Flora and vegetation of Israel and adjacent areas

Avinoam Danin

Introduction

Israel is a meeting area of plant geographical regions and has high climatic, lithologic, and edaphic diversity. These factors together with prolonged influence of human activity have led to the development of a rich flora and diverse vegetation. Eig (1931-1932, 1946) has established the foundations of the botanical research in Israel. The history of geobotanical and floristic research until the 1970's was reviewed by Zohary (1962, 1973). The basic taxonomic research on the country's flora, "Flora palaestina", was completed in 1986 (Zohary 1966, 1972; Feinbrun-Dothan 1978, 1986). Recently, a new "Analytical Flora" was published (Feinbrun-Dothan & Danin 1991).

In the last two decades many Ph.D. and M.Sc. theses were carried out. Many of these theses were written in Hebrew and are not accessible to those who do not read this language. The vegetation of parts of the Galilee was studied by Rabinovitch (1970, 1979), and Berliner (1971); that of Mt. Hermon by Shmida (1977a); that of the Judean foothills by Sapir (1977); and that of the southern Negev by Lipkin (1971). Much of the present information was summarized in Waisel (1984).

In the following chapter a general description of the flora, i.e., the inventory of species with their geographical affinities, and of the vegetation of Israel is presented. In order to present the description of vegetation to a wider audience I have avoided the use of the modern phytosociologic nomenclature and have used the general non-ranked term "plant community" to describe the principal vegetation units of the country.

Flora

Within Israel's present boundaries, the number of plant species is 2630 in an area of 29,600 km^2. This number is high compared as with many other countries. For example, the Californian coastal zone, with an area more than twice as large as Israel, has 2325 species (Johnson & Raven 1970). The number of species divided by the area or the log species/log area ratio of Israel has the highest value of any Mediterranean and European country (Table 1). Israel's high species diversity expressed as species/area ratio or log species/log area ratio results from two factors: (1.) Its position in a meeting zone between plant geographical regions, each with a typical flora; and (2.) the existence of many habitats to support these species. The wealth of habitats derives from the climatic transition between the relatively moist area in the northern part of the country and the desert in the southern part. Topography is a second factor, creating the warm climates of the Jordan, Dead Sea, and Arava valleys and the relatively cold climate of Mt. Hermon. In a similar way other highlands and lowlands have local climatic influence which increases Israel's habitat diversity.

Table 1. Number of species and area (in km^2) of several countries compared with those of Israel.

	country	species	area	species/area log	species/log area
1	Israel	2530	29,600	0.0855	0.7611
2	California	2325	63,479	0.0366	0.7009
3	Sinai	889	61,100	0.0145	0.6161
4	Greece	4200	132,562	0.0317	0.7073
5	Italy	5600	301,100	0.0186	0.6841
6	France	4210	550,986	0.0076	0.6313
7	Hungary	3039	93,030	0.0327	0.7009
8	Britain	1666	229,850	0.0072	0.6009
9	Netherlands	1357	43,800	0.0310	0.6749

Notes: California is in fact Californian coastal area; Britain is the British Isles. Information for countries 2, 8 and 9 is from Johnson & Raven (1970), for countries 4,5,6 and 7 from Pignatti (pers. comm.)

The geomorphological structures are relatively small but the number of rock types is high. As a result, many soil types develop in a small area (Dan & Raz 1970), increasing the diversity of habitats. A long history of human activity of cultivation and grazing by domestic animals led to strong stress on the existing flora and enabled the introduction of many alien species. Many of the latter get established in synanthropic habitats (Zohary 1973, Danin & al. 1982, Danin 1991a, b).

According to Eig (1931-1932), Zohary (1962, 1966, 1972), Feinbrun-Dothan (1978, 1986), and Danin & Plitmann (1986), the flora of Israel is divided into seven groups on the basis of general distribution area as follows:

1. Mediterranean (M) species, which are distributed around the Mediterranean sea.
2. Irano-Turanian (IT) species, which also inhabit Asian steppes of the Syrian desert, Iran, Anatolia, and the Gobi desert.
3. Saharo-Arabian (SA) species, which also grow in the Sahara, Sinai, and Arabian deserts.
4. Sudano-Zambesian (S) species, typical to the subtropical savannas of Africa.
5. Euro-Siberian species, also known in countries with a wetter and cooler climate than Israel; growing mainly in wet habitats and along the Mediterranean coasts.
6. Bi-regional, tri-regional, and multi-regional species that grow in more than one of the regions mentioned above.
7. Alien species from remote countries, propagating without human assistance. The principal countries of origin are the Americas, Australia, and South Africa.

Eig (1938), followed by Zohary (1962), delineated four plant geographical territories in Israel: (1.) Mediterranean, (2.) Irano-Turanian, (3.) Saharo-Sindian, and (4.) Sudano-Decanian enclaves. Zohary (1966) renamed some of the phytogeographical regions and regarded Eig's Saharo-Sindian as Saharo-Arabian and Eig's Sudano-Decanian as Sudanian. Eig's Sudano-Decanian enclaves in the Dead Sea area became a "territory of Sudanian penetration" (Zohary 1966).

In a recent analysis of the plant geographical territories of Israel and Sinai (Danin & Plitmann 1986), the criteria for subdividing the country were based on more than 80,000 observations of plant location in a 5 x 5 km square grid. Similarity of prevalence of the first two chorotypes was used to lump individual squares into provisional plant geographical territories. Floristic lists were prepared for these territories and the frequency of each chorotype was recalculated. Statistical analysis (the log-likelihood ratio for contingency = G-test, Zar 1984) was operated for each pair of territories. In addition, the floristic lists for the districts of Sinai (Danin 1983, Danin & al. 1985) were analysed by the same method. The threshold of chi-square probabilities for lumping two districts in Sinai into a plant geographical territory was $p < 5$ %. The same test and threshold were used to analyse the plant geographical territories of Israel and Sinai.

The result of the latter analysis is a map with pie diagrams for each of the territories. The Mediterranean territory is rather similar in extent to that of Eig (1931-1932). All other territories are "complex territories" where the second most frequent chorotype is in parentheses. These included the following: M(M-IT), SA(M), SA(IT), SA(S), IT(SA), and S(SA) (cf. Fig. 1).

Endemics

There are 46 endemic species in Israel as listed by Zohary (1966, 1972) and Feinbrun-Dothan (1978, 1986). Those species that occur in Israel and one or more of the neighbouring countries, such as Lebanon, Jordan, Syria and Egypt ("subendemics" *sensu* Shmida 1984), were not included here. This low proportion (1.8 %) reflects the poverty of unique habitats and habitats that function as refuge in the country. The highest concentrations of endemics are on the coastal plain on sandy soils (17 species) and in the Negev highlands on smooth-faced limestone outcrops (9 species).

The number of endemics in Sinai is 28 (Danin 1986), which is 3.2 % of Sinai's flora. The "subendemics" (as defined above) are not included. In Sinai the highest number of endemics (16 = 57.1 % of the endemic species) occurs in the southern Sinai massif. This area has a wetter climate than most of the rest of Sinai. The large outcrops of smooth-faced rocks often support species rare in deserts (Danin 1972, 1978, 1983). All the endemics of the southern Sinai massif are confined to rocky habitats or local small springs in rocky terrain. Altogether, 25 species (89.3 %) of the Sinai endemics are found in the mountainous districts. The occurrence of high proportions of endemics in mountainous areas has been discussed at length by many investigators and reviewed by Shmida (1984).

The fundamental taxonomic research needed to determine whether a certain taxon is a palaeo-endemic or a neo-endemic has not yet been conducted for most of the endemics of the area.

Vegetation

The plant communities that occur in a particular place are influenced by their phytogeographical position, climatic factors, lithology, soil, and human activities. The principal plant communities that make up the vegetation map units (Fig. 2) are listed below in the legend's sequence with a description of the environmental factors affecting their distribution.

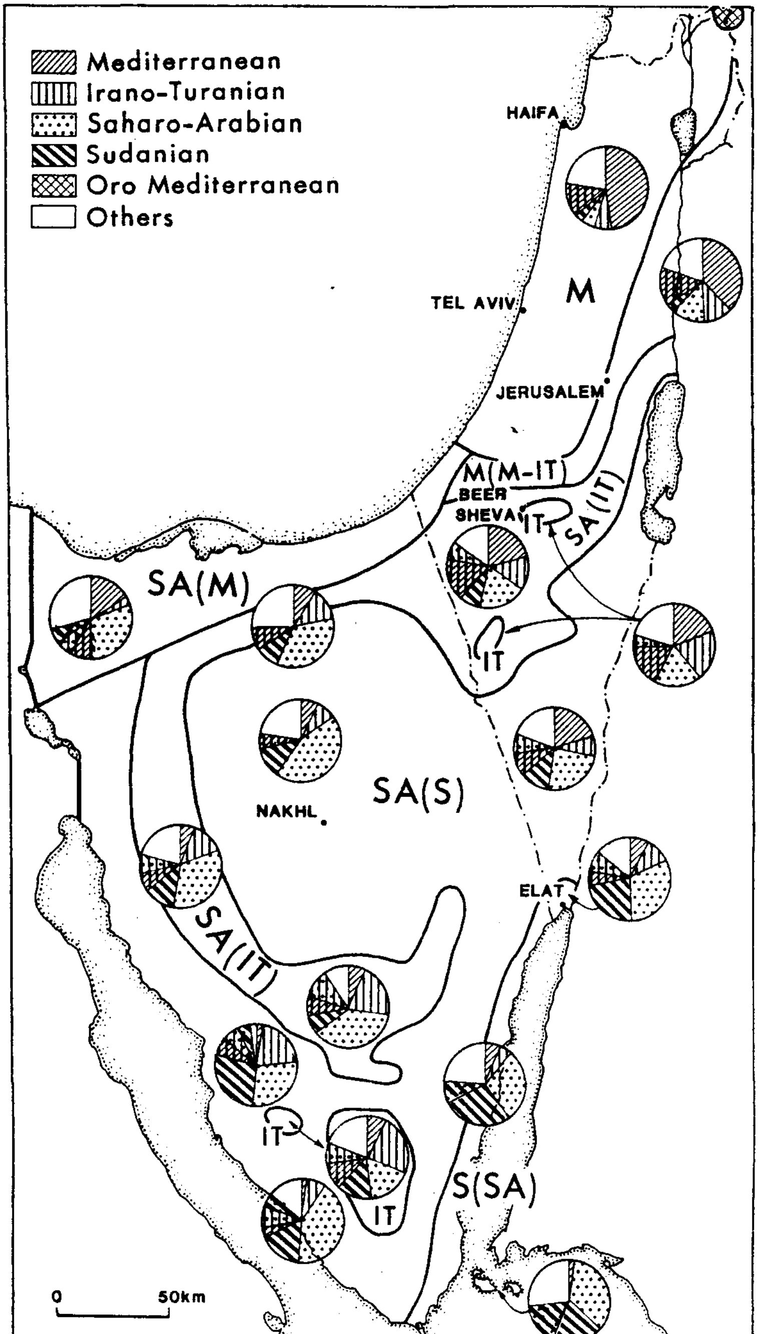

Fig. 1. Plant geographical territories of Israel and Sinai. The abbreviations for the plant geographical regions are: M = Mediterranean; IT = Irano-Turanian; SA = Saharo-Arabian; S = Sudanian. Pie diagrams represent the distribution of the chorotypes in the flora of each territory. (From Danin & Plitmann 1986).

1. Maquis and forests

The principal woodlands are found in the mountains of Judea, Carmel, and Galilee. In most of the area cultivated plants have replaced the spontaneous trees. A few thousand years ago, people in Israel, as in the neighbouring Mediterranean countries, started to clear the natural vegetation to create agricultural land. Trees that have been domesticated from the spontaneous flora of Israel (Zohary & Spigel-Roy 1975), such as olives (*Olea europaea*) and almonds (*Amygdalus communis*), today cover large parts of the previous woodland areas. The timber derived from the forests and maquis was used for the construction of houses, for agricultural tools, and for fuel. Areas of suppressed maquis support herbaceous vegetation that has higher nutritional value than the evergreen trees and shrubs. For the last few millennia shepherds burned large woodland areas to open them for the domestic animals and to improve pasture quality by clearing the arboreal vegetation.

After cultivated ground is abandoned, the area is colonized by low herbaceous lignified plants, lasting dozens of years. This vegetation formation of Mediterranean semi-shrubs covers vast areas and is locally known as "batha" (= phrygana). In the last century, a large proportion of these batha areas has been reforested by the State of Israel. *Pinus halepensis* which grows spontaneously all over this mapping unit was the principal planted forest tree.

Thus, the area of this potential vegetation unit now consists of a mosaic of patches that have been influenced to a varying extent by human activity. In areas only slightly influenced, it is still possible to study the relationship between vegetation and edaphic factors. Trees that survived at the margin of cultivated land or sacred trees assist us in identifying the woodland boundaries.

1.1. Quercus calliprinos woodland on limestone

The principal rock types of this vegetation unit are hard limestone and dolomite. Terra Rossa soil is found on those rocks. This soil is well aerated and is poor in nutrients due to the efficient leaching. Tree roots penetrate into joints and crevices in the rock to a depth of 8-10 m and use soil resources down to that depth. Evergreen sclerophyllous maquis, dominated by *Quercus calliprinos*, develops on this substratum. A stand of such maquis may consist solely of trees accompanied by a few vines and plants adapted to shade. In many sites the trees are many-stemmed as a result of human activity; after a tree is cut, overgrazed, or burnt, many new stems sprout from the rootstock.

A woodland with 10-12 m tall trees of *Quercus calliprinos*, *Q. boissieri*, and *Arbutus andrachne* occurs in the upper Galilee, in the Mt. Meiron nature reserve. In most other maquis areas, the tree canopy is less than 4-5 m high. A few sacred trees have overcome the hazards of human activity. The graves of holy men in their shade furthers the Moslems' belief that a curse will fall on whom who cuts the tree stems, or on his herds. This credence has protected such trees for centuries. They are found all over the unit area; in Hebron, Jerusalem, and En Hemed (Aquabella) in the Judean mountains, the "Wood of the Forty" on Mt. Carmel, and near many graves in the Hermon, Golan, Galilee, and Samaria.The companions of *Quercus calliprinos* vary according to edaphic and climatic conditions. In the upper Galilee, where the climate is moistest in Israel, the mesophytic companions are: *Rhamnus alaternus*, *R. punctata*, *Eriolobus trilobatus*, *Acer obtusifolium*, *Crataegus azarolus*, *C. monogyna*, *Laurus nobilis*, *Hedera helix*, *Ruscus aculeatus*, *Paeonia mascula*, and many herbaceous species. None of these

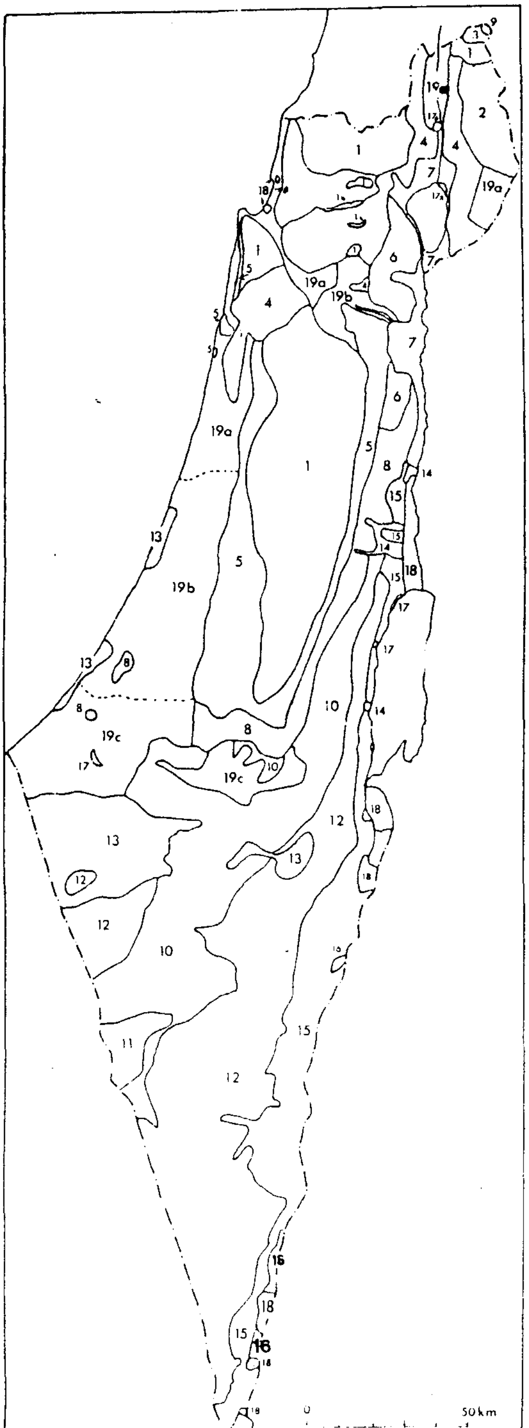

Fig. 2. Vegetation map of Israel. 1, maquis and forests; 2, *Quercus calliprinos* woodlands on basalt; 3, montane forest of Mt. Hermon; 4, park forest of *Quercus ithaburensis*; 5, park forest of *Ceratonia siliqua* and *Pistacia lentiscus*; 6, *Ziziphus lotus* with herbaceous vegetation; 7, savannoid Mediterranean vegetation; 8, semi-steppe batha; 9, tragacanth vegetation of Mt. Hermon; 10, steppe vegetation; 11, steppes with trees of *Pistacia atlantica*; 12, desert vegetation; 13, sand vegetation; 14, oases with sudanian trees; 15, desert savannoid vegetation; 16, *Haloxylon persicum* on sands; 17, swamps and reed thickets; 18, wet salines; 19, synanthropic vegetation: a. with remnant *Quercus ithaburensis* trees, b. with *Ziziphus spina-christi* trees, c. with *Ziziphus spina-christi* and *Acacia raddiana* trees.

mesophytic components occur in the maquis of the Judean mountains. In the driest maquis stands, *Rhamnus lycioides* subsp. *graeca* is the only arboreal companion of *Q. calliprinos*.

In the Galilee, special edaphic conditions are reflected in the maquis composition. In the western Galilee, near Maálot, *Laurus nobilis* dominates the maquis. Rabinovitch (1979) found that the Terra Rossa there is poor in magnesium. *L. nobilis* is the tree best adapted to this kind of stress.

Kaolinitic Terra Rossa develops on Eocene limestone in the eastern Galilee, Mt. Gilboa, and near Shechem (Nablus). This soil has a low moisture holding capacity, low cation exchange ability, and a relatively high phosphorus content. These conditions, especially the high phosphorus content, promote the development of herbaceous annuals and perennials. These herbaceous plants compete with tree seedlings for water and intensify fire hazards in summer. As compared to other Terra Rossa areas, the kaolinitic areas are green in wet winters but look like deserts in summer. The most common semi-shrub that grows on abandoned Terra Rossa soils (excluding the kaolinitic Terra Rossa) is *Sarcopoterium spinosum*. It dominates bathas at the boundary between the Mediterranean territory and the steppe. It is believed that its primary habitat is in the steppe area because when the maquis components develop and cast shade the *S. spinosum* shrubs die. The typical semi-shrub companions of *S. spinosum* in the moist Mediterranean bathas are: *Fumana arabica*, *Cistus creticus*, *C. salviifolius*, *Salvia fruticosa*, *Teucrium divaricatum*, *T. capitatum*, and *Phlomis viscosa*.

1.2. Quercus boissieri woodland

Maquis dominated by *Quercus boissieri* develops in the upper Galilee, on north-facing slopes where solar radiation is low, and on relatively moist Terra Rossa soils. The winter-deciduous *Q. boissieri* is accompanied by deciduous trees such as *Cercis siliquastrum*, *Pyrus syriaca*, *Prunus ursina*, and *Crataegus azarolus*.

1.3. Pinus halepensis and Arbutus andrachne woodland

Marly-chalk is another common rock type. It has a high moisture holding capacity and when weathered it is covered with Light Rendzina soil. The aeration of the rhizosphere of trees that penetrate the soft rock is poor, and only specially adapted plants develop there. Much of the nitrogen in this soil is in the form of ammonium ions whereas in the Terra Rossa it is in the nitrate form (Rabinovitch 1979). The vegetation cover of the Light Rendzinas on marlychalk is poor as compared to Terra Rossa. There are only few annual companions in the batha or maquis stands on this soil. In sites with high clay content in the rock and with low aeration, *Arbutus andrachne* is dominant. Symbiosis of tree roots and fungi (mycorrhiza) seems to enable its success . Its only arboreal companion is *Pinus halepensis*; the mycorrhizal fungus of which (*Suillus granulatus*) is the most common edible winter mushroom species in Israel. *P. halepensis* grows on marly, chalk without *A. andrachne* in sites with low clay content. Near Bet Jan in the Upper Galilee is the only known slope in Israel where *Juniperus oxycedrus* accompanies *P. halepensis* and *A. andrachne*. Among the trees or in clearings there are stands dominated by one or a few semi-shrubs: *Fumana thymifolia*, *Coridothymus capitatus*, *Cistus creticus*, *C. salviifolius*, *Helianthemum syriacum*, *Satureja thymbra*, *Thymbra spicata*, and *Teucrium creticum*. They are accompanied by many *Orchidaceae* species, the number of which increases from the Judean mountains to the Galilee.

2. Quercus calliprinos woodland on basalt

Maquis dominated by *Quercus calliprinos* develops on basalt and other volcanic substrata in the Golan at an elevation of more than 500 m above sea level (a.s.l.). There are very few lignified semi-shrub, shrub, or tree companions to the dominant oaks. Judging from 100 year old maps, the woodland range has substantially decreased in recent times. In many parts of this unit, maquis has developed on shallow rocky soil and form a pattern of straight hedge lines between agricultural fields. Since at least 1967 there is no ploughing there and rich ephemeral herbaceous vegetation develops among the trees. No establishment of new tree seedlings takes place in the grassland among the "hedges".

Near Mas'ada, at elevations of 900-1000 m, the gentle north facing slope of the ancient volcanic cone of Har Odem is covered by a dense maquis of *Quercus calliprinos*. It is accompanied by *Q. boissieri*, *Crataegus monogyna*, *C. aronia*, and *Prunus ursina*. Among the trees, the rich ephemeral vegetation includes some 20 species of *Trifolium*. There are a few *Orchidaceae* in the tree shade. Most trunks are covered by mosses and lichens that probably profit from the frequent wetting by low clouds. In other parts of the oak woodland there are *Pistacia palaestina* trees in the hedges and at the centre of open rectangular spaces with herbaceous vegetation. At elevation of 800-900 m, there are trees of *Quercus ithaburensis* and *Pistacia atlantica*. The latter are known as components of a more drought-resistant vegetation. The proportion of oak trees decreases towards the boundaries of the dense woodland; solitary occasional trees, mostly of *Crataegus aronia* and *Prunus ursina*, indicate the former existence of oak woodlands in much larger areas.

Many species that develop in a similar maquis in the Upper Galilee on Terra Rossa do not grow here. Such are *Arbutus andrachne*, *Laurus nobilis*, *Pinus halepensis*, *Rhamnus alaternus*, *R. punctata*, *Acer obtusifolium*, *Pistacia lentiscus*, *Cercis siliquastrum*, and *Ceratonia siliqua*. Semi-shrubs of the batha are also missing or are extremely rare, such as: *Sarcopterium spinosum*, *Cistus salviifolius*, *C. creticus*, *Fumana thymifolia*, *F. arabica*, *Satureja thymbra*, *Thymbra spicata*, and *Coridothymus capitatus*. The successful development of herbaceous plants and the lack of all the above listed lignified plants are undoubtedly related to nutritional problems. There is preliminary evidence (Ruhama Berliner pers. comm.) that nutritional requirements of the mycorrhizal fungi of *Cistus creticus* limit the distribution of this shrub. Further research in this direction may lead to a better understanding of the general alleged "calciphilic" nature of these species.

3. Montane forest of Mt. Hermon

At elevations of 1300-1800 m there are remnants of trees and shrubs that withstand low temperatures, and high intensity, speed and perseverance of wind. As in the other Mediterranean countries, montane forests are composed of many winter-deciduous trees. Some of the species may be found at lower elevations as well; however, it is here that they reach dominance.

In most of the area there is a pronounced human influence by the inhabitants of the villages Majdal Shams and Shab'a. For centuries they have cut the wood and their goats have grazed on the young sprouts. Since 1967 part of the area is protected. Many plants that are not known from other parts of Israel are found here. The typical arboreal species are *Quercus boissieri*, *Q. libani*, *Juniperus drupacea*, *Acer monspessulanum* subsp. *microphyllum*, *Cotoneaster nummularia*, *Crataegus monogyna*, *Prunus ursina*, and *Amygdalus korschinskit*. These trees are accompanied by a few perennial grasses and many annuals; some of these are typical for higher elevations, others are Mediterranean maquis plants, and others yet are typical of the semi-steppe bathas. Most of the semi-shrubs here are known also from the "tragacanth vegetation" (cf. unit 9).

4. Park forest of Quercus ithaburensis

Park forest is a vegetation formation of trees, the canopies of which do not totally cover the area. In many places of Israel and its neighbouring countries, it is evident that such a formation is found in drier and warmer areas than *Quercus calliprinos* woodland. This latter develops in the Golan (unit 2) at elevations of 500-1200 m, whereas from 0 to 500 m there is a park forest of *Q. ithaburensis* or its remnants. Within the areas covered by *Q. ithaburensis* , relatively moist habitats, such as steep north-facing slopes and very rocky areas, are covered by *Q. calliprinos* or its companions.

Quercus ithaburensis is a Mediterranean tree but belongs to a section of the genus that originated in the Irano-Turanian region. Its relatives constitute park forests over large areas of the Zagros mountains in Iran (Zohary 1973). *Q. ithaburensis* dominates on three principal soil types, and it is not clear yet what they have in common. Hamra (sandy-loam) is a soil derived from Pleistocene sand dunes in the Sharon between the Yarkon river and Mt. Carmel. There is ample evidence that its *Q. ithaburensis* woodlands prevailed in the coastal area of Israel until the last century. A few remnants of *Q. ithaburensis* forest on Hamra occur in the Sharon. The largest reserve includes some 20 large sacred trees in Horvat Cherkes near Pardes Hanna. It was a cemetery of a Cherkes village that existed in the vicinity. The Hamra soil has a clay layer at a depth of 2-3 m, where much of the oak roots develop. It is a rather unique type of soil and supports several endemic and many rare species. Most of the area in the Sharon that was covered by *Q. ithaburensis* forest has been turned into orange orchards in the last century. In areas that have been cultivated and abandoned a *Centaurea procurrens* and *Desmostachya bipinnata* community develops.

At the Alonim-Shefaram and the Menashe Hills, there is a park forest of *Quercus ithaburensis* on Eocene hard chalk with Dark Rendzina (Aloni & Orshan 1972). The tree roots penetrate these rocks and use much of their resources. Therefore, rock quality seems to have an important influence on the success of that oak. The principal semi-shrub companion is *Majorana syriaca*; there is a rich herbaceous vegetation of grasses and legumes. In spring carpets of *Cyclamen persicum* and *Anemone coronaria*, both in diverse colours, develop among the trees. The arboreal companions are: *Styrax officinalis*, *Pistacia atlantica*, *P. palaestina*, *Rhamnus lycioides* subsp. *graeca*, and *Quercus calliprinos*. It is here that Nari crusts (hard rock developing during pedogenetic processes on top of soft rocks) and north facing slopes mainly support *Quercus calliprinos* and its companions.

The Yahudia forest reserve, in the Golan, is principally a park forest of *Q. ithaburensis* on basalt. The trees grow mainly on large rock mounds accumulated by man some 4000 years ago (Epstein 1974). There are very few arboreal companions to the oak, such as *Pistacia atlantica*, *Ziziphus spina-christi*, and *Z. lotus*. The latter two develop mainly on stony ground among the rock mounds. The open areas between the trees support a rich annual herbaceous vegetation dominated by grasses with large seeds, such as *Triticum dicoccoides* (wild wheat), *Hordeum spontaneum* (wild barley), and *Avena sterilis* (wild oat). These are strong competitors to the tree seedlings, and only in the rock mounds where annuals do not grow can such seedlings survive the first summer and the frequent fire hazards. Rodents (mainly wood-mice, *Apodemus*) that live in the mounds commonly eat the non-bitter half of the oak acorn, and leave in the mound the remaining bitter half that contains the embryonic root and shoot. Another reason for oak establishment in the mounds may be the protection of the acorns from wild pigs.

Pistacia atlantica, which accompanies *Quercus ithaburensis*, is the principal tree of the park forest on hard limestones of the eastern Galilee between Har Kena'an and Metula. Tree density here is less than in the *Q. ithaburensis* woodlands. The arboreal companions of *P. atlantica* are *Amygdalus korschinskii*, *Rhamnus lycioides* subsp. *graeca*, *Styrax officinalis*, *Pistacia palaestina*, and *Crataegus aronia*. Many seedlings of trees establish themselves in rock crevices, where they are protected from competition and fire hazards associated with the rich annual vegetation, as discussed above for *Q. ithaburensis* in the Golan. The principal annual companions here are the same species of *Triticum*, *Hordeum*, and *Avena* with plenty of other *Gramineae*, *Papilionaceae* , and *Compositae* species.

5. Park forest of Ceratonia siliqua and Pistacia lentiscus

Ceratonia-Pistacia lentiscus park forest develops on all the limestone hills at the foot of the central mountain range of the Mediterranean zone of Israel in Judea, Samaria, Carmel, Gilboa, and Galilee. This plant community is more drought and heat resistant than that of *Quercus calliprinos*, and develops at elevations of 0-300 m a.s.l.

On calcareous sandstone (Kurkar) this community develops close to the Mediterranean coast from Netanya to Mt. Carmel. Here it is accompanied by typical sand plants that develop on coastal dunes (Kutiel & al. 1979-1980, Danin & Yaalon 1982). Sand covering the park forest led in places to its complete destruction. The vegetation developing on the sand leads to amelioration of its water regime by producing humus and becoming a trap for airborne fine grains. At the first stages of plant succession desert plants such as *Artemisia monosperma*, *Helianthemum stipulatum*, and *Retama raetam* grow on the sand. As the moisture regime improves, the desert shrubs die and are replaced by typical Mediterranean shrubs such as *Calicotome villosa*, *Rhamnus lycioides* subsp. *graeca*, *R. alaternus*, and *Pistacia lentiscus*. *Ceratonia siliqua* germinates and establishes itself in the shade of *Pistacia lentiscus*. It is evident that on sand the carob seedlings can survive only in such micro-habitats. Further research is needed to discover the role of the mother rock in the carob re-establishment.

The composition of the *Ceratonia siliqua - Pistacia lentiscus* community varies with edaphic and climatic influences. On the southern Judean foothills *Rhamnus lycioides* subsp. *graeca* is the principal companion. On the Carmel and in the western Galilee *Olea europaea* (wild olives) and *Quercus calliprinos* accompany *Pistacia lentiscus* which is the principal shrub companion there. On the south facing cliffs of Mt. Carmel the companions are rock plants such as *Micromeria fruticosa*, *M. myrtifolia*, *M. nervosa*, *Chiliadenus* (*Varthemia*) *iphionoides*, and *Stachys palaestina*. Perennial grasses of Sudanian origin, such as *Hyparrhenia hirta*, *Pennisetum asperifolium*, and *Tricholaena teneriffae*, grow in the rock crevices as well. Here they get sufficient warmth and their rhizosphere is protected by the rocks from competition with Mediterranean herbaceous plants.

The *Ceratonia-Pistacia lentiscus* community covers large areas east of the water divide of the Samaria, Gilboa, and Galilee mountains. The occurrence of a few carob trees along the western boundary of the Judean desert and north of the Negev may indicate the former existence of a similar *Ceratonia-Pistacia lentiscus* park forest in that area.

6. Ziziphus lotus with herbaceous vegetation

The southeastern hilly area of the Galilee looks like a park forest without trees. Instead, there are scattered shrubs of *Ziziphus lotus* over large areas of the typical Mediterranean grasses. The herbaceous plants are species of *Hordeum*, *Triticum*, *Aegilops*, *Avena*, *Trifolium*, *Medicago*, and other *Graminae*, *Papilionaceae*, and *Compositae*. The substratum in the northern area of this unit is basalt, and in this respect it is similar to the southern Golan; however, this is a drier area and no *Quercus ithaburensis* trees develop here except for near Mt. Tabor at the western part of this unit. *Z. lotus* is one of the most drought resistant shrubs in Israel that grow in the northeastern parts of the country. It sheds leaves in winter and renews its growth in spring. Its spiny shrubs serve as a hiding and resting place for many animals which enrich the soil with their droppings. Under and around the *Z. lotus* shrubs there is a lush herbaceous vegetation of much larger plants than in the open between the shrubs. Ruderal plants such as *Chrysanthemum coronarium* and *Silybum marianum* often grow in this microhabitat.

7. Savannoid Mediterranean vegetation

Spiny trees of Sudanian origin, mainly *Ziziphus spina-christi* and in a few places *Acacia albida*, grow in areas that seem to be too warm and dry to support Mediterranean trees. These trees are accompanied by Mediterranean herbaceous vegetation. Since in the true East African savannas the spiny trees are accompanied by Sudanian herbaceous species that do not grow here, we use the term "savannoid" to designate our savanna-like vegetation. In the Golan, from sea level to 200 m below sea level, *Z. spina-christi* grows all over the slopes and is accompanied by herbaceous vegetation similar to that of unit 6. South of lake Kinneret the companion grass is *Stipa capensis* that grows in desert areas as well. In this area and to the south *Z. spina-christi* grows in wadis and near springs. At the foot of Kokhav Hayarden, near Gesher, there is a dense savannoid vegetation dominated by *Acacia albida* which reproduces vegetatively from roots, with only a few large specimens producing pods with one or two seeds in each. Elsewhere, *A. albida* occurs in Israel in a few isolated thickets near Nahallal, the Esderaelon plain, in Emek Haella at the Judean foothills, near Kefar Menahem and Galon, near Ramla, and on the Mediterranean coastal plain near Ashdod and Ashqelon. The principal area of the species are savannas in East and South Africa. In its African primary habitats it reproduces from seeds. Its occurrence in Israel is regarded as a disjunct relic of Tertiary origin (Halevy 1971). *Z. spina-christi* is an East African tree that sheds leaves there in the dry season. In Israel it grows in habitats with sufficient water; however, in some areas it may suffer from low temperatures in winter and may shed leaves in response to this kind of stress. In considerable parts of the coastal plain south of the Yarkon river there are stands of this vegetation unit. The principal tree there is *Z. spina-christi*, which is accompanied by various Mediterranean elements, depending on the particular soil type (unit 19b).

8. Semi-steppe batha

The vegetation boundary of the Mediterranean territory towards the desert, where mean annual rainfall is 250-350 mm, is represented by batha of semi-shrubs with no trees. In addition to Mediterranean species there are various plants that grow in neighbouring desert areas as well. Many species living in primary habitats here grow in synanthropic habitats in the centre of the Mediterranean territory. *Sarcopoterium spinosum* dominates over large areas in this unit and there are no competitors that might throw shade over the plant and cause its death. In the centre of the Mediterranean territory bathas of *S. spinosum* are replaced in time by shrub and tree formations.

Only a few species grow over the entire area of this vegetation unit; such are *Phlomis brachyodon* and *Ballota undulata*. The entire vegetation order was named *Ballotetalia undulatae* (Zohary 1973). Hard limestone in the southern Judean mountains is occupied by communities of *Sarcopterium spinosum*, *Phlomis brachyodon*, and *Thymelaea hirsuta*. *Astragalus bethlehemiticus* and *Euphorbia hierosolymitana* accompany *S. spinosum* on the high terrain near Har Amasa.

Chalky ground is covered by communities dominated by *Echinops polyceras*, *Alkanna strigosa*, *Ononis natrix*, and *Artemisia sieberi*. Some of the typical desert plants, that grow in these communities because of the poor moisture regime, are: *Artemisia sieberi*, *Noaea mucronata*, *Bellevalia desertorum*, *Scorzonera judaica*, and *Fagonia mollis*.

The vegetation of the deep clay soils in small valleys and on plateaux include many herbaceous taxa that were regarded by several authors as exclusive weeds of similar but cultivated soils in the Mediterranean territory. Such areas which, lying near the 1948-1967 border in southern Judean mountains, were not cultivated for 19 years now harbour *Phlomis pungens*, *Salvia syriaca*, *Astoma seselifolium*, *Ferula biverticillata*, and *Scolymus maculatus* indicating that these species are not obligatory weeds but plants adapted to the specific conditions of deep clay soil (grumusol), involving water logging in winter and root tearing in summer as a result of soil shrinkage during desiccation. Many areas in this unit are almost devoid of active vegetation for a considerable part of the year. Overgrazing by herds and wood cutting of for fuel led to the establishment of perennial non-lignified and non-palatable plants such as *Asphodelus ramosus* and *Urginea maritima*.

9. Tragacanth vegetation of Mount Hermon

Snow covers much of the area of Mt. Hermon above 1900 m a.s.l. for at least 3-5 months a year. The dominant vegetation formation is composed of spiny, rounded, dense and small shrubs often known as "cushion-plants". Several species belong to *Astragalus* sect. *Tragacantha* , also known as a separate genus, *Astracantha* Podlech. Therefore, the whole formation is often referred to as tragacanth vegetation (Zohary 1973, Shmida 1977a). Plants here must survive the hardships of two seasons, snow cover and low temperatures in winter, and 4-5 months of drought in summer in those areas with no snow accumulation. The west facing slopes become desiccated by strong winds. The snow, which is the principal water source at these elevations, is carried away by the winds and accumulates on the eastern slopes. Snow depth east of small ridges may vary from a few metres to dozens of metres in one season. The western slopes are covered by a plant community dominated by cushion-plants such as *Astragalus cruentiflorus* and *Onobrychis cornuta*. The principal companions here are *Acantholimon libanoticum*, *A. echinus*, and *Astragalus echinus*. Geophytes, annuals and other plants with soft stems grow inside the shrubs, with only a few of them occurring in the open space among the shrubs. This is likely due to the protection against wind, herbivores, and snow hazards that the cushion-plants offer.

The depth of snow accumulating on the leeward slopes is influenced by local topography. When the snow melts in spring, a narrow, shifting belt of blooming plants covers the wet soil at the snow margin. Most prominent are *Romulea nivalis* and *Ranunculus demissus*. Cushion-plants also grow on parts of the eastern slopes that are covered by snow in winter.

The valleys here are commonly karst depressions. Dolines filled with fine-grained leached soil are a common habitat all over the peaks of Mt. Hermon. Snow-melt is the principal source of water in these dolines and the soil is waterlogged for a long time. *Polygonum cedrorum* and its many dwarf and prostrate companions cover the doline bottom.

10. Steppe vegetation

Semi-shrubs grow over most of the slopes and hills in areas with 80-250 mm mean annual rainfall. This vegetation formation is often referred to as steppe. Monod (1931) named this pattern of distribution "mode diffus", as opposed to a "mode contracté" where plants occur mainly in dry water courses known as wadis. The distribution of steppe communities of the Judean desert and the Negev is highly correlated with rock and soil properties. On hard and fissured limestone and dolomite most of the rain water penetrates the ground and accumulates in the soil filling the fissures and crevices. The water is protected here from direct evaporation. Such rocks support semi-shrubs on their slopes even in areas with less than 50 mm mean annual rainfall.

The most common dominant of these soils is *Artemisia sieberi*. *Thymelaea hirsuta* is the co-dominant in that part of the Negev that is close to the Mediterranean semisteppe bathas. *Noaea mucronata* is the co-dominant over large areas of the Judean desert and the Negev. *Reaumuria negevensis* is the co-dominant in the central Negev highlands, where there is some chalk component in the limestone rocks. *Gymnocarpos decander* is the co-dominant in the northern Negev anticlines (i.e., the Sede Boqer area) where many small outcrops of fissured limestone occur. These plant communities are rich in semi-shrubs, geophytes and annual plants have.

Soils that develops on clay sediments, soft chalk, marl, and loessial soils have a different moisture regime. Due to the high moisture holding capacity of the fine-grained substratum, rain water is absorbed by the upper soil layers. Much of this water is lost by direct evaporation from the soil surface and the small quantities of sea salts in the rain water (about 8 ppm) accumulate (Yaalon 1963). In mature soils there is a NaCl-rich layer at the depth of maximal water penetration. This also delimits the rhizosphere of the perennials in these soils. In rainy years, when the soil is leached, annuals cover the area densely.

The chalk and marl outcrops are characterized by plant communities that are poor in species, mostly with only one semi-shrub species. There are areas where no plants grow in normal years and where only in extremely rainy ones annual halophytes develop. The most common semi-shrub halophytes that dominate are *Reaumuria negevensis*, *R. hirtella*, *Atriplex glauca*, *Bassia* (*Chenolea*) *arabica*, and *Salsola damascena*. The annual xerohalophytes are: *Pteranthus dichotomus*, *Salsola inermis*, *Spergularia diandra*, *Mesembryanthemum nodiflorum*, and *Aizoon hispanicum*.

The plant communities developing on uncultivated loess soils are also characterized by dominance of one xerohalophyte. *Hammada scoparia* dominates in the relatively dry parts of the Negev, whereas *Anabasis syriaca* does so in moister areas. Loess in wide wadis with a gentle slope receives much higher quantities of water than the slopes proper. There are patches where *Hordeum spontaneum* dominates in such wadis.

The most interesting vegetation is found in crevices and soil pockets of smooth-faced rock outcrops and cliffs. Here water from a large area accumulates in the few crevices. The amount of available water in the crevices is several times that of other soils in the same area. Many Mediterranean plants grow in such crevices, at the foot of the rock outcrops, and in wadis that have such rocks in their catchment. It is assumed that they are relics from periods when a wetter climate prevailed in the Negev (Danin 1972, Shmida 1977b). Among the dozens such relics are: *Sarcopoterium spinosum*, *Narcissus tazetta*, *Sternbergia clusiana* (grows also on Mt. Meiron, unit 1), and the maquis elements *Prasium majus* and *Ephedra foemina*.

11. Steppes with trees of Pistacia atlantica

Most of the area of this unit is covered by *Artemisia sieberi* steppes, as described in unit 10. Trees are found here and there on rocky terrain above an elevation of 800 m. *Pistacia atlantica*, an Irano-Turanian tree (Zohary 1972) is the most common tree species there. It develops in three principal rocky habitats (Danin & Orshan 1970). Dwarf trees that never flower but may be several dozen years old are confined to rock crevices. Their growth is limited by the small size of the soil pockets forming their rhizosphere. At the foot of large rock outcrops there are 4-5 m tall trees which may be situated a few dozen metres below the mountain top. The most spectacular trees are those in the wadis (Fig. 3). Trees more than 10 m tall with even larger crown diameter are not rare. *P. atlantica* keeps germinating and establishing in the Negev, in all the habitats with hundreds of seedlings some of which are one or two and others a few dozen years old. When compared with the old large trees these may still be regarded as "seedlings" and display the continuous reproduction of *P. atlantica* populations in the Negev. The number of large *P. atlantica* trees in the Negev highlands, counted from aerial photographs, is 1400. The endemic almond *Amygdalus ramonensis* is even rarer. Its entire population is estimated to less than 200 individuals. Other rare arboreal plants of these highlands are *Rhus tripartita* and *Rhamnus disperma*. The endemic semi-shrub *Origanum ramonense* and the endemic perennial herb *Ferula negevensis* are confined to the smooth-faced rocks of this area.

The steppes of the Central Negev Highlands become very spectacular in rainy years. A community of *A. sieberi* with *Helianthemum vesicarium* looks like a blooming garden. The colour diversity of *H. vesicarium* populations is very high; there are various lilac, white, and purple flowers with many transitional colours. These are accompanied by the spectacular *Tulipa systola*, *T. polychroma*, and *Erodium crassifolium*. In dry years there is not even one flower over huge areas.

12. Desert vegetation

There is a gradual transition between steppe vegetation, in areas with more than 80 mm mean annual rainfall, and desert vegetation in drier areas. Many Saharo-Arabian species prevail on slopes with 70-90 mm mean annual rainfall. Within this area, edaphic conditions and microtopography are the most important factors affecting moisture regime and thus the distribution of plant communities. Areas of fissured hard limestone are populated by communities of *Zygophyllum dumosum* and *Gymnocarpos decander*, which are floristically less rich than the steppe vegetation. On the soft rocks there are plant communities of the xerohalophyte semi-shrubs *Suaeda asphaltica* (Fig. 4), *Agathophora* (*Halogeton*) *alopecuroides*, *Salsola tetrandra*, and others. Their typical feature is the dominance of one semi-shrub species that is hardly accompanied by any other one.

In drier parts of the desert, vegetation develops mostly in a contracted pattern, i.e., in wadis. On most soil and rock types there is not sufficient water in the substratum of the slopes to support perennial vegetation. Hard and fissured limestone and dolomite rocks support impoverished diffuse communities of *Zygophyllum dumosum* on their slopes. When descending from the water divide into the wadi, the catchment area grows progressively. The wadi beds change according to the increasing erosive potential of the wadi's water; the amount of water penetrating into the soil increases along the wadi course. The vegetation of the wadis changes along its course, and each section characterized by the dominance of one or two species is regarded as pertainig to one plant community. The other stands of that plant community are found in a similar section of the neighbouring wadis.

Fig. 3. *Pistacia atlantica* in Nahal Eliav, central Negev highlands (from Danin 1983).

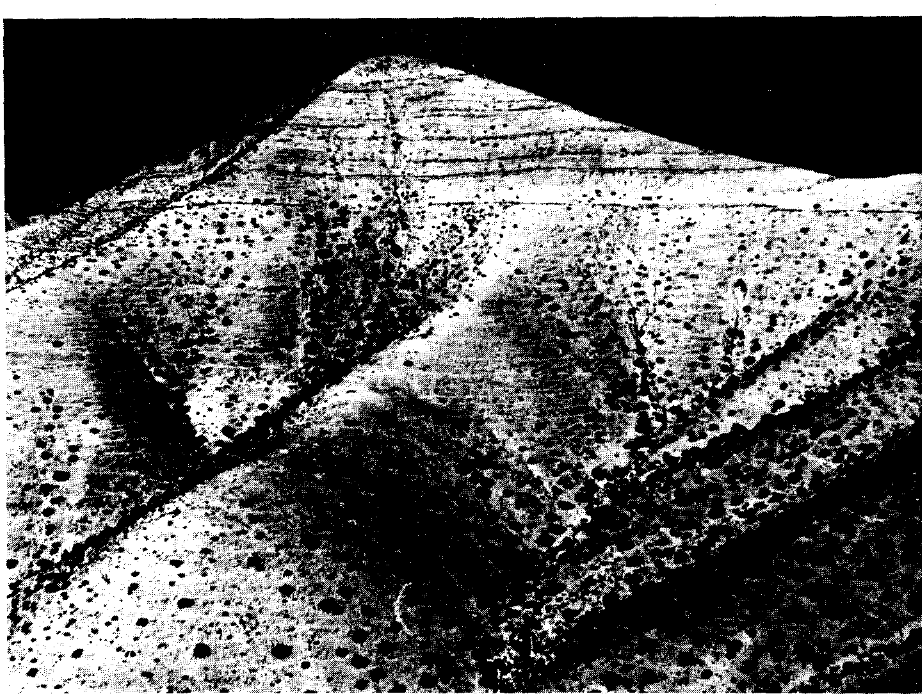

Fig. 4. A typical landscape with a *Suaeda asphaltica* plant community in the Judean Desert (from Danin 1983).

The general sequence of communities along wadis in extreme desert condition is the following: in the top section there are annual species in rainy years; below, short-lived small semi-shrubs prevail, which are accompanied in rainy years by species of the annual community and other companions; the third section is dominated by larger semi-shrubs that live from a few dozen to a few hundred years; in the fourth section 1-3 m tall shrubs dominate, accompanied by species of the previous communities and others. *Acacia* trees are the dominants of the first tree community in the wadis. Of the three *Acacia* species in the Negev, *A. gerrardii* subsp. *negevensis* develops at the highest elevations, *A. raddiana* prevails in *Acacia* community of warmer sites, and *A. tortilis* grows in the warmest areas (Halevy & Orshan 1972). Parts of the *Acacia* community belong to unit 15, i.e., the Dead Sea and Arava valleys. In the lower section of the *Acacia* unit in large wadis the underground water is close to the surface and the dominant tree is *Tamarix nilotica*.

There are dozens of semishrub communities along wadis of the Southern Negev. The most prominent are those of *Zygophyllum dumosum* on step-like outcrops of hard limestone and dolomite in the wadi; of *Gymnocarpos decander* which prevails in wadi sections where the substratum has outcrops of flint, limestone, granite, or other magmatic rocks; of *Artemisia sieberi*, dominant in wadis with silty beds of gravel plains of the southern Negev north-west of Elat; of *Hammada salicornica* which dominates in sandy wadis; of *Reaumuria hirtella*, *Salsola tetrandra*, *Agathophora* (*Halogeton*) *alopecuroides*, *Anabasis setifera*, and *Hammada negevensis*, dominant in wadis on soft chalk or marl. *Anabasis articulata* dominates in wadis which are similar to those with *Artemisia sieberi* but at a lower elevation, or with less silt and more gravel in the substratum of the wadi channel. The principal dominant of the shrub communities on chalk and marl is *Atriplex halimus*. On other soil types the shrubs are *Lycium shawii*, *Retama raetam*, and *Ochradenus baccatus*.

13. Sand vegetation

Each of the three main sandy areas in Israel is situated in a different climatic zone, and the origin of their sand is also different. The Mediterranean coastal sands are the youngest, and because of their coarse texture and unstable situation they support but a poor vegetation cover. The Haluza and Agur sands are older and have a finer texture and denser vegetation cover. The sands of the Rotem-Yamin plain, the Mamshit Valley and the valley between Yerokham and Dimona are derived from Tertiary sandstones by weathering and are composed of coarse sand and airborne silt. The sands of the Arava Valley are derived mainly from Cretaceous and Tertiary sandstones. Coarse sand is mixed there with alluvial material of varying texture and support the *Haloxylon persicum* plant community. This vegetation unit resembles a vegetation formation of Central Asia and is discussed separately (see unit 16).

The typical plant community of the coastal sand dunes along the Mediterranean sea is that of *Ammophila arenaria*. This perennial grass is characteristic of sands all along the coasts of the Mediterranean and the Atlantic seas. It produces adventive roots from the internodes of sand-covered stems and grows through the sand cover. When exposed its roots die. In the wind shadow of *A. arenaria*, *Artemisia monosperma* germinates. This is a desert plant that is adapted to the poor moisture regime of sand. An adult *A. monosperma* shrub survives both sand coverage of its stems and exposure of its roots. The sand, trapped within the shrub and protected from wind erosion, builds up a mound. These mounds, also known as biogenic mounds or phytogenic hillocks, lead to sand stabilization. When sand movement ceases, *Ammophila arenaria* dies and in the *Artemisia monosperma* shade other plants establish themselves that need and use the shade and the humus. In the moist environs of Caesarea amelioration of soil conditions (see under unit 5) takes place in a long process that leads to the development of soil that may support trees. In the south of the coastal plain the climate is drier and the *A. monosperma* community does not become so dense as to result in dust trapping; the stable sand is covered by communities dominated by *A. monosperma*, *Retama raetam*, *Scrophularia hypericifolia*, and *Moltkiopsis ciliata*.

Stipagrostis scoparia dominates on mobile sand dunes in the Haluza and Agur sands in a way similar to *A. arenaria* in the Mediterranean sands. In the first stages of stabilization, the sands become colonized with the perennial grasses *Panicum turgidum* and *Pennisetum divisum*. Old stable sand is populated with *Artemisia monosperma*, *Convolvulus lanatus*, *Pituranthos tortuosus*, and *Atractylis carduus*. Airborne silt and clay trapped at the sand surface improve the moisture regime there and enable the development of a microphytic crust with filamentous cyanobacteria as the principal component. This crust decreases sand mobility and promotes sand stabilization (Danin & al. 1989).

Large areas of sandy-loess soils in the northwestern part of unit 13 were cultivated by Bedouins in the past; they marked the boundaries of their fields by planting the large geophyte *Urginea maritima*. Beyond the border of Israel, in Egypt, intensive grazing and trampling by Bedouin herds, and cutting of lignified plants for fuel, led to destruction of the microphytic crust. This interference promoted reworking and wind erosion of the once stable sands on the Egyptian side of the border. This resulted in the striking borderline between the two countries that can be easily seen from space (Fig. 5).

The sandy soils of the northeastern Negev are characterized by dominance of *Anabasis articulata*, accompanied by various plants depending on local environmental conditions. *Thymelaea hirsuta*, that prevails in wadis on most soil types, grows in a diffuse pattern on unconsolidated sandstone between Yerokham and Dimona. One of the most prominent species that accompanies the *A. articulata* and *T. hirsuta* community is the rare *Iris petrana*. In Israel it grows only in two sandy valleys near Dimona. The *A. articulata* and *Artemisia sieberi* community is confined to those parts of the valley where large quantities of loess are mixed with the sand. Sand covers the ancient sandstone relief in the Yamin-Rotem plain. When protected from trampling, a cyanobacterial crust develops here as well. No semi-shrubs grow on the sandstone outcrops; it is the lignified annual *Anastatica hierochuntica* (rose of Jericho) that is confined to this habitat. When the exposed rock contains many pebbles, the dominant plant is *Zygophyllum dumosum*. *Anabasis articulata* dominates in sites where the sand cover is less than 1 m deep, and *Calligonum comosum* where it is deeper. *Calligonum comosum* and *Retama raetam* grow along the wadis.

14. Oases with Sudanian trees

The Arava, Dead Sea and Jordan valleys constitute the warmest zone in our country. Temperatures are much higher than in the neighbouring areas at the same latitude. This zone is also the base of erosion, i.e., runoff water and underground water accumulate in it. Large springs have flown for hundreds of thousands of years along the fault lines that bound this rift valley. Constant supply of fresh water and high temperatures enabled thermophilous trees of Sudanian origin to get established in oases. The distribution of each tree is limited by its demands for high temperatures or resistance to low ones, and by its tolerance of soil salinity. Several desert springs support the salinity resistant date palm, *Phoenix dactylifera*, that is accompanied by *Juncus arabicus* (Fig. 6). There is growing evidence that such spontaneous date palms could have been the progenitors of the cultivated varieties. Many Sudanian trees occur in En Gedi where fresh water springs flow at elevations higher than the level of the Lisan Lake (the precursor of the Dead Sea which existed between 70.000 and 11.000 years B.P., Begin & al. 1974).

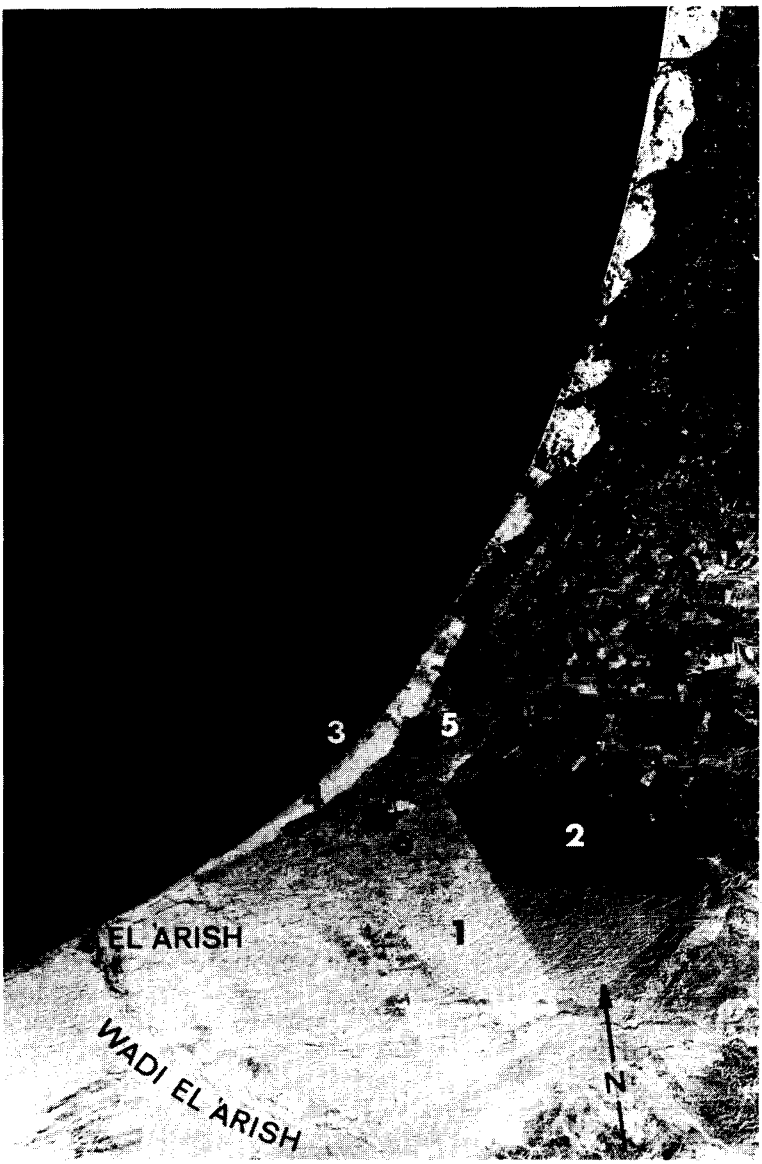

Fig 5. Landsat imagery of the boundary between Israel and northeastern Sinai as it appeared in 1973. 1, sand vegetation destroyed; 2, sand occupied by intact vegetation; 3, date palm plantations on the coast of the Mediterranean sea; 4, shifting sands; 5, sandy soil covered by various cultivated plants; 6, fenced area of Sadot where grazing and direct plant cutting ceased after 1970 (from Danin 1983).

The following are some such Sudanian trees: *Calotropis procera*, *Moringa peregrina*, *Salvadora persica*, *Cordia sinensis*, *Ziziphus spina-christi*, *Ficus carica*, *Acacia tortilis*, and *A. raddiana*. Several Sudanian species grow in Jericho and the large wadis west and north-west of it; however, the list of spontaneous Sudanian trees of this area is shorter than that of En Gedi. The relatively cool temperature regime may be responsible for this decrease. The common trees of Jericho and its environs are *Ziziphus spina-christi*, *Balanites aegyptiaca*, *Calotropis procera*, and *Ficus carica*. The same trees prevail further north to the Jiftlik area at the oasis of Nahal Tirza (Wadi Fara'a). *Loranthus acaciae* is a prominent Sudanian semi-parasite that grows on a few of these Sudanian trees.

Ziziphus spina-christi, the most cold-resistant Sudanian tree, forms savannoid vegetation further north (unit 7). The *Acacia* species are the most drought-resistant trees and form savannoid vegetation along the Arava Valley (unit 15).

15. Desert savannoid vegetation

The amount of mean annual rainfall gradually increases in the rift valley from 30 mm near Elat to more than 150 mm north of Jericho. This quantity enables the growth of desert plants in most of the area. The amount of water is much higher at a depht of a few meters than in the upper soil layers. Sudanian trees, the roots of which penetrate through the upper layers in wadis, may take advantage of the high water table in this area of poor rainfall. Thus, some areas in the rift valley look like East African savannas, but with Saharo-Arabian companions and with no perennial grasses (Fig. 7). Of the *Acacia* species of Israel, *A. tortilis* is most drought resistant and thermophilous. *A. raddiana* demands more water and grows in cooler sites. The distribution of their desert companions is closely related to the edaphic conditions (Rudich & Danin 1978). *Anabasis articulata* is co-dominant in gravel plains with flint pebbles and with low quantities of sand. *Hammada salicornica* and *Salsola cyclophylla* prevail in wadis with a sandy-gravelly substratum. *Haloxylon persicum* accompany the *Acacia* species in wadis with deep sand filling. *Nitraria retusa*, *Alhagi graecorum* and *Desmostachya bipinnata* accompany the *Acacia* trees at the margin of large wet salines, where the upper soil layers are salty but the underground water is not so saline. In the magmatic massif near Elat many Saharo-Arabian and Sudanian companions are found in wadis, such as *Lavandula coronipifolia*, *L. pubescens*, *Pergularia tomentosa*, *Crotalaria aegyptiaca*, *Abutilon fruticosum*, *Tricholaena teneriffae*, *Stipagrostis raddiana*, and *Panicum turgidum*.

16. Haloxylon persicum on sands

Deep sands in the Arava valley are covered by a sparse woodland of *Haloxylon persicum*. These are 2-4 m tall trees with *Hammada salicornica* and *Calligonum comosum* scattered in between. A similar formation dominated by related species of *Haloxylon* occupies large territories in Central Asia; it is called "saxsaul", the vernacular name of the dominants.

Much of the area that was once covered by *Haloxylon persicum* is intensively cultivated at present. There are large *H. persicum* and *Tamarix aphylla* trees that germinated near the wadi and were covered since by 2-4 m high sand mounds.

17. Swamps and reed thickets

Waterlogged soils on river banks support dense vegetation with low species diversity. We list here a few of the typical hydrophytic habitats. *Phragmites australis*, *Arundo*

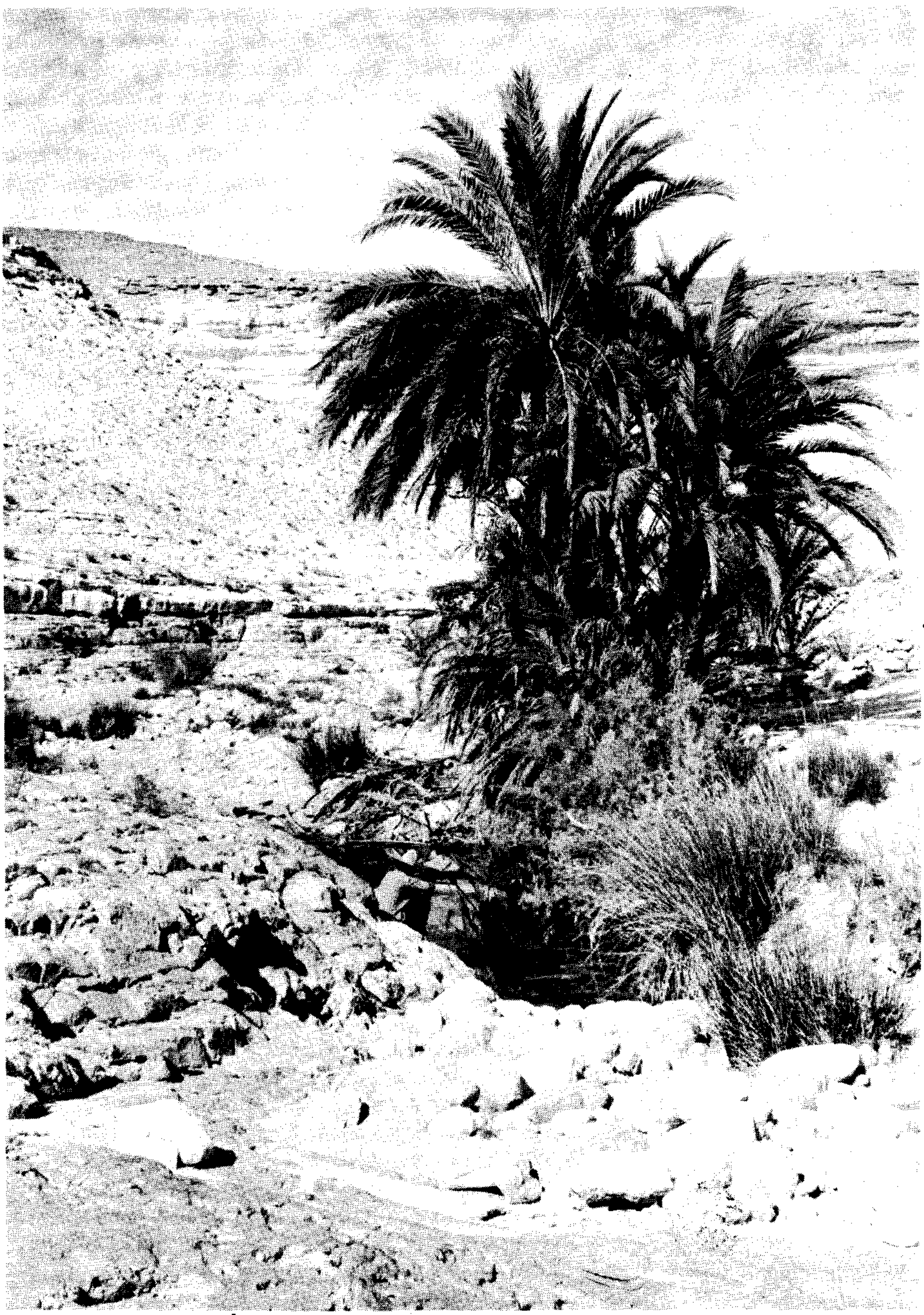

Fig. 6. A spring in limestone and chalk desert terrain, with *Phoenix dactylifera* and *Juncus arabicus*.

donax, and *A. plinii*, together with *Rubus sanguineus*, often form impenetrable thickets near springs and on river banks. *Typha domingensis* prevails in sites where fresh water (even sewage water) flows slowly or is standing. A few *Juncus* species grow in places with a high water table, where the period when this water is exposed above the ground is short. A few *Juncus* species withstand soil salinity. The date palm (*Phoenix dactylifera*), regarded by many researchers as a spontaneous species of this country, grows near many desert springs such as En Ziq, En Aqev, En Zin, and En Aqrabim. These sites and many others are too small to be shown on in our map. It has been suggested that during the domestication of date palms, such populations were used as a source.

Typical riparian trees are: *Platanus orientalis* that grows in the Upper Galilee; *Salix acmophylla* and a few *Tamarix* species that occur along many rivers all over the country; and *Populus euphratica* which is the principal tree near the river Jordan and near a few desert springs.

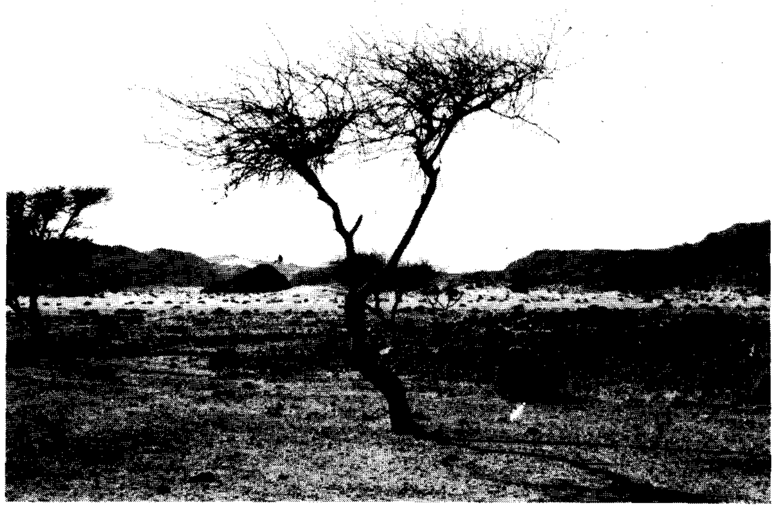

Fig. 7. *Acacia raddiana*, accompanied by various Saharo-Arabian semishrubs, thus forming savannoid desert vegetation.

18. Wet salines

Salines where salty water moistens the soil throughout the year occur along the Jordan, Dead Sea and Arava valleys, and near the Mediterranean sea at Akko (Danin 1981). The geological structure along most of the Mediterranean coast of Israel causes water to flow from the land to the sea. In the Zevulun valley between Akko and Mt. Carmel, the west-to-east rift enables underground flow of seawater inland and its mixing with freshwater. The low-lying areas of salt marshes are populated by *Arthrocnemum macrostachyum*, *Sarcocornia fruticosa*, *Limonium narbonense*, *Atriplex portulacoides*, and *Tamarix tetragyna*. Sandy soils that cover the salt marshes support a rich vegetation of halophytic and non-halophytic annuals. Their coexistence here is made possible by the leaching of the soil, in a non-homogeneous pattern, by large quantities of rain-water. Before the draining of these salt marshes vegetation belts could easily be seen (Orshan & Zohary 1955). The salt marshes in the desert parts of the country differ by the scarcity of annuals. In most years the soil is too saline to enable their development.

The prominent plants in the salt marshes of the desert are: *Suaeda monoica*, *S. fruticosa*, *S. vermiculata*, *Arthrocnemum macrostachyum*, *Nitraria retusa*, and *Seidlitzia rosmarinus*. *Tamarix nilotica* and other *Tamarix* species, which are highly resistant to salinity, thrive in desert salines. The largest continuous salt marshes are those in the southern Dead Sea area, and near Yotvata. There are no higher plants in the constantly wet salty center of these marshes. A few plant communities that are arranged in belts around the sources of saline water can be seen in both areas (Bourvine 1963, Danin 1983).

19. Synanthropic vegetation

The vegetation in the areas that are intensively managed by man can be easily differentiated from that of the intact areas, or areas of small interference. The history of human activity in the Levant is long, and according to Zohary (1983) we are now in the Neo-Segetal era. The most intensively cultivated areas along the coastal plain and the Esdraelon Valley (unit 19) are divided into three principal subunits: (19a) the cultivated areas where remnants of *Quercus ithaburensis* occur; (19b) where the spontaneous trees are *Ziziphus spina-christi*; and (19c) where both *Z. spina-christi* and *Acacia raddiana* can be found. Synanthropic species occur all over the country (Danin 1991a). Examples from specific habitats are listed below. For the last 20 years the roadsides of the main highways were sprayed with herbicides, the main purpose being to prevent the development of winter annuals. These can become a "fire bridge" lit by burning cigarettes thrown from passing vehicles and igniting the area near the road. The herbicides used for this purpose are triazines that affect the young seedlings when emerging from the seed coat. Perennial and annual summer grasses germinate at the end of the winter, when the herbicides have already disintegrated. Such grasses are: *Hyparrhenia hirta*, *Dichanthium annulatum*, *Sorghum halepense*, *S. virgatum*, *Tricholaena teneriffae*, *Cynodon dactylon*, *Panicum maximum*, *P. capillare*, and *Paspalum dilatatum* (Danin 1991b). *Prosopis farcta* and *Alhagi graecorum*, which emerge from perennial underground organs, start developing in spring and are not affected by the herbicides.

When the use of herbicides ceases the first colonizers that invade the open space among the grasses are the wind-dispersed three *Conyza* species and *Aster subulatus*, which are all of American origin and arrived in Israel during the last 100 years.

A few dozen adventive plant species that reached the country from afar have developed in man-managed habitats, where the primary vegetation was destroyed for a certain time and the area is opened for colonization. Such habitats occur at the margins of agricultural areas and on the sides of major roads, where rocky or stony material was deposited on the local soil. In a similar way, building sites may harbour colonizers until the entire area is adequately managed.

Some of the wheat and barley fields of the Arab farmers are cultivated and managed by ancient farming methods. Many of the Biblical descriptions of the agricultural life are matched by this style of farming.

The weeds of winter cereal fields are similar to those found in the area a few millennia ago when these cereals were domesticated. *Lolium temulentum* and *Cephalaria syriaca* have large seeds that are not dispersed at maturity. The entire plants are harvested with the cereals, and their seeds, being of similar weight and size, are not separated from the cereal seeds on the threshing site but are sown again together with the crop seeds.

The weeds in the intensive and modern Israeli agricultural areas are different (Danin & al. 1982). The species composition depends on agrotechnical management and on the type of herbicides used. The summer irrigated fields harbour species of: *Amaranthus*, *Xanthium*, *Conyza*, *Eragrostis*, *Echinochloa*, *Chloris*, and *Paspalum*. *Abutilon* *theophrasti*, *Datura* and *Xanthium* species, that were not known in the dry farming, became noxious weeds in cotton fields.

Orchards of orange and other fruit trees harbour a rather unique assemblage of weeds. They include wild and cultivated plants, which are dispersed by birds that eat the juicy fruits and excrete the undigested hard seeds under the orchard trees.

Thus several ornamental species of *Asparagus*, *Prasium majus*, *Lantana camara*, *Morus alba*, *Melia azedarach* and *Washingtonia filifera* became established in orchards of the coastal area.

Apart from these, there are plenty of alien species that are found in synanthropic habitats as well as local species that abound in these habitats and become synanthropic (Danin 1991a).

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Address of the author:
Prof. A. Danin, Department of Evolution, Systematics and Ecology. The Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Israel 91904.