Crop diversification in the Egyptian Nile Region; viewpoint of spatial, climatic, and human features

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Abstract

Plant diversity is undoubtedly influenced by spatial and climatic factors, as well as others as architecture, human effects, and population percentage. This research demonstrates how site characteristics influence crop species diversity. One hundred eighty-five cultivated centers of 20 governorates forming the Egyptian Nile Region were examined regarding to their crop diversity from March 2021 to March 2022, including 170 crop species, sub-species and varieties. These cultivated centers were classified using two-way cluster analysis (TWCA) into 62 groups according to their floristic composition; and ordinated along the first and second axes of Principal Coordinates Analysis (PCOA) with type of irrigation supply. Group 51 had the uppermost species richness (333.5 species group⁻¹), while group 44 had the uppermost species turnover (9). Eighteen least cultivated species were recorded: 12 species in 2 centers e.g., Actinidia chinensis and Carica papaya and 6 in 3 e.g., Carya illinoinsenis and Cyperus papyrus, while 60 species are common in >50 cultivated centers. Significant correlations were depicted between the species richness and X and Y coordinates, while insignificant correlation with area (m²) of each cultivated centre. Precipitation (mm yr⁻¹), relative humidity (%) and temperature (°C) were depicted an insignificant correlation. Species density (Species m⁻²) was depicted an insignificant correlation, while population percentage had an insignificant correlation. Descriptively, a regular relationship between species diversity and type of irrigation supply and main human activities in each centre was observed.

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1. Introduction

Egypt has an arid climate, with annual average rainfall ranging from 60 to 190 mm along the Mediterranean coast from 25 to 60 mm in the Nile delta and less than 25 mm in the upper Egypt and neighboring areas. It is located in North Africa and spans temperate grassland, desert, and semi-desert biomes (https://www.fao.org/3/v9978e/v9978e0e.htm, Lomolino et al. 2017). Egypt is one of Africa’s most populous countries. The majority of Egypt’s 102 million inhabitants reside along the Nile River’s banks, in a 40,000-square-kilometer area where the only fertile land is situated. The Sahara Desert is sparsely populated in broad areas. About half of Egypt’s population lives in cities, with the majority of them concentrated in Greater Cairo, Alexandria, and other important cities in the Nile Delta. Egypt’s fertile land area is around 3.3 million acres, with nearly a quarter of it recovered desert land. Reclaimed lands, on the other hand, only add 7% to the entire value of agricultural produce. Despite the fact that just 3% of the land is arable, it is incredibly productive and can be cropped twice or even three times per year. The majority of land is cultivated at least twice a year, although salinity, climate change, and pollution limit agricultural productivity (El-Ramady et al. 2013). Annually, around 11.5 million acres are cropped, representing a cropping ratio of approximately 2:1. (https://www.fao.org/3/v9978e/v9978e0e.htm).

Food security is a complicated concept. It encompasses not just the manufacturing and processing of nutrient-dense foods, but also individuals’ access to the full spectrum of nutrients required to live a healthy and active lifestyle. Food security hinges on crop diversification. In the face of a rapidly changing world, it sustains today’s industry and provides the raw material required to ensure future supplies (FAO 2003). Cropping diversity is a systemic technique to reducing production fluctuations and increasing resistance to a variety of environmental challenges. More diversified crop...
rotations and their synergistic effects with reduced tillage have been well reported in terms of yield benefits, but few studies have measured the influence of these management strategies on yields and their stability when soil moisture is scarce or abundant (Gaudin et al. 2015). Thus, it is required to study the crop diversity in each country in relation to the spatial and climate feature from a side and human behavior and needs from another side.

Where, plant richness is influenced by spatial and climatic conditions, as well as other factors such as architecture, human effects, and population percentage. This study focuses on the effect of location features on the crop species diversification. Location features are quantities factors, which are classified into spatial features as: UTM coordinates per meters (X and Y) and area per m², climate features as: annual precipitation (mm day⁻¹), relative humidity at 2 m (%) and temperature range at 2 m (°C); and human/other features as: population percentage and species density (species/m²), and also descriptive factors such as type of irrigation supply and main activity of local inhabitants. In addition, assessment of the local distribution and species occurrence in the 185 cultivated centers forming the Egyptian Nile Region. Also classification of these 185 cultivated centers using two-way cluster analysis (TWCA) according to their floristic composition; and ordinated by the Principal Coordinates Analysis (PCOA).

2. Material and methods

2.1. Study area, raw data collection, cultivated trips and local occurrence

According to the world biome map (Lomolino et al. 2017), Egypt is located in northeastern Africa, with the Egyptian Nile region spanning temperate grassland, desert, and semi-desert biomes, with a length of about 1520 km (23% of the total length of the river) and an estimated population of 80 million people. Egypt's Nile Region is divided into three sections: The Nile Delta, Nile Fayium, and Nile Valley. The Nile Delta is a depression below sea level formed by wind erosion 1.8 million years ago, stretching approximately 240 km from Alexandria at Abu Quir in the west to Port Said in the east; the Nile Fayium is a depression below sea level formed by wind erosion 1.8 million years ago, covering approximately 12,000 square kilometers; The Nile Valley is around 800 km long, stretching from Aswan to Cairo’s suburbs (El-Shabrawy and Dumont 2009). Egypt's Nile area is divided into 20 governorates, each of which has about 185 administrative centers (Map 1, a). The Egyptian climate varies from arid to hyper-arid, with the Nile Delta’s northern half categorized as arid and the Nile Valley and southern part designated as hyper-arid. Annual rainfall fluctuated between 80 and 200 mm year⁻¹ (https://power.larc.nasa.gov/). The Mediterranean shore has the highest precipitation levels (e.g., around Alexandria). From May until October, the hot, dry summer season lasts (https://weather-and-climate.com).

Raw data was acquired from March 2021 to March 2022 by visiting the agricultural management in each governorate of the investigated area and filling out a questionnaire regarding cultivated crops in the centers of each governorate. The dates were then confirmed using the Egyptian annual agricultural newspapers published by the Ministry of Agriculture and Reclamation for 185 centers from 2011 to 2022. Twenty-four field trips throughout the research region were conducted (from March 2021 to March 2022) to validate the data acquired. In addition, herbarium sheets of Egyptian crops were checked in the Agricultural Museum’s herbarium in Cairo (CAIM).

2.2. Local distribution and species occurrence

Each governorate of 20 governorates forming the studied Egyptian Nile Region, Alexandria, Beheira, Kafr El-Shaikh, Gharbia, Menoufa, Dakhalia, Damietta, Sharqiyyah, Qalyubia, Cairo, Giza, Helwan, Fayium, Beni Suef, Minya, Assuit, Sohag, Qena, Luxor, and Aswan (Map 1, a and b), had its own list of cultivated crops (Ammar, 2022). Each governorate’s agriculture crops were determined by its pictorial and topographical characteristics, soil fertility, citizen demands, and crop exports and imports in accordance with country strategy. The author obtained information of crop diversification from the Agricultural Directorate of each governorate, in addition to the performed field trips.

2.3. Analysis of quantitative features

Relationships between quantitative features of cultivated centers (independent variables) and the number of species in these studies cultivated centers (dependent variable) and their significance were analysed by linear regression model using Origin Pro 2019. Theses quantities factors are spatial features as: UTM coordinates per meters (X and Y) and area per m², climate features as: annual precipitation (mm day⁻¹), relative humidity at 2 m (%), c. temperature range at 2 m (°C), and human/other features as: population percentage and species density (species/m²).

2.4. Analysis of descriptive parameters

Relationship between species diversity and descriptive factors such as type of irrigation supply. Source of irrigation supply (direct supply: direct Nile branch (e.g., Nile valley, Rosetta branch or Damietta branch) or indirect supply (Nile extending branches e.g., small Nile branches, canals and lakes); and main activity of local inhabitants: the main human activity in the cultivated centers (Agriculture, industry, fishing, mining, commerce or tourism).

2.5. Multivariate analysis

PC-ORD 7 provides ways to relate data on species traits (trait matrix) to community samples (main matrix) and environmental data (second matrix). While many of these operations can be done in the other PC-ORD menu items, the Traits menu provides several operations specific to this kind of data. Classification and ordination techniques of multivariate analysis were applied in the present study. Both techniques have their merits in helping to understand the vegetation (main matrix) in terms of climate factors and areas of cultivated centers (second matrix) (Wildi, 2013). Two-way Cluster Analysis (Classification technique) is to graphically expose the relationship between cluster analyses and your individual data points. The resulting graph makes it easy to see similarities and differences between rows in the same group, rows...
in different groups, columns in the same group, and columns in different groups. Principal Coordinates Analysis (PCOA) (Ordination technique) is an Eigen analysis technique similar to Principle component analysis (PCA), except that one extracts eigenvectors from a distance matrix among sample units (rows), rather than from a correlation or covariance matrix. In PCOA one can use any square symmetrical distance matrix, including semi-metrics such as Soren sen distance, as well as metric distance measures such as Euclidean distance (Wildi, 2013).

Both techniques were applied to each of the floristic composition of 185 cultivated centers of crop plants in the 20 governorates of the Nile Region (Map 1, b). Main matrix; it represents the species distribution in cultivated centers, vegetation composition as presence/absence. Secondary matrix; it represents garden factors that describe the vegetation composition within cultivated centers as following; Quantitative character: 1. UTM coordinates per meters (Measured by using Arc GIS Map 10.6.1 software), 2. Areas per hectare (measured by https://earth.google.com/web/), 3. Climate factors; annual precipitation (mm day\(^{-1}\)), relative humidity at 2 m (%) and temperature range at 2 m °C (https://power.larc.nasa.gov/), 4. Crop diversity; number of crop species cultivated inside each filed center, and finally 5. Population percentage in the cultivated field center (https://capmas.gov.eg/). Qualitative character; type of irrigation supply; source of irrigation supply (direct supply: direct Nile branch (e.g., Nile valley, Rosetta branch or Damietta branch) or indirect supply (Nile extending branches e.g., small Nile branches, canals and lakes), and main activity of local inhabitants; the main human activity in the cultivated centre (Agriculture, industry, fishing, mining, commerce or tourism) (https://www.eeaa.gov.eg/ar-eg).

3. Results

3.1. Local distribution and species occurrence

Seventy current crop species were surveyed in the whole studied 185 cultivated centers in 20 governorates which forming the Nile Region, while there are 18 least cultivated species: 12 species recorded in 2 centers (Actinidia chinensis, Carica papaya, Citrullus colocynthis, Dahlia variabilis, Datura stramonium, Dianthus sinensis, Eugenia jambolana, Mentha piperita, Prunus cerasus, Saccharum officinarum, Sesamum oleiferum, and Tagetes erecta; Table 1). Sixty species are common in >50 cultivated centers from 185 cultivated centers in 20 governorates which forming the cultivated field center (https://capmas.gov.eg/). Two techniques were applied to each of the floristic composition of the 185 cultivated centers of crop plants in the 20 governorates of the Nile Region (Map 1, b). Main matrix; it represents the species distribution in cultivated centers, vegetation composition as presence/absence. Secondary matrix; it represents garden factors that describe the vegetation composition within cultivated centers as following; Quantitative character: 1. UTM coordinates per meters (Measured by using Arc GIS Map 10.6.1 software), 2. Areas per hectare (measured by https://earth.google.com/web/), 3. Climate factors; annual precipitation (mm day\(^{-1}\)), relative humidity at 2 m (%) and temperature range at 2 m °C (https://power.larc.nasa.gov/), 4. Crop diversity; number of crop species cultivated inside each filed center, and finally 5. Population percentage in the cultivated field center (https://capmas.gov.eg/). Qualitative character; type of irrigation supply; source of irrigation supply (direct supply: direct Nile branch (e.g., Nile valley, Rosetta branch or Damietta branch) or indirect supply (Nile extending branches e.g., small Nile branches, canals and lakes), and main activity of local inhabitants; the main human activity in the cultivated centre (Agriculture, industry, fishing, mining, commerce or tourism) (https://www.eeaa.gov.eg/ar-eg).

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3.2. Analysis of quantitative features

For spatial features, there is a direct relationship between area of cultivated centers (m\(^2\)) and number of species with a non-significant slope from zero equal (4.4 * 10\(^{-4}\)), t-value (2.1) and a probability of t-test (0.0) (Table 2). Regarding to Anova analysis; F-value is significant equal to (4.4) with f-probability at the 0.05 level is (0.0) (Table 3). For climate features, there is a direct relationship between amount of precipitation over cultivated centers (mm day\(^{-1}\)) and number of species with a non-significant slope from zero equal (0.1), t-value (1.4) and a probability of t-test (0.1) (Table 2). Regarding to Anova analysis; F-value is (2.1) and F-probability at the 0.05 level is non-significant equal (0.1) (Table 3). There is a direct relationship between amount of relative humidity at 2 m over cultivated centers (%) and number of species with a non-significant slope from zero equal (0.4), t-value (1.5) and a probability of t-test (0.1) (Table 2). Regarding to Anova analysis; F-value is (2.3) and F-probability at the 0.05 level is non-significant equal (0.1) (Table 3). There is an inverse relationship between temperature range at 2 m °C over cultivated centers and number of species with a non-significant slope from zero equal (0.03), t-value (0.03) and a probability of t-test (1.0) (Table 2). Regarding to Anova analysis; F-value is (6.4 * 10\(^{-4}\)) and F-probability at the 0.05 level is non-significant equal (1.0) (Table 3).

About human and other features, there is an inverse relationship between Species density (Species/m\(^2\)) and number of species with a non-significant slope from zero equal (4.4 * 10\(^{-3}\)), t-value (3.1) and a probability of t-test (0.0) (Table 2). Regarding to Anova analysis; F-value is (9.4) and F-probability at the 0.05 level is significant equal (0.0) (Table 3).

3.3. Analysis of descriptive parameters

Regarding to type of irrigation supply, one hundred cultivated centers have a direct irrigation supply, direct Nile branch (e.g., Nile valley, Rosetta branch or Damietta branch), while 85 cultivated
**Fig. 1.** Frequency of the recorded crop species in the Nile Region in relation to the 6 classes of cultivated centers.

**b.** Relationship between number of species and number of field centers according to their type of irrigation supply. Types of irrigation supply; di: direct irrigation supplies and in: indirect irrigation supplies.

**Table 2**

Linear regression model between garden parameters (independent variables) and number of species in these studied cultivated centers (dependent variables). Garden parameters are: A: Area of garden (m²), B: X coordinate (m), C: Y coordinate (m), D: Precipitation (mm day⁻¹), E: Relative humidity at 2 m (%), F: Temperature range at 2 m (°C), G: Species density (species/m²) * 10⁻⁴ and H: Population whom served.

| Parameters | Value   | Standard Error | t-Value | Prob>|t| |
|------------|---------|----------------|---------|-----|-----|
| A Intercept| 44.2    | 3.9            | 11.3    | 0   |
| Slope      | 1.1 * 10⁻⁸| 1.0 * 10⁻⁸     | 1.1     | 0.3 |
| B Intercept| 400.9   | 150.09         | 2.7     | 8.2 * 10⁻¹|
| Slope      | −11.3   | 4.8            | −2.4    | 0.0 |
| C Intercept| −51.4   | 46.8           | −1.1    | 2.7 * 10⁻¹|
| Slope      | 3.3     | 1.6            | 2.1     | 0.0 |
| D Intercept| 39.6    | 5.8            | 6.9     | 9.3 * 10⁻¹|
| Slope      | 0.1     | 7.0 * 10⁻²     | 1.4     | 0.1 |
| E Intercept| 27.978  | 12.64957       | 2.21E+00| 2.8 * 10⁻²|
| Slope      | 0.4     | 0.3            | 1.5     | 0.1 |
| F Intercept| 46.0    | 14.9           | 3.1     | 2.3 * 10⁻³|
| Slope      | 0.03    | 1.1            | 0.03    | 1.0 |
| G Intercept| 46.6    | 3.3            | 13.9    | 0   |
| Slope      | −28108  | 51846.7        | −0.5    | 0.6 |
| H Intercept| 30.6    | 6.1            | 5.0     | 1.2 * 10⁻⁶|
| Slope      | 4.4 * 10⁻³| 1.5 * 10⁻⁵  | 3.1     | 0.0 |
centers have an indirect irrigation supply, Nile extending branches (e.g., small Nile branches, canals and lakes) (Fig. 2, a). Regarding to the relationship between number of species and irrigation supplies of the studied cultivated centers; there is a regular increasing of species number by increasing the number of cultivated centers that have indirect irrigation supplies, but there is a zigzag increasing (with up and down peaks) of species number by increasing the number of cultivated centers that have direct irrigation supplies (Fig. 2, b).

For main human activity, agriculture is the main human activity in 96 cultivated centers, followed by industry in 41 cultivated centers, while tourism in 19, fishing in 16, trade in 12, while mining acts as a main human activity in Minya cultivated center only (Fig. 3, a). About the relationship between number of species and main human activities of the studied cultivated centers; there is a regular increasing of species number by increasing the number of cultivated centers according to main human activities of them. Mining is occurred as a main human activity in Minya cultivated center only (80 cultivated crop species) (Fig. 3, b).

### 3.4. Multivariate analysis

Regarding to the computerized main matrix of species presence/absence of the studied cultivated centers in the Nile Region; cross ponding to the computerized secondary matrix of 12 characters of cultivated centers (10 quantities characters [e.g., area m² and UTM coordinates x and y, precipitation (mm day⁻¹), relative humidity at 2 m (%), temperature range at 2 m (°C), species number, species Density (species/m²) and population number whom served, and 2 descriptive characters [e.g., type of irrigation supply and main human activity]).

One hundred eighty-five studied cultivated centers were classified of two-way cluster analysis (TWCA) into 62 groups of cultivated centers according to their floristic composition at 100% gradient percentage (Fig. 4); and this was more significant with irrigation supply to crop cultivated s and also ordered at the first and second axes of Principal Coordinates Analysis (PCOA) (Table 4, Fig. 5).

Twenty-four groups included only one garden (e.g., Groups 1, 2, 6, 8, 10, 11, 13, 58, 60, 61 and 62); while 12 groups include 2 cultivated centers (e.g., Groups 7, 12, 9, 16, 19, 26, 34, 52 and 57). On the other hand, 10 groups only include >5 cultivated centers (e.g., 22, 23, 27, 37, 40, 44, 46, 48, 50 and 54) (Table 4). Group 51 had the highest species richness (333.5 species group⁻¹), while Groups 30 and 62 had the lowest (2.0 species group⁻¹). Group 44 had the highest species turnover (9), while 23 groups had the lowest (0) (e.g., Groups 1, 2, 6, 8, 10, 11, 13, 17, 21, 24, 30, 33, 39, 41, 43, 45, 47, 49, 56, 58, 60, 61 and 62) (Table 4).

### 4. Discussion

#### 4.1. Local distribution and species occurrence

With 2022, 10.6% of the total 170 surveyed crop species in the study area were the least cultivated: 66.7% of them in 2 centers, while 60 species (35.3% of the total) were common in > 50 cultivated centers (Ammar, 2022). (Ammar, 2015) recorded in her study to the crop diversity in the Egyptian Nile Delta only that 54 least cultivated species were identified (31.6% of the recorded total), from them 46 species (85.2%) recorded in 1 cultivated centre. This means that Most cultivated crops, which were least cultivated, became common cultivated with years. Consequently, more crop species, sub-species and varieties were widely cultivated according to the local and global market requirements, especially with the rapid overpopulation.

#### 4.2. Analysis of quantitative features

For spatial features, a direct non-significant relationship between the area of cultivated centre (m²) and species diversity was observed. This indicates that the area of cultivated fields is not effective to the crop diversity. This normal as a result of the abolition of the agricultural cycle and the agricultural sector of supply and demand harmed the farmer through many decades, thus farms were used to cultivate special economic crops in their fields in each season respectively according to the market demands.
locally and globally. Regardless, the benefits of crop diversity for the soil fertility, aeration and health, so the soil productivity deceased with time, needing continuous supply of fertilizers, which may lead to soil sanitization with years and desertification (Richards 1980, El-Ramady et al. 2013, Elsaid Saeed 2021, Arab Republic of Egypt and Center 2018, Mohamed et al. 2019).

Significant relationships between crop species diversity with X coordinate and Y coordinate were detected. This indicates that locations have nearest UTM coordinates had similar species content due to their similarity in their environmental conditions and the availability of plant migration between them due to short interstitial distances.

For climate features, the relationship between amount of precipitation over cultivated centers (mm day$^{-1}$) and species diversity with a direct non-significant, where cultivation of crops depends mainly on the water of irrigation rather than rain water, except in the dry farming in desert and remote sites that depends on underground water and rains (Widtsoe 1920). Also, non-significant relationship between amount of relative humidity at 2 m over cultivated centers (%) and temperature with crop species diversity was estimated. This is expected because farmers grow crops according to their demands and the conditions of supply and demand in a seasonal manner commensurate with the environmental conditions that require the crop in its life cycle, such as temperature and humidity, which achieves them the required economic security regardless of the crop diversity.

Regarding to human and other features; an inverse non-significant relationship between species density (species/m²) and...
crop species diversity was detected. This means number of species diversity inside the same area is very low, where farmers usually cultivate the same crop species along wide acres in the same cultivated centre with a few diversity, where each centre is distinguished with cultivation of specific crop species such as \textit{Saccharum officinarum} L. in Nag Hammadi, \textit{Vicia sativa} L. in centers of Aswan and \textit{Medicago sativa} L. in centers of New Valley Governorate (Al Balkeny 1949, Hagras 1996, Ammar, 2015, Ministry of Agriculture and Land Reclamation 2004). A direct relationship between population percentage and crop species diversity, where with the rapid overpopulation and looking forward new cultures via internet or travel, people tends to introduce new crop species especially for daily economic uses e.g., cooking and furniture.

4.3. Analysis of descriptive parameters

According to a type of irrigation supply, a regular increasing of species diversity by increasing the number of cultivated centers that have indirect irrigation supplies, but there is a zigzag increasing (with up and down peaks) of species diversity by increasing the number of cultivated centers that have direct irrigation supplies. Since Pharaonic era till now, irrigation in Egypt mainly depends on the Nile water (Westermann 1919, El Getta 1950). Thus, most population in Egypt lives along the Nile in 5.5% of the area of Egypt (1000.000 Km²), from it 3% represented the cultivated area only (Hagras 1996, El-Ramady et al. 2013). With time and overpopulation, the digging of canals and water supplies became necessary for extension of cultivated lands. Dry farming especially for cereals as also in remote and desert lands depends on other type of water supplies such as underground wells and rainfall (El-Beltagy et al. 1997).

According to main human activity, the relationship between number of species and main human activities of the studied cultivated centers; there is a regular increasing of species number by increasing the number of cultivated centers according to main human activities of them. Since ancient times, the ancient Egyptian was cultivating crops according to his needs and basic activity, so the textile industry was associated with the cultivation of flax (\textit{Linum usitatissimum} L.), as well as the paper industry with the cultivation of papyrus (\textit{Cyperus papyrus} L.) (Manniche 2006). Since then after the abolition of the agricultural cycle system in Egypt, the residents of each region grow crops according to their requirements and the needs of supply and demand according to the requirements of the local and global market.

4.4. Multivariate analysis

One hundred eighty-five studied cultivated centers were classified of two-way cluster analysis (TWCA) into 62 groups of cultivated centers according to their floristic composition at 100% gradient percentage; and this was more significant with the type irrigation supply and also ordinated at the first and second axes of Principal Coordinates Analysis (PCOA).

Ammar (2015) and El-Beheiry et al. (2015) recorded that 98 cultivated centers of crop plants in the Nile Delta were classified into 22 groups at level six of TWINSPAN according to their floristic composition and ordinated at the second and third axes of DEC-ORANA, while the more implicated in this study that PCORD-7 classified and ordinated the studied centers according to their floristic composition by given the spatial and climate features such
as type of the irrigation supply in addition to other affected human features, so this gives more adjust of classification and ordination of the studied centers.

5. Conclusion

Most cultivated crops, which were least cultivated, became common cultivated with years, consequently more crop species, sub-species and varieties were widely cultivated according to the local and global market requirements, especially with the rapid overpopulation. The area of cultivated crop fields was not effective overpopulation. The area of cultivated crop fields is not effective to the crop diversity as a result of the abolition of the agricultural cycle and the agricultural sector of supply and demand harmed the farmer through many decades, thus farms were used to cultivate special economic crops in their fields in each season respectively to the crop diversity for the soil fertility, aeration and special economic crops in their fields in each season respectively.
health, so the soil productivity deceased with time, needing continuous supply of fertilizers, which may lead to soil sanitization with years and desertification, so it is necessary to reuse the new technological agricultural cycles in the Egyptian cultivation to insure cultivation of numerous crops, which are suitable to the Egyptian climate without stress and degradation of soil fertility. The nearest UTM coordinates had similar species content due to their similarity in their environmental conditions and the availability of plant migration between them due to short interstitial distances. Non-significant relationships were noticed between climate factors and crop diversity, where farmers grow crops according to their demands and the conditions of supply and demand in a seasonal manner commensurate with the environmental conditions that require the crop in its life cycle, such as temperature and humidity.

| Group of cultivated centers | Number of cultivated centers | Cultivated centers | Number of species | Total species | Species richness (Species cultivated center-1) | Species turnover |
|-----------------------------|-----------------------------|-------------------|------------------|--------------|-----------------------------------------------|-----------------|
| 1                           | 1                           | Matarieiah, Cairo | 46               | 46           | 46.0                                          | 0               |
| 2                           | 1                           | Maadi, Cairo      | 30               | 30           | 30.0                                          | 0               |
| 3                           | 2                           | Maamourah, Alexandria | 45             | 88           | 44.0                                          | 1               |
| 4                           | 3                           | Mit Ghamr, Dakhillah | 71            | 199          | 66.3                                          | 2               |
| 5                           | 3                           | Manzalah, Dakhillah | 64             | 189          | 63.0                                          | 2               |
| 6                           | 1                           | Talkha, Dakhillah | 62               | 62           | 62.0                                          | 0               |
| 7                           | 2                           | Dikrinis, Dakhillah | 62             | 137          | 68.5                                          | 1               |
| 8                           | 1                           | Rasheed, Beheria  | 67               | 67           | 67.0                                          | 0               |
| 9                           | 4                           | Badr, Beheria     | 67               | 270          | 67.5                                          | 3               |
| 10                          | 1                           | Etaib Barod, Beheria | 68             | 68           | 68.0                                          | 0               |
| 11                          | 1                           | Abu Matameer, Beheria | 112           | 112          | 112.0                                         | 0               |
| 12                          | 2                           | Shubra Khteer, Beheria | 68             | 135         | 67.5                                          | 1               |
| 13                          | 1                           | Abu Homous, Beheria | 71             | 71           | 71.0                                          | 0               |
| 14                          | 3                           | Kom Hamada, Beheria | 68             | 186         | 62.0                                          | 2               |
| 15                          | 3                           | Qalyub, Qalyubia  | 57               | 164          | 54.7                                          | 2               |
| 16                          | 2                           | Qanater Khayreyah, Qalyubia | 60           | 118          | 59.0                                          | 1               |
| 17                          | 1                           | Kafri Saad, Damietta | 51             | 51           | 51.0                                          | 0               |
| 18                          | 3                           | Farashour, Damietta | 48             | 127         | 42.3                                          | 2               |
| 19                          | 2                           | Aamerya, Alexandria | 49             | 82           | 41.0                                          | 1               |
| 20                          | 3                           | Shebeen kom, Menufia | 50             | 125         | 41.7                                          | 2               |
| 21                          | 1                           | Birkat Sab, Menufia | 43             | 43           | 43.0                                          | 0               |
| 22                          | 6                           | Qwawysna, Menufia  | 41             | 198          | 33.0                                          | 5               |
| 23                          | 7                           | Abu Kbeere, Sharquia | 58             | 353         | 50.4                                          | 6               |
| 24                          | 1                           | Telkaer, Sharquia  | 43             | 43           | 43.0                                          | 0               |
| 25                          | 4                           | San hagar, Sharquia | 48             | 191         | 47.8                                          | 3               |
| 26                          | 2                           | Kasaseen Arshar, Sharquia | 43         | 90           | 45.0                                          | 1               |
| 27                          | 8                           | Diarb negm, Sharquia | 46             | 433         | 54.1                                          | 7               |
| 28                          | 2                           | Metobais, Kaf Sheikh | 34             | 66           | 33.0                                          | 1               |
| 29                          | 3                           | Qleen, Kaf Sheikh  | 26             | 79           | 26.3                                          | 2               |
| 30                          | 1                           | Foah, Kaf Sheikh  | 2             | 2            | 2.0                                           | 0               |
| 31                          | 4                           | Reiaad, Kaf Sheikh | 25             | 126         | 31.5                                          | 3               |
| 32                          | 2                           | Bessoun, Gharbia  | 37             | 77           | 38.5                                          | 1               |
| 33                          | 1                           | Qtouri, Gharbia   | 38             | 38           | 38.0                                          | 0               |
| 34                          | 2                           | Samannoud, Gharbia | 39             | 80           | 40.0                                          | 1               |
| 35                          | 4                           | Santa, Gharbia    | 35             | 192         | 48.0                                          | 3               |
| 36                          | 3                           | Ooseem, Giza      | 55             | 166         | 55.3                                          | 2               |
| 37                          | 7                           | Badrasheen, Giza  | 52             | 320         | 45.7                                          | 6               |
| 38                          | 3                           | Fashien, Beni Suef | 51             | 146         | 48.7                                          | 2               |
| 39                          | 1                           | Ihnsaya, Beni Suef | 42             | 42           | 42.0                                          | 0               |
| 40                          | 7                           | Beba, Beni Suef   | 48             | 321         | 45.9                                          | 6               |
| 41                          | 1                           | Ghanaieem, Assuat | 40             | 40           | 40.0                                          | 0               |
| 42                          | 5                           | Qwawseyah, Assuat | 39             | 209         | 41.8                                          | 4               |
| 43                          | 1                           | Edwah, Minya      | 39             | 39           | 39.0                                          | 0               |
| 44                          | 10                          | Maghahag, Minya  | 43             | 324         | 32.4                                          | 9               |
| 45                          | 1                           | Juhanah, Sohag    | 22             | 22           | 22.0                                          | 0               |
| 46                          | 9                           | Saqalatat, Sohag  | 23             | 267         | 29.7                                          | 8               |
| 47                          | 1                           | Nasr Nubia, Asswan | 24             | 24           | 24.0                                          | 0               |
| 48                          | 6                           | Abu Tesht, Qena  | 29             | 140         | 23.3                                          | 5               |
| 49                          | 1                           | Waaf, Qena       | 18             | 18           | 18.0                                          | 0               |
| 50                          | 9                           | Naqadah, Qena    | 19             | 199         | 22.1                                          | 8               |
| 51                          | 2                           | Kaf Sheikh       | 72             | 667         | 333.5                                         | 1               |
| 52                          | 2                           | Banha, Qalyubia  | 91             | 183         | 91.5                                          | 1               |
| 53                          | 3                           | Hoosh Elsa, Beheria | 69             | 248         | 82.7                                          | 2               |
| 54                          | 9                           | Sohag           | 84             | 636         | 70.7                                          | 8               |
| 55                          | 5                           | Gamalia, Dakhillah | 10            | 66          | 13.2                                          | 4               |
| 56                          | 1                           | Nebaor, Dakhillah | 16             | 16          | 16.0                                          | 0               |
| 57                          | 2                           | Matarieih, Dakhillah | 13            | 25          | 12.5                                          | 1               |
| 58                          | 1                           | Shubra Khayma, Qalyubia | 18           | 18          | 18.0                                          | 0               |
| 59                          | 4                           | Mana, Qena       | 16             | 86          | 21.5                                          | 3               |
| 60                          | 1                           | Ras Bar, Damietta | 13             | 13          | 13.0                                          | 0               |
| 61                          | 1                           | Hagagah, Damietta | 12             | 12          | 12.0                                          | 0               |
| 62                          | 1                           | Qena Coast, Qena | 2              | 2           | 2.0                                           | 0               |
which achieves them the required economic security regardless of the crop diversity.

A non-significant relationship between species density (species/m²) and crop species diversity was detected. Farmers usually cultivate the same crop species along wide acres in the same cultivated centre with few diversities. A direct relationship between population percentage and crop species diversity, where with the rapid overpopulation and looking forward new cultures via internet or travel, people tends to introduce new crop species especially for daily economic uses e.g., cooking and furniture. A regular rise of species number by increasing the number of cultivated centers was observed according to main human activities. The abolition of agriculture, the cycle system in Egypt, the residents of each region grow crops according to their requirements and the needs of supply and demand according to the requirements of the local and global market. The studied cultivated field centers were classified and ordinated according to their floristic composition according to the spatial and climate features such as type of the irrigation supply in addition to other affected human features, so this gives more adjust of classification and ordination of the studied cultivated field centers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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