19 August 1960, Volume 132, Number 3425 SCIENCE

CURRENT PROBLEMS IN RESEARCH

Deforestation in Northern Morocco

Burning, cutting, and browsing are changing a naturally wooded area into a land of scrub.

Marvin W. Mikesell

Students of the Mediterranean landscape have long been aware of the fact that scrub formations are expanding at the expense of forest, and that man and his flocks are largely responsible for this trend (*1*). It is no longer necessary to demonstrate that deforestation has taken place, but there is still need to assess the effects of destructive practices and determine the magnitude of change. The purpose of this article is to attempt such an assessment and determination for the Mediterranean environment of northern Morocco.

There are several reasons why it is easy to find evidence of deforestation on the African side of the Inland Sea. First and most basically, in North Africa serious erosion and a rapid increase of population necessitate constant clearing of new land. Deforestation is encouraged further by the fact that North Africans depend upon wood or charcoal for fuel. Even more important is the fact that North Africans maintain large herds of goats. Another reason why the study of deforestation is especially rewarding in North Africa is that one can find remnants of the natural plant cover preserved in cemeteries and near the shrines of holy men. Such sites often constitute islands of verdure in the midst of denuded land.

The author is assistant professor of geography at the University of Chicago. This article is based on a paper presented 29 December 1959 at the Chicago meeting of the AAAS.

Climate and Relief

In Morocco, as in the American Southwest, relief plays an obtrusive role as a determinant of climate. The transition from Saharan to Mediterranean or Atlantic influences is abrupt where mountains form rain shadows and gradual where relief is subdued. On the Moroccan coasts, precipitation decreases toward the east and south, from 32 inches (810 millimeters) at Tangier to 16 inches (414 millimeters) at Melilla and 11 inches (287 millimeters) at Mogador (*2*). In highland areas exposed to Atlantic influences, annual precipitation fulfills the moisture requirements of relatively mesophytic plants. The proportion of such plants decreases on south- and east-facing slopes, and they do not occur at all in lowland areas located south of a line drawn through Rabat and Fez (Fig. 1).

Northern Morocco, the area of special interest in this article, is a land of contrasts. Moving from the Atlantic coast toward the east, the traveler is confronted with an abrupt transition from alluvial plains and terraces to a highland zone of steep slopes and narrow, knife-like ridges. Annual precipitation averages about 20 to 30 inches (500 to 800 millimeters) on the Atlantic coast, rises to 40 or 50 inches (1000 to 1500 millimeters) on exposed slopes in the highlands, and then drops to about 10 inches (250 millimeters) in the valley of Wad Moulouya. Peaks rising above an elevation of 5000 feet (1500 meters) are snow-capped during the winter months. Generally speaking, northern Morocco can be divided into three climatic provinces: the subhumid Atlantic littoral, the humid or subhumid highlands, and the semiarid eastern plains. In each of these provinces the precipitation regime is of the Mediterranean type, with cool-season rains and summer drouth.

Forest and Scrub

In northern Morocco, as elsewhere in the Mediterranean region, the prevalent vegetation can be described under the headings of "forest" and "scrub." As Fig. 2 indicates, forests now cover only a small part of the area (compare Fig. 3). The largest stands are formed of cork oak (*Quercus suber*), and the commercial importance of the bark helps to explain the preservation of the tree. The cork oak grows on consolidated dunes close to the Atlantic coast, and on sandstone outliers of the Rif chain. It is also scattered through the western half of the highlands, again largely on soils weathered from sandstone. The Moroccan fir (*Abies pinsapo*) and the Atlas cedar (*Cedrus atlantica*) are restricted to the highest peaks of the Rif chain, the former on limestone and the latter on arenaceous or schistose material. Cedar forests are also found in the High and Middle Atlas (*3*) (Fig. 4). The best summary that can be made of the distribution shown in Fig. 2 is that only three species form sizable forests and that most of the wooded area is in the mountains.

The more prevalent scrub formations can be subdivided into "palmetto scrub" and "thorn scrub." Palmetto scrub is so named because its most conspicuous component is the dwarf fan palm (*Chamaerops humilis*). The dominant species of thorn scrub is the jujube or "camel thorn" (*Zizyphus lotus*). For the purpose of this discussion the important facts to remember

about the palmetto are that it grows rapidly, reproduces from shoots, prefers abundant light, and has roots too deep to be destroyed by the primitive Moroccan plow. Camel thorn, as the name suggests, is well adapted to survive in a land which is overrun with livestock.

In addition to the three trees mentioned above there are others that may once have formed closed stands. In the areas covered with palmetto scrub there are scattered specimens of holly oak (*Quercus ilex*), deciduous oaks (*Q. faginea, Q. pyrenaica*), strawberry madrone (*Arbutus unedo*), juniper (*Juniperus oxycedrus*), and the oleaster or wild olive tree (*Olea europaea* var. oleaster). In thorn scrub there are scattered specimens of sumac (*Rhus pentaphylla*), pistacia (*Pistacia atlantica*), and the Barbary thuya or sandarac tree (*Callitris articulata* = *Tetraclinis articulata*).

The natural ranges of most of the trees found in northern Morocco are shown in Fig. 5. Since this pattern is one of complete overlap, it is difficult to make a case for climatically asylvatic areas. Six species—*Pistacia lentiscus, P. atlantica, Rhus pentaphylla, Quercus ilex, Pinus halepensis,* and *Callitris articulata*—grow in the driest parts of the area; and in the Atlas Mountains cedars and deciduous oaks grow on peaks higher than any in the Rif chain. Edaphic factors impose some limitations. The cork oak, for example, will not grow on calcareous soils, and most trees will not grow on poorly drained bottom land. Nevertheless, the areas that are barren of trees as a result of

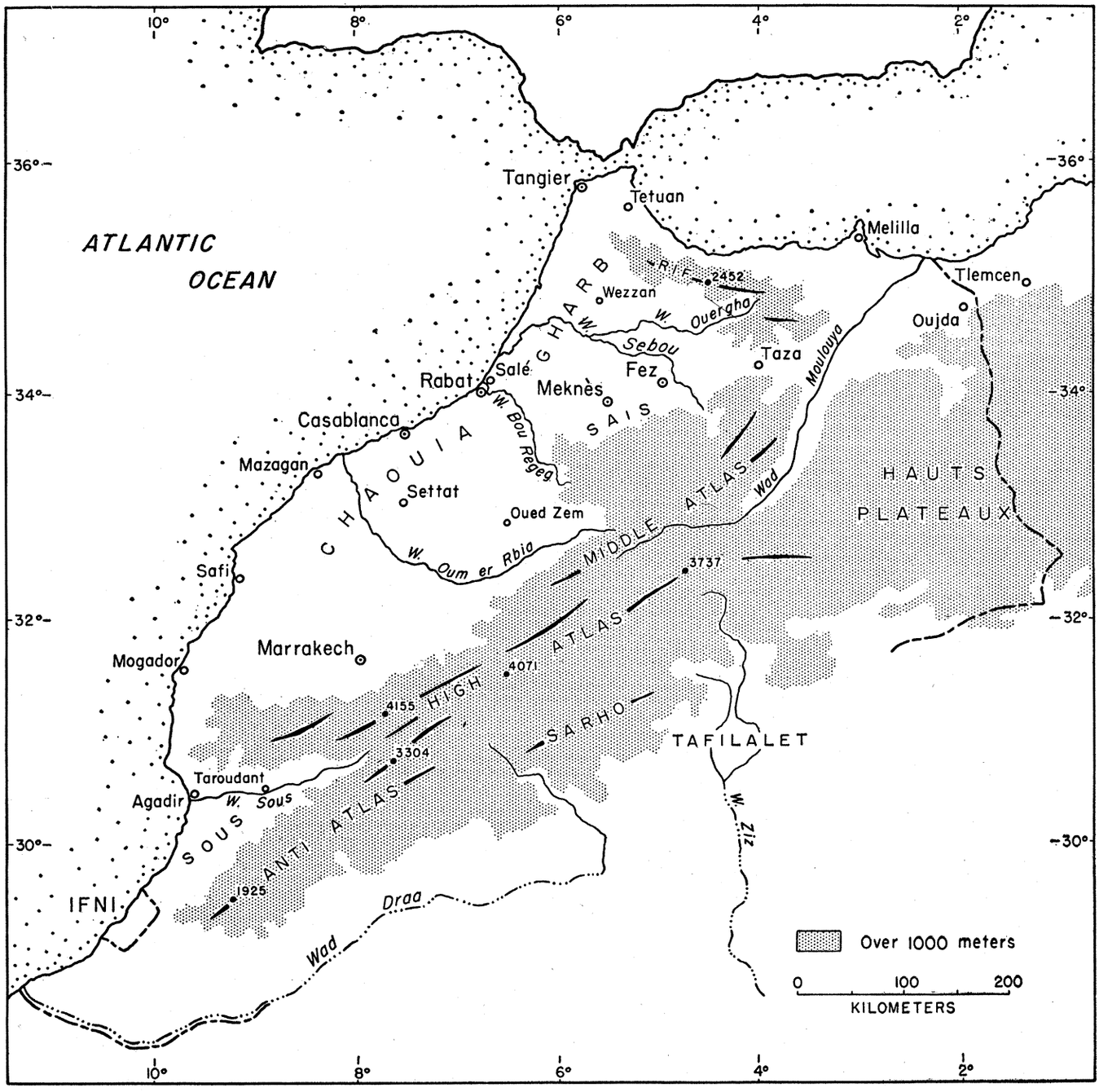

Fig. 1. Orientation map of Morocco. The area of special interest in this article is the northern or Rifian zone, which was a Spanish protectorate until April 1956.

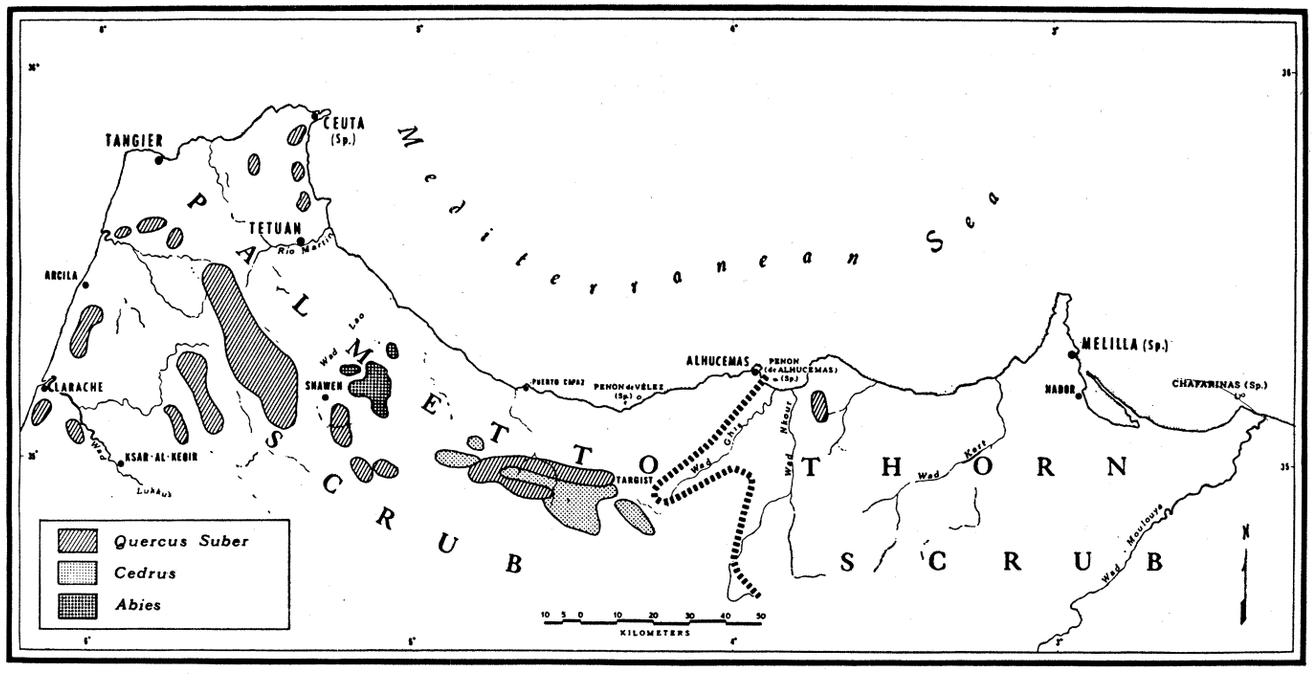

Fig. 2. Present distribution of wooded areas and scrub in Northern Morocco.

natural causes constitute only a small part of northern Morocco.

Suggestions from History

At the beginning of the Christian era Strabo described Mount Abyla, near Ceuta, as being clothed with a mantle of great trees (*4*). This specific reference is interesting, for only a few clusters of Aleppo pine appear in the area at present. It is known that Rome received wood from the North African provinces during the later period of the Empire. Beams of cedar were imported for the roofs of temples and other fine buildings, and the wood of the sandarac was imported for furniture and cabinets. The greatest of the wood-devouring industries probably was shipbuilding. In addition, lumber and fuel were needed at each settlement. It would be rash to make sweeping generalizations on the basis of a few references after the lapse of centuries, yet there is reason to believe that the North African forests were depleted in Roman times (*5*).

The Arab conquest of North Africa in the 7th century and the great immigration of pastoral nomads from the 11th to the 14th centuries intensified

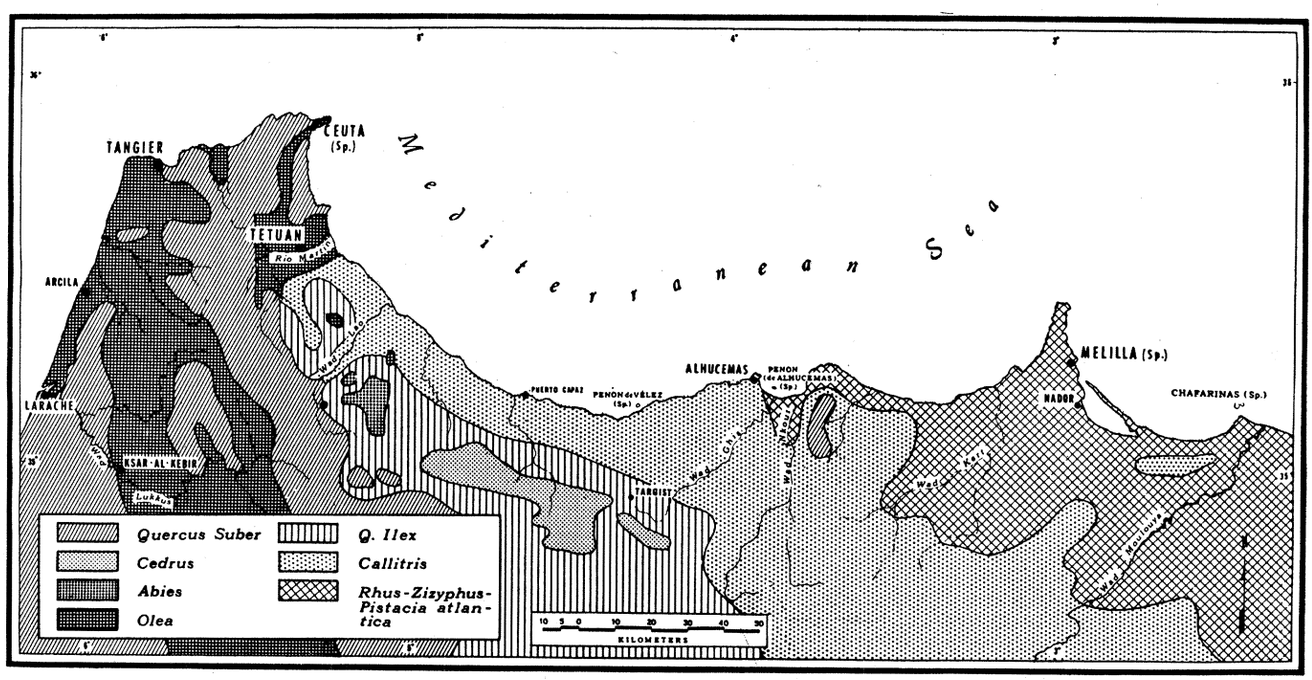

Fig. 3. Primordial or potential forests in Northern Morocco.

Fig. 4. View of the cedar forest in the Middle Atlas Mountains. The Atlas cedar (*Cedrus atlantica*) still clothes many slopes in the Moroccan mountains, but handsome specimens such as these are rare.

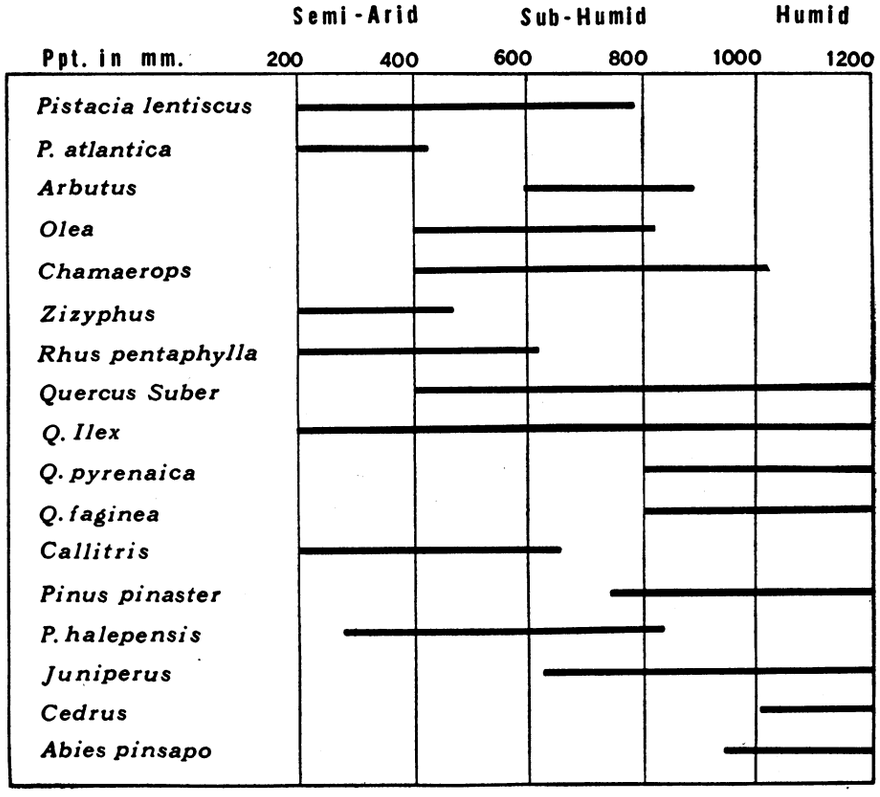

Fig. 5. Range of prominent species according to average annual precipitation (in millimeters).

destructive trends. The first Arab invaders wanted to build an urban civilization comparable to that already established in the Muslim heartland. In each new settlement wood was needed for building material, fuel, and countless domestic and industrial purposes. By the end of the 10th century the North African towns had become devourers of wood (*6*).

Scholars seeking a dramatic explanation of deforestation attribute most of the destruction to the nomads; one author even refers to their "hatred of trees" (*7*). Pastoral disturbance should be emphasized, for the havoc wrought by domestic animals lies not only in the destruction of palatable plants but also in the prevention of new growth. But it is seldom possible to distinguish one among the several causes of deforestation. It is easy to conclude that Arab nomads "destroyed" the North African forests, just as it is easy to conclude that the Mesopotamian irrigation system was "ruined" by the Mongols. In both cases, alien invasions accelerated but did not initiate the destructive trend.

During the Arab invasion of the 7th century one chronicler described North Africa as a land of "continuous shade" (*8*). This was probably a poetic exaggeration, for the North African highlands would appear lush and verdant even today after a trip across Egypt and Libya. Later accounts are more specific, and several of these refer to northern Morocco. Perhaps the most interesting reports are those that contain references to shipbuilding on the Rifian coast, for it would be difficult to find timber there for such an industry today.

At the end of the 15th century the forests of northern Morocco began to attract the attention of the Spanish. Moorish pirates had been raiding the Andalusian coast, and it was impossible for an unarmed vessel to pass through the Strait of Gibraltar. The distress of the Spanish resulted not only from the daring of the Moors but also from the fact that the latter had astonishingly fast and maneuverable boats. Contemporary accounts praise the "alerce" wood used in the Moorish boats and rate it higher than Spanish oak or pine. Opinions differ as to the identity of this wood, but descriptions of it suggest the sandarac. Leo Africanus (*9*), who visited the Rifian coast a few decades later, indicated that ships were no longer being built, and the impli-

cation of his remarks may be that shipbuilding had ceased because good specimens of "alerce" were no longer plentiful. In any case, his observations, and those of other travelers, suggest that the forests of northern Morocco had suffered substantial depletion. By the end of the 17th century most of the lowlands had been cleared.

Causes of Deforestation

The principal causes of deforestation have been and continue to be (i) domestic and industrial consumption of wood, (ii) burning to clear land for cultivation, and (iii) destruction of palatable plants by livestock. The effects of these uses and abuses are clearly evident, but it is difficult to determine their relative importance. Selective logging may regenerate a forest, but indiscriminate cutting followed by repeated burning or browsing causes deforestation. Most of the broadleaf trees reproduce from shoots, but in areas overrun by goats the shoots are browsed down and the trees that survive have a stunted and distorted form. In tangled scrub formations it is often difficult to tell whether the main agent of disturbance has been fire, teeth, or the ax.

The amount of wood consumed as charcoal must be enormous, for a brazier of some sort burns in every workshop and home. Charcoal is usually obtained from the denser hardwoods, and this preference helps to explain why most stands of the holly oak are badly degraded. Tannin is extracted from the roots and bark of many trees, and this operation causes further destruction. The cork oak is especially vulnerable, for tannin is scraped from the delicate inner bark immediately after the cork tissue has been removed. Careless stripping of the bark of the sumac, a source of red dye, also destroys many trees.

The great wooden gates that used to stand in the openings of city walls demonstrate the historic importance of the lumber trade. Only fragments of these gates still exist, but it is certain that planks of cedar were used in most towns. Logging operations were extended and intensified after the Spanish gained effective control of northern Morocco in 1928. The Spanish cut deciduous oaks for use as railroad ties and exploited cedar forests for lumber. Profiting from long experience in Algeria, the French carried on a more constructive program in their zone. The system of management in French Morocco was based upon periodic thinnings—a procedure intended to reconcile the interests of the tribesmen with good forestry practice. If effectively enforced (but it could not be), this practice would have permitted the production of fuel before the forests had reached the normal age of exploitation, and would have improved pastoral conditions by facilitating the movement and supervision of livestock (*10*).

In the semiarid area east of the Rif chain the plant cover is generally too sparse to maintain fires, and on the Atlantic littoral there is little land left to clear. But in most of northern Morocco the beginning of the agricultural year, in late September, is marked by fires set to clear new fields, and the haze of smoke lingers until the arrival of the first rains. Some attempt is usually made to control the spread of fires, but conflagrations develop when tinderlike shrubs are fanned by brisk winds.

Plants that are more or less resistant to fire or are stimulated to multiply and reproduce by fire have been called "pyrophytes" (*11*). There are many kinds of pyrophytes, for resistance to or stimulation from fire may be achieved in many ways. Stimulated pyrophytes are plants that grow rapidly and produce abundant seed. Among trees, the best candidate for this label is the Aleppo pine; among shrubs, the candidates are various species of the rock rose, mint, pulse, and heath families. When their aerial organs are destroyed, both the cork and holly oaks reproduce from shoots. An occasional fire may even serve to regenerate a forest, but care must be taken to prevent recurrent fires, for the secondary growth is highly inflammable. Under undisturbed conditions, forests of cedar and fir have little underbrush to serve as kindling, but the fire hazard is again increased with every proliferation of shrubs and herbs. If fires recur before seedlings reach maturity, regeneration may be impossible. The critical interval for the cedar is disadvantageously long, for the cedar does not produce abundant seed until it is 40 to 50 years old. Moreover,

Fig. 6. Effects of browsing by goats on a young cedar. Each unit of the scale is equal to 1 foot.

reproduction is difficult unless there is an opportune cycle of unusually wet years.

It would be hard to overemphasize the destruction wrought by livestock. More than a half-million sheep and a million goats are maintained in northern Morocco (*12*). These figures are striking in themselves, but the really impressive fact is that such a large number of animals is maintained by sedentary farmers. No tribe in northern Morocco is truly nomadic, and seasonal migration (transhumance) is practiced only by a few people in the valley of Wad Moulouya. In most of this region animals are confined within areas that they can traverse in a few hours, and there is constant consumption of palatable plants.

Most of the sheep kept in northern Morocco are in the semiarid area east of the Rif chain. Woody plants are too tough and massive to be damaged by grazing, but sheep can destroy shoots and seedlings. Where goats are numerous, deforestation is greatly accelerated, for no hillside is too steep to daunt this prodigiously agile creature, and few plants escape its voracious appetite (Fig. 6). In Arcila, goats climb the nearly vertical Portuguese walls, and in southwestern Morocco they climb into the crowns of argan trees (*Argania spinosa*). It is not surprising that the goat should be described as an "ecologic dominant," and that many naturalists would like to see it become extinct, except in zoos (*13*). In this connection it may be noted that trees are sometimes protected by a cluster of relatively resistant plants. For example, in open places in cork forests young trees usually do not attain a normal form unless they are protected by a cluster of palmetto. On the semiarid plains of northeastern Morocco the pistacia rarely survives unless it is protected by a ring of camel thorn. In the Sous Valley the camel thorn plays an even more vital role as a protector of young argan trees. In the Rif mountains seedlings of cedar are sometimes protected by junipers or thorny Leguminosae.

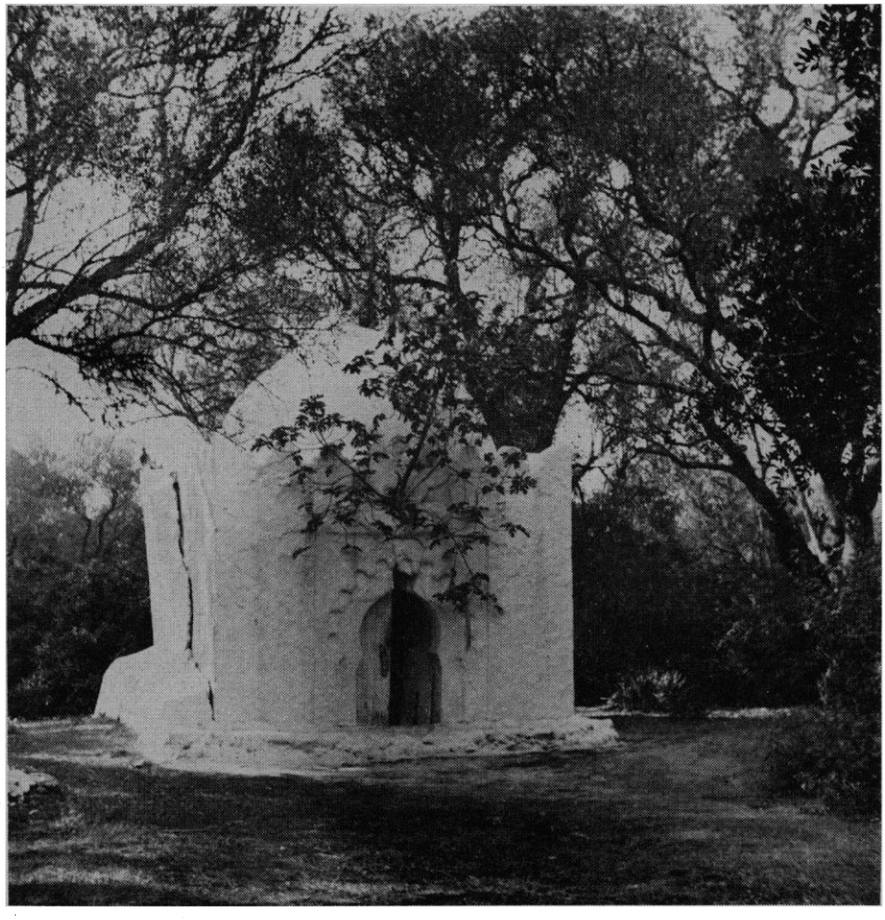

Fig. 7. Sacred grove of wild olive (*Olea europaea* var. Oleaster) at the shrine of a holy man. In the background the olive forest grades into a scrub formation dominated by *Pistacia lentiscus*.

Protected Growth on Sacred Sites

Moroccans never consciously disturb plants growing in cemeteries. Areas in the immediate vicinity of tombs or shrines of holy men are also considered sacred. To the student of plant ecology the important consequence of this attitude is that the plant cover on such sites often differs markedly from that on adjacent, profane land. This difference may be manifest in the composition and density of formations or in the height and girth of individual plants. The protected growth may be a single shrub or tree or thickets and groves. Readers of Sir James Frazer's *Golden Bough* will be aware that sacred groves and superstitions about the sanctity of trees can be found in many parts of the world. In Morocco, examples of protected vegetation are extraordinarily numerous.

In the center of sacred groves one often finds tall trees, deep shade, and little underbrush (Fig. 7). On the edge of groves, trees are replaced by shrubs and herbs that demand more light. The boundary between sacred and profane land is usually quite sharp (Fig. 8). Contrasts of this sort can be explained in two ways. In some areas the protected growth may be a remnant of the primordial cover. In other areas such growth represents regeneration encouraged by the suppression of destructive practices. Since it is seldom possible to assign specific dates to cemeteries or shrines, it is difficult to ascertain whether the vegetation on such sites indicates survival or recovery. In any case, one can speak of a contrast between *prevalent* conditions (what is) and *potential* conditions (what might be).

In the Rifian highlands the vegetation on sacred sites suggests that deforestation involves a retrogression from cedar, fir, or oak forests to formations of scrub. In the coastal lowland south of Tangier, sacred groves are usually dominated by tall oleasters (Fig. 7); in the western foothills of the Rif chain such sites are covered with cork or holly oak. Given this evidence, one can hardly avoid the inference that the natural plant cover of the subhumid area of northwestern Morocco should be a forest of oleaster or oaks, and that the present cover of palmetto scrub represents degradation. Using the same type of evidence one can recognize that the sandarac should be a tall tree and that the more prevalent dwarf forms are produced by burning or browsing. On

the semiarid plains east of the Rif chain, sacred sites may be covered with oleaster, sandarac, sumac, or pistacia. Protected stands of one or more of these trees, and the sacred groves of Aleppo pine on the Melilla peninsula, suggest that thorn scrub is a regressive formation and not a "climax."

Magnitude of Change

The extent of deforestation is suggested by the contrasting patterns shown in Figs. 2 and 3. The details of these two maps are less important than their general outlines. One implication is clear: the present wooded area constitutes only about one-tenth of the area that would be wooded if destructive practices were suppressed. If cutting, burning, and browsing ceased, most of the area now covered with palmetto scrub would eventually be clothed with forests of oleaster (on alluvium), cork oak (on sandstone), and holly oak (on limestone). Under undisturbed conditions the provinces of the cedar and fir probably would not be greatly extended, but the existing forests would be denser and would have less underbrush. There is no reason to believe that, if disturbance were eliminated, the semiarid sector of northeastern Morocco would continue to be dominated by tussock grass, camel thorn, and other animal-resistant plants.

Conclusion

In summary, the evidence presented here supports the thesis now accepted by most students of Mediterranean vegetation, that the prevalent scrub formations are produced and maintained by man. In Morocco the principal trend has been an expansion of species that are (i) tolerant of light, (ii) resistant to drouth, (iii) relatively impalatable, and (iv) able to reproduce from shoots or to produce abundant seed. This trend is evident along the margins of many subhumid and semiarid lands. Destruction of the canopy of trees increases the amount of isolation near the ground. Hence, if deforestation takes place in subhumid or semiarid environments, mesophytic species are discouraged and colonization by more aggressive xerophytes is favored (*14*). In northern Morocco this process of invasion and displacement explains the prominence of plants that are more

Fig. 8. Dense cluster of Aleppo pine (*Pinus halepensis*) on the site of a cemetery. *Cistus monspeliensis* covers the slope below the lower right corner of the grove, and the gully crossing to the left contains *Nerium Oleander*. The rest of the area has been cleared.

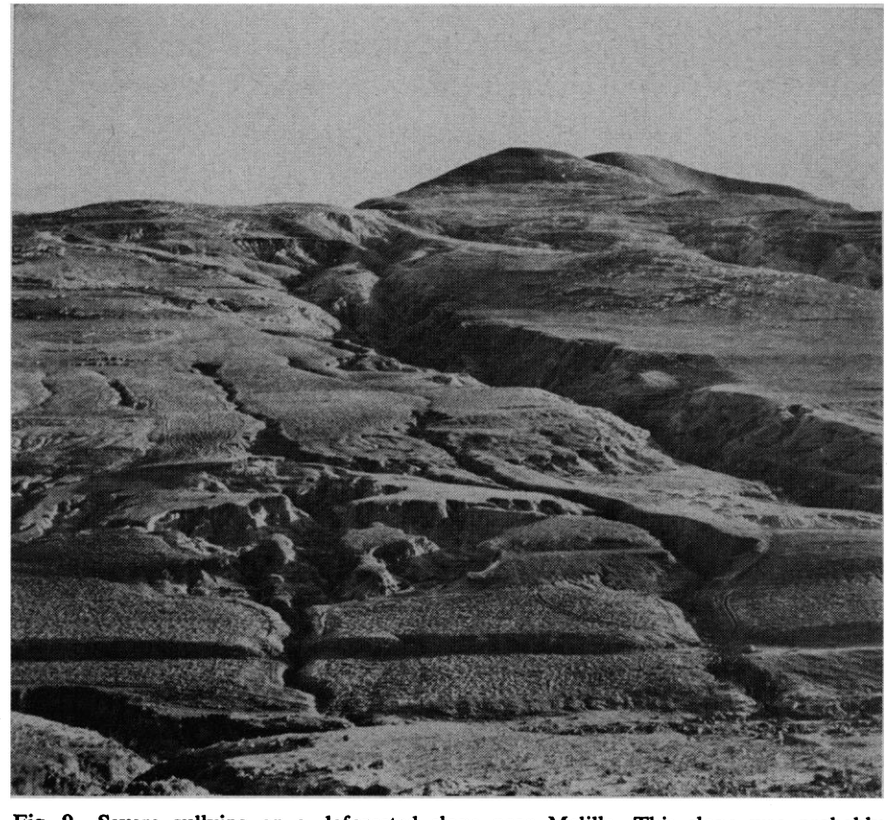

Fig. 9. Severe gullying on a deforested slope near Melilla. This slope was probably once covered with sandarac (*Callitris articulata*) and Aleppo pine (*Pinus halepensis*).

at home in the desert or steppe. Unless the climate itself has changed, and this is not likely to have occurred within historic time (*15*), the proliferation of such plants should be ascribed to the disturbing influence of man.

The most unfortunate consequence of deforestation is that it increases the danger of soil erosion (Fig. 9). The steep slopes prevalent in most of northern Morocco favor rapid runoff and prevent the formation of deep residual soils. Moreover, torrential rains during the winter and spring follow vigorous mechanical weathering during the dry summer months. It would be hard to imagine an area more vulnerable to erosion, and the natural hazard is greatly increased by the destruction of protective vegetation. In northern Morocco, as elsewhere in the Mediterranean region, deforestation and erosion are linked in a chain of causes and effects that begins with the mismanagement of land by man (*16*).

References and Notes

1. See, for example, G. Giordano, "The Mediterranean Region," in S. Haden-Guest, J. K. Wright, E. M. Teclaff, Eds., *A World Geography of Forest Resources* (Ronald, New York, 1956, pp. 317–352.
2. *Atlas du Maroc*, planche 4*a*: "Précipitations annuelles" (Rabat, 1958). The figures cited in this and the following paragraph are taken from the *"notice explicative"* which accompanies the map.
3. *Atlas du Maroc*, planche 19*a*: "Forêts et ressources végétales"; L. Emberger, "Aperçu général sur la végétation du Maroc," in E. Rübel and W. Lüdi, Eds., *Ergebnisse der internationalen Pflanzengeographischen Exkursion durch Marokko und Westalgerien, 1936* (Huber, Bern, Switzerland, 1939).
4. Strabo, *Geography*, book 17, chap. 3.
5. H. C. Darby, "The Clearing of the Woodland in Europe," in W. L. Thomas, Jr., Ed., *Man's Role in Changing the Face of the Earth* (University of Chicago Press, Chicago, 1956), pp. 183–216, especially pp. 184–188.
6. J. Despois, *L'Afrique du Nord* (Presses Universitaires de France, Paris, 1949), p. 84.
7. A. Bernard, *Afrique septentrionale et occidentale* (Colin, Paris, 1937), vol. 1, p. 65.
8. E. Lévi-Provençal, *Arabica* **1**, 40 (1954).
9. *The History and Description of Africa* (Hakluyt Society, London, 1896), vol. 1, pp. 494–539.
10. P. Boudy, *Economie forestière nord-africaine* (Larose, Paris, 1948–1955); for a more concise statement see J. P. Challot, *Rev. Eaux et Forêts* **84**, 233 (1946).
11. G. Kuhnholtz-Lordat, *La Terre incendiée: essai d'agronomie comparée* (Maison Carrée, Nimes, 1939); *J. Agr. trop. et Botan. appl.* **3**, 785 (1956).
12. The statistical handbook of Spanish Morocco for 1952–53 lists 661,000 sheep, 1,104,000 goats, and 1,026,000 human beings. The human population grew by 100,000 in the preceding decade, and the number of goats probably increased correspondingly.
13. R. Furon, "The gentle little goat: Arch despoiler of the earth," *Unesco Courier* **1958**, 30 (Jan. 1958).
14. This trend has been documented in many parts of the world. For a clear illustration see A. Aubréville, *Climats, forêts et désertification de l'Afrique tropicale* (Editions Maritimes et Coloniales, Paris, 1949).
15. For a brief review of the arguments for and against climatic change within historic time see R. Murphey, *Ann. Assoc. Am. Geographers* **41**, 116 (1951).

16. Field studies were made possible by a grant from the Ford Foundation.

Strontium-90 in Man IV

The strontium-90 concentration in human bone increased in 1958 and 1959, will probably reach a maximum in 1960.

J. Laurence Kulp, Arthur R. Schulert, Elizabeth J. Hodges

The moratorium on nuclear detonations has made it possible to define several critical factors in the distribution of fission products over the surface of the earth and their uptake in man. This article (*1*) gives new data on the strontium-90 content of human bone from the world-wide network of sampling stations. Earlier contributions (*2–4*) outlined the geographical variation, the age effect, and the mean concentration of strontium-90 in the human population. This new work permits further refinement of these parameters and indicates the situation in 1959. With the aid of important new data on the stratospheric inventory and residence times (*5*) and the relative importance of the rate of fallout of strontium-90 as against cumulative deposition in the soil (*6*), it is possible to make more reliable predictions of future levels of strontium-90 in man as a result of past weapon tests. It is also possible to indicate the nature of the distribution curve for the bulk of the world population. These new data also have important implications for the situation that would exist in the event of nuclear warfare.

Since the beginning of this study, in 1953, some 9000 samples of human bone have been procured. These have included fetuses, single bone samples from individuals of all ages, and whole skeletons. The bulk of the analyses for strontium-90 have been carried out at several commercial laboratories under contract with the Atomic Energy Commission (*7*). Most of the analyses in 1953–55 were carried out in this laboratory, and a few of the samples collected since then have been analyzed here (*8*).

The absolute calibration at all laboratories is based on NBS standards and is good to 2 to 3 percent. The standard deviation of the radiochemical procedures is ±7 percent, as determined on milk samples and spiked bones with concentrations equivalent to 10 to 1000 disintegrations per minute per sample. For those human bone samples in which the level is at least 5 disintegrations per minute, the over-all reproducibility among the various laboratories is about ±10 percent. This category includes virtually all children's bones, all whole-skeleton ash samples from individuals who died from 1957 to 1960, and large samples consisting of many bones from adults who died in 1958, 1959, and 1960, from the latitude band 30° to 70°N. The other samples, of lower strontium-90 activity, carry larger errors. Laboratory contamination was monitored with analytical reagent grade $Ca_3(PO_4)_2$ and human bone from individuals who died before 1945. Samples of adult bone containing less than 2.0 grams of calcium and children's bones containing less than 0.5 gram of calcium have not been included in this summary because of the larger inherent errors resulting from the low total activity. From 1958 on, most adult bones were composited, equal weights

The authors are on the staff of the Geochemistry Laboratory, Lamont Geological Observatory, Columbia University, Palisades, N.Y.