Ethnobotanical uses of medicinal plants across health-related disease groups in Taza Province, Northern Morocco

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Ethnobotany Research and Applications 35:69 (2026) - http://dx.doi.org/10.32859/era.35.69.1-30
Manuscript received: 11/06/2026 - Revised manuscript received: 17/09/2026 - Published: 19/09/2026

Research

Abstract

Background: Taza province in northern Morocco is ecologically diverse, resulting in a wide variety of flora. Quantitative ethnobotanical indices are a useful tool for highlighting the importance of local medicinal species and contributing to the conservation and sustainable dissemination of traditional phytotherapeutic practices in this area.

Methods: This study statistically analyzed 58 medicinal plant taxa reported by 186 informants across 10 communes in Taza Province, based on an ethnobotanical survey conducted between March and September 2025. The data were processed using IBM SPSS Statistics 26 software. Several indices were calculated: Citation Frequency (CF), Relative Frequency of Citation (RFC), Use Value (UV), Fidelity Level (FL), Informant Consensus Factor (ICF) and Informant Agreement Ratio (IAR). Principal component analysis (PCA) was performed.

Results: These medicinal plants cover 35 therapeutic uses, belonging to 12 disease groups. *Mentha pulegium* L., *Rosmarinus officinalis* L., and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman has the highest RFC values (1). *Mentha pulegium* L. has the highest usage value (UV) (3.011), and 36 species achieve a maximum fidelity level (FL) of 100%. The disease categories with the highest ICF and IAR are, respectively, infectious and parasitic diseases (IAR = 0.987; ICF = 0.993) and digestive diseases (ICF = IAR = 0.98). PCA revealed a clear structuring of both disease categories and plant species according to ethnobotanical indices, distinguishing between highly cited, widely used, and therapeutically specific taxa, as well as between disease groups characterized by high species diversity and those with strong informant consensus.

Conclusions: The findings of this study document the important role of medicinal plants in the traditional therapeutic practices reported by the local population of Taza Province. They also highlight the importance of preserving local ethnobotanical knowledge and ensuring its transmission, in order to promote the sustainable management of plant resources.

Keywords: Ethnobotanical survey, Medicinal plants, Therapeutic uses, Disease groups, Ethnobotanical indices, Taza province.

Background

Since the earliest days of antiquity, the therapeutic use of plant resources has been a fundamental health response, particularly for rural communities where distance from modern healthcare centers and economic barriers necessitate the use of local alternatives (Létard *et al*. 2015). This observation has been validated internationally by the World Health Organization (2013), which estimates that traditional pharmacopoeia provides primary health care for nearly 80% of the African population. In Morocco, herbal medicine is not just a simple medical alternative; it is a structural component of sociocultural identity, ensuring historical continuity between ancestral knowledge and everyday practices, both in rural and urban households (El Aboui *et al*. 2024, Ghabbour *et al*. 2024a, Ghabbour *et al.* 2026b). This cognitive capital, which is essentially oral, represents a scientific heritage that must now be codified to prevent its dilution (Fakchich & Elachouri 2014). Moroccan ethnobotanical knowledge also includes traditional plant-processing practices, such as fermentation, which may enhance their health-related properties (Ghabbour *et al.* 2026c). Recent evidence indicates that ethnobotanical and ethnopharmacological research in Morocco has expanded considerably over the last three decades, with more than 420 studies conducted nationwide (Ghabbour *et al.* 2026b). These investigations have documented a vast body of traditional knowledge and have increasingly served as a foundation for biochemical, microbiological, and pharmacological studies on medicinal plants (Ghabbour *et al.* 2026b).

The Kingdom of Morocco, with its complex bioclimates and pivotal geographical position, is home to exceptional floral biodiversity, over 4,000 taxa, around 12% of which are recognized for their medicinal or aromatic properties (Hmamouchi 1999, Ismaili *et al*. 2021). The current Moroccan pharmacopoeia, with more than 800 species listed in around 100 botanical families, reflects this ecological diversity (Bouyahya *et al*. 2017, Ennabili *et al*. 2023). The importance of this plant heritage is reinforced by a high rate of endemism, making the country a natural laboratory for bioprospecting and the discovery of new active ingredients with pharmaceutical potential (Süntar 2020, Verma & Singh 2008). However, this wealth is increasingly vulnerable. The gradual erosion of traditional knowledge, under the effect of modernisation and the breakdown of intergenerational transmission, threatens the survival of this collective memory, particularly in isolated mountain areas (Barkaoui *et al*. 2017, Ghabbour *et al*. 2024b, Salhi *et al*. 2010). Ethnobotany is thus emerging as a pivotal discipline, capable of transforming these empirical observations into quantifiable and usable scientific data (Fleurentin & Balansard 2002). A recent national review further highlighted that ethnobotanical surveys constitute the principal source of information guiding the selection of medicinal plants for laboratory investigations, particularly studies focusing on phytochemical characterization and antimicrobial activities (Ghabbour et *al.* 2026b).

Northern Moroccan regions have received considerable scientific attention; recent national assessments emphasize the need for additional local studies to improve the documentation of traditional knowledge and medicinal plant uses (Ghabbour *et al.* 2026b). Given its remarkable floristic richness, extensive ethnobotanical heritage, and the highest concentration of ethnobotanical studies reported nationally, the Fez-Meknes Region can be regarded as the principal hub of ethnobotanical research in Morocco (Ghabbour *et al.* 2026b).

The province of Taza, located in the Fez-Meknes Region, constitutes a genuine ecological crossroads characterized by extensive forest areas and remarkable botanical diversity (Ghabbour *et al*. 2026b). It therefore represents a priority research area where the specific characteristics of local plant uses require rigorous and systematic investigation. The province possesses a rich body of ethnobotanical knowledge, reflected in the diverse use of numerous medicinal plant species, the variety of disease categories treated, and the complex relationships identified among these elements (El Aarage *et al*. 2026, Ghabbour *et al*. 2023, Ghabbour *et al*. 2024a and Ghabbour *et al*. 2024b). Previous studies have already documented several important aspects of the ethnobotanical knowledge of the province, including medicinal plant diversity, local uses, and the sociodemographic characteristics of the populations surveyed. However, these studies have not provided a comprehensive quantitative assessment of the medicinal uses of the identified species across different disease categories throughout the province. This body of knowledge therefore requires further investigation aimed at quantitatively assessing the disease categories treated in previously under-investigated areas. Furthermore, the increasing number of ethnobotanical studies conducted in Taza Province reflects its growing contribution to Moroccan ethnobotanical research (Ghabbour *et al.* 2026b). Recent analyses have identified Taza as one of the most active territories within the Fez-Meknes Region, highlighting both its rich traditional knowledge and its potential to support future phytochemical, microbiological, and pharmacological investigations (Ghabbour *et al*. 2026b).

The originality of this study lies particularly in its investigation of 10 municipalities in Taza Province that were not included in the study by Ghabbour *et al*. (2023), 5 of which were surveyed ethnobotanically for the first time (El Aarage *et al*. 2026). The present study involved 186 informants and was conducted across these 10 municipalities, thereby extending the geographical

coverage of previous ethnobotanical investigations in the province. Indeed, the originality of this work also stems from its scientific objective, methodological approach, and geographical coverage. Whereas our previous study (El Aarage *et al*. 2026) primarily focused on cataloguing the medicinal plants used by local populations, identifying the species, and documenting the sociodemographic characteristics and ethnobotanical knowledge of the surveyed population, the present study deepens the analysis of these data by examining their therapeutic applications across different disease categories. It also relies on a quantitative analysis based on several ethnobotanical indices and multivariate statistical methods. Accordingly, the specific objective of the present study was to quantitatively assess the medicinal uses of the previously identified plant species, determine their associations with different health-related disease categories, and identify the species and disease categories most strongly supported by informant consensus and ethnobotanical indices. Through the complementary nature of the studies conducted to date, all 38 municipalities of Taza Province are now documented from an ethnobotanical perspective. This approach contributes to completing the ethnobotanical documentation of the province while providing an updated assessment of medicinal plant uses and the different disease categories in one of Morocco's most important regions from an ethnobotanical perspective. Ultimately, these findings will provide additional scientific information to support the conservation of endangered species, promote traditional herbal medicine, and open new avenues for pharmacological research.

The novelty of this study lies primarily in the updating and detailed characterization of ethnobotanical knowledge in the province of Taza, particularly through the diversity of uses, their association with different categories of illness, and the variations observed in comparison with previous studies. This approach contributes to a better understanding of the local organization of therapeutic knowledge and its relationship with available plant resources, in line with the recommendations of Yebouk (2025) and the value of comparative approaches highlighted by Yebouk et al. (2026). From a conservation perspective, the results highlight the need to preserve both medicinal species and the traditional knowledge associated with them. Documenting this knowledge is therefore an essential step towards ensuring its transmission and promoting the sustainable use of local plant resources.

This study aimed to determine whether medicinal plant use across health-related disease categories in Morocco exhibits distinct patterns of citation, use specificity, and ethnobotanical importance, and whether multivariate analyses can identify plant species and disease categories characterized by particularly strong associations. We hypothesized that medicinal plant use would not be uniformly distributed across disease categories but would instead show specific patterns of plant-disease associations, reflected in differences in citation frequency, use specificity, and informant consensus. We further hypothesized that multivariate analysis would reveal clusters of medicinal plant species and disease categories sharing similar ethnobotanical patterns.

Materials and Methods

Scientific contribution of this study

Recent analyses have highlighted Taza Province as a major center of floristic and ethnobotanical richness in Morocco, characterized by a continuous and diversified spatio-temporal evolution of research activities (Ghabbour *et al*. 2026b). With a view to promoting and consolidating ethnobotanical knowledge in the province of Taza, this study builds upon and complements previous research (Ghabbour *et al*. 2026b) by questioning the municipalities not surveyed (El Aarage *et al*. 2026). On the one hand, it supplements the ethnobotanical survey conducted by El Aarage *et al*. (2026), and, on the other hand, extends the research carried out by Ghabbour *et al.* (2023), Ghabbour *et al*. (2024a), and Ghabbour *et al*. (2024b), which covered 28 of the province's 38 municipalities. As such, this study aims to examine the remaining 10 municipalities (5 were surveyed for the first time) in order to fill this gap and provide a more comprehensive overview of traditional practices relating to the use of plants in the region.

Study area

The province of Taza, situated in north-eastern Morocco within the Fez-Meknes region, occupies a pivotal geographical position between the Rif to the north and the Middle Atlas to the south. This transitional location results in a highly varied landscape, featuring a succession of mountain ranges, plateaus and lowland areas. The region has a Mediterranean climate with continental influences, characterized by harsh and relatively wet winters, particularly at higher altitudes, as well as hot, dry summers with semi-arid tendencies. This physical and climatic diversity contributes to the development of a rich and varied flora, particularly in terms of aromatic and medicinal species (Ourgha *et al*. 2024, Hakkour *et al*. 2016).

Administratively, the province is organised into four urban municipalities and thirty-four rural municipalities. According to the 2024 General Population and Housing Census, the total population stands at 500,971 inhabitants, of whom 212,713 live

in urban areas compared with 288,258 in rural areas (RGPH, 2024). This distribution highlights the predominantly rural nature of the province, where economic activities rely mainly on agriculture, livestock farming and the traditional use of plant resources. Against this ecological and socio-economic backdrop, this study was carried out in several rural municipalities in the province of Taza. Its targeted herbalists as well as ordinary residents in ten rural municipalities out of the thirty-eight in the province, namely: Sidi Ali Bourakba, Bourd, Brarha, Rbaa El Fouki, Beni Frassen, Ait Saghrou, Smia, Zrarda, Tazarin and Bouyablane (El Aarage *et al*. 2026).

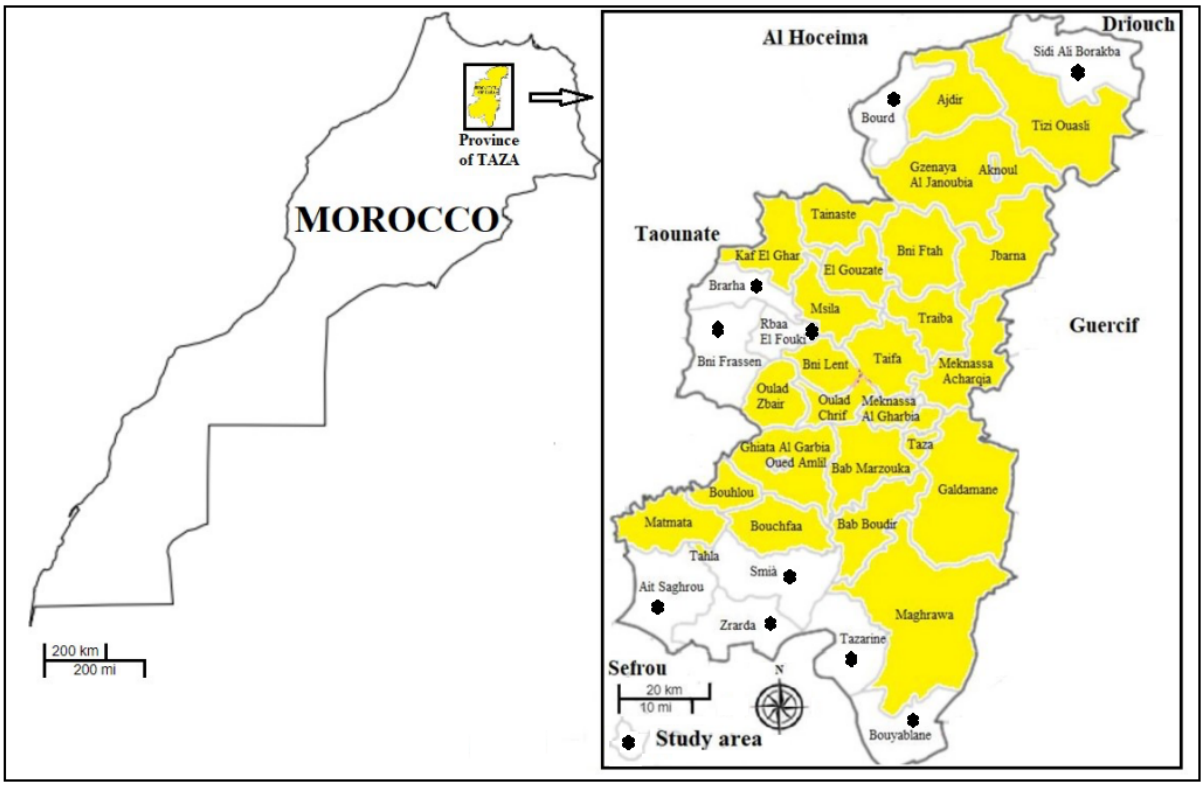

Figure 1. Map showing the study area, indicating the communities surveyed in the province of Taza (El Aarage *et al*. 2026).

Ethnobotanical Survey and Data Collection

The ethnobotanical data analyzed in the present study were obtained from a descriptive and exploratory field survey conducted between March and September 2025 in the studied municipalities of Taza Province. The survey involved 186 participants, including 163 ordinary citizens and 23 herbalists, aged 21-80 years, who were selected through random sampling. All participants voluntarily agreed to take part in the study. Data were collected through individual face-to-face interviews using a semi-structured questionnaire developed based on previous ethnobotanical studies, together with field note-taking. Each questionnaire corresponded to a single participant. Interviews were conducted mainly in Amazigh and Moroccan Arabic, according to the language used by each participant. No audio or video recordings or follow-up interviews were conducted.

The questionnaire consisted of two main parts. The first focused on the sociodemographic characteristics of the participants, including their status (ordinary citizen or herbalist), age, place of residence, occupation, sex, marital status, educational level, monthly income, socioeconomic status, and spoken language. The second part aimed to document the medicinal uses of plants, including the diseases and health conditions treated, the reasons for their use, the sources of ethnobotanical knowledge, the patient's condition after treatment, and the different plants used for each disease category. It also addressed harvesting periods, the condition of the plants used, plant parts employed, preparation and administration methods, drying methods, storage conditions, and patterns of medicinal plant use, whether plants were used alone, in mixtures, or in combination with conventional medicines. Vernacular plant names, medicinal uses, and relevant ethnobotanical information were recorded during the interviews.

Plant specimens were collected with the assistance of the participants, and their taxonomic identification was verified by a botanist. The specimens were subsequently coded and used to establish a reference herbarium. Individual participant responses were kept separately to allow the analysis of citation frequencies and different medicinal uses. Detailed

sociodemographic characteristics of the participants, as well as general information on the ethnobotanical survey methodology, have already been presented and analyzed in our previous publication (El Aarage *et al*. 2026). In the present manuscript, the analysis specifically focuses on data related to the medicinal uses of the identified plant species, the diseases and health conditions treated, and the quantitative ethnobotanical parameters associated with these uses, in accordance with the objective of the present study.

Determination of Scientific Names and Voucher Specimens

A comprehensive list of the vernacular names of the medicinal plants reported by the surveyed population was established following the methodological approach previously described by Ghabbour *et al.* (2024a). The phonetic transcription of these vernacular names was carried out based on the correspondence between Arabic and Latin characters (French-inspired), as follows: ف = f, غ = ɣ, ع = ʔˤ, ط = tˤ, ض = dˤ/ðˤ, ص = sˤ, ش = ʃ, س = s, ز = z, ر = r, د = d, خ = x, ح = ħ, ج = dʒ/ʒ/g, ث = θ, ت = t, ب = b, ا = aː, ق = q, ك = k, ل = l, م = m, ن = n, ه = h, و = w/uː, and ي = j/iː.

All 58 taxa identified during the survey were collected in the field between March and September 2025, properly preserved, and prepared as herbarium specimens. Each taxon was assigned a voucher specimen bearing a specific code. The voucher specimens were deposited at the Laboratory of Natural Resources and Environment, Faculty of Polydisciplinary Studies of Taza, Sidi Mohamed Ben Abdellah University, Fez.

Botanical identification and validation of the scientific names were carried out by Professor Khabbach Abdelmajid (Laboratory of Biotechnology, Environment, Agri-Food and Health, Faculty of Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fez 30000, Morocco), using the same specialized floristic and taxonomic references adopted by Ghabbour *et al*. (2024a), particularly Fennane *et al*. (1999, 2014), Nègre (1962), Quézel and Santa (1962-1963), and Valdés *et al*. (2002).

Information on the identified taxa, scientific names, vernacular names, and voucher specimen codes is provided in the taxonomic table. This study therefore constitutes a complementary and more in-depth contribution to the work previously reported by Ghabbour *et al*. (2024a) and El Aarage *et al*. (2026), while ensuring methodological consistency and reliability of botanical identification.

Quantitative data analysis

The International Classification of Diseases (WHO, 2019) was adopted to categorize the different medicinal uses reported by the study population. Quantitative ethnobotany was used to assess the importance of plants to local communities, based on indices that constitute standard tools for transforming qualitative data into quantitative measures in the biological and social sciences (Hoffman & Gallaher, 2007). Among the indices most commonly used in quantitative ethnobotanical studies are the informant consensus factor (ICF), fidelity level (FL), use value (UV), relative frequency of citation (RFC), and informant agreement ratio (IAR) (Houéhanou *et al*. 2016).

Relative Frequency of Citation (RFC)

Relative Frequency of Citation (RFC), the Local importance of each plant species was calculated based on the following reference (Tardio & Pardo-De Santayana, 2008).

$$RFC = FC/N$$

Where Fc is the number of informants who mentioned the use of the species, and N is the total number of informants (N).

Use Value (UV)

Use Value (**UV**) of (Phillips and Gentry, 1993) modified, evaluates the importance of a plant for a given community (Rossato *et al.* 1999).

$$UV = \sum_{I=1}^{In} Ui/_{n}$$

Where Ui is the number of uses mentioned by an informant I, and n present the total number of informants interviewed

Fidelity Level (FL)

Fidelity Level (**FL**) used for medicinal use, quantifies the importance of a species for a given purpose (Friedman *et al*. 1986).

$$FL = \mathrm{Np/N}$$

Where Np is the number of informants mentioning a species for a certain use p, and N is the number of information mentioning the species for any use.

Informant Consensus Factor (ICF)

Informant Consensus Factor (**ICF**) used for medicinal use and more apt to indicate the homogeneity of ethnomedicinal information (Heinrich *et al.* 1998).

$$ICF = \frac{\text{Nur} - \text{Nt}}{\text{Nur} - 1}$$

Where Nur is the number of times that a particular category p of affection was mentioned, and Nt is the number of a plant(s) mentioned for the treatment of this particular affection P.

Informant Agreement Ratio (IAR)

Informant Agreement Ratio (**IAR**) indicates the agreement that exists between users of medicinal plants in the treatment of diseases (Ernst *et al.* 2015).

$$IAR_{disease} = 1 - (N_t/N_u)$$

Where N_t is the number of a plant(s) mentioned for the treatment of a particular disease category, and N_u is the total number of uses.

Data processing and principal component analysis (PCA)

Information collected from the survey forms was entered and analyzed using IBM SPSS Statistics version 26. Data processing was based on descriptive quantitative statistical methods, including the calculation of various ethnobotanical indices. To explore the relationships between these indices and the studied variables. Principal component analysis (PCA), a multivariate descriptive (factorial) method widely applied in ethnobotany, was performed using XLSTAT 2016, as previously reported by Ghabbour et al. (2023). Two separate PCA analyses were conducted according to the objectives of the study. The first PCA was performed to examine the relationships between disease categories and the corresponding ethnobotanical indices. Disease categories were coded according to the International Classification of Diseases (WHO, 2019), as described in the Materials and Methods section. The second PCA was performed to explore the relationships between the ethnobotanical indices and the studied medicinal plant species.

Results

Collection of ethnobotanical data

As part of an ethnobotanical survey conducted in Taza Province, 186 informants were interviewed across ten communities (Figure 1). The study identified 58 plant species belonging to 35 botanical families (El Aarage *et al.* 2026), used by the local population for various purposes. Each species is reported with its scientific name, vernacular name, family, and medicinal uses (Table 1).

Medicinal use

The data presented in Table 1 show that the plant species identified have a wide variety of therapeutic uses, mainly in the treatment of digestive disorders, diabetes, respiratory conditions, anaemia and high blood pressure. In total, 35 distinct medicinal uses were reported by the informants. Two species were also reported for the treatment of wounds when applied externally, whilst their internal use was reported to be toxic, demonstrating both the richness of local therapeutic knowledge and an empirical understanding of the risks associated with certain plants.

Digestive system disorders constitute the most common therapeutic category, with 24 species, followed by diabetes (20 species), stomach pain (17 species), fever (13 species), intestinal disorders (12 species) and disorders of the nervous system (8 species).

Certain species stand out in particular for the diversity of their therapeutic applications. *Artemisia herba-alba* Asso. has the highest number of uses, with 13 medicinal indications, covering in particular diabetes, high blood pressure, digestive disorders, microbial infections, depression, stomach pain, fatigue, diarrhea, flu, allergies and gallbladder disorders. It is followed by *Mentha pulegium* L., with 11 uses, mainly relating to metabolic, digestive and respiratory disorders, as well as fever, coughs, colds and intestinal problems. *Rosmarinus officinalis* L. also plays an important role, with 9 uses, notably for digestive, respiratory, renal and nervous disorders.

Other species also exhibit significant therapeutic versatility. *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman has 8 uses, whilst *Origanum compactum* Benth. and *Origanum vulgare* L. each have 7 medicinal uses. These species are mainly used to treat diabetes, digestive disorders, fever, respiratory conditions, stomach pain, diarrhea and intestinal disorders. Furthermore, *Dittrichia viscosa* Greuter, *Tetraclinis articulata (*Vahl) Mast., *Ceratonia siliqua* L., *Lavandula officinalis* L. and *Olea europaea* subsp. europaea each have six therapeutic uses, confirming their importance in the local traditional pharmacopoeia.
Furthermore, *Aristolochia fontanesii* Boiss. & Reut*., Lavandula stoechas* L., *Salvia officinalis* L. and *Aloysia citriodora* Palau each have five therapeutic uses. *Thymus vulgaris* L. has four therapeutic uses. *Ammodaucus leucotrichus* Coss. & Dur., *Trigonella foenum-graecum* L. and *Nigella sativa* L. each have three therapeutic uses. *Matricaria chamomilla* L., *Marrubium vulgare* L., *Mentha rotundifolia* (L.) Huds., *Punica granatum* L. and *Ziziphus lotus* (L.) Lam. each have two therapeutic uses. Finally, the other species recorded each have a single medicinal use.

This wealth of medicinal uses attests to the cultural and ethnobotanical importance of these plant species within the province of Taza.

Classes of diseases treated by medicinal plants
Table 2 was compiled by classifying the 35 medicinal uses identified amongst the population of Taza province according to the International Classification of Diseases (Ghabbour *et al.* 2023). The species identified are used in the treatment of 12 groups of diseases. Diseases of the digestive system (K00-K93) constitute the most widely represented category, with 27 species, accounting for 37.69 per cent of uses. Endocrine, nutritional and metabolic diseases (E00-E90) rank second, with 22 species (16.34%), followed by diseases of the respiratory system (J00-J99), represented by 19 species (23.65%).

Diseases of the nervous system (G00-G99) are covered by 7 species, representing 5.62%, whilst injuries, poisonings and certain other consequences of external causes (S00-T98) concern 6 species (6.22%). Diseases of the skin and subcutaneous tissue (L00-L99) and diseases of the genitourinary system (N00-N99) are each represented by 5 species, accounting for 2.45 % and 1.46% respectively.

Infectious and parasitic diseases (A00-B99) and mental and behavioral disorders (F00-F99) are each associated with 2 species, accounting for 4.51% and 0.83% of uses respectively. Diseases of the blood and hematopoietic organs, as well as certain disorders of the immune system (D50-D89), involve 4 species (0.83%). Finally, diseases of the circulatory system (I00-I99) and diseases of the musculoskeletal system and connective tissues (M00-M99) are the least represented categories, with 3 species (0.29%) and 2 species (0.11%) respectively.

Table 1. Medicinal uses of species with their number. VC=Voucher codes, Nu=Number of uses.

Family	Scientific name	Vernacular name	VC	Medicinal use	NU
Amaranthaceae	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Mxiːnza:	1	Fever	1
Anacardiaceae	*Pistacia lentiscus* L.	Fa:dˁiːsˁ	2	Stomach ache	1
Apiaceae	*Ammodaucus leucotrichus* Coss. & Dur.	Ka:muːn sˁuːfiː.	3	Stomach ache/ Diuretic / Intestines	3
	Visnaga daucoides Gaertn.	Bʃniːxa:	4	Diabetes	1
	Carum carvi L.	Lka:rwiːja:	5	Digestive system	1
	Coriandrum sativum L.	Quːsˁbr	6	Digestive system	1
Apocynaceae	*Nerium oleander* L.	A:riːriː /Dfla:	7	Immune deficiency	1
Arecaceae	*Chamaerops humilis* L.	Duːm / Lɣa:z	8	Digestive system	1
Aristolochiaceae	*Aristolochia fontanesii* Boiss. & Reut.	Brz tˁa:m	9	Diabetes/ Digestive system/ Intestines/ Injury/ Prostate	5
Asteraceae	*Artemisia herba-alba* Asso.	ʃiːħ/ ʤaʔˁda:	10	Diabetes/ Hypertension/ Digestive system/ Microbial infection/ Depression/ Stomach ache/ Fatigue/ Signs of injury/ Diarrhea/ Flu/ Allergy/ Injury/ Gallbladder	13
	Dittrichia viscosa L. Greuter	Ma:gra:mn / Tiːddʒr	11	Digestive system/ Stomach ache/ Signs of injury/ Constipation/ Eczema/ Injury	6
	Matricaria chamomilla L.	Lba:buːnj	12	Digestive system / Nervous system	2
Berberidaceae	*Berberis hispanica* Boiss. & Reut.	Aɣriːs	13	Diabetes	1
Brassicaceae	*Lepidium sativum* L.	ħabrʃa:d	14	Diabetes	1
Capparaceae	*Capparis spinosa* L.	Lkbba:r	15	Cold	1
Illecebraceae	*Herniaria hirsuta* L.	Hra:st lħʤa:r	16	Renal system	1
Coriariaceae	*Coriaria myrtifolia* L.	Owiːz	17	Injury (Toxic)	1
Cupressaceae	*Tetraclinis articulata* (Vahl)	Lʔˁa:rʔˁa:r/ Ama:rziː	18	Digestive system/ Cough/ Fever/ Stomach ache/ Intestines/ Dizziness	6
Caesalpiniaceae	*Ceratonia siliqua* L.	Lxa:rruːb	19	Diabetes/ Digestive system/ Stomach pain/ Diarrhea/ Intestines/ Prostate	6
	Lotus ornithopodioides L.	Tiːzduːziːn	20	Injury (Toxic)	1
	Lupinus albus L.	Tiːrmiːs	21	Diabetes	1
	Ononis natrix L.	Afzaːz	22	Anticoagulant	1
	Trigonella foenum graecum L.	Lha:lba:	23	Digestive system/ Stomach ache/ Diarrhea	3
Fagaceae	*Quercus suber* L.	A:draːn /Lba:lluːtˁ /Lkuːrriːʃ	24	Diabetes	1

Gentianaceae	*Centaurium erythraea* Rafn	Kesˁa:t Lha:ya:	25	Diabetes	1
Juglandaceae	*Juglans regia* L.	Elkorka:ʔˁ	26	Diabetes	1
Lamiaceae	*Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman	Ma:nta: /Ta:mi:nta:	27	Diabetes/ High blood pressure/ Digestive system/ Cold/ Cough/ Fever/ Stomach ache/ Nervousness	8
	Lavandula officinalis L.	Xza:ma:	28	Digestive system/ Fever/ Stomach ache/ Dry hair/ Bowels/ Nervousness	6
	Lavandula stoeckade L.	Lħa:lħa:l	29	Digestive system/ Cold/ Respiratory system/ Stomach ache/ Injury	5
	Marrubium vulgare L.	Ta:mr-ri:wt	30	Digestive system/ Cold	2
	Mentha rotundifolia (L.) Huds	Ta:ma:r sˁi:tˁa / mʃi:ʃru:	31	Digestive system/Fever	2
	Mentha pulegium L.	Fli:u:/ Fri:u:	32	Diabetes /Respiratory system/ Stomach ache / Digestive system/ Sore throat/ Blood pressure / Cough/ Fever/ Intestines/Flu/ Cold	11
	Origanum compactum Benth.	Zʔˁtˁa:r/ Zu:i:	33	Diabetes/ Digestive system/ Fever/ Respiratory system/ Stomach ache/ Diarrhea/ Intestines	7
	Origanum majorana L.	Ma:rda:doʃ	34	Respiratory system	1
	Origanum vulgare L.	Zʔˁtˁa:r/ zu:i:	35	Diabetes/ Digestive system/ Fever/ Respiratory system/ Stomach ache/ Diarrhea/ Intestines	7
	Rosmarinus officinalis L.	A:zi:r	36	Digestive system/ Cough/ Fever/ Renal system/ Stomach ache/ Dry hair/ Intestines/ Hair loss/ Nervousness	9
	Salvia officinalis L.	Sˁa:lmi:a:/ Mrmi:a :	37	Diabetes/ Digestive system/ Fever/ Stomach ache/ Nervousness	5
	Thymus vulgaris L.	Zʔˁitˁra:/ zu:ʃn /Tsa:i:t	38	Digestive system/ Cough/ Fever/ Respiratory system	4
Lauraceae	*Cinnamomum cassia*	Qa:rfa:	39	Diabetes	1
Malvaceae	*Hibiscus sabdariffa* L.	Ka:rka:di:l	40	Diabetes	1
Moringaceae	*Moringa oleifera* Lam.	Mu:ri:nga:	41	Heart patients	1
Myrtaceae	*Eucalyptus globulus* Labill.	Lka:litˁu:s	42	Fever	1
	Syzygium aromaticum (L.) Merr. & L.M. Perry.	Lqru:nfl	43	Immune deficiency	1
	Myrtus communis L.	Ri:ħa:n	44	Nervous system	1
Oleaceae	*Olea europaea* subsp. europaea	Zi:tu:n	45	Diabetes/ High blood pressure/ Cough/ Nervousness/ Tension/ Eczema	6
Pinaceae	*Pinus Halipensis Mill.*	Ta:i:da:	46	Fever	1
Poaceae	*Pennisetum typhoides* Rich	I:lla:n /A:ʤba:r	47	Osteoporosis	1
Punicaceae	*Punica granatum* L.	Rma:n	48	Digestive system/ Hair loss	2
Ranunculaceae	*Nigella sativa* L.	Sˁa:nu:ʤ/ Lħa:ba	49	Cough/Heart disease/Fatigue	3

Rhamnaceae	*Rhamnus alaternus* L.	A:mli:la:s	50	Anaemia	1
	Ziziphus lotus (L.) Lam.	Sa:dra:	51	Stomach/intestinal pain	2
Rubiaceae	*Rubia tinctorum* L.	Lfu:wa:	52	Anaemia	1
Rutaceae	*Ruta chalepensis L.*	A:wra:m /Fi:ʤa:l	53	Digestive system	1
Salicaceae	*Populus alba* L.	Sˁa:fsˁa:f	54	Intestine	1
Solanaceae	*Solanum nigrum* L.	ʔˁi:n la:rna:b	55	Diabetes	1
Thymelaeaceae	*Daphne gnidium* L.	A:la:zza:z	56	Hair loss	1
Urticaceae	*Urtica dioica* L.	Hu:rri:ga:	57	Heart disease	1
Verbenaceae	*Aloysia citriodora* Palau.	Lwi:za:	58	Diabetes/ Digestive system/ Stomach ache/ Intestines/ Nervousness	5
Totale	**58**				

Table 2. Ethnobotanical parameters associated with medicinal plant use across disease categories.

SPECIES	FC														
	I: A00-B99	III: D50-D89	IV: E00-E90	V: F00-F99	VI: G00-G99	IX: I00-I99	X: J00-J99	XI: K00-K93	XII: L00-L99	XIII: M00-M99	XIV: N00-N99	XIX: S00-T98	T(FC)	UV	RFC	FL%
Dysphania ambrosioides (L.) Mosyakin & Clemants							14						14	0.075	0.075	100
Pistacia lentiscus L.								28					28	0.151	0.151	100
Amm. leucotrichus Coss. Et Dur.								4			2		6	0.032	0.021	66.67
Visnaga daucoides Gaertn.			4										4	0.022	0.022	100
Carum carvi L.								17					17	0.091	0.091	100
Coriandrum sativum L.								6					6	0.032	0.032	100
Nerium oleander L.		10											10	0.054	0.054	100
Chamaerops humilis L.								68					68	0.366	0.366	100
Aristolochia fontanesii Boiss. & Reut.			4					9	13		13		39	0.210	0.07	33.33
Artemisia herba-alba Asso.	22	4	22	23			4	53	10	1			139	0.747	0.285	38.13
Dittrichia viscosa L. Greuter								12	37				49	0.263	0.199	75.51
Matricaria chamomilla L.					21			20					41	0.220	0.113	51.22
Berberis hispanica Boiss. & Reut.			4										4	0.022	0.022	100
Lepidium sativum L.			10										10	0.054	0.054	100
Capparis spinosa L.							4						4	0.022	0.022	100
Herniaria hirsuta L.											22		22	0.118	0.118	100
Coriaria myrtifolia L.												24	24	0.129	0.129	100
Tetraclinis articulata (Vahl)				6			27	62					95	0.511	0.333	65.26
Ceratonia siliqua L.			20					63			13		96	0.516	0.338	65.62
Lotus ornithopodioides L.												25	25	0.134	0.134	100
Lupinus albus L.			4										4	0.022	0.022	100
Ononis natrix L.		11											11	0.059	0.059	100
Trigonella foenum graecum L.								27					27	0.145	0.145	100
Quercus suber L.			12										12	0.065	0.065	100
Centaurium erythraea Rafn			4										4	0.022	0.022	100
Juglans regia L.			4										4	0.022	0.022	100

Calamintha nepeta subsp. *spruneri* (Boiss.) Nyman		68	26	186	20				300	1.613	1	69.33
Lavandula officinalis L.			1	30	32			28	91	0.489	0.172	35.16
Lavandula stoeckade L.				4	58	22			84	0.452	0.312	69.05
Marrubium vulgare L.				61	52				113	0.608	0.339	53.98
Mentha rotundifolia (L.) Huds				14	65				79	0.425	0.349	82.28
Mentha pulegium L.	136	105		186	133				560	3.011	1	33.21
Origanum compactum Benth.		3		15	184				202	1.086	0.989	91.09
Origanum majorana L.				8					8	0.043	0.043	100
Origanum vulgare L.		3		18	27				48	0.258	0.161	56.25
Rosmarinus officinalis L.			61	70	186		1	85	403	2.167	1	46.15
Salvia officinalis L.		77	25	3	36				141	0.758	0.419	55.32
Thymus vulgaris L.				148	64				212	1.140	0.796	69.81
Cinnamomum cassia		4							4	0.022	0.022	100
Hibiscus sabdariffa L.		4							4	0.022	0.022	100
Moringa oleifera Lam.			4						4	0.022	0.022	100
Eucalyptus globulus Labill.				7					7	0.038	0.038	100
Syzygium aromaticum (L.) Merr. & L.M. Perry.	4								4	0.022	0.022	100
Myrtus communis L.			27						27	0.145	0.145	100
Olea europaea subsp. europaea		18	4	4		4			30	0.161	0.097	60
Pinus Halipensis Mill.				5					5	0.027	0.027	100
Pennisetum typhoides Rich		67							67	0.360	0.36	100
Punica granatum L.					9			11	20	0.108	0.059	55
Nigella sativa L.			2	21		3			26	0.140	0.113	80.77
Rhamnus alaternus L.		65							65	0.349	0.349	100
Ziziphus lotus (L.) Lam.					50				50	0.269	0.269	100
Rubia tinctorum L.		61							61	0.328	0.328	100
Ruta chalepensis L.					10				10	0.054	0.054	100
Populus alba L.					4				4	0.022	0.022	100
Solanum nigrum L.		4							4	0.022	0.022	100
Daphne gnidium L.								45	45	0.242	0.242	100
Urtica dioica L.			4						4	0.022	0.022	100
Aloysia citriodora Palau.		6	32		22				60	0.323	0.177	55

Total	158	29	573	29	197	10	829	1321	86	4	51	218	3505
Percentage%	4.51	0.83	16.34	0.83	5.62	0.29	23.65	37.69	2.45	0.11	1.46	6.22	100
Species number	2	4	22	2	7	3	19	27	5	2	5	6	57
IAR	0.987	0.862	0.961	0.931	0.964	0.7	0.977	0.98	0.941	0.5	0.901	0.972	0.984
ICF	0.993	0.892	0.963	0.964	0,969	0.77	0.978	0.98	0.953	0.66	0.92	0.977	0.984

Legend:

FC/CF=Frequency of Citation, **T(FC)**=Total Frequency of Citation, **RFC** =Relative Frequency of Citation, **UV**=Use Value, **FL**=Fidelity Level, **ICF**=Informant Consensus Factor, **IAR**=Informant Agreement Ratio, **I (A00-B99)** =Certain infectious and parasitic diseases. **III (D50-D89)** =Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism. **IV (E00-E90)** =Endocrine, nutritional and metabolic diseases. **V (F00-F99)** =Mental and behavioral disorders. **VI (G00-G99)** =Diseases of the nervous system. **IX (I00-I99)** =Diseases of the circulatory system. **X (J00-J99)** =Diseases of the respiratory system. **XI (K00-K93)** =Diseases of the digestive system. **XII (L00- L99)** =Diseases of the skin and subcutaneous tissue. **XIII (M00-M99)** =Diseases of the musculoskeletal system and connective tissue. **XIV (N00-N99)** =Diseases of the genitourinary system. **XIX (S00-T98)** =injury, poisoning and certain other consequences of external causes.

Quantitative Data Analysis

Citation frequency (CF) and total citation frequency T(CF)

The data presented in Table 2 show that the highest citation frequencies (CF) were recorded for *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman and *Mentha pulegium* L., each with a CF of 186 for diseases of the respiratory system, whilst *Rosmarinus officinalis* L. had the highest citation frequency for diseases of the digestive system (CF = 186). Within the various disease categories, *Mentha pulegium* L. was the most frequently cited species for infectious and parasitic diseases (CF = 136) and endocrine, nutritional and metabolic diseases (CF = 105). *Ononis natrix* L. had the highest value for diseases of the blood and hematopoietic organs and certain disorders of the immune system (CF = 11), whilst *Artemisia herba-alba* Asso was the most frequently cited for mental and behavioral disorders (CF = 23). For diseases of the nervous system, *Rosmarinus officinalis* L. had the highest CF (61). *Eucalyptus globulus* Labill. and *Urtica dioica* L. shared the highest value for diseases of the circulatory system (CF = 4). *Dittrichia viscosa* L. Greuter was the most frequently cited species for diseases of the skin and subcutaneous tissue (CF = 37), whilst *Nigella sativa* L. had the highest value for diseases of the musculoskeletal system and connective tissues (CF = 3).

Herniaria hirsuta L. was the most frequently cited species for diseases of the genitourinary system (CF = 22), whilst *Rosmarinus officinalis* L. had the highest value for injuries, poisonings and other consequences of external causes (CF = 85). With regard to the total frequency of citation (TFC), *Mentha pulegium* L. had the highest value (TFC = 560), followed by *Rosmarinus officinalis* L. (TFC = 403) and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman (TFC = 300). Other species with relatively high values were *Thymus vulgaris* L. (TFC = 212), *Origanum compactum* Benth. (TFC = 202), *Salvia officinalis* L. (TFC = 141), *Artemisia herba-alba* Asso. (TFC = 139) and *Marrubium vulgare* L. (TFC = 113). The other species recorded had total citation frequencies of less than 100.

Relative frequency of citation (RFC)

The relative frequency of citation (RFC) was calculated exclusively for the disease category in which each species had the highest frequency of citation. For example, *Rosmarinus officinalis* L. recorded its highest frequency of citation for diseases of the digestive system (FC = 186). Based on these data, the RFC values presented in Table 2 were found to be particularly high for several species, notably *Mentha pulegium* L. (RFC = 1), *Rosmarinus officinalis* L. (RFC = 1), *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman (RFC = 1), *Origanum compactum* Benth. (RFC = 0.989) and *Thymus vulgaris* L. (RFC = 0.796).

Level of fidelity (FL)

The fidelity index (FL) was used to assess the degree of agreement amongst informants regarding the use of a plant species for a given condition (Ghabbour *et al*. 2023). In the present study, FL values ranged from 33.21% to 100% (Table 2), and 36 species had the maximum value of 100%. The values obtained for certain species included 82.28% for *Mentha rotundifolia* (L.) Huds, 60% for *Olea europaea* subsp. europaea, 46.15% for *Rosmarinus officinalis* L., 69.33% for *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman, 91.09% for *Origanum compactum* Benth. and 69.81% for *Thymus vulgaris* L. The minimum value (33.21%) was recorded for *Mentha pulegium* L.

Use value (UV)

In order to assess the relative importance of plant species within the study area, the utility value (UV) was calculated for the various species recorded (Table 2). The UV values obtained in this study range from 0.022 to 3.011.

The highest UV values were recorded for *Mentha pulegium* L. (UV = 3.011), followed by *Rosmarinus officinalis* L. (UV = 2.167) and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman (UV = 1.613). These species thus have the highest utility values among the plants studied.

Conversely, the lowest UV values (UV = 0.022) were recorded for *Visnaga daucoides* Gaertn., *Berberis hispanica* Boiss. & Reut., *Capparis spinosa* L., *Centaurium erythraea* Rafn, *Juglans regia* L., *Cinnamomum cassia*, *Hibiscus sabdariffa* L., *Moringa oleifera* Lam., *Syzygium aromaticum* (L.) Merr. & L.M. Perry., *Populus alba* L., *Solanum nigrum* L. and *Urtica dioica* L.

The results thus show significant variation in the value of use amongst the species studied, with some species being heavily represented in local medicinal practices, whilst others are of lesser ethnomedical importance.

Informant Agreement Ratio (IAR) and Informant Consensus Factor (ICF)

The IAR and ICF values were calculated for each disease category in order to assess whether certain groups of diseases are more frequently treated using medicinal plants (Table 2). These indices measure the degree of agreement amongst informants regarding the use of plants for specific disease categories within the study area. They show that, for several

categories, the two indices have identical or very similar values, suggesting that they generally provide similar information (Ghabbour *et al*. 2023).

The results show that the IAR and ICF values are generally high across several disease categories and, in most cases, are identical or very similar. The highest values were recorded for Class I (A00-B99), corresponding to certain infectious and parasitic diseases (IAR = 0.987; ICF = 0.993), followed by Class XI (K00-K93), relating to diseases of the digestive system (IAR = 0.980; ICF = 0.980), and Class X (J00-J99), corresponding to diseases of the respiratory system (IAR = 0.977; ICF = 0.978), and class XIX (S00-T98), covering injuries, poisonings and certain other consequences of external causes (IAR = 0.972; ICF = 0.977).

Class E00-E90, corresponding to endocrine, nutritional and metabolic diseases, also shows high values (IAR = 0.961; ICF = 0.963). This category includes, in particular, diabetes, which is amongst the conditions cited by the study population.

Diseases of the digestive system and diabetes are among the main categories of conditions treated with medicinal plants. A total of 27 species are reported for digestive disorders, whilst 20 species are used for the treatment of diabetes (Table 1). Diseases of the nervous system also show a high ICF value (0.969).

Overall, the results indicate a high degree of agreement amongst informants across several disease categories, particularly for infectious and parasitic diseases, digestive disorders, respiratory diseases, metabolic disorders and injuries.

Principal Component Analysis (PCA)

Figure 2 shows a biplot diagram of the PCA. The first two principal components explained 98.60% of the total variance (PC1 = 69.94%; PC2 = 28.66%), providing a highly informative two-dimensional representation of the relationships among the variables included in the analysis. PC1 is strongly and positively associated with the number of species and the percentage of citations, whilst PC2 is mainly associated with the IAR and the ICF. Categories XI (K00-K93), IV (E00-E90) and X (J00-J99) lie in the direction of high numbers of species and high percentages of citations. Categories I (A00-B99), XIX (S00-T98) and VI (G00-G99) are more strongly associated with the IAR and the ICF. Categories XIII (M00-M99) and IX (I00-I99) appear relatively isolated in the factor space.

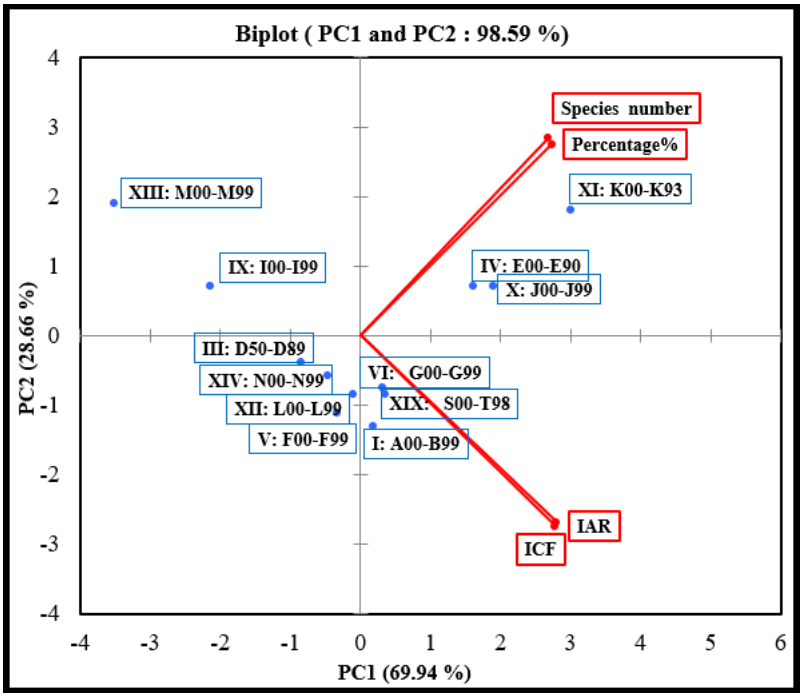

Figure 2. Principal Component Analysis (PCA) of ethnobotanical indices and disease categories. **I (A00-B99)** =Certain infectious and parasitic diseases. **III (D50-D89)** =Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism. **IV (E00-E90)** =Endocrine, nutritional and metabolic diseases. **V (F00-F99)** =Mental and behavioral disorders. **VI (G00-G99)** =Diseases of the nervous system. **IX (I00-I99)** =Diseases of the circulatory system. **X (J00-J99)** =Diseases of the respiratory system. **XI (K00-K93)** =Diseases of the digestive system. **XII (L00- L99)** =Diseases of the skin and subcutaneous tissue. **XIII (M00-M99)** =Diseases of the musculoskeletal system and connective tissue. **XIV (N00-N99)** =Diseases of the genitourinary system. **XIX (S00-T98)** =injury, poisoning and certain other consequences of external causes.

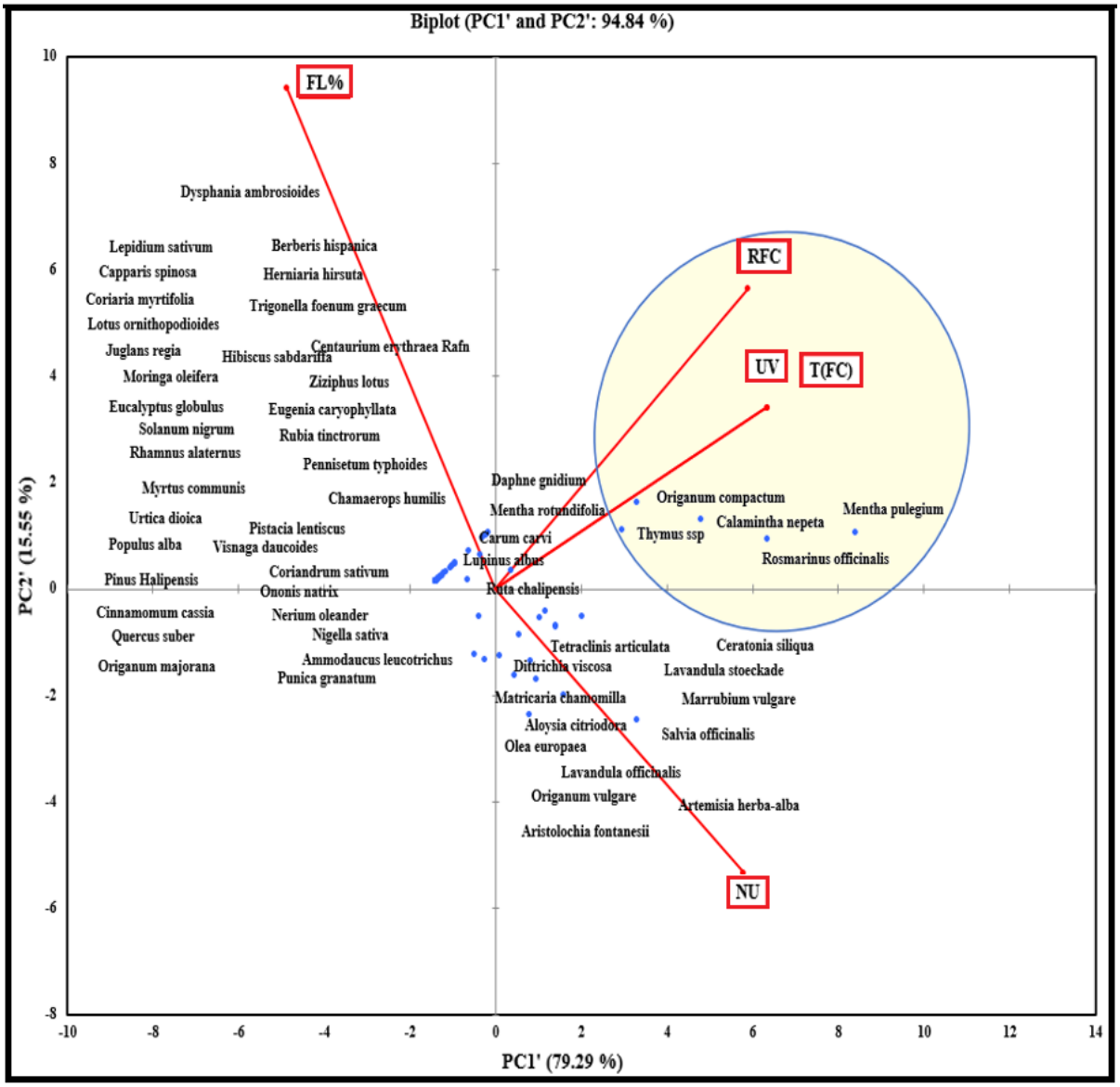

Figure 3. Principal Component Analysis (PCA) of plant species distribution based on ethnobotanical indices.

Discussion

Medicinal use

The highest number of medicinal uses recorded in our study was for *Artemisia herba-alba* Asso, with 13 medicinal uses, a figure almost comparable to that reported by Ghabbour *et al*. (2023), who identified 14 medicinal uses for this species. As regards *Mentha pulegium* L., we recorded 11 medicinal uses, which is fewer than the number reported by Ghabbour *et al*. (2023), who identified 14. Similarly, *Rosmarinus officinalis* L. has 9 medicinal uses in our study, a figure significantly lower than the 24 uses reported by Ghabbour *et al*. (2023), making this species the one with the highest number of uses in their study. Nevertheless, its importance in the province is further supported by its documented phytochemical richness and antioxidant and antimicrobial activities, which varied among populations from seven sites in Taza Province (Ghabbour *et al.*, 2026a). Furthermore, *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman has a total of 8 medicinal uses, compared with the 13 reported by Ghabbour *et al*. (2023). Similarly, *Origanum compactum* Benth. and *Origanum vulgare* L. each have 7 medicinal uses, which is fewer than the 14 medicinal uses reported by Ghabbour *et al*. (2023). Conversely, some species have higher numbers than those reported by Ghabbour *et al*. (2023). For example, *Ceratonia siliqua* L. has 6 medicinal uses in our study, compared with only 3 in their study. Similarly, *Lavandula stoeckade* L. has 5 medicinal uses, which is also higher than the 3 uses reported by Ghabbour *et al*. (2023).

These differences in the diversity of uses can be interpreted as the result of an interaction between the availability of species, accessibility, cultural significance, the transmission of knowledge and perceptions of therapeutic efficacy. The number of

uses attributed to a species therefore does not depend solely on its presence in the environment. A species may be widely available but have a limited number of uses within a community, whilst another, sometimes less abundant, may be associated with several indications due to its importance in the local pharmacopoeia. In the case of *Artemisia herba-alba*, which has the highest number of uses in our study, this versatility may reflect a particularly well-established knowledge of the species within the communities studied, as well as the diversity of indications traditionally associated with this plant. The fact that its value is very close to that reported by Ghabbour *et al*. (2023) also suggests a certain stability in its therapeutic importance in the province of Taza. Conversely, the differences observed for *Rosmarinus officinalis* L., *Mentha pulegium* L., *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman and species of the genus *Origanum* may reflect local variations in the transmission and specialisation of medicinal knowledge, as well as differences in the populations surveyed and in the ecological contexts of the areas studied. The higher values observed for *Ceratonia siliqua* L. and *Lavandula stoeckade* L., meanwhile, suggest that certain species may have particular therapeutic significance in the municipalities studied, which is not necessarily reflected with the same intensity in other surveys.

The high number of medicinal uses identified in our study is consistent with the findings reported by Ghabbour *et al*. (2023), El Aboui *et al*. (2025), El Hajli *et al*. (2024), El Hilaly *et al*. (2003) and El Khomsi *et al*. (2022). The digestive system, which constitutes the most widely represented therapeutic category in terms of the number of species in our study, is also the category most frequently cited in the works of Ghabbour *et al*. (2023), El Aboui *et al*. (2025), El Hajli *et al*. (2024), Daoudi *et al*. (2016), Boulfia *et al*. (2018), Haouari *et al*. (2018), Fatiha *et al*. (2019), Hayat *et al*. (2020) and El Khomsi *et al*. (2022). The number of species (24 species) identified in our study for the treatment of digestive system disorders is lower than that reported by Ghabbour *et al*. (2023), who recorded 62 species. It is, however, close to the number reported by El Alami *et al*. (2016), who recorded 25 species, and is lower than the figures recorded by Daoudi *et al*. (2016) (63 species), El Khomsi *et al*. (2022) (34 species), El Hajli *et al*. (2024) (36 species), El Aboui *et al*. (2025) (47 species) and Bammou *et al*. (2024) (48 species).

The prevalence of digestive disorders can be explained by several interrelated factors. These conditions are commonly encountered in everyday life and can be managed, according to traditional practices, using simple and readily available herbal preparations. The presence of numerous aromatic plants in the local pharmacopoeia may also contribute to this trend, as several of these species are traditionally associated with digestive disorders. The availability of plants in cultivated areas, on pastureland, in woodland and around dwellings may facilitate their collection and use. However, the prevalence of this category cannot be attributed solely to ecological availability: the transmission of knowledge within families, the experience accumulated by local communities and the perceived effectiveness of the plants are likely to be important factors as well. The recurrence of this trend across several regions of Morocco thus suggests the existence of a common cultural foundation of knowledge regarding plants used for digestive purposes, whilst also revealing local variations in the number of species utilised.

With regard to the treatment of diabetes, the 20 species identified in our study are fewer than the 61 species reported by Ghabbour *et al*. (2023), but remain close to the 22 species reported by Ouhaddou *et al*. (2020) and 18 species reported by Lkhalidi et *al.* (2026). This figure is also lower than those reported by Tahraoui *et al*. (2007) (63 species), Eddouks *et al.* (2002) (37 species) and El Aboui *et al*. (2025) (30 species). The prominence of diabetes in the pharmacopoeia studied may be linked to the place occupied by chronic diseases in communities' health concerns. Unlike certain acute conditions, diabetes requires long-term management, which may encourage repeated use of local medicinal resources and the transmission of various recipes or plant species within families. The diversity of plants cited for this condition therefore likely reflects the importance attached locally to plant resources in the traditional management of chronic diseases. However, this interpretation relates to the ethnobotanical significance of the plants and does not allow us to conclude that they are effective against diabetes.

With regard to the treatment of fever, our study identified 13 species, a figure relatively close to the 16 species reported by Ghabbour *et al*. (2023). This figure is higher than the 9 species recorded by El Aboui *et al*. (2025), but lower than the 22 species reported by Dagni *et al*. (2023). The diversity of species used to treat fever can be explained by the frequent occurrence and ease of identification of this symptom, as well as by the transmission of various traditional preparations intended to relieve feverish conditions. The differences observed between studies may, however, reflect the specific characteristics of local flora and the therapeutic preferences particular to each community.

This study identified numerous medicinal uses, which are also corroborated by several studies carried out in the province of Taza. Indeed, Ghabbour *et al*. (2023) report uses primarily related to the digestive system (62 species), diabetes (61 species), the respiratory system (23 species), the cardiovascular system (22 species), high blood pressure (21 species) and stomach pain (21 species). Similarly, El Hajli et al. (2024) identified uses dominated by disorders of the digestive system (36 species),

followed by respiratory disorders (19 species), metabolic diseases (16 species), skin conditions (18 species), nervous system disorders (10 species) and disorders of the urinary and muscular systems (6 species each). The findings of El Aboui *et al*. (2025) also confirm the predominance of digestive disorders (47 species), followed by diabetes (30 species), hypertension (13 species) and fever (9 species). Furthermore, Khabbach *et al*. (2012) highlight the frequency of gastrointestinal disorders (33 species), joint disorders, ENT conditions and headaches (24 species), as well as skin problems (11 species).

Similar trends have been observed in other Moroccan provinces. El Alami *et al*. (2016) report that medicinal uses were mainly related to skin and hair conditions (26 species), the digestive system (25 species), metabolic disorders (14 species), the respiratory system (11 species), urogenital conditions (8 species) and the nervous system (5 species). Daoudi *et al.* (2016) also highlight the predominance of digestive disorders (63 species), followed by dermatological conditions (24 species), urogenital and rheumatological disorders (23 species each), respiratory conditions (20 species) and cardiovascular conditions (15 species), as well as neurological, infectious and ENT disorders (42 species). Other studies confirm these trends. Eddouks *et al*. (2002) report, in particular, a high number of uses related to the treatment of diabetes (37 species), as well as heart disease and hypertension (73 species). El Khomsi *et al.* (2022) also indicate a predominance of digestive disorders (34 species), followed by skin conditions (30 species), metabolic and nervous system disorders (12 species each), respiratory conditions (8 species), rheumatic disorders (7 species) and urogenital conditions (6 species). Finally, Jouad *et al*. (2001) and Tahraoui *et al*. (2007) confirm the high frequency of medicinal uses associated with diabetes (54 to 63 species), high blood pressure (19 to 54 species), heart disease (11 species) and kidney disorders (33 species).

The general consistency of these findings shows that certain therapeutic categories, in particular digestive disorders and metabolic diseases, occupy an important place in traditional Moroccan pharmacopoeias. However, the discrepancies observed between the studies also show that Morocco's ethnobotanical heritage is not homogeneous. These differences may stem from the specific flora of each region, ecological conditions, access to plants, as well as cultural practices and the structure of knowledge within communities. The province of Taza is of particular interest in this regard due to the diversity of its environments and the coexistence of communities with local practices and traditions that may give rise to different patterns of use.

These findings confirm the existence of a close and dynamic relationship between human populations and plant resources in the province of Taza. Local communities utilise the available plant resources to meet their healthcare needs, thereby demonstrating a deep empirical understanding of the therapeutic properties of plants and the capacity of traditional knowledge to adapt to environmental and cultural realities. However, this relationship should not be interpreted as one determined solely by the abundance of plants. The frequency with which a species is cited is likely the result of an interaction between its availability, accessibility, therapeutic reputation, perceived efficacy and the continuity of its cultural transmission. A plant that is available in the environment but absent from local practices may therefore be of little ethnobotanical significance, whilst a culturally valued plant may retain a high frequency of citation despite more limited availability.

Finally, *Coriaria myrtifolia* and *Lotus ornithopodioides* were reported by informants as being traditionally used in the treatment of injuries, mainly through external application. Their classification under the 'Injury' category therefore refers to this traditional therapeutic use and does not imply that their external application is considered toxic. The toxicity reported for these two species is instead associated with their internal use, particularly their ingestion or consumption. Thus, the ethnobotanical information gathered makes it possible to distinguish between their traditional external use in the treatment of injuries and the risk of toxicity associated with their internal consumption. This information reflects the traditional knowledge and practices reported by informants and does not, in itself, constitute experimental evidence of toxicity. This distinction is a particularly relevant aspect of local knowledge, as it demonstrates that the documented ethnobotanical knowledge relates not only to the beneficial properties attributed to the plants, but also to the methods of use and precautions associated with certain species.

Classes of diseases treated by medicinal plants

The results obtained in this study highlight a predominance of medicinal uses for the treatment of digestive disorders, followed by endocrine, nutritional and metabolic diseases. This trend is consistent with the observations reported by Ghabbour *et al*. (2023), El Aboui *et al*. (2025), El Hajli *et al*. (2024), Maache *et al*. (2024), Jaouad *et al*. (2025) and El Assri *et al*. (2021), who also identified digestive disorders as one of the main therapeutic categories. In contrast, mental and behavioral disorders, diseases of the skin and subcutaneous tissue, and disorders of the musculoskeletal system and connective tissues are represented by a relatively small number of plant species in our study.

Compared with the data published by Ghabbour *et al*. (2023), the figures obtained in this study are lower for several disease categories, notably Group I (A00-B99), with 37 species (9.57%), Group III (D50-D89), with 14 species (1.71%), Group VI (G00-G99), with 24 species (5.53%), Group IX (I00-I99), with 39 species (10.14%), Group XIII (M00-M99), with 7 species (0.44%), Group XIV (N00-N99), with 22 species (4.74%), and Group XIX (S00-T98), with 10 species (1.8%).

Lower figures are also observed for the dominant groups, notably Group XI (K00-K93), with 67 species (23.66%), and Group IV (E00-E90), with 63 species (33.89%). Conversely, Ghabbour *et al*. (2023) reported a higher number of species for group X (J00-J99), corresponding to respiratory system diseases, with 30 species (6.15%). They also noted a lower number of species for group V (F00-F99), with 8 species (1.36%), which is broadly consistent with the trends observed in the present study.
At national level, similarities were also observed with the work of Maache *et al.* (2024) concerning the group of diseases of the blood and hematopoietic organs, as well as certain disorders of the immune system, and with that of El Assri *et al*. (2021) for the group of mental and behavioral disorders. However, a slightly higher number of species was recorded than that reported by El Assri *et al*. (2021) for the group comprising diseases of the blood and hematopoietic organs as well as certain disorders of the immune system with one additional species and for the group comprising injuries, poisonings and certain other consequences of external causes with three additional species.

Conversely, lower diversity was observed for the group of infectious and parasitic diseases compared with the studies by Maache *et al*. (2024) (12 species), Jaouad *et al*. (2025) (14 species) and El Assri *et al*. (2021) (18 species). A similarly lower species richness was recorded for the group comprising diseases of the blood and hematopoietic organs and certain disorders of the immune system, compared with the findings of Jaouad *et al*. (2025), who identified 9 species.

With regard to endocrine, nutritional and metabolic diseases, the species richness recorded in our study remains significantly lower than that reported by Arraji *et al*. (2024) (47 species), El Ouadni *et al*. (2025) (212 species), Maache *et al*. (2024) (33 species) and Jaouad *et al*. (2025) (44 species). A similar trend is observed for mental and behavioral disorders, where the number of species remains lower than that reported by Amaghnouje *et al*. (2020), with 55 species.

Similar discrepancies are also observed for diseases of the nervous system, when compared with the studies by Aitbaba *et al*. (2024) (50 species), Jaouad *et al*. (2025) (25 species) and Maache *et al*. (2024) (25 species). The same applies to the group comprising injuries, poisonings and certain other consequences of external causes, when compared with the results of El Ghazal *et al*. (2025) (46 species) and Mrabti *et al*. (2022) (40 species).

Finally, for diseases of the circulatory system and diseases of the respiratory system, the results obtained in our study remain lower than those reported by El Moumen *et al*. (2025) (80 species), Maache *et al*. (2024) (6 species) and Jaouad *et al*. (2025) (11 species) for the circulatory system, as well as those of Maache *et al*. (2024) (24 species), Jaouad *et al*. (2025) (36 species) and El Assri *et al*. (2021) (31 species) for the respiratory system.

The predominance of diseases of the digestive system (K00-K93), represented by 27 species in this study, could be explained by the prevalence of digestive disorders in the population and by the importance of medicinal plants in their traditional management, particularly for stomach pain, intestinal disorders and diarrhea. This trend, also reported in several Moroccan ethnobotanical studies, highlights the central role of common ailments in local phytotherapeutic practices. The high representation of endocrine, nutritional and metabolic diseases, mainly related to diabetes, may in turn reflect the importance attached to traditional treatments for chronic conditions. Similarly, the use of a relatively high number of species for respiratory conditions highlights the role of aromatic plants in the traditional treatment of coughs, colds, fever and respiratory disorders. Conversely, the low representation of mental, circulatory and osteoarticular disorders could be linked to their less frequent management using plants or to the use of other forms of care. The trends observed are consistent with those reported by Ghabbour *et al*. (2023) and several other Moroccan studies, whilst showing differences in the specific richness of the pathological categories. These differences may be linked to the floristic and ecological characteristics of each region, but also to therapeutic practices, health priorities and the socio-cultural characteristics of the populations studied. Thus, the findings from Taza highlight the existence of a common foundation of ethnomedical knowledge in Morocco, whilst revealing a local expression of this heritage, shaped by the available plant resources, their therapeutic use and the needs of the population. This organization of the local pharmacopoeia is a key factor in understanding the relationship between the communities of Taza and their plant environment and contributes to updating the ethnobotanical knowledge of the region.

Quantitative Data Analysis

Citation frequency (CF) and total citation frequency T(CF)

The high citation frequencies recorded for *Mentha pulegium* L., *Rosmarinus officinalis* L. and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman indicate that these species play an important role in traditional medicinal practices in the province of Taza. Their high frequency of citation may be linked to the diversity of their uses, their presence in the local environment and the widespread knowledge of them amongst the population. The frequent use of these plants for common ailments, particularly digestive and respiratory problems, may also contribute to their continued use in therapeutic practices. The particularly high value for *Mentha pulegium* L. (TFC = 560) may be associated with its use for several conditions, which naturally increases the number of recorded mentions. Similarly, the high frequency of *Rosmarinus officinalis* L. (TFC = 403) could be linked to the variety of ailments for which this species is mentioned. Conversely, the lower frequencies observed for other species may correspond to more specific uses or to limited use within the population studied.

A comparison with previous studies shows, however, that the relative importance of species varies according to the regions and populations studied. The results obtained are consistent with those of El Hajli *et al*. (2024) and Jeddi *et al.* (2021), who also highlight the importance of *Rosmarinus officinalis* L. and *Mentha pulegium* L. However, the TFC values obtained in our study for *Mentha pulegium* L. (560), *Rosmarinus officinalis* L. (403) and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman (300) are higher than those reported by Ghabbour *et al*. (2023), whilst *Salvia officinalis* L. has a lower value in our study (141 versus 206). These differences may be linked to the specific characteristics of the populations surveyed, the local availability of the species, therapeutic preferences and the conditions under which the data were collected. They demonstrate that the frequency of citation does not depend solely on a plant's medicinal properties, but also on its ecological and cultural context. The results thus highlight certain distinctive features of the traditional pharmacopoeia of Taza, notably the importance attached to *Mentha pulegium* L., *Rosmarinus officinalis* L. and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman, whilst confirming the existence of a set of medicinal species common to various regions of Morocco.

Fréquence relative de citation (RFC)

The RFC values obtained in this study are higher than those reported in several Moroccan ethnobotanical studies. Ghabbour *et al*. (2023) recorded RFC values of 0.088 for *Mentha pulegium* L., 0.126 for *Rosmarinus officinalis* L., 0.053 for *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman, 0.132 for *Origanum compactum* Benth. and 0.047 for *Thymus vulgaris* L. El Assri *et al*. (2021) reported values of 0.363 for *Mentha pulegium* L., 0.308 for *Rosmarinus officinalis* L. and 0.438 for *Origanum compactum* Benth. Similarly, Jeddi *et al*. (2024) obtained RFC values of 0.087 for *Origanum compactum* Benth. and 0.065 for *Rosmarinus officinalis* L., whilst Aniba *et al*. (2025) reported values of 0.675 and 0.852 for *Origanum compactum* Benth. and *Mentha pulegium*, respectively. El Moumen *et al*. (2025) recorded RFC values of 0.026 for *Mentha pulegium* L., 0.063 for *Rosmarinus officinalis* L. and 0.022 for *Thymus vulgaris* L.. Values of 0.189 for *Rosmarinus officinalis* L. and 0.33 were also reported by Chaachouay *et al*. (2022) and Ghanimi *et al*. (2022), respectively. At national level, the maximum value obtained in our study (RFC = 1) also exceeds those reported by Ghabbour *et al*. (2023) (0.294), Chaachouay *et al*. (2022) (0.189), El Moumen *et al*. (2025) (0.219), El Ghazal *et al*. (2025) (0.199), Aniba *et al*. (2025) (0.852), Jeddi *et al*. (2024) (0.664), El Ghazouani *et al*. (2024) (0.47), Yassara *et al*. (2025) (0.90), Ghanimi et al. (2022) (0.53), El Brahimi *et al*. (2022) (0.64), Idm'hand et al. (2020) (0.32) and Rahman *et al*. (2015) (0.25).

High RFC values, notably the maximum value of 1 observed for three species, indicate a strong convergence of knowledge amongst informants regarding the use of these plants. This convergence may be linked to their availability and accessibility in the Taza region, their use for common ailments, and the regular transmission of knowledge about their uses within families and the community. The therapeutic versatility of *Mentha pulegium* L., *Rosmarinus officinalis* L., and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman may also contribute to their recognition by a large number of informants. Conversely, the lower RFCs reported in certain studies may reflect differences in plant availability, therapeutic practices, cultural preferences or the composition of the populations surveyed. These discrepancies thus demonstrate that the relative importance of a medicinal plant depends not only on its therapeutic uses, but also on the ecological and sociocultural context in which knowledge is transmitted and practised. The results therefore highlight a high degree of homogeneity in certain areas of ethnomedical knowledge in Taza, whilst also revealing local particularities in comparison with other Moroccan pharmacopoeias.

Fidelity Level (FL)

The results obtained for the fidelity index (FL) show that several species exhibit a high degree of consensus regarding specific therapeutic uses. In the present study, 36 species achieved an FL of 100%, indicating that, amongst the informants who cited these species, their use is strongly oriented towards a specific condition or category of diseases. This figure is higher than

those reported by Ghabbour *et al*. (2023) (17 species), El Ghazouani *et al*. (2024) (6 species), Chaachouay *et al*. (2019a) (12 species) and Srinivasan *et al*. (2022) (18 species), but lower than the values recorded by Jeddi *et al*. (2024) (43 species), Idm'hand *et al.* (2020) (38 species) and El Brahimi *et al*. (2022) (37 species). These results may reflect a certain degree of homogeneity in therapeutic practices and a relatively stable transmission of certain plant-disease relationships within the study population. For example, *Mentha rotundifolia* (L.) Huds and *Olea europaea* subsp. europaea have FL values of 82.28% and 60% respectively, compared with 100% and 83.33% reported by Ghabbour *et al*. (2023). The range of FL observed in our study (33.21-100%) remains comparable to those reported by Ghabbour *et al*. (2023) (28.48-100%) and El Hajli *et al*. (2024) (16-100%).

The low FL value recorded for *Mentha pulegium* L. (33.21%) may be linked, in particular, to its therapeutic versatility, as this species is used to treat several categories of diseases. Conversely, the higher values obtained for *Rosmarinus officinalis* L. (46.15%), *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman (69.33%), *Origanum compactum* Benth. (91.09%) and *Thymus vulgaris* L. (69.81%) compared with Ghabbour *et al*. (2023), who reported 28.48%, 34.62%, 54.88% and 47.06% respectively, indicate a more specific association of these species with certain uses in the study area. However, the values reported by El Hajli *et al*. (2024) for *Rosmarinus officinalis* L. (96%) and *Origanum compactum* Benth. (100%) remain higher than those obtained in our study. These differences may be linked to the ecological, cultural and therapeutic characteristics of the populations studied, as well as to the diversity of uses attributed to each species.

A particular pattern is observed in certain species that exhibit a high FL combined with a relatively low RFC. This combination indicates that their use is relatively specific amongst the informants who are familiar with them, but that it remains uncommon amongst the surveyed population as a whole. This pattern may reflect specialized traditional uses, limited transmission of certain knowledge, or less frequent use of these species. Thus, the combination of a high FL and a low RFC highlights specific but relatively limited knowledge, which may constitute a distinctive feature of the local ethnobotanical heritage.

Finally, it should be emphasized that the FL is not a measure of a plant's pharmacological efficacy. A high FL primarily reflects a significant degree of consensus or specificity in the use of a species for a given condition. The combined interpretation of the FL and the RFC therefore makes it possible to better distinguish between species that are widely known and used and those whose uses are more specific but limited to a small number of informants. This approach thus provides a more nuanced understanding of the ethnomedical knowledge of the province of Taza, highlighting both widely shared uses and more localized therapeutic knowledge.

Use value (UV)

Use value serves as an indicator of the relative importance of plant species in traditional medicinal practices. In this study, the particularly high values recorded for *Mentha pulegium* L. (UV = 3.011), *Rosmarinus officinalis* L. (UV = 2.167) and *Calamintha nepeta* subsp. *spruneri* (UV = 1.613) suggest that these species play a significant role in the local traditional pharmacopoeia. This importance may be linked to their frequency of use, their application in the treatment of various conditions, and their availability within the study area.

The utility value for *Rosmarinus officinalis* L. obtained in our study (UV = 2.167) is significantly higher than those reported by Ghabbour *et al*. (2023) (UV = 0.444), El Hajli *et al*. (2024) (UV = 0.184) and Chaachouay *et al*. (2019b) (UV = 0.325). Similarly, *Mentha pulegium* L. exhibits a UV value (UV = 3.011) that is considerably higher than those reported by Ghabbour *et al*. (2023) (UV = 0.265) and El Hajli *et al*. (2024) (UV = 0.048). These differences may be attributed to the specific characteristics of therapeutic practices and ethnobotanical knowledge particular to each population, as well as to the availability and accessibility of the species in the various areas studied.

More generally, the maximum values reported in other studies are generally lower than those obtained for the main species in our study. Ghabbour *et al*. (2023) reported the highest values for *Salvia officinalis* L. (UV = 0.606), *Trigonella foenum-graecum* L. (UV = 0.453) and *Rosmarinus officinalis* L. (UV = 0.444). El Hajli *et al*. (2024) obtained maximum values of 0.184 for *Rosmarinus officinalis* L. and *Origanum compactum* Benth. and 0.177 for *Thymus vulgaris* L. Other maximum values were reported for *Origanum compactum* Benth. (UV = 0.62) and *Myrtus communis* L. (UV = 0.52) by Bouyahya *et al*. (2017), *Anchusa italica* Retz. (UV = 0.196) by El Khomsi *et al*. (2022), *Lavandula angustifolia* Mill. (UV = 1.8) by Redouan *et al*. (2023) and *Allium sativum* L. (UV = 0.23) by Alami *et al*. (2021). The highest value reported in these studies was recorded for *Dioscorea deltoidea* (UV = 3.6) by Ovais *et al*. (2022), a value slightly higher than that of *Mentha pulegium* L. in the present study.

A comparison of UV intervals also confirms this trend. The present study reports a range of 0.022 to 3.011, which is wider than those reported by El Hajli *et al*. (2024) (0.007-0.184), Ghabbour *et al*. (2023) (0.003-0.606) and Idm'hand *et al*. (2020) (0.010-0.340). In contrast, Barkaoui *et al*. (2017) reported a range of between 1 and 1.83. These differences highlight the variability in ethnomedical practices across populations and regions.

The low UV values observed for *Visnaga daucoides*, *Berberis hispanica* Boiss. & Reut., *Capparis spinosa* L., *Centaurium erythraea* Rafn, *Juglans regia* L., *Cinnamomum cassia*, *Hibiscus sabdariffa* L., *Moringa oleifera* Lam., *Syzygium aromaticum* (L.) Merr. & L.M. Perry., *Populus alba* L., *Solanum nigrum* L. and *Urtica dioica* L. (UV = 0.022) may reflect a more limited or specialized use of these species in local traditional medicine. They may be used on an ad hoc basis, for a limited number of conditions, or be less accessible to the local population. A low UV value therefore does not necessarily indicate a lack of medicinal importance, but rather less frequent use within the context of the study.

Some species also have a high UV value combined with a moderate FL value. This can be explained by the versatile nature of their therapeutic use. Indeed, the UV primarily reflects the importance and frequency of a species' use within the community, whilst the FL reflects the degree of consensus amongst informants regarding its use for a particular condition. Thus, a plant that is frequently used and cited for several categories of conditions may have a high UV value, whilst having a moderate FL, when the informants' citations are spread across different therapeutic indications. This observation highlights that the frequency of use of a species does not necessarily reflect a high level of consensus for a single medicinal indication but may instead indicate its therapeutic versatility within the local traditional pharmacopoeia.

The differences observed between the UV values in this study and those reported in the literature show that the ethnomedical importance of a species varies according to local populations and contexts. This variation may be influenced by cultural practices, the transmission of traditional knowledge, therapeutic preferences, the range of ailments treated, as well as the availability and accessibility of plant resources. Thus, a species that is little used in one region may have a high utility value in another.

Overall, the utility values obtained highlight a high degree of heterogeneity in the importance attached to different species by the populations studied. The high values for *Mentha pulegium* L., *Rosmarinus officinalis* L. and *Calamintha nepeta* subsp. *spruneri* reflect their major role in the local traditional pharmacopoeia, whilst the low values observed for certain species indicate a more limited or specialized use.

Informant Agreement Ratio (IAR) and Informant Consensus Factor (ICF)

The high IAR and ICF values obtained in this study indicate a strong consensus amongst informants regarding the use of medicinal plants for several categories of diseases. The particularly high values recorded for infectious and parasitic diseases (IAR = 0.987; ICF = 0.993), digestive diseases (IAR = ICF = 0.980), respiratory diseases (IAR = 0.977; ICF = 0.978) and injuries (IAR = 0.972; ICF = 0.977) are higher than those reported by Ghabbour *et al*. (2023) for the same categories, with respective IAR values of 0.83, 0.88, 0.78 and 0.76. These differences suggest a particularly high level of consensus within the study population.

Digestive disorders and diabetes also feature prominently in local therapeutic practices. The high value obtained for digestive disorders (IAR = ICF = 0.980) may be linked to the large number of species used for this category, namely 27 species. Similarly, the values recorded for endocrine, nutritional and metabolic disorders (IAR = 0.961; ICF = 0.963) are associated with the use of 20 species for the treatment of diabetes. The IAR value obtained for diabetes (0.961) is close to those reported by Ghabbour *et al*. (2023) and Chaachouay *et al*. (2019b), who obtained a value of 0.98. For diseases of the digestive system, our value (0.980) is also close to that reported by Ghabbour *et al*. (2023) and El Khomsi *et al*. (2022), with a value of 0.90.

The ICF values obtained in our study are also higher than those reported in several previous studies. El Hajli *et al*. (2024) recorded ICF values of 0.839 for genitourinary diseases, 0.775 for neurological diseases, 0.831 for endocrine diseases, 0.778 for respiratory diseases and 0.750 for digestive diseases. Eddouks *et al*. (2017) reported an ICF value of 0.29 for respiratory and digestive diseases, whilst the maximum values reported by Idm'hand *et al*. (2020) (0.97) and Ghabbour *et al*. (2023) (0.92) remain lower than some of the values obtained in the present study. Furthermore, the ICF values obtained for neurological (0.969), respiratory (0.978) and digestive (0.980) diseases exceed those reported by Bouyahya *et al*. (2017), with respective values of 0.69, 0.69 and 0.63.

Beyond their mere numerical values, the high ICF and IAR scores provide insight into the structure and distribution of ethnobotanical knowledge within the community under study. They reflect a high degree of convergence in knowledge amongst informants, indicating that the therapeutic uses associated with certain categories of ailments are widely shared and relatively consistent. This convergence may reflect a stable intergenerational transmission of knowledge and the existence of plants recognized as important in the local pharmacopoeia. The particularly high values observed for digestive, respiratory and infectious diseases thus suggest that knowledge relating to these categories is particularly well-structured and consensual. However, a high ICF or IAR does not constitute proof of the pharmacological efficacy of the plants; these indices primarily reflect the stability, repetition and convergence of traditional medicinal practices and knowledge.

The differences observed between this study and previous research may be linked to the ecological and socio-cultural characteristics of the populations studied. The local availability of plant species, floristic richness, therapeutic practices, the extent to which traditional knowledge is passed on, and the methodological characteristics of the surveys notably the size and composition of the sample may influence the values obtained.

Overall, the high values for the IAR and the ICF highlight a significant level of ethnomedical consensus within the population studied and particularly emphasize the structured nature of knowledge relating to digestive, respiratory, infectious and metabolic disorders.

The Taza region is characterized by a high degree of ecological and floristic diversity, linked to the presence of contrasting natural habitats and its geographical location between different biogeographical units in north-eastern Morocco. This heterogeneity of habitats fosters the coexistence of a large number of plant species and creates a diversity of resources potentially available to local communities. From an ethnobotanical perspective, this ecological diversity is accompanied by a diversity of medicinal uses and a well-structured body of traditional knowledge. The high values of certain ethnobotanical indices obtained in this study, notably the UV, RFC and TFC, as well as the IAR and ICF for several categories of diseases, suggest that certain plants occupy a particularly important place in the local pharmacopoeia. The Taza region is thus characterized not only by the availability of diverse plant resources, but also by the existence of local knowledge enabling their identification, selection and therapeutic use.

This distinctive feature may also be linked to the diversity of communities, cultural practices and modes of knowledge transmission. Ethnobotanical knowledge may vary between localities and populations depending on their environment, traditions and access to plant resources. The Taza region thus constitutes an area where ecological and socio-cultural factors interact in the development and transmission of traditional medicinal practices.

Consequently, the differences observed between Taza and other Moroccan regions should not be attributed to a single factor. They are likely the result of the interaction between habitat diversity, floristic composition, plant accessibility, local therapeutic practices, the intergenerational transmission of knowledge and the sociocultural characteristics of the communities. This combination of factors helps to explain the distinctive ethnobotanical profile observed in the province of Taza.

Principal Component Analysis (PCA)

The PCA reveals a coherent organization of ethnobotanical information across several complementary dimensions. In Figure 2, the positive correlation between PC1 and the number of species and the percentage of mentions indicates that certain categories of diseases notably digestive, endocrine and metabolic, and respiratory conditions are characterized by both a high diversity of plants used and a high frequency of mentions. Conversely, the association of infectious and parasitic categories, injuries and nervous system disorders with the IAR and ICF suggests that certain categories may show a strong consensus amongst informants despite the use of a relatively limited number of species. The more isolated categories may correspond to more specific uses or those less widely shared within the studied population. This organization thus demonstrates that species richness, frequency of use and informant consensus constitute distinct yet complementary dimensions of ethnobotanical knowledge.

In Figure 3, the close association of RFC, UV and TFC on PC1 highlights a group of species that are particularly important in the local pharmacopoeia. *Origanum compactum* Benth., *Mentha pulegium* L., *Rosmarinus officinalis* L., *Thymus vulgaris* L. and *Calamintha nepeta* subsp. *spruneri* (Boiss.) Nyman are thus distinguished by their high citation frequency, widespread recognition within the community and significance in terms of usage (El Aarage *et al*. 2026). Conversely, the fact that NU points in the opposite direction suggest that therapeutic versatility does not necessarily coincide with a high frequency of

citation. Similarly, the association of FL with PC2 confirms that specificity constitutes a dimension distinct from the general indices of frequency and popularity: certain species may be cited infrequently but exhibit a high degree of specificity of use for a particular condition.

Thus, the ACP reveals that ethnobotanical knowledge is structured along three main dimensions: the popularity and overall importance of species (RFC, UV and TFC), the diversity of their uses (NU) and therapeutic specificity (FL), whilst, for disease categories, it primarily distinguishes between the diversity and frequency of plant use and the level of consensus amongst informants. This organization shows that the most frequently cited species are not necessarily those with the greatest number of uses or the highest therapeutic specificity. These results are broadly consistent with those reported by Ghabbour *et al*. (2023), who also highlighted relationships between the various ethnobotanical indices and disease categories, confirming the value of the multivariate approach for characterizing the structure of ethnomedical knowledge and practices.

Study Limitations and Perspectives

Despite the relevance of the findings obtained, several limitations should be considered when interpreting the results. First, the information collected was largely based on the knowledge and experiences reported by the informants and may therefore be affected by recall bias, particularly regarding the diseases treated, preparation methods, treatment duration, and perceived therapeutic effects. Although a semi-structured questionnaire and a standardized face-to-face interview approach were used, interviewer bias cannot be completely excluded, as the interaction between the interviewer and participants may, to some extent, influence the information provided or its interpretation.

Furthermore, differences in the number of informants among the municipalities studied may represent a potential source of sampling bias and may have influenced certain citation frequencies and ethnobotanical indices. The medicinal uses documented in this study should also be considered as traditional therapeutic practices reported by the informants rather than as evidence of established clinical or pharmacological efficacy. Similarly, information regarding potential toxic or adverse effects reflects the knowledge reported by participants and does not constitute an experimental toxicological assessment.

Regarding botanical identification, the collected species were prepared as voucher specimens and identified and validated by a specialized botanist using recognized floristic and taxonomic references, thereby contributing to taxonomic reliability. Nevertheless, certain limitations inherent to botanical identification cannot be completely excluded.

Finally, the cross-sectional nature of the survey, conducted between March and September 2025, allows the description of local ethnobotanical knowledge and practices during the study period but does not allow their evolution over time to be assessed or causal relationships to be established. Therefore, the findings should be interpreted within the geographical and sociocultural context of the communities studied.

Further pharmacological, toxicological, and longitudinal studies are needed to validate the therapeutic potential and safety of the most frequently cited medicinal species, as well as to further investigate the evolution and intergenerational transmission of traditional medicinal knowledge.

Conclusion

This quantitative ethnobotanical study on the use of medicinal plants by the population of the Taza region reveals the richness and diversity of local knowledge in traditional healthcare. A total of 35 therapeutic uses were identified, divided into 12 disease groups, covering both common ailments and more specific pathologies. Our survey covered 10 municipalities, 5 of which were studied for the first time, highlighting new practices and contributing to the expansion of the region's ethnobotanical heritage.

The results show a significant consensus among the population regarding the use of certain plants for specific diseases, highlighting targeted relationships between humans and plants and the transmission of knowledge deeply rooted in local culture. Plants are not only remedies; they are also central elements of daily life and community identity, reflecting how inhabitants interact with their environment, adapt practices to the seasons and available resources, and preserve valuable empirical knowledge.

Multivariate analysis (PCA) provided deeper insight into the structuring of ethnobotanical knowledge by revealing clear patterns of association between plant species, ethnobotanical indices, and disease categories. It highlighted a differentiation between highly cited and widely used species, multi-use plants, and those characterized by strong therapeutic specificity.

Similarly, disease groups were structured according to their relative importance in terms of species richness and informant consensus. These findings strengthen the reliability of the quantitative approach and confirm the consistency of ethnobotanical knowledge within the studied population. These data offer significant ethnobotanical insights, particularly for the documentation, promotion and transmission of traditional knowledge. They can serve as a basis for comparative studies between regions, the identification of common or specific cultural practices, and the promotion of a sustainable and respectful approach to natural resources. The study thus highlights the central role of medicinal plants in the relationship between communities and their environment, emphasizing the importance of preserving and transmitting this ethnobotanical heritage to future generations. These results also provide a valuable framework for future pharmacological and phytochemical investigations targeting the most relevant species identified through combined ethnobotanical indices and multivariate analysis.

Declarations

List of abbreviations: VC=Voucher codes. **Nu**=Number of uses. **FC/CF**=Frequency of Citation, **T(FC)**=Total Frequency of Citation, **RFC** =Relative Frequency of Citation, **UV**=Use Value, **FL**=Fidelity Level, **ICF**=Informant Consensus Factor, **IAR**=Informant Agreement Ratio, **I (A00-B99)** =Certain infectious and parasitic diseases. **III (D50-D89)** =Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism. **IV (E00-E90)** =Endocrine, nutritional and metabolic diseases. **V (F00-F99)** =Mental and behavioral disorders. **VI (G00-G99)** =Diseases of the nervous system. **IX (I00-I99)** =Diseases of the circulatory system. **X (J00-J99)** =Diseases of the respiratory system. **XI (K00-K93)** =Diseases of the digestive system. **XII (L00- L99)** =Diseases of the skin and subcutaneous tissue. **XIII (M00-M99)** =Diseases of the musculoskeletal system and connective tissue. **XIV (N00-N99)** =Diseases of the genitourinary system. **XIX (S00-T98)** =injury, poisoning and certain other consequences of external causes.

Ethics Approval: The study was reviewed and approved by the Institutional Review Board of the Laboratory of Natural Resources and Environment (RNE), Polydisciplinary Faculty of Taza, Sidi Mohammed Ben Abdellah University. All participants were informed about the purpose of the study, the voluntary nature of their participation, the intended scientific use and publication of the information provided, and the measures adopted to ensure confidentiality. Oral prior informed consent was obtained from each participant before the interview

Consent for publications: Oral consent was considered appropriate for the face-to-face ethnobotanical interviews conducted within local communities. Participants were informed that they could decline to answer any question or withdraw at any time. All authors agreed to the submission.

Data Availability: Data is available on demand.

Conflict of Interest: Authors have no conflict of interest.

Funding: Authors have not received any funding during this research. The resources available at the Natural Resources and Environment Laboratory have been used.

Authors' Contribution: N. GHABBOUR selected the study design, supervised, conducted the survey, orientation and corrected the manuscript. K. HAMMANI supervised, selected the study design, and corrected the manuscript. A. KHABBACH identified, updated scientific species names and corrected the manuscript. F. ELHLOU database compilation, updated and performed corrections. I. GHABBOUR selected the study design, conducted the survey, prepared the database, performed statistical and multivariate analyses, conducted orientation and validation, and corrected the manuscript. B. El AARAGE conducted the survey, database compilation, statistical analysis, wrote the manuscript, updated, performed corrections, edited and submitted. All authors read and approved the manuscript.

Acknowledgements

The authors thank the reviewers and the section editor for their constructive comments.

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