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Deer and Forestry in Germany: Half a Century After Aldo Leopold

Michael L. Wolfe

Friedrich-Christian V. Berg

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Deer and Forestry in Germany

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Half a Century After Aldo Leopold

A contemporary look at the correlation between wildlife and forest damage.

by Michael L. Wolfe and Friedrich-Christian v. Berg

In 1936, Aldo Leopold published several articles on then-contemporary wildlife management, game administration, and nature protection in prewar Germany. The most significant of these was a two-part article published in the JOURNAL OF FORESTRY entitled "Deer and Dauerwald in Germany" (Leopold 1936). Leopold described the "mutual interference" between deer management and contemporary forest management and cited the emergence of the *Dauerwald* (literally, "permanent woods") movement, which was supposed to reform this situation.

The essence of Leopold's observations is contained in that article, page 460: ". . . we have traced the slow but inexorable growth of a system of silviculture incompatible with a natural and healthy game stand, and a system of game management incompatible with a natural and healthy silviculture." The silviculture system to which he referred was that of even-aged spruce *(Picea abies)* monocultures maintained by artificial regeneration and intensive timber-stand improvement techniques. The closed forest canopy of massed stems in all but the youngest stands excluded palatable and, for the most part, shade-intolerant browse species.

Game management in Germany is characterized by a long history of excessive deer husbandry that dates back to the feudal period. Inevitably, this combination of overstocked forests and virtual absence of natural forage (especially in winter) resulted in substantial damage to forest plantations from deer browsing young stems and stripping

bark from older stems. To cope with the negative consequences of this mutual interference, German foresters resorted to numerous complicated and expensive measures, including fencing young forest cultures, protecting the stems of older trees from barking, supplemental winter feeding, and even compensating for deer damages.

Fifty years and a world war have elapsed since Leopold's visit to eastern Germany in 1935. Today, the forests of central Europe face an unprecedented crisis. Forest dieback has increased dramatically during the past several

Michael L. Wolfe is associate professor, Department of Fisheries and Wildlife, Utah State University, Logan. Friedrich-Christian v. Berg is research associate, Institut für Wildbiologie und Jagdkunde, der Universität Göttingen, Federal Republic of Germany.

Bark damage caused by antler rubbing.

M.L. Wolfe

and legislation will not solve all the dieback problems. The deleterious effects of other stressors, including excessive deer populations, must be dealt with.

Forest dieback could conceivably result in improved habitat conditions for deer. In areas with high tree mortality, opening of the canopy should promote growth of shade-intolerant forbs and browse species. Furthermore, in some situations the growth of certain species may be enhanced by the fertilizing effects of nitrogen and sulfur compounds (Johnson et al. 1982).

Assuming that research and legislative efforts provide the means to decrease levels of atmospheric pollutants and reduce forest dieback, extensive reforestation will be required, at least in areas that have suffered severe damage. Obviously, deer densities and the intensity of browsing damage will be an important determinant of the success of these efforts. It is therefore instructive to examine the current status of the deer-forestry question in Germany.

Leopold's description of the prewar situation was based on observations made in both eastern and western parts of the country as well as in Czechoslovakia. The discussion here focuses on contemporary conditions in the Federal Republic of Germany (FRG). The situation is very similar, but not identical, in the German Democratic Republic, Austria, and Czechoslovakia.

Forest Composition and Silvicultural Systems

Leopold provided no quantitative data on the area and species composition of forested lands in prewar Germany. However, it is obvious from his discussion that Norway spruce and Scotch pine *(Pinus sylvestris)* monocultures predominated. In this respect, present-day Germany has not changed much. Currently, forested areas of the FRG cover approximately 7.3 million hectares, or about 30 percent of the country. Forty-five percent is privately owned, 25 percent is owned communally or by corporations, and 35 percent is under federal or state ownership.

years and is now estimated to affect, in varying degrees, more than 50 percent of the forested area in the Federal Republic of Germany. Although the precise causes have yet to be determined, dieback has been linked to increased levels of atmospheric pollutants (mainly SO_2 and NO_x), which cause acid rain.

Given this, it would seem that the importance of wildlife damage might have paled in comparison to pollutant problems. However, one hypothesis suggests that forest dieback is not a result of one single factor but the cumulative effects of several, including insect and wildlife damage and weather conditions. Each factor subjects the trees to stress, thereby increasing their susceptibility to the other factors. If this is the case, then decreasing the level of atmospheric pollutants via research

Spruce and pine comprise 40 percent and 20 percent, respectively, of the total forested area, followed by beech (*Fagus sylvatica,* 17 percent), oak (*Quercus* spp., 8 percent), larch (*Larix* spp., 7 percent), and fir (*Abies alba,* 2 percent). The prevailing silvicultural system is even-aged monocultures with clearcuts and artificial regeneration. Rotation periods for spruce stands range from 80 to 100 years. Only 4 percent of the total forested area is in the early stages of regeneration. The remainder comprises young and maturing stands of various ages, which offer very little natural forage for wildlife 10 years or more after establishment.

Contrary to Leopold's predictions, spruce coverage has increased progressively during the past century (*fig. 1*). This trend is particularly pronounced in privately owned forests. For example, data comparing 80- to 100-year-old stands with 0- to 20-year-old stands in 50,000 hectares of privately owned forests in Baden-Württemberg revealed that the proportion of spruce and Douglas fir *(Pseudotsuga menziesii)* increased from 41 percent to 88 percent (Ott 1981). Concomitantly, the proportion of true fir, pine, and beech declined from levels of 15 to 21 percent to 3 to 4 percent.

Numerous factors have contributed to the increase in spruce stands, not the least of which are economic ones. Regeneration costs for spruce are only about one-third to one-half those for hardwood species such as oak or beech. Following World War II, spruce was virtually the only species available as seedlings for reforestation of stands decimated during the war. Spruce also has a relatively short rotation period compared to hardwood species. These three factors have great economic appeal to private landowners.

Deer Populations

Although other ungulates may have significant impacts on forestry in localized areas, red deer *(Cervus elaphus)* and roe deer *(Capreolus capreolus)* constitute the principal species in the study area. The ecological niches of
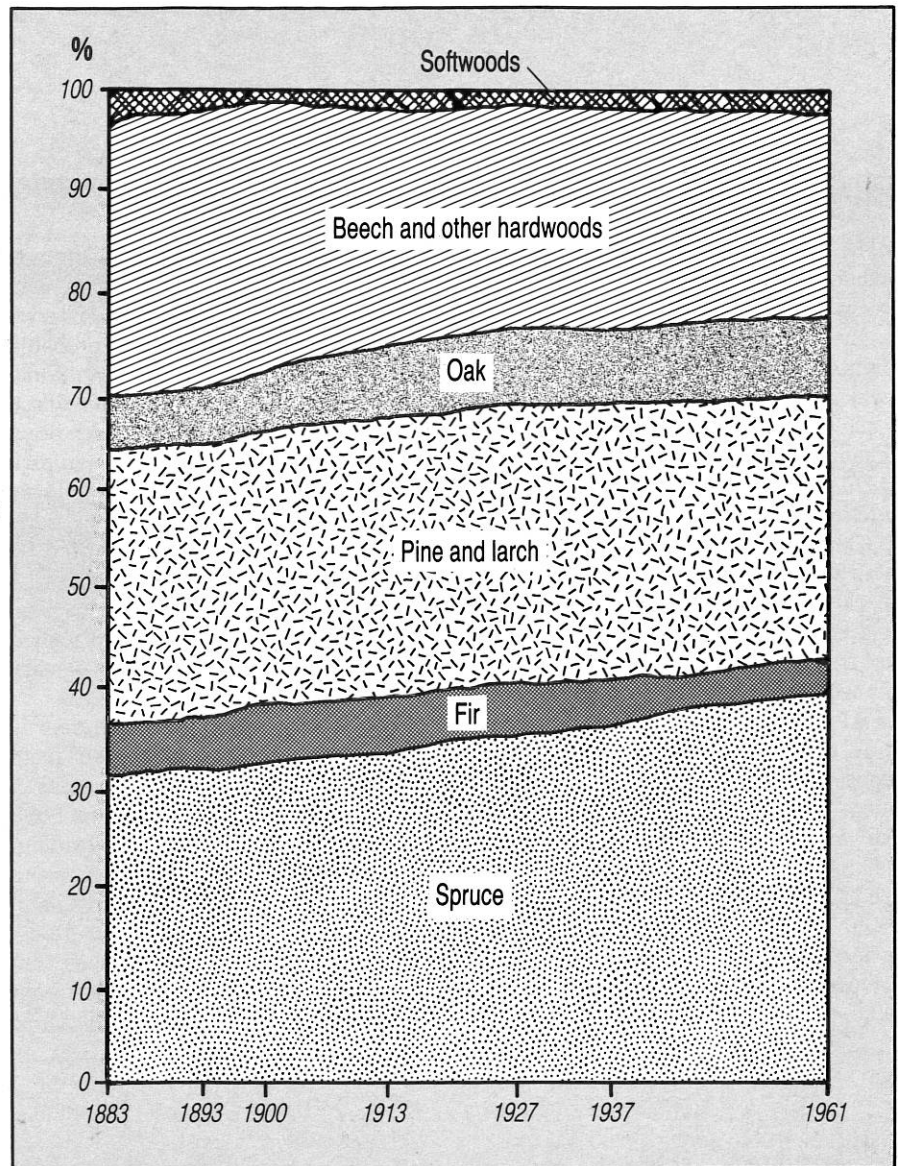

Figure 1. Changes in the species composition of forests in the Federal Republic of Germany (Schmidt-Vogt 1977:257).

these species roughly parallel those of wapiti *(C.e. canadensis)* and white-tailed deer *(Odocoileus virginianus),* respectively, in North America. Because of its large size and efficient digestive system, the red deer can subsist on a broad range of forage of surprisingly low nutritional quality. In contrast, the small body size and higher metabolic rate of the roe deer, coupled with its relatively small rumen capacity, dictates the need for a variety of higher quality food items. Once considered a rare woodland dweller in many areas of Europe, the roe deer has benefited from the increasing interspersion of forest parcels and small agricultural units as well as conservative hunting regulations. The result is that roe deer are more numerous today than

ever before. They can be found everywhere in Germany except in the higher elevations of the Bavarian Alps.

By contrast, red deer are presently limited to some three million hectares, which represent approximately 40 percent of the FRG's forested area or about 16 percent of the country. In 1976, of some 80 discrete red deer populations, only 12 comprised more than 1,000 animals (Kleymann 1976). Originally inhabitants of grassland and parkland, red deer were gradually displaced by humans (a trend dating back to the end of the Middle Ages) and forced into the forested tracts that currently constitute their primary habitat.

In the FRG, numbers of both deer species have increased substantially since World War II. Today the annual kill approximates 700,000 and 30,000 for roe and red deer, respectively *(fig. 2)*. These harvests represent increases of 40 to 50 percent since the late 1950s, when levels were similar to those of the prewar years (1936–39). Converting kill statistics to estimates of the actual pop-

ulation is a problem (as Leopold noted). If kill figures represent roughly one-third the total population (a conservative assumption), there are probably 100,000 red deer and more than 2 million roe deer. Dividing the assumed red deer population by the total area occupied (3 million hectares) yields an estimated average density of three animals per 100 hectares. For roe deer, a crude density estimate can be computed by dividing total estimated population by combined forested and agricultural land available for hunting (23.6 million hectares), yielding an average density of eight roe deer per 100 hectares.

The density estimate for roe deer is less than half that computed from Leopold's data in 1935 for four areas in Bavaria and Baden-Württemberg. Such a comparison is probably misleading, however. The current density estimates represent an average for various habitats, while Leopold's statistics were derived primarily from forest areas that often had higher densities. Moreover, these areas were probably selected to

Figure 2. Annual harvests of red and roe deer in the Federal Republic of Germany, 1958–85.

Sociopolitics of the

The Federal Hunting Law (BJG) in the Federal Republic of Germany leaves little room for conflicts between deer and forestry. Its opening paragraph obliges the holder of hunting rights to preserve wildlife habitat and to maintain a healthy and diverse wildlife resource that is compatible with scenic values and land-use interests (Wolfe 1970, 1980). Game husbandry must be practiced in a manner that would preclude excessive wildlife damages to agriculture and forestry. The law also prescribes mandatory shooting plans for deer and compensation for wildlife depredation by the person or corporation holding the hunting rights on the land where such damage occurs.

One conflict arises from the emphasis throughout central Europe on trophy management, which is the preservation (and eventual harvest) of a few selected males from a larger pool of younger age classes. Individuals with poorer antlers are progressively culled from the population. This system necessitates carrying a sizeable underpinning of other animals (Schröder 1977) and is predicated on high deer densities. For example, sustaining an annual harvest of 10 red deer stags (10 years or older) requires a population of more than 500 animals of all sex and age classes (Schröder 1977).

A particularly thorny problem is the question of supplemental feeding. The BJG mandates protecting wildlife from food shortages. This is usually interpreted as an obligation to feed wildlife (primarily deer) during critical periods. However, both the actual intent of the provision and the precise meaning of "critical periods" are subject to different interpretations and currently constitute a very controversial element of the deer-forestry issue.
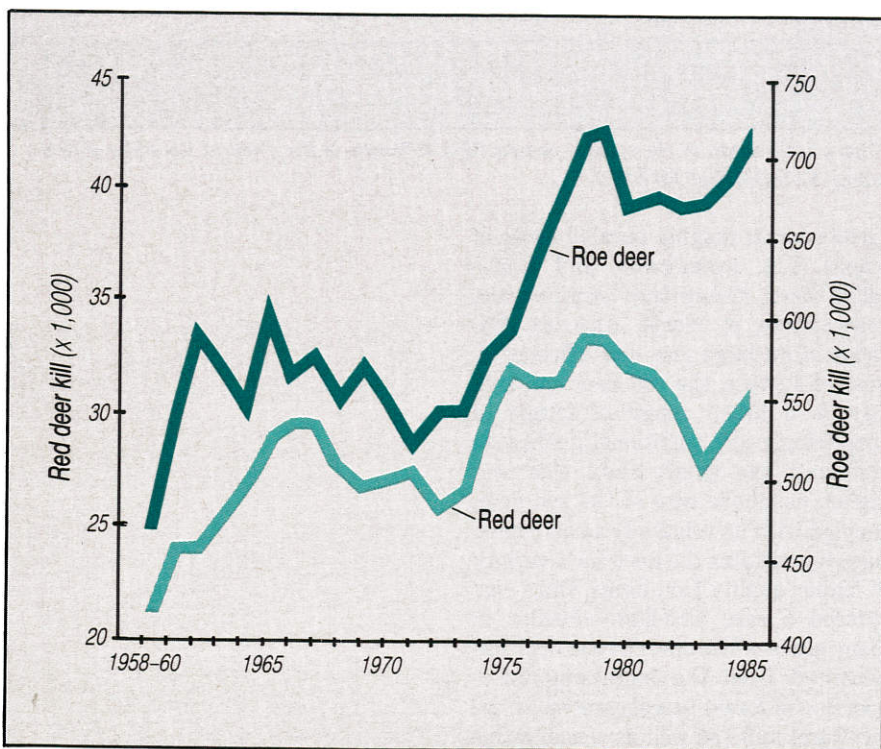
Deer-Forestry Issue

Leopold (1936, p. 462) noted: "Artificial feeding, by keeping alive deer which would otherwise starve, of course enlarges the discrepancy between game density and natural forage, and thus also enlarges the variety and intensity of game damage to forest vegetation and to adjoining agriculture."

In many instances, the extent of artificial feeding far exceeds that required to ensure the survival of local or regional deer populations during severe winters or under other exceptional circumstances. Each year the animals are fed for extended periods of time with high-quality foodstuffs that often contain minerals, vitamins, and even certain prophylactic medicinal preparations. Although seldom expressed formally, ulterior motives exist for these efforts. Artificial feeding can maintain higher deer densities than the natural vegetation of many areas could otherwise support; it also allows heavier body weights and thus larger trophies (v. Berg 1985). This problem prompted a recent but unsuccessful legislative initiative from the Green Party to eliminate from the BJG the provision for mandatory feeding of big game animals.

The deer-forestry issue has been exacerbated by circumstances that either did not exist or were of minimal significance at the time of Leopold's visit. Most important is the increased human population density and attendant increased recreational use of forest areas. Seventy percent of a population of 61 million people uses the forests for recreation (Plochmann 1981), and federal law guarantees public access to all forests. Cross-country skiing in winter, jogging and hiking in summer, and numerous other recreational activities all contribute to increased disturbance and shyness of the deer. Consequently, the

Deer at a winter feeding station.

animals remain in closed forest stands for longer periods of time rather than venturing into openings to feed during the daylight hours. This behavior probably contributes to increased levels of peeling and rubbing damages in mature stands with red deer populations. It also poses difficulties for counting the animals and, more importantly, often precludes fulfillment of prescribed shooting quotas by conventional hunting methods. In some cases, the only time of year when deer congregate in openings for any appreciable length of time is when they are fed. However, the notion of killing deer directly at feeding stations is prohibited by law and by ethics.

The conflict has led to increased polarization between hunting interests and those of nature and environmental protection. Although these sectors have long been subject to two separate legal codes, the German public traditionally considered the interests of hunting, forest

protection, and nature protection as compatible if not synonymous. Indeed, the average citizen frequently viewed the "green capes" (hunters and foresters) as guardians of both the forest and wildlife. This attitude led Leopold (1936, p. 463) to conclude that the Germans ". . . would rather put up with forest damage than forgo their pleasure in having and seeing deer."

The past decade has seen an increased awareness that the interests of hunters and of environmentalists are not identical. The preservation efforts of the former are often directed primarily or solely toward game species, even though such efforts may negatively affect habitat quality and even the welfare of certain nongame species. Such efforts have engendered increased activism by nature and environmental protection groups. For some of the more radical protectionist organizations, the underlying issue may well be more antihunting than proforestry.

What Happened to the *Dauerwald* Movement?

As Leopold (1936) noted, the *Dauerwald* or "permanent woods" concept sprang from recognition of the deleterious effects of repeated rotations of spruce monocultures (i.e., soil compaction and acidification as well as increased susceptibility to windthrow and insect epidemics). *Dauerwald* embodied a planned conversion to mixed stands of hardwoods and conifers maintained by selection cuts and natural regeneration rather than by artificial regeneration. The transition to *Dauerwald* was mandated in the early 1930s during the Third Reich but expired with the end of that era.

The essential elements of the idea reemerged in 1949 with the formation of the Society for Natural Forestry. The fundamental objective of this organization is to manage the forest as an ecosystem rather than as a mechanistic entity strictly for production (Wobst 1954). Although timber production is recognized as the primary function of silviculture, the organization advocates maintenance of forest diversity to preserve or enhance its inherent resistance to natural perturbations such as wind and snow damages, periodic droughts, and insect pests. Such a silvicultural system embodies several aspects, including encouraging stands of mixed species and uneven-aged composition, stocking with species appropriate to prevailing climatic and local site conditions, allowing sustained harvest, and harvesting individual stems in lieu of periodic clearcuts. Acceptance of the precepts of natural forestry has been slow among the older generation of foresters but is growing among younger practitioners.

The diverse structure and numerous small openings created by such management practices should result in increased natural forage for deer. Paradoxically, this would require reduction of deer densities to preclude severe browsing damages. With the present large deer population, severe browsing damages could hinder regeneration, and selective browsing could lead to eliminating the hardwood component, thereby producing conifer monocultures. Proponents of natural forestry advocate reducing deer numbers (rather than fencing or other artificial measures) to eliminate this problem and to allow regeneration of mixed-species stands.

illustrate the deer-forestry problem. Nevertheless, summer densities of 20 to 30 roe deer per 100 hectares of forest are by no means uncommon in certain areas of the FRG today; winter densities in some locations may even be twice this level. Generally accepted estimates of economic carrying capacity vary with habitat quality but range from 1.0 to 1.5 red deer per 100 hectares or 4 to 5 roe deer per 100 hectares for sites of low to moderate quality, as would likely occur in closed monocultures with few openings and little interspersion of agricultural lands (Ueckermann 1969).

Effects of Deer on Forestry

The direct and most visible effects of deer on forestry are economic. Based on figures from the late 1970s (Speidel 1980), the estimated annual losses inflicted by red and roe deer to forests in the FRG and the cost of protective and preventive measures approached US$200 million, which was equivalent to a 10 percent devaluation of the total net production of the forest industry. In state-owned forests, the annual cost of protective measures alone was estimated at $12 to $15 per hectare.

Most discussions of the effects of deer on forests have focused on the more spectacular stripping damages by red deer and the consequences of these damages, such as increased susceptibility to insects and fungi. It is only during the past decade that the impact of selective deer browsing has been recognized. The insidious ecological effects of elevated deer densities, especially those attributable to the more abundant roe deer, are more difficult to quantify. However, they should not be overlooked. The palatability of various hardwood species such as oak, beech, and maple (*Acer* sp.) ranks higher than the palatability of spruce and pine. Consequently, the former are selectively browsed in unprotected stands of regeneration, which in turn often results in the differential survival of spruce in mixed-species stands. In this manner, high densities of deer undoubtedly play a role in the transition toward spruce.

Another significant development during the last 10 to 15 years has been recognition that roe deer densities are almost always underestimated. This has led some wildlife biologists (e.g., Schröder 1975) to question the necessity of formal harvest quotas for roe deer. The alternative, which would result in more liberal harvest regulations, would be to treat the species as a small game animal.

Conclusions

It appears that the basic elements of the deer-forestry problem described by Leopold 50 years ago remain largely unchanged, if not accentuated, because of increased deer densities and continued spruce monocultures. A major difference is that the issue has assumed greater urgency in light of its possible relationship to the problem of forest dieback. This, coupled with a greater awareness of the economic and poten-

tial ecological consequences of excessive deer densities, has focused public attention on the conflict. Germans have long prided themselves on their forests and wildlife, and the question has long been which should enjoy primacy. Contemporary law dictates that the requirements of agriculture and forestry take precedence over hunting interests and that game husbandry be practiced to minimize damages to field and forest. However, a tradition-based and powerful hunting lobby, and a harvest system predicated on high deer densities, have precluded consequent adherence to these strictures. We predict that public pressure will ultimately result in legislation that will bring about modifications in deer densities. This may permit implementation of a more natural system of forestry. ∎

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A Test of Aerial Scanner Imagery in Timber Type Mapping

A comparison of aerial photography with multispectral scanner imagery.

By William A. Befort and Kevin S. Evans

On paper or as input to computerized resource information systems, type maps display spatial distribution of timber resources and stratify them into homogeneous categories for sampling. A timber type map is conventionally compiled by stereoscopic interpretation of vertical airphotos, followed by transfer of type boundaries to a planimetric base map. Type labels ordinarily express species composition, tree size class, and stocking class.

One potential rival to aerial photography in timber typing is multispectral scanner imagery. Use of aerial and spacecraft multispectral scanners in forest resource assessments is reviewed by Heller and Ulliman (1983). A multispectral scanner samples incoming radiation in its field of view, splits it into discrete spectral bands, and produces for each band a mosaic of picture elements (pixels) representing brightness. Scanners usually subdivide the electromagnetic spectrum more narrowly than photographic films and can also access spectral bands closed to film sensors. Digitized scanner output is well adapted to computer processing. However, the scanners are costly, their spatial resolution is comparatively low, and they do not provide a stereo view.

Various firms in the United States use aircraft-mounted scanners for agricultural tasks such as plant vigor assessment and disease detection. Because rapid analysis is essential in these applications, no elaborate image processing is carried out. Rather, pixel brightness values in a single spectral band are grouped into a dozen or so brightness classes, and each class is assigned a color for output on a printer. Such "level-sliced" scanner images resemble color photos closely enough to suggest the possibility of substituting scanner images for color photos. With this in mind, representatives of a forest products firm asked us to test a set of scanner images by type-mapping an area of the company's forestlands in Maine.

Methods

A set of 65 images in the 0.4–0.8 micrometer (visual to near-infrared) band was provided. Taken in August 1985 by a Kansas-based agricultural imaging firm, they covered a study area of about 12 square miles. Individual picture elements had ground dimensions of about 5 feet by 5 feet; the images were printed at a scale of 1:3,500.

For comparison, the firm provided current forest type maps at a scale of 1:15,840, compiled by conventional photointerpretive methods and found acceptably accurate for field use. Fifteen cover types were delineated on the maps. Two—water and roads—were

William A. Befort is assistant professor and Kevin S. Evans is a graduate student, Department of Forest Resources, University of New Hampshire, Durham.

nonforest types. Another was for recently cutover land. The remaining 12 types included four broad composition classes at three levels of stocking: hardwood (H), softwood (S), and two mixed composition classes (H/S or S/H, de-pending on dominance); and stocking levels 1 (0 to 39 percent crown closure), 2 (40 to 69 percent closure), and 3 (70 to 100 percent closure). There was no classification of tree size, and no types covering less than 10 acres had been delin-eated. The scanner imagery was to be used to compile a similar map, which would then be compared with the reference map. The firm stipulated that significant differences would be presumed to indicate unreliability in the scanner-produced map. The test comprised four steps:

(1) A type interpretation guide was developed for the scanner imagery.

(2) The scanner images were interpreted by using the guide to compile a type map.

(3) A set of sample points was selected for accuracy analysis.

(4) Scanner-derived map classifications were compared with reference map classifications at these locations.

Development of the guide drew upon extensive cruising experience in the study area by one of the authors. In addition, composition and stocking data were available from 70 variable-radius plots. These were grouped by cover type and located on the scanner imagery; image color and other characteristics were then compiled for each cover type.

The scanner images were so large in scale that each covered little ground. To assist interpretation, they were mounted together as a semicontrolled mosaic about 6 feet square. Viewing this assemblage as a single unit, with a base map in hand for geographic orientation, the analyst applied the interpretation guidelines and delineated cover types on images to a minimum type area of 10 acres. Type boundaries were transferred to a 1:15,840 planimetric base map by reflecting projector.

Analysis of type-mapping accuracy usually involves sampling randomly located points across the mapped area and comparing interpreted types with reference data at those points. The acceptance-sampling tables produced by Ginevan (1979) were used to set sample size; they give both the minimum number of points that must be sampled and the maximum number of misclassifications that can be tolerated.

The lower bound of acceptable agree-

ment was set at 85 percent, with a 5 percent chance of mistakenly accepting a lower level of agreement. The upper accuracy bound was set at 95 percent, with a 5 percent risk of rejecting the scanner map if it actually agreed with the reference map 95 percent of the time. At least 93 sample points were required, and 8 misclassifications could be tolerated. An identical grid was imposed on both maps, and 95 sample points were located using a random number table.

Results

Of the 95 points tested, 67 were placed in the same cover type by both the reference map and the scanner map; 28 were placed in different classes. We therefore concluded that the maps were not identical and that, based on the reference map as the standard of accuracy, interpretation of scanner imagery had not produced a satisfactory type map.

The results of the test are displayed as an error matrix in *figure 1*. Entries for which interpretations from the scanner image agree with reference data descend from left to right along the diagonal element of the table.

An interpreter who has a good idea of the relative proportions of categories present will usually get some answers right by pure guesswork. Cohen's (1960) method of discounting for this effect has been extended to analysis of remote-sensing error matrices by Congalton and Mead (1983) and others. Cohen's K statistic expresses the percentage of agreement between two classifications (in this case, between reference map and scanner interpreta-

	S1	S2	S3	H1	H2	H3	SH1	SH2	SH3	HS1	HS2	HS3	WATER	ROADS	CUTOVER	Totals
S1	2		4												2	8
S2	5	5						1								11
S3		1	30				2	2	3						1	39
H1																0
H2																0
H3																0
SH1							1									1
SH2			2				1	2								5
SH3			2						1							3
HS1																0
HS2											2					2
HS3			1													1
WATER													5			5
ROADS														2		2
CUTOVER			1												17	18
Totals	2	6	45	0	0	0	4	4	5	0	2	0	5	2	20	95
% Correct	100	83	66	–	–	–	25	50	20	–	100	–	100	100	85	

Proportion in agreement: .70
Proportion of chance agreement expected: .25
K (agreement adjusted for chance): .60
Confidence interval of K: ±.12

Figure 1. Error matrix, reference map vs. scanner-produced map. Entries show actual (reference) cover type and scanner-interpreted cover type of 95 total test points. Composition class S = softwood, H = hardwood, SH = softwood dominance, and HS = hardwood dominance. Stocking class 1 is 0 to 39 percent crown closure; 2 is 40 to 69 percent crown closure; and 3 is 70 to 100 percent crown closure.

tion) after chance agreement has been removed:

$$K = (Po - Pc) / (1 - Pc)$$

where Po is the proportion of samples in which agreement occurs and Pc is the proportion of samples in which agreement would be expected to occur by chance. The value of K ranges between 0 and 1. In remote-sensing applications the method yields a rather conservative estimator, as it very effectively deflates straight percentage-of-agreement figures while giving no credit for "near misses."

Calculated K for this test was 0.60, compared to a raw percentage agreement of 0.70. The standard error of K was 0.06, which yields lower and upper 95 percent confidence limits on K of 0.48 and 0.72. On the basis of this test, then, and across the range of cover types represented in it, similar visual cover-type interpretations made from color-sliced scanner data might be expected to agree with reference data about 50 to 75 percent of the time.

If stocking class is ignored and only composition is considered, classification results improve somewhat. *Figure 2* is a simplified error matrix cast in these terms. Raw agreement is 82 percent; discounting chance agreement leaves a K of 0.70. The 95 percent confidence limits on this K are 0.58 and 0.82; thus the improvement in K is not statistically significant.

Discussion

Results of this attempt to create a forest type map from multispectral scanner images were unsatisfactory. This statement deserves several qualifications:

• The test was technically a test of agreement rather than of accuracy, since the stipulated standard of comparison was a photointerpreted type map rather than "ground truth."

• The study area was small. Few stands of hardwood type were present, and none appeared in the sample; therefore, nothing of this category is known apart from the little that is conveyed by the absence of commission errors.

• Only a single band of imagery was available. These images were, functionally, only black-and-white photographs with each gray level displayed in a different color; that is, they were not multispectral images in the sense in which the term is usually understood.

• The images had received only minimal processing. They needed not just coloring but sharpening as well; standard edge-enhancement techniques are available for this purpose.

Nevertheless, it may be doubted whether visual interpretation is the proper approach to this kind of imagery. Successful users of multispectral scanner data in type mapping have invariably employed computer image analysis and statistical classification techniques (e.g., Rohde and Olson 1972, Fox et al. 1980, Hoffer et al. 1982). In remote sensing as elsewhere, analytical methods must correspond to data characteristics. In dealing with images of high spatial resolution and low spectral resolution (black-and-white stereophotos, for example), visual interpretation is efficient. Where image characteristics are the opposite of these, a different approach is indicated. ■

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		REFERENCE DATA							
		S	H	SH	HS	W	R	C	Totals
S C A N N E R D A T A	S	47		8				3	58
	H								0
	SH	4		5					9
	HS	1			2				3
	WATER					5			5
	ROADS						2		2
	CUTOVER	1						17	18
	Totals	53	0	13	2	5	2	20	95
	% Correct	88	–	38	100	100	100	85	

Proportion in agreement: .82

Proportion of chance agreement expected: .40

K (agreement adjusted for chance): .70

Confidence interval of K: ±.12

Figure 2. Error matrix, reference map vs. scanner-produced map, stocking classes omitted. Entries show actual (reference) cover type and scanner-interpreted cover type of 95 total test points. Composition class S = softwood, H = hardwood, SH = softwood dominance, and HS = hardwood dominance.