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PLANT BIODIVERSITY OF HYRCANIAN RELICT FORESTS, N IRAN: AN OVERVIEW OF THE FLORA, VEGETATION, PALAEOECOLOGY AND CONSERVATION

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Abstract

The Hyrcanian forests stretch from Talish in Republic of Azerbaijan and cover the northern slopes of the Alborz Mountains in North Iran, in Gilan, Mazandaran and Golestan provinces. The vegetation is composed mostly of deciduous forests. In the lower altitudes it is represented by a number of relict Arcto-Tertiary thermophilous species such as *Parrotia persica*, *Gleditsia caspica*, *Zelkova carpinifolia* and *Pterocarya fraxinifolia*. The diversity of tree species increases at higher elevations where the subalpine forests and scrubs of low shrubs of the timber-line are replaced by alpine grasslands in the northern slopes and the Irano-Turanian thorn-cushion steppe at the exposed summits and southern slopes. So far, 3234 species belonging to 856 genera and 148 families of vascular plants have been reported from the northern provinces of Iran and Talish in the Republic of Azerbaijan. Main vegetation types of the Hyrcanian forest zone include: i) sand dune vegetation along the Caspian Sea coasts; ii) C_4-dominated grass communities on rocky outcrops; iii) aquatic vegetation on wetlands; iv) riverine and valley forests; v) alluvial and lowland deciduous forests; vi) submontane and montane deciduous forests; vii) subalpine deciduous forests (*Quercus macranthera*); viii) successional and transitional scrub and woodlands; ix) *Cupressus sempervirens* and *Thuja orientalis* woodlands; x) juniper woodlands; xi) subalpine and alpine meadows; xii) montane steppe dominated by xerophytic and thorn-cushion species; xiii) rock cliff communities; xiv) halophytic communities; xv) *Artemisia spicigera* steppe and desert like dunes; xvi) ruderal habitats and xvii) cultural landscapes and artificial forests. Evidence from studies on loess/palaeosol sequences, long-term Caspian Sea-level fluctuations, and peat/lake deposits in northern Iran give some indication of the climate and vegetation history of the south Caspian region. Based on these investigations, during the early-Pleistocene, at least parts of the area were covered by steppe-like vegetation and the climate was slightly warmer than today. It is also postulated that northern Iran was an extensive area of increased dust accumulation and loess formation during the Pleistocene glaciations, which is contemporaneous with and similar to major climatic changes as in SE Central Europe and Central Asia. These studies further suggest pronounced climate changes for the north of the country in which a dry and cool climate changed to moist and warm conditions during the Pleistocene glaciations. Similarly, a markedly dry period occurred during the early Holocene for the south Caspian area, parallel to the climatic optimum in Europe. Palynological studies have also shown intensified human impact on the lowland forest composition and structure of the area over the last centuries. The forests of the south Caspian area are severely degraded and deforested; in particular, in the alluvial lowlands where only small remnants exist. There are several protected areas in the Alborz Mountains and south Caspian area which suffer from mis-management. Therefore, improving their protection quality and increasing their area or addition of new sites are crucial to guarantee conservation of this very important natural heritage of SW Asia.

Introduction

The Hyrcanian (from "*Hyrcania*", the Greek form of an old Iranian word to describe the region of Gorgan) forests stretch in an arc along the southern shores of the Caspian Sea from the Talish region in Azerbaijan (at longitude 48ºE) to Golestan National Park in Iran (at longitude 56ºE) and between latitudes 38º55'N in Azerbaijan Republic and 35º05'N in Iran (Miller, 1994). Apart from this continuous belt located in provinces Gilan, Mazandaran and Golestan, there are some isolated forests, one in the west known as Arasbaran forest, located in East Azerbaijan and the forest isolates near Joozak located at 55 km W of Bojnurd, in Northern Khorassan province. Also, a few patches of scrub forests rich in Hyrcanian species exist in Turkmenistan. The total area covers approximately 50,000 km^2. The forest zone is bounded northwards by the Caspian Sea shores and southwards by the Alborz Mountain range. It displays a high habitat heterogeneity grading from sandy coastal shores along the Caspian Sea, extensively cultivated and settlement areas almost entirely in the lowland plain, extensive river and wetland systems, scattered remnant of alluvial forests, closed deciduous lowland and montane forests, *Juniperus* and *Cupressus* woodlands, various types of scrub in degraded forests, valley beds, rocky slopes and transitional high altitude scrub in timber-line-montane steppe zone, rock cliffs and alpine and subalpine habitats.

In spite of intensive floristic and vegetation studies in the Caspian forests, there is still no comprehensive up-to-date information on the biodiversity of the area. Our knowledge on the flora of this area is restricted to: Flora Iranica (Rechinger, 1963-2010), papers concerning protected areas, National Parks, and to local floristic studies (Buhse & Winkler, 1899; Djavanchir, 1971; Akhani, 1996, 1998; Akhani & Scholz, 1998; Akhani, 1999; Akhani & Ziegler, 2002; Hamzeh'ee *et al.*, 2008; Jafari & Akhani, 2008; Naqinezhad *et al.*, 2008; Khodadadi *et al.*, 2009). There are also a number of short papers which report new records for the area, mostly published in two Iranian botanical journals namely '*The Iranian Journal of Botany*' and '*Rostaniha*'.

This is the first part of two planned papers dealing with the plant biodiversity of the Hyrcanian forests. In the first paper, an overview of the floristic diversity, vegetation, vegetation history, Quaternary palaeoecology, and conservation issues of the area is presented. The second part deals with distribution patterns of the flora, and an annotated list of all known endemics of the Hyrcanian area, their distribution maps and conservation status. These data are based on evaluation of available literature, mostly based on Flora Iranica (Rechinger, 1963-2010) and field studies of the first author over the last 23 years along the Caspian forests. Based on available publications, a database was prepared in which all floristic records from the Caspian forest area are included. In this database we have included all floristic records from the three provinces of Gilan, Mazandaran and Golestan, completed by floristic data from forest isolates in the Arasbaran Protected Area and Joozak forest in east Azerbaijan and northern Khorassan provinces. At this stage, it is not possible to separate floristic records which are only from forest zones from those of non-forested montane and lowland steppe.

Geology

The Hyrcanian region can be subdivided into two major geological (tectono-sedimentary) units of SW Asia, i.e. the southern edge of the "south Caspian compressional depression" in the north (Berberian, 1983) and the "Alborz Mts" in the south (Stöcklin, 1968). The remarkably abrupt topographic break between the Caspian Sea coastal areas (*ca.* 26 m below sea level) and the seaward foothills of the Alborz and Talish Mts (> 2000 m) in south and west is mainly due to the vertical reverse movements along the big faults located between Caspian basin and surrounding mountain ranges including the Khazar active reverse fault (Berberian, 1983). Palaeogeographic reconstructions indicate that the area corresponding to the southern part of the present Alborz Mts were non-depositional/erosional areas and most likely formed a mountain range since the Late Cretaceous time at *ca.* 65 Ma. However, unlike southern section of the Alborz, the northern section is a geologically younger area which was subsiding and under the Paratethys Ocean until the middle Miocene about 15 – 10 Ma (Berberian & King, 1981). It is thus certain that large water bodies were present in the current area of the Caspian and Aral seas and might have been a major source of humidity for the south Caspian region since the early Cenozoic. The size of these water bodies was considerably bigger than that of the Caspian Sea, as we know it today, during the main part of the Palaeogene and the early Neogene to the end of the Miocene (*ca.* 5.2 Ma) when a major tectonic movement disconnected the Caspian basin from the oceans. Even during the last glacial period, the Caspian Sea level raised to up to +50 m and became connected to the Black Sea signifying that it had a considerably larger size during some time intervals (Yanko-Hombach *et al.*, 2010).

Climate

Regional climatic system

The climate of the south Caspian region is controlled by several components of regional atmospheric circulation pattern and is strongly modulated by a complex topography and the maritime effect of Caspian Sea. Westerly disturbances which bring significant moisture from the north Atlantic Ocean, Mediterranean Sea and Black Sea to the Middle East, contribute to the autumn-winter-spring precipitation of the south Caspian region (Kendrew, 1961; Alijani & Harman, 1985). Siberian anticyclone, formed over N Eurasia and occasionally extending into Central Asia, blocks the eastward penetration of these disturbances during the autumn and winter months but results in high rainfall during the summer and especially autumn in the Caspian coastal area (see below) (Alijani & Harman, 1985; Khalili, 1973). The spatial analysis of precipitation seasonality shows that the western and eastern parts of the Hyrcanian region have markedly different precipitation regimes (Domoers *et al.*, 1998). The higher amount of rainfall over the western Hyrcanian region during autumn is due to the location of this area at the head of north-easterly winds originating from the Siberian anticyclone or polar front. These winds sweep the surface of the Caspian Sea and bring much moisture to the south Caspian region before becoming de- stabilized at the front zone with the hot/dry continental air masses descending from the central Iranian high plateau (Khalili, 1973). Subtropical anticyclones which cause hot/dry air descent over the Iranian plateau especially during winter months become strengthened as a result of the long-distance interaction between Asian monsoon region and southern flanks of mid-latitude westerlies (Rodwell & Hoskins, 1996). Marine-effect precipitation of the Caspian Sea is the second most important mechanism of rainfall in the area after the westerly disturbances (Alijani & Harman, 1985) but is enough to minimize the length and even suppress the summer drought.

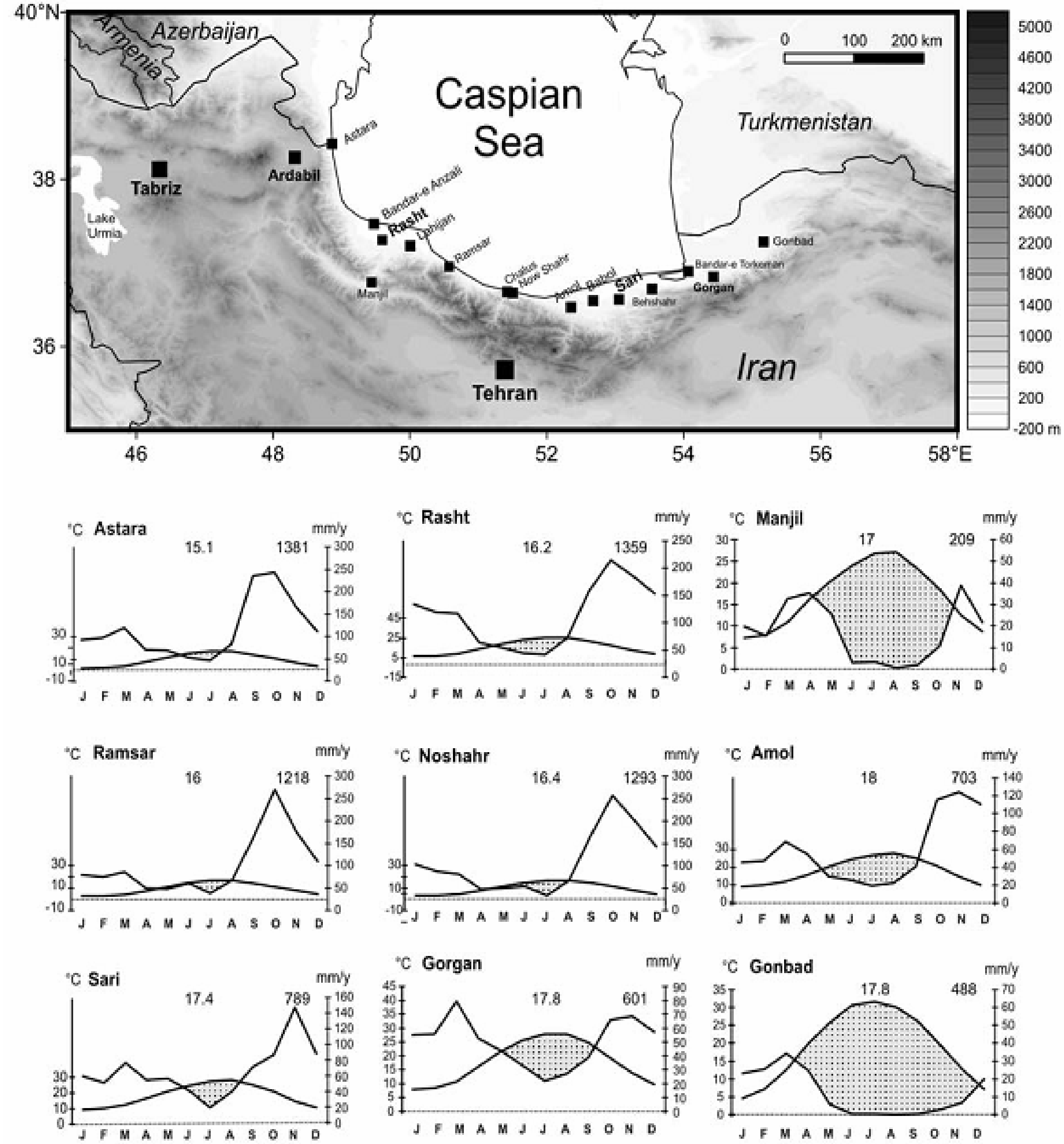

Fig. 1. Relief map of northern Iran and climatic diagrams of nine stations along the south Caspian forests.

Bioclimatic features

The south Caspian region has contrasted bioclimatic differences with other parts of Iran. Some of the main bioclimatic particularities of this region are**:**

(1) High amount of annual precipitation decreasing from west to east ranging from *ca.* 2045 mm/yr in Pilambra (49.08°E, 37.58°N, 6m: 1968-2003) to *ca.* 213 mm/yr in Agh Togheh (55.7°E, 37.9°N, 250m:1988-2003).

(2) Relatively even distribution of annual precipitation with maximum rainfall occurring during the early autumn.

(3) Very short duration or absence of a dry season (P < 2T) especially in the western Hyrcanian region.

(4) High percentages of mean annual relative air humidity exceeding 80% in some stations (e.g. Astara, Rasht, Ramsar, Nowshahr) creating almost permanent fogs in higher altitudes.

(5) Very low degrees of continentality index (Ic) relative to the Iranian plateau and Central Asia (Ic=Tmax-Tmin; where Tmax and Tmin are the mean temperature of the hottest and coldest months of the year, respectively)

(6) Average of minima of temperatures of the coldest month (m) higher than the freezing point (0 °C).

Overall, the above features have created a very particular narraw bioclimatic refugial zone in the south of the Caspian Sea that has maintained the relict thermo-mesophilous forest of the Hyrcanian region.

Floristic diversity and phytogeography

Based on the database, we have recently completed for the flora of the south Caspian Area, a total number of 3234 species belonging to 856 genera and 148 families of vascular plants are known from the geographic boundaries of the three provinces Gilan, Mazandaran and Golestan and Talish in Azerbaijan Republic. This list includes 15 families, 23 genera and 43 species of ferns and fern allies. Gymnosperms with three families, five genera and only 11 species are the lowest diverse vascular plant groups. Four genera and six species belong to basal angiosperms and intermediate between Eudicots and Monocots (Nymphaeaceae, Aristolochiaceae and Ceratophyllaceae). Monocots with 28 families, 172 genera and 563 species comprise17.5% of the total flora and the Eudicots with 99 families, 652 genera and 2611 species comprise 80.7% . The largest Monoct family is Poaceae with 246 species. The largest Eudicot families are Asteraceae with 404, Fabaceae with 326, Brassicaceae with 157, Rosaceae with 155, Lamiaceae with 153, Caryophyllaceae and Apiaceae each with 146, and Boraginaceae and Scrophulariaceae each with 102 species, respectively, forming the largest plant groups in the area. More analysis is still needed to determine the exact number of species which occur in different habitats of the South Caspian forests and their phytogeographic area. Certainly, a large number of these species are xerophytic and montane steppe elements which belong to Irano-Turanian species growing in drier parts of the Alborz range. In term of conservation and biodiversity, the occurrence of 44% of the total known species in Iran (3234 out of 7300 species, *cf.* Akhani 2006) only in 6% of the Iranian surface area is of great interest. Only *ca.* 280 species are endemic and subendemic in the Hyrcanian area and *ca.* 500 species are Iranian endemics.

The Hyrcanian forests provide diverse habitats for a large number of other mesophytic groups such as Bryophytes and Fungi. Among 437 known bryophytes from Iran (Akhani and Kürschner, 2004), 338 species (77%) are known from south Caspian provinces of N Iran. The endemic bryophytes in the Hyrcanian area are very rare. The only true Hyrcanian endemic bryophyte is the pleurocarpous moss *Pseudoleskeella laxiramea*. This epiphytic species and two other Near and Middle Eastern endemics

Leucodon immersus, Palamocladium euchloron occur as widely distributed epiphytes along the Hyrcanian forests (Frey, 1979; Kürschner *et al.*, 2000).

Most of the mycological and lichenological studies in Iran have been concentrated on the forests zone of Iran with steady increase of the number of species (Ershad, 1995; Hallenberg, 1980, 1981; Sohrabi & Sipman, 2007; Zare & Asef, 2008; Sohrabi & Ramezani, 2010).

The Hyrcanian forests are known as refugia for many Arcto-Tertiary relict elements (Tralau, 1963; Zohary, 1973; Leestmans, 2005). These species are grouped into Hyrcanian and Euxino-Hyrcanian elements. Some species of the Hyrcanian forests are of Indo-Malesian origin, such as *Diospyros lotus* L.*, Albizia julibrissin* Durazz*, Buxus hyrcana* Pojark*, Nelumbo nuccifera* Gaertn.. Many descendents of the Arcto-Tertiary flora occur now in the xerophytic habitats of the Irano-Turanian parts of Iran (Frey *et al.*, 1999).

A detailed analysis of the phytogeographic status of the area awaits evaluation of the whole flora. Based on available data and recently published information from the Golestan National Park (Akhani, 1998), the flora of Caspian forests can be grouped into the following categories with some prominent examples:

1- Hyrcanian endemics: *Parrotia persica* (DC.) C. A. Mey., *Acer velutinum* Boiss., *Gleditsia caspica* Desf., *Quercus castaneifolia* C. A. Mey., *Alnus subcordata* C. A. Mey. and *Pyrus boissieriana* Buhse. A complete list of these species with their distribution maps will be presented elsewhere.

2- Euxino-Hyrcanian species: *Zelkova carpinifolia* (Pall.) K. Koch*, Pterocarya fraxinifolia* (Poir.) Spach*, Dryopteris caucasica* (A.Braun) Fraser-Jenk. & Corely, *Acer cappadocicum* Gled., *Acer hyrcanicum* Fisch. & C. A. Mey., *Bupleurum marschallianum* C. A. Mey., *Trinia leiogona* (C. A. Mey.) B. Fedtsch., *Periploca gracea* L., *Vincetoxicum scandens* Sommier & Levier.

3- Omni-Euro-Siberian elements: *Anthemis tinctoria* L., *Arctium minus* (Hill) Bernh., *Artemisia absinthium* L., *Carlina vulgaris* L., *Inula vulgaris* (Lam.) Trevis., *Lapsana communis* L., *Petasites hybridus* (L.) P. Gaertn., *Berberis vulgaris* L., *Lithospermum purpureocaeruleum* L., *Myosotis alpestris* F. W. Schmidt, *Campanula glomerata* L., *Campanula latifolia* L., *Carpinus betulus* L., *Euphorbia amygdaloides* L., *Astragalus glycyphyllos* L., *Vicia cassubica* L., *Vicia grandiflora* Scop., *Calamintha nepeta* (L.) Savi, *Mentha aquatica* L., *Salvia glutinosa* L., *Fraxinus excelsior* L., *Sorbus torminalis* (L.) Crantz

4- Euro-Siberian/Mediterranean elements: *Polypodium interjectum* Shivas, *Taxus baccata* L., *Anthriscus cerefolium* (L.) Hoffm., *Tordylium maximum* L., *Vinca herbacea* Waldst. & Kit., *Linosyris vulgaris* Cass. ex Less., *Alnus glutinosa* (L.) Gaertn., *Cerinthe minor* L., *Alyssum alyssoides* (L.) L., *Campanula rapunculus* L., *Agrostemma githago* L., *Moehringia trinervia* (L.) Clairv., *Petrorhagia prolifera* (L.) P. W. Ball & Heywood, *Silene conica* L., *Scabiosa columbaria* L., *Trifolium arvense* L., *Vicia pannonica* Crantz, *Geranium purpureum* Vill., *Lamium purpureum* L., *Epilobium montanum* L., *Polygonum mite* Schrank, *Potentilla micrantha* Ramond, *Ulmus minor* Mill., *Parietaria officinalis* L., *Carex remota* L., *Juncus maritimus* Lam., *Luzula forsteri* (Sm.) DC., *Cephalanthera damasonium* (Mill.) Druce, *C. rubra* (L.) Rich., *Epipactis microphylla* (Ehrh.) Sw., *Limodorum abortivum* (L.) Sw., *Orchis coriophora* L., *O. simia* Lam., *Platanthera bifolia* (L.) Rich.

5- Euro-Siberian/Mediterranean/Irano-Turanian elements: A considerable number of Hyrcanian species have a common distribution in the Irano-Turanian, Mediterranean and Euro-Siberia area. Examples are: *Falcaria vulgaris* Benth., *Anthemis altissima* L., *Chondrilla juncea* L., *Filago arvensis* L., *Inula oculus-christi* L., *Lactuca serriola* L., *Arabis glabra* (L.) Bernh., *Arabis nova* Vill., *Erophila verna* (L.) Chevall., *Rapistrum rugosum* (L.) All., *Sinapis arvensis* L., *Thlaspi perfoliatum* L., *Arenaria leptoclados* (Rchb.) Guss., *Silene latifolia* Poir., *Stellaria pallida* (Dumort.) Piré, *Cuscuta europaea* L., *Dipsacus laciniatus* L., *Euphorbia falcata* L., *E. virgata* Waldst. & Kit., *Lathyrus aphaca* L., *L. hirsutus* L., *Securigera varia* (L.) Lassen, *Trifolium pratense* L., *Trifolium resupinatum* L., *Vicia narbonensis* L., *V. peregrina* L., *Fumaria densiflora* DC., *Geranium divaricatum* Ehrh., *G. rotundifolium* L., *Melissa officinalis* L., *Linum austriacum* L., *Epilobium parviflorum* Schreb., *Orobanche alba* Stephan, *Adonis aestivalis L.*, *Agrimonia eupatoria* L., *Potentilla reptans* L., *Rosa canina* L., *Rubus caesius* L., *Galium spurium* L., *Salix alba* L., *Kickxia elatine* (L.) Dumort., *Veronica hederifolia* L., *Solanum dulcamara* L., *Thymelaea passerina* (L.) Coss. & Germ., *Carex otrubae* Podp., *Orchis palustris* Jacq., *Bromus sterilis* L., *Milium vernale* M. Bieb., *Phleum pratense* L., *Sclerochloa dura* (L.) P. Beauv.

6- Pluri-regional species and widespread subcosmopolitan/cosmopolitan elements: These species occur mostly as weeds and ruderal plants in the area or as hygrophilous and aquatic plants. Examples are *Asplenium adiantum-nigrum* L., *Polystichum aculeatum* (L.) Roth, *Equisetum ramosissimum* Desf., *Cystopteris fragilis* (L.) Bernh., *Matteuccia struthiopteris* (L.) Tod., *Polypodium vulgare* L., *Pteridium aquilinum* (L.) Kuhn, *Berula angustifolia* (L.) Mert. & W. D. Koch., *Conium maculatum* L., *Torilis arvensis* (Huds.) Link, *Torilis japonica* (Houtt.) DC., *Artemisia scoparia* Waldst. & Kit., *Asteriscus spinosus* (L.) Sch.-Bip., *Carpesium abrotanoides* L., *Hieracium umbellatum* L., *Sonchus oleraceous* L., *Tanacetum parthenium* (L.) Sch.-Bip., *Eruca sativa* Mill., *Asperugo procumbens* L., *Kochia scoparia* (L.) Schrad., *Lotus corniculatus* L., *Medicago lupulina* L., *Trigonella foenum-graceum* L., *Hypericum perforatum* L., *Origanum vulgare* L., *Prunella vulgaris* L., *Viscum album* L., *Lythrum salicaria* L., *Circaea lutetiana* L., *Chelidonium majus* L., *Polygonum convolvulus* L., *Anagallis arvensis* L., *Samolus valerandi* L., *Ranunculus sceleratus* L., *Thalictrum minus* L., *Galium aparine* L., *Hyoscyamus niger* L., *Tribulus terrestris* L., *Alisma lanceolatum* With., *Schoenoplectus mucronatus* (L.) Palla, *Juncus effusus* L., *Epipactis helleborine* (L.) Crantz, *Listera ovata* (L.) R. Br., *Bothriochloa bladhii* (Retz.) S. T. Blake, *Calamagrostis epigejos* (L.) Roth, *Dactylis glomerata* L.

7. Neophytes: *Amaranthus albus* L., *A. cruentus* L., *A. retroflexus* L., *A. viridis* L., *Conyza canadensis* (L.) Cronquist, *Conyzanthus squamatus* (Spreng.) Tamamsch., *Azolla filiculoides* Lam., *Euphorbia nutans* Lag., *E. heterophylla* L., *Phytolacca americana* L.

Vegetation

Followings are the main vegetation types are found in the Caspian area. Details on the vegetation can be found in given references. The vegetation map of Caspian area is given in Fig. 2 according to Frey & Kürschner (1989).

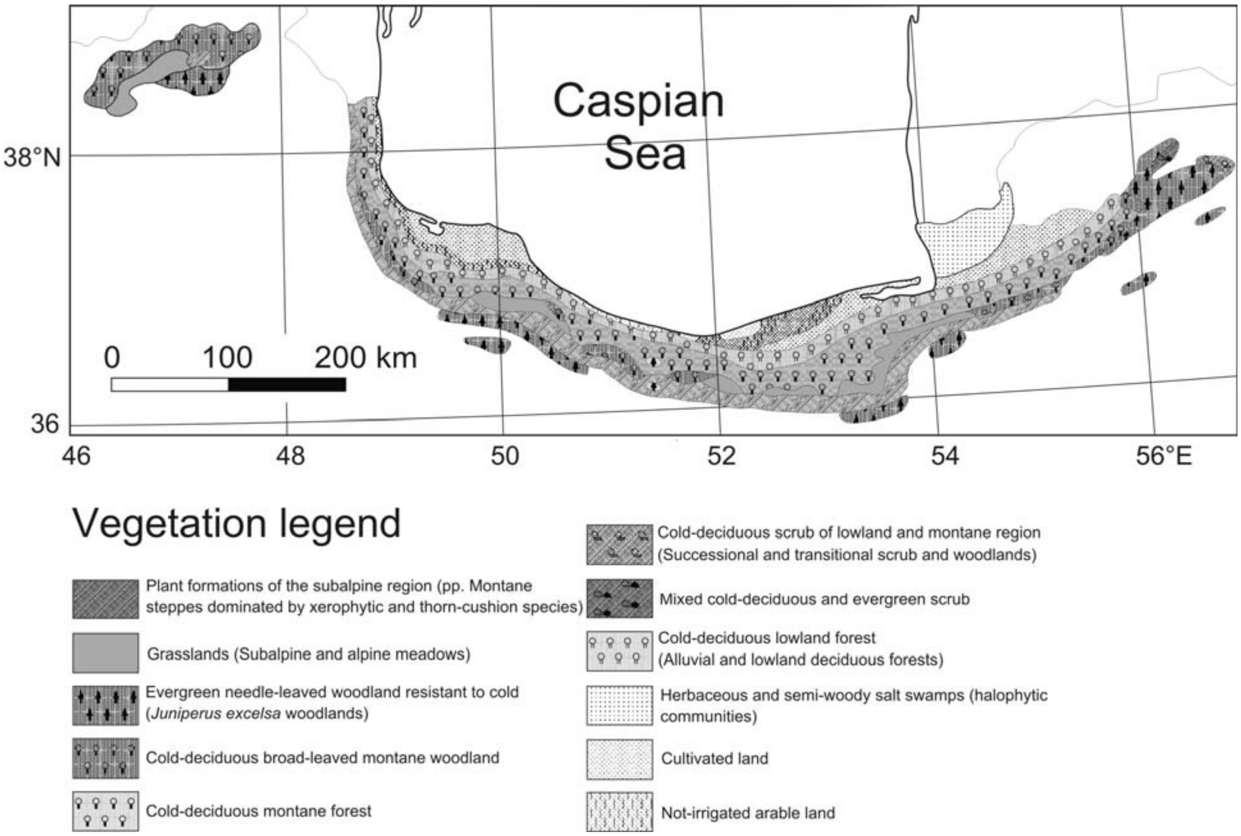

Fig. 2. Vegetation map of northern Iran (adopted from Frey & Kürschner, 1989).

1. ***Sand dune vegetation along the Caspian Sea*****:** Large parts of sandy dunes along the coast have been degraded and fragmented due to intensive urbanization, transforming into agricultural lands and industry. In the easternmost coasts of the south Caspian Sea there are still some parts with well preserved sand dune vegetation. The salty coasts consisted of a few species such as *Arguzia sibirica* (L.) Dandy, *Convolvulus persicus* L. and *Cakile maritima* Scop.. The sand dune vegetation consists of typical psammophytes like *Artemisia tcherviniana* Besser (Fig. 3A), which associates with *Plantago psyllium* L., *Maresia nana* (DC.) Batt., *Medicago minima* (L.) Bartalini, *Daucus littoralis* Smith subsp. *hyrcanicus* Rech. f., *Corispermum orientale* Lam., *Agriophyllum squarrosum* (L.) Moq., *Cutandia memphitica* (Spreng.) Benth., *Briza minor* L., *Trifolium campestre* Schreb. *Lophochloa phloides* (Vill.) Reichenb., *Vulpia persica* (Boiss. & Buhse) V. I. Krecz., *Carex distans* L., *Corynephorus articulatus* (Desf.) P. Beauv., *Digitaria sabulosa* Tzvelev**,** and a large number of ruderals including *Xanthium strumanium* L., *Conyza canadensis* (L.) Cronquist, *Salsola tragus* L., *Tribulus terresteris* L., *Artemisia annua* L., *Abutilon theophrasti* Medicus, *Chenopodium album* L., *Solanum* spp., *Chrozophora tinctoria* (L.) A. Juss., *Paspalum dilatatum* Poir, *Datura stramonium* L. and *Rubus sanctus* Schreb.. The latter occurs as dense thickets in many dedgraded and non-degarded dunes which co-occur in the eastern parts with dense *Punica granatum* L.. A peculiar feature of sand dune vegetation of eastern parts of the S. Caspian coasts is the occurrence of C_4-dominated grasslands mostly occupied by *Imperata cyclindrica* (L.) P. Beauv. (Frey & Probst, 1974b; Akhani, 2003).

2. ***C_4-dominated grass communities on rocky outcrops:*** A combination of subtropical-like climatic conditions (high annual temperatures associated with summer rainfall) (Fig.

1), and suitable habitats on rocky outcrops located within the closed forests has provided good conditions for developing C_4 grass dominated ecosystems. The southern slopes of the low altitude steep rocky outcrops of the Golestan National Park and some fragmented spots along the eastern and central Alborz and Arasbaran forest provide microhabitats for C_4-dominated grasslands with scattered shrubs. The grass vegetation has similarities with tropical savanna but the scrub vegetation is composed of temperate elements such as *Carpinus orientalis* Mill., *Crataegus* spp., *Colutea buhsei* (Boiss.) Shapar., *Quercus castaneifolia* C. A. Mey., and *Celtis caucasica* Willd. The herbaceous and grass communities of these habitats are temporarily dominated by C_3 plants during spring and C_4 grasses during late summer and early autumn. Grasses like *Bothriochloa ischaemum* (L.) Keng, *B. bladhii*, *Cleistogenes serotina* (L.) Keng and *Heteropogon contortus* (L.) P. Beauv. are typical elements of this type of vegetation (Akhani & Ziegler, 2002; Barani & Ownegh, 2007).

3. ***Aquatic vegetation on wetlands:*** There are many freshwater wetlands in Gilan and Mazandaran and several saline and brackish wetlands and lagoons in Golestan province and east of Mazandaran. Additionally, the rice fields and irrigation canals provide suitable habitats for aquatic flora. In most wetlands, *Phragmites australis* is the dominant element. Anzali and Amirkelayeh are two very large and most important freshwater areas in the Caspian lowlands where large numbers of the aquatic flora of Iran can be found. *Nelumbo nucifera* Gaertn. as an Indo-Malesian element occurs in Anzali wetland (Fig. 3B). The introduced invasive and extremely competitive fern *Azolla filiculoides* Lam. covers almost all wetlands and threatens most of the rare aquatic species (Hashemloian & Ataei Azimi, 2009; Khoshravesh *et al.*, 2009). Other well represented aquatic plants in the area are *Ceratophyllum demersum* L., *Schoenoplectus lacustris* (L.) Palla, *Iris pseudacorus* L., *Hydrocotyle ranunculoides* L., *H. vulgaris* L., *Lemna minor* L., *L. gibba* L., *L. trisulca* L., *Salvinia natans* (L.) All., *Spirodela polyrrhiza* (L.) Schleid., *Trapa natans* L., *Nymphaea alba* L., *Hydrocharis morsus-ranae* L., *Alisma plantago-aquatica* L., *Marsilea quadrifolia* L., *Nymphoides indicum* (L.) O. Kuntze, *Nasturtium officinale* R. Br., *Myriophyllum spicatum* L., *M. verticillatum* L., *Batrachium trichophyllum* (Chaix) Bossche, *Zannichellia palustris* L., *Sparganium erectum* L., *Typha latifolia* L., *Potamogeton* spp., *Sagittaria trifolia L.,* (Scott, 1989; Dianatnejad & Eftekhari, 1996; Asri & Eftekhari, 2002; Asri & Moradi, 2006). Sulukli lake, a recently discovered isolated wetland in Golestan National Park supports a large number of aquatic species in Caspian forest, several of them known only from this area in Iran (Akhani, 1998; Akhani & Scholz, 1998; Joharchi & Akhani, 2006).

4. ***Riverine and valley forests:*** The riverine vegetation in the Caspian forest is largely degraded by human impact and most importantly by dams. The hygrophilous trees like *Alnus glutinosa*, *Populus caspica* Bornm., *Salix aegyptiaca* L., *S. alba* L., *Pterocarya fraxinifolia*, *Acer velutinum* Boiss., *Diospyros lotus* L. are the most abundant species in such habitats (Fig. 4A). A well protected, 15-km long, riverine forest existed along a river passing through the Golestan National Park a few years ago. This site was largely destroyed by two successive floods in 2001 and 2002. Furthermore, road construction activities have disturbed establishment and succession process of this ecosystem. In deep valleys "Schlucht" the surrounding steep rocks and high moisture along the rivers provide unique ecosystems with shade tolerant species like *Danae racemosa* (L.) Moench and several fern species such as *Athrium filix-femina* (L.) Roth., *Dryopteris pallida* (Bory) C. Chr. ex Maire & Petit., *Polypodium vulgare* L., *Cystopteris fragilis* (L.) Bernh. and *Polystichum aculeatum* (L.) Roth (Khoshravesh *et al.*, 2009).

5. ***Alluvial and lowland deciduous forests:*** The alluvial forests of the South Caspian area are almost entirely replaced by cultural landscapes. Only small sites exist in some protected forests such as Khoshke Daran, Kelarabad, Namak-Abrud, Sisangan and Gisum in Gilan and Mazandaran Provinces. The arboreal elements in this vegetation type are comparable with the riverine forests and is composed mainly of *Alnus glutinosa* associated with *Populus caspica*, *Pterocarya fraxinifolia*, *Ulmus minor*, *Cornus australis*, *Alnus subcordata*, *Diospyros lotus*, *Buxus hyrcana* and *Ilex spinigera* (oder Alnetalia subcordatae) (Djazirei, 1965; Hamzeh'ee *et al*., 2008). The Hyrcanian endemic Alnus subcordata occurs mostly in monate zone of the hygrophilous communities. The lowland forests occur in altitudes up to 700 m and are dominated by summer green cold-sensitive species (Frey & Probst, 1974a). They further include thermophilous trees such as *Parrotia persica*, *Gleditsia caspica*, *Albizia julibrissin*, *Zelkova carpinifolia*, *Acer velutinum*, *Pterocarya fraxinfolia* together with species like *Quercus castaneifolia* and *Carpinus betulus* which penetrate into upper zone. The occurrence of several evergreen species such as *Hedera pastuchovii* Woron., *Ruscus hyrcanus* Woron. and *Buxus hyrcana* Pojark., *Danae racemosa*, and *Laurocerasus officinalis* Roemer determine the physiognomy of most of these forests (Rastin, 1983).

6. ***Submontane and montane deciduous forest:*** Although there is not a clear boundary between lowland and montane forests, we follow Frey and Probst (1974a) and consider the absence of thermophilous species in higher altitudes as a criterion which can separate the former zone with this vegetation type. A transition zone (i.e. submontane forests) exists in which density and abundance of thermophilous species decline and more cold tolerant species prevail. Locally, the amount of rain and clouds increases in the montane zone (Frey & Probst, 1974a). In the eastern parts of the Caspian forests, *Quercus castaneifolia* and *Carpinus betulus* dominate large parts of this transition zone at elevations between ca. 700 to 1400 m (Fig. 4B). The montane forests are located above the transition zone and are characterized by rather dense understory vegetation. The understory vegetation is composed of grasses (*Poa nemoralis* L. and *Festuca drymeia* Mert. & Koch), ferns (*Drypoteris caucasica*, *Athyrium filix femina*) and *Ilex spinigera* and large number of cold resistance trees such as *Carpinus betulus*, *Sorbus torminalis*, *Ulmus glabra*, *Tilia caucasica*, *Fraxinus excelsior*, *Acer hyrcanicum* (Akhani, 1998). In central and western Caspian forests the montane and submontane zones are mostly dominated by Fagus orientalis (Fig. 4C) (Mobayen & Tregubov, 1970; Asli & Nedialkov, 1973).

7. ***Subalpine deciduous forest (*****Quercus macranthera*****):*** The uppermost zone of montane forests is replaced by subalpine forest above 1800 m and stretches up to 2500 m and occasionally to 2800 m (Fig. 5A). The Euxino-Hyrcanian species Quercus macranthera Fisch. & C. A. Mey. occurs along the high altitude forests of Alborz and is associated with Acer hyrcanicum, A. *monspessulanum* L., *A. campestre* L., and *Sorbus torminalis* (Akhani, 1998). The association *Aceri-hyrcani–Quercetum macrantherae* Klein et Lacoste was described from Central Alborz (Djirchal) with three subassociations (Klein & Lacoste, 1989). Due to particular topographic and orographic structure, and further intensive tree cutting, grazing and browsing, the subalpine oak forest is fragmented and receives much sunshine. Trees are small and their open intervals are covered by various montane steppe vegetation types of the Irano-Turanian zone, transitional scrubs and meadows of the Euro-Siberian zone.

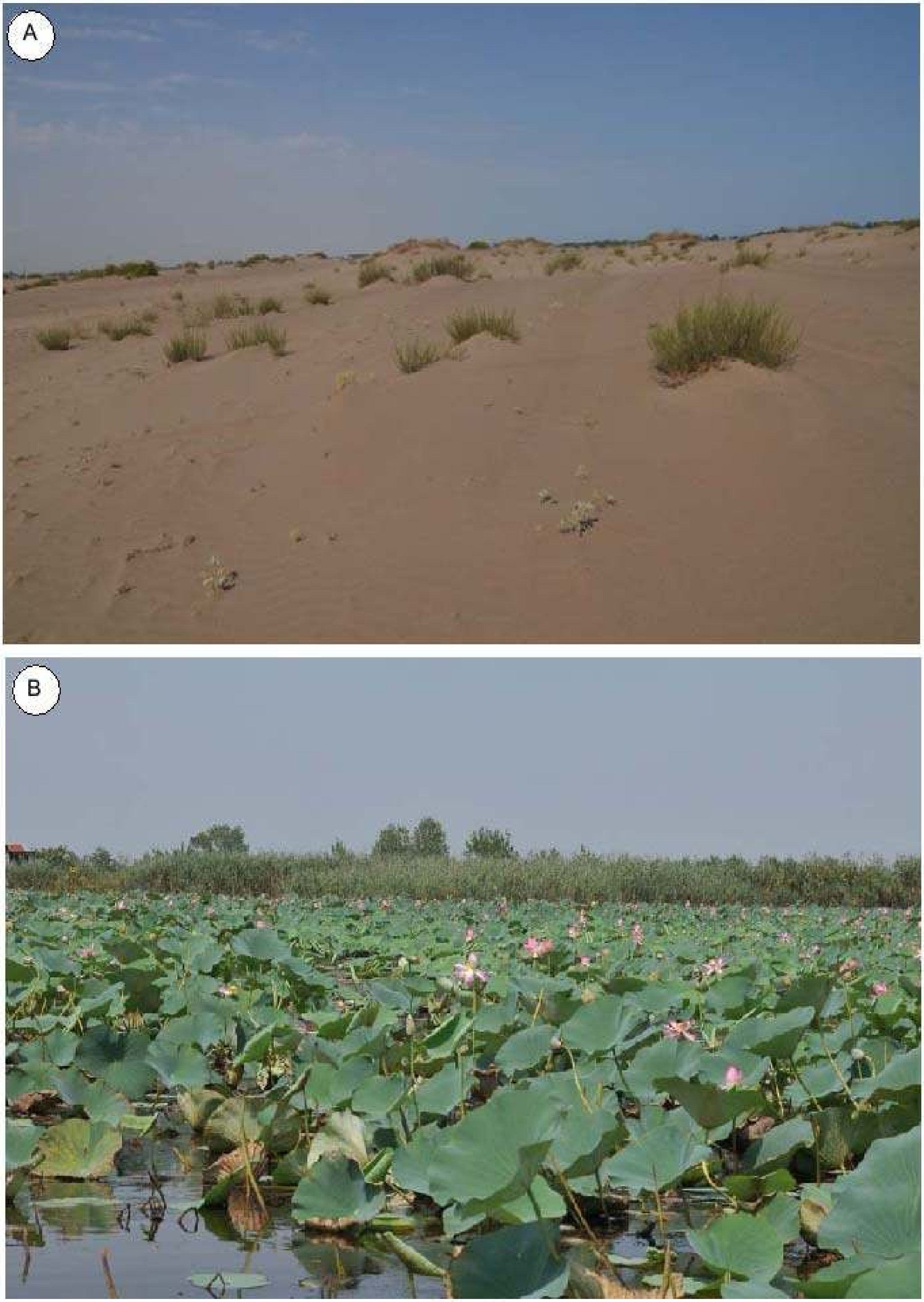

Fig. 3. A. Coastal sand dunes, ca.15 km E of Babolsar, dominated by *Artemisia tcherviniana*, *Agriophyllum squarrosum*, *Chrezophora tinctoria*; B. *Nelumbo nucifera*, Anzali wetland.

8. ***Successional and transitional scrubs and woodlands:*** The scrub and woodland vegetation in the Caspian forests have three main origins (Akhani, 1998):

a) *Transitional origin*: towards drier habitats and higher altitudes, the closed forests are usually surrounded by transitional scrubs. The timber-line and shrub-line in Alborz mountains varies from 2200 to 3000 m (Noroozi *et al.*, 2008) (Fig. 5A). The transitional scrub in this zone mainly consists of *Juniperus communis* L. subsp. *nana* (Willd.) Syme, *J. sabina* L., *Carpinus orientalis, Lonicera iberica* M. Bieb., *Ribes melananthum* Boiss. & Hohen. and *Rhamnus cathartica* L.. A transitional shrubland dominated by *Paliurus spina-christi* Mill. (Fig. 5C), *Crataegus azarolus* L. var. *pontica* (K.Koch) K.I.Chr., *C. pentagyna* Waldst. & Kit. ex Willd., *Acer monspessulanum* L. subsp. *turcomanicum* (Pojark.) Rech. f. has been established in a zone of reduced rainfall in the east of the south Caspian forests.

b) *Edaphic origin*: in most parts of the Hyrcanian forest zone, the closed forests are interrupted by steep rocky slopes. The rocky substrate without a distinct or only a thin soil layer favor the establishment of xerophytic shrubs such as *Carpinus orientalis*, *Crataegus*

c) *Successional origin*: this type of shrubland can be found in agricultural and previous settlement areas whose vegetation is regenerated after protection. In Golestan National Park, large areas of previously agricultural lands and residential area are now regenerated by formation of *Paliurus spina-christi*, *Prunus divaricata, Rubus sanctus* and *Crataegus pentagyna* scrubs.

9. Cupressus sempervirens ***and*** **Thuja orientalis** ***woodlands:*** The Cypress open woodlands occur in rain shadow of deep valleys cutting the Alborz range in Chalus (Hassan Abad, close to Marzanabad, Fig. 5A), Sefidrud valley near Rudbar and Manjil, and Sourkesh forest near Katool valley (Gorgan) (Sabeti, 1976; Razavi & Hassan Abbasi, 2009). The Mediterranean-type climate of this zone is characterized by vigorous olive (*Olea europaea*) plantations and occurrence of some typical Mediterranean elements such as *Myrtus communis*, *Jasminum fruticans*, *Asteriscus spinosus*, and *Salvia viridis*. In east of Gorgan, near Fazelabad, small stands of natural *Thuja orientalis* forest occur in local Mediterranean climatic conditions (Hosseini & Mirkazemi, 2003).

10. ***Juniper woodlands:*** *Juniperus excelsa* woodlands are typical of the Irano-Turanian area and occur in the southern slopes of Alborz Mountains and Khorassan-Kopedagh Mountains in the NE Iran and neighbouring Turkmenistan. Among the sites with juniper as a major component in the eastern part of the Caspian zone are Jahan Nama Protected area, Golestan National Park (Jafari & Akhani, 2008) and, further to the east, Qorkhod Protected Area with very dense *Juniperus excelsa* woodlands. In the road between Galoogah and Damghan (Mazandaran and Semnan provinces), the subalpine forests connect with *Juniperus excelsa* woodlands.

Fig. 4. A. Riverine forests dominated by *Pterocarya fraxinifolia* and *Alnus glutinosa*, between Fuman and Masooleh, Gilan; B. *Carpinus betulus* and *Quercus castaneifolia* dominated montane forest, Golestan National Park; C. *Fagus orientalis* foggy forest between Fuman and Khalkhal (13.5.2009).

11. ***Subalpine and alpine meadows:*** The subalpine and alpine meadows occur above the timber-line in the northern slopes of the Alborz Mountains in places with a well developed soil layer. Such areas are usually covered by snow throughout winter which may remain to mid-spring and even later to early summer depending on altitude, exposure and annual temperature fluctuation. The meadows comprise grass species (*Poa*, *Festuca*, *Phleum*, *Elymus*, *Koeleria*) and hemicryptophytes and geophytes like *Rumex*, *Primula*, *Fritillaria, Ranunculus, Anemone, Thalictrum, Draba, Arabis, Potentilla, Alchemilla, Plantago, Androsace, Helichrysum, Leontodon, Scilla* and *Scabiosa* (Frey & Probst, 1974a) (Fig. 6A). The association *Alchemilletum plicatissimae* Klein et Lacoste was described from the central Alborz at 2400-3200 m elevations (Klein & Lacoste, 1994) which represent the easternmost fringes of the *Festuco-Brometea*.

12. *Montane steppe dominated by xerophytic and thorn-cushion species:* The xerophytic communities dominated by thorn-cushion formations are not typical of Hyrcanian forest zone. These typical Irano-Turanian plant formations cover stony and gravelly ground towards the southern slopes of the Alborz or on exposed mountain summits along the Alborz ranges. They are covered by thorny subshrubs belonging to *Astragalus*, *Acantholimon*, *Acanthophyllum*, *Onobrychis cornuta, Arenaria* and non-thorny cushion forms such as *Aethionema grandiflora*. Detailed description of this type of vegetation are given by (Klein, 1994) who described these communities under *Onobrychidetea cornutae*. The montane steppes are also rich in tall herbaceous and thorny hemicryptophytes such as *Prangos*, *Ferula*, *Verbascum*, *Cousinia*, *Echinops*, *Hypericum, Eremostachys* and *Salvia*, and grasses such as *Festuca sclerophylla*, *F. arundinacea*, *Psathyrostachys fragilis* and *Elymus longearistatus*.

13. Rock cliff communities. The Hyrcanian cliff flora and vegetation is highly interesting in that they support many endemics and relict species such as *Crucianella platyphylla* Ehrend. & Schönb.-Tem., *Ferula laseroides* (Akhani) Spalik et S. R. Downie (=*Leutea laseroides* Akhani), *Ferula glaucopruinosa* (Rech.f.) Akhani (=*Peucedanum glaucopruinosum* Rech.f.), *Dionysia aretioides* (Lehm.) Boiss., *Viola spathulata* Willd., *Eriocycla ghafooriana* Akhani, *Campanula lourica* Boiss., *Allium vavilovii* Popov & Vved. and *Andrachne colchica* Fisch. & C. A. Mey. The cliff vegetation is less investigated because of its physical inaccessibility. In Golestan National Park, the cliffs are represented by scattered shrubs mostly composed of *Carpinus orientalis*, *Rhamnus pallasii, Celtis caucasica* and *Ficus carica*. The low altitude cliffs are dominated by thermophilous species, mostly C_4 grasses, but in the higher altitudes the relict species *Ferula laseroides* and *Crucianella platyphylla* occur (Akhani & Ziegler, 2002). The vertical cliffs of Jahan Nama Protected area have *Crucianella platyphylla*, *Saxifraga wendelboi* Schönb.-Tem. In the central Alborz near Sangdeh and Takhte Soleyman the association *Saxifragetum iranicae* Klein was described in which several chasmophytic species such as *Erigeron hyrcanicus* Bornm. et Vierh., *Saxifraga iranica* Bornm., *Potentilla cryptophila* Bornm. and *Paraquilegia caespitosa* (Boiss. et Hohen.) Drumm. et Hutch occur (Klein, 1982). *Gypsophila aretioides* is a cliff species occuring on exposed mountain peaks, rocky timber-line, and vertical cliffs. It forms very dense, large and hard mats.

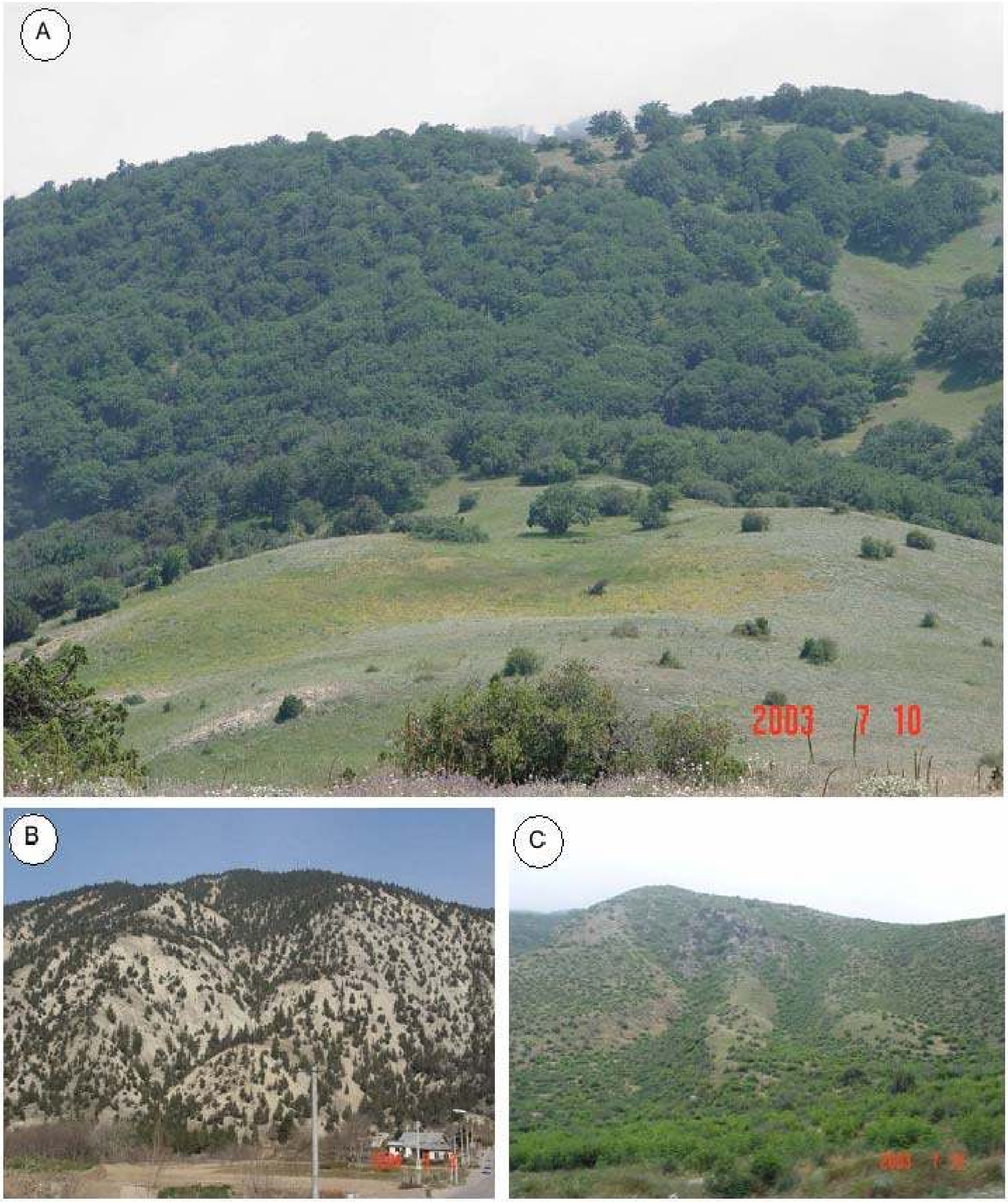

Fig. 5. A. *Quercus macranthera* forest, Divar Kaji, 2200 m, Golestan National Park, B. *Cupressus sempervirens* woodland, Marzanabad, Chalus valley C. *Paliurus spina-chisti* scrub, Golestan National Park, near Sharlegh, 900-1000 m, transition between forest and steppe.

14. ***Halophytic communities:*** The high rainfall over the central and western parts of the south Caspian lowlands provides few habitats for halophytes. Only a few salt tolerant psammophytes grow in a narrow strip close to the shores such as *Arguzia sibirica* (L.) Dandy, *Convolvulus persicus* L., *Cakile maritima* Scop., *Paspalum dilatatum* Poir and *Salsola tragus* L. The reduction of precipitation in the southeastern parts of the Caspian Sea (e.g. 462 mm/yr in Bandar Torkman) and reduction of water depth around Gorgan bay and Gomishan lagoon provide suitable habitats for halophytes. Large *Phragmites* *australis* communities grow inside and around the bay and lagoon, with dense communities of submerged aquatics like *Potamogeton* spp., (Gomishan Lagoon) and *Ruppia maritima* (Gorgan Bay). The tidal zone is composed of *Salicornia* sp.c., *Aster tripolium* L. and *Suaeda crassifolia* Pall. Furthermore, species of *Juncus*, *Typha*, *Tamarix* and *Alhagi maurorum* Medik. cover large saline soils around the Gorgan Bay. The Gomishan lagoon surrounded seawards by an island-like narrow strip which is completely protected from grazing. A unique halophytic vegetation occurs where halophytic grasslands of *Puccinellia distans* (L.) Parl. are developed over a large area with 100% coverage. The lowlands of the northern Gorgan (Turkman Sahra) are semi-arid and the entire area has salty soils where large number of halophytes constitute extensive halophytic communities including a very dense unique community of *Psylliostachys spicata* (Willd.) Nevski, not seen in other part of Iran.

15. Areas of Artemisia spicigera steppes and desert like dunes: *Artemisia* steppe is typical vegetation of the interior and Irano-Turanian parts of Iran. In some rain-shadow parts of the Caspian area (e.g. between Polsefid and Firuzkuh and 45 km S. Amol in the Haraz road) large areas are covered by *Artemisia spicigera* C. Koch and associate with *Salsola montana* Litw. (= *S. masenderanica* Botsch.) and *Krascheninnikovia ceratoides* (L.) Gueldenst. The formation of *Artemisia* communities in Northern Iran may be interpreted by the long-term land use of cutting the Mediterranean elements like *Cupressus sempervirens*, and may represent refugees from drier periods. The soil salinity of the substrate is an explanation for the occurrence of halophytes and salt tolerant species which are well represented near Manjil, where *Suaeda dendroides* (C. A. Mey.) Moq., *Kaviria tomentosa* (Moq.) Akhani [= *Salsola tomentosa* (Moq.) Spach] and *Halimocnemis rarifolia* (C. Koch) Akhani [= *Halanthium rarifolium* C. Koch], *Reaumuria alternifolia* (Labill.) Britten grow on halo-gypsum hills.

Similarly, small areas of desert like dunes occur in the Sefid-Rud valley near Rudbar, where a number of interesting desert growing species such as *Calligonum persicum* (Boiss. & Buhse) Boiss., *Heliotropium aucheri* Moq. (described as independent taxon under *H. minutiflorum* Bunge var. *rudbaricum* Bornm.), *Corispermum aralocaspicum* Iljin occur. This type of vegetation was almost completely destroyed by the recent construction of a highway connecting Tehran and Rasht.

16. Ruderal habitats: The intensive human impact on all types of vegetation has caused colonization of ruderal species all around the south Caspian forests. Ruderal species occur in dried rivers, deforested areas, around cultivated lands, and urbanized and industrialized regions. The climatic peculiarities of the area favours a large number of weedy, introduced, invasive and ruderal species of tropical or temperate origin. The Irano-Turanian flora of the Iranian highlands provides a major source of invaded species which favour open habitats analogous to the drier parts of Iran. During summer time, many C_4 weedy and ruderal grasses like *Setaria* spp., *Digitaria* spp. *Paspalum* spp., *Cynodon dactylon*, *Bothriochloa ischaemum*, *Sorghum halepense*, *Imperata cylindrica* occur in gardens, coastal dunes, and around agricultural areas. The overgrazed montane forests and meadows are covered by dense communities of *Stachys byzantina*. Degraded forests and nitrified habitats around forests are covered by *Pteridium aquilinum*, *Artemisia annua*, *Conyza canadensis, Conyzanthus squamatus, Sambucus ebulus, Urtica dioica, Marrubium vulgare, Phytolacca americana*, and *Lythrum salicaria* (Fig. 6B). The latter mostly occurs around rice fields and road sides where more water is available.

17. Cultural landscapes and artificial forests: The south Caspian area is an important centre for the domestication of cultivated trees and shrubs (Khoshbakht & Hammer, 2006). The agricultural area of the south Caspian zone plays an important role in the agronomy of Iran. The very rich soils of the alluvial South Caspian lowlands provide extensive agronomic activities including rice, wheat, colza, citrus fruits, kiwi, peach, strawberry and tea cultivations (Fig. 6C). Olive is a major product of the local Mediterranean bioclimatic zones of the area which is concentrated mostly in Sefid-Rud valley and Gorgan.

The history of re- and afforestation activities goes back to 1952. Thereafter, many exotic trees along with a few native species have been planted in the area either for commercial or ornamental purposes. Among them are: *Pinus brutia* subsp. *eldarica*, *Eucalyptus* spp., *Robinia pseudoacacia*, *Cryptomeria japonica*, *Taxodium distichum*, *Cupressus sempervirens*, *Populus nigra*, *Ailanthus altissima*, and *Picea abies* (Rezaiee, 2000; Gorji Bahri, 2004).

Vegetation history and Quaternary paleoecology

The occurrence of many Arcto-Tertiary relict elements, such as *Zelkova carpinifolia, Parrotia persica*, and *Pterocarya fraxinifolia*, has led biogeographers to the consensus that the Caspian forest has been an important refugium of temperate broad-leaved trees during the Quaternary glaciations (Tralau, 1963; Zohary, 1973; Probst, 1981; Leroy & Roiron,1996; Leroy & Arpe, 2007). The main difference between Tertiary and Holocene forests of N America and southeast Asia is the impoverished species diversity in the latter group due to the Pleistocene glaciations. Fossil records from Willerhausen near Göttingen show that 29 species of the area are identical with living Caspian tree elements and 16 species are almost identical (Probst 1981). It is supposed that the late Tertiary climate of the Iranian highlands, particularly in the north and northwest, was more humid favouring the extension of forests elements more pronouncedly than today. The discovery of *Pterocarya fraxinifolia* in the Zagros mountains in western Iran is potential evidence of such wetter climates (Akhani & Salimian, 2003). Still, little effort has so far been undertaken to elucidate the Pleistocene and Holocene vegetation history of this region.
Earlier investigators on the extent of contemporaneous and Pleistocene glaciations in Iran concluded that the climatic snow-line during the Pleistocene was 600 to 1100 m lower than the present level (Bobek, 1937). It was also postulated that the temperature structure was similar to today except that the mean temperature was 4 to 5 °C lower and the precipitation/evaporation ratio was higher (Ferrigno, 1988). However, these estimates seem to have underestimated the real extent of glaciations of Iran as given in the most detailed glacio-geomorphological study of Iran (Kuhle, 2008); the snowline descent has been estimated approximately 1400 to1600 m with temperature decline of 11 to 15 °C in Zagros. Based on Bobek (1953-1954), a markedly dry period prevailed from ca. 9,000 – 4,000 BC for the south Caspian area, parallel to the climatic optimum in Europe Bobek, (1953-1954). Similarly, Kazancı *et al*., 2004) concluded from a study on the sedimentary and environmental characteristics of Lake Anzali in northern Iran that a dry, wind-dominated climate prevailed in that region at 10,000-8,000 BP. This period roughly corresponds to the early Holocene drier conditions in the Zagros-Anti-Taurus mountains in W Iran and SE Turkey (Djamali *et al.*, 2010).

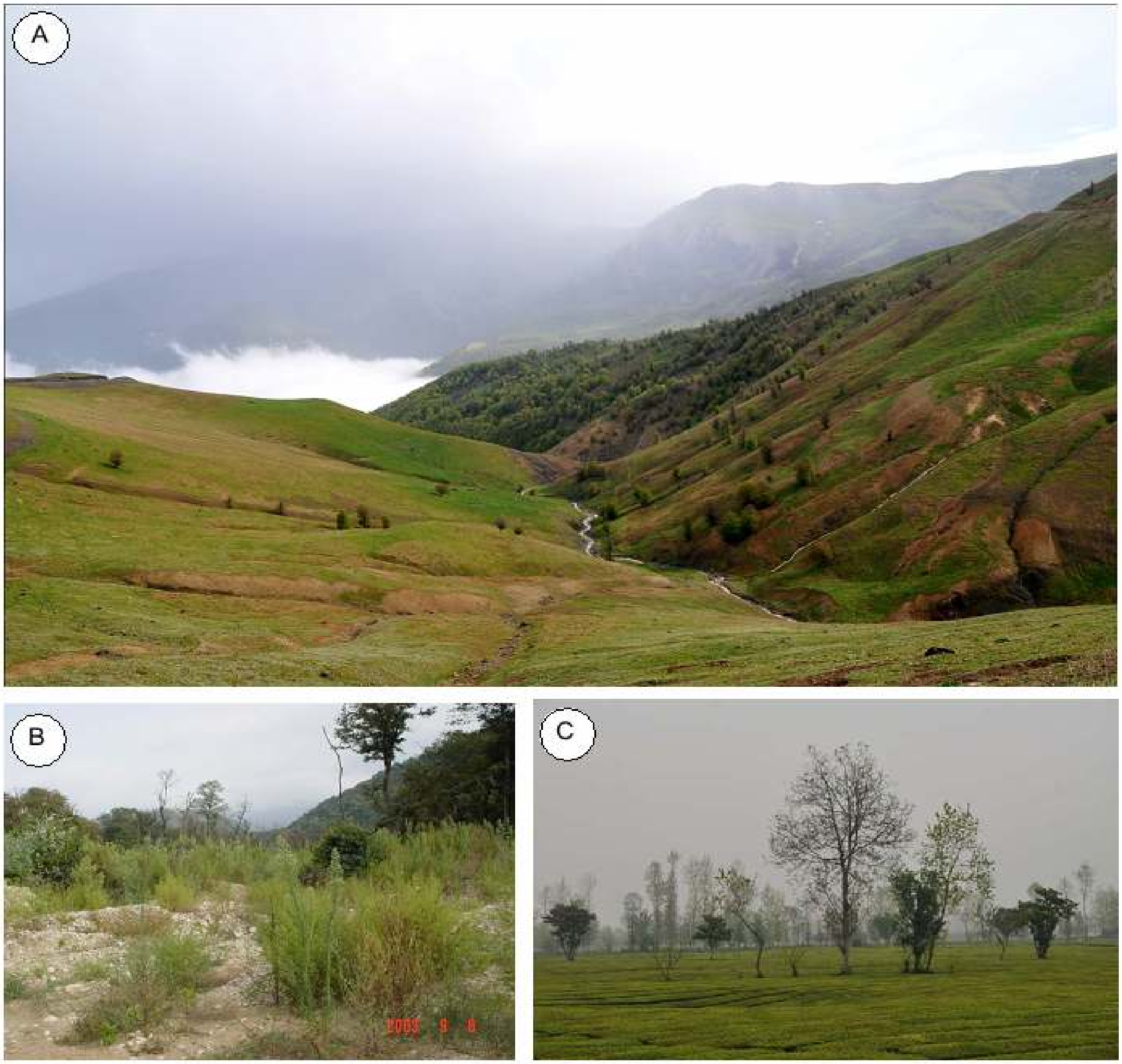

Fig. 6. A. Timber-line and alpine grassland in E of Masooleh towards Khalkhal, 2150 m; B. Ruderal community dominated by *Conyza canadensis* in flooded river bed in Golestan National Park, C. Tea plantation between Fuman and Massoole with scattered *Populus nigra* trees.

To our knowledge, the earliest palynological study in northern Iran was made by von der Brelie (1961) on early-Pleistocene sediments of the palaeolake Lar (2600 m; Figure 1), situated in the climatically dry south slope of the Damavand volcano. Although no palynogram was constructed because of insufficient pollen content von der Brelie(1961) concluded that the vegetation around the lake was steppe-like and the climate was slightly warmer than today.

The Middle-Pleistocene and Holocene climate change, short- to long-term Caspian Sea-level fluctuations, and the late-Holocene vegetation history in N Iran have recently been reconstructed using a range of archives, including marine and lake sediments (Mamedov, 1997; Kazancı *et al.*, 2004 ; Leroy *et al.*, 2007), loess deposits (Barbier, 1960; Lateef, 1988; Okhravi & Amini, 2001; Kehl *et al.*, 2005; Frechen *et al.*, 2009), and peat/lake deposits (Ramezani *et al.*, 2008).

It was revealed from the study of loess/palaeosol sequences of the Caspian lowlands that during the Pleistocene glaciations, N Iran was an area of increased dust accumulation and loess formation similar to SE Central Europe and Central Asia (Kehl *et al.*, 2005; Frechen *et* *al.*, 2009). The stratigraphy of these loess deposits is characterized by the alternation of thick loess deposits intercalated with periods of whether strongly-developed or weakly-developed soil horizons. While the loess units were deposited during the dry glacial intervals, the soil horizons formed during the interglacial and interstadial periods depending on their degree of development. It should be noted that loess deposits are allogenic glacial sediments originating from central and northern Eurasia (Okhravi & Amini, 2001) during the glacial periods and do not necessarily offer information about local temperature and precipitation regimes in northern Iran. They indicate, however, that strong north-easterly dust-loaded winds affected the south Caspian region during the Pleistocene glaciations. The present state of knowledge on the Quaternary climate change in Iran has recently been reviewed by Kehl (2009).

In the eastern limits of Hyrcanian forests, a short pollen diagram from Lake Sulukli located in Golestan National Park (Djamali, unpublished data) indicates the replacement of a steppe (characterized by *Artemisia*, Chenopodiaceae, and *Ephedra* pollen) with a closed forest ecosystem (dominated by *Quercus* and *Carpinus*) at a recent time (certainly before 450 cal yr BP): This dramatic change might have been caused by both a decreasing anthropogenic pressure and the natural recolonization of previously strongly grazed lands and/or a recent dramatic climatic event favoring the forest expansion. Low quality of pollen preservation in the lowest half of this pollen record precludes giving a more detailed vegetation picture of the area.

Palynological reconstruction of forest history deduced from a pollen profile of peat deposits of a small mire (EIG mire; 550 m a.s.l.; Nowshahr forest, Mazandaran province) in central parts of the Caspian forests, has shown long-term continuity of forest cover over the past millennium, with some imprints of climate and man on the vegetation (cf. (Ramezani *et al.*, 2008). A simplified pollen diagram of the corresponding mire is shown in Fig. 7.

The EIG pollen record starts with an erosional event (Zone EIG-A, before 1100 AD) that falls in the "Medieval Climatic Anomaly", a period with significantly higher temperatures and prolonged droughts in some areas and exceptional rains in others (Bradley *et al.*, 2003). Also tree ring data of (Touchan *et al.*, 2007) suggest a concentration of wet years in southwestern Anatolia in the 11th century. Furthermore, the formation of the basin, probably as a result of intensified karstification, is an indication of radical hydrological changes during that period.
Overall, *Alnus* and *Carpinus* have been the most prominent taxa in the vicinity of the mire over almost the whole period. Also *Quercus, Ulmus,* and *Parrotia* appear to have been continuously but less predominantly present, while *Fagus, Pterocarya, Acer,* and *Diospyros* display distinct fluctuations (Ramezani *et al.*, 2008). A remarkable and still puzzling feature concerning forest composition changes is the case of *Pterocarya cf. fraxinifolia*. All pollen diagrams, so far produced for the central parts of the Caspian forests, i.e. EIG, MZG (cf. Ramezani, 2009), and PHL (Ramezani, unpublished data) have shown a "*Pterocarya* decline at around 1200-1000 cal. yr BP. Similarly, *Pterocarya* prevailed in Colchis area (western Georgia) in the same period but was followed by a sharp decline afterwards (cf. Connor *et al.*, 2007; De Klerk *et al.*, 2009). As *Pterocarya* is primarily a riparian element, this evidence may point to a regional climatic phenomenon, through which a wet climate shifted to a drier environment and decreased fluvial activities.

The extent and intensity of early human interference the forest composition and structure are not fully detected yet. Archaeological finds of wood-cutting for metal smelting in the central Caspian forests suggest anthropogenic impacts since at least 1500-2000 BC (Dr. Seyed Mehdi Mousavi, Tarbiat Modarres University, Iran, personal communication, 2007). Historical records also provide evidence for long-term human habitation in the Caspian coastal areas in Chalus (Mahjoori, 2002).

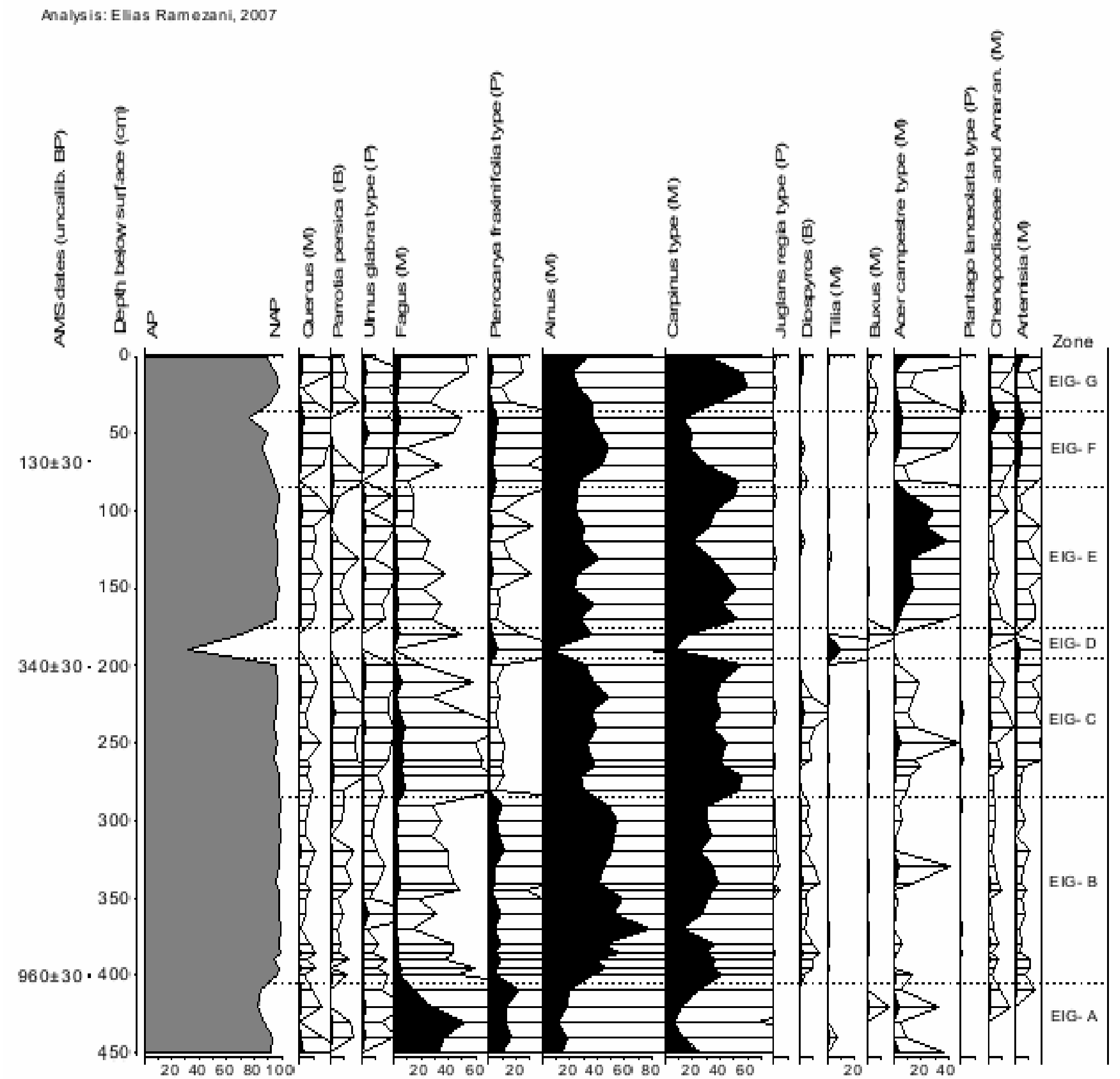

Fig. 7. Simplified pollen diagram from the EIG site (Cortesy of the Holocene, Ramezani *et al.* 2008).

The early human presence in the Caspian lowlands has also been palynologically evidenced by the occurrence of *Juglans* pollen since ca. 2,300-2,200 cal. yr BP (Ramezani, 2009).Increased non-arboreal pollen (NAP) values in the existing pollen diagrams, i.e. EIG and DJM (Ramezani, 2009), from the central Caspian forests suggest intensified human impact since the beginning of the nineteenth century. Further to the west, a large-scale deforestation of *Alnus* forest around Amirkelayeh wetland is also evident in a pollen diagram (Leroy *et al.*, unpublished data) indicates that the lowland forest was the subject of stronger human impact. Similar broad-scale human impacts have been described for the lowlands of Colchis, where forest cover was largely destroyed and replaced with plantations of tea, citrus, etc. in the twentieth century (Connor *et al.*, 2007; de Klerk *et al.*, 2009).

The perspectives for further palaeoecological research of the late-Quaternary vegetation history of the Hyrcanian region are very promising. Preliminary results of a recently (Ramezani, 2008) investigated site in the central Hyrcanian forest have enabled us to reconstruct the palaeoecological history of the area since the Last Glacial Maximum (LGM). In the eastern Hyrcanian forest, the retrieval of a few mid- to late Holocene sediment cores with a relatively good pollen preservation will also shed more light on the history of vegetation of this area in relation to both climatic events and particularly strong anthropogenic activities deduced by archaeological works (Omrani Rekavandi *et al.*, 2007).

Conservation and threats

The Caspian forests are among the highly threatened ecosystems in Iran for several reasons. First, due to the mild climatic conditions and very fertile soil, the area is heavily populated. Extensive urbanization and industrialization activities have concentrated in the area during the last century. In addition to local people living in the area, many people from other parts of the country, in particular from Tehran, have a second home for weekends or holidays. Based on available statistics, ca. 7 million people (ca. 10% of the Iranian population) live in three northern provinces (Statistical Center of Iran: http://www.amar.org.ir). Second, the area provides large parts of the country's timber needs. Third, the Caspian forest, like other parts of Iran, suffer from severe grazing pressures. Fourth, the pleasant climate, beautiful landscape and the Caspian Sea coasts attract millions of tourists coming from arid and semi-arid zone of Iran during holiday times has resulted in much destruction, especially with litter. Fifth, the forest area is very sensitive to fire and every year large parts of the Caspian forests are damaged by fires almost entirely man-made. Sixth, the needs for transportation of millions of people passing from the southern parts of Alborz to reach the lowland Caspian forests have resulted in extensive road building which has damaged many virgin forests and natural landscapes. Based on some estimates, the area of Caspian forests in Iran has been reduced in recent decades from 3.6 milion hectares to 1.8 milion hectares (Anonymous, 2005). The other threats are here including intensive dam building (Zafarnejad, 2009), invasion of exotic plants and exploitation of medicinal and ornamental wild plants.

The lowland relict forests of the Caspian plain are certainly the most intensively suffering parts of the Hyrcanian forest. These forests host the main habitats for some of the most endangered endemic plants such as *Gleditsia caspica*. Among the major threats to this tree species are habitat loss, fragmentation, and even hybridization with introduced species (*G. triacanthos*) (Schnabel & Krutovskii, 2004). The very limited remaining stands of such tree species should be urgently put under more rigorous protection and the possibility of increasing surface areas and connectivities between protected isolates should be seriously taken into consideration. Unfortunately, restoration ecology in Iran, is currently in a very primitive state and the protection strategies are often not based on modern concepts of eco-system ecology. It should not be forgotten that good protection of the Hyrcanian forest, not only guarantees the survival of one of the most magnificent relict ecosystems of the northern hemisphere, but is also very important for eco-tourism which is only in its early stages of development in Iran and the Azerbaijan Republik.

Several protected areas are designated in the Caspian forests (Table 1). The protected areas are not just forests; they include surrounding montane steppe and even lowland semi-arid zone and wetlands which are protected primarily because of their resident and migrant waterfowl. In some cases, they are located in borderline between two or even three provinces such as Golestan National Park, Lar and Alborz Protected Areas.

In the Caspian forests, there are a number of interesting species with high protection need. Only a few of them are legally protected. The only subendemic species which is legally protected is *Lilium ledebourii* "Soosane Chelcheragh" whose habitat, near Damash village, was declared protected as the first Iranian Natural National Monument in 1974. Another marvellous Natural National Monument of this area is the very old *Cupressus sempervirens* tree (protected in the village Harzvil) reputed to be 5000 years old (Sabeti, 1976).

There are many other endemics and subendemics which urgently need protection because of habitat degradation or rarity in the area. Examples are *Aconitum iranshahrii* H. Riedl, *Hyacinthella persica* (Boiss. & Buhse) Chouard, *Crocus gilanicus* Mathew, *Campanula ghilanensis* Pall. ex Schult., *Euonymus velutina* (C. A. Mey.) Fisch. & C. A. Mey., *Erodium dimorphum* Wendelbo, *Hypericum fursei* N. Robson, *Phuopsis stylosa* (Trin.) Hook.f., *Daphne rechingeri* Wendelbo, *Aristolochia hyrcana* Davis & M. S. Khan and *Centaurea golestanica* Akhani & Wagenitz.

Table 1. List of Protected areas of the Caspian forests including Arasbaran forests in east Azerbaijan Province (Madjnoonian, 2000). The list is updated by the latest information kindly provided by the Office of Natural Habitats and Protected Areas of Iranian Department of Environment. Abbreviations: PA=Protected Area, NM=Natural National Monument, NP=National Park, WR=Wilde life Refuge.

Name	Province	Area (ha)	Botanical studies
Abshare Shirgah PA (Waterfall)	Mazandaran	3639	
Alagol, Almagol and Ajigol Wetlands	Golestan	1400	
Alamkuh peaks (Alamkuh, Siahkaman and Takhte-Soleiman NM	Mazandaran	4077	Klein, 1994
Alborz-e-Markazi PA (Central Alborz)	Mazandaran-Tehran	398820	Klein, 1994
Amirkelayeh WR	Gilan	1084	Asri & Moradi, 2006; Ghahreman *et al.*, 2004
Arasbaran PA	Ardabil	80,255	Assadi, 1987, 1988; Dehdar Dargahi & Makhdoum, 2001; Thompson *et al.*, 2001; Zarrinkamar, 2001; Zarrinkamar *et al.*, 2002; Jalili *et al.*, 2003; Asef, 2007, 2008, 2009
Balas Kuh PA	Mazandaran	11211	
Bola PA	Mazandaran	3907	
Boujagh NP	Gilan	3176	Naqinezhad *et al.*, 2006
Chaharbagh PR	Mazandaran	19482	
Chokam WR	Gilan	347	
Demavand Peak NM	Mazandaran	1192	
Dasht-e-Naz WR	Mazandaran	56	
Dodangeh WR	Mazandaran	16868	Gholipour *et al.*, 2005
Esas PR	Mazandaran	2997	
Fakjoor Damkesh Spring NM (Cheshmeh)	Gilan	0.05	
Fereidoonkenar WR	Mazandaran	46	
Gashte Roodkhan and Siah Mazgi PA	Gilan	39514	

Table1. (Cont'd.).

Name	Province	Area (ha)	Botanical studies
Golestan NP	Golestan, N-Khorassan	87402	Akhani, 1998, 2005; Kürschner *et al.*, 2000; Akhani & Ziegler, 2002; Sohrabi & Sipman 2007
Haraz PR	Mazandaran	15481	
Harzvil Cypress (*Cupressus sempervirens*) NM	Gilan	0.6	
Hezar Jarib PA	Mazandaran	6195	
Jahan Nama PR	Golestan	30511	Jafari & Akhani, 2008; Sepehry & Mottaghi 2002
Khoshkeh Daran NM	Mazandaran	254	
Kiasar NP	Mazandaran	9027	
Khiboos and Anjilsi PA	Mazandaran	3471	
Lilium ledebourii NM	Gilan	1	Saeedifard *et al.*, 2008
Lar PA	Mazandaran-Tehran	31000	
Lisar PA	Gilan-Ardabil	31142	
Lavandville WR	Gilan	1074	
Loveh PA	Golestan	3589	Marvie Mohadjer 1983, Dorostkar, 1974
Miankaleh WR	Mazandaran	66933	Ejtehadi *et al.*, 2003; Ramzannejad *et al.*, 2006; Asri *et al.*, 2007
Paband NP	Mazandaran	24445	
Sarvelat and Javaherdasht PR	Gilan	21254	
Selkeh WR	Mazandaran	360	
Semaskandeh WR	Mazandaran	1041	
Shesh Rudbar PA	Mazandaran	7922	
Siahgeshim PA	Gilan	5215	Asri & Eftekhari, 2002
Siahrud Rudebar	Gilan	28289	
Sorkhangol WR	Gilan	448	
Vaz PA	Mazandaran	9646	
Zav PA	Golestan	14323	

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References

Akhani, H. 1996. Studies on the flora and vegetation of the Golestan National Park, NE Iran, I: A new species and some new plant records. *Ann. Nathist. Mus. Wien 98B Suppl.*: 97-105.

Akhani, H. 1998. Plant biodiversity of Golestan National Park, Iran. *Stapfia* 53: 1-411.

Akhani, H. 1999. Studies on the flora and vegetation of the Golestan National Park, NE IranIII. Three new species, one new subspecies and fifteen new records for Iran. *Edinb.J.Bot.* 56:1-31.

Akhani, H. 2003. Notes on the flora of Iran: 4. Two new records and synopsis of the new data on Iranian Cruciferae since Flora Iranica. *Candollea* 58: 369-385.

Akhani, H. 2005. The Illustrated Flora of Golestan National Park, Iran. Vol. 1. Tehran University Press. Tehran.

Akhani, H. 2006. Flora Iranica: facts and figures and a list of publications by K. H. Rechinger on Iran and adjacent areas. *Rostaniha* 7 (suppl. 2): 19-61.

Akhani, H. and H. Kürschner. 2004. An annotated and updated checklist of the Iranian bryoflora. *Cryptogam. Bryol.* 25: 315-347.

Akhani, H. and H. Ziegler. 2002. Photosynthetic pathways and habitats of grasses in Golestan National Park (NE Iran), with an emphasis on the C_4-grass dominated rock communities. *Phytocoenologia*, 32(3): 455-501.

Akhani, H. and M. Salimian. 2003. An extant disjunct stand of *Pterocarya fraxinifolia* (Juglandaceae) in the central Zagros Mountains, W Iran. *Willdenowia* 33: 113-120.

Akhani, H., Scholz, H. 1998. Studies on the flora and vegetation of the Golestan National Park, NE Iran II: A new *Poa* and some new and noteworthy grass records for Iran. *Edinb. J. Bot.* 55(3): 443-453.

Alijani, B. and J.R. Harman. 1985. Synoptic climatology of precipitation in Iran. *Annal. Assoc. Am. Geogr.*, 75: 404-416.

Anonymous, 2005. Current Status of Biodiversity Conservation and Sustainable Development in the Islamic Republic of Iran, In: *National CBD Reports, I.R. Iran*. Downloaded from http://www.caspianenvironment.org/biodiversity/iran/first.htm.

Asef, M.R. 2007. [Macrofungi flora of Arasbaran 1. *Cortinarius* subgenus *Myxacium*]. *Rostaniha* 8(2): 178-185 (Persian Pages), 84-86 (English summary).

Asef, M.R. 2008. [Macrofungi of Arasbaran (N. W. Iran) 2. *Boletes* (Families Boletaceae and uillaceae)]. *Rostaniha* 9 (2): 210-229 (Persian Pages), 91-95 (English Summary).

Asef, M.R.R. 2009. [Macrofungi of Arasbaran (N. W. Iran) 3. *Cortinarius* subgenus *Phlegmacium*]. *Rostaniha* 10 (1): 80-90 (Persian Pages), 38-40 (Englsih Summary).

Asli, A. and S.T. Nedialkov. 1973. The structure of virgin stands of *Fagus orientalis* in the high forests of northern Iran. *Schweiz. Z. Forstw.* 124(6): 403-414.

Asri, Y. and T. Eftekhari. 2002. [An introduction to the flora and vegetation of Siah-Keshim Wetland]. *J. Envir. Stud.,* 28(29):1-19 (In Persian).

Asri, Y., Moradi, A. 2006. Plant associations and phytosociological map of Amirkelayeh protected area. *Pajouhesh- va-Sazandegi Nat. Res.,* 19 (1): 54-64 (In Persian).

Asri, Y., Sharifnia, F., Gholami Terogeni, T. 2007. [Plant association in Miankaleh biosphere reserve, Mazandaran Province (N. Iran)]. *Rostaniha*, 8(1): 1-16 (In Persian).

Assadi, M. 1987. Plants of Arasbaran Protected Area, NW. Iran (Part I). *Iran. J. Bot.* 3(2): 129-175.

Assadi, M. 1988. Plants of Arasbaran protected area, NW Iran. (Part II). *Iran. J. Bot.* 4 (1): 1-59.

Barani, H., Ownegh, M. 2007. Affinity between climatic variables (temperature and moisture) and presence of some Sahara-Sindian plant species in Eastern margin of Caspian region. *J. Agric. Sci. Natur. Resour.* 14(1):110-123 (In Persian).

Barbier, R. 1960. Découverte de loesses d'une ancienne vallée remblayée dans le cours inférieur du Séfid-Roud (versant nord de l'Elbourz,Iran). *Comp. Rend. Acad. Sci. Paris* 250:1097–1098.

Berberian, M. 1983. The southern Caspian: a compressional depression floored by a trapped, modified oceanic crust. *Can. J. Earth Sci.* 20:163-183.

Berberian, M., King, G. C. P. 1981. Towards a paleogeography and tectonic evolution of Iran. *Can. J. Earth Sci.* 18:210-265.

Bobek, H. 1937. Die Rolle der Eiszeit in Nordwestiran. *Z. Gletscher.* 25:130-183.

Bobek, H. 1953-1954. Klima und Landschaft Irans in vor- und frühgeschichtlicher Zeit. *Geogr. Jahresber. Österr.* 25:1-42.

Bradley, R.S., Briffa, K.R., Cole, J., Hughes, M.K., Osborn, T.J. 2003. The climate of the last millennium. In: Alverson, K., R.S. Bradley and T.F. Pedersen (eds.) *Paleoclimate, Global Change and the Future*. Springer Verlag, Berlin, 105-141.

Buhse, A., Winkler, C. 1899. Die Flora des Alburs und der kaspischen Südküste.-Die bisherigen Forschungsergebnisse auf diesem Gebiet. *Arbeiten des Naturforschenden Vereins zu Riga* 8:1-61, 10. Tafel, 1 Karte.

Connor, S. E., Thomas, I., Kvavadze, E. V. 2007. A 5600-yr history of changing vegetation, sea levels and human impacts from the Black Sea coast of Georgia. *Holocene* 17:25-36.

de Klerk, P., Haberl, A., Kaffke, A., Krebs, M., Matchutadze, I., Minke, M., Schulz, J., Joosten, H. 2009. Vegetation history and environmental development since ca. 6000 cal yr BP in and around Ispani 2 (Kolkheti lowlands, Georgia). *Quart. Scien. Rev.* 28:890–910.

Dehdar Dargahi, M., Makhdoum, M. F. 2001. Land use planning for forest catchments of Arasbaran. *J. Environ. Stud.* 26: 25-34 (In Persian).

Dianatnejad, H., Eftekhari, T. 1996. Phytosociological study and preparation of vegetation map in the south-west of Anzali wetland (Siah-Keshim). *Iran. J. Biol.* 5:111-134 (In Persian).

Djamali, M., Akhani, H., Andrieu-Ponel, V., Bracconnot, P., Brewer, S., de Beaulieu, J.-L., Fleitmann, D., Fleury, J., Gasse, F., Guibal, F., Jackson, S. T., Lézine, A.-M., Médail, M., Ponel, P., Roberts, N., Stevens, L. 2010 Indian Summer Monsoon variations could have affected the early Holocene woodland expansion in the Near East. *Holocene* 20:813-820.

Djavanchir, K. 1971. Quelques observations sur les forêts de l'ouest de l'Iran. *Rev. Fores. Franç.* 23: 440-442.

Djazirei, M. H. 1965. Contribution à l'etude des forêts primaires de la caspienne. *Bull. Inst. Agron. Stat. Rech. Gembloux* 33(1):35-75.

Domoers, M., Kaviani, M. , Schaefer, D. 1998. An analysis of regional and intra-annual precipitation variability over Iran using multivariate statistical methods. *Theor. Appl. Climatol.* 61:151-159.

Dorostkar, H. 1974. Contribution à l'étude des forêts du district hyrcanien oriental (chaîne de Gorgan). Fac. Sci. Agronomique de l'Etat. Gembloux.

Ejtehadi, H., Amini, T., Kianmehr, H., Assadi, M. 2003. Floristical and chorological studies of vegetation in Myankaleh wildlife Refuge, Mazandaran Province, Iran. *Iran. Intern. J.Sci.* 4(2):107-120.

Ershad, D. 1995. *Fungi of Iran*. 2ed edition. Agricultural Research, Education and Extension Organization. Tehran.

Ferrigno, J. G. 1988. Glaciers of the Middle East and Africa - Glaciers of Iran. In: Williams, R.S. & Ferrigno, J.G. (eds.). Satellite Image Atlas of Glaciers of the World. U.S. Geological Survey Professional Paper 1386-G-2. 31-47.

Frechen, M., Kehl, M., Rolf, C., Sarvati, R., Skowronek, A. 2009. Loess chronology of the Caspian Lowland in Northern Iran. *Quatern. Intern.* 198: 220–233.

Frey, W., Kürschner, H. . 1979. *Die epiphytische Mossvegetation im hyrkanischen Waldgebiet (Nordiran)*. Beih. Tübinger Atlas des Vorderen Orients, Reihe A (Naturwissenschaften). Dr. Ludwig Reichert, Weisbaden.

Frey, W., Kürschner, H. 1989. *Die Vegetation im Vorderen Orient*: Erläuterungen zur Karte A VI 1 Vorderer Orient. Tübinger Atlas des Vorderen Orients Reihe A. - Dr. Ludwig Reichert, Weisbaden.

Frey, W., Kürschner, H., Probst, W. 1999. Flora and vegetation, including plant species and larger vegetation complexes in Persia. In: Yarshater, E. (ed.) *Encyclopaedia Iranica* **10 (1):** 43-63. Costa Mesa, California, Mazda Publishers.

Frey, W., Probst, W. 1974a. Vegetation und Klima des Zentralelburs und der südkaspischen Küstenebene (Nordiran). In: Ehlers, E. H. (ed.) *Beiträge zur Physischen Geographie Irans. Marburger Geog. Schrift.* 62: 93-116.

Frey, W., Probst, W. 1974b. Vegetationsanalytische Untersuchungen im Dünegebiet bei Babolsar (Kaspisches Meer, Iran). *Bot. Jahrb. Syst. Pflanzengesch. Pflanzengeogr.* 94:96-113.

Ghahreman, A., Naqinezhad, A. R., Attar, F. 2004. Habitats and flora of the Chamkhaleh - Jirbagh coastline and Amirkelayeh wetland. *J. Environ. Stud.* 30(33):46-67.(In Persian).

Gholipour, A., Zehzad, B., Assadi, M., Azizian, D. 2005. Vegetation of Dodangeh and Chardangeh wildlife refuge. *J. Environ. Stud.* 30(36):99-105. (In Persian).

Gorji Bahri, Y. 2004. [Results of loblolly pine (*Pinus taeda* L.) and Caucasian alder (*Alnus subcordata* C. A. M.) silvicultural operations in the Caspian low land regions of Iran]. *Pajouhesh- va-Sazandegi Nat. Res.* 17(2):2-9 (In Persian).

Hallenberg, N. 1980. New taxa of Corticiaceae from N, Iran (Basidiomycetes). *Mycotaxon* 11(2):447-475.

Hallenberg, N. 1981. Synopsis of wood-inhabiting Aphyllophorales (Basidiomycetes) and Heterobasidiomycetes from. N. Iran. *Mycotaxon* 12(2):473-502.

Hamzeh'ee, B., Naqinezhad, A., Attar, F., Ghahreman, A., Assadi, M., Prieditis, N. 2008. Phytosociological survey of remnant Alnus glutinosa ssp barbata communities in the lowland Caspian forests of northern Iran. *Phytocoenologia* 38 (1-2): 117-132.

Hashemloian, B. D., Ataei Azimi, A. 2009. Alien and exotic *Azolla* in northern Iran. *African J. Biotech.* 8(2):187-190.

Hosseini, S. M., MirKazemi, Z. 2003. Ecology of "*Thuja orientalis*" in Hyrcanian Forests of Iran. *For. Sci.* 3:49-54.

Jafari, S. M., Akhani, H. 2008. Plants of Jahan Nama Protected Area, Golestan Province, N. Iran. *Pak. J. Bot.* 40(4):1533-1554.

Jalili, A., Hamzeh'ee, B., Asri, Y., Shirvany, A., Yazdani, S., Khoshnevis, M., Zarrinkamar, F., Ghahramani, M. A., Safavi, R., Shaw, S., Hodgson, J. G., Thompson, K., Akbarzadeh, M., Pakparvar, M. 2003. Soil seed banks in the Arasbaran Protected Area of Iran and their significance for conservation management. *Biol. Cons.* 109(3):425-431.

Joharchi, M.R., Akhani, H. 2006. Notes on the flora of Iran 6: eight new plant records from Iran collected from Khorasan and Golestan provinces (N. E. Iran). *Rostaniha* 7(suppl.2):131-141 (En.).

Kazancı, N., Gulbabazadeh, T., Leroy, S. A. G., Ileri, Ö. 2004 Sedimentary and environmental characteristics of the Gilan-Mazenderan plain, northern Iran: influence of long- and short-term Caspian water level fluctuations on geomorphology. *J. Mar. Sys.* 46:145-168.

Kehl, M. 2009. Quaternary climate change in Iran - The state of knowledge. *Erdkunde* 63(1):1-17.

Kehl, M., Sarvati, R., Ahmadi, H., Frechen, M., Skowronek, A. 2005. Loess paleosol-sequences along a climatic gradient in Northern Iran. *Eiszeit. Gegen.* 55:149–173.

Kendrew, W. G. 1961. *The Climates of the Continents.* Oxford University Press. London

Khalili, A. 1973. Precipitation patterns of Central Elburz. *Theor. Appl. Climat.* 21:215–232.

Khodadadi, S., Saeidi Mehrvarz, S., Naqinezhad, A. R. 2009. Contribution to the flora and habitats of the Estil wetland (Astara) and its surroundings, northwest Iran. *Rostaniha* 10(1): 44-63. (110-111 Persian Summary).

Khoshbakht, K., Hammer, K. 2006. Savadkouh (Iran) - an evolutionary centre for fruit trees and shrubs. *Genet. Resour. Crop Evol.* 53(3):641-651.

Khoshravesh, R., Akhani, H., Eskandari, M., Greuter, W. 2009. Fern and fern allies of Iran. *Rostaniha* 10(Supplement 2):1-130.

Klein, J. C. 1982. Un groupement rupicole de l'Alborz central (Iran): le *Saxifragetum iranicae* ass. nov. *Doc. Phytosoc.* 6:191-201.

Klein, J. C. 1994. *La végétation altitude de l'Alborz central (Iran), entre les régions irano-turanienne et euro-Sibérienne.* . Institute Français de Recherche en Iran. Téhéran

Klein, J. C., Lacoste, A. 1989. Les chênaies à *Quercus macranthera* F. & M. dans le massif de l'Alborz (Iran) et les chaines limitrophes (Grand et Petit Caucase). *Ecol. Medit.* 15(3/4): 65-93.

Klein, J. C., Lacoste, A. 1994. Les pelouses subalpines (*Alchemilleatum plicatissimae* ass. nov.) de l'Alborz central (Iran): ultime avanée sud-orientale de l'aire des Festuco-Brometea Br.-Bl. et Tx. 1943. *Phytocenologia* 24:401-421.

Kuhle, M. 2008. The Pleistocene Glaciation (LGP and pre-LGP, pre-LGM) of SE Iranian Mountains Exemplified by the Kuh-i-Jupar, Kuh-i-Lalezar and Kuh-i-Hezar Massifs in the Zagros. *Polarforschung* 77: 71 – 88.

Kürschner, H., Papp, B., Akhani, H. 2000. New records to the bryophyte flora of Iran Studies on the flora and vegetation of the Golestan National Park, NE Iran IV. *Nova Hedwigia* 71(3-4):509-518.

Lateef, A. S. A. 1988. Distribution, provenance, age and paleoclimatic record of the loess in Central North Iran. In: Eden, D.N. & Furkert, R.J. (eds), *Loess - Its Distribution, Geology and Soil.* Rotterdam, Balkema**:** 93–101.

Leestmans, R. 2005. Le refuge caspiens et son importance en biogéographie. *Linn. Belg.* 20 (3): 97-102.

Leroy, A. G. S., Arpe, K. 2007. Glacial refugia for summer-green trees in Europe and south-west Asia as proposed by ECHAM3 time-slice atmospheric model simulations. *J. Biogeogr.* 34:2115–2128.

Leroy, A. G. S., Marret, F., Gibert, E., Chalié, F., Reyss, J.-L., Arpe, K. 2007. River inflow and salinity changes in the Caspian Sea during the last 5500 years. *Quat. Sci. Rev.* 26: 3359–3383.

Leroy, S. A. G., Roiron, P. 1996. Latest Pliocene pollen and leaf floras from Brenasso paleolake (Escandorgue Massif, Hérault, France). *Rev. Palaeobot.Palynol.* 94: 295-328.

Madjnoonian, H. 2000. [*Protected Areas of Iran: Principles and guidelines for Conservation and Managment of Protected Areas*]. Department of the Environment. Tehran (In Persian).

Mahjoori, E. 2002. [*History of Mazandaran*]. Toos Publisher. Tehran (In Persian).

Mamedov, A. V. 1997. The late Pleistocene–Holocene history of the Caspian Sea. *Quat. Intern.* 41/42:161–166.

Marvie Mohadjer, M. R. 1983. The structure of Iranian Oak-forests (*Quercus castaneifolia* C. A. Mey.) in the eastern part of the caspian forests. *Iran. J. Nat. Res.* 37:41-55 (In Persian).

Miller, A. G. 1994. Hyrcanian forests, Iran and Azerbaijan. In: Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) *Centres of Plant Diversity, A Guide and Strategy for their Conservation* Oxford, IUCN. **1:** 343-344.

Mobayen, S., Tregubov, V. 1970. *Carte de la vegetation naturelle de l'Iran [Map of the natural vegetation of Iran].* Faculte des Forets et Paturages, Universite de Tehran. Tehran

Naqinezhad, A. R., Saeidi Mehrvarz, S., Noroozi, M., Faridi, M. 2006. Contribution to the vascular and bryophyte flora as well as habitat diversity of the Boujagh National Park, N. Iran. *Rostaniha* 7(2): 83-105 (125-126, Persian Summary).

Naqinezhad, A., Hamzeh'ee, B., Attar, F. 2008. Vegetation-environment relationships in the alderwood communities of Caspian lowlands, N. Iran (toward an ecological classification). *Flora* 203 (7): 567-577.

Noroozi, J., Akhani, H., Breckle, S. W. 2008. Biodiversity and phytogeography of the alpine flora of Iran. *Biodiv. Cons.* 17(3):493-521.

Okhravi, R., Amini, A. 2001. Characteristics and provenance of the loess deposits of the Gharatikan watershed in Northeast Iran. *Glob. Planet. Chan.* 28:11–22.

Omrani Rekavandi, H., Sauer, E., Wilkinson, T. E. A. 2007. An imperial frontier of the Sasanian Empire: further fieldwork at the Great Wall of Gorgan. *Iran* 45:95-136.

Probst, W. 1981. Zur Vegetationsgeschichte und Klimaentwicklung des Südkaspischen Waldgebietes (Noriran). In: Frey, W. & Uerpman, H-PH. *Beiträge zur Umweltgeschichte des Vorderen Orients.* Beihefte zum Tübinger Atlas des Vorderen Orients, Reihe A (Naturwiss.) Nr. 8: 26-39. Dr. Ludwig Reichert, Weisbaden.

Ramezani, E. 2009. The Holocene development of the Caspian forests: a palynological study with silvicultural applications (case study: Mashalak forests). University of Tehran. PhD Thesis: 132pp (In Persian with English Abstract).

Ramezani, E., Mohadjer, M. R. M., Knapp, H. D., Ahmadi, H., Joosten, H. 2008. The late-Holocene vegetation history of the central Caspian (Hyrcanian) forests of northern Iran. *Holocene* 18(2):307-321.

Ramzannejad, G. R., Mekhala, R., Krian, T. 2006. Algal flora of Miankaleh wetlands of Iran. *J. Phycol.* 42: 97.

Rastin, N. 1983. Vegetationskundliche Untersuchungen in Hochwaldresten der Kaspischen Ebene. *Phytocoenologia* 11(2):245-289.

Razavi, S. A., Hassan Abbasi, N. A. 2009. A Floristic and Chorology Investigation of Oriental Arborvitae in Sourkesh Reserve (FazelAbad-Golestan Province). *J. Wood Forest Sci. Tech.* Vol. 16:84-100.

Rechinger, K. H. (ed.) 1963-2010. *Flora Iranica, 1-178*. Akademsiche Druck- u. Verlagsanstalt und Naturhistorisches Museum Wien. Graz & Wien.

Rezaiee, A. A. 2000. [An investigation on growth and yield of norway spruce in Ladjim forest region]. *Pajouhesh & Sazandegi* 13(3 [48]):56-59 (In Persian).

Rodwell, M., Hoskins, B. J. 1996. Monsoons and the dynamics of deserts. *Quart. J. Roy. Meteorol. Soc.* 122:1385-1404.

Sabeti, H. 1976. *Forests, trees and shrubs of Iran*. Ministry of Agriculture and Natural Resources. Tehran.

Saeedifard, M., Hosseini, S. M., Padasht Dehkaie, M. N. 2008. Modelling of the spatial distribution of the rare plant *Lilium ledebourii*]. *Rostaniha* 9(2): 137-150 (In Persian, 69-73 English Summary)

Schnabel, A., Krutovskii, K. V. 2004. Conservation genetics and evolutionary history of Gleditsia caspica: Inferences from allozyme diversity in populations from Azerbaijan. *Cons. Gen.* 5:195-204.

Scott, D. A. 1989. *A directory of Asian Wetlands*. IUCN, Gland. Switzerland & Cambridge, United Kingdom

Sepehry, A., Mottaghi, M. R. 2002. Using vegetation indices for estimation of canopy cover percentage of rangeland vegetation (in protected area of Jahan-Nama, Gorgan). *Iran. J. Nat. Res.* 55(2): 259-270 (In Persian).

Sohrabi, M., Ramezani, E. 2010. Some remarkable epiphytic lichens of the Hyrcanian forests in Mazandaran Province (N. IRAN). *Rostaniha* (in Press).

Sohrabi, M., Sipman, H. J. M. 2007. Lichenized fungi of Golestan National Park, NE (Iran). *Mycol. Balcan.* 4:87-92.

Stöcklin, J. 1968. Structural history and tectonics of Iran: a review. *Am. Assoc. Petrol. Geologist. Bul.* 52:1229-1258.

Thompson, K., Jalili, A., Hodgson, J. G., Hamzeh'ee, B., Asri, Y., Shaw, S., Shirvany, A., Yazdani, S., Khoshnevis, M., Zarrinkamar, F., Ghahramani, M. A., Safavi, R. 2001. Seed size, shape and persistence in the soil in an Iranian flora. *Seed Sci. Res.* 11(4):345-355.

Touchan, R., Akkemik, Ü., Hughes, M. K., Erkan, N. 2007. May–June precipitation reconstruction of southwestern Anatolia, Turkey during the last 900 years from tree rings. *Quat. Res.* 68:196–202.

Tralau, H. 1963. Asiatic Dicotyledonous affinities in the Cainozoic flora of Europe. *Kungl. Svenska Vetens. Handl. 4, Ser. 9, 3: 1-87 + 5 plates.*

von der Brelie, G. 1961. Recherches sur les pollens dans les argiles du Lar (Demavend, Iran). *Pollen Spores* 3:77-84.

Yanko-Hombach, V., Kroonenberg, S., Leroy, S. A. G. 2010. Caspian-Black Sea-Mediterranean Corridors during the last 30 ka: Sea level change and human adaptive strategies proceedings of IGCP 521 and 481 INQUA 501 Third Plenary Meeting and Field Trip. *Quat. Int.* doi: 10.1016/j.quaint.2010.06.014.

Zafarnejad, F. 2009. The contribution of dams to Iran's desertification. *Intern. J. Envir. Stud.* 66: 327-341.

Zare, R., Asef, M. R. 2008. Some phialidic fungicolous fungi from the southern Caspian coasts. *Rostaniha* 9 (1): 1-22 (In Persian, 1-5 English Summary).

Zarrinkamar, F. 2001. Foliar anatomy of the Caryophyllaceae family in Arasbaran, NW. Iran. *Iran. J. Bot.* 9(1):93-102.

Zarrinkamar, F., Jalili, A., Hamzeh'ee, B., Asri, Y., Hodgson, J. G., Thompson, K., Shaw, S. 2002. Foliar anatomy of *Carex* in Arasbaran, NW. Iran. *Iran. J. Bot.* 9(2):261-270.

Zohary, M. 1973. *Geobotanical Foundation of the Middle East.* Gustav Fische Verlag. Stuttgart, Amsterdam.