COMPARING POTENTIAL WITH REALIZED PRODUCTIVITY: DEVELOPING A MANAGEMENT STRATEGY

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ABSTRACT.—Extensive areas of timberland in the Lake States currently produce low levels of wood fiber because of inherently low timber-growing potential, because the stands are understocked and are not capturing the full potential of the site, and/or because stands are past optimal rotation age. Because of the size of the timberland resource and its economic and environmental contributions, developing a management strategy to improve the productivity of timberlands in the Lake States is important. Based on traditional estimates of potential productivity, average annual net growth in this region could be increased by 40%. Analyses of (1) realized growth compared to potential productivity (expressed as average annual net growing-stock growth); and (2) potential productivity by ownership group, stocking levels, and physiographic class are completed to portray the arenas with the greatest opportunity for increasing timberland productivity.

Global consumption of wood fiber has consistently risen. However, the available supply of wood fiber has been able to meet demand through increases in price, the opening of new sources, and improvements in technology and management. However, in the near future a shortfall in the world's wood fiber supply is expected that could reach more than 315 million cubic meeters by the year 2020 (Aspey and Reed 1994). This global shortfall will have consequences for the United States, where projected roundwood harvests are estimated to increase by 35% for coniferous species and 51% for deciduous species by the year 2040 (Haynes *et al*. 1995). I expect that the projected gap will be closed on a global basis, but regional shortages will exist.

To meet the increasing demand for wood fiber, harvesting in the United States has rapidly accelerated. For example, 20 of the southern U.S. 51 USDA Forest Service Forest Inventory and Analysis (FIA) forest survey units have coniferous removals that exceed growth with an average growth to drain ratio of 0.74 (Cubbage *et al*. (1995). A ratio of less than one is no problem if there is sufficient unused forest inventory to tap from, and if efficient reforestation is carried out after harvesting. With increasing harvest levels, concerns about wood fiber supply and the potential for overharvesting are being raised.

Currently, overharvesting is not occurring in the northern U.S., but concerns have been raised, especially regarding selective harvesting (Irland and Maass 1994). The continued increase in urban population and resulting land conversion may become a major drawback to forest utilization as rural forest land essentially becomes off-limits to the forest products industry (Rooks 1998). Additional factors that are expected to impact future wood fiber supply include the potential elimination of harvests on national and state forests, extension of pine rotations to protect late-successional species, elimination of clearcutting, and other environmental considerations (Barrett 1993, Random Lengths 1997). As a result, I have compared the realized productivity with the potential productivity of Lake States timberlands to determine current status and to develop potential management strategies.

Extensive areas of timberland in the Lake States currently produce low levels of wood fiber largely because of inherently low timber-growing potential, because the stands are understocked and are not capturing the full potential of the site, and/or because stands are past optimal rotation age. We know that we may not match realized growth with potential growth; however, we also know that realized growth rates can be increased through management. Across the United States, average annual net growth on timberland is estimated to be 38 ft^3/ac/yr while the potential productivity of timberlands is estimated at 74 ft^3/ac/yr (Spurr and Vaux 1976).

Increased management to improve productivity will be one of the primary methods of closing the gap between available supply and demand. It is vitally important to improve the productivity of timberlands in the Lake States through management because of the size of the resource (about the same area of forest land as Finland—52 million acres forest land) and its economic (about US $20 billion annual value) and environmental contributions.

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METHODOLOGY

Data presented are derived from the USDA Forest Service, North Central Research Station's FIA program's most recent inventories for the three Lake States: Michigan—1993 (Schmidt *et al*. 1997), Minnesota—1990 (Leatherberry *et al*. 1995), and Wisconsin—1996 (Schmidt 1998). Data are based on FIA field measurements from more than 27,400 plots across the three states. Timberlands are analyzed (in lieu of forest lands) in the Lake States because of the availability of data and because timberlands imply that the forest lands are capable of producing minimal levels of wood fiber (capable of growing at least 20 ft^3/ac/yr). Forest lands that do not meet this minimum standard have little potential to increase their growth rates and thus fall out of the sphere of concern for this paper. Timberlands also exclude reserved forest lands (parks, wilderness, etc.) where harvesting is not permitted.

Data presented focus on average annual net growth of growing stock classified by realized productivity, potential productivity, ownership, forest type, stocking levels, and physiographic class. Average annual net growth of growing stock is the annual change in cubic foot volume of sound wood in growing-stock trees greater than 5 inches dbh, and the total volume of trees entering this size class through ingrowth, less volume losses resulting from natural causes. Realized forest productivity is the actual growth or increase in wood fiber that occurred within a forest stand between the past two inventories (13 years for the three Lake States). Potential productivity is a measure of the biological and/or site potential to produce wood fiber averaged over a normal rotation from fully stocked natural stands and is reported as the potential growth in merchantable ft^3/ac/yr at culmination of mean annual increment. Because of the dominant use of potential productivity class in this analysis, only those timberland stands that are classified as poletimber and sawtimber size (average dbh of dominant and co-dominant trees ($\geq$5 inches) are analyzed. Potential productivity is based on field observations of forest type and site index. In reality, it is based on normal or fully stocked yield tables developed in earlier decades.

FIA estimates potential productivity of timberlands through the use of normal yield tables that give the estimated volume of even-aged forest stands that fully occupy the land at a given age and on a given site quality. The normal yield table approach has some shortcomings (Spurr and Vaux 1976) including: (1) forests are often not even-aged (I recognize that the Lake States do not have a complete even distribution of stand age classes across all forest types that could skew average expected growth rates); (2) yield tables are often developed from stands that appear to be fully stocked, but that does not represent similar stands at a different age; (3) yield tables are sometimes lacking in their ability to predict growth for stands that are not fully stocked; and (4) yield tables are sometimes lacking in their ability to include the impact of management on stand establishment and growth. While these shortcomings need to be considered, FIA estimates of potential productivity are used because other sources of estimates of site potential for Lake States timberlands are very limited.

Stocking level is the degree of occupancy of live trees (measured by basal area and/or the number of trees in a stand by size or age and spacing) compared to the basal area and/or number of trees required to fully utilize the growth potential of the land. Forest type is a classification of timberland based on the species forming a plurality of live tree stocking. Physiographic class is a measure of soil and water conditions that affect tree growth on a site.

Comparisons regarding average annual growing-stock growth by slope and aspect were made but do not appear in the results because they followed the norm expected. This is an important point because it serves to verify the use of site-index curves and empirical yield tables to predict productivity. The greatest levels of growth occurred on the highest rated sites on north-, east-, and west-facing slopes. As expected and predicted, the lowest levels of growth occurred on the lowest rated sites on south-facing slopes.

Analyses generally compare results for the Lake States with those for Minnesota. Specific data for Wisconsin and Michigan are available from the author but were not included due to space limitations. By presenting data for both an individual state and the Lake States region, I hope to present a general view of the important trends that have application across the region.

RESULTS

Comparison of Realized to Potential Growth

We know that potential growth is greater than current growth and that it is unlikely we will match realized growth with potential growth due to individual site circumstances and actual stand conditions. To adjust for on-the-ground conditions that inherently restrict realized growth, potential net growth estimates in this study are lowered by 20%. Based on the literature (for example, Spurr and Vaux 1976 suggest a 10% adjustment), a 20% adjustment is conservative but strengthens the results and conclusions formed.

In the most recent inventories, realized average annual net growth is about 72% of the adjusted potential net growth across the Lake States (table 1). Michigan, with almost 83%, leads the way among individual Lake States in terms of realized to potential productivity followed by Minnesota with 67% and Wisconsin with 62%. As a comparison, the United States ratio of realized to potential net growth was 60% in 1992 (Powell *et al*. 1993). Thus, while the Lake States compare favorably with the rest of the United States, there is still a tremendous amount of potential wood fiber production that could be realized. Opportunities for improvements in average annual net growth in the Lake States appear to be on sites with higher potential productivities, creating an ideal situation for treatment. For example, across the Lake States the ratio of realized net growth to potential net growth is 0.88 on the lowest productivity sites compared to 0.64 and 0.68 on the sites with the greatest potential productivity.

I anticipate that the average annual net growth rate could be increased by up to 40% with adequate land management and investments (table 1). This increase represents an annual addition of more than 500 million cubic feet of wood fiber in the Lake States. To put this volume in perspective, the total current timber product output for the Lake States is about 1 billion cubic feet [Michigan (1994) 335 million cubic feet, Wisconsin (1994) 396 million cubic feet, Minnesota (1992) 264 million cubic feet].

Potential Productivity by Ownership

Across the Lake States, growing-stock growth on timberlands averages 39 ft^3/ac/yr (table 2). Non-industrial private landowners have the greatest realized productivity with an average of 41 ft^3/ac/yr. On sites with a potential productivity of 20 to 49 ft^3/ac/yr (a midpoint production of 34.5 ft^3/ac/yr), a growth rate of almost 27 ft^3/ac/yr is obtained by forest industry, which comes the closest to maximizing growth potential. On sites with a potential productivity of 50 to 84 ft^3/ac/yr (a midpoint production of 67 ft^3/ac/yr), a growth rate of almost 44 ft^3/ac/yr is obtained by forest industry. For both of these site classes, even the ownership group with the most potential for maximizing growth produces wood fiber at only two-thirds of the average site potential.

Table 1.—*Comparison of potential to realized average annual net growth of growing-stock on timberland in stands with average diameters greater than 5 inches dbh in the Lake States*

Potential productivity class (ft^3/ac/yr)	Timberland area	Potential net growth per acre	Unadjusted total potential net growth	Adjusted (20%) total potential net growth	Realized net growth	Adjusted total potential minus realized net growth
	Thousand acres	*Ft^3/ac/yr*	*- - - - - - - - - Thousand ft^3/yr*			*- - - - - - - - - -*
Lake States						
120 +	1,609.4	142.0	228,542	182,833	124,267	58,566
85 to 119	7,954.0	102.0	811,304	649,043	417,146	231,897
50 to 84	13,765.7	67.0	922,302	737,842	538,523	199,319
20 to 49	11,797.6	34.5	407,017	325,614	286,663	38,951
	35,126.7		2,369,165	1,895,332	1,366,599	528,733
Michigan						
120 +	801.8	142.0	113,856	91,084	67,695	23,389
85 to 119	3,428.4	102.0	349,697	279,757	207,929	71,828
50 to 84	5,936.7	67.0	397,759	318,207	271,563	46,644
20 to 49	3,979.3	34.5	137,286	109,829	115,615	-5,786
	14,146.2		998,597	798,878	662,802	136,076
Wisconsin						
120 +	697.5	142.0	99,052	79,241	47,747	31,494
85 to 119	2,855.3	102.0	291,237	232,989	131,871	101,118
50 to 84	5,078.1	67.0	340,233	272,186	174,460	97,726
20 to 49	2,193.7	34.5	75,682	60,546	45,158	15,388
	10,824.6		806,204	644,963	399,236	245,727
Minnesota						
120 +	110.1	142.0	15,634	12,507	8,825	3,682
85 to 119	1,670.3	102.0	170,371	136,296	77,346	58,950
50 to 84	2,750.9	67.0	184,310	147,448	92,500	54,948
20 to 49	5,624.6	34.5	194,049	155,239	125,890	29,349
	10,155.9		564,364	451,491	304,561	146,930

Table 2.—*Average annual growing-stock growth per acre per year on timberland stands with average diameters greater than 5 inches dbh by ownership and potential productivity class*

Lake States ownership	Total	Potential productivity class 120+	85 to 119	50 to 84	20 to 49
		- - - - - - *Ft³/ac/yr*	- - - - - -		
National forest	37.5	81.0	54.3	36.8	20.8
Other federal**	33.8	49.5	43.2	36.4	25.5
Indian	31.5	66.6	46.6	38.5	16.0
State	38.1	88.1	58.0	41.6	23.5
County & municipal	34.7	71.3	52.5	35.9	22.3
Forest industry	39.3	74.0	55.3	43.7	26.8
Private	40.6	74.0	51.1	39.0	25.9
Total	39.0	75.7	52.4	39.1	24.3

Minnesota ownership	Total	Potential productivity class 120+	85 to 119	50 to 84	20 to 49
		- - - - - - *Ft³/ac/yr*	- - - - - -		
National forest	31.2	90.8	52.4	35.0	20.8
Other federal**	28.3	88.5	23.3	34.0	24.3
Indian	29.0	68.8	47.9	44.2	19.3
State	27.3	100.2	46.2	36.0	19.7
County & municipal	32.0	67.9	49.9	34.5	24.2
Forest industry	31.6	96.5	55.8	32.6	20.7
Private	30.0	73.5	42.3	31.5	23.7
Total	30.1	80.1	46.3	33.6	22.4

** Note limited total timberland area in this class with a resulting large sampling error.

The highest growth rates per acre on the most productive sites in the Lake States occur on state-owned timberlands. On sites with a potential productivity of 85 to 119 ft^3/ac/yr (a midpoint production of 102 ft^3/ac/yr), a growth rate of 58 ft^3/ac/yr is obtained by the states. On sites with a potential productivity of more than 120 ft^3/ac/yr (a midpoint production of 142 ft^3/ac/yr), a growth rate of 88 ft^3/ac/yr is attributed to forest industry. As with the lower site classes and forest industry, the ownership group with the most potential for maximizing growth on the best sites produce wood fiber at less than two-thirds of the average site potential.

In Minnesota, the county and municipal, forest industry, and national forest ownership groups have the greatest average annual growing-stock growth per acre rates (32.0, 31.6, and 31.2, respectively). Minnesota's growth per acre rate is below the Lake States average for the three lowest potential productivity classes, only exceeding the regional average for the highest potential productivity class (120+ ft^3/ac/yr). In total, growing-stock growth on timberlands in Minnesota averages 30 ft^3/ac/yr compared to a Lake States regional average of 39 ft^3/ac/yr.

Ownership by Forest Type

In the Lake States, red pine has the greatest average annual growing-stock growth rate at 87 ft^3/ac/yr (table 3). Red pine realized productivity is greatest in private ownership groups and state/county and municipal public ownerships. This high growth rate reflects the more desirable sites and greater degree of management associated with red pine in the Lake States. In addition, these ownership groups have the majority of the red pine plantations that show above average growth rates. These high growth rates reflect some of the advantages associated with land management investments such as above average stocking rates on sites with above average potential productivity. Another indication of the role of site potential is the growing-stock growth rate for swamp conifers of 21 ft^3/ac/yr, the lowest of all forest type groups in the Lake States. Forest industry, private non-industrial owners, and state governments own the most productive timberlands typed as aspen-birch in the Lake States.

Across the Lake States, forest industry has above average growing-stock growth rates for the jack pine, red pine,

Table 3.—*Average annual growing-stock growth per acre per year on timberland stands with average diameters greater than 5 inches by forest type and ownership group*

Lake States	**Total**	**National forest**	****Other Federal**	**Indian**	**State**	**County & municipal**	**Forest industry**	**Private**
	- - - - - -	- - - - - -	- - - - - -	- - *Ft³/ac/yr* - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Jack pine	30.2	25.4	26.5	18.7	27.6	35.0	39.4	32.5
Red pine	87.1	77.0	49.1	54.4	85.8	86.3	94.2	98.2
White pine	54.9	54.7	52.9	58.3	48.3	58.5	52.5	56.3
Spruce-fir	34.9	35.5	45.3	22.5	39.6	27.0	28.8	36.7
Swamp conifers	20.5	15.3	28.7	4.8	19.2	14.9	20.0	27.1
Oak-hickory	34.1	35.9	25.2	51.5	37.1	38.8	35.3	33.2
Elm-ash-cottonwood	31.1	22.2	39.1	23.7	26.6	18.3	25.9	34.8
Maple-beech-birch	42.3	36.4	38.7	37.9	45.7	34.8	42.3	43.9
Aspen-birch	40.5	37.3	32.7	34.8	41.6	38.1	46.5	41.3
Total	39.0	37.5	33.8	31.5	38.1	34.7	39.3	40.6

Minnesota	**Total**	**National forest**	****Other Federal**	**Indian**	**State**	**County & municipal**	**Forest industry**	**Private**
	- - - - - -	- - - - - -	- - - - - -	- - *Ft³/ac/yr* - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Jack pine	33.8	26.5	25.4	24.4	26.7	38.7	38.8	38.3
Red pine	71.1	69.0	59.1	51.2	69.9	61.2	77.3	85.0
White pine	52.1	63.4	67.8	90.0	68.8	22.1	36.8	48.5
Spruce-fir	28.3	27.4	60.0	21.5	28.0	24.2	22.0	35.8
Swamp conifers	15.8	10.9	26.1	10.3	14.9	16.4	16.1	23.5
Oak-hickory	26.6	50.5	21.6	53.1	29.2	37.0	36.0	25.5
Elm-ash-cottonwood	18.5	12.4	23.5	31.0	18.6	18.1	14.2	18.5
Maple-beech-birch	26.7	28.9	36.4	25.3	30.1	34.4	26.2	23.5
Aspen-birch	36.4	35.5	27.4	38.0	35.7	37.4	39.7	36.0
Total	30.1	31.2	28.3	29.0	27.3	32.0	31.6	30.0

** Note limited total timberland area in this class with a resulting large sampling error.

oak-hickory, maple-beech-birch, and aspen-birch forest types. These forest types are economically the most important, exhibiting the interconnected role of both investment and accelerated management. Of interest is that jack pine has below average growth rates across the Lake States region, but above average rates in Minnesota. Other forest types with above average growth rates in Minnesota include red pine, white pine, and aspen-birch.

Potential Productivity by Stocking Level

As expected, average annual growing-stock growth increased with increased stocking levels and with greater potential productivities (table 4). Sites that are adequately stocked tend to most closely match realized growth with potential productivity. For both the Lake States and Minnesota, average annual growth on the highest productive sites exceeded the overall average growth rates for all stocking classes, indicating that site productivity is of greater importance than stocking level concerning growth rates. The lowest potential productivity class had below average annual growth rates for all stocking classes, further emphasizing this point. Average annual growing-stock growth rates exceed the regional and state averages at basal area stocking rates above 40 ft^2/a on sites with a potential productivity greater than 85 $ft^3/ac/yr$ and at basal area stocking rates above 80 ft^2/a on sites with potential productivity greater than 50 $ft^3/ac/yr$.

Potential Productivity by Physiographic Class

In the Lake States, xeromesic to mesic sites have the greatest average annual growing-stock growth rates for all potential productivity classes (table 5). As an average across the Lake States, growing-stock growth rates were below average for all hydromesic and mesic forest sites. The lowest levels of annual growth occur on hydric sites in the lower potential productivity classes. Based on these results, an overabundance of water or limited drainage is a limiting factor for growth on timberlands in the Lake States across all potential productivity classes. This situation is similar to that found in the southern U.S. but opposite that found in the Great Plains and West.

Table 4.—*Average annual growing-stock growth per acre per year on timberland stands with average diameters greater than 5 inches by stock level (basal area) and potential productivity class*

Lake States Stocking level	Total	Potential productivity class 120 +	85 to 119	50 to 84	20 to 49
	- - - -	- - - -	*Ft³/ac/yr*	- - - -	- - - -
Basal area					
0 to 40 ft^2/ac	17.2	44.5	20.6	16.9	9.4
41 to 80 ft^2/ac	27.1	48.1	37.9	28.1	17.9
81 to 120 ft^2/ac	39.5	71.0	50.8	39.5	26.7
120 + ft^2/ac	50.4	97.8	67.5	49.2	29.9
Total	39.0	77.2	52.4	39.1	24.3

Minnesota Stocking level	Total	Potential productivity class 120 +	85 to 119	50 to 84	20 to 49
	- - - -	- - - -	*Ft³/ac/yr*	- - - -	- - - -
Basal area					
0 to 40 ft^2/ac	10.5	31.9	22.8	9.5	7.5
41 to 80 ft^2/ac	21.9	55.3	32.8	25.9	16.8
81 to 120 ft^2/ac	32.4	73.8	45.2	36.0	25.1
120 + ft^2/ac	40.1	100.1	61.5	44.1	28.7
Total	30.1	80.2	46.3	33.6	22.4

Results are similar for the Lake States average and for Minnesota regarding growth and physiographic class except that forests found on higher productive hydromesic sites had above average growth rates. This difference in growth rates perhaps reflects the different species composition among states in this region and the differences in site potentials. Overall, Minnesota has a lower potential site productivity than the other two Lake States. However, Minnesota has a greater average annual growth rate for forests classified in the most productive class overall and for xeromesic, mesic, and hydromesic sites when compared to the Lake States average.

CONCLUSIONS

The advantage of increasing net growth is that it does not take additional acres of timberland to increase the supply of wood fiber. With expanding populations, potential pressure for increasing agricultural production to feed the growing numbers of people, and ensuing land-use pressures on the limited land base, the potential for increased production by expanding the timberland acreage base will be limited. The most efficient method of meeting the increasing demand for wood fiber is through more intensive management on existing timberlands. In addition, increasing the production from the existing acres will result in greater value of the timberlands and resulting increased income for the landowners. As income from their timberlands increases, landowners are perhaps not as likely to convert their forests to other uses.

It appears that in the United States we are developing less integrated roles for different ownerships. We appear to be looking for economic/wood fiber production from privately owned timberlands (both NIPF and forest industry) with a larger biological/conservation role expected from many public lands. If society is developing these different roles, then perhaps we should encourage different management strategies. I would suggest that the management strategy for wood fiber production on private lands focus on site quality characteristics and investment to return ratios. Major gains in forest productivity can be made with large-scale species conversions and intensive management. However, the profitability of such operations is questionable, and the sites' economic potential should be considered. On some timberland sites of lower productivity, the real cost of growing wood fiber may exceed the real value of the wood fiber produced (based on current supply/demand and resulting economic values). It is important to select timberlands for increased management that have high levels of both economic and biological potentials. We need to focus management when and where economic and environmental opportunities present themselves. However, for a given ownership, the land manager will always have to work with what is given.

Across the United States, almost 60% of the private forest landowners have less than 10 acres and less than 1% of the private landowners have 45% of the total timberland (Birch 1996, Nilsson *et al*. 1998). In the Lake States, 37% of the private forest landowners have less than 10 acres (Birch 1996). In 1994, only 5% of the private forest

Table 5.—*Average annual growing-stock growth per acre per year on timberland stands with average diameters greater than 5 inches by physiographic class and potential productivity class*

Lake States		**Potential productivity class**			
Physiographic class	**Total**	**120 +**	**85 to 119**	**50 to 84**	**20 to 49**
	- - - - - - - - - *Ft^3/ac/yr* - - - - - - - - -				
Xeric**	43.1	—	51.8	46.0	22.5
Xeromesic	42.8	100 +	64.8	36.8	24.6
Mesic	42.3	74.8	52.5	40.1	28.1
Hydromesic	29.9	65.3	46.4	34.8	21.5
Hydric	21.4	55.0	46.2	28.7	15.8
Total	39.0	77.2	52.4	39.1	24.3

Minnesota		**Potential productivity class**			
Physiographic class	**Total**	**120 +**	**85 to 119**	**50 to 84**	**20 to 49**
	- - - - - - - - - *Ft^3/ac/yr* - - - - - - - - -				
Xeric**	26.0	—	45.5	41.4	16.1
Xeromesic	38.5	100+	60.6	36.6	25.8
Mesic	34.0	71.5	46.8	34.3	26.0
Hydromesic	22.0	88.4	36.8	28.2	19.3
Hydric	14.8	51.7	13.0	19.5	14.4
Total	30.1	80.2	46.3	33.6	22.4

** Note limited total timberland area in this class with a resulting large sampling error.

landowners had a written management plan (fortunately, they did control 39% of the private forest land). It was estimated in the 1980's that more than 40% of privately owned timberlands in the southern U.S.needed treatment to reach their production potential (USDA Forest Service 1988). Recommended treatments related primarily to concerns about stocking, i.e., improve regeneration, thin overstocked young stands, control stocking of undesirable trees. These same factors, the great need for treatment and a large NIPF ownership contingent, apply in the northern U.S. as well. In Birch's 1994 study, less than 10% of the private forest landowners in the Lake States identified either investment or timber production as their primary or secondary reason for owning forest land. At the same time, more than one-third of the private land-owners identified recreation or esthetic enjoyment as their primary reason for owning forest land. A major challenge facing the forestry profession in the Lake States is to persuade these private landowners to make investments to improve wood fiber production.

Where should management be focused in the Lake States regarding the potential to improve the wood fiber supply? Results indicate that privately owned mesic to xeromesic sites with potential productivity classes above 50 ft^3/ac/yr, with basal area stocking levels of 0 to 80 ft^2/ac, in pine, maple-beech-birch, oak-hickory, and aspen-birch forest types should receive high priority for management investments. One of the more common reasons for forest stands not meeting their potential regarding productivity is related to stocking. Stands are often either understocked or stocked with species that are off-site, outcompeted, or susceptible to problems. From a timber productivity perspective, the focus should be on overmature stands where, due to high mortality rates, growth has been minimal. An important point to note is that while these stands are growing at low rates, they may be making other significant ecological contributions (critical wildlife habitat, water quality protection, etc.) that need to be considered in management planning.

Timberland sites in Minnesota are below the Lake States average overall regarding growth rates. However, this does not imply that investments should occur in other regions of the Lake States but rather that investments need to be closely analyzed to ensure that they are on the correct sites to improve the potential for a long-term owner or societal return. For example, in the highest productivity classes, Minnesota has above average growth rates. Additionally, we know that realized growth rates can be increased through management. Thus, manage-ment strategies need to closely analyze the potential of each site and determine the potential for returns on the investments.

Sites differ not only in their existing potential but also in their capability to produce greater returns through different forest types. Are the timberlands of the Lake

States growing what they should to maximize the productivity of the region (see Kotar *et al*. 1988 for an in-depth discussion of matching site potential with species)? For example, the current estimated potential productivity could theoretically be increased because it is based on the existing species; if there was a change in species composition, then theoretically there could be a change in potential productivity. If a site can produce either red or jack pine, should red pine production be emphasized based on its greater wood fiber production potential? This question is not easily answered as factors such as wildlife habitat, water quality, demands for particular types of wood fiber, and other factors also need to be addressed.

Finally, measures of productivity are also measures of the current health of the forest ecosystem. Land owners and society have an increasing interest in the broad suite of benefits that flow from forests; increasing research in forest productivity will provide an improved understanding of all kinds of benefits and how management can best provide for overall sustainability.

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