A RECONSTRUCTION OF CHANGES IN LAND USE/LAND COVER IN VERMONT RELATIVE TO SENSITIVITY OF SURFACE WATERS TO ACIDIC DEPOSITION

by

SHARON ELAINE CLARKE

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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A RECONSTRUCTION OF CHANGES IN LAND USE/LAND COVER IN VERMONT RELATIVE TO SENSITIVITY OF SURFACE WATERS TO ACIDIC DEPOSITION

ABSTRACT: Patterns of land use/land cover explain some of the spatial variability in sensitivity of surface waters to acidic deposition. Historic changes in land use/land cover may further explain some of the spatial variability. A map of land use/land cover changes needs to be compiled before this relationship can be analyzed. The objectives of this research are: 1) to determine the feasibility of mapping historic land use/land cover changes using Vermont as a pilot study, 2) to map the historic land use/land cover changes for Vermont, and 3) to evaluate and describe the resultant map. Relevant literature on land use/land cover is reviewed for maps and other descriptive information. The first step in compiling the map is to determine the classes of change which would influence the sensitivity of surface waters to acidic deposition. The map is constructed using present land use/land cover maps, topographic maps, and a 1935 map on quality of land for farming. These maps are augmented by descriptions of land use/land cover changes, information on successional stages, and relationships between land uses and physiography. The mapped categories are: nonforested lands, forested lands with agricultural potential, permanently coniferous forest, permanently deciduous forest, permanently mixed forest, permanently forested wetland, ski areas, and water. The composition and spatial location of each of these categories is discussed. In addition, an assessment of the reliability of the map is made using estimates of the percentage of each county in each of the major land uses or land covers.

Introduction

Purpose

The National Acid Precipitation Assessment Plan gave the U.S. Environmental Protection Agency (U.S. EPA) the leading role in identifying factors controlling the susceptibility of surface waters to acidic deposition, in determining factors causing acidification of surface waters, and in quantifying the extent of sensitive and acidified surface waters (Interagency Task Force on Acid Precipitation 1982). Historic land use/land cover changes may control the susceptibility or cause the acidification of surface waters (Art and Dethier 1986, Krug et al. 1985, deVries and Breeuwsma 1984a, deVries and Breeuwsma 1984b, Krug and Frink 1983, and Rosenqvist et al. 1980). The identification of areas of change may also be useful for extrapolating sample data to the larger population of lakes, or as a stratum for sample design, to give better estimates of the extent of sensitive and acidified surface waters.

The relationship between land use and susceptibility of surface waters to acidification was indicated from the work by Omernik and Kinney (1985). They found a spatial association between land use and alkalinity values. (Alkalinity is a measure of the acid-neutralizing capacity of surface waters.)

> In general, surface water alkalinity was low in areas of ungrazed forest and high where cropland predominated. Intermediate types of land use generally reflected alkalinity values that corresponded to the degree of agricultural use. Streams draining areas with high agricultural potential tend to have higher alkalinity values than those with little or no agricultural potential because of the natural composition of the soil (Omernik and Kinney 1985, 7).

Land with "agricultural potential," i.e., land that was once farmed but is now forested, may fall within this continuum.

The U.S. EPA has spent considerable resources sampling surface waters to determine the extent of waters acidified and susceptible to acidic deposition (Linthurst et al. 1986, Overton et al. 1986, and Kanciruk et al. 1986) If a relationship between land use/land cover changes and susceptibility of surface waters to acidification can be shown, then this relationship could be a factor to consider when extrapolating sample data to other surface waters where watersheds have undergone similar land use or land cover change. In addition, future sampling efforts could use either land use or land cover change as a sampling design stratum.

The contribution of land use/land cover changes to these research areas can best be assessed by looking at spatial relationships between land use/land cover change and indicators of acidified or sensitive surface waters. Before an assessment of these spatial relationships can be made for any area, a map of land use/land cover change should be compiled. The northeastern United States was targeted for the initial assessment.

Past research on reconstructing land use/land cover changes for the Northeast has generally been descriptive (Meeks 1986, Cronon 1983, Johnson 1980, Barrett 1962, and Wilson 1936). Accompanying maps were either nonexistent or very generalized. Better maps and more detailed studies were available only for small areas , such as a forest or a specific watershed. Historic patterns of change in land use/land cover have not been synthesized and mapped for the Northeast.

The purpose of this research was to construct a map of land use/land cover changes which may be related to sensitivity of surface waters to acidic deposition. The specific objectives were : 1) to determine the feasibility of mapping historic land use/land cover changes using Vermont as a pilot study, 2) if feasible, to map the historic land use/land cover changes for Vermont, and 3) to evaluate and describe the resulting map.

To accomplish the objectives, a review of the literature was made for information on historic land use and land cover patterns, focusing on mapped or mappable information. The information was evaluated and the feasibility of mapping determined. A methodology, using the best available information, was outlined to construct the map. Then the map of historic land use/land cover changes was compiled. The map was described and the reliability of each of the mapped categories evaluated. The description included information on location and composition of the mapped components.

Background

Vermont, as well as the rest of the Northeast, has undergone several periods of change in which the composition of the land use or land cover was profoundly altered because of cultural, economic, or political factors. The major changes are outlined here.

When Europeans settled in Vermont, they encountered a forested landscape. Survival meant using the forest as a resource as well as clearing it for agriculture. The latter use of the land quickly dominated. Wilson (1936) estimated that by 1870 almost 70 percent of Vermont was "improved land." Most of the forested lands not cleared for agriculture were culled of the larger trees and better species, but were not clear-cut.

With the opening up of the prime agricultural lands of the Midwest and the growth of urban areas, agricultural self-sufficiency became less and less a necessity of life. Marginal farmlands were abandoned and quickly reclaimed by forests. As farmlands were reverting to forests, virgin forests were being cut. The use of the portable steam sawmill made it economically feasible to harvest large tracts of forests and, except for inaccessible areas, large-scale cutting of the remaining forests became standard practice. Merchantable forests of old-fields were also cut.

Forestry is still important to Vermonters, while dairying remains important on the good farmlands. Kingsley (1977) estimated the amount of forested land in 1973 to be 75 percent of Vermont's total area, which leaves almost 25 percent in agriculture. (Other nonforested lands are only a small percentage of the total land area of Vermont.)

Literature Review

Many studies have described the land use/land cover history of the eastern United States, New England or Vermont. Some of the more important studies, relative to the reconstruction of land use/land cover changes, are discussed according to type of study and area covered.

Descriptive Historical Studies

Descriptive historical studies were most useful in determining when the major periods of land use change occurred. In some cases, the nature of the change was addressed, but was not mappable without specific information on the extent and location of the change. However, these descriptive historical studies augmented other studies which included maps.

Eastern United States. Smith (1976) studied how people have altered the eastern forest since 1600. The study focused on the different types of alterations such as clearing for agriculture, logging, fires, and urban development.

New England. Barrett (1962) described the general forest history of New England and gave a silvicultural description of the major forest type groups. Causes of changes in New England's landscape during the Colonial

Period were discussed by Cronon (1983). Irland (1982) wrote the story of New England's forests, concentrating on time periods and the effect of agriculture, logging, recreation, and urban development on the forests.

Northern New England. Wilson (1936) discussed the causes and periods of social and economic change in the hill country of northern New England. Each period was analogous to one of the seasons: summer, 1790-1830; autumn, 1830-1870; winter, 1870-1900; and spring, 1900-1930.

Vermont. A general overview of Vermont's land use history was given by Johnson (1980). He describes landscape changes that have occurred since precolonial times. The composition and general present day location of the two major forest associations, coniferous and northern hardwoods, were discussed. A recent study by Meeks (1986) on land use changes in Vermont focused on significant periods of change and gave insight into the reasons for the change. The nature and location of changes were only cursorily addressed.

Two other types of studies were valuable. One addressed the reconstruction of the precolonial forest. (Other terms such as "virgin," "presettlement," "original," and "primeval," were also used to refer to the forests as they appeared before European settlement.) The other type was a description of the land use or land cover as it appeared at the time of the study. These are called point-in-time studies. The two types will be treated separately in the following pages.

Reconstruction of the Precolonial Forest

United States. Although Küchler (1964) was not attempting to map the precolonial forests, his map and text on potential natural vegetation was a useful approximation of the precolonial forest. Küchler (1964, 2) defined potential natural vegetation as "the vegetation that would exist today if man were removed from the scene and if the resulting plant succession were telescoped into a single moment." Spurr and Barnes (1973) evaluated four methods useful in determining the composition of the original forest, i.e., contemporary writings, survey records, old growth remnants, and second growth stands, providing the stand was never completely cleared.

Northeast. Day (1953) examined the importance of the Indian in shaping the forest. In some areas, the Indians' use of fire and clearing for agriculture was significant in altering the precolonial forest. He advised that studies reconstructing the precolonial forest should not overlook the possible effect of the Indian because the forest was not necessarily virgin.

New England. To determine the composition of the original forests, Hawley and Hawes (1912) studied records of the early forest industries and the laws which were passed regulating forest use. Hawes (1923) used early travelers' records and studies of preserved virgin forests to describe the original forest. Neither study made any attempt to map the information. However, maps were produced by Westveld et al. (1956) and Carroll (1973). Carroll's map of presettlement forest regions was very generalized, with New England divided into three forest regions. Most of Vermont was in the spruce-hardwood region and the rest of Vermont, primarily along the Connecticut River, was delineated in the hemlock-white pine-hardwood region. Westveld et al. analyzed present forest cover types in conjunction with topographic position and knowledge of successional stages to reconstruct the types of forests that originally existed. On their map, Vermont was delineated in three forest vegetation zones: spruce-fir-northern hardwoods, northern hardwoods-hemlock-white pine, and transition hardwoods-white pine-hemlock.

Vermont. Only one study focused on Vermont. Siccama (1963) mapped the presettlement forest cover of northern Vermont and of Chittenden County in detail. Both maps were constructed using the location of major species recorded by early surveyors of town lines.

Point-In-Time Studies

North America. In 1950, Braun mapped the forest regions, divisions, and sections of eastern North America using field observations and other available information. The mapping was very general. Most of Vermont was located in the New England section of the northern Appalachian highland division of the hemlock-white pine-northern hardwoods region. But the text further subdivided each section into forest types. The composition of the northern hardwood forest was discussed in detail by Frothingham (1915).

New England. Davis (1933) gave a short historical overview of agriculture in New England. The major thrust of his chapter was the present conditions and major problems of agriculture.

Vermont. In the Tenth Census of the United States, Sargent (1884) estimated the percentage of woodland for each county in Vermont and gave general locations for the areas of woodland in some counties. Two Hundred Vermonters (1931) wrote about the people of their state. They gave a detailed description of agriculture as well as statistics on changes in farm area by county. In a more current study of the state, Siccama (1968) described the altitudinal distribution of forest vegetation in the Green Mountains. Kingsley (1977) mapped the major forest types of Vermont using field surveys and provided summary tables on the extent and types of forests in each county.

The descriptive historical studies were most useful in determining major periods of land use/land cover changes and providing descriptions of the types of changes. The reconstruction of the precolonial forest and point-in-time studies were more useful for providing maps and detailed information on the composition and extent of forest types.

Methodology

To construct a map of land use/land cover change, two decisions were made. First, the major periods of change were identified and second, the land use/land cover classification scheme was developed. Once these decisions were made, maps and ancillary information were sought to fit the needs of the project.

Major periods of change were determined to maintain organization and ensure thoroughness in mapping land use/land cover. After reviewing publications by Meeks (1986), Irland (1982), Johnson (1980), Siccama (1963), Barrett (1962), Wilson (1936), and Hawes (1923), four periods of change were identified: pre and early colonial to 1760, agricultural development from 1761 to 1870, agricultural abandonment from 1871 to 1920, and modern from 1921 to 1978. (Nineteen seventy-eight is the date of the latest published land use/land cover map used in this study.) The years used to define each of the periods represent approximations of the time when the majority of the land use/land cover activity occurred.

The classification scheme was chosen to show broad categories of change which may relate to sensitivity of surface waters to acidic deposition. The categories are: nonforested lands, forested lands with agricultural potential, permanently coniferous forest land, permanently deciduous forest land, permanently mixed forest land, forested wetland, ski areas, and water. Changes in land use/land cover that were not related to sensitivity of surface waters to acidic deposition were not identified; therefore, all categories do not reflect changes. In the case of the nonforested land and ski areas categories, change was not as important as the current conditions in determining relationships.

For Vermont, the change from fields to forest has the potential for being related to susceptibility of surface waters to acidification. Lands that have undergone this change are called forested lands with agricultural potential. It is anticipated that surface waters on these lands are not as sensitive as surface waters on permanently forested lands and more sensitive than lands in predominantly agricultural areas. The basis for this expectation is the study by Omernik and Kinney (1985). While analyzing spatial patterns of alkalinity, they found that in areas of high agricultural potential, streams tend to have higher alkalinity values than areas with low agricultural potential.

The change from a deciduous forest to a coniferous forest may also affect the sensitivity of surface waters to acidic deposition. Rosenqvist et al. (1980) and Krug et al. (1985) speculated that this change may be a contributor to non-anthropogenic acidification. Although this type of change does not occur regionally in Vermont, except as a seral stage in areas previously used for agriculture, the major forest types were mapped as separate categories so they could be used as controls for comparisons with areas in which the change did occur.

Initial research focused on finding maps of land use/land cover for each period of change. Although many maps were located, most could not be used because of one or more of the following reasons: 1) the scale of the map was too small; 2) the map was old and inaccurate; 3) the focus of the map was either agriculture or forestry, but not both for a specific time period; 4) different classification schemes were used; 5) the map was too generalized; or 6) the map had very few or no reference points besides the state border.

After evaluating the initial results, further research focused on finding maps and supplemental information from which a map of land use/land cover change could be constructed. The best maps found were: 1) U.S. Geological Survey (USGS)1:250,000 Land Use/Land Cover maps; 2) USGS topographic maps; and 3) a Vermont Division of Farmlands map (Meeks 1975). Descriptive information on land use/land cover changes and forest type habitats augmented the mapped information. The changes were mapped at a 1:250,000 scale because both the land use/land cover maps and the topographic maps were published at this scale.

The USGS Land Use/Land Cover maps were used as the mapping base for the final map. These maps were an integral part of this mapping process; however, two problems were encountered. Both problems were caused because two of the maps were open file maps. First, the diazo process used to print these maps onto paper resulted in non-linear map distortions. In addition, political, cultural, and physical features (map bases) were not printed on the maps, making placement of class lines more difficult.

To compensate for distortions, county lines and water bodies were drawn on an overlay using the 1:250,000 topographic maps. All mapping was done on this overlay. Each county was mapped separately and the overlay was readjusted for each county, using the water bodies as points of reference. In many cases, topographic map features were relied upon to determine placement of boundary lines between categories. Where map bases were printed on the Land Use/Land Cover map, the location of topographic features on the Land Use/Land Cover map was determined easily; without the map bases and only water bodies as points of reference, registration was more difficult.

Although all land use/land cover changes categories were mapped using the same basic procedure, different types of supplemental information and thought processes were used for each category. Each category is discussed separately because of these differences.

Nonforested Land

The nonforested land category was mapped by shading in all the present agricultural lands, urban lands, and nonforested wetlands on the Land Use/Land Cover maps. Lines delineating these areas were drawn on the overlay and the area was colored. Generalization was necessary to show patterns of change, so the nonforested land category contains small amounts of other land uses or land covers. The percentage of other land use/land cover types varied depending upon the homogeneity of the area. The minimum mapping unit resolution of 16 hectares (40 acres) for cropland and forestland used by the USGS was too detailed for this study and, in addition, it was inconsistent with the level of resolution of the other information used in constructing the land use/land cover change map.

Most of the nonforested land category was comprised of agricultural land. Urban land and nonforested wetland were also included in the nonforested category because they usually are found on lower elevation and flatter land similar to the type of land on which agriculture is found. Ski slopes and adjacent resorts, often classified by the USGS as urban or built-up land, were an exception and were mapped as a separate class. They were not included with adjacent forested classes because the chemistry of surface waters in these areas could be affected by the use of the land as a ski area.

Forested Land With Agricultural Potential

No direct information was available on the maximum areal extent of agricultural land before farmland abandonment began around 1875 (Wilson 1936). Therefore, it was necessary to make inferences from the available data. To approximate the location of land with agricultural potential, the Division of Farmlands map (Meeks 1975) was used. It showed poor, marginal, and good farmland. The map was used with the assumption that at the peak of agricultural development, most of the good and marginal farmlands were used. To back up this assumption, the area of poor farmland was estimated using a planimeter. The resulting estimate of 41 percent was compared to Wilson's (1936) estimate of 32 percent of land not farmed at the peak of agricultural development. This indicates that although some poor farmland was used at the height of agricultural development, the assumption is generally valid.

The poor farmland class was visually transferred to the 1:250,000 scale USGS topographic maps. The Division of Farmlands map was compiled in 1935 and the class lines generally corresponded to topographic features if some margin of error was allowed to account for the lack of mapping technology in 1935. Assuming steeper and higher elevation lands were less likely to be farmed, the topography was used to adjust these class lines. Then the poor farmland class lines were transferred to the mapping overlay. These lines were not used as the forested lands with agricultural potential boundary lines. Rather, the poor farmland class lines served as guidelines and in conjunction with other supplemental information final boundary lines were drawn for the forested with agricultural potential category.

One of the strongest pieces of evidence indicating that the land had previously been farmed was small blocks of forest land and agricultural land intermixed on the Land Use/Land Cover map. This was especially true if the forest was coniferous, because most old fields are naturally reforested with white pine at lower elevations and red spruce at higher elevations (Westveld et al.1956). Several other indicators helped define the extent of abandoned farmlands. The proximity to large areas of current agriculture provided a clue. In addition, Siccama (1968) found most slopes below 550 meters (1800 feet) in the Green Mountains had at one time been cleared for agriculture or pasture. Finally, in the Northern Hardwood Region where most of the lands with agricultural potential were found, Hawley and Hawes (1912) found that 10 percent of the rougher and higher portions of the region was cleared and that 75 to 80 percent of the land in the stream valleys was cleared.

Permanently Forested Land

The three forested classes--deciduous, coniferous, and mixed--were determined using the Land Use/Land Cover maps. In mapping these three classes an assumption was made that no significant regional changes in species had occurred since precolonial time, recognizing that most of these stands had been logged at least once, impacted by natural forces, and had changed in forest structure and composition. This assumption was made based upon the studies by Smith (1976), Spurr and Barnes (1973), Carroll (1973), Siccama (1963), and Two Hundred Vermonters (1931).

Although the forested wetland class was of little significance in its spatial extent, it was mapped as a separate class. This was done, in part, because it did not fit into any of the previously mapped categories, but also because forested wetlands can have a significant influence on surface water chemistry. Depending on the location, the wetland might be either primarily deciduous or coniferous, but this distinction was not mapped on the Land Use/Land Cover maps. As with the other forested classes, it was assumed that the species comprising these forested wetlands had not changed.

Water

Water bodies were mapped separately for two reasons:

1) they were good points of reference when drawing lines, and 2) they did not logically fit into any other class.

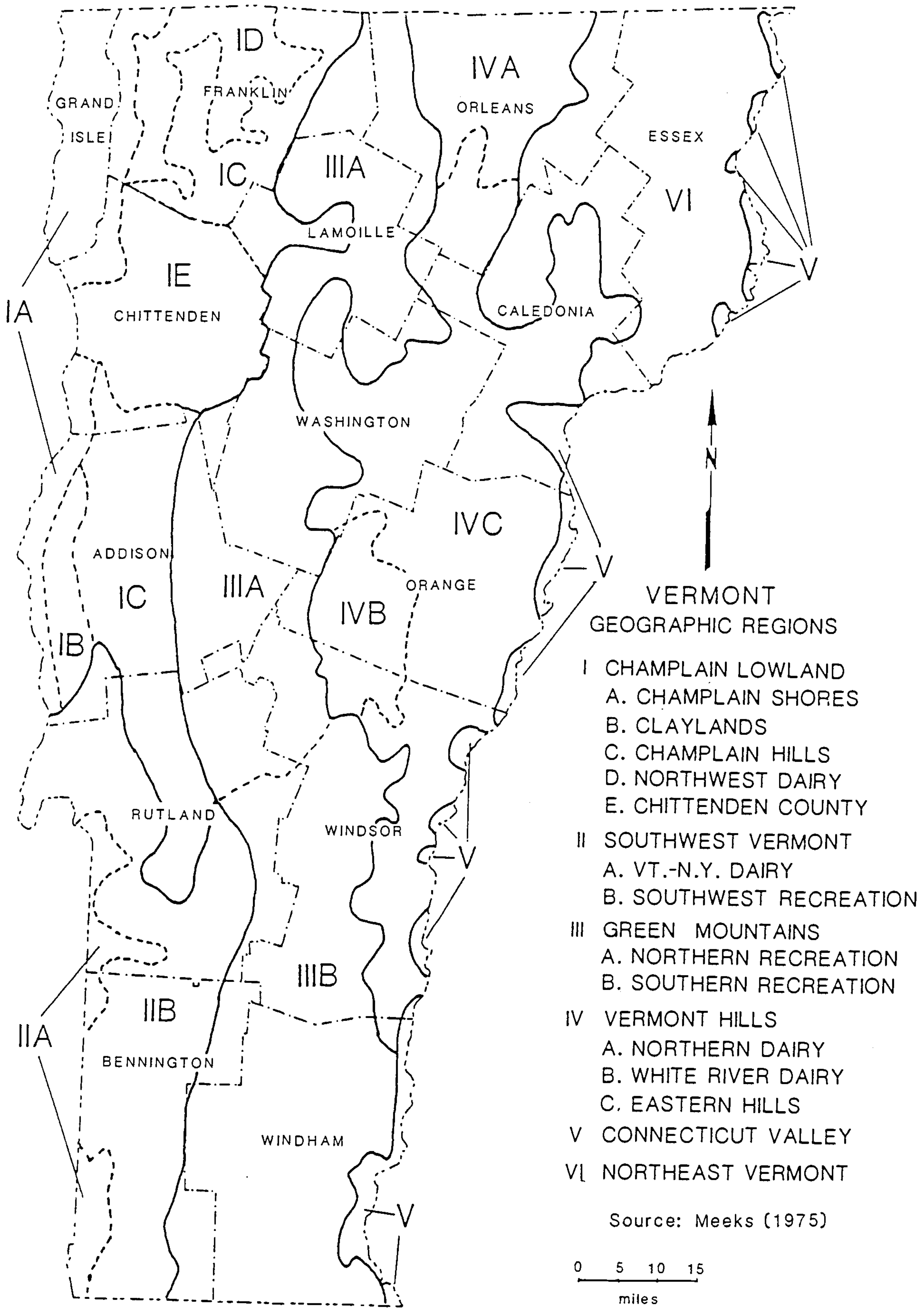
Results and Discussion

The described methodology was used to produce the map of land use/land cover changes(Figure 1). This section describes the map and discusses the map's limitations. In general, mapping in the eastern part of the state was more difficult than in the western part. The main reason for this is the distinction between the Green Mountains and the Champlain Valley of Vermont is more apparent than between the Green Mountains and the Vermont Hills (piedmont section).

The evaluation of each category was made by: 1) judging the subjectivity and difficulty involved in drawing the class boundary lines, 2) comparing the mapped percentage of the three major land use/land cover types with the percentage obtained from Kingsley's (1977) and Sargent's (1884) reports for each county, and 3) comparing the mapped categories with Meek's (1975) description and map of geographic regions. Meek's map is included (Figure 2) to facilitate discussions of the land use/land cover map and for locational reference.

The comparison between the mapped percentage area of each of the major land use/land cover and the report percentage was a graphic comparison as opposed to a statistical comparison because of the uncertain quality of

Figure 2. Vermont: Geographic Regions



the estimates made in 1880. To estimate the percentage of nonforested lands in each county, Kingsley's (1977) report was used. He used field surveying techniques to calculate the area of nonforested lands. To approximate the percentage of forested land with agricultural potential in each county, the percentage of woodland in 1880 (Sargent 1884) was subtracted from the percentage of woodland in 1973 (Kingsley 1977). Sargent's (1884) estimate of the percentage of woodland in each county in 1880 was used as a surrogate for the percentage of permanently forested lands. In making comparisons using the 1880 estimates several points were kept in mind: 1) the values given were rough estimations; 2) the estimates were made a few years after the height of agricultural development (Wilson 1936); 3) the rise and fall of agricultural development was not uniform throughout the state; and 4) the term woodland was not defined.

The mapped percentage of the categories for each of the counties was obtained using an equidistant dot grid. The dot grid was randomly overlaid on each of the counties and the number in each category counted. This was done twice. The sum number of dots in each category was divided by the total number of dots to obtain an estimate of the percentage area of each category.

For the comparison, the four permanently forested categories were combined. Table 1 shows the comparison between the mapped and the report percentages for each county in the three major land use/land cover categories: nonforested land, forested land with agricultural potential, and permanently forested land. Figures 3, 4, and 5 are graphic representations of each of the comparisons in the table.

A general estimate of the reliability and the bias of the mapped categories for each county was made by looking at each of the plotted points in comparison to the 1:1 line. The plotted point for each county is labelled on the graph to aid the interpretation. For discussion purposes, a difference of five percent or less between the mapped and the report percentage was assumed to be insignificant.

Nonforested Land

Most of the nonforested land is agriculture. The rest is either urban or nonforested wetland. Several extensive agricultural regions are identified on the map of land use/land cover change. Most were named by Meeks (1975): the Northern Dairy, the White River Dairy, the Connecticut Valley, and the Vermont-New York Dairy. The valley of the Lamoille River also stands out as being predominantly agricultural. Pockets of agriculture occur elsewhere around the state, frequently in river valleys. As can be seen by the names used by Meeks to identify the regions, the primary agricultural activity is dairying. Included in the

COUNTY	NONFORESTED LAND	FORESTED LAND WITH AGRICULTURAL POTENTIAL	PERMANENTLY FORESTED LAND
	MAP%/REPORT%	MAP%/REPORT%	MAP%/REPORT%
GRAND ISLE	94/100	0/0	6/25
FRANKLIN	51/44	23/28	20/28
ORLEANS	36/26	42/24	20/50
ESSEX	6/6	13/11	80/83
LAMOILLE	29/16	27/42	42/42
CALEDONIA	29/25	50/40	21/35
CHITTENDEN	42/38	30/43	12/20
ADDISON	54/42	18/25	23/33
WASHINGTON	25/19	38/48	36/33
ORANGE	28/24	57/51	14/25
RUTLAND	31/23	30/37	37/40
WINDSOR	20/19	57/52	22/29
BENNINGTON	16/13	26/20	58/67
WINDHAM	13/14	55/48	31/38

Table 1. Comparison of the mapped percentage of the three major land use/land cover change categories with the percentage obtained from Kingsley's (1977) and Sargent's (1884) reports

NONFORESTED LAND

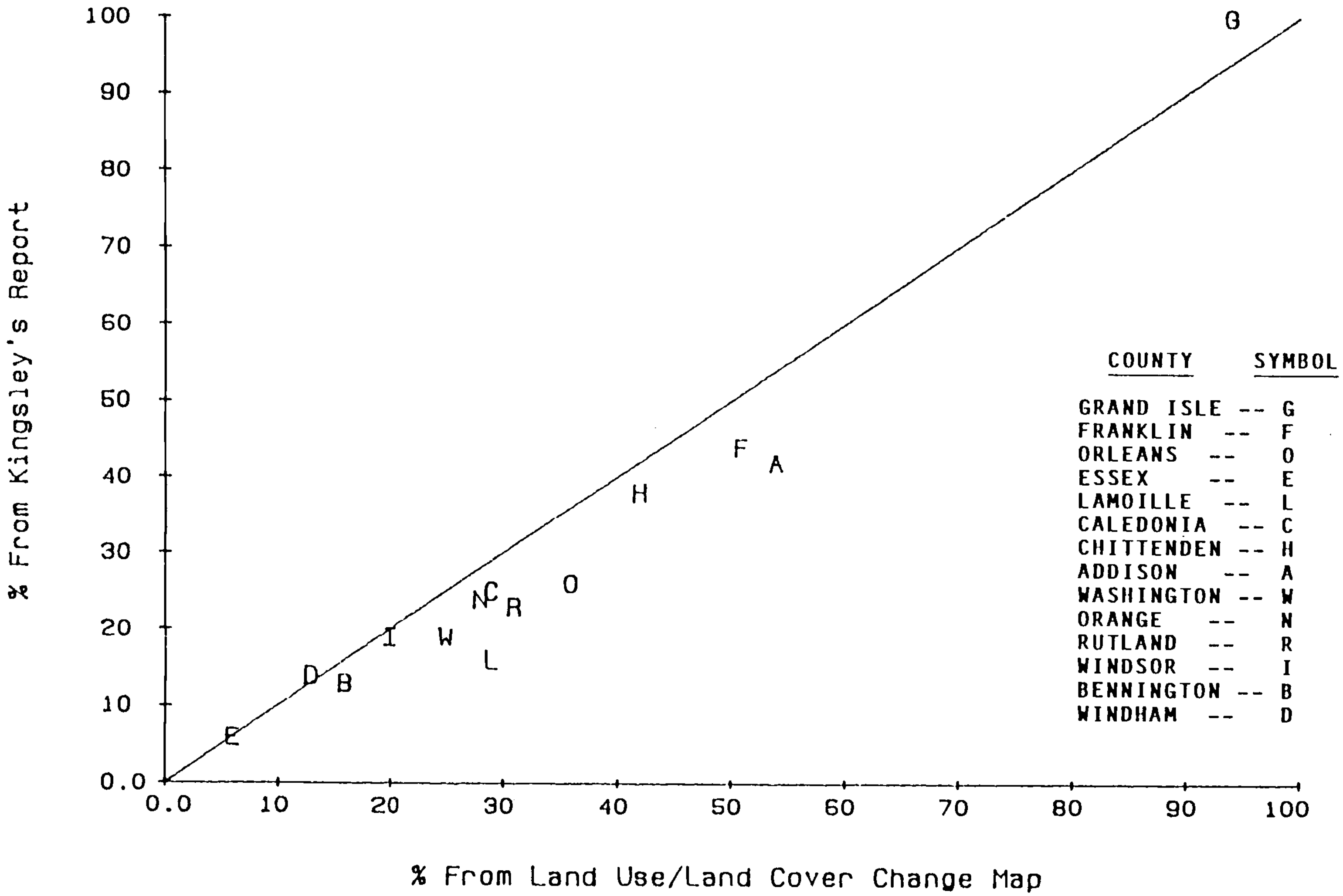


Figure 3. Comparison of the mapped percentage of the nonforested land category with the percentage obtained from Kingsley's (1977) report

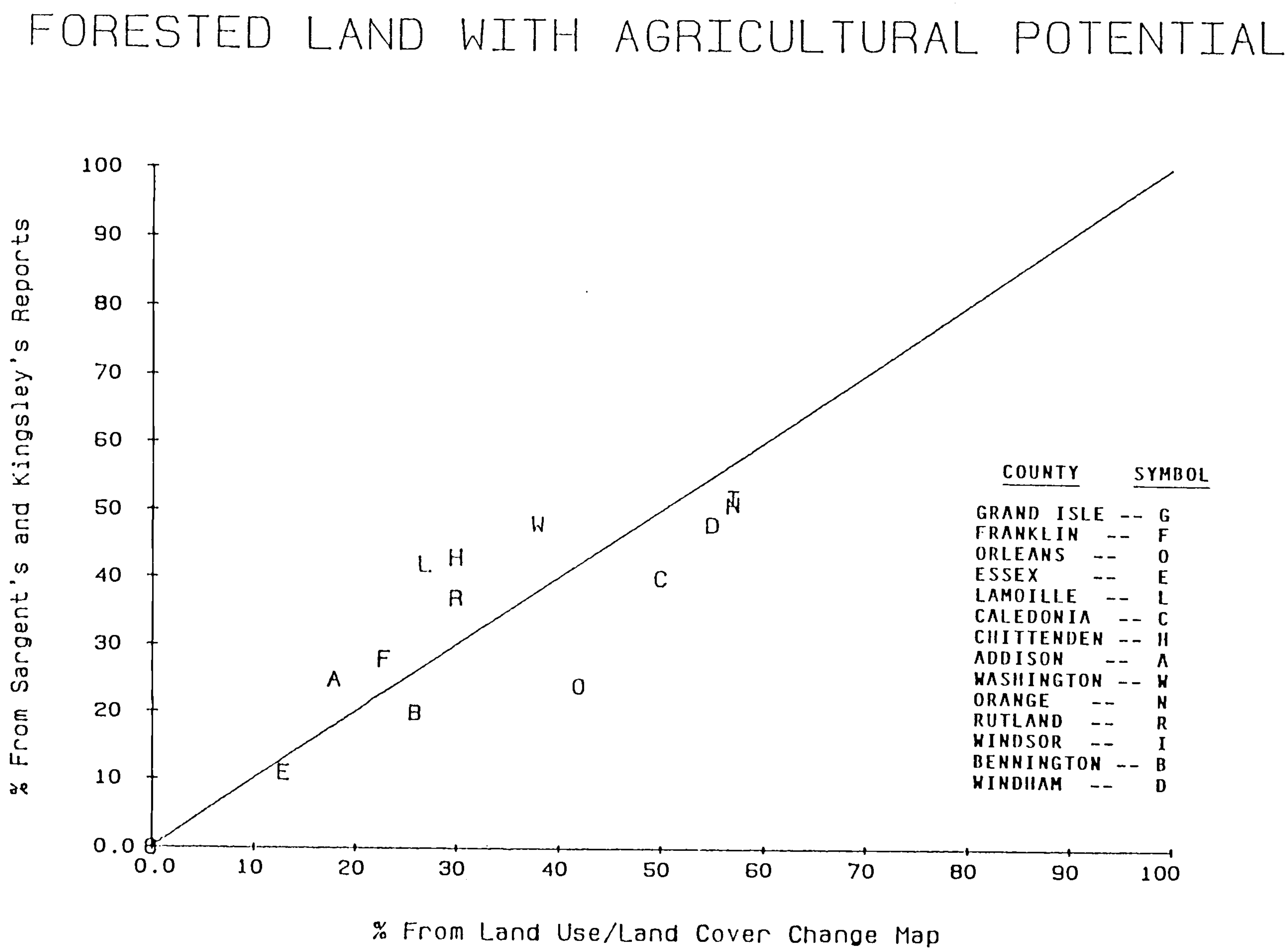


Figure 4. Comparison of the mapped percentage of the forested with agricultural potential category with the percentage obtained from Sargent's (1884) and Kingsley's (1977) reports

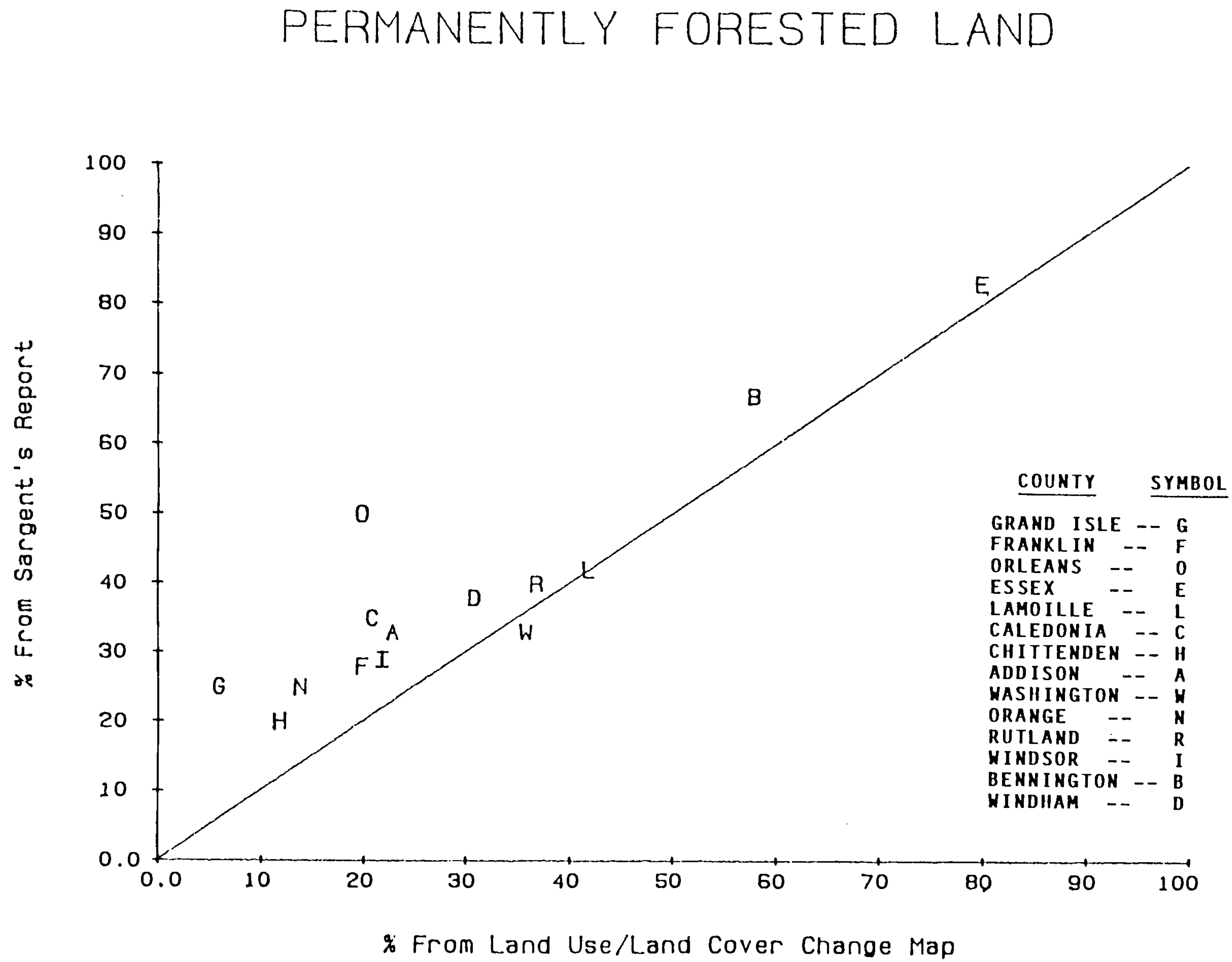


Figure 5. Comparison of the mapped percentage of the permanently forested land category with the percentage obtained from Sargent's (1884) report

nonforested land category are the urban centers of Burlington, Montpelier/Barre, Bennington, Rutland, St. Albans, and Springfield. The majority of the nonforested wetlands are located in Addison County and, even here, they are not of any significance spatially.

The nonforested lands were mapped directly from the Land Use/Land Cover maps. The generalization was lowest in areas of agricultural homogeneity, for example, the Champlain Lowlands and the Vermont-New York Dairy Region. The Northern Dairy, Lamoille Valley, and, to a greater degree, the White River Dairy were more heterogeneous. This heterogeneity made it impossible to exclude all the small pockets of forests; therefore, only larger areas of forestland were delineated. Conversely, not all nonforested lands were mapped. Small farms, and in some cases, urban areas were scattered throughout the state, especially in Caledonia, Orange, Windsor, and Windham Counties. In most cases, they were mapped as forested with agricultural potential.

For most of Vermont, the correspondence between the mapped and the report percentages of nonforested land was reasonably good. In Franklin, Orleans, Lamoille, Addison, Washington, and Rutland Counties the mapped extent of the nonforested land was greater than the report estimation. Four of these counties are on the western side of the Green Mountains. Orleans and Washington Counties are on the eastern slopes of the Green Mountains. Grand Isle was the only county for which the mapped extent was less than the report percentage.

Forested Land With Agricultural Potential

The forested with agricultural potential category was underestimated on the map in Lamoille, Chittenden, Addison, Washington, and Rutland Counties. The category was overestimated in Orleans, Caledonia, Orange, Bennington, and Windham Counties. Except for Bennington and Washington Counties, the underestimated counties are on the east side of the state and the overestimated counties are on the west side. For the counties in which the forested with agricultural land category was overestimated, the excess land probably should be obtained from the permanently forested land category. For counties in which the category was underestimated, the deficit probably should be made up from the nonforested lands category. In terms of determining relationships with alkalinity, the underestimation is less of a problem, since these nonforested areas are less sensitive to acidic deposition.

Although the comparison did not show any majow problems, differentiating between abandoned farmlands and permanently forested lands was difficult in the southern counties because this was an important area of early hill farming (Meeks 1986). These marginal hill farms were probably among the first to be abandoned (Wilson 1936). The land patterning which aided delineation of the forested with agricultural potential category elsewhere had been obscured by regrowth.

Most of these reforested lands fall into the Northern Hardwood-Hemlock-White Pine or the Transitional Hardwood-Hemlock-White Pine zone (Westveld et al. 1956). The major species of both zones are beech, paper birch, sugar maple, white pine, and hemlock. The transitional zone differs from the other zone in the percentage of each species, plus it probably has some oak. Some of the land is in the Spruce-Fir-Northern Hardwood zone, where red spruce and balsam fir occur with yellow and paper birch, sugar maple, and beech (Westveld et al. 1956).

Permanently Forested Land

Most of the land which has always been forested is found in the three mountain ranges: Green, White, and Taconic. The other patches of forestland are scattered throughout the eastern hill region. In general, the mapped extent of forestland correlates fairly well to the report estimation. The percentage of permanently forested land on the map, however, is consistently underestimated. This discrepancy is most apparent in Orleans county. There are two possible explanations for this. First, this is an isolated dairy region and part of this county has experienced a recent increase in dairy farming (Meeks 1975). The land may not have been cleared at the peak of agricultural development. Therefore, the use of Sargent's (1884)report estimation as a surrogate for the amount of land which had never been farmed would not be valid for this county. Second, the mapping in this area was difficult because the distinction between potential farmland and forest was not apparent from the topography. Meeks (1975) also had trouble categorizing parts of this region. In the Passumpsic Valley, he found farms and forests alternated without pattern.

For the most part, the quality of the mapping of the permanently deciduous or permanently mixed categories is directly related to the quality of the forested with agricultural potential category. For example, an error of omission in one category would translate into an error of commission for the other. The permanently coniferous is generally at too high an elevation to be confused with the forested with agricultural potential category. Both of these permanently forested categories and the permanently coniferous forest category were mapped directly from the Land Use/Land Cover maps, so the reliability of the mapped patterns is fairly high.

The dominant permanently forested category is permanently deciduous. These are the northern hardwoods, sugar maple, beech, and yellow birch. At higher elevations, some red spruce and balsam fir are found. Hemlock and white pine comprise part of the stand at lower elevations. When either coniferous or deciduous trees comprise more than one-third of the stand, the mixed category is used (Anderson et al. 1976).

The majority of the permanently coniferous forest is located in the White Mountains and the rest is located along the crest of the Green Mountains. The dominant species are balsam fir, paper birch, and red spruce.

The only significant forested wetlands are found in Essex, Grand Isle, and Chittenden Counties. This category was mapped directly from the Land Use/Land Cover maps, so the reliability is high. Small patches of forested wetlands have been included with other forested categories.

Summary

A map of Vermont was produced depicting land use/land cover changes from precolonial times to present. The map is a representation of the major regional changes. In the case of the nonforested category the map is of current conditions because the mapping of change was not as important as the current condition in determining relationships with alkalinity of surface waters.

The comparison of the mapped percentage of the three major land use/land cover change categories with the percentages obtained from Kingsley's (1977) and Sargent's (1884) reports had a reasonably good correspondence, although some bias can be found. For most counties, the map underestimated the percentage of permanently forested land and overestimated the percentage of nonforested land. The consistent underestimation of the permanently forested land category was the result of either an overestimation in the nonforested land category in the western part of the state or the forested land with agricultural potential in the eastern part. Because the permanently forested land and the nonforested land are separated along an elevational gradient by the forested with agricultural potential category, the excess higher elevation nonforested land is probably forested land with agricultural potential, moving higher elevation forested land with agricultural potential to permanently forested land. As with any generalities, this east/west pattern has some minor exceptions: Bennington, Grand Isle, Washington, and Lamoille Counties. The last three are easily explainable. Grand Isle is an island county and the isolation would create different periods of land use/land cover changes. Both Washington and Lamoille Counties are more centrally located than either east or west.

In general, the forested with agricultural potential was the most difficult to map. Inaccuracies in the forested with agricultural potential category directly affected both the permanently deciduous, permanently mixed forested category, and the nonforested category. The permanently coniferous, and forested wetland categories are the most reliable. For all categories, the homogeneity of an area made mapping easier and increased the reliability of the map.

Conclusion

It is feasible to map for Vermont the land use/land cover changes from precolonial times to present. The relationship between these changes in land use/land cover and susceptibility of surface waters to acidification is the subject of future research. The U.S. Environmental Protection Agency is funding research to compare alkalinity data obtained during its National Surface Water Survey to land use/land cover changes. For Vermont, the main reason for this comparison is to determine if values for alkalinity are higher in areas with agricultural potential than in areas which have always been forested.

Another land use/land cover change of interest--deciduous to coniferous forest does not normally occur in Vermont, except in areas of agricultural potential. Even here, it is a seral stage. Consequently, the relationship of land use/land cover changes to the non-anthropogenic acidification of surface waters cannot be studied for Vermont.

However, the methodology and rationale used in this study may be transferrable to other states. The two major types of maps used, the Land Use/Land Cover and the topographic maps are available for the northeastern United States and for most of the Upper Midwest. The availability of other necessary information will have to be evaluated. In some areas, more detailed or better locational information may be available, reducing the number of subjective decisions. In addition, mapping across state lines using different sources of information will serve as a quality check.

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