Market ethnobotany at the Strait: trade, traditional knowledge, and sustainability of medicinal and aromatic plants in Northern Morocco

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Research

Abstract

Background: Medicinal and aromatic plant (MAP) markets act as sentinels of plant demand, trade structure and perceived resource pressure. Quantitative, voucher-based market ethnobotany remains scarce for northern Morocco, a Strait-of-Gibraltar crossroads linking Mediterranean, Rif-mountain, Atlantic and trans-regional plant-use traditions. This study documents the MAP trade of the Tangier-Tetouan-Al Hoceima region and characterises vendor knowledge, market composition, price structure and perceived sustainability.

Methods: Structured interviews were conducted with 93 herb vendors (ʿ**aṭṭārīn**) across 11 markets spanning permanent urban, peri-urban/coastal and rural weekly typologies. Voucher specimens were deposited at the LAMSE/FST Tangier herbarium. Relative Frequency of Citation (RFC), Use Value (UV), Informant Consensus Factor (ICF) and Fidelity Level (FL) were recomputed from raw use reports, and market floristic similarity was assessed by Jaccard index with NMDS/PCoA ordination.

Results: The inventory comprised 83 vouchered taxa in 39 families (82 entering quantitative analysis), dominated by Lamiaceae, Apiaceae and Asteraceae, yielding 5791 use reports. Women were 54 of 93 vendors (58.1%). The most salient taxa were *Trigonella foenum-graecum* L. (RFC = 0.925), *Zingiber officinale* Roscoe (0.914) and *Mentha spicata* L. (0.871). Digestive ailments accounted for 2424 use reports across 30 taxa. ICF was uniformly high and market composition highly similar (mean Jaccard similarity 0.865). Declining availability was reported disproportionately for locally wild-harvested taxa.

Conclusions: Northern Moroccan markets sustain a broad but highly shared, commercially convergent MAP repertoire organised around a high-salience core of culinary-medicinal taxa. Vendor-perceived decline concentrates on wild-harvested species, identifying priority taxa for targeted ecological assessment.

Keywords: market ethnobotany; medicinal and aromatic plants; quantitative ethnobotanical indices; ʿaṭṭārīn; northern Morocco; Rif; access and benefit-sharing

Background

Medicinal and aromatic plant (MAP) markets are not merely commercial spaces but dynamic knowledge interfaces where plant selection, naming, preparation, pricing, and perceived resource change are continuously negotiated between vendors and users (Albuquerque *et al.* 2007, Cunningham 2001, Monteiro *et al.* 2010). A vendor's stall reveals which species are culturally salient, which plant parts circulate, which materials are supplied locally or through wider trade routes, and which taxa are perceived as increasingly scarce. Markets are therefore efficient, though commercially filtered, windows onto a regional pharmacopeia (Quiroz *et al.* 2014, van Andel *et al.* 2015, Williams *et al.* 2000).

Northern Morocco, and particularly the Tangier-Tetouan-Al Hoceima region, is strategically positioned between the Mediterranean, the Rif mountains, Atlantic-influenced lowlands, and cross-regional trade corridors. This setting gives local MAP markets a distinctive role. They connect urban herbal shops, rural weekly souks, cultivated aromatic plants, wild-harvested mountain taxa and imported materia medica. They do so within multilingual knowledge systems that include Darija and Amazigh/Tarifit vernacular nomenclature (Bellakhdar 1997, Bellakhdar *et al.* 1991, Chaachouay *et al.* 2019, 2022, El-Hilaly *et al.* 2003, Ennabili *et al.* 2000, Hmamouchi 1999, Merzouki *et al.* 2000).

Despite the importance of Moroccan herbal markets, many market-based studies are limited by partial taxonomic documentation, insufficient reporting of vendor demographic structure, incomplete voucher deposition, or the uncritical use of quantitative indices without stating how raw data were coded. Contemporary reporting standards emphasise the documentation of sampling, prior informed consent, voucher collection, taxonomic verification and the exact calculation of indices. They also require that high consensus values be interpreted cautiously, because market consensus reflects a curated commercial repertoire rather than ecological abundance or independent household practice (Heinrich *et al.* 2018, Leonti 2022, Weckerle *et al.* 2018).

The present study documents the MAP inventory traded across markets in northern Morocco and recomputes all quantitative indices from the raw vendor-taxon records. It addresses three questions. First, does market typology structure the traded repertoire? Permanent urban, peri-urban and rural weekly markets draw on different supply networks, and we test whether this translates into distinct species compositions or whether a single regional repertoire circulates throughout. Second, what does vendor consensus measure in a commercial setting? We examine whether high consensus values reflect convergent therapeutic knowledge or the structural effect of a shared commercial assortment and of the coding scheme used. Third, does commercial origin predict perceived scarcity? We test whether reports of declining availability concentrate on locally wild-harvested taxa relative to cultivated and imported material and identify which taxa this implicates. The novelty lies in combining a fully vouchered market inventory, raw-data-recomputed indices, vendor demographic reporting and price documentation for a strategically important Moroccan strait region.

Materials and Methods

This study follows the ConSEFS reporting standards for ethnopharmacological field studies (Heinrich *et al.* 2018, Weckerle *et al.* 2018).

Study area

The survey covered 11 markets in the Tangier-Tetouan-Al Hoceima region and adjacent northern Moroccan market circuits, spanning permanent urban markets, a specialized urban ʿaṭṭārīn market, peri-urban and peri-urban coastal markets, and rural weekly souks (Table 1; Fig. 1). Market coordinates, vendor counts, species richness, and use reports are given in Table 1. Fieldwork was conducted from August 2025 to March 2026.

Sampling and vendor interviews

Herb vendors (ʿaṭṭārīn) were the target informants; 93 vendors were interviewed (7-12 per market), generating 3480 vendor-taxon records. For each taxon, vendors reported the plant part, form (fresh/dried), commercial origin (local-wild, local-cultivated, imported), primary use category, number of distinct uses, preparation, administration route, vending unit and price, and perceived availability trend and sustainability concern. Each vendor was characterized by market, typology, gender, age class, experience, knowledge-transmission mode, and language. Age and gender are reported explicitly because they condition knowledge transmission and market specialization. Interviews were conducted in Darija and/or Tarifit by vendor preference (Albuquerque *et al.* 2014, Bernard 2011, Martin 1995).

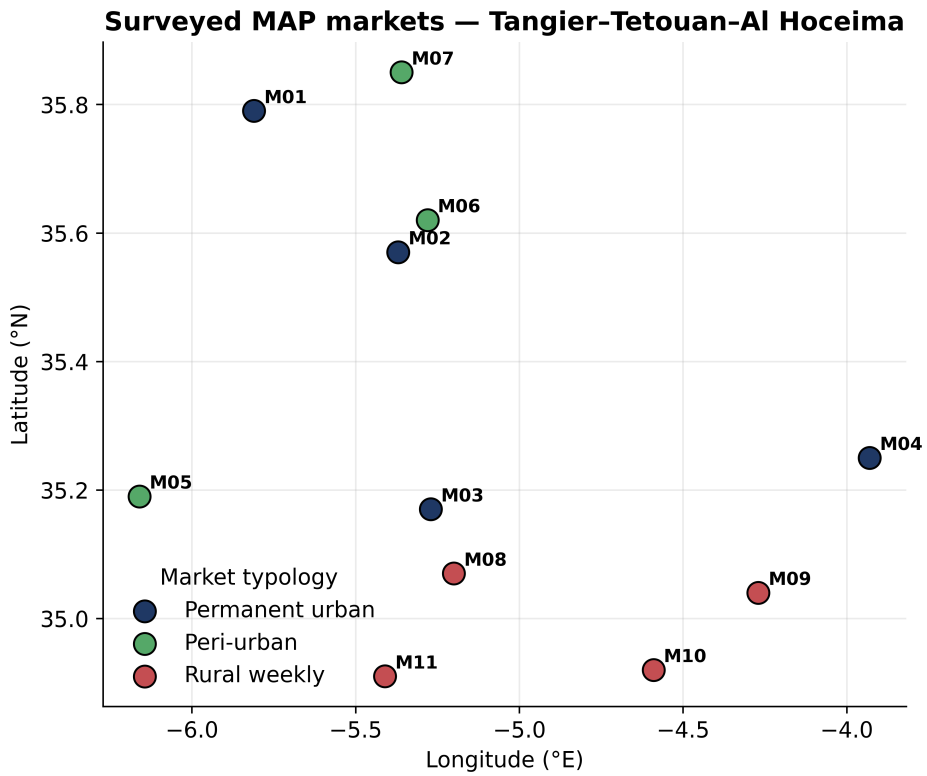

Figure 1. Location of the 11 surveyed markets in the Tangier-Tetouan-Al Hoceima region, coded by typology (permanent urban, peri-urban/coastal, rural weekly). Coordinates from Table 1.

Table 1. Markets surveyed: typology, coordinates, vendors interviewed, species richness, and use reports. All values reconcile with the raw survey.

Code	Market	Province/Prefecture	Typology	Long. (°E)	Lat. (°N)	Vendors (n)	Richness	Use reports
M01	Souk Dakhel / Grand Socco	Tangier	Permanent urban	-5.810	35.79	12	76	747
M02	Tetouan medina herbal stalls	Tetouan	Permanent urban	-5.370	35.57	11	78	679
M03	Chefchaouen ʿaṭṭārīn	Chefchaouen	Permanent urban (specialized)	-5.270	35.17	10	77	649
M04	Al Hoceima centre	Al Hoceima	Permanent urban	-3.930	35.25	9	74	571
M05	Larache market	Larache	Peri-urban	-6.160	35.19	8	72	487
M06	Martil market	Martil	Peri-urban coastal	-5.280	35.62	7	74	439
M07	Fnideq market	Fnideq	Peri-urban coastal	-5.360	35.85	7	73	420
M08	Bab Taza weekly souk	Chefchaouen prov.	Rural weekly	-5.200	35.07	8	74	498
M09	Bni Hadifa weekly souk	Al Hoceima prov.	Rural weekly	-4.270	35.04	7	70	418
M10	Issaguen weekly souk	Al Hoceima prov.	Rural weekly	-4.590	34.92	7	72	425
M11	Brikcha weekly souk	Ouezzane prov.	Rural weekly	-5.410	34.91	7	73	458
Total						**93**	**82**	**5791**

Ethics and Prior Informed Consent

This was an observational, non-clinical market study based on interviews with adult herb vendors about commercially traded plant material. No biomedical intervention was involved, no biological samples were taken from participants, and no personal identifiers were collected. No formal ethics-committee review was sought. The Faculty of Sciences and Techniques of Tangier does not operate a review procedure for non-interventional socio-economic surveys of this type, and no competent authority was asked to issue a determination on whether such review was required. Oral Prior Informed Consent

was obtained from every vendor before each interview: participants were informed of the study aims, the voluntary and unpaid nature of participation, their right to decline any question or withdraw at any time, and the procedures used to protect their anonymity. No names, contact details, or other identifying information were recorded; vendors are referred to only by anonymized codes (V001-V093). The study followed the ethical principles of the International Society of Ethnobiology Code of Ethics (International Society of Ethnobiology 2006) and the reporting standards for ethnopharmacological field studies (Heinrich *et al.* 2018, Weckerle *et al.* 2018).

Voucher specimens and taxonomy

Voucher specimens were purchased directly from the interviewed vendor at the point of interview and prepared on the same day. Each of the 83 documented taxa is represented by a unique voucher (LAMSE-001 to LAMSE-083), deposited in the LAMSE reference collection, Faculty of Sciences and Techniques, Tangier (Table 2).

Identification followed a stepwise procedure adapted to the physical condition of the traded material. Fresh and morphologically intact material was identified directly against regional floristic references (Fennane *et al.* 1999). Dried but diagnostic material — aerial parts, leaves, flowers, fruits, seeds, bark and rhizomes — was identified on macro- and micromorphological characters, including leaf and inflorescence architecture, indumentum and glandular trichomes, fruit and seed surface sculpturing, rhizome and bark anatomy, and odour, by comparison with authenticated reference material of the same taxon. Photographs taken at the point of purchase supported these comparisons.

Imported material was identified from the diagnostic organ actually traded — rhizome, bark, fruit, seed or resin — and cross-checked against the vendor's trade name and stated supply route. Material that was fragmented, powdered or otherwise processed beyond the point where diagnostic characters remained was not assigned to species: one such entry ("īlān") is reported as unidentified and excluded from all analyses. Identifications were made by Bahia Abdelfattah and independently verified by Jaber Maataoui.

All scientific names were checked against World Flora Online (WFO 2026; accessed 25 May 2026), cross-checked against APG IV, the Shenzhen Code, and Moroccan floristic references where needed (Angiosperm Phylogeny Group 2016, Borsch *et al.* 2020, Fennane *et al.* 1999, Turland *et al.* 2018). Accepted names are used throughout, with notable synonyms given parenthetically at first mention: *Salvia rosmarinus* Spenn. is the WFO-accepted name (≡ *Rosmarinus officinalis* L.), *Mentha* × *rotundifolia* (L.) Huds. is treated as a hybrid (M. longifolia × M. suaveolens), and *Saussurea costus* (Falc.) Lipsch., currently accepted in WFO, is recognized as a synonym of *Dolomiaea costus* (Falc.) Kasana & A.K.Pandey in Plants of the World Online and is listed in CITES Appendix I (Table 2, footnote). One dried-price entry, "īlān" (pending identification), has no voucher and is not part of the vouchered inventory (Table 6, footnote); it is excluded from all quantitative analyses.

Quantitative ethnobotanical indices

All indices were recomputed from 04_Raw_survey_long (N = 93). A use report (UR) is one citation by one vendor of one taxon within one ailment category; total UR = 5791.

Relative Frequency of Citation: **RFC = FC / N**, where FC is the number of distinct vendors citing a taxon (Hoffman & Gallaher 2007, Tardío & Pardo-de-Santayana 2008).
Use Value: **UV = ΣUR / N**, the summed use reports for a taxon divided by N (Phillips & Gentry 1993a, 1993b, Prance *et al.* 1987).

Informant Consensus Factor: **ICF = (Nur − Nt) / (Nur − 1)**, computed per raw primary use category, where Nur is the use reports in the category and Nt the number of contributing taxa (Heinrich *et al.* 1998, Trotter & Logan 1986). The raw data use 14 categories with one primary category per taxon, so categories partition the 82 cited taxa (ΣNt = 82). Four single-taxon categories return ICF = 1.000 by construction and are interpreted cautiously.

Fidelity Level: **FL (%) = (Np / Ns) × 100**, where Np is the number of vendors citing a species for its principal category and Ns the total citing it (Friedman *et al.* 1986). Because each taxon maps to one primary category, FL reflects coding consistency rather than exclusive therapeutic use.

Price documentation

Prices were recorded during the interview as vendor-reported selling prices for the retail unit actually in use at the stall: per kilogram for dried material, and per bunch, per leaf or per small quantity for fresh material. For each vendor–taxon record,

the vendor was asked for the lowest and the highest price at which the taxon is normally sold in that unit. Prices were not negotiated, were not obtained through test purchases, and were not converted between units.

Table 6 reports the modal dried-MAP price, that is the single most frequently reported price across all vendors trading the taxon, not an arithmetic mean. In Table 7, the minimum and maximum columns give the lowest and highest values reported across vendors; fresh-MAP prices are presented as ranges only, because stall units are not standardised between vendors and a modal value would not be comparable across them.

All prices are in Moroccan dirham (MAD) at the time of fieldwork (August 2025 to March 2026) and refer to retail sale to end users, not to wholesale transactions. Quality grade, seasonality and volume discounts were not systematically recorded, so prices for a given taxon may correspond to material of differing grade.

Statistical and comparative analysis

Descriptive statistics summarized vendor demographics, inventory composition, indices, prices, and sustainability perceptions. Market composition was compared with presence-absence species lists and pairwise Jaccard similarity (Jaccard 1901), visualized by non-metric multidimensional scaling (NMDS) and principal coordinates analysis (PCoA) on Jaccard distance (Legendre and Legendre 2012). Analyses are descriptive; no inferential test generalizes beyond the surveyed markets. Computation used Python 3.12 with pandas, NumPy, SciPy 1.17, scikit-learn 1.8 and matplotlib 3.10; reproducible code is provided in Appendix A.

Results

Markets and vendor profile

The dataset documents 93 vendors across 11 markets (Table 1; Fig. 1), with the largest contingents at Souk Dakhel / Grand Socco (M01; n = 12), Tetouan medina (M02; n = 11), and Chefchaouen ʿaṭṭārīn (M03; n = 10). Women represented 54 vendors (58.1%) and men 39 (41.9%) (Fig. 2). Age was distributed across classes: <30, 13 vendors (14.0%); 30-44, 29 (31.2%); 45-59, 29 (31.2%); ≥60, 22 (23.7%) — 42 vendors (45.2%) under 45 and 51 (54.8%) aged 45 or older. Knowledge was mainly inherited within families (51; 54.8%), then by apprenticeship (30; 32.3%) and self-teaching (12; 12.9%). Vendors were Darija-Tarifit bilingual (53; 57.0%), Darija only (36; 38.7%), or other (4; 4.3%). The mean number of taxa traded per vendor was 37.4 (range 30–47). This figure was essentially flat across gender, age and experience strata, indicating that trade breadth is shared widely across the vendor community rather than concentrated in any subgroup.

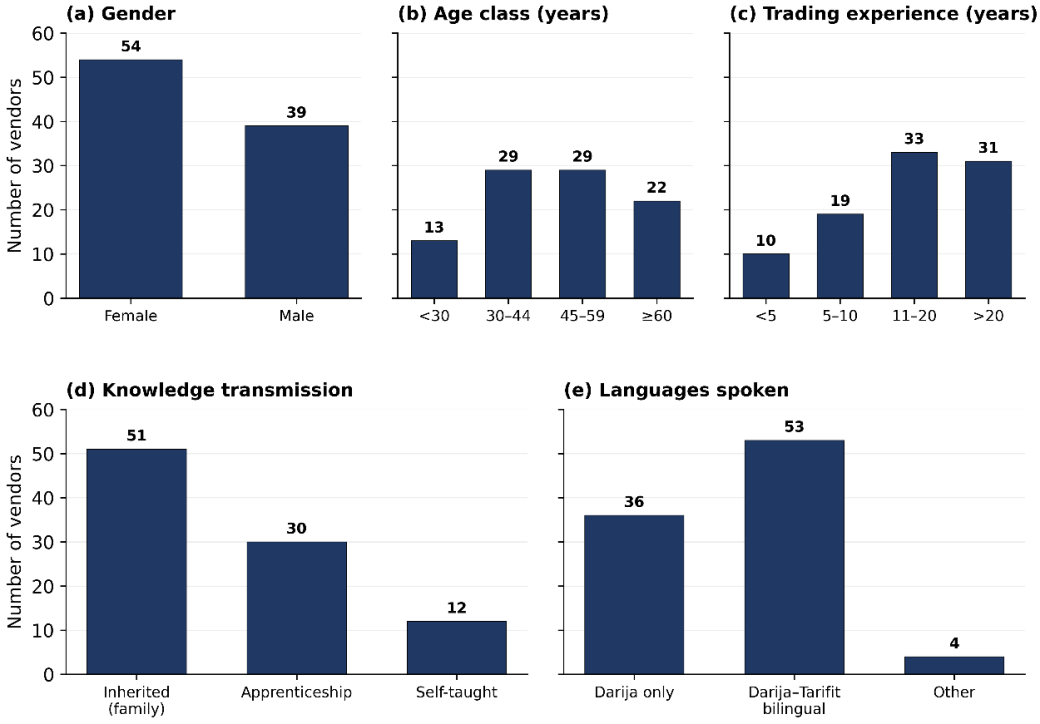

Figure 2. Sociodemographic profile of the 93 interviewed vendors: (a) gender, (b) age class, (c) trading experience, (d) mode of knowledge transmission, (e) languages spoken. Values are vendor counts; percentages are given in the text.

Table 2. Full inventory of 83 vouchered taxa (LAMSE series), ordered by descending frequency of citation (FC), with family, vernacular (Darija/Amazigh) name, plant part, form, commercial origin, primary use category, and salience indices. *Footnote: Capparis spinosa L. (LAMSE-044) was vouchered but received no use citation during interviews (FC = RFC = UV = 0); it is retained in the documented inventory (83 taxa) but excluded from quantitative analysis (82 taxa). Nomenclature follows World Flora Online (WFO, 2026). Saussurea costus (Falc.) Lipsch. is currently accepted in WFO but treated as a synonym of Dolomiaea costus in Plants of the World Online and is listed in CITES Appendix I.*

Voucher	Scientific name	Family	Vernacular (Darija/Amazigh)	Part	Form	Origin	Primary use	FC	RFC	UR	UV	Status
LAMSE-034	*Trigonella foenum-graecum* L.	Fabaceae	al-ḥalba	Seed	Dried	Local-cultivated	Metabolic	86	0.925	145	1.559	Included
LAMSE-042	*Zingiber officinale* Roscoe	Zingiberaceae	al-skinjbīr	Rhizome	Dried	Imported	Digestive	85	0.914	139	1.495	Included
LAMSE-005	*Mentha spicata* L.	Lamiaceae	naʿnaʿ	Aerial parts	Fresh	Local-cultivated	Digestive	81	0.871	138	1.484	Included
LAMSE-018	*Coriandrum sativum* L.	Apiaceae	al-qazbūr	Leaf	Fresh+dried	Local-cultivated	Digestive	80	0.860	127	1.366	Included
LAMSE-008	*Salvia officinalis* L.	Lamiaceae	sālmiyya	Aerial parts	Dried	Local-cultivated	Digestive	80	0.860	136	1.462	Included
LAMSE-030	*Nigella sativa* L.	Ranunculaceae	sānūj	Seed	Dried	Local-cultivated	Immunological	79	0.849	123	1.323	Included
LAMSE-039	*Olea europaea* L.	Oleaceae	al-zaytūn	Leaf	Dried	Local-cultivated	Cardiovascular	79	0.849	135	1.452	Included
LAMSE-003	*Origanum compactum* Benth.	Lamiaceae	zaʿatar berri	Aerial parts	Dried	Local-wild	Respiratory	78	0.839	132	1.419	Included
LAMSE-015	*Rosa damascena* Mill.	Rosaceae	al-ward	Flower	Fresh+dried	Local-cultivated	Dermatological	78	0.839	121	1.301	Included
LAMSE-004	*Salvia rosmarinus* Spenn.	Lamiaceae	azīr / iklīl	Aerial parts	Fresh+dried	Local-cultivated	Circulatory	78	0.839	139	1.495	Included
LAMSE-021	*Lawsonia inermis* L.	Lythraceae	al-ḥinnā	Leaf	Dried	Local-cultivated	Dermatological	77	0.828	128	1.376	Included
LAMSE-025	*Linum usitatissimum* L.	Linaceae	zarrīʿat al-kattān	Seed	Dried	Local-cultivated	Digestive	77	0.828	123	1.323	Included
LAMSE-061	*Piper nigrum* L.	Piperaceae	al-fulful	Fruit	Dried	Imported	Digestive	77	0.828	135	1.452	Included
LAMSE-022	*Senna alexandrina* Mill.	Fabaceae	sannā makkī	Leaf	Dried	Imported	Digestive	76	0.817	126	1.355	Included
LAMSE-071	*Camellia sinensis* (L.) Kuntze	Theaceae	al-atāy	Leaf	Dried	Imported	Aromatic	75	0.806	133	1.430	Included
LAMSE-017	*Petroselinum crispum* (Mill.) Fuss	Apiaceae	al-maʿdnūs	Leaf	Fresh	Local-cultivated	Urinary	75	0.806	117	1.258	Included
LAMSE-011	*Eucalyptus globulus* Labill.	Myrtaceae	kāliptūs	Leaf	Fresh+dried	Local-cultivated	Respiratory	74	0.796	133	1.430	Included
LAMSE-002	*Thymus satureioides* Coss.	Lamiaceae	zaʿatar	Aerial parts	Dried	Local-wild	Respiratory	74	0.796	125	1.344	Included
LAMSE-009	*Aloysia citrodora* Palau	Verbenaceae	luwīza	Leaf	Fresh+dried	Local-cultivated	Nervous	71	0.763	121	1.301	Included
LAMSE-050	*Artemisia herba-alba* Asso	Asteraceae	al-shīḥ	Aerial parts	Dried	Local-wild	Digestive	68	0.731	119	1.280	Included
LAMSE-007	*Matricaria chamomilla* L.	Asteraceae	bābūnj	Flower	Dried	Local-cultivated	Digestive	67	0.720	110	1.183	Included
LAMSE-059	*Cinnamomum verum* J.Presl	Lauraceae	al-qurfa	Bark	Dried	Imported	Digestive	66	0.710	112	1.204	Included
LAMSE-035	*Mentha × piperita* L.	Lamiaceae	naʿnaʿ ḥurr	Aerial parts	Fresh	Local-cultivated	Digestive	59	0.634	98	1.054	Included
LAMSE-057	*Allium sativum* L.	Amaryllidaceae	al-thūm	Bulb	Fresh	Local-cultivated	Cardiovascular	58	0.624	101	1.086	Included
LAMSE-001	*Mentha pulegium* L.	Lamiaceae	fliyou	Aerial parts	Fresh+dried	Local-wild	Digestive	58	0.624	83	0.892	Included
LAMSE-060	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	Myrtaceae	al-qurnful	Flower	Dried	Imported	Dental	58	0.624	97	1.043	Included
LAMSE-041	*Curcuma longa* L.	Zingiberaceae	al-kurkum	Rhizome	Dried	Imported	Anti-inflammatory	57	0.613	101	1.086	Included
LAMSE-040	*Punica granatum* L.	Lythraceae	al-rumān	Fruit	Dried	Local-cultivated	Digestive	56	0.602	83	0.892	Included
LAMSE-024	*Moringa oleifera* Lam.	Moringaceae	mūringā	Leaf	Dried	Imported	Metabolic	55	0.591	91	0.978	Included
LAMSE-006	*Lavandula stoechas* L.	Lamiaceae	ḫzāma	Inflorescence	Dried	Local-wild	Nervous	54	0.581	86	0.925	Included
LAMSE-028	*Cuminum cyminum* L.	Apiaceae	kāmūn	Seed	Dried	Imported	Digestive	51	0.548	86	0.925	Included

Voucher	Scientific name	Family	Vernacular (Darija/Amazigh)	Part	Form	Origin	Primary use	FC	RFC	UR	UV	Status
LAMSE-023	*Saussurea costus* (Falc.) Lipsch.	Asteraceae	qust al-hindī	Root	Dried	Imported	Digestive	50	0.538	91	0.978	Included
LAMSE-019	*Malva sylvestris* L.	Malvaceae	al-khubīza	Leaf	Fresh	Local-wild	Digestive	47	0.505	73	0.785	Included
LAMSE-051	*Artemisia absinthium* L.	Asteraceae	al-shujayra	Aerial parts	Dried	Local-wild	Digestive	44	0.473	72	0.774	Included
LAMSE-070	*Hibiscus sabdariffa* L.	Malvaceae	al-karkadeh	Flower	Dried	Imported	Cardiovascular	44	0.473	71	0.763	Included
LAMSE-014	*Pelargonium graveolens* L'Hér.	Geraniaceae	al-ʿaṭrashā	Leaf	Fresh	Local-cultivated	Aromatic	43	0.462	71	0.763	Included
LAMSE-033	*Carum carvi* L.	Apiaceae	al-kerwiyya	Seed	Dried	Local-cultivated	Digestive	42	0.452	62	0.667	Included
LAMSE-010	*Myrtus communis* L.	Myrtaceae	mursīn	Leaf	Fresh+dried	Local-wild	Dermatological	41	0.441	60	0.645	Included
LAMSE-081	*Citrus limon* (L.) Osbeck	Rutaceae	al-ḥāmiḍ	Fruit	Fresh+dried	Local-cultivated	Respiratory	40	0.430	68	0.731	Included
LAMSE-072	*Glycyrrhiza glabra* L.	Fabaceae	ʿirq al-sūs	Root	Dried	Imported	Digestive	40	0.430	73	0.785	Included
LAMSE-046	*Marrubium vulgare* L.	Lamiaceae	al-marriwyt	Aerial parts	Dried	Local-wild	Respiratory	39	0.419	61	0.656	Included
LAMSE-026	*Ricinus communis* L.	Euphorbiaceae	zarrīʿat al-kharwaʿ	Seed	Dried	Local-wild	Digestive	39	0.419	67	0.720	Included
LAMSE-063	*Boswellia sacra* Flück.	Burseraceae	al-jāwī	Resin	Dried	Imported	Ritual	38	0.409	65	0.699	Included
LAMSE-065	*Ceratonia siliqua* L.	Fabaceae	al-kharrūb	Fruit	Dried	Local-wild	Digestive	37	0.398	61	0.656	Included
LAMSE-055	*Anethum graveolens* L.	Apiaceae	al-shibth	Leaf	Fresh+dried	Local-cultivated	Digestive	36	0.387	55	0.591	Included
LAMSE-062	*Elettaria cardamomum* (L.) Maton	Zingiberaceae	al-hāl	Fruit	Dried	Imported	Aromatic	35	0.376	71	0.763	Included
LAMSE-029	*Trachyspermum ammi* (L.) Sprague	Apiaceae	kāmūn ṣūfī	Seed	Dried	Imported	Digestive	35	0.376	57	0.613	Included
LAMSE-056	*Apium graveolens* L.	Apiaceae	al-krāfes	Leaf	Fresh	Local-cultivated	Urinary	34	0.366	49	0.527	Included
LAMSE-068	*Argania spinosa* (L.) Skeels	Sapotaceae	argān	Seed	Oil	Local-wild	Cardiovascular	34	0.366	53	0.570	Included
LAMSE-013	*Ocimum basilicum* L.	Lamiaceae	al-rīḥān	Leaf	Fresh+dried	Local-cultivated	Aromatic	32	0.344	51	0.548	Included
LAMSE-054	*Calendula officinalis* L.	Asteraceae	al-jamra	Flower	Dried	Local-cultivated	Dermatological	31	0.333	55	0.591	Included
LAMSE-082	*Aloe vera* (L.) Burm.f.	Asphodelaceae	ṣabbār ḥurr	Leaf	Fresh	Imported	Dermatological	30	0.323	53	0.570	Included
LAMSE-016	*Citrus aurantium* L.	Rutaceae	zhar al-burtuqāl	Flower	Fresh	Local-cultivated	Aromatic	30	0.323	52	0.559	Included
LAMSE-012	*Cymbopogon citratus* (DC.) Stapf	Poaceae	ḥashīshat al-līmūn	Leaf	Fresh+dried	Local-cultivated	Digestive	29	0.312	46	0.495	Included
LAMSE-074	*Peganum harmala* L.	Nitrariaceae	al-ḥarmal	Seed	Dried	Local-wild	Ritual	28	0.301	55	0.591	Included
LAMSE-020	*Opuntia ficus-indica (L.) Mill.*	Cactaceae	al-ṣabbār	Cladode	Fresh	Local-cultivated	Metabolic	26	0.280	43	0.462	Included
LAMSE-053	*Chamaemelum nobile (L.) All.*	Asteraceae	bābūnj al-rūmī	Flower	Dried	Local-wild	Nervous	24	0.258	41	0.441	Included
LAMSE-036	*Origanum majorana L.*	Lamiaceae	al-mardadūsh	Aerial parts	Dried	Local-cultivated	Respiratory	24	0.258	40	0.430	Included
LAMSE-058	*Allium cepa L.*	Amaryllidaceae	al-baṣla	Bulb	Fresh	Local-cultivated	Respiratory	22	0.237	37	0.398	Included
LAMSE-049	*Mentha × rotundifolia (L.) Huds.*	Lamiaceae	al-tīmiriya	Aerial parts	Fresh	Local-wild	Digestive	22	0.237	35	0.376	Included
LAMSE-027	*Ziziphus lotus* (L.) Lam.	Rhamnaceae	al-sidr	Leaf	Dried	Local-wild	Dermatological	22	0.237	39	0.419	Included
LAMSE-032	*Pimpinella anisum* L.	Apiaceae	al-ḥabba ḥlāwa	Seed	Dried	Local-cultivated	Digestive	21	0.226	30	0.323	Included
LAMSE-064	*Pistacia lentiscus* L.	Anacardiaceae	al-ḍrū	Resin	Dried	Local-wild	Digestive	20	0.215	33	0.355	Included
LAMSE-037	*Cistus ladanifer* L.	Cistaceae	al-tūzāla	Aerial parts	Dried	Local-wild	Dermatological	19	0.204	24	0.258	Included
LAMSE-073	*Ammi visnaga* (L.) Lam.	Apiaceae	al-bishnīn	Seed	Dried	Local-wild	Urinary	18	0.194	33	0.355	Included
LAMSE-077	*Hypericum perforatum* L.	Hypericaceae	al-mīsk	Aerial parts	Dried	Local-wild	Nervous	18	0.194	27	0.290	Included

Voucher	Scientific name	Family	Vernacular (Darija/Amazigh)	Part	Form	Origin	Primary use	FC	RFC	UR	UV	Status
LAMSE-031	*Foeniculum vulgare* Mill.	Apiaceae	al-basbās	Seed	Dried	Local-cultivated	Digestive	16	0.172	26	0.280	Included
LAMSE-045	*Urtica dioica* L.	Urticaceae	al-ḥurriqa	Aerial parts	Dried	Local-wild	Cardiovascular	16	0.172	27	0.290	Included
LAMSE-076	*Withania somnifera* (L.) Dunal	Solanaceae	al-shīt al-hindī	Root	Dried	Imported	Nervous	15	0.161	30	0.323	Included
LAMSE-080	*Plantago major* L.	Plantaginaceae	al-massāsa	Leaf	Fresh	Local-wild	Wounds	13	0.140	23	0.247	Included
LAMSE-079	*Borago officinalis* L.	Boraginaceae	al-ḥurmush	Aerial parts	Fresh	Local-wild	Respiratory	12	0.129	19	0.204	Included
LAMSE-047	*Calamintha nepeta* (L.) Savi	Lamiaceae	al-mintā al-jabaliyya	Aerial parts	Dried	Local-wild	Digestive	11	0.118	17	0.183	Included
LAMSE-075	*Aristolochia baetica* L.	Aristolochiaceae	barzṭam	Root	Dried	Local-wild	Ritual	10	0.108	25	0.269	Included
LAMSE-048	*Salvia verbenaca* L.	Lamiaceae	khiyāṭa	Aerial parts	Dried	Local-wild	Wounds	10	0.108	14	0.151	Included
LAMSE-078	*Verbena officinalis* L.	Verbenaceae	luwīza barriya	Aerial parts	Dried	Local-wild	Nervous	10	0.108	24	0.258	Included
LAMSE-038	*Cistus albidus* L.	Cistaceae	al-tūzāla bēḍa	Aerial parts	Dried	Local-wild	Dermatological	8	0.086	12	0.129	Included
LAMSE-043	*Crocus sativus* L.	Iridaceae	al-zaʿfrān	Stigma	Dried	Local-cultivated	Aromatic	8	0.086	13	0.140	Included
LAMSE-067	*Juniperus phoenicea* L.	Cupressaceae	al-ʿarʿar al-fīnīqī	Fruit	Dried	Local-wild	Urinary	8	0.086	14	0.151	Included
LAMSE-069	*Salvia microphylla* Kunth	Lamiaceae	mīramiyya	Aerial parts	Dried	Local-cultivated	Digestive	8	0.086	11	0.118	Included
LAMSE-066	*Tetraclinis articulata* (Vahl) Mast.	Cupressaceae	al-ʿarʿar	Leaf	Dried	Local-wild	Dermatological	8	0.086	11	0.118	Included
LAMSE-052	*Achillea millefolium* L.	Asteraceae	al-jaʿda	Aerial parts	Dried	Local-wild	Wounds	5	0.054	7	0.075	Included
LAMSE-083	*Ammi majus* L.	Apiaceae	al-bishnīn al-kbīr	Seed	Dried	Local-wild	Dermatological	1	0.011	1	0.011	Included
LAMSE-044	*Capparis spinosa* L.	Capparaceae	al-kabar	Bud	Dried	Local-wild	Rheumatic	0	0.000	0	0.000	Excluded (vouchered, not cited)

Species inventory: families, plant parts, forms, and origins

The inventory comprises 83 vouchered taxa in 39 families (Table 2); 82 received at least one use citation and entered analysis. *Capparis spinosa* L. (LAMSE-044) had FC = RFC = UV = 0 and was excluded from quantitative interpretation. Lamiaceae was richest (15 taxa), followed by Apiaceae (11) and Asteraceae (7); Fabaceae (4), Zingiberaceae and Myrtaceae (3 each) followed (Fig. 3). Aerial parts (22 taxa) and leaves (20) were the commonest plant parts, then seeds (13), flowers (7), and fruits (6) (Fig. 4). Most taxa were sold dried (57), with 14 fresh, 11 fresh+dried, and one as oil (*Argania spinosa*). Origin was evenly split between local-cultivated (33) and local-wild (33), with 17 imported.

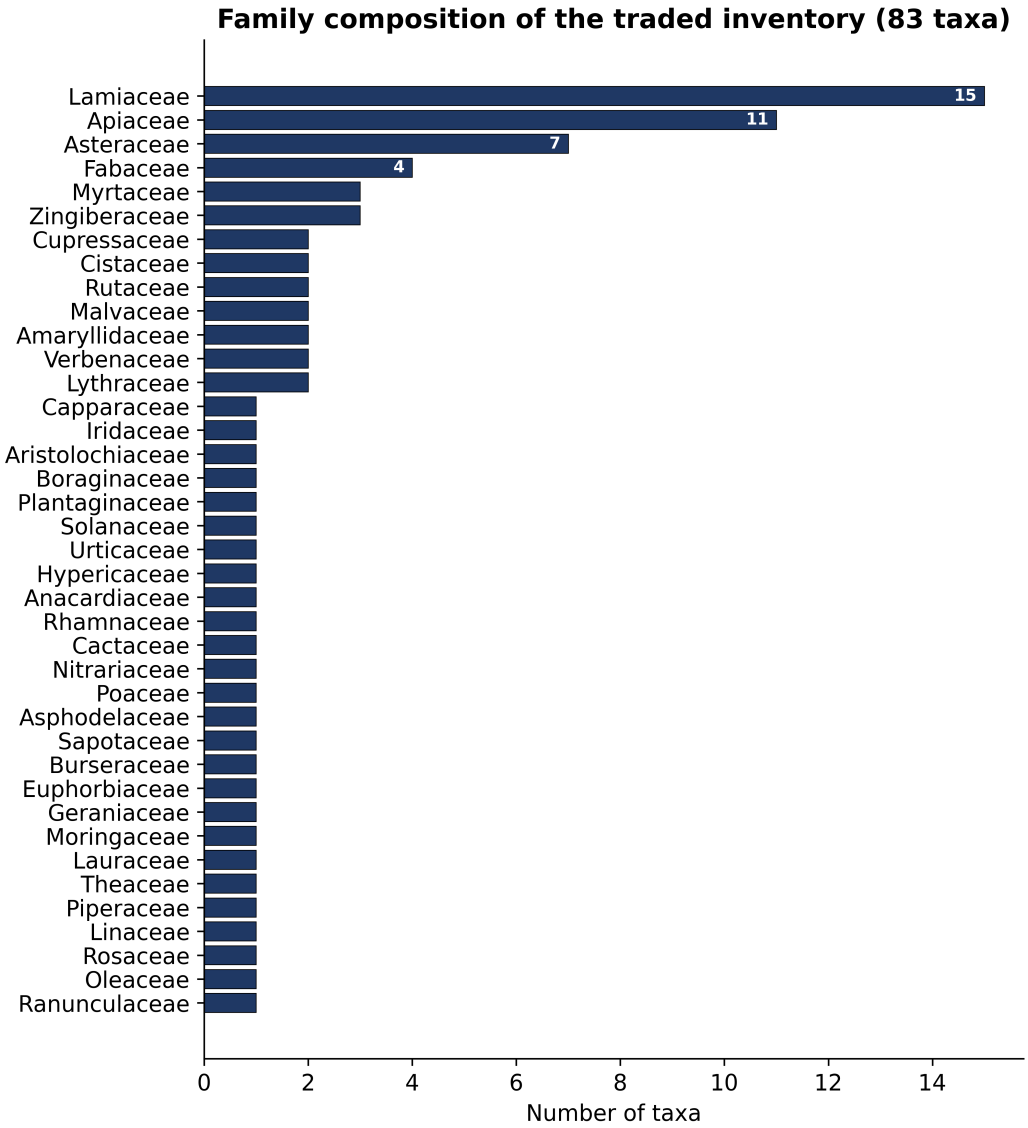

Figure 3. Family composition of the traded inventory (39 families; 83 taxa). Lamiaceae and Apiaceae dominate.

Salience: RFC and UV

The leading taxon by both measures was *Trigonella foenum-graecum* (FC = 86; RFC = 0.925; UV = 1.559), followed by *Zingiber officinale* (RFC = 0.914; UV = 1.495) and *Mentha spicata* (RFC = 0.871; UV = 1.484) (Tables 2, 3). A coherent high-salience core of roughly 15-20 culinary-medicinal taxa — dominated by Lamiaceae and Apiaceae, with fenugreek, ginger, olive leaf, black seed, henna, and senna — was cited by three-quarters or more of vendors (RFC ≥ 0.806 for the top 16). RFC ranged from 0.011 (*Ammi majus*) to 0.925 and UV from 0.011 to 1.559; rankings were broadly concordant, with minor re-ordering where taxa carried many uses per citing vendor (e.g., *Salvia rosmarinus*, *Camellia sinensis*).

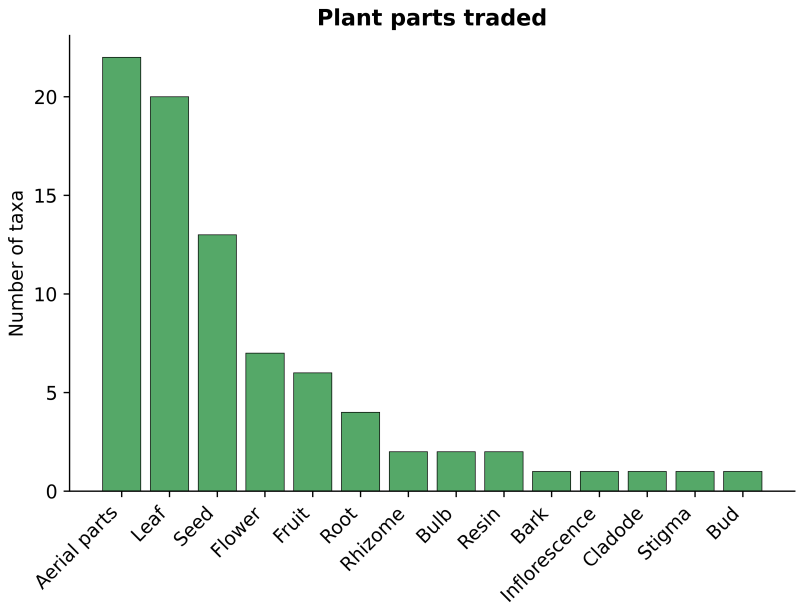

Figure 4. Distribution of traded plant parts across the 83 taxa.

Table 3. Twenty highest-salience taxa by RFC, with FC, summed use reports (ΣUR), and UV. N = 93.

Rank	Scientific name	Family	FC	RFC	ΣUR	UV
1	*Trigonella foenum-graecum* L.	Fabaceae	86	0.925	145	1.559
2	*Zingiber officinale* Roscoe	Zingiberaceae	85	0.914	139	1.495
3	*Mentha spicata* L.	Lamiaceae	81	0.871	138	1.484
4	*Salvia officinalis* L.	Lamiaceae	80	0.860	136	1.462
5	*Coriandrum sativum* L.	Apiaceae	80	0.860	127	1.366
6	*Nigella sativa* L.	Ranunculaceae	79	0.849	123	1.323
7	*Olea europaea* L.	Oleaceae	79	0.849	135	1.452
8	*Rosa damascena* Mill.	Rosaceae	78	0.839	121	1.301
9	*Salvia rosmarinus* Spenn.	Lamiaceae	78	0.839	139	1.495
10	*Origanum compactum* Benth.	Lamiaceae	78	0.839	132	1.419
11	*Lawsonia inermis* L.	Lythraceae	77	0.828	128	1.376
12	*Linum usitatissimum* L.	Linaceae	77	0.828	123	1.323
13	*Piper nigrum* L.	Piperaceae	77	0.828	135	1.452
14	*Senna alexandrina* Mill.	Fabaceae	76	0.817	126	1.355
15	*Petroselinum crispum* (Mill.) Fuss	Apiaceae	75	0.806	117	1.258
16	*Camellia sinensis* (L.) Kuntze	Theaceae	75	0.806	133	1.430
17	*Eucalyptus globulus* Labill.	Myrtaceae	74	0.796	133	1.430
18	*Thymus satureioides* Coss.	Lamiaceae	74	0.796	125	1.344
19	*Aloysia citrodora* Palau	Verbenaceae	71	0.763	121	1.301
20	*Artemisia herba-alba* Asso	Asteraceae	68	0.731	119	1.280

Consensus: ICF by ailment category

Use reports concentrated in digestive complaints (2424 reports; 30 taxa; 41.9% of all UR), then respiratory (615; 8 taxa), dermatological (504; 10), aromatic (391; 6), and cardiovascular (387; 5) (Table 4). ICF ranged from 0.953 (Wounds) to 1.000, with most categories 0.98-0.99. Four single-taxon categories (Circulatory, Immunological, Anti-inflammatory, Dental) returned ICF = 1.000 by construction; among multi-taxon categories, Metabolic was highest (0.993). High ICF indicates strong vendor convergence on a small number of taxa per therapeutic area. This is interpreted below as a curated commercial repertoire rather than as independent agreement between informants.

Table 4. Informant Consensus Factor (ICF) by ailment category, recomputed from the raw Primary_use_category field (14-category scheme; ΣNt = 82; total use reports = 5791). ICF = (Nur − Nt)/(Nur − 1). Single-taxon categories return ICF = 1.000 by construction.

Ailment category	N taxa (Nt)	Use reports (Nur)	ICF
Digestive	30	2424	0.988
Respiratory	8	615	0.989
Dermatological	10	504	0.982
Aromatic	6	391	0.987
Cardiovascular	5	387	0.990
Nervous	6	329	0.985
Metabolic	3	279	0.993
Urinary	4	213	0.986
Ritual	3	145	0.986
Circulatory	1	139	1.000
Immunological	1	123	1.000
Anti-inflammatory	1	101	1.000
Dental	1	97	1.000
Wounds	3	44	0.953

Fidelity Level

FL was 100% for all 15 principal-use taxa (Table 5) because each taxon maps to a single primary category in the survey design; for example, *Trigonella foenum-graecum* was coded Metabolic for all 86 citing vendors and *Origanum compactum* Respiratory for all 78. This uniformity is a structural feature of the coding and should not be read as clinical specificity.

Table 5. Fidelity Level (FL) for the 15 highest-RFC taxa (raw primary categories). FL = (Np/Ns) × 100.

Scientific name	Principal use	Np	Ns	FL (%)
Trigonella foenum-graecum L.	Metabolic	86	86	100
Zingiber officinale Roscoe	Digestive	85	85	100
Mentha spicata L.	Digestive	81	81	100
Salvia officinalis L.	Digestive	80	80	100
Coriandrum sativum L.	Digestive	80	80	100
Nigella sativa L.	Immunological	79	79	100
Olea europaea L.	Cardiovascular	79	79	100
Rosa damascena Mill.	Dermatological	78	78	100
Salvia rosmarinus Spenn.	Circulatory	78	78	100
Origanum compactum Benth.	Respiratory	78	78	100
Lawsonia inermis L.	Dermatological	77	77	100
Linum usitatissimum L.	Digestive	77	77	100
Piper nigrum L.	Digestive	77	77	100
Senna alexandrina Mill.	Digestive	76	76	100
Petroselinum crispum (Mill.) Fuss	Urinary	75	75	100

Market-composition comparison

Per-market species richness ranged from 70 to 78 taxa and use reports from 418 to 747 (Table 1). Tetouan medina (M02) was richest (78 taxa). Pairwise Jaccard similarity was high (0.775-0.949; mean 0.865); the most similar pair was M01-M02 (0.949) and the least similar M09-M10 (0.775). NMDS (stress ≈ 0.14; Fig. 5) and PCoA (first two axes ≈ 31% and 23%) separated markets only weakly and not strongly by typology, indicating a regionally homogeneous pharmacopeia traded throughout.

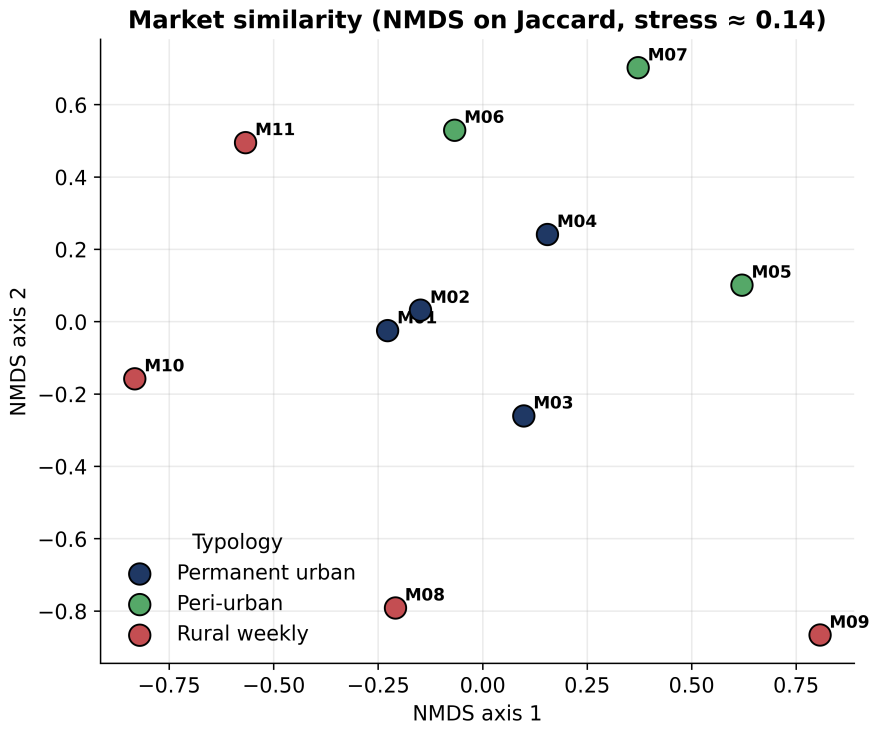

Figure 5. Non-metric multidimensional scaling (NMDS) of the 11 markets on Jaccard dissimilarity of species presence/absence (stress ≈ 0.14). Markets separate only weakly and not strongly by typology, reflecting high compositional similarity (mean Jaccard similarity 0.865).

Price structure

Dried-MAP modal prices ranged from 25 MAD/kg (flaxseed; "īlān", excluded) to 300 MAD/kg (Table 6; Fig. 6). The highest modal prices attached to imported and premium taxa — *Moringa oleifera* and *Rosa damascena* (300), *Trachyspermum ammi (280), Senna alexandrina and Saussurea costus (200)* — while bulk local seeds and common herbs occupied the lower band. Fresh-MAP prices ranged from 2 MAD (parsley, coriander) to 30 MAD (*Rosa damascena*) per bunch or small quantity (Table 7). Prices are indicative of relative value, not audited transactions.

Table 6. Vendor-reported modal dried-MAP prices (MAD/kg) and commercial origin. Footnote: the entry "īlān" [Ilan] (pending ID) is unidentified, unvouchered, and excluded from analysis.

Scientific name	Vernacular	Unit	Modal (MAD)	Origin
Linum usitatissimum	zarrīʿat al-kattān	per kg	25	Local-cultivated
[Ilan] (pending ID)	īlān	per kg	25	Local-wild
Ricinus communis	zarrīʿat al-kharwaʿ	per kg	60	Local-wild
Lawsonia inermis	al-ḥinnā	per kg	80	Local-cultivated
Ocimum basilicum	al-rīḥān	per kg	80	Local-cultivated
Mentha pulegium	fliyou	per kg	80	Local-wild
Ziziphus lotus	al-sidr	per kg	100	Local-wild
Thymus satureioides	zaʿatar	per kg	120	Local-wild
Salvia rosmarinus	azīr / iklīl	per kg	120	Local-cultivated
Lavandula stoechas	ḵzāma	per kg	120	Local-wild
Salvia officinalis	sālmiyya	per kg	150	Local-cultivated
Matricaria chamomilla	bābūnj	per kg	180	Local-cultivated
Aloysia citrodora	luwīza	per kg	180	Local-cultivated
Senna alexandrina	sannā makkī	per kg	200	Imported
Saussurea costus	qust al-hindī	per kg	200	Imported
Trachyspermum ammi	kāmūn ṣūfī	per kg	280	Imported
Moringa oleifera	mūringā	per kg	300	Imported
Rosa damascena	al-ward	per kg	300	Local-cultivated

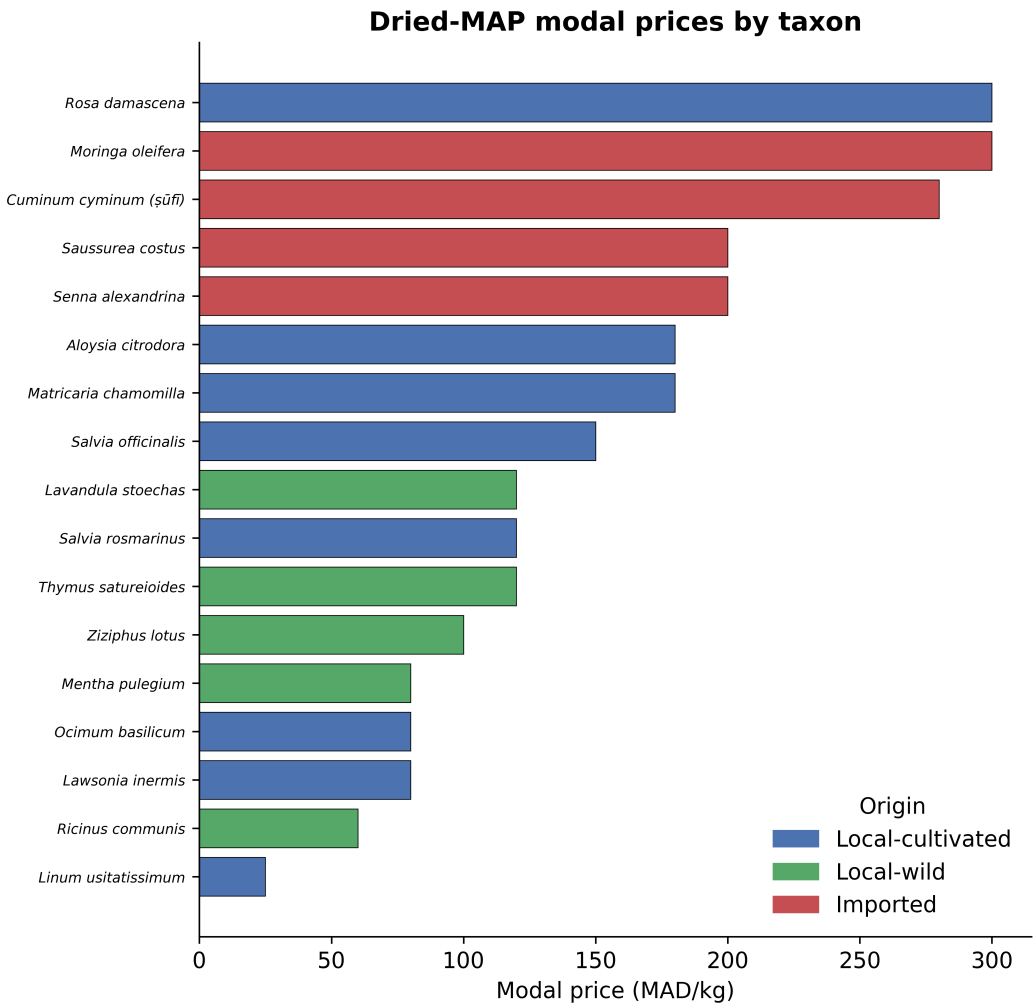

Figure 6. Modal dried-MAP prices (MAD/kg) by taxon, coloured by commercial origin. The unidentified "īlān" entry is excluded.

Table 7. Vendor-reported fresh-MAP price ranges (per bunch/leaf/small quantity, MAD).

Scientific name	Vernacular	Unit	Min (MAD)	Max (MAD)
Petroselinum crispum	al-maʿdnūs	per bunch	2	4
Coriandrum sativum	al-qazbūr	per bunch	2	4
Mentha spicata	al-naʿnaʿ	per bunch	2	5
Salvia rosmarinus	azīr	per bunch	3	7
Mentha pulegium	fliyou	per bunch	5	10
Aloysia citrodora	luwīza	per bunch	5	10
Thymus satureioides	zaʿatar	per bunch	5	10
Salvia officinalis	sālmiyya	per bunch	5	10
Eucalyptus globulus	kāliptūs	per bunch	5	10
Cymbopogon citratus	ḥashīshat al-līmūn	per bunch	5	15
Myrtus communis	mursīn	per bunch	5	15
Ocimum basilicum	al-rīḥān	per bunch	5	15
Pelargonium graveolens	al-ʿaṭrashā	per bunch	5	15
Opuntia ficus-indica	al-ṣabbār	per leaf	5	15
Malva sylvestris	al-khubīza	per bunch	15	20
Citrus aurantium	zhar al-burtuqāl	small qty	10	25
Rosa damascena	al-ward	per bunch	10	30

Sustainability perceptions

Across the 3480 records, availability was stable in 2072 (59.5%), declining in 856 (24.6%), and increasing in 552 (15.9%); an explicit sustainability concern appeared in 366 records (10.5%). At least one concern record was present for 31 taxa, most frequently *Origanum compactum* (28), *Artemisia herba-alba* (28), *Thymus satureioides* (25), *Mentha pulegium* (22), *Lavandula stoechas* (21), and *Marrubium vulgare* (21). Reports of declining availability were proportionally most frequent for local-wild taxa (approximately 50% of wild-origin records), compared with local-cultivated (approximately 17%) and imported taxa (approximately 13%). Wild-harvested material is therefore the axis along which vendors most often perceive supply to be contracting.

Discussion

A commercially convergent regional pharmacopeia

The surveyed markets show a broad inventory (83 taxa, 39 families) but a strongly shared commercial core, with high Jaccard similarity (mean 0.865) across urban, peri-urban, and rural sites. This is consistent with markets as connected nodes where wild-harvested, cultivated, and imported materia medica converge (Bellakhdar 1997; Merzouki *et al.* 2000; Monteiro *et al.* 2010; Quiroz *et al.* 2014). The dominance of Lamiaceae and Apiaceae matches the broader Moroccan and Mediterranean medicinal flora (Bellakhdar *et al.* 1991; Hmamouchi 1999; Chaachouay *et al.* 2019). Because the data are market-based, they should not be read as a complete inventory of household practice or wild availability.

The high-salience core species

The leading taxa combine kitchen and pharmacy roles, plausibly underlying both their high citation frequency and their multiple uses per vendor. *Trigonella foenum-graecum* is the single most salient taxon in the dataset and a widely traded metabolic and tonic remedy across North Africa (Eddouks *et al.* 2002, Tahraoui *et al.* 2007, Ziyyat *et al.* 1997). Regionally characteristic Lamiaceae such as *Origanum compactum* and *Thymus satureioides* anchor the respiratory category. Both are of particular biogeographic and economic interest for the Rif (Bellakhdar 1997, Chaachouay *et al.* 2019, Fakchich & Elachouri 2014). These market-salience patterns should be tested against household-use studies and phytochemical/pharmacological evidence (Andrade-Cetto & Heinrich 2011, Heinrich *et al.* 2018).

Interpreting ICF and FL with caution

ICF values were uniformly high, from 0.953 to 1.000. This should not be read as evidence of therapeutic efficacy. ICF measures the extent to which informants converge on the same taxa within an ailment category; it says nothing about whether those taxa are pharmacologically active.

Three features of the present design raise ICF independently of any therapeutic property. First, the informants are vendors rather than patients or households. Their repertoires are shaped by wholesale availability, shelf life, customer demand, price and inter-vendor imitation, so convergence partly reflects a shared commercial assortment (Leonti 2022, Weckerle *et al.* 2018). Second, ICF approaches 1 as Nur grows relative to Nt, so a category with many use reports and few contributing taxa is structurally high whatever its content. Digestive complaints illustrate this: 2424 use reports distributed over 30 taxa yield ICF = 0.988 by arithmetic alone. Third, four categories contain a single taxon and return ICF = 1.000 by construction; they carry no information about consensus and are reported only for completeness.

The same caution applies to Fidelity Level. FL = 100% for all 15 taxa examined because the survey assigned one primary use category per taxon, which forces Np = Ns. This uniformity is an artefact of the coding scheme and carries no information about therapeutic specificity. A design allowing multiple categories per taxon would be required for FL to be informative.

We therefore interpret both indices as descriptors of market consensus and repertoire concentration. Any inference about efficacy would require phytochemical characterisation and pharmacological testing, which lie outside the scope of a market survey (Andrade-Cetto & Heinrich 2011, Heinrich *et al.* 2018).

Prices and value-chain signals

Price structure tracks origin and processing: bulk local seeds and common herbs are inexpensive, while imported taxa and premium *Rosa damascena* command the highest prices; the presence of introduced materia medica is consistent with local pharmacopoeias incorporating non-native species through trade (Bennett and Prance 2000). The dataset lacks the wholesale/retail, grade, seasonality, and volume detail needed to attribute causes; future work should resolve these (Hamilton 2004, Schippmann *et al.* 2002, van Andel *et al.* 2015, Williams *et al.* 2007).

Sustainability and conservation implications

Vendors reported declining availability disproportionately for locally wild-harvested taxa, with roughly half of wild-origin records described as declining. This is a perception of what reaches the stall, not a measurement of population status. It is nevertheless consistent with the harvest pressure documented for wild Rif populations of aromatic Lamiaceae, Cistaceae and other groups (Cunningham 2001, Hamilton 2004, Schippmann *et al.* 2002, Ticktin 2004). Conservation attention should prioritise high-demand wild taxa flagged as declining, with cultivation and sustainable-harvest schemes as mitigation, supported by ecological monitoring rather than market perception alone (van Andel *et al.* 2015, WHO *et al.* 1993). Several of the most frequently flagged taxa are Moroccan or western-Mediterranean endemics of conservation concern: *Origanum compactum*, endemic to Morocco and southern Spain, is considered threatened by over-harvesting and habitat loss (Aboukhalid *et al.* 2017), and *Thymus satureioides* is widely described as endangered and over-harvested for medicinal and artisanal use (Rankou *et al.* 2013). More broadly, the endemic Moroccan flora carries a high extinction risk yet remains largely unassessed under the global IUCN Red List (Rankou *et al.* 2013). The dataset also includes *Saussurea costus*, listed in CITES Appendix I. This mismatch between the limited availability of formal conservation assessments and the locally reported harvest pressure documented here underscores the value of market-based early-warning signals and the need for systematic national-level Red List assessment of traded wild MAPs. Because these reports describe supply as it appears at the stall, they can be driven by changes in the number of harvesters, in intermediary supply chains, or in demand, as well as by change in the wild populations themselves. They are best treated as an early-warning signal that identifies candidate taxa for targeted ecological assessment, rather than as a substitute for population monitoring. Their value lies in being inexpensive, repeatable and regionally broad, which formal Red List assessment of Moroccan MAPs currently is not.

Nagoya Protocol and access-and-benefit-sharing implications

Morocco is a Party to the Convention on Biological Diversity and to the Nagoya Protocol, which entered into force on 12 October 2014, and maintains a national Clearing-House Mechanism for access-and-benefit-sharing (CBD National Clearing-House Mechanism of Morocco 2026). The dataset presented here documents commercially relevant traditional knowledge linked to named taxa, vernacular names, preparations, prices and perceived availability change. We raise access-and-benefit-sharing not as a compliance statement for the present study, which accessed no genetic resource for research or development, but because market-level documentation of this kind has direct implications for how subsequent work should be conducted.

Three points follow. First, any study that moves from documentation to phytochemical screening, bioprospecting or product development on these taxa would fall under national ABS procedures and would require prior informed consent and mutually agreed terms with the competent national authority and with the knowledge holders concerned (Convention on Biological Diversity 2011, Greiber *et al.* 2012, Morgera *et al.* 2014). Documentation is best understood as the stage at which those relationships should already be established, not as a stage exempt from them.

Second, vendor knowledge becomes public once published. Decisions about attribution and anonymisation are therefore consequential for the communities concerned, and the choice made here — full anonymisation of individual vendors, with collective acknowledgement of the market communities — reflects the terms agreed during consent (International Society of Ethnobiology 2006).

Third, benefit-sharing in a market context is most plausibly realised through non-monetary channels: return of results in accessible form and language, support for cultivation of wild taxa under harvest pressure, and inclusion of vendors in regional conservation planning. Royalty-based mechanisms designed for genetic-resource transactions map poorly onto a study of this kind.

Limitations

First, the data are market-vendor evidence; they do not measure household use, clinical efficacy, pharmacological activity, or ecological abundance, and vendor consensus is a curated commercial repertoire rather than independent agreement. Second, ICF and FL depend on the one-primary-category coding used in the survey, which reflects how vendors classify a taxon's headline use rather than therapeutic specificity. Third, one traded taxon ("īlān") is unidentified and excluded, and a small number of price-sheet entries lack author citations pending reconciliation with the voucher inventory and WFO. Fourth, the study lacks trade volumes, supplier identities, seasonal replication, and independent ecological assessment of declining taxa, all of which are priorities for future work.

Conclusion

Northern Moroccan markets sustain a diverse yet highly shared MAP repertoire: 83 vouchered taxa in 39 families, documented from 93 vendors and 5791 use reports across 11 markets. This repertoire is organised around a high-salience commercial core led by *Trigonella foenum-graecum*, *Zingiber officinale* and *Mentha spicata*. Digestive uses dominated, vendor consensus was uniformly high (interpreted cautiously as curated market knowledge), and market composition was regionally homogeneous. Price data separate cheap local bulk herbs from premium imports and *Rosa damascena*, and vendor-perceived decline concentrates on wild-harvested taxa. These findings provide a transparent, reproducible baseline for conservation prioritisation of wild MAPs and a starting point for discussing how the regional MAP trade relates to the access-and-benefit-sharing and prior informed consent frameworks to which Morocco is a Party. Priorities for future work include ecological assessment of the wild-harvested taxa most frequently flagged as declining, longitudinal monitoring of market volumes and prices, and the integration of household-use surveys to complement the vendor-level evidence reported here.

Declarations

List of abbreviations: MAP - Medicinal and Aromatic Plant; RFC - Relative Frequency of Citation; UV - Use Value; ICF - Informant Consensus Factor; FL - Fidelity Level; UR - Use Report; FC - Frequency of Citation; ABS - Access and Benefit-Sharing; PIC - Prior Informed Consent; WFO - World Flora Online; APG - Angiosperm Phylogeny Group; CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora; NMDS - Non-metric Multidimensional Scaling; PCoA - Principal Coordinates Analysis; MAD - Moroccan Dirham; FST - Faculty of Sciences and Techniques; LAMSE - Laboratory of Materials, Natural Substances and Environment.

Ethics approval and consent to participate: This was an observational, non-clinical market study based on interviews with adult herb vendors about commercially traded plant material. No biomedical intervention was involved, and no biological samples were taken from participants. No formal ethics-committee review was sought. The Faculty of Sciences and Techniques of Tangier does not operate a review procedure for non-interventional socio-economic surveys of this type, and no competent authority was asked to issue a determination on whether such review was required. Oral Prior Informed Consent was obtained from every vendor before each interview: participants were informed of the study aims, the voluntary and unpaid nature of participation, their right to decline any question or withdraw at any time, and the procedures used to protect their anonymity. No names, contact details, or other identifying information were recorded; vendors are referred to only by anonymized codes (V001-V093). The study followed the ethical principles of the International Society of Ethnobiology Code of Ethics (International Society of Ethnobiology 2006) and the reporting standards for ethnopharmacological field studies (Heinrich *et al.* 2018, Weckerle *et al.* 2018). Plant material was purchased in open commercial markets as ordinary retail transactions and used solely for taxonomic verification and voucher deposition in a national institution. No genetic or biochemical analysis was performed, no material was exported, and no product development was undertaken. On this basis, no national access-and-benefit-sharing permit and no Nagoya Protocol certificate of compliance was applied for or obtained, and no competent national authority was asked to determine whether one was required. We therefore make no claim of formal ABS compliance; the considerations discussed in the Discussion are presented as ethical and policy context.

Consent for publication: Not applicable.

Availability of data and materials: The anonymized market-level and taxon-level dataset, together with the reproducible analysis code (Appendix A), is available as supplementary material. Raw vendor identifiers are coded (V001-V093) to protect participant identity, consistent with the anonymity commitments described in Materials and Methods.

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

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Author contributions:

JM designed the study, conducted the fieldwork and the vendor interviews, prepared the voucher specimens, verified the botanical identifications, performed the quantitative analyses and wrote the manuscript. BA carried out the botanical identifications of the LAMSE-001 to LAMSE-083 series. RWB reviewed the taxonomic treatment and the nomenclature and revised the manuscript critically for intellectual content. MK supervised the laboratory work and provided institutional resources. NC contributed to the design of the survey instrument and revised the manuscript. All authors read and approved the final version.

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Appendix A. Reproducible analysis code

The complete Python script used to recompute all indices and generate Figures 1-7 from the raw workbook (Market_Ethnobotany_dataset.xlsx) is provided as supplementary material. It uses pandas, NumPy, SciPy 1.17, scikit-learn 1.8, and matplotlib 3.10 under Python 3.12; indices follow the equations in Section 2.5, and the market-similarity ordination uses Jaccard distance with NMDS (and PCoA as an alternative)

```
"""
==========================================================================
Appendix A — Reproducible analysis code
==========================================================================
Supplementary material for:
   Market ethnobotany at the Strait: trade, traditional knowledge, and
   sustainability of medicinal and aromatic plants in Northern Morocco

Purpose
-------
This script recomputes every quantitative result reported in the main
manuscript directly from the raw survey workbook, and regenerates all six
figures. Running it end-to-end reproduces:

 - Sample size (N = 93 vendors), total use reports (5791), and species
   counts (83 vouchered / 82 quantitatively analysed).
 - The four quantitative ethnobotanical indices:
      RFC — Relative Frequency of Citation
      UV  — Use Value
      ICF — Informant Consensus Factor (14 raw primary-use categories)
      FL  — Fidelity Level (for the 15 highest-RFC taxa)
 - Per-market species richness and use reports (Table 1 columns).
 - The pairwise Jaccard similarity matrix among the 11 markets
   (min / max / mean).
 - Figures 1-6 as PNG files at 600 dpi.

Environment
-----------
   Python 3.12
   pandas, NumPy, SciPy 1.17, scikit-learn 1.8, matplotlib 3.10, openpyxl

Input
-----
   Market_Ethnobotany_dataset.xlsx (place next to this script, or set MES_DB)

Output
------
   figs/Fig1_map.png ... figs/Fig6_prices.png (600 dpi)
   Console printout of all index tables and verification checksums.

Reproducibility
---------------
   A fixed random seed (42) is used for the NMDS ordination so the figure
   is bit-for-bit reproducible.

Data integrity note
-------------------
   All indices are computed from the raw long-format survey sheet
```

```
   (`04_Raw_survey_long`), not from any pre-summarised sheet. The Informant
   Consensus Factor uses the 14-category `Primary_use_category` field
   (one primary category per taxon), so categories partition the 82 cited
   taxa exactly (Sum Nt = 82). Capparis spinosa L. (voucher LAMSE-044) is
   vouchered but received no use citation and is therefore excluded from
   quantitative analysis.

Contact
-------
   Corresponding author: see the main manuscript.
================================================================================
"""

from __future__ import annotations

import os
from collections import Counter, defaultdict
from pathlib import Path

import matplotlib as mpl
import matplotlib.patches as mpatches
import matplotlib.pyplot as plt
import numpy as np
import openpyxl
from scipy.spatial.distance import pdist, squareform
from sklearn.manifold import MDS

# ---------------------------------------------------------------------------
# Configuration
# ---------------------------------------------------------------------------

DB = Path(os.environ.get("MES_DB", "Market_Ethnobotany_dataset.xlsx"))
FIGDIR = Path("figs")
FIGDIR.mkdir(exist_ok=True)

# Figure style: journal-friendly, 600 dpi, sans-serif, minimal chartjunk.
mpl.rcParams.update(
   {
      "font.size": 11,
      "font.family": "DejaVu Sans",
      "savefig.dpi": 600,
      "figure.dpi": 150,
      "axes.titlesize": 13,
      "axes.titleweight": "bold",
      "axes.spines.top": False,
      "axes.spines.right": False,
      "savefig.bbox": "tight",
   }
)

# Consistent palette across figures.
COL_URBAN = "#1F3864"
COL_PERIURBAN = "#55A868"
COL_RURAL = "#C44E52"
```

```
ORIGIN_COL = {
   "Local-cultivated": "#4C72B0",
   "Local-wild": "#55A868",
   "Imported": "#C44E52",
}

# Column layout of the raw long-format survey (`04_Raw_survey_long`).
# Header names below are those documented in Materials and Methods.
RAW_HEADERS = [
   "Vendor_ID",
   "Market_code",
   "Market_typology",
   "Vendor_gender",
   "Vendor_age_class",
   "Vendor_experience",
   "Vendor_language",
   "Voucher_ID",
   "Scientific_name",
   "Family",
   "Vernacular_Darija",
   "Plant_part",
   "Form",
   "Primary_use_category",
   "N_uses_cited",
   # Optional 16th column, used only for panel (d) of Figure 2. If it is
   # absent the panel is skipped and a message is printed.
   "Vendor_transmission",
]
COL = {h: i for i, h in enumerate(RAW_HEADERS)}

# Column layout of `09_Prices_dried`:
# Scientific_name | Vernacular | Unit | Min | Max | Modal | Origin
PRICE_NAME, PRICE_MODAL, PRICE_ORIGIN = 0, 5, 6

# Display order for the categorical vendor variables (Figure 2).
AGE_ORDER = ["<30", "30-44", "45-59", ">=60"]
EXP_ORDER = ["<5", "5-10", "11-20", ">20"]
TRANS_ORDER = ["Inherited (family)", "Apprenticeship", "Self-taught"]
LANG_ORDER = ["Darija only", "Darija-Tarifit bilingual", "Other"]


# ---------------------------------------------------------------------------
# Workbook loading helpers
# ---------------------------------------------------------------------------

def load_workbook(path: Path) -> openpyxl.Workbook:
   if not path.exists():
      raise FileNotFoundError(
         f"Dataset not found at {path}. Place Market_Ethnobotany_dataset.xlsx "
         f"next to this script, or set the MES_DB environment variable."
      )
   return openpyxl.load_workbook(path, data_only=True)


def sheet_rows(wb: openpyxl.Workbook, name: str, min_row: int = 4) -> list:
```

```
    """Return non-empty rows from a sheet, skipping the two header rows and the
    column-name row (data starts on row 4 in every sheet of this workbook)."""
    return [
        r
        for r in wb[name].iter_rows(min_row=min_row, values_only=True)
        if r and r[0] is not None
    ]


# ---------------------------------------------------------------------------
# Index computation
# ---------------------------------------------------------------------------

def compute_species_indices(raw: list, N: int) -> dict:
    """Return {species: dict(FC, RFC, SUR, UV)} computed from the raw survey."""
    fc = defaultdict(set)   # distinct vendors per species
    sur = defaultdict(int)  # summed use reports per species
    for r in raw:
        sp = r[COL["Scientific_name"]]
        fc[sp].add(r[COL["Vendor_ID"]])
        sur[sp] += r[COL["N_uses_cited"]]
    return {
        sp: {
            "FC": len(fc[sp]),
            "RFC": len(fc[sp]) / N,
            "SUR": sur[sp],
            "UV": sur[sp] / N,
        }
        for sp in fc
    }


def compute_icf(raw: list) -> dict:
    """Return {category: dict(Nt, Nur, ICF)} using the raw 14-category scheme.

    ICF = (Nur - Nt) / (Nur - 1)

    Single-taxon categories yield ICF = 1 by construction and are noted as such
    in the manuscript.
    """
    nur = defaultdict(int)
    taxa = defaultdict(set)
    for r in raw:
        c = r[COL["Primary_use_category"]]
        nur[c] += r[COL["N_uses_cited"]]
        taxa[c].add(r[COL["Scientific_name"]])
    return {
        c: {
            "Nt": len(taxa[c]),
            "Nur": nur[c],
            "ICF": (nur[c] - len(taxa[c])) / (nur[c] - 1) if nur[c] > 1 else 1.0,
        }
        for c in nur
    }
```

```
def compute_fidelity(raw: list, top_species: list) -> dict:
   """Return {species: dict(principal_use, Np, Ns, FL_pct)} for the given species.

   FL (%) = (Np / Ns) * 100, where Np = vendors citing the species for its
   principal category and Ns = total vendors citing the species.
   """
   ns = defaultdict(set)
   np_ = defaultdict(lambda: defaultdict(set))
   for r in raw:
      sp = r[COL["Scientific_name"]]
      ns[sp].add(r[COL["Vendor_ID"]])
      np_[sp][r[COL["Primary_use_category"]]].add(r[COL["Vendor_ID"]])

   out = {}
   for sp in top_species:
      cats = np_[sp]
      principal = max(cats, key=lambda k: len(cats[k]))
      Np = len(cats[principal])
      Ns = len(ns[sp])
      out[sp] = {
         "principal_use": principal,
         "Np": Np,
         "Ns": Ns,
         "FL_pct": (Np / Ns) * 100 if Ns else float("nan"),
      }
   return out


def market_stats(raw: list) -> dict:
   """Return per-market {code: dict(vendors, richness, use_reports)}."""
   v = defaultdict(set)
   sp = defaultdict(set)
   ur = defaultdict(int)
   for r in raw:
      m = r[COL["Market_code"]]
      v[m].add(r[COL["Vendor_ID"]])
      sp[m].add(r[COL["Scientific_name"]])
      ur[m] += r[COL["N_uses_cited"]]
   return {
      m: {"vendors": len(v[m]), "richness": len(sp[m]), "use_reports": ur[m]}
      for m in sorted(v)
   }


def jaccard_market_matrix(raw: list):
   """Return (market codes, presence-absence matrix, Jaccard distance matrix)."""
   msp = defaultdict(set)
   for r in raw:
      msp[r[COL["Market_code"]]].add(r[COL["Scientific_name"]])
   codes = sorted(msp)
   species = sorted({r[COL["Scientific_name"]] for r in raw})
   M = np.array(
      [[1 if s in msp[m] else 0 for s in species] for m in codes], dtype=int
   )
```

```
   D = squareform(pdist(M, metric="jaccard"))
   return codes, M, D


def vendor_attributes(raw: list) -> dict:
   """Collapse the long-format survey to one record per vendor.

   Returns {vendor_id: {gender, age, experience, language, transmission}}.
   `transmission` is None when the optional 16th column is absent.
   """
   out = {}
   for r in raw:
      vid = r[COL["Vendor_ID"]]
      if vid in out:
         continue
      trans_idx = COL["Vendor_transmission"]
      out[vid] = {
         "gender": r[COL["Vendor_gender"]],
         "age": r[COL["Vendor_age_class"]],
         "experience": r[COL["Vendor_experience"]],
         "language": r[COL["Vendor_language"]],
         "transmission": r[trans_idx] if len(r) > trans_idx else None,
      }
   return out


# ---------------------------------------------------------------------------
# Figures
# ---------------------------------------------------------------------------

def figure_1_map(markets: list) -> None:
   """Fig. 1: study-area map (points at market coordinates, coloured by typology)."""
   fig, ax = plt.subplots(figsize=(7.2, 6))
   seen = set()
   for r in markets:
      typ = str(r[3])
      if "Rural" in typ:
         c, lab = COL_RURAL, "Rural weekly"
      elif "Peri" in typ:
         c, lab = COL_PERIURBAN, "Peri-urban"
      else:
         c, lab = COL_URBAN, "Permanent urban"
      ax.scatter(
         r[4], r[5], s=120, c=c, edgecolor="k", zorder=3,
         label=lab if lab not in seen else None,
      )
      seen.add(lab)
      ax.annotate(
         r[0], (r[4], r[5]), xytext=(5, 4), textcoords="offset points",
         fontsize=9, fontweight="bold",
      )
   ax.set_xlabel("Longitude (°E)")
   ax.set_ylabel("Latitude (°N)")
   ax.set_title("Surveyed MAP markets — Tangier–Tetouan–Al Hoceima")
   ax.legend(title="Market typology", frameon=False, loc="lower left")
```

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    ax.grid(alpha=0.25)
    plt.savefig(FIGDIR / "Fig1_map.png")
    plt.close()


def _profile_panel(ax, title, labels, values, show_ylabel, ymax):
    bars = ax.bar(labels, values, color=COL_URBAN, edgecolor="k",
                  linewidth=0.4, width=0.62)
    for b, v in zip(bars, values):
        ax.text(b.get_x() + b.get_width() / 2, b.get_height() + ymax * 0.02,
                str(v), ha="center", va="bottom", fontsize=9, fontweight="bold")
    ax.set_title(title, loc="left", pad=8, fontsize=11)
    ax.set_ylim(0, ymax)
    if show_ylabel:
        ax.set_ylabel("Number of vendors")
    else:
        ax.set_yticklabels([])
    ax.tick_params(axis="x", labelsize=9)
    ax.grid(axis="y", alpha=0.22, linewidth=0.6)
    ax.set_axisbelow(True)


def figure_2_vendor_profile(vendors: dict) -> None:
    """Fig. 2: sociodemographic profile of the interviewed vendors.

    Replaces the vendor demographic table of the previous version.
    Panel (d) is omitted if the optional `Vendor_transmission` column is absent.
    """
    def counts(key, order):
        c = Counter(v[key] for v in vendors.values() if v[key] is not None)
        keys = [k for k in order if k in c] + [k for k in c if k not in order]
        return keys, [c[k] for k in keys]

    panels = [("(a) Gender", *counts("gender", ["Female", "Male"]))]
    panels.append(("(b) Age class (years)", *counts("age", AGE_ORDER)))
    panels.append(("(c) Trading experience (years)", *counts("experience", EXP_ORDER)))

    has_transmission = any(v["transmission"] is not None for v in vendors.values())
    if has_transmission:
        panels.append(("(d) Knowledge transmission", *counts("transmission", TRANS_ORDER)))
    else:
        print("  ! Vendor_transmission column not found: panel (d) skipped.")
    letter = "(e)" if has_transmission else "(d)"
    panels.append((f"{letter} Languages spoken", *counts("language", LANG_ORDER)))

    ymax = max(max(v) for _, _, v in panels) * 1.18
    n_bottom = len(panels) - 3

    fig = plt.figure(figsize=(10.4, 7.0))
    gs = fig.add_gridspec(2, 6, hspace=0.42, wspace=0.28)
    axes = [fig.add_subplot(gs[0, 0:2]),
            fig.add_subplot(gs[0, 2:4]),
            fig.add_subplot(gs[0, 4:6])]
    if n_bottom == 2:
        axes += [fig.add_subplot(gs[1, 0:3]), fig.add_subplot(gs[1, 3:6])]
```

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    else:
        axes += [fig.add_subplot(gs[1, 0:3])]

    for i, (ax, (title, labels, values)) in enumerate(zip(axes, panels)):
        _profile_panel(ax, title, labels, values, show_ylabel=i in (0, 3), ymax=ymax)

    plt.savefig(FIGDIR / "Fig2_vendor_profile.png")
    plt.close()


def figure_3_families(inventory: list) -> None:
    """Fig. 3: family composition of the traded inventory (83 taxa)."""
    fam = dict(sorted(Counter(r[2] for r in inventory).items(), key=lambda x: x[1]))
    fig, ax = plt.subplots(figsize=(7.2, 9))
    ax.barh(list(fam.keys()), list(fam.values()), color=COL_URBAN,
            edgecolor="k", linewidth=0.4)
    ax.set_xlabel("Number of taxa")
    ax.set_title(f"Family composition of the traded inventory ({len(inventory)} taxa)")
    for i, v in enumerate(fam.values()):
        if v >= 4:
            ax.text(v - 0.15, i, str(v), va="center", ha="right",
                    color="w", fontsize=8, fontweight="bold")
    plt.savefig(FIGDIR / "Fig3_families.png")
    plt.close()


def figure_4_parts(inventory: list) -> None:
    """Fig. 4: distribution of plant parts across the 83 taxa."""
    parts = Counter(r[4] for r in inventory).most_common()
    fig, ax = plt.subplots(figsize=(7.6, 4.8))
    ax.bar([p[0] for p in parts], [p[1] for p in parts],
           color=COL_PERIURBAN, edgecolor="k", linewidth=0.4)
    ax.set_ylabel("Number of taxa")
    ax.set_title("Plant parts traded")
    plt.xticks(rotation=45, ha="right")
    plt.savefig(FIGDIR / "Fig4_parts.png")
    plt.close()


def figure_5_nmds(codes: list, D: np.ndarray, market_typologies: dict) -> float:
    """Fig. 5: NMDS ordination on Jaccard distance. Returns the stress value."""
    nmds = MDS(
        n_components=2, dissimilarity="precomputed", metric=False,
        random_state=42, n_init=10, max_iter=500, normalized_stress="auto",
    )
    xy = nmds.fit_transform(D)

    fig, ax = plt.subplots(figsize=(7.2, 6))
    seen = set()
    for code, (x, y) in zip(codes, xy):
        typ = market_typologies.get(code, "")
        if "Rural" in typ:
            c, lab = COL_RURAL, "Rural weekly"
        elif "Peri" in typ:
            c, lab = COL_PERIURBAN, "Peri-urban"
```

```
        else:
            c, lab = COL_URBAN, "Permanent urban"
        ax.scatter(x, y, s=130, c=c, edgecolor="k", zorder=3,
                   label=lab if lab not in seen else None)
        seen.add(lab)
        ax.annotate(code, (x, y), xytext=(5, 4), textcoords="offset points",
                    fontsize=9, fontweight="bold")
    ax.set_xlabel("NMDS axis 1")
    ax.set_ylabel("NMDS axis 2")
    ax.set_title(f"Market similarity (NMDS on Jaccard, stress ≈ {nmds.stress_:.2f})")
    ax.legend(title="Typology", frameon=False)
    ax.grid(alpha=0.25)
    plt.savefig(FIGDIR / "Fig5_NMDS.png")
    plt.close()
    return float(nmds.stress_)


def figure_6_prices(dried_rows: list) -> None:
    """Fig. 6: dried-MAP modal prices, coloured by commercial origin.

    The unidentified "īlān" entry has no voucher and is excluded from analysis.
    """
    rows = [r for r in dried_rows if r[PRICE_NAME] and "Ilan" not in str(r[PRICE_NAME])]
    rows = sorted(rows, key=lambda r: r[PRICE_MODAL])

    fig, ax = plt.subplots(figsize=(7.4, 8))
    ax.barh(
        [r[PRICE_NAME] for r in rows], [r[PRICE_MODAL] for r in rows],
        color=[ORIGIN_COL.get(r[PRICE_ORIGIN], "#888") for r in rows],
        edgecolor="k", linewidth=0.4,
    )
    ax.set_xlabel("Modal price (MAD/kg)")
    ax.set_title("Dried-MAP modal prices by taxon")
    ax.legend(
        handles=[mpatches.Patch(color=v, label=k) for k, v in ORIGIN_COL.items()],
        title="Origin", frameon=False,
    )
    for lab in ax.get_yticklabels():
        lab.set_fontstyle("italic")
        lab.set_fontsize(7)
    plt.savefig(FIGDIR / "Fig6_prices.png")
    plt.close()


# ---------------------------------------------------------------------------
# Main pipeline
# ---------------------------------------------------------------------------

def main() -> None:
    wb = load_workbook(DB)
    raw = sheet_rows(wb, "04_Raw_survey_long")
    inv = sheet_rows(wb, "03_Species_inventory")
    markets = [r for r in sheet_rows(wb, "01_Markets")
               if not str(r[0]).startswith("Total")]
```

```
N = len({r[COL["Vendor_ID"]] for r in raw})
total_ur = sum(r[COL["N_uses_cited"]] for r in raw)
n_taxa_inv = len(inv)
n_taxa_cited = len({r[COL["Scientific_name"]] for r in raw})

print("=" * 70)
print("VERIFICATION CHECKSUMS (should match the main manuscript)")
print("=" * 70)
print(f"  Vendors interviewed (N)          : {N} (expected 93)")
print(f"  Vendor x taxon records           : {len(raw)} (expected 3480)")
print(f"  Vouchered taxa in inventory      : {n_taxa_inv} (expected 83)")
print(f"  Cited taxa (entered analysis)    : {n_taxa_cited} (expected 82)")
print(f"  Total use reports (Sum N_uses)   : {total_ur} (expected 5791)")

# ---------------------------------------------------------------------
# Species indices — RFC, UV
# ---------------------------------------------------------------------
idx = compute_species_indices(raw, N)
top10 = sorted(idx.items(), key=lambda kv: -kv[1]["RFC"])[:10]
print("\nTop 10 taxa by RFC")
print("-" * 70)
print(f"{'Rank':>4}  {'Scientific name':<38} {'FC':>4} {'RFC':>7} {'UV':>7}")
for rank, (sp, v) in enumerate(top10, 1):
    print(f"{rank:>4}  {sp[:38]:<38} {v['FC']:>4} {v['RFC']:>7.3f} {v['UV']:>7.3f}")

# ---------------------------------------------------------------------
# ICF — 14 raw categories
# ---------------------------------------------------------------------
icf = compute_icf(raw)
print("\nICF by ailment category (raw 14-category scheme)")
print("-" * 70)
print(f"{'Category':<20} {'Nt':>4} {'Nur':>7} {'ICF':>7}")
for c in sorted(icf, key=lambda k: -icf[k]["Nur"]):
    v = icf[c]
    print(f"{c:<20} {v['Nt']:>4} {v['Nur']:>7} {v['ICF']:>7.3f}")

# ---------------------------------------------------------------------
# Fidelity Level for the 15 highest-RFC taxa
# ---------------------------------------------------------------------
top15 = [sp for sp, _ in sorted(idx.items(), key=lambda kv: -kv[1]["RFC"])[:15]]
fl = compute_fidelity(raw, top15)
print("\nFidelity Level for the 15 highest-RFC taxa")
print("-" * 70)
for sp in top15:
    v = fl[sp]
    print(f"{sp[:38]:<38} {v['principal_use']:<18} "
          f"Np={v['Np']:>3} Ns={v['Ns']:>3} FL={v['FL_pct']:>5.1f}%")

# ---------------------------------------------------------------------
# Market-level statistics and Jaccard similarity
# ---------------------------------------------------------------------
mstats = market_stats(raw)
print("\nPer-market vendor counts, richness, and use reports")
print("-" * 70)
for m, s in mstats.items():
```

```
        print(f"  {m}  vendors={s['vendors']:>2}  richness={s['richness']:>3}  "
              f"use_reports={s['use_reports']:>5}")

    codes, M, D = jaccard_market_matrix(raw)
    S = 1 - D  # Jaccard similarity
    iu = np.triu_indices(len(codes), 1)
    print(f"\nJaccard SIMILARITY among {len(codes)} markets")
    print("-" * 70)
    print(f"  min  = {S[iu].min():.3f}")
    print(f"  max  = {S[iu].max():.3f}")
    print(f"  mean = {S[iu].mean():.3f}")

    # ---------------------------------------------------------------------
    # Figures 1-6
    # ---------------------------------------------------------------------
    print("\nGenerating figures at 600 dpi ...")
    figure_1_map(markets)
    figure_2_vendor_profile(vendor_attributes(raw))
    figure_3_families(inv)
    figure_4_parts(inv)
    typologies = {r[0]: str(r[3]) for r in markets}
    stress = figure_5_nmds(codes, D, typologies)
    figure_6_prices(sheet_rows(wb, "09_Prices_dried"))

    print(f"  NMDS stress = {stress:.3f}")
    print(f"  Figures written to: {FIGDIR.resolve()}")
    for f in sorted(FIGDIR.iterdir()):
        print(f"    {f.name:<26} {f.stat().st_size // 1024:>4} KB")

    print("\nDone.")


if __name__ == "__main__":
    main()
```