Agriculture and Forestry—Identification, Vigor, and Disease

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The Chesapeake Bay watershed is situated in the middle of a rapidly developing region which is becoming very heavily populated. The condition of the vegetation and general land use is most important in maintaining a suitable environmental quality of both the land and the Bay. The vegetation not only provides food, feed, and fiber, but protects the soil from erosion and the Chesapeake Bay from siltation and high turbidity.

The agricultural production of the tidewater region of the watershed is of great value to the human population. The economic value is estimated to be about $500 million per year. The agricultural production and forestry is threatened by urban encroachment and pollution in addition to the usual plant diseases and insect and other infestations. Accurate inventory and assessment of these threats are required.

Poor management of agricultural areas is leading to erosion and depletion of fertility. Better ecological knowledge is required to understand the problems so that better land management could be effected.

This paper describes the agricultural and forestry areas in the watershed as well as the production of the watershed; outlines major problems of the watershed; discusses remote sensing as it relates to identification of plant species and vigor, pollution, disease, and insect infestation; and presents the recent results of remote sensing of the Rhode River watershed.

AGRICULTURE AND FORESTRY

The Chesapeake Bay watershed including the tidewater counties of Maryland, Virginia, and Delaware covers an area of about 100 by 200 miles or about 20 000 square miles. This area is divided as follows:

	Square miles
Maryland	6800
Virginia	6700
Delaware	2100
Chesapeake Bay and tributaries	4400
Total	20 000

The Bay receives water from a watershed of about 65 000 square miles with over 50 tributary rivers. The Susquehanna River drains 50 percent of the basin. About 15 000 square miles are in the coastal plain and about 50 000 square miles are in the Piedmont region.

Of the 20 000 square miles of the Chesapeake Bay watershed, 15 600 square miles are land. Table 1 shows the distribution of this land into forests, agricultural land, pasture, urban areas, and marsh wetlands.

The forest land covers an area of slightly over 6 million acres or 9450 square miles. Forests include 68 percent of the tidewater counties of Maryland, 60 percent of Virginia, and 48 percent of Delaware. The total value of the cut timber (stumpage) is about $13 million in Maryland, $13 million in Virginia, and $0.5 million in Delaware.

The forests of the Chesapeake Bay include the combination of oak, hickory, and pine as the major type, but, in the

TABLE 1.–Land Use in Chesapeake Bay Watershed

Use	Maryland (percent)	Virginia (percent)	Delaware (percent)
Forest	68	60	48
Agricultural crops	23	23	32
Pasture	6	2	2.5
Urban/industrial	3	6	9
Coastal marsh	–	–	8.5

southern part, the combinations are oak with hickory, oak with pine, loblolly pine with shortleaf pine, and oak with gum and cypress. In many areas with better soils there are a large number of mixed mesophytic deciduous species with maple, tulip tree, beech, gum, various species of oak, floodplain species of ash, elm, maple, sycamore, birch, and many other species. The main timber trees are red and white oak, tulip tree, pine, sweetgum and various other hardwoods.

The agricultural cropland of the tidewater counties covers an area of 2 348 861 acres or 3670 square miles. The agricultural cropland of the watershed in Maryland is 23 percent, in Virginia 23 percent, and in Delaware 32 percent. The value of agricultural crops and livestock of this region is an estimated $500 million dollars.

Figure 1 shows the agricultural crops of the Chesapeake Bay watershed. These include mainly corn, soybeans, barley, potatoes, tobacco, peanuts, hay, and tomatoes and other vegetables. The eastern shore of Maryland is agriculturally suited for truck crops because of its sandy productive soil, sufficient water, and long growing period. The most important crops are soybeans, corn, wheat, and vegetable crops. On the western shore of Maryland the major crops are hay, corn, tobacco, wheat, and some soybeans and vegetables. In the Virginia region, the main agricultural crops are corn, soybeans, peanuts, wheat, barley, and tobacco. In the Delaware area the main crops are corn, soybeans, hay, barley, rye, oats, and lima beans, and other vegetables.

The livestock and poultry industry is fairly extensive and includes dairy and beef cattle, hogs, and chickens. In Delaware the value of the livestock, poultry, and products is about $95 million per year.

Extensive vegetation along the Chesapeake Bay shoreline includes salt marshes and wetlands. This vegetation is estimated to be 8.5 percent of the land area in Delaware alone. These areas are of great importance to wildlife and production of aquatic life. The main vegetation is grass of various types, saltbush, cattail, and many other species of plants. Salt grass is mowed in some of the regions and is valuable for mulch and other uses.

Floating aquatic vegetation has been a major cause of clogging in the navigable waterways. In 1968 an estimated 200 000 acres were infested with European waterfoil *Myriophyllum spicatum*. However, the plant decreased greatly in amount due to disease.

Figure 2 shows the state parks, state wildlife management areas, state forests, private research and natural areas, and national wildlife refuges. The total area in the watershed is about 400 square miles. Much of this is located in salt marshes and wetlands. The wildlife includes many species of birds and mammals, both terrestrial and aquatic. The main hunted species are ducks and geese, quail, rail, rabbit, squirrel, and deer.

PROBLEMS

Ecological Understanding and Proper Land Management

The major problem is to achieve proper understanding of the ecology of the region. Optimal land management requires accurate census and inventory of present land use, changes and trends in use, and adequate knowledge of such specifics as the soils, rainfall, erosion, fertility, pests, food, animal feed, and timber requirements. The data then must be analysed and synthesized for land use planning.

In Virginia, a conservation-needs inventory was published in February 1970 showing that 52 percent of the land needed conservation treatment of some kind. This includes 64 percent of cropland, 70 percent of pasture, 46 percent of woodland and 33 percent of other land. Susceptibility to erosion and unfavorable soil conditions in the root zones were the most serious problems. This report was based on available data, "grass roots" knowledge, and committee estimates.

Some areas in the watershed are farmed using very poor practices, resulting in loss of soil and fertility. Much worn out and eroded land is abandoned and reverts to unused unmanaged scrubland. Abandoned tobacco land is a major source of this problem. Accurate inventories of these areas are needed.

The total land area in farms in Maryland was about 5 million acres in 1900 and about 3.5 million in 1955. There is a decrease in cropland at present on the western and northern shore areas but an increase on the eastern shore.

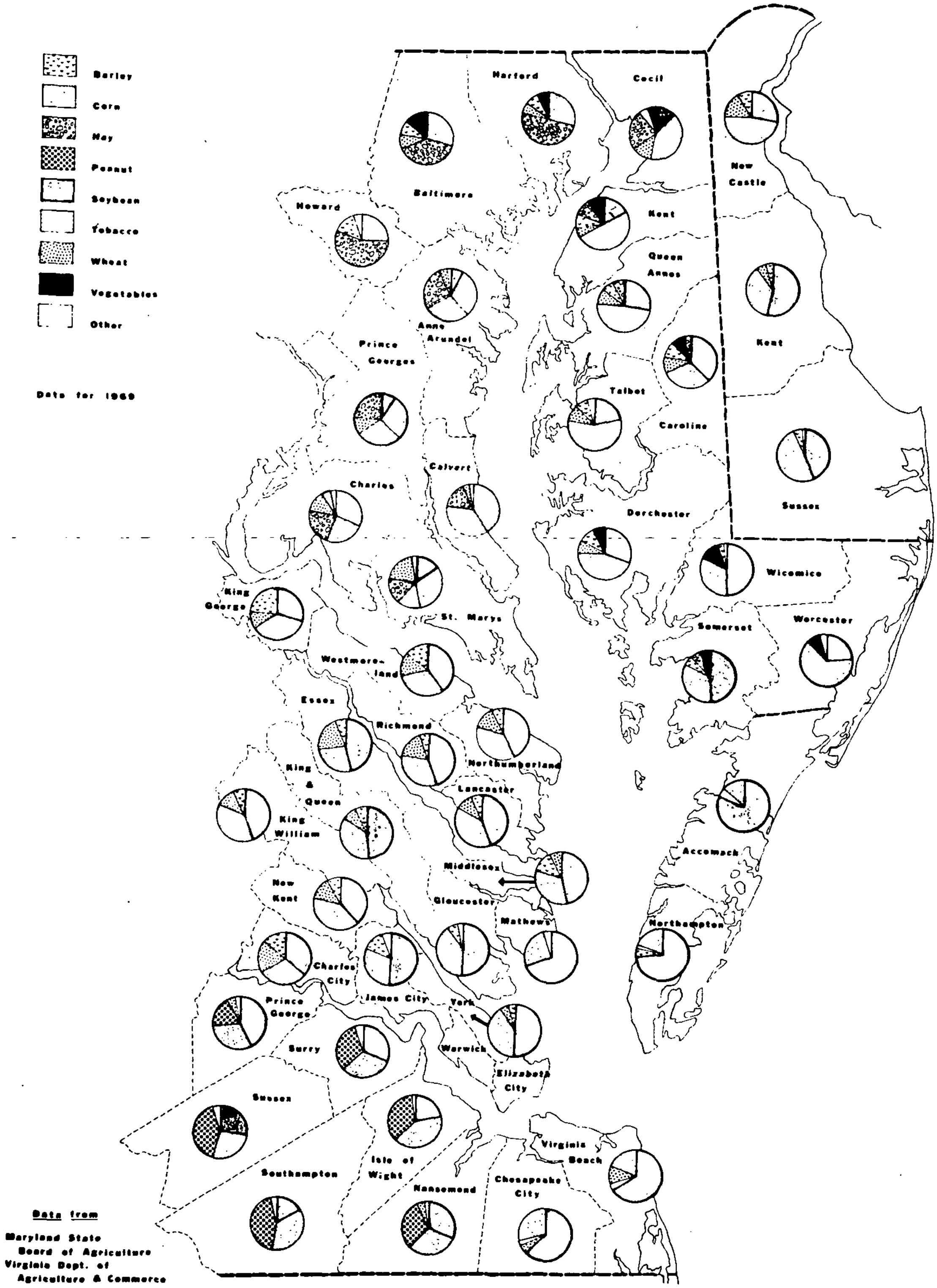

Figure 1.–Crop production on the coastal plain of Delaware, Maryland, and Virginia.

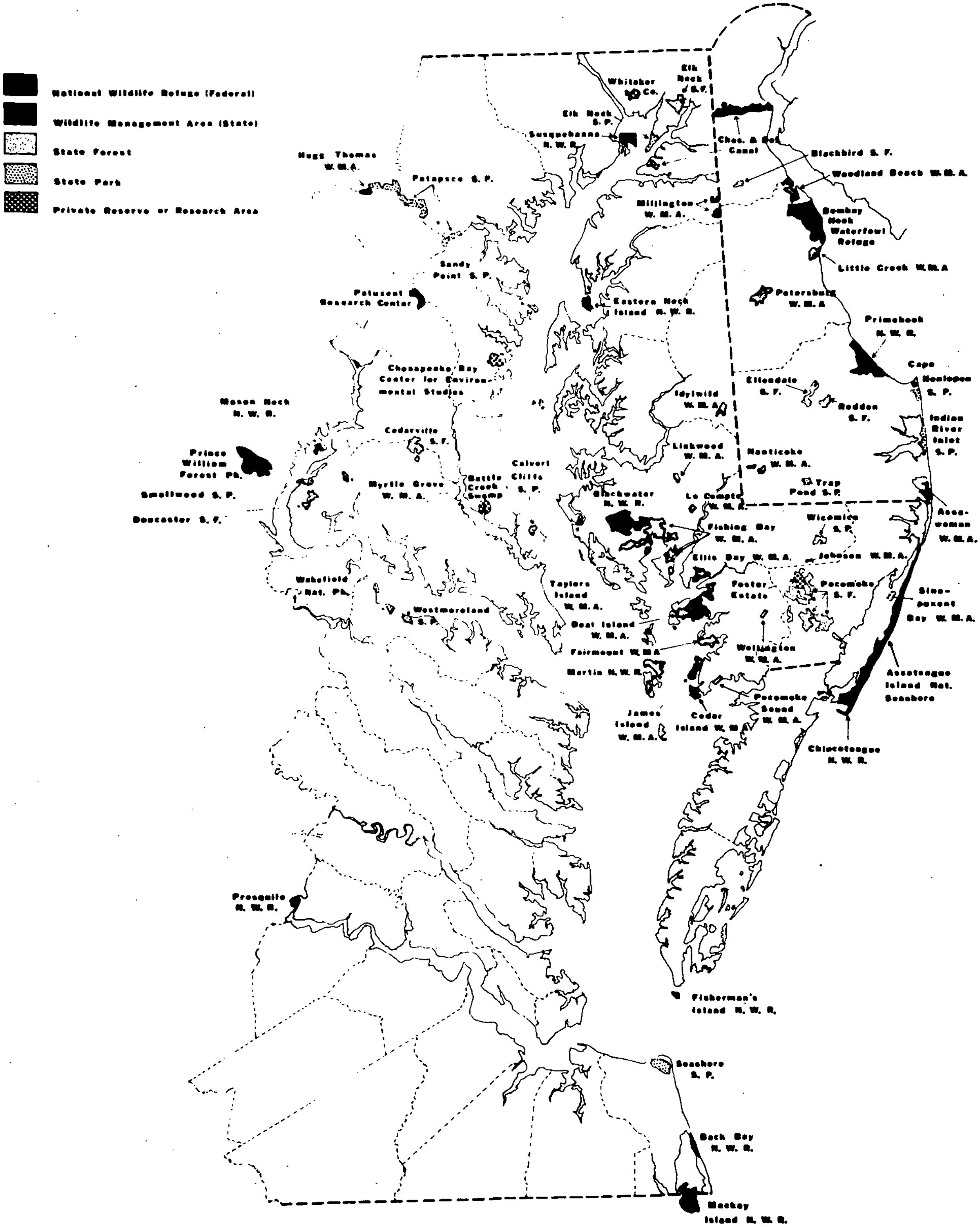

Figure 2.–Protected areas on the coastal plain of Delaware, Maryland, and Virginia.

Population Increase

A second major problem is the population increase in the watershed. Population expansion and suburban encroachment result in development of urban areas with housing, paving, industrial facilities, highways, and other facilities. Installation of these facilities results in destruction of forests, agricultural land, and waterfront. In addition, the bulldozing, grading, and changes in drainage result in greatly increased erosion and pollution. The presence of people, with accompanying air pollution from burning of coal, factory exhaust, automobile exhaust, and other air pollutants, results in air pollution injury to plants and destruction or damage to various species. (The population of the immediate Bay area was 2.8 million people in 1960 and is expected to double by 1985.)

Remote sensing can document these changes accurately and show the rate of urbanization and loss of forest and agricultural area. Eroded areas and resulting sedimentation in the streams and estuaries can also be observed.

Damage to Agricultural Crops and Forests

The major causes of damage to the agricultural crops and forest of the watershed are air pollution, diseases, insect infestations, and drought.

The air pollution damage to agricultural crops, forests, and livestock in the watershed is relatively unknown and needs to be assessed. It has been estimated that the total damage to plants in the entire United States from air pollution is about $500 million per year. The watershed is heavily populated, contains large cities, industrial areas, and many automobiles. Some of the crops such as tobacco and vegetables are quite susceptible to air pollution damage. Surveys of air pollution damage to plants should be concentrated in the vicinity of and down wind from major cities and industrial areas.

Plant diseases are known to cause much damage to many agricultural crops and some damage to forests in the watershed. Some of the most important plant diseases are southern corn leaf blight, soybean stem blight, potato leaf blight, and root rot of various forest species. The southern corn leaf blight is expected to be very serious in the watershed in the 1971 season and could result in nearly complete loss of the crop. The T-strain of hybrid corn presently planted in the region is highly susceptible, and overwintering blight in the region from 1970 is anticipated to be the source of severe damage. Accurate surveys in the 1971 growing season are essential.

Insect damage to the agricultural crops of the watershed is fairly extensive and most of the crops require insecticide treatments. In addition nematodes and spider mites also produce damage. Surveys of the insect damage are required to permit proper treatment. A special problem is the southern pine beetle which is destroying much loblolly pine in the watershed. Studies have already been carried out to determine the effectiveness of remote sensing to detect insect infestation of the pines.

REMOTE SENSING

Vegetation and Animals

Identification of species of plants by remote sensing has been developed into a science for certain species. Aerial photography has been used for about 30 years in studying vegetation, especially in forestry. Identification of species of vegetation by multispectral remote sensing has been developed rapidly during the last few years. A major advance has been the use of spectral signatures that permit identification without necessarily resolving spatial properties. Identification of certain species of forest, range, or crop plants can be determined with a high degree of accuracy and precision if the right conditions and techniques are utilized. The correct combination of spectral bands at the right altitude, season, time of day, condition of crop, and with proper light conditions, permits accurate identification in the hands of experienced photointerpreters.

Forest surveys of conifers and deciduous species have been made with accurate species identification in mountainous and other areas. A forester who knows the species of conifers and deciduous species in some areas can readily identify all of the species using color infrared photography. Identification of species on air photographs is difficult in the eastern deciduous forest where there may be many species which appear quite similar in various spectral bands during most of the summer. Air photographs taken at the time of fall leaf coloration helps identify species and groups of species.

In the identification of plant species in the fields of forestry, agriculture, and ecology, sensor-signature research is the single most important pacing element upon which progress depends. Specifically, accurate data on emission and reflectance properties of biological and physical materials are needed. This includes variations of reflectivity and emissivity with wave length (i.e., spectra) and with spatial position (i.e., shape), polarization introduced by the material or its condition, and variations of reflectivity and emissivity with time, including diurnal and seasonal cycles.

Crop plant identification of various species in monoculture has progressed rather rapidly. It is presently possible to distinguish between closely related species, such as wheat and oats, using multispectral sensing under specific selected conditions. The identification characteristics using many spectral bands have been computerized so that automatic identification is potentially possible.

Multispectral sensors using a variety of regions of the electromagnetic spectrum has been shown to be highly effective in making identifications not otherwise possible. This includes particularly the spectrum from 0.3 to 15 microns from ultraviolet to infrared and, in addition, microwave and radar. Use of photographic film from 0.3 to 0.9 micron images allows additional selection of methods. Multiple processing systems further enhance the effectiveness of remote sensing. In photography the pictures can be enhanced by color and electronic methods and accurately measured with densitometers.

The use of remote sensing for making censuses and counting wildlife and domestic animals is now limited to surveying animals the size of sheep or larger. Present techniques include low altitude aircraft photography using black and white, color, and infrared film, and infrared optical scanning.

Animals can be observed and their movements, migration, and effects on the environment determined. Larger animals, particularly larger ungulates such as deer, elk, and cattle can be distinguished by an infrared thermal scanner in the 8 to 14 micron range with a 3 milliradians (3 feet/1000 feet altitude) field of view with a 1°C temperature differential between the animal and its background. This is a compromise between temperature sensitivity and resolution. Successful population census counts have been made of white-tailed deer using infrared sensing. Ideal conditions for detecting animals were little or no wind, snow background, high overcast sky, daytime, and absence of leaves on deciduous trees. Differentiation between different animal species by infrared scanning would be possible only with animals of very different size.

Cattle, sheep, and horses were differentiated and counted using panchromatic black-and-white film at 1:5000 scale during early morning hours, with winter-spring green grass. In cultivated areas the correlation of ground count to image counts was excellent, but in open range, errors were greater. Good results were obtained using color transparencies at 1:2500 scale in addition to black and white at 1:5000 scale.

Larger flocks of geese, ducks, and seabirds can be observed by remote sensing. Swan have been counted on Chesapeake Bay using infrared film. Bird migration has been studied using radar. Nocturnal bird migrations have been scanned by radar equipment at the NASA Wallops Station.

Changes in plant growth vigor may be due to disease, insect and animal damage, air pollution, soil pollution or mineral or nutrient deficiency, senescence, insufficient water supply, or other causes of physiological stress. These may result in changes of geometry and density of foliage, including loss of leaves, loss of turgor in leaves, wilt and shrivel, browning or change in color of the leaves, exposure of bark and branches and shadow areas as well as a decrease in evapotranspiration, and an increase in temperature of the leaves. All of these factors produce changes in the spectral signatures of the plants and show that a change has occurred. From examination of air photographs it is not usually possible to identify the cause of change unless accompanied by ground-truth observations which identify the cause. Since many of the changes produce effects sensed in the near infrared but not visible to the human eye, remote sensing using infrared film and infrared scanning can detect early changes in plants before a trained observer can detect them on the ground.

Identification of plant disease and insect infestation is very important, especially during the early stages, to permit more effective treatment or to take appropriate action. Also it is very helpful to be able to make rapid surveys to determine the extent and specific area of the outbreaks. Experimental studies of plant disease and insect infestations have shown that many types of outbreaks can be detected using multispectral sensing, particularly in the infrared. A variety of plant disease outbreaks has been detected by remote sensing using infrared. Some of these techniques are already being used with various degrees of success in certain areas. Various insect pest infestations have been identified using remote sensing. Identification of beetle-infested trees has been of main interest.

Ecological Changes

Alteration of natural ecosystems is, of course, manifest in all resource problems. Without change–depletion, erosion, pollution, accrual, or epidemic–the problem is seldom recognized. This is perhaps the easiest type of information to procure by repetitive aerial surveillance and has been exploited with photography in the visual wavelengths. Thus, with time, old conventional aerial photography may gain value as indices to change, but until repetitive aerial reconnaissance is widely practiced, long-term and widespread change, man-caused or natural, will often be difficult to assess. Once trends of change or the consequences of technology are evaluated, alternatives can often be developed from the same data. This is perhaps the most promising application for photography from spacecraft.

In the study of the ecology of an area, use of infrared photography, multispectral sensing, and particularly sequential survey can show many changes and dynamic processes. The following have been remotely sensed or are showing great promise for the future:

Fire–including fire, smoke, burn area, and revegetation

Wind–damage to crops and forest

Flooding–extent of flood and damage assessment

Waterlogging of soils

Erosion–increase of gullies and river erosion

Disease–crop and forest diseases, local and epiphytotic

Insect infestation–crop and forest, and locust plagues

Drying–low moisture in plants, drought

Grazing–overgrazing, animal trails

Salinization–mineral deficiency; e.g., chlorosis

Harvesting of crops and indication of yield

Lumbering–volume of timber cut

Weed infestation and spread

Radiation effects on survival and growth

Planting and growth

Revegetation and pioneer plants

Leaf out and flowering, color change, and leaf fall

Maturing of fruit and crops

Succession of vegetation communities

Vegetation zones and community boundaries

Cultivation of nonarable land; fencing

Change in land use

Sequential surveys using "change detection analysis" greatly enhance the entire remote sensing system. More specific identifications can be made as well as identification of significant and important changes. These may be very short time periods, measurable in minutes, involving fires, animal movements, or floods, or the changes may take days or weeks and involve changes in animal migration and movement, fires, floods, vegetation changes, insect outbreaks or disease infestations. Changes over months involve crop changes including maturation, harvesting, disease and insect infestation, lumbering, clearing, reseeding, overgrazing, and others. Changes involving years include plant succession, forest growth, land use change, and urbanization.

REMOTE SENSING OF THE RHODE RIVER ESTUARY

Ecological research involving the use of remote sensing (multispectral aerial photographic techniques) was initiated by NASA Wallops Station and the Smithsonian Institution in September 1970. The study site is the Rhode River estuary watershed which is located about seven miles south of Annapolis on the western shore of Chesapeake Bay (fig. 3). The watershed includes about 12 square miles of land area and about four square miles of estuary. The Smithsonian Institution owns 1272 acres of relatively undisturbed land which is the location of the Chesapeake Bay Center for Environmental Studies. The watershed is the site of an ecosystem study and a community action planning program. Studies are underway by scientists from the Smithsonian, Johns Hopkins University, the University of Maryland, and the U.S. Geological Survey (fig. 4).

The Rhode River watershed is well suited for the remote sensing program because of its convenient location and because many of the characteristics of the much larger Chesapeake Bay watershed, which NASA has already chosen as a prime target study site, can be studied there in smaller scale.

The objectives of the Rhode River watershed project are:

(1) To evaluate the applicability of remote sensing data to analyses of the composition of forest, field, agricultural crops, and marsh vegetation in the Chesapeake Bay area

(2) To determine how well these data correlate with soil types and the various physical, chemical, and biological factors of the water surface of the Rhode River estuary

(3) To determine the value of remote sensing in studying population encroachment and community and suburban planning and development

The results to date of the vegetation studies are summarized here:

The Rhode River watershed is predominantly an agricultural area which is slowly becoming more heavily populated by suburban encroachment. The eastern shore of Rhode River is populated by the towns of Mayo and Beverly Beach. The western shore remains undeveloped since most of it is owned either by the Smithsonian or by families interested in the preservation of wildlife and the natural environment of the area. This particular shoreline (approximately 13.5 miles long) is one of the largest relatively undisturbed areas remaining on the western side of the Chesapeake Bay. The topography of the Rhode River watershed is chiefly rolling upland, much dissected by narrow stream valleys which broaden to level floodplains along the courses of Muddy Creek, the principal tributary stream.

Approximately 45 percent of the land area of the watershed is cultivated to grain, tobacco, and truck farms. The recent farmers have wisely left most of the stream valleys and floodplains covered with forest, so soil erosion is presently minimal. Forests cover approximately 35 percent of the watershed. The remaining 20 percent includes abandoned fields, marshes, and the towns of Mayo and Beverly Beach (fig. 4).

The watershed has been flown by NASA helicopters, the University of Michigan's DC-7, the NASA's RB-57, and the Air Force's B-57. The area has been photographed using black-and-white and color infrared, and black-and-white film, color film, and infrared scanning from 4.5 to 5.5 microns and 8 to 14 microns. Various areas have been flown in the summer, fall, winter, and early spring.

The search for reliable ground-truth correlations with remote sensing data has followed two approaches:

(1) The preparation of a detailed vegetation map of the entire watershed

(2) The selection of four small areas for intensive study of young and moderately mature deciduous forest, recently abandoned farmland, and salt marsh

A detailed reconnaissance and mapping of the forest vegetation in the Rhode River watershed was begun in November 1970 to obtain ground-truth data which could be correlated with a photographic survey of the watershed

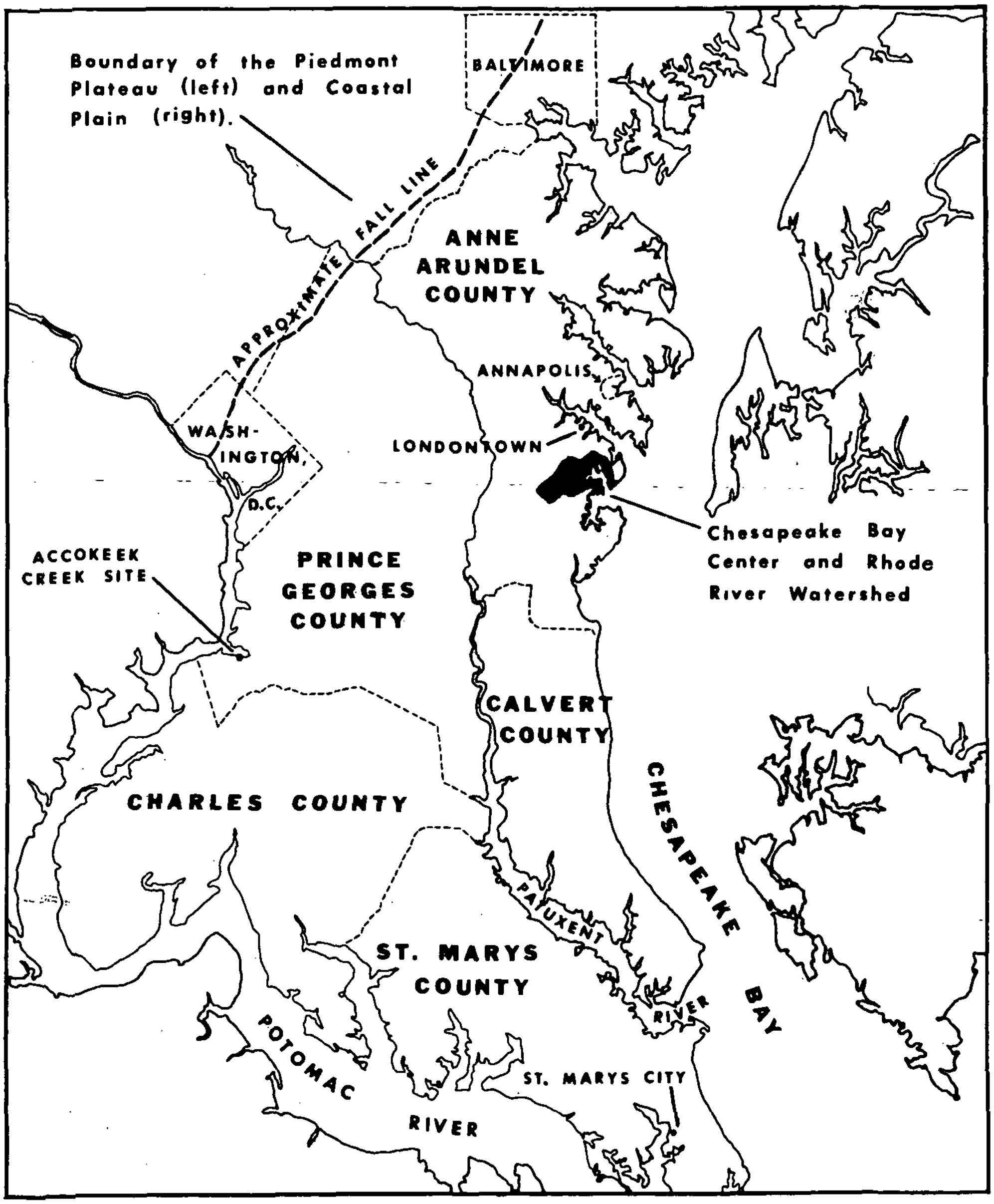

Figure 3.–Location of the Chesapeake Bay Center and related sites, west shore.

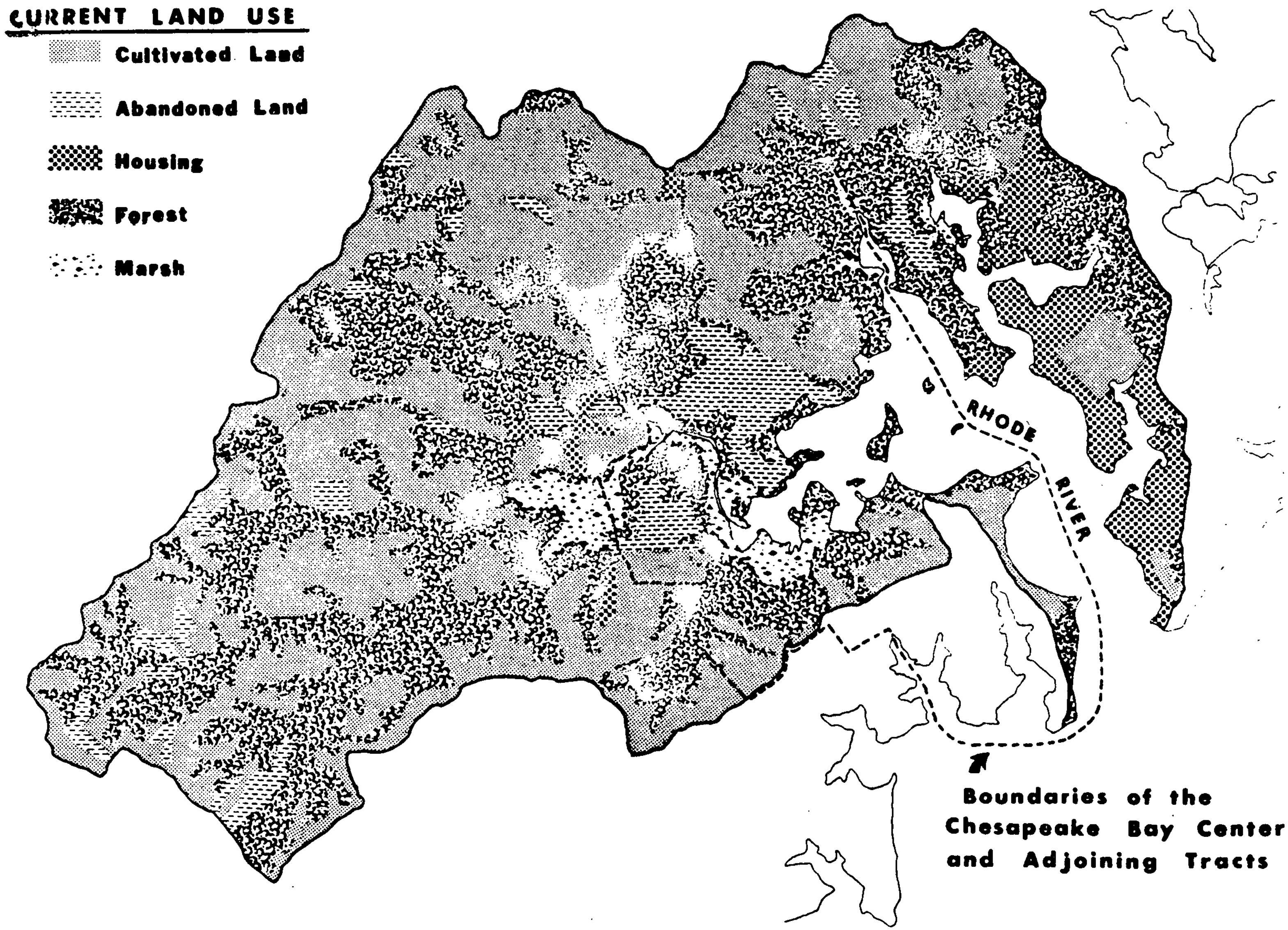

Figure 4.–The watershed of Rhode River.

under different seasonal conditions. Since most of the watershed which is not under cultivation is covered with deciduous forest, completion of the field survey was desired before all the leaves had fallen.

The forest areas were surveyed on foot. The composition of the canopy was typed on the basis of species which dominated or characterized particular forest communities. Typing was done on a biomass-dominance basis where the species of greatest biomass were considered dominants in an area (biomass was determined subjectively from basal area, height, coverage, and density determinations). These types were recorded on topographic maps. Those features of the subcanopy vegetation which might be observable from the air in winter or early spring were noted (the presence of flowering dogwoods, evergreen, honeysuckle, etc.). Major topographic variations and the presence of streams and swampy areas were also recorded because of their potential value in aerial identification of forest vegetation types.

The vegetation was mapped on a mosaic of aerial photographs taken in 1968 at a scale of 1:5000. Forest types, types of vegetation in swamps, and abandoned fields were also mapped.

Remote sensing data have already confirmed the locations of stands of coniferous trees and of several patterns in the hardwood forest canopy. Increasingly close correlations between the field notes and the remote sensing data are expected as more photographs of the watershed are examined and continued study of the four test areas provides more criteria for the identification of plant associations, individual species, and environmental features.

For more detailed correlation of aerial photos with ground data, four intensive study sites were selected in the watershed. The four test areas were photographed several times in different spectra and at different altitudes providing the best material for establishing reliable criteria in identifying single trees or the composition of small stands. Plant communities were most easily delimited in the salt marsh and abandoned fields. In these areas also, the relatively low level of vegetation facilitated the placement of markers visible from the air to pinpoint specific locations. Exact locations and community boundaries have been more difficult to place in the forest areas, and work there has concentrated on individual trees that are easily discerned, both from the air and ground.

In the Hog Island marsh study, the island was mapped for correlation of hue, chroma, and value, as well as crown texture, with individual trees. The delineation of individual crowns has been accomplished with stereoscopic analysis of photos taken from low altitude (1200 feet).

Attention has been given to the identification of photographs of vegetation over the entire watershed as well as over the four intensive study sites. In some cases individual plants or small, homogeneous stands are distinguishable from the background vegetation. Recent winter photographs show understory species and ground cover which may be valid indicators of canopy types, differentiation of conifer types, and drainage patterns.

Large, isolated trees along roads in the watershed were identified and recorded during the fall on 1:5000 scale maps and notes taken on their color and amount of leaf fall. These data are being used in conjunction with the intensive study area data for correlation of leaf color on the ground and on aerial photos.

Variations in the colors of autumn leaves were used to attempt to distinguish species of deciduous trees on aerial photographs. Although weather and other environmental factors might influence the time of leaf changing from year to year, the colors should provide a permanently reliable indication of the species.

The majority of tree species consistently turned a single color, usually fading to brown, although variations still occurred over the crowns of individual trees. A few species, notably dogwood and black gum, could be easily recognized consistently by their colors. Such species as sweetgum, sassafras, and red maple often exhibited a mixture of red and yellow leaves on the same tree. Observations of changes in leaf coloration were made for 18 species of trees and shrubs in late October and for 23 species in early November. Based on preliminary study of the photos available, natural color and color infrared film allowed the greatest differentiation of vegetation types, individual species, and drainage patterns. Transparencies were superior to prints because of the higher resolution and intensity of color. Stereo photos are essential for differentiating crowns in the intensive study areas and for identifying drainages over the whole watershed.

Low altitude (1200-foot) photos are superior to those of higher altitude for positive identification of individual trees; this superiority is due to haze reduction (especially in natural color photos) and increase in scale. Because of the variety of leaf colors in fall, photos in that season were deemed best for general photointerpretation. Winter photos were superior for characterization of understory, ground cover, and drainage patterns as well as being most useful for identification of conifers, semi-deciduous hardwoods, and hardwoods with highly reflective branches such as beech.

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