter season was found to be dry sub-humid or humid period, whereas the summer season was humid period. The distribution of the annual aridity index values showed a similar pattern to that for the summer season, and it were in the range of 0.89~2.29, and it seems that summer precipitation had a pronounced influence on the annual aridity index values.

3.2 Distribution of Aridity Index Trends

Monthly, seasonal, and annual Mann-Kendall nonparametric trend analyses were conducted with the Z-scores for the aridity index values at 56 stations in South Korea, and geographical distributions of seasonal and annual P/PET trends (Z-score) are shown in Fig. 3. When considering the aridity index trends on a seasonal base, most of study sites showed downward trends (negative Z-scores) in the aridity index during the spring season and upward trends (positive Z-scores) during the summer season; variable upward and downward trends were observed in the aridity index during the autumn and winter seasons. Most of study sites showed the overall upward trends in the annual aridity index.

The distribution of aridity index trends in each season showed also regional differences throughout South Korea. For example, during the spring season, the significant downward trend of aridity index at the 0.05 level of significance was shown at Station 35 but the insignificant upward

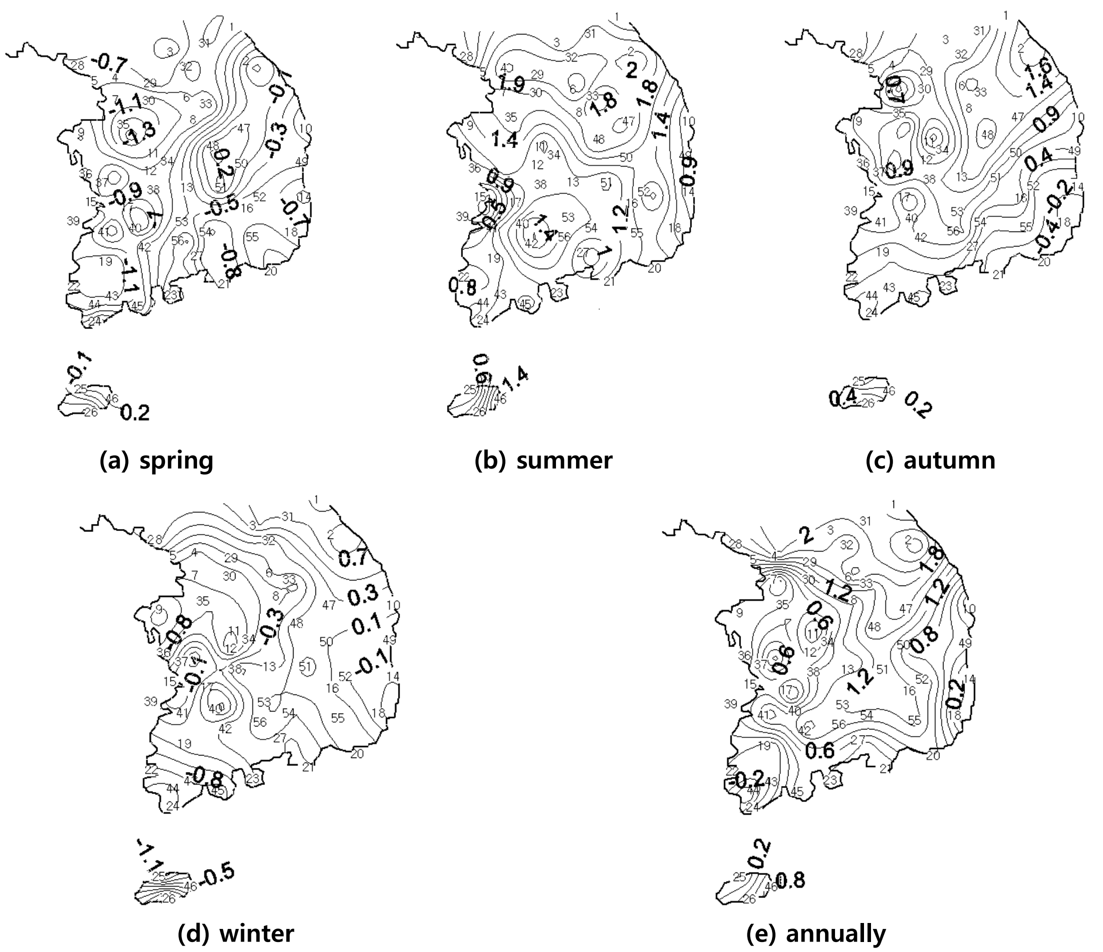

Fig. 3. Geographical distribution of aridity/humidity index trends (Z-scores) for (a) spring, (b) summer, (c) autumn, (d) winter, and (e) annually

trend at the 0.1 level of significance was shown at Station 46. Only 6 stations (Stations 17,19,35,39,40,43) had absolute values of Z-scores more than 1.285, indicating significant trends of aridity index at the 0.1 level of significance. This issue in the seasonal and regional differences in the aridity index trend was also mentioned by previous studies [13,18,19,27]. Geographical effects on aridity/humidity trends in each season were studied further in the following section 3.3 by using more specific geographical information throughout South Korea.

3.3 Geographical Effects on Aridity/Humidity Trends

In regard to the monthly, seasonal, and annual effects on aridity/humidity trends, the relative importance of geographical factors (elevation, freshwater area, urbanization, and proximity to the coast) was studied. This issue was studied because as mentioned in section 3.1, South Korea has distinct geographical characteristics which may affect aridity/humidity conditions in a region. [17] reported that the regional difference in the aridity index was significant and that aridity index changes had inherent implications for land-use over the region [13]. However, previous study results were not based on specific geographical information; therefore, detailed data on geographical characteristics were considered in this study to find the relative importance of geographical factors on aridity/humidity trends.

As for the monthly aridity/humidity trends, the elevations of the study stations showed a positive correlation with the aridity index trend, and other geographical factors showed positive or negative correlation with the aridity index trend. As for the seasonal aridity/humidity trends, elevation showed significant effect on the aridity/humidity trends in all seasons. Regardless of the season, elevation had a positive correlation with the aridity index trends. As the elevation of the study stations increased, the Z-scores for aridity index trends in all seasons increased significantly. This indicates that humidity advanced at a faster pace in regions with relatively higher elevations. Climate data sets in the worldwide mountains in most middle-latitude also showed that there are lower evaporative demand and higher rainfall as the elevation increases [28]. Freshwater area and urbanization did not show significant effects on the aridity/humidity trends in all seasons. Urbanization affects trend towards warmer and drier climate [22]. Proximity to the coast showed significant effects on the aridity/humidity trends in spring season.

On an annual basis, only the freshwater area showed a negative correlation with the aridity index trend and the other geographical factors showed a positive correlation with the aridity index trend. When statistical significance level of $\alpha = 0.05$ (two-tailed test) was applied, the elevation had a significant effect on the annual aridity/humidity trend ($p \leq 0.05$), and it had a greater effect on the annual aridity/humidity trend than the urbanization rate, freshwater area, and proximity to the coast. [12] reported that annual aridity index increased in the coastal region of Israel but decreased in most other regions. Complex topographical features in South Korea, including the lifting effect of the mountain, play important roles in precipitation formation, therefore, aridity/humidity of regional climate.

3.4 Relationship between the Aridity/Humidity Trends and Trends of Climatic Factors

On monthly, seasonal, and annual bases, the relationships between trends of climatic factors and aridity/humidity trends were studied (Table 2). On a monthly basis, the study results revealed that precipitation and relative humidity trends had a positive correlation with the aridity index trends ($p \leq 0.05$). This indicates that the Z-scores for aridity index trends increased in direct proportion to the precipitation and relative humidity trends. Wind speed and solar radiation trends had a negative correlation with the aridity index trends. The temperature trend had a negative correlation with the aridity index trends in all months except July, August, and September. [18] have studied the implications of precipitation and potential evapotranspiration trends on aridity trends in Iran, and concluded that increasing precipitation trend and decreasing potential evapotranspiration trend are closely related to the increasing aridity index trend.

On a seasonal basis, the precipitation trend had a significant positive correlation with the aridity index trends in all seasons ($p \leq 0.05$), and significant increases in the Z-scores for aridity index trends were detected in regions with heavy precipitation trends. The temperature trend had a weak positive correlation with aridity index trends

Table 2. Relationship between the aridity/humidity trends and climate trends

	R	Prec. Δ(Sig.)	Tem. Δ(Sig.)	Wind speed Δ(Sig.)	Relative humidity Δ(Sig.)	Solar radiation Δ(Sig.)
Jan.	0.963(0.000)	0.936(0.000)	−0.072(0.084)	−0.246(0.000)	0.228(0.000)	−0.018(0.655)
Feb.	0.945(0.000)	0.863(0.000)	−0.045(0.375)	−0.157(0.002)	0.226(0.000)	−0.030(0.542)
Mar.	0.977(0.000)	0.971(0.000)	−0.068(0.064)	−0.134(0.000)	0.130(0.000)	−0.107(0.002)
Apr.	0.970(0.000)	0.928(0.000)	−0.073(0.054)	−0.186(0.000)	0.090(0.016)	−0.171(0.000)
May	0.988(0.000)	0.881(0.000)	−0.056(0.028)	−0.061(0.018)	0.091(0.001)	−0.135(0.000)
Jun.	0.971(0.000)	0.833(0.000)	−0.019(0.613)	−0.066(0.069)	0.092(0.015)	−0.256(0.000)
Jul.	0.945(0.000)	0.906(0.000)	0.045(0.391)	−0.038(0.459)	0.085(0.085)	−0.417(0.000)
Aug.	0.970(0.000)	0.927(0.000)	0.099(0.019)	−0.021(0.580)	0.172(0.000)	−0.097(0.013)
Sep.	0.970(0.000)	0.927(0.000)	0.099(0.019)	−0.021(0.580)	0.172(0.000)	−0.097(0.013)
Oct.	0.970(0.000)	0.952(0.000)	−0.090(0.029)	−0.097(0.014)	0.100(0.008)	−0.091(0.015)
Nov.	0.984(0.000)	0.931(0.000)	−0.010(0.715)	−0.219(0.000)	0.061(0.032)	−0.058(0.031)
Dec.	0.925(0.000)	0.852(0.000)	−0.023(0.690)	−0.318(0.000)	0.147(0.017)	−0.111(0.050)
Spring	0.884(0.000)	0.842(0.000)	0.021(0.776)	−0.110(0.129)	0.183(0.013)	−0.165(0.019)
Summer	0.928(0.000)	0.805(0.000)	0.063(0.287)	−0.019(0.747)	0.171(0.004)	−0.513(0.000)
Autumn	0.915(0.000)	0.822(0.000)	0.048(0.489)	−0.241(0.000)	0.165(0.011)	−0.237(0.000)
Winter	0.874(0.000)	0.718(0.000)	0.004(0.963)	−0.374(0.000)	0.307(0.000)	−0.123(0.101)
Year	0.875(0.000)	0.585(0.000)	0.034(0.685)	−0.332(0.000)	0.340(0.000)	−0.424(0.000)*

Numbers in bold indicate the significant correlation at the 0.05 level of significance (two-tailed test); R=correlation coefficient of the MLR; Δ=standardized coefficient; Sig=significance probability

in all seasons. Wind speed trends had a weak negative correlation with aridity index trends in spring and summer and a significant positive correlation with aridity index trends in autumn and winter. Relative humidity trends showed a positive correlation with aridity index trends in all seasons, and significant increases in the Z-scores for aridity index trends were detected in regions with high relative humidity trends. Solar radiation trends showed a negative correlation with aridity index trends in all seasons, and decreases in the Z-scores for aridity index trends were detected in regions with high solar radiation trends. The trends for all climate variables except temperature showed significant correlations with the aridity index trend.

On an annual basis, aridity index trend had significant positive correlation with precipitation and relative humidity trends and significant negative correlation with wind speed and solar radiation trends ($p \leq 0.05$). Only temperature trend showed insignificant positive correlation with the aridity index trend ($p \leq 0.05$). Based on study results in China, the effect of temperature increase on aridity index change was offset by the increase in precipitation and vapor pressure and the decrease in wind speed [16]. As shown in Table 2, monthly, seasonal, and annual MLR equations for the aridity index trends were significant and the aridity/humidity trends in South Korea were driven mainly by changes in precipitation. The close relationship between precipitation change and aridity index change in China was also reported by [16].

3.5 Relative Importance of Geographical Factors and Trends of Climatic Factors

The relative importance of geographical factors and trends of climatic factors with respect to aridity index trends was studied (Table 3). Compared with geographical factors, trends of climatic factors showed much higher correlations with the aridity index trends. The aridity index trends showed the most significant correlations with precipitation trends ($p \leq 0.05$); and they also showed significant correlations with relative humidity trends; but they did not show any significant correlations with temperature trends. Urbanization did not show any significant correlations with the monthly, seasonal and annual aridity index trends. On an annual basis, the aridity index trend showed a significant correlation with elevation and proximity to the coast as geographical factors, and a significant correlation with all other climate trends except temperature trend. Based on study results, it can be concluded that aridity/humidity trends in South Korea are much more closely related to variation of climate factors than geographical factors. When considering the effective management of water resources in South Korea, the variation of climate factors should be considered more important than geographical factors.

Table 3. Relative importance of geographical factors and trends of climatic factors with respect to the aridity/humidity trends (as determined by the stepwise regression method)

R		Geographical factors				Climatic factors				
		Elev. Δ	Freshwater area Δ	Urban Δ	Proximity to coast Δ	Prec. Δ	Temp. Δ	Wind speed Δ	Relative humidity Δ	Solar radiation Δ
Jan.	0.961					0.939		−0.227	0.254	
Feb.	0.951				0.138	0.801		−0.171	0.235	
Mar.	0.975					0.969		−0.110	0.153	−0.117
Apr.	0.968					0.929		−0.165	0.098	−0.183
May	0.985					0.894			0.121	−0.135
Jun.	0.977				0.117	0.810		−0.066	0.105	−0.228
Jul.	0.940					0.899				−0.377
Aug.	0.934					0.911			0.183	−0.271
Sep.	0.970					0.928	0.104		0.178	−0.093
Oct.	0.970				0.089	0.925		−0.080	0.116	−0.081
Nov.	0.984					0.932		−0.215	0.064	−0.058
Dec.	0.935	−0.152	−0.137			0.885		−0.309	0.178	
Spring	0.877					0.838			0.188	−0.140
Summer	0.925					0.807			0.158	−0.488
Autumn	0.925				0.148	0.796		−0.287	0.154	−0.209
Winter	0.901		−0.259			0.729		−0.431	0.309	
Year	0.898	0.161			0.141	0.486		−0.388	0.295	−0.385

Numbers in bold indicate the significant correlation at the 0.05 level of significance (two-tailed test); R=correlation coefficient of the MLR; Δ=standardized coefficient

4. CONCLUSIONS

The findings of the relative importance of geographical factors and trends of climatic factors on aridity/humidity trends suggested that the trends of climatic factors are relatively more important than geographical factors. Therefore, for the effective management of water resources in South Korea, the variation of climate factors should be considered more important than geographical factors. The aridity/humidity trends were driven mainly by changes in precipitation; and the changes in other climate factors (wind speed, relative humidity, and solar radiation) also showed significant correlations with the aridity/humidity trend. Precipitation and relative humidity trends showed strong positive correlations with the aridity index trends, whereas, wind speed and solar radiation trends showed strong negative correlations with the aridity index trends.

Aridity index trends showed positive or negative correlations with geographical factors. Only the freshwater area showed negative correlations with the annual aridity index trends, whereas other geographical factors showed positive correlations with the annual aridity index trends. The elevation had a significant effect on the aridity/humidity trends, and this effect was greater than that of urbanization rate, freshwater area, and proximity to the coast.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Xiong Y, Huang S, Chen F, Ye H, Wang C, Zhu C. The impacts of rapid urbanization on the thermal environement: A remote sensing study of Guangzhou South China. Rmote Sens. 2012;4:2033-2056.
2. IPCC, Stocker TF, Qin D, Plattner GK, Tignor M, others (eds). Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panal on Climate Change. Cambridge University Press, Cambridge; 2013.
3. Rajabi A. Analysis of SPI drought class transitions due to climate change. Case study: Kermanshah (Iran), Water Resources. 2016;43:238-248.
4. Jakimavičius D, Kriaučiūienė J. The climate change impact on the water balance of Curonian Lagoon. Water Resources. 2013;40:120-132.
5. UNCCD, United Nations convention to combat desertification in countries experiencing serious drought and/or desertification, particularly in Africa, Permanent Secretariat UNCCD, Bonn; 1994.
6. Sahin S. An aridity index defined by precipitation and specific humidity. Journal of Hydrology. 2012; 444-445:199-208.
7. Tsakiris G, Vangelis H. Towards a drought watch system based on spatial SPI. Water Resources Management. 2004;18:1-12.
8. Khalili D, Farnoud T, Jamshidi H, Kamgar-Haghighi AA, Zand-Parsa S. Comparability analyses of the SPI and RDI meteorological drought indices in different climatic zones, Water Resources Management. 2011;25:1737-1757.
9. Gao Y, Li X, Leung R, Chen D, Xu J. Aridity changes in the Tibetan Plateau in a warming climate. Environ. Res. Lett. 2015;10:034013.
10. Zarch MAA, Sivakumar B, Sharma A. Assessment of global aridity change. Journal of Hydrology. 2015;520:300-313.
11. Moussa R, Lhomme JP. The Budyko functions under non-steady state conditions: new approach and comparison with previous formulations. Hydrol. Earth Syst. Sci. Discuss; 2016. DOI:10.5194/hess-2016-379.
12. Kafle H, Bruins H. Climatic trends in Israel 1970-2002: Warmer and increasing aridity inland. Climatic Change. 2009;96:63-77.
13. Sulieman HM, Elagib NA. Implications of climate, land-use and land-cover changes for pastoralism in eastern Sudan. Journal of Arid Environments. 2012;85:132-141.
14. Ahani H, Kherad M, MKousari MR, Roosmalen LV, Aryanfar R. Non-parametric trend analysis of the aridity index for three large and semi-arid basins in Iran. Theoretical and Applied Climatology. 2013;112:553-564.
15. Nastos PT, Politi N, Kapsomenakis J. Spatial and temporal variability of the aridity index in Greece. Atmospheric Research. 2013;119:140-152.
16. Liu X, Zhang D, Luo Y, Liu C. Spatial and temporal changes in aridity in northwest China: 1960 to 2010. Theor Appl Climatol. 2013;112:307-316.
17. Salvati L, Zitti M, Bartolomei RD, Perini L.

Climate aridity under changing conditions and implications for the agricultural sector: Italy as a case study. Hindawi Publishing Corporation Geography Journal. 2013;923173:7.
18. Some'e BS, Ezani A, Tabari H. Spatiotemporal trends of aridity index in arid and semi-arid regions of Iran. Theor. Appl. Climatol. 2013;111:149-160.
19. Tabari H, Aghajanloo MB. Temporal pattern of aridity index in Iran with considering precipitation and evapotranspiration trends. Int. J. Climatol. 2013;33:396-409.
20. Fu Q, Feng S. Responses of terrestrial aridity to global warming. J. Geophys. Res Atmos. DOI:10.1002/2014; JD021608.
21. Kenawy A, McCabe MF, Vicente-Serrano SM, López-Moreno JI. Recent changes in continentality and aridity conditions over the Middle East and North Africa region, and their association with circulation patterns. Clim. Res. 2016;69:25-43.
22. Mavrakis A, Papavasileiou C, Salvati L. Towards (Un) sustainable unban growth? Industrial development, land-use, soil depletion and climate aridity in a Greek agr-forest area. Journal of Arid Environments. 2015;121:1-6.
23. Allen RG, Peretira LS, Raes D, Smith M. Crop evapotranspiration: Guidelines for computing crop water requirements, FAO irrigation and drainage paper No. 56. FAO, Rome; 1998.
24. Shadmani H, Marofi S, Roknian M. Trend analysis in reference evapotranspiration using Mann-Kendall and Spearman's rho test in arid region of Iran. Water Resources Management. 2012;26:211-224.
25. Huang H, Han Y, Gao M, Song J. Spatial-temporal variation of aridity index of China during 1960-2013. Advances in Meteorology. 2016;1536135.
26. UNEP, World Atlas of Desertification; 1992.
27. Türkes M. Spatial and temporal variations in precipitation and aridity index series of Turkey. In: Bolle H-J(ed), Mediterranean climate: Variability and trends, Springer. 2003;181-213.
28. Leuschner C. Are high elevations in tropical mountains arid environments for plants? Ecology. 2000;81:1425-1436.

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