INTRODUCTION
The site of the el-Wad cave and terrace, Mount Carmel, Israel, has long been considered one of the major Natufian base camps, or hamlets, of the Mediterranean core-area, west of the Jordan River (Bar-Yosef 1983; Garrod 1957). Its large area, together with typical characteristics, such as dense occupational layers, architectural remains, a large and stratified cemetery and heavy ground stone implements, suggests that it was possibly a sedentary settlement (Weinstein-Evron 1998, and references therein). Based on the results of Garrod's excavations at the site and those portions exposed by her, namely the outermost chamber of the cave and the terrace in front of it (Garrod and Bate 1937), el-Wad has been considered among the medium-sized (400-500 m$^2$) Natufian sites (Bar-Yosef 1983). More recent estimates, however, based on excavations and geophysical analyses within the cave, archival material of the early excavations (Weinstein-Evron 1998; and unpublished data), coupled with a geophysical survey (Weinstein-Evron et al. 2003) and renewed excavations on the terrace (Weinstein-Evron et al. n.d.), suggest that the site occupied an area of no less than 1,000 m$^2$. The Natufians also sporadically utilized the other caves of the same cliff
(Tabun, Jamal and Skhul) (Weinstein-Evron 1997). Thus, el-Wad should be considered as one of the larger Natufian base camps. Significantly, el-Wad has been found to contain one of the most complete Natufian sequences in the Levant (Weinstein-Evron 1998), spanning from the Early Natufian, through the Late Natufian (Garrod and Bate 1937) to its final stage (Valla et al. 1986). A radiocarbon age determination for the Early Natufian in the cave, 12,950 ± 200 bp (RT-1368) (15,700-15,000 Cal. BP), has provided the earliest estimate for the beginning of the Natufian to date (Weinstein-Evron 1991, 1998). While an additional date of 10,680 ± 190 (RT-1367a) (12,820-12,370 Cal. BP) from the cave probably represents the Late Natufian of the site, no direct radiometric age estimates are available for the end of the Natufian sequence at el-Wad. The final Natufian is believed to have been of a relatively short duration and its end coincides with the last of the Natufians, or the beginning of the Neolithic, about 11,500/11,000 years ago (calibrated 14C dates) (Bar-Yosef 2002). Thus, the el-Wad sequence altogether represents some 3,500-4,000 years of Natufian occupation of the site. As we have just seen, el-Wad can be considered as a relatively large long-term Natufian occupation, yet it is impossible to determine whether it was occupied to its full size during the whole sequence of occupation. It is quite probable that at el-Wad, as at other Natufian sites (Bar-Yosef 2002), there was an occupational gap between the Early and Late Natufian. Moreover, there seems to have been some additional variations in the duration and intensity of the various phases of occupation within the Natufian period at el-Wad. The Early Natufian, the longest of the three Natufian phases at el-Wad, inhabited both the cave and the terrace (Garrod and Bate 1937). This is also the only phase for which a long-term occupation was attested by architectural remains. The shorter Late Natufian was probably limited to the terrace. No architectural remains belonging to this phase have been unearthed at the site, which may correspond to the apparent increased mobility typical of human groups at this stage of the Natufian (Bar-Yasef 2002 and references therein). The Final Natufian was probably short in duration and spatially limited (Weinstein-Evron n.d.; Weinstein-Evron et al. n.d.).

Charcoal remains from the Early Natufian layers of el-Wad cave (Lev-Yadun and Weinstein-Evron 1993, 1994) indicate that typical East Mediterranean woody species were utilized by the Natufian inhabitants of the site. This was supported by the palynological data (Weinstein-Evron 1994). A similar picture of a typical East Mediterranean forest/maquis emerges from an analysis of charcoals in the southern part of Mount Carmel from the Kebara Cave at an earlier period, about 60,000-30,000 years ago (Baruch et al. 1992); these charcoals probably also represent the vegetation in the vicinity of the cave. In general, a Mediterranean climate characterized the region for a very long time (Horowitz 1979).

To date, the studies modeling the human impact on the vegetation of ancient Israel in relation to life style and site sizes have all been of agricultural communities or central
situates of such communities (Gophna et al. 1986/7; Lev-Yadun 1997, 2006, in press; Liphschitz et al. 1989; Waisel 1986). The approach used in such studies is based on the size and modes of activity of human populations, and tries to evaluate their impact on a given area according to their demands in arable land, grazing area and wood supply. In such models, there is the possibility that human demands are below the carrying capacity of the territory. For later periods, as they are relevant, trade, taxation, war and other human affairs are taken into consideration in the modeling process. There was no detailed effort to model the impact of human needs on the woody vegetation in pre-agricultural societies in Israel. A different approach is to model the potential carrying-capacity of an environment, rather than the human demands. The pioneer study of Vita-Finzi and Higgs (1970) on Mount Carmel led to the development of the procedure known as “site catchment analysis”. Site catchment analysis evaluates the maximal potential of the environment to provide for human needs, irrespective of the size and demands of the actual or estimated population.

THE SIZE OF POPULATION OF EL-WAD
It is difficult to estimate the size of Near-Eastern hunter-gatherer bands with much certainty. Current estimates for bands in hunter-gatherer societies emerge from various remote ecosystems that greatly differ from the Near-Eastern Mediterranean one. Moreover, we are much too distant in time and lifestyle from Near-Eastern hunter-gatherer societies to get a direct understanding of such people. In later periods, in certain sites and strata, we can calculate the number of houses in an excavated area and, by comparing such data to ethnographic studies (i.e., Biger and Grossman 1993; Kramer 1982) and censuses from previous centuries (i.e., Hütteroth and Abdulfattah 1977) within the Near East, arrive at what seems to be a close estimation of the density and total number of people in a specific site (Broshi 1980, 1993; Broshi and Finkelstein 1992; Broshi and Gophna 1984, 1986; Garfinkel 2002; Shiloh 1980; Zorn 1994). Population estimates of a Natufian band in a core-area basecamp range between 30 and 50 people (Belfer-Cohen et al. 1991), or the size of an extended family (Bar-Yosef 2002). Since we are, in fact, unable to make reliable estimates of the number of inhabitants in a Natufian site such as el-Wad, and since we want to be sure that we use the maximal exploitation values, we will model the use of wood by the Natufians of el-Wad according to four different hypothetical estimates of the number of people: 20, 50, 100 and 200, although it is probable that 200 people is much too high an estimate.

THE WOODY VEGETATION NEAR EL-WAD DURING THE NATUFIAN PERIOD
We reconstruct the types of wood used by the Natufians in the light of our previous
archaeobotanical studies on the charcoals from the Natufian layers of el-Wad (Lev-Yadun and Weinstein-Evron 1993, 1994). Based on the analyzed botanical remains, which included woody plants of both the forest/maquis (i.e., evergreen and deciduous oaks) and riverbank and wet lowlands (i.e., tamarisk and willow), it seems that the environmental setting of Natufian el-Wad in an ecotone (Weinstein-Evron 1998) is not just a geographical definition, but that the wood remains actually indicate the exploitation of both regions (oaks of the hill region and tamarisk of the marshes). The hill region thus seems to have been covered by a typical East Mediterranean forest/maquis. The lowland was probably at least partly covered by some kind of marshes, as indicated by the charred wood remains (Lev-Yadun and Weinstein-Evron 1994; Weinstein-Evron 1998), palynology of contemporary coastal marshes (Galili and Weinstein-Evron 1985; Kadosh et al. 2004; Weinstein-Evron 1994) and faunal data (Bar-Oz et al. 2004; Bate 1937; Rabinovich 1998; Valla et al. 1986). The forest and maquis in the hill region were represented in the Natufian botanical finds by Quercus calliprinos (kermes oak), Q. ithaburensis (Mount Tabor oak), Cupressus sempervirens (Italian cypress) and Myrtus communis (myrtle) (Lev-Yadun and Weinstein-Evron 1994). Most of the common dicotyledonous trees and shrubs are found in the region today. Interestingly, the common woody plant species found in the excavation, regenerate well after cutting.

The Younger Dryas, the cold and dry climatic episode in Europe, probably had a very limited impact in the Near East, which was very far from the glaciation, as evident from Near-Eastern pollen records (Bottema 1995; Weinstein-Evron 2002). The composition of the woody vegetation, as reflected by the species composition of el-Wad charcoals (Lev-Yadun and Weinstein-Evron 1994), suggests that the ecological conditions at Mount Carmel during the Natufian period were quite similar to those at present. The same is suggested by the palynological assemblages (Weinstein-Evron 1994), which include several species that were also found in the charcoals. The woody species that characterized the arboreal vegetation of the Central Negev Highlands during the Natufian and Harifian (Baruch and Goring-Morris 1997) also indicate that a long dry phase such as the Younger Dryas was not prominent in southern Israel. The measurements that agree with a possible considerable Levantine impact of the Younger Dryas (e.g., Bar-Matthews et al. 1997, 1999) are based on isotopic data that might be influenced by little-understood fractionation processes in the soil and rock layers above the cave, and by the non-local source of rain, a known effect in our region (e.g., Yakir et al. 1996). Since the rain-derived isotopic signal found in sediments in Israel is largely influenced by water that flows into the Mediterranean Sea from Europe via the rivers and rainfall, and possibly also from the Atlantic Ocean via the Straits of Gibraltar, there is thus an as yet unsolved issue of an unknown magnitude in studying the actual conditions in the Levant by using isotopes originating from rain water. Moreover, the botanical assumptions concerning the rise of bush-type vegetation
dominated by C₄-type plants in the Soreq Cave region presented in Bar-Matthews et al. (1996, 1997), which continued in later papers of this group, are not supported by what we know about C₄-type plant distribution and amounts of rainfall (e.g., Zohary 1980). The northward spread of C₄-type plants occurred following the impact of grazing, burning and cutting in the last several millennia (Zohary 1983). The Levantine palynological data, and all other local types of botanical evidence, such as charcoal analysis or geobotanical information, also do not support the dominance or even existence of C₄-type plants there. If the Younger Dryas was colder than usual, we should expect that the thermophyllus C₄-type plants (e.g., Vogel et al. 1986) would be restricted to hot habitats, such as the lower Jordan Valley or the Arava, and would not grow in the Judean Mountains. The proportion of shrubs of the Chenopodiaceae did not change significantly during the Younger Dryas in the only detailed relevant Israeli pollen record from the Hula (Baruch and Bottema 1999; Bottema 1995, 2002). Moreover, Artemisia pollen levels (a possible indication of cold and dry conditions) were very low in the proposed Younger Dryas phase (Weinstein-Evron 1998). The palynological studies that argue for a clear Younger Dryas event in the Levant (Rossignol-Strick 1993, 1995) are based mostly on marine cores usually drilled far from Israel and the Levant, indicating that the relative contribution of the Levantine vegetation is unclear. We conclude that, concerning Israel, both pollen (Baruch and Bottema 1999; Bottema 1995, 2002) and charcoal (Baruch and Goring-Morris 1997) studies do not support statements such as “there is no other ground-cover than desert in lowest and upper altitudes, with Chenopodiaceae, and semi-desert with sage-brush” (Rossignol-Strick 1993:150). The recent attempt to re-interprate the Huleh and Ghab pollen diagrams (Meadows 2005) suffers from the well-known inherited deficiency in the original data - the lack of reliable dating. This problem cannot be solved without new careful and broad sampling, and all attempts to progress with some modification of the old data seem to be futile. We therefore argue that proposals for a drastic climatic change in Israel during the Younger Dryas should be embraced less enthusiastically until several complicated issues are better understood.

THE MODEL

Concerning el-Wad, we model the need for firewood and the possible ways of providing it with the Natufian technology. We give the figures according to several hypothesized population sizes (20, 50, 100, 200 people), and evaluate the size of the area influenced significantly by such Natufian populations. The model is based on the human need for firewood, compared to traditional societies in various parts of the world. Firewood was the only significant source of fuel for heating and cooking, before the use of dung from domesticated animals, coal or fossil oil.
To estimate the environmental impact of the activity of the occupants of el-Wad, we need an estimate of the size of the population, the per-capita consumption of firewood, the duration of the occupation, the forest biomass per unit area and the rate of forest regeneration. Several attempts have been made to estimate such needs in ancient Israel. The basis for such calculations is the use of firewood by traditional societies, because they bear a closer resemblance to ancient societies than any other current ones (Gophna et al. 1986/7; Lev-Yadun 1997, 2006, in press; Waisel 1986). Waisel (1986) proposed that the per-capita daily wood consumption was 2.5 kg (0.91 ton/year). This amount of wood is in the range of the current per-capita firewood consumption in developing countries, although higher figures for firewood consumption have also been reported (Agarwal 1983; Dewees 1989; Wood and Baldwin 1985). For earlier periods, when forests had not yet been damaged for millennia and wood was not as scarce as it is now, we assume that the annual per-capita firewood consumption was 2 tons.

A mature humid Mediterranean forest in southern Europe supplies 26 tons per 1,000 m² (Lieth 1975). In the more arid eastern Mediterranean region, the forest should have had lower productivity than in southern Europe. Moreover, we assume that the Natufian technology was less efficient in felling trees than in later periods. However, the virgin forest probably had more easy-to-collect dead wood than the current younger woody formations. All in all, we estimate that five tons of firewood per 1,000 m² of forest/maquis could have been exploited, even if large and thick oak trunks were avoided. On the basis of the current regeneration rate of the local woody formations (see Aloni 1996; Samoch et al. 1980; Shamir 1987), even after millennia of large-scale damage, including soil erosion and the consequent reduced carrying capacity, we estimate a fair regeneration of the forest in 50 years. Thus, we assume that the cumulative damage of 50 years is the maximal possible damage to the forest if occupational phases were not longer than several hundred years. After 50 years, the Natufians could have used the regenerated, previously damaged trees again, as if they were not damaged in the past. This, of course, is the maximal figure of damage. There is a high probability that partially regenerated trees were already used only 10-20 years after the previous phase of cutting, when their branches were thinner and thus easier to cut than those of undamaged intact trees. We do not propose pollarding (repeated cutting of young regrowth of branches), although this method could have been used, because there is no evidence for such a practise here. Pollarding can be evident in the structure of growth rings of trees (Haas and Schweingruber 1993). Our estimate of 5 tons of firewood per 1,000 m² is probably lower than the actual harvest of wood. We use this lower figure, however, because we prefer to risk an over-estimation of the size of the damaged area, rather than to under-estimate it, in order to ensure a reliable evaluation. We also do not assume that large forest fires were intentionally ignited by the inhabitants as a management practise, because we have no evidence for such a practise in this region. We will, however, discuss this possibility below.
RESULTS (ENVIRONMENTAL DAMAGE ESTIMATES)

If an individual needs an annual supply of 2 tons of firewood, in 50 years (the time needed for full regeneration) a person will use 100 tons of firewood. Assuming a supply of 5 tons of firewood per 1,000 m², a single person would exploit wood from an area of 20,000 m². In this area, the trees regenerate regularly and no severe soil erosion is expected. A band of 20 people would thus damage an area of 400,000 m²; a population of 50 people 1,000,000 m²; a population of 100 people, 2,000,000 m²; and a population of 200 people, 4,000,000 m². Assuming a circular damaged area, the radii are about 360 m, 560 m, 800 m and 1,130 m respectively. The dominance of oaks and tamarisks in the charcoal remains from the el-Wad cave indicate that the Natufians used both hill region and lowland as sources for firewood. Thus, although we cannot assume an exactly circular catchment for firewood, this indicates that the inhabitants got their firewood from a nearby area. Had they brought most of the wood from the hill region, or alternatively mostly from the lowland, the oak/tamarisk ratio in the charcoal remains from el-Wad would not have been close to 1:1 (Lev-Yadun and Weinstein-Evron 1994).

DISCUSSION

The occupational history of Natufian el-Wad should have been reflected in the level of its impact on the environment, including the damage to the woody vegetation. Since the largest occupation occurred in the Early Natufian, the maximal damage should have been inflicted then. It is probable that the assumed occupational gap between the Early and Late Natufian allowed for a full regeneration of the woody plants. If there were additional intermediate occupational gaps, even if they were only several decades long, they would also have allowed for a good, or even full regeneration of the forest. The environmental influence of el-Wad, taking into account the possibility that during the Early Natufian it was occupied continuously (for some 2,000 years), is also taken into consideration. The opening in the ecosystem following hundreds of years of continuous occupation, probably could form a partially cleared area with thick, intact trunks and a repeatedly pruned canopy, within a radius of just over 1 km. if 200 people lived there for the whole length of the Early Natufian (2,000 years), and a smaller area if the population was smaller. Such trees were seen in 2003 by one of the authors (S. L-Y) in the vicinity of a village in a sparsely populated, forested area of Greece. Even within this damaged area, most of the damage would have been caused near the site. Even a farming community, such as the Pottery Neolithic Nahal Zehora II settlement in the southern Mount Carmel, that practiced both farming and grazing, could have considerably influenced the environment only within a radius of 1–2 km (Lev-Yadun 2006). The trampling of the soil and the garbage heaps probably resulted in the establishment of ruderal plants that tend to spread under such
conditions (see Zohary 1962). Interestingly, the palynological study of el-Wad clearly indicates the occurrence of ruderal plants (Weinstein-Evron 1994). Similarly, the house mouse emerges as a commensal at the Natufian layers of Hayonim Cave (Tchernov 1991), and its occurrence has been demonstrated recently in the Late Natufian layers of el-Wad (Weissbrod et al. 2004). The damaged area within the virgin forest, either in the hill region or the lowland, was probably too small and the occupational phases too short to allow for genetic adaptations to the man-made changes in the environment at the level of speciation of plants.

If the Early Natufians occupied el-Wad continuously for 2,000 years, they could have damaged the woody vegetation near the site more than if they had several occupational gaps. Current tree-ring studies indicate that the oak trees growing in Israel, similar to those that seem to have dominated the vicinity of the site, may live for several centuries (Lev-Yadun, unpublished data). Repeated damage to the trees and the use of acorns could have lowered their natural regeneration ability. At some age, the trees probably died, and if natural regeneration was lower than usual because of various types of human activity, the region near the site should have lost some of its tree cover. In this case, the radius of the damaged area would have been somewhat larger than the values calculated. If we thus assume that the Natufians influenced an area double that previously modeled, the radii of influence should have been 505, 800, 1,130 and 1,600 m for 20, 50, 100 and 200 people, respectively, rather than 360, 560, 800 and 1,130 m, respectively, when assuming occupational gaps.

An important issue that should be addressed is the possibility that forest fires were set regularly by the Natufians as a management practice aimed at increasing resources. Such a view concerning human activity in the Mount Carmel environs has been proposed by Naveh (1999). Indeed, hunter-gatherers in Australia used this practice on a large scale until recently (Bowman 1998; Kershaw et al. 2002). We briefly discuss the type of evidence needed for accepting (with only a low probability of a mistake) the proposal for such a practice by the Natufians of Mount Carmel. We agree that it is tempting to propose that the Natufians used fire for environmental management. However, contrary to the intuitive view, from our field experience following the serious fires on Mount Carmel in 1983 and 1989, we conclude that the impact of fire on the environment might have a greater risk of reducing the available resources, rather than increasing them. Firewood availability would be greatly reduced for several decades and similarly, acorns, pine nuts, wild olives and edible fruit of other trees and shrubs would not be available at all in the burnt area for years. Certain edible mushrooms would also disappear until new colonization occurs. The annual plants that may only partly compensate for these losses cannot grow in large quantities for several years since the establishment of large populations in the newly formed territory is a slow process. Collection of their seeds by
the Natufians during the first years would not allow for the establishment of adequate plant populations. Moreover, since many of the woody plants on Mount Carmel re-sprout or germinate after fire, the area would not have been open for large-scale colonization of annuals, even though it was still not a forest. The possible compensation for all the losses following fires, by improved conditions for certain grazers that may be hunted, does not seem to compensate for the great losses in food, firewood and construction wood resources. Even if we do not wish to dismiss this possibility, there is no evidence for such a practice. In Australia, charcoals in sediments and some palynological indications support the burning hypothesis. Such evidence is not available for Natufian Mount Carmel or elsewhere in Israel. When clear, unequivocal and well-dated positive indications for ancient fires in the Mount Carmel region emerge, the possibility that prehistoric hunter-gatherer groups in the Levant used fire for environmental management should be re-examined. As we have shown, a large forest fire, in the vicinity of the site may even have triggered an occupational gap, because of the resulting lower carrying capacity for humans.

When the Early Natufians inhabited el-Wad, they entered a largely undisturbed forest/maquis in the hill region, probably with dense vegetation along the wadi and in the marshes or non-flooded lowland. Earlier occupations of the cave had probably ended some time before the Natufian, and the environment should have fully recovered from any environmental damage. Gradually, the trees near el-Wad were damaged and a more open formation, with thick trunks, but thinner branches or secondary stems that grew after cutting became dominant (see Kaplan and Gutman 1996). The newly formed gaps between the trees could have enabled the growth of more annuals and other low plants than in the dense and dark forest or maquis. Some of these, such as legumes, cereals, aromatic shrubs and geophytes, could have provided some food and medicines for the Natufians. A similar model of the process of concentric belts of various levels of environmental damage was described for the fauna (Tchernov 1991). This process was reversed during every occupational gap. If the occupational gap was longer than 50 years, the forest should have returned to its primary condition. The probable limited damage to the thick trees and the lack of agriculture should have resulted in no considerable soil erosion. Thus a quick regeneration and closure of the forest openings would be expected.

We conclude that according to the botanical remains and models of the possible impact of the Natufians on the forest, the Natufians of el-Wad did not change their environment to a large extent. Their significant impact on the vegetation was limited to a radius of several hundred meters from the cave if the band was of 30-50 people. Only a population of 100-200 people, a number much higher than the estimated Natufian population of the site, could considerably damage the forest over a radius of 800-1,100 meters. This was still a small
level of damage to the natural vegetation, too small to result in a population crisis due to limited resources. Even doubling the damaged area according to a model that assumes no occupational gaps for 2,000 years, does not greatly change the radius of the damaged area. If the amount of wood used per capita were more moderate than the large value of two tons per capita per year we used in our model, or if the population were smaller, or there were more occupational gaps, the damage would have been restricted to even a smaller area. We propose that, concerning the forest and maquis, the Natufians operated in balance with the environment except for the immediate vicinity of the site. Since plants compose the basic level in the food chain, even the documented Natufian pressure on slow-moving game such as tortoise (Stiner et al. 1999), does not seem to have caused irreversible environmental damage. The resilience of the Mediterranean vegetation (Perevolotsky and Seligman 1998) probably enabled good regeneration of the biota during the occupational gaps and after the end of the Natufian period. Even if there had been a dryer phase, in which the annual precipitation decreased by 25%, the Mount Carmel vegetation would still have been typically Mediterranean, with a similar carrying capacity.

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