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Assessment of industrial crops biodiversity in Kermanshah province during 2013-2022

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ABSTRACT

Agroecosystem health is a function of biodiversity; however, less attention has been paid to the importance of this issue in agricultural systems. Therefore, this study evaluated the biodiversity of industrial crops in Kermanshah Province. The required data, including industrial crops and their cultivation areas, were collected from the statistics and information bank of the agricultural organization for the years 2013-2022. Then biodiversity indices including species richness, Shannon-Wiener, evenness, and Sorenson's similarity were calculated. Among the counties, Kermanshah, Sarpol-e Zahab, and Sahneh had the highest species richness in most years, while Gilan-e Gharb county showed the lowest species richness. The highest Shannon-Wiener index value for the entire province was 1.11 at 2013, and the lowest was 0.78 at 2015. The counties of Sarpol-e Zahab, Gilan-e Gharb, Kermanshah, and Ravansar had the highest Shannon-Wiener biodiversity index values in most crop years, while Songhor county had the lowest value of this index, such that at 2013, the value of this index was 0.104 and decreased annually by approximately 0.8 units to about 0.020 at 2022. Among the province's counties, the highest Sorenson's similarity index was observed between Kermanshah and Islamabad (1.0), and the lowest was between Sahneh and Songhor counties (0.8). The highest evenness index was found in Islamabad-e Gharb, Ravansar, Gilan-e Gharb, and Sahneh with values of 0.05, 0.16, 0.17, and 0.094, respectively, while the lowest was in Songhor with a value of 0.003.

Highlights

- Shannon-Wiener index fell from 1.11 (2013) to 0.912 (2022); Songhor hit 0.020.
- Sorenson similarity highest (1.0) Kermanshah-Islamabad; lowest (0.8) Sahneh-Songhor.
- Evenness peaked in Ravansar (0.16), Gilan-e Gharb (0.17); Songhor lowest (0.003).
- Five industrial crops studied; cultivation area grew most in Kermanshah, shrank in Kangavar.

1. Introduction

Biodiversity refers to all living organisms and their interrelationships, representing genetic diversity, species diversity of living organisms, and the diversity of ecosystems in which these organisms live (Alibeygi et al., 2019). Agricultural diversity, as a component of biodiversity, is a combination of life forms and their interactions with each other and the physical environment that has made Earth habitable for humans (Lima and Pereira, 2023). Agricultural biodiversity has been recognized as one of the most important factors in establishing and enhancing agricultural sustainability, as maintaining and increasing biodiversity in agricultural ecosystems creates a balance between food production and other ecosystem services (Jackson et al., 2007; Shrestha et al., 2010). Furthermore, biodiversity can act as a support system in environmental processes and ecosystem service formation. Currently, many plant and animal species worldwide are at risk of extinction, with habitat destruction due to various human activities being the primary cause (Hilton-Taylor and Brackett, 2000).

Assessing agricultural biodiversity requires estimating the geographical area covered by species, varieties belonging to these species, population size, and existing

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genetic diversity (Brown, 2000). Such assessments require the development and implementation of various methods. Species richness is the simplest method for evaluating biodiversity. Species richness indicates the total number of species or varieties present at a point in time (Hubbell, 2001). Species evenness expresses the number of individuals or areas belonging to each species or variety. The Shannon-Wiener and Simpson diversity indices combine the concepts of richness and evenness, providing computational and numerical methods for determining ecosystem diversity (McCune and Grace, 2002).

Koocheki et al. (2004b), in a study on the biodiversity of horticultural crops and vegetables in Iran, found that 31 horticultural species and 14 vegetable species were cultivated throughout the country. These researchers considered the diversity of horticultural and vegetable crops in the country's provinces to be relatively appropriate. In another study on cereals, it was reported that the lowest Shannon-Wiener index in the entire country belonged to Gilan province, indicating the dominance of rice species (Nasiri Mahalati et al., 2005). Estimates indicate that improved varieties have led to the loss of 90% of local varieties worldwide. The functioning of natural and agricultural ecosystems is based on biodiversity, and the destruction of biodiversity poses a serious threat to the survival of agricultural ecosystems and ultimately global food security (Blackshaw et al., 2001). Assessment of agricultural systems biodiversity in Ilam province also showed that over twelve years, the overall trend of changes in agricultural systems diversity decreased (Asgharipour et al., 2019). Additionally, an evaluation of the biodiversity status of agricultural and horticultural crops in Golestan province over 15 years revealed a decrease in agricultural crop biodiversity (Kazemi et al., 2018). Pourghasemian and Moradi (2016) found in their research that the highest and lowest evenness indices for horticultural crops belonged to Isfahan (0.83) and Semirom (0.192) counties respectively, and the highest and lowest Shannon-Wiener biodiversity indices in agricultural crops were observed in forage plants (0.929) and cucurbits (0.442) respectively.

Assessment of agricultural plant diversity in Kermanshah province also showed that, in general, the biodiversity of irrigated farms is higher than that of rainfed farms, demonstrating the impact of water resources on biodiversity (Asgari et al., 2018). Research results by Mondani et al. (2015) indicated that 16 medicinal plant species were cultivated in Kermanshah province, and among the counties of this province, Harsin, Kermanshah, and Kangavar had the highest number of species, while Qasr-e Shirin and Islamabad-e Gharb had the lowest. They reported that among the province's counties, the highest and lowest Shannon-Wiener biodiversity indices belonged to Kermanshah (1.28) and Sahneh (0.47), respectively. Allahyari et al. (2015) also showed that 29 crop species were cultivated in Kermanshah province, indicating relatively diverse agricultural products, with the highest number of crop species observed in Kermanshah, Sahneh, and Harsin counties, and the lowest in Paveh. They also stated that among the counties, the highest 10-year average Shannon-Wiener diversity index for agricultural crops belonged to Harsin (1.7) and the lowest to Dalahu (1).

Among the country's provinces, Kermanshah, with an area of over 2.3 million hectares, plays a significant role in agricultural production due to its diverse climatic conditions. In preliminary general assessments conducted by Koocheki et al. (2004c), the biodiversity status of agricultural products in this province was reported as favorable. However, to maintain and increase agricultural biodiversity, such studies need to be conducted more precisely at the county level within the province. Undoubtedly, the protection and proper utilization of existing biodiversity in agricultural ecosystems depends primarily on understanding its characteristics and spatial distribution, which itself requires studying biodiversity at various levels, including ecosystem levels, crop species, and their genotypes. Therefore, given the importance of this issue, this study was conducted to evaluate the trends in biodiversity changes of industrial crops by county in Kermanshah province over 10 years from 2013 to 2022.

2. Materials and Methods

2.1. Study area and data collection

This study was conducted in Kermanshah province (between 33° to 35° N latitude and 45° to 47° E longitude) located in western Iran at 2024 (Figure 1). The required data were obtained from the Statistics and Information Technology Department of the Ministry of Agriculture Jihad (MJA, 2024). These data included the cultivation area of agricultural products, particularly industrial plants, by species in 9 counties of Kermanshah province, recorded during the period from 2013 to 2022. Data collection was conducted either through in-person visits to the Agricultural Jihad Organization or retrieved from the organization's information database.

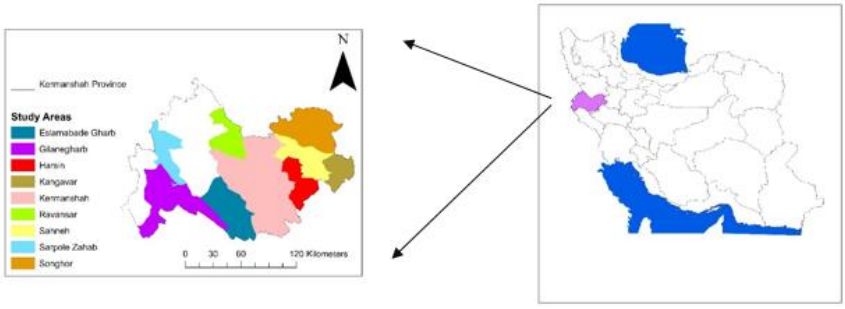

Figure 1. The study area in Kermanshah province by county

2.2. Measured biodiversity indices

2.2.1. Species richness

Species richness indicates the number of species present in an area, which was estimated by counting the number of industrial crop species cultivated in the province and by county (Barnes, 1998).

2.2.2. Shannon-Wiener index

The Shannon-Wiener index (H) is a more suitable index for measuring biodiversity, calculated based on species richness and relative abundance of species according to Equation 1 (Shannon and Wiener, 1949).

$$H = -\Sigma[(ni/N)\times\ln(ni/N)] \quad (1)$$

In this equation, ni is the number of individuals of each species (*i*th species), and N is the total number of individuals in an area. In this index, ni/N represents the proportion or relative frequency of a species. In this study, for calculating the Shannon diversity index, ni/N was considered as the cultivation area of each genotype of the *i*th species relative to the total cultivation area of that species. Additionally, to calculate the Shannon-Wiener diversity index for all industrial agricultural crops in the province (H'), equation (1) was used, but here ni/N represented the ratio of cultivation area of the *i*th industrial crop species to the total cultivation area of agricultural crops in the province.

2.2.3. Evenness index

With the Shannon-Wiener diversity index (H) known, the evenness index was calculated using Equation 2 (Magurran, 1988).

$$E = H/\ln(S) \quad (2)$$

In this equation, E is the evenness index, and S is the number of species (cultivation area of plant species). This index is a measure of the intensity of distribution uniformity of the number or cultivation area among genotypes of an agricultural species, and its value is equal to or less than 1. E=1 indicates equal cultivation area among all genotypes of an agricultural species, while E<1 indicates non-uniform distribution.

2.2.4. Sorenson's similarity index

Similarity indices show the difference in species composition and diversity changes in different habitats. There are several similarity indices, with Sorenson's similarity index (S) being the most common (Equation 3) (Magurran, 2004).

$$S = 2Vij/(Vi + Vj) \quad (3)$$

In this equation, Vij represents the number of common species present in both areas A and B, Vi and Vj represent the number of species present in area A but not in area B, and the number of species present in area B but not in area A, respectively. Sorenson's similarity index varies between zero (complete dissimilarity) and one (complete similarity between two areas or counties). Finally, Excel software version 2016 was used for data analysis and creating figures and tables. Linear regression was used to perform statistical analyses.

3. Results and discussion

3.1. Species richness

The results showed that, regardless of the province's counties, 5 industrial crop species including sugar beet, canola, confectionery sunflower, sesame, and cotton were cultivated in Kermanshah province (Table 1). The species richness of agricultural crops varied across different counties of the province during 2013 to 2022 (Table 1). Among the counties, Kermanshah, Sarpol-e Zahab, and Sahneh had the highest species richness in most years, while Gilan-e Gharb showed the lowest species richness. Among industrial agricultural crops from 2013 to 2022, the cultivation share of sugar beet, canola, and sunflower was higher than other plants. Kermanshah county, compared to other counties, has a larger area, which is why most of the agricultural crops cultivated in the province are also present in this county, such that during the years under study, approximately 80 percent of all agricultural species cultivated in the province were observed in this county. In Gilan-e Gharb county, the industrial plants cultivated represented about 60 percent of all species cultivated in the province. Biodiversity is considered one of the necessities of sustainable agriculture; therefore, improving biodiversity through the introduction of agricultural crops that have functions similar to off-farm inputs reduces the dependency of agricultural ecosystems and leads to increased self-sufficiency and sustainability (Mahdavi Damghani et al., 2007).

3.2. Changes in cultivation area

Results showed that among the province's counties, Kermanshah County had the highest cultivation area of industrial plants while Kangavar County had the lowest (Table 2). The trend of changes in cultivation area for other counties was increasing during these 10 years. In Kermanshah County, the cultivation area of industrial plants for the base year (2013) was approximately 1,490 hectares, which increased to 6,629 hectares at 2022 with a growth rate of about 455 hectares per year (Table 2). It appears that greater access to suitable equipment and increased extraction of groundwater resources during these 10 years compared to previous years were the main reasons for the increase in cultivation area. Results also showed that the trend of changes in cultivation area in Kangavar county was decreasing during the studied years, with a reduction of 244 hectares per year for this county (Table 2).

3.3. Shannon-Wiener biodiversity index

Regardless of the studied counties, the Shannon-Wiener biodiversity index value for the entire province was approximately 1.0 (Figure 2). The total Shannon-Wiener biodiversity index in different counties varied between 0.78 and 1.0. The highest value of this index was observed at 2013 (1.11), and the lowest was observed at 2015 (0.78). The Shannon-Wiener biodiversity index of industrial plants for the entire province decreased from 1.11 to 0.912 during the studied period, with an annual decrease of approximately 0.005 units. It appears that the low Shannon-

Wiener biodiversity index for Kermanshah province as a whole may be due to one or two industrial plants being dominant species in most counties (Table 1), which could lead to increased sensitivity of agricultural ecosystems to environmental and management changes. Another study has also stated that a low Shannon-Wiener biodiversity index indicates the dominance of a few specific species (Mondani et al., 2015).

Table 1. Species richness of industrial crops in the counties of Kermanshah province during 2013-2022

Counties	Year									
	2013	2014	2015	2015	2017	2018	2019	2020	2021	2022
Islamabad-e Gharb	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet
Ravansar	Rapeseed	Rapeseed	Sugar beet	Sugar beet	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed
Sarpol-e Zahab	Sunflower Sugar beet Sesame	Rapeseed Sesame	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed Sesame	Sugar beet Rapeseed Sesame	Sunflower Sugar beet Rapeseed Sesame	Sugar beet Rapeseed	Sugar beet Rapeseed Sesame	Sugar beet Rapeseed Sesame	Sugar beet Rapeseed Sesame
Songhor	-	Sesame	Sunflower	Sunflower Sugar beet Sesame	Sunflower Sugar beet	Sunflower Sugar beet	Rapeseed	Rapeseed	Cotton Rapeseed	Rapeseed
Sahneh	Sunflower Sugar beet Rapeseed	Sugar beet	Sugar beet	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed
Kermanshah	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed Sesame	Sunflower Sugar beet Rapeseed Sesame	Sunflower Sugar beet Rapeseed Sesame	Sunflower Sugar beet Rapeseed Sesame	Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed
Kangavar	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed
Gilan-e Gharb	Rapeseed	Rapeseed	Rapeseed	Rapeseed	Rapeseed	Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed
Harsin	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sunflower Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed	Sugar beet Rapeseed
Total Province	4	5	5	5	4	4	3	4	6	5

Table 2. Changes in the cultivation area of industrial crops by county in Kermanshah province during 2013-2022.

Counties	Lowest	Heights	Equation	R^2	Yearly change
Islamabad-e Gharb	3327	4898	y = 62.812x - 122456	0.118	62.8
Ravansar	85	462	y = 24.897x - 49914	0.3303	24. 9
Sarpol-e Zahab	66	712	y = 56.195x - 113108	0.5866	56.2
Songhor	697	3083	y = 195.16x - 391507	0.5308	195.2
Sahneh	3388	5176	y = 157x - 312304	0.3667	157.0
Kermanshah	1490	7109	y = 481.67x - 967626	0.6962	481.7
Kangavar	1819	4999	y = -244.73x + 496995	0.4255	-244.7
Gilan-e Gharb	20	352	y = 31.837x - 64043	0.632	31.837
Harsin	352	1514	y = 125.86x - 252917	0.8127	125.86

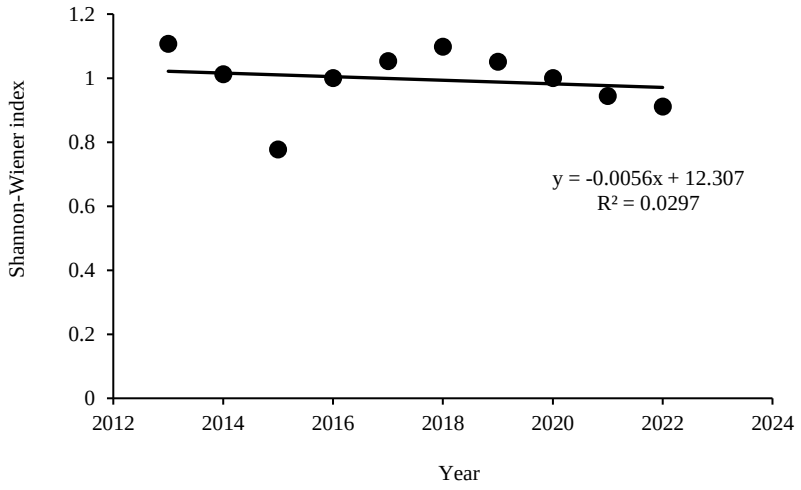

Figure 2. Changes in Shannon-Wiener biodiversity of total industrial crops in Kermanshah province during 2013-2022.

Except for Songhor County, the Shannon-Wiener biodiversity index increased among Kermanshah province's counties during the studied years (Table 3). Sarpol-e Zahab, Gilan-e Gharb, Kermanshah, and Ravansar had the highest Shannon-Wiener biodiversity index values in most crop years, while Songhor had the lowest value during these 10 years. This index value was 0.104 at 2013, and decreased annually by approximately 0.8 units, reaching 0.020 at 2022 (Table 3). In Gilan-e Gharb county, the increase in the Shannon-Wiener biodiversity index was higher compared to other counties, such that in the base year (2013), this index value was zero and increased annually by approximately 0.11 units, reaching 0.96 at 2022 (Table 3).

Table 3. Changes in the Shannon-Wiener Index of Industrial Products by County in Kermanshah Province during 2013-2022.

Counties	Lowest	Heights	Equation	R^2	Yearly change
Islamabad-e Gharb	0.01	0.63	y = 0.0379x - 76.083	0.2996	0.038
Ravansar	0.06	0.99	y = 0.0896x - 180.17	0.5114	0.090
Sarpol-e Zahab	0.49	1.20	y = 0.0219x - 43.328	0.1122	0.022
Songhor	0.020	0.24	y = -0.0038x + 7.8079	0.0257	0.004
Sahneh	0.62	1.07	y = 0.0133x - 26.012	0.0737	0.013
Kermanshah	0.55	1.08	y = 0.0102x - 19.687	0.0282	0.010
Kangavar	0.52	1.03	y = 0.0115x - 22.334	0.0539	0.012
Gilan-e Gharb	0	0.99	y = 0.1197x - 240.99	0.7902	0.120
Harsin	0.23	0.91	y = 0.0098x - 19.215	0.0185	0.010

A high Shannon-Wiener biodiversity index indicates that dominance is not limited to one specific species, all species have similar population numbers, and they possess higher diversity, cultivation area, and species richness. The decrease in Shannon-Wiener index value is due to reduced species richness or dominance of one species and reduced evenness. Fields with a Shannon-Wiener index of zero indicate the presence of only one species (Niazmoradi et al., 2023; Kazemi et al., 2020).

Climatic conditions are among the factors influencing agricultural crop biodiversity. Climate changes have been cited as determining factors for biodiversity in agricultural ecosystems, and the impact of climatic diversity on species diversity is usually more important than other environmental factors (Alaei Bazkiaei et al., 2022; Stocking, 1999). Diversity is not determined solely by the number of species; species abundance is also an important factor in increasing diversity. The Shannon-Wiener biodiversity index is calculated based on the cultivation area of each species and its ratio to the total cultivation area (Magurran, 2004). Furthermore, this index is a combination of species richness and relative abundance and is considered one of the most practical indices for diversity assessment (Thrupp, 1998).

3.4. Sorenson similarity index

The Sorenson similarity index showed relatively high values in the province's counties during 2013-2022 (Table 4), such that the counties had the highest similarity in industrial plant cultivation, and what caused differences between counties was the cultivation area of industrial plants. The highest Sorenson similarity was observed between Kermanshah and Islamabad-e Gharb counties (1), and the lowest was between Sahneh and Songhor counties (0.8). It appears that one reason for the similarity of cultivated species in Kermanshah province's counties was their geographical proximity, which created relatively similar environmental conditions. Overall, the similarity between counties regarding industrial crop species was high, due to the shared presence of several species among all counties, which led to an increase in the Sorenson index value. A high Sorenson similarity index indicates similar diversity in industrial plants cultivated in these regions (Koozehgar Kalaji et al., 2022). It appears that the diversity of existing agricultural systems aligns with climatic diversity, and soil characteristics of agricultural areas also influence this matter, which is also affected by climatic features (Koocheki et al., 2011).

Table 4. Changes in the Evenness index of industrial products by county in Kermanshah province during 2013-2022.

Counties	Lowest	Heights	Equation	R^2	Yearly change
Islamabad-e Gharb	0	0.08	y = 0.0045x - 9.0032	0.2949	0.0045
Ravansar	0.01	0.17	y = 0.0138x - 27.709	0.4405	0.0138
Sarpol-e Zahab	0.10	0.24	y = -0.0015x + 3.2774	0.0103	-0.0015
Songhor	0.002	0.031	y = -0.0007x + 1.4905	0.0577	-0.0007
Sahneh	0.07	0.12	y = 0.0012x - 2.3721	0.0515	0.0012
Kermanshah	0.068	0.125	y = 0.0002x - 0.3904	0.0013	0.0002
Kangavar	0.067	0.131	y = 0.0025x - 5.0074	0.1606	0.0025
Gilan-e Gharb	0	0.18	y = 0.0208x - 41.779	0.6858	0.0208
Harsin	0.038	0.135	y = 7E-05x - 0.0636	5E-05	7E-05

Gliessman (1992) showed that from an ecological perspective, climate and soil physical and chemical properties, which are themselves functions of climate, are the basis for the formation and diversity in agricultural ecosystems. Therefore, it appears that the spatial distribution and grouping of some counties were based on their climatic characteristics. Another study also found that in regions with unfavorable climatic and soil fertility conditions, fewer vegetable species are cultivated, and the cultivation area is unevenly distributed among species, leading to the dominance of fewer agricultural crops and ultimately greater similarity in agricultural systems (Koocheki et al., 2004a). The main application of the Sorenson similarity index is to examine the degree of similarity or compare regions in terms of species similarity (Magurran, 2004). The numerical value of this index ranges between zero and one; when all species in two regions are similar, the index value equals one, indicating 100%

similarity (Kazemi et al., 2020). Reasons for this level of similarity can include uniform soil fertility, relatively similar agricultural management, available water, uniform field slopes, and proximity of plots to each other (Koozehgar Kalaji et al., 2022).

3.5. Evenness index

The results of this study showed that the highest evenness index for industrial crops was observed in Islamabad-e Gharb, Ravansar, Gilan-e Gharb, and Sahneh counties, with values of 0.05, 0.16, 0.17, and 0.094, respectively (Table 5). The lowest evenness index for industrial crops was observed in Songhor County with values of 0.003 (Table 5). In this county, the largest cultivation area was allocated to confectionery sunflower, and due to the uneven distribution of land among industrial crops, this index decreased during 2013-2022 (Alaei Bazkiaei et al., 2022), indicating that monoculture has become more prevalent over time (Table 5).

Table 5. Changes in the Sorenson index of industrial products by city in Kermanshah province during 2013-2022.

Counties	Lowest	Heights	Equation	R^2	Yearly change
Islamabad-e Gharb whit Kermanshah	0.8	1	y = 0.0154x - 30.169	0.3154	0.015
Ravansar whit Sarpol-e Zahab	0.4	0.85	y = 0.0357x - 71.317	0.4634	0.036
Songhor whit Sahneh	0.4	1	y = 0.0131x - 25.696	0.0333	0.013
Kangavar whit Kermanshah	0.8	1	y = 0.0263x - 52.198	0.8497	0.026
Gilan-e Gharb whit Harsin	0.5	1	y = 0.0438x - 87.621	0.566	0.044

A low evenness index indicates the dominance of a particular crop. Higher species evenness indicates that the cultivation area of plant species is more uniform and the dominance of one or few plant species is lower (Koocheki et al., 2011). Counties with greater crop diversity and more balanced cultivation areas relative to each other have higher evenness. An evenness index of 1 means that the cultivation area of all species was equal; therefore, when the evenness index relative to all agricultural species in the province is less than one, it indicates greater unevenness in the cultivation area of agricultural species (Razavi et al., 2012). Additionally, the evenness or heterogeneity index is directly influenced by the Shannon-Wiener biodiversity index and species richness (Alaei Bazkiaei et al., 2022).

4. Conclusion

Understanding the benefits of biodiversity and distribution patterns of agricultural plants can be useful in policy-making related to sustainable agriculture objectives. The results of this study showed that in Kermanshah province, Kermanshah, Sarpol-e Zahab, and Sahneh counties had the highest species richness, while Gilan-e Gharb county had the lowest value in most crop years. The Shannon-Wiener biodiversity index for all agricultural crops decreased during 2013-2022. Sarpol-e Zahab, Gilan-e Gharb, Kermanshah, and Ravansar had the highest Shannon-Wiener biodiversity index values in most crop years, while Songhor county showed the lowest value of this index. The Sorenson similarity index showed relatively high values in the province's counties. All counties in the province had the highest similarity in industrial crop cultivation, and what caused differences between counties was the cultivation area of industrial crops. Furthermore, results showed that the highest evenness index for industrial crops was observed in Islamabad-e Gharb, Ravansar, Gilan-e Gharb, and Sahneh counties. These results indicate that the dominance of a single crop during the studied years was lower in these countries. The lowest evenness index for industrial crops was observed in Songhor county, as the largest cultivation area in this county was allocated to confectionery sunflowers.

Understanding and comprehending the effects of agricultural crop biodiversity and its impacts on agricultural production systems requires comprehensive data collection about different cultivated varieties for all counties and the distribution of these crops. Unfortunately, due to a lack of access to accurate statistics regarding variety names for most industrial crops, assessment of biodiversity at the variety level was not possible. It is hoped that in the future, through better and more accurate access to information about cultivated varieties at the county level, a more precise assessment of biodiversity benefits can be conducted.

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