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Research paper

Pollen–vegetation relationships in the central Caspian (Hyrcanian) forests of northern Iran

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ABSTRACT

We studied pollen–vegetation relationships along an altitudinal transect in the Caspian (Hyrcanian) forests of northern Iran. We collected surface samples from 20 plots of 400 or 625 m^2 in the major forest communities and compared pollen percentages of the most abundant plant taxa with the vegetation abundances (cover and basal areas) in the pollen plots and in areas of different radii (100, 250, 500 and 1000 m) around the pollen plots using both linear regression and qualitative methods. The results show that anemophilous taxa (i.e. *Quercus*, *Fagus*, and *Carpinus*) in general produce more pollen relative to entomophilous taxa (i.e. *Acer*, *Parrotia*, *Diospyros*, and *Hedera*). Taxa with light pollen grains, such as *Quercus* and *Carpinus*, show large positive intercepts in linear regression analysis, while heavier pollen grains or those possessing a patterned exine, such as *Diospyros*, *Parrotia*, *Acer*, and *Hedera* show small or even negative intercepts. Larger intercepts indicate that a higher proportion of pollen in the samples arrives from outside the area covered by the vegetation analysis. Our findings indicate that light pollen grains are deposited more slowly than heavy pollen grains. Dissimilarity matrices using the Bray–Curtis index showed that the overall relationship between species composition of vegetation plots and pollen assemblages is better for the areas with 100 m radius than for the pollen plots.

1. Introduction

Reconstruction of vegetation history through pollen analysis requires thorough knowledge of how vegetation composition and pattern are reflected by pollen assemblages (Wright et al., 1967; Bottema, 1974; Jackson, 1990). Due to differences in pollen production and dispersal between taxa, pollen percentages do not unequivocally reflect the abundance of corresponding plant species in the vegetation around the pollen sample site (Prentice, 1985; Prentice et al., 1987). Since the inception of palynology (von Post, 1918), the link between vegetation coverage and pollen rain has been explored both theoretically and empirically (e.g. Davis, 1963; Andersen, 1970; Prentice, 1985; Prentice et al., 1987; Jackson, 1990, 1991; Jackson and Smith, 1994; Sugita, 1994; Hicks and Birks, 1996; Jackson and Kearsley, 1998; Broström, 2002; Bunting et al., 2005; Theuerkauf et al., 2012; for a review of theoretical models see Broström, 2002). An important tool to interpreting fossil records is the study of the relationship between extant vegetation and its contemporary pollen rain, especially in regions where little is known about pollen production and dispersal (Wright, 1967).

Pollen rain studies in mountainous areas are an extra challenge, since atmospheric temperature stratification and resulting wind patterns are complex and strong temperature and moisture gradients define a spatially condensed geographic distribution of plant communities (Solomon and Silkworth, 1986). In such areas, a sampling design of surface samples along altitudinal transects crossing the main forest belts, in combination with a detailed analysis of the major vegetation units, has been proven useful (Wright, 1967; Janssen, 1981).

The first pollen–vegetation calibration study in the Caspian (Hyrcanian) forests of northern Iran, using both multivariate and descriptive approaches, was performed over a forest–steppe transect in Golestan National Park, in the extreme northeastern part of the forests (Djamali et al., 2008). Wright et al. (1967) studied pollen–vegetation relationships along terrestrial surface sample transects in the Zagros Mountains of western Iran in order to interpret the regional vegetation and climate history since the late Pleistocene from a sediment core from Lake Zeribar. The latter study is the only survey of regional pollen rain for western Iran and one of the most extensive for semi-arid areas (Wright, 1967). Yazvenko's study of the forests of Azerbaijan provides information on pollen source area and pollen dispersal of both insect- and wind-pollinated taxa from the southeast Caucasus (Yazvenko,

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1991). Analyzing surface lake and wetland sediments along an altitudinal transect in southern Georgia (Caucasus), Connor et al. (2004) pointed out the importance of indicator pollen types to detect tree-line variation and deforestation in the Holocene. A review of pollen–vegetation relationship studies performed in neighboring regions is provided by Beer et al. (2007).

The main objectives of our study are (1) to explore how contemporary vegetation is represented in surface sample pollen assemblages along an altitudinal transect in the central Caspian forests, (2) to examine the relationship between pollen deposition and plant abundance, and (3) to estimate the source area of various pollen types. By pollen source area we mean the area that shows the best pollen type-taxon abundance relationship.

2. Study area

The broad-leaved deciduous Hyrcanian forests form a 20–70 km wide and 800 km long belt parallel to the southern coast of the Caspian Sea. These forests cover the northern slopes of the Alborz[1] Mountains of northern Iran and extend from the Caspian lowlands up to 2500 m (or occasionally 2800 m) elevation covering an area of ca. 1.9 million ha (Sabeti, 1994; Sagheb-Talebi et al., 2004). Because of the occurrence of many Arcto-Tertiary relict plant species such as *Zelkova carpinifolia*, *Parrotia persica*, and *Pterocarya fraxinifolia*, the Caspian forests are considered to have been an important refugium of summer-green trees during the Quaternary glaciations (Zohary, 1973; Leroy and Roiron, 1996; Leroy and Arpe, 2007; Ramezani et al., 2008).

Differences in forest composition and structure reflect the gradients in climatic and edaphic conditions (Zohary, 1973; Sabeti, 1994; Ramezani et al., 2008). Mean annual precipitation decreases from 2000 mm in the west to ca. 600 mm in the east (Sabeti, 1994; Sagheb-Talebi et al., 2004). From north to south forest communities change as a consequence of rapid changes in temperature and moisture along the strong altitudinal gradient. We investigated an altitudinal transect running in a north–south direction in the Mashalak forests, south of Nowshahr (=Noshahr) (Fig. 1).

The meteorological station nearest to the studied transect is Nowshahr (20.9 m below sea level), situated at the coast of the Caspian Sea, with a mean annual precipitation of 1310 mm, a mean annual temperature of 16.1 °C, and mean temperatures of the coldest month (February) and warmest month (August) of 2.3 and 29.2 °C, respectively.

The bedrock of the highest part of the transect consists predominantly of sandstone and siltstone, over which rendzine and brown earth soils have developed. In mid- to low-elevations, brown earth and occasionally pseudogley soils have formed over limestone (Forest, Range and Watershed Organization of Iran FRWO (1997a,b, 2002)).

3. Materials and methods

3.1. Vegetation survey

In 2004 and 2005 we studied vegetation composition, structure, and distribution of forest communities along a 20 km long altitudinal transect. The transect extends from the uppermost natural forest at Djamand peak (2400 masl) down to the Caspian lowlands, where human impact has removed the forests below 50 masl. The clear vegetation zonation along the transect was described on the basis of characteristic and dominant tree species (Fig. 2) and served as a guide for our sampling strategy (see below).

Vascular plant nomenclature follows Mozaffarian (1998).

3.2. Pollen sampling, preparation, and counting

Palynological samples were taken as moss polsters every 100–150 m of elevation change in representative closed-canopy stands so that the transect of 20 sample points covered all vegetation zones (Figs. 1 and 2, Table 1).

Within quadrates of 25×25 or 20×20 m ('pollen plots'), about 10 moss polsters were randomly collected (without differentiating for moss species) from rock outcrops or tree bases located between 0.1 and 0.5 m above the forest floor and pooled into one sample of 4–5 cm^3 (cf. Räsänen et al., 2004). We collected both green and brown tissues of mosses to obtain samples covering several years.

Sample preparation followed Fægri and Iversen (1989) and included treatment with HCl and KOH, sieving (120 μm), treatment with HF, acetolysis (7 min) and mounting in silicon oil (2000 cSt).

Pollen and spore counts were made using a Zeiss Axiolab microscope with 400× magnification. Larger magnification was used to identify problematic pollen grains. Calculation of pollen and spore frequencies was based on the sum of all arboreal pollen types (AP) (average per sample 922, min. 613, and max. 1725 grains), as such sum – because of the general better dispersal of arboreal pollen – provides a more stable calculation base than one also including non-arboreal pollen types (NAP).

Pollen-morphological types are displayed in the text and in the pollen diagrams by SMALL CAPITALS to clearly distinguish them from plant taxa (Joosten and de Klerk, 2002). Pollen and spores were identified and named after (M): Moore et al. (1991), (B): Beug (2004), (P): the Northwest European Pollen Flora (Punt et al., 1976–2003), and the reference collection of the Institute of Botany and Landscape Ecology at Greifswald University. PTERIS CRETICA was identified with help of figures of (R): Reille (1992) and the reference collection.

For calculation and presentation of the palynological data we used the computer program Tilia 1.7.16 (Grimm, 2011).

3.3. Forest inventory data

Vegetation data were collected as (1) percentage of cover of trees, shrubs, lianas, and herbs within the pollen plots and within a circle with a 100 m radius from the center of each pollen plot and as (2) percentage of basal area of tree species within circles with a 250 m, 500 m, and 1000 m radius from the pollen plots. The crown cover of each tree species in a pollen plot was determined by measuring each crown in two perpendicular directions and expressed as a proportion of the plot area. For the calculation of the crown cover within the circles of 100 m radius, the number of trees from each species was multiplied by the average crown area of that species in the pollen plots. The cover of other vascular plant species (shrubs, lianas, and forest floor vegetation) within the pollen plots and 100 m circles was estimated visually using the Braun–Blanquet scale (cf. Mueller-Dombois and Ellenberg, 2002). For the 250 m, 500 m, and 1000 m circles the FRWO (1997a,b, 2002) 150×200 m grid was used, which provides the diameter at breast height (dbh) of all trees (>12.5 cm dbh) within a 1000 m^2 circular plot around each grid point. The abundance of each species was expressed as the mean abundance of all grid plots within the respective radii, whereby tree species producing similar pollen types (e.g. all species of *Acer*) were pooled (cf. Jackson, 1990).

3.4. Data analysis

We used both qualitative and quantitative approaches to explore pollen–vegetation relationships.

In a first step we investigated the overall relationship between the species composition of vegetation plots at two spatial scales (pollen plots and 100 m plots) and the pollen assemblages, after square root transformation of the relative abundances of both species and pollen types. For the three resulting plot×species/pollen type abundance

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[1] Also spelled "Alburz", or "Elburz ".