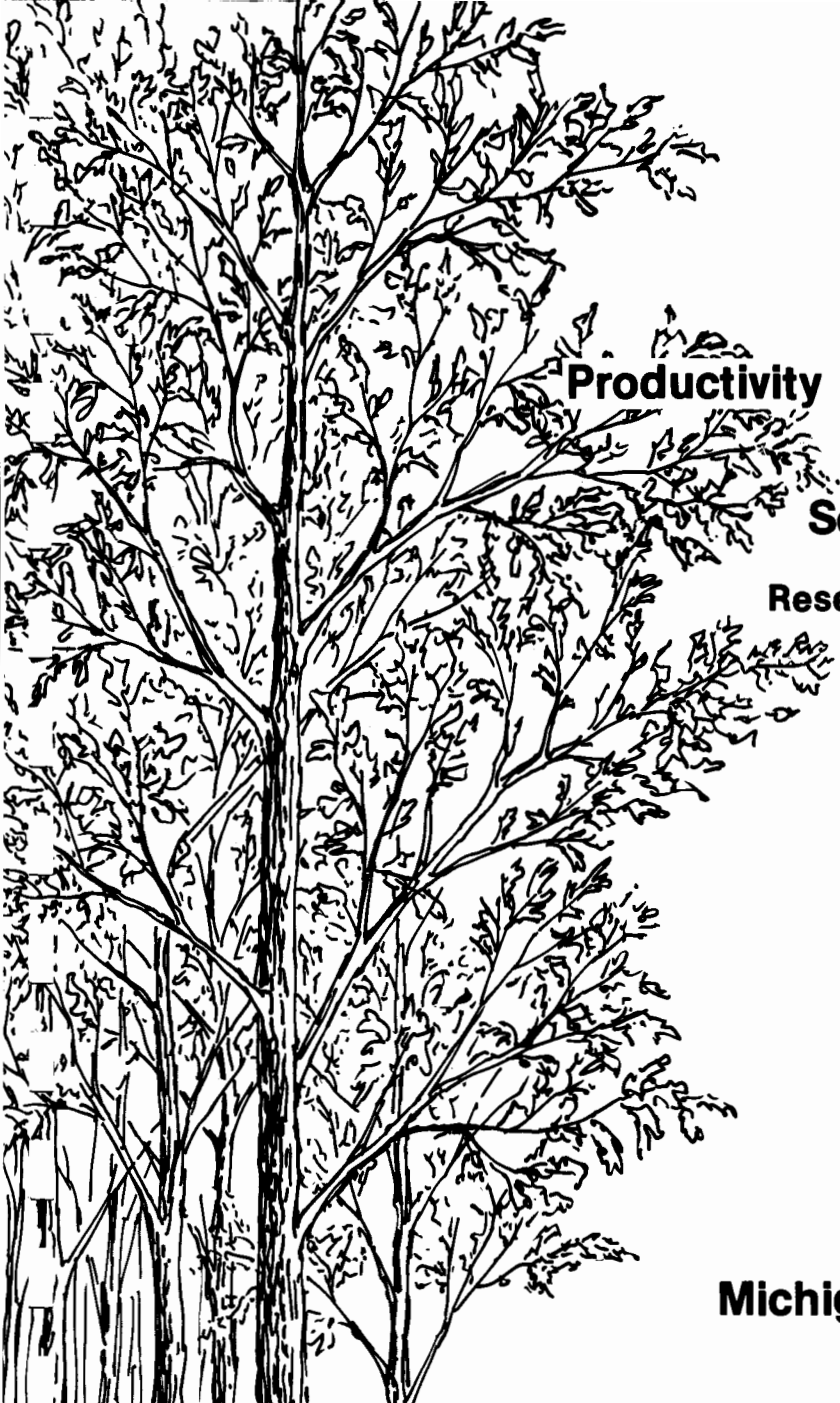

Research
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Report

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Research Information Report No. 88-1

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PRODUCTIVITY ESTIMATES FOR RED PINE PLANTATIONS BASED ON SOIL SERIES AND HABITAT TYPE

ABSTRACT

Forest managers are often faced with a choice of multiple estimates of forest productivity. This paper discusses a statistically valid method of combining these estimates into one measure of productivity. An example is given for red pine plantations in Upper Michigan. Two alternative estimates of site index and mean annual increment, one from soil/site equations and one from a habitat type classification system, are available to managers. For some sites the two estimates agree closely while on other sites they are quite different. Combining these two estimates into one is illustrated using data from a recent soil survey in Upper Michigan.

PRODUCTIVITY ESTIMATES FOR RED PINE PLANTATIONS BASED ON SOIL SERIES AND HABITAT TYPE

Most studies undertaken to develop potential forest productivity estimates concentrate on one component of the total ecosystem such as soil, habitat type, or forest stand conditions. When applied to given sites, these different methods of estimating productivity often produce unequal estimates. The forest manager is forced either to choose one set of estimates over another or to somehow combine these estimates into one estimated productivity value for a site. In this study, the objective is to combine productivity estimates for red pine plantations in Upper Michigan from a habitat classification system (Coffman and others 1983) and from soil/site equations (Bottenfield 1986).

These two sources may or may not provide similar productivity estimates for a given site. For some combinations of soil characteristics the soil/site equations produce more precise estimates than the habitat classification system, but for other conditions the habitat classification system is more precise. This study illustrates a procedure given by Cochran and Carroll (1953) which is used to combine the estimates from these two sources of information to arrive at a statisically valid overall estimate of productivity. The emphasis of this study will be to provide a methodology to combine any set of estimates into one estimate. One must recognize that the estimates from the sources are not of the same quality and that the estimates in the example illustrated here have not been validated in the field.

Two measures of plantation productivity were available from both the soil/site equations and the habitat classification system: site index, in feet at age 50, and mean annual increment, in cubic feet per acre per year to a 3-inch top. Their standard errors were also available from each source of information. This allowed the construction of confidence intervals for the combined estimates. A table of the combined productivity estimates was then developed for combinations of soil series and habitat types observed to occur in Baraga, Dickinson, and Menominee counties in Michigan.

SOIL/SITE EQUATIONS

Bottenfield (1986) gives soil/site equations for estimating site index (feet) and mean annual increment (cubic feet per acre per year to a 3-inch top) for red pine plantations in Upper Michigan based on variables from a field soil profile description.

$$SI = 100.394 - 0.244\ BTEX + 2.243\ BCONS + 0.0117\ H2OU$$
$$- 0.0361\ H20A + 0.02000\ ROZO + 0.856\ AHOR - 3.443\ DRAIN$$
$$R^2 = 0.43 \quad S = 7.05$$
$$MAI = 184.365 - 1.289\ BTEX + 23.724\ BCONS + 0.0699\ H2OU$$
$$- 0.0170\ H20A + 0.282\ ROZO + 3.002\ AHOR - 7.260\ DRAIN$$
$$R^2 = 0.22 \quad S = 46.0$$

where SI and MAI are predicted site index and mean annual increment, respectively, BTEX is the sum of the percent silt and percent clay in the B horizon, BCONS is the consistency of the B

horizon, H20A is the hydraulic conductivity of the B horizon adjusted for the percent of coarse fragments in the rooting zone, ROZO is the depth (in) to the deepest horizon where roots were recorded, AHOR is the depth of the A horizon (in), and DRAIN is the drainage class code. Coded variables (consistency of the B horizon, drainage class, and hydraulic conductivity) use values given by Corns and Pluth (1984). Confidence intervals as described by Draper and Smith (1981) were calculated as follows:

$$CI_s = \hat{Y}_S \pm t_{\alpha,df} S\sqrt{X'_0(X'X)^{-1}X_0}$$

where

CI_s = confidence interval for the soil/site estimates

$\hat{Y}_S$ = predicted estimate (SI or MAI) from the soil/site equations

$t_{\alpha,df}$ = Student's t-value for the appropriate α-level using the error degrees of freedom from the regression data (43 for Bottenfield's data)

S = square root of the mean square error from the regression equation (7.054 for SI and 46.020 for MAI for Bottenfield's equations)

X_0 = vector of soil profile characteristics for a site whose order is (1, AHOR, ROZO, H2OU, H2OA, BTEX, BCONS, DRAIN)

$(X'X)^{-1}$ = inverse of variance-covariance matrix

The estimated red pine plantation site index and mean annual increment are given in Table 1 for a number of selected soil series found in Michigan's Baraga, Dickinson, and Menominee Counties.

Table 1. Estimated productivity measures for selected soil series in Michigan's Baraga, Dickinson, and Menominee Counties using Bottenfield's (1986) equations.

Series	Site Index Feet At Age 50	Mean Annual Increment $Feet^3$/Acre/Year (3-inch Top)
Amasa	71 ± 13.2[a/]	121.7 ± 86.3
Channing	81 ± 15.8	146.3 ± 103.2
Karlin	64 ± 5.4	104.0 ± 35.4
Kinross	68 ± 12.5	79.3 ± 81.3
Grayling	53 ± 5.1	48.7 ± 33.2
Mancelona	66 ± 7.5	96.3 ± 49.2
Nadeau	77 ± 13.9	136.0 ± 90.6
Ocqueoc	58 ± 6.2	58.6 ± 40.5
Onaway	82 ± 18.0	178.2 ± 117.8
Pemene	68 ± 8.2	119.3 ± 53.4
Pence	72 ± 11.5	111.0 ± 75.2
Peshekee	69 ± 18.8	100.4 ± 122.6
Rousseau	58 ± 6.2	56.6 ± 40.5
Rubicon	53 ± 4.6	54.3 ± 29.8
Vilas	59 ± 4.8	88.4 ± 31.2
Zimmerman	53 ± 5.5	51.0 ± 36.1

a/ Estimated value plus or minus a 95 percent confidence interval.

ESTIMATES FROM HABITAT CLASSIFICATION

Coffman and others (1983) give estimated site index and mean annual increment values and their standard errors for red pine plantations on several habitat types in Upper Michigan. These values are given in Table 2 for all habitat types for which red pine plantation data were available. The confidence interval information in Table 2 was derived using the standard errors of the estimates given by Coffman and others (1983).

COMBINED ESTIMATES

Cochran and Carroll (1953) describe methods of calculating weighted means which are used here to combine the productivity estimates from the two sources of information. Each estimated value is weighted by the inverse of its standard error, thus giving greater weights to the information with the highest precision. The combined productivity estimate is given by:

$$\hat{y} = \frac{w_S \hat{y}_S + w_H \hat{y}_H}{(w_S + w_H)}$$

where the weights are defined as:

$$w_S = 1/S^2_{\hat{y}_S} \qquad w_H = 1/S^2_{\hat{y}_H}$$

and

w_S = weight for the estimate from the soil/site equation

w_H = weight for the estimate from the habitat classification system.

Table 2. Estimated productivity measures for red pine plantations from the habitat classification field guide (Coffman and others 1983).

Habitat Type	Site Index Feet At Age 50	Mean Annual Increment Feet³/Acre/Year (3-inch Top)
Acer-Quercus-Vaccinium (AQVac)	66 ± 4.2[a/]	100.0 ± 20.8[a/]
Acer-Quercus-Viburnum (AQVib)	76 ± 5.2	142.0 ± 26.0
Acer-Tsuga-Dryopteris (ATD)	80 ± 4.2	168.0 ± 26.0
Acer-Viola-Osmorhiza (AVO)	80 ± 4.2	168.0 ± 26.0
Pinus-Vaccinium-Deschampsia (PVD)	43 ± 6.2	b/
Quercus-Acer-Epigaea (QAE)	54 ± 9.4	75.0 ± 20.8
Tsuga-Maianthemum (TM)	80 ± 4.2	168.0 ± 26.0
Tsuga-Maianthemum-Vaccinium (TMV)	75 ± 6.2	128.0 ± 36.4

a/ Estimated value plus or minus a 95 percent confidence interval.

b/ Mean annual increment information for red pine plantations on the PVD habitat type is not given in the habitat classification field guide.

continued:

$\hat{y}_S$ = predicted estimate (SI or MAI) from the soil/site equation

$\hat{y}_H$ = predicted estimate (SI or MAI) from the habitat classification system

$S^2_{\hat{y}_S}$ = mean square error from the soil/site equation for a given estimate (SI or MAI)

$S^2_{\hat{y}_H}$ = mean square error from the habitat classification system for a given estimate (SI or MAI)

As indicated by Burk and others. (1981), this method is appropriate if the two alternative estimators are independent and unbiased. This methodology was applied to combine the soil/site and habitat classification estimates of site index into one estimate as well as combining mean annual increment values into one estimate.

Computing approximate confidence intervals for the combined estimates was done using an approximate variance formula given by Meier (1953) where:

$$S^2_{\hat{y}} = \frac{1}{w_S + w_H} \left[\frac{1 + 4w_S w_H}{(w_S + w_H)^2} \left(\frac{1}{n_S} + \frac{1}{n_H} \right) \right]$$

where

$s^2_{\hat{y}}$ = variance of the combined estimate (SI or MAI)

n_S = number of observations used to develop the soil/site equations (51 for Bottenfield's 1986 equations)

n_H = number of observations used to develop the standard error estimate in the habitat classification field guide (assumed to be 20).

and w_S and w_H are the weights as defined previously.

APPLICATION

During the soil surveys of Baraga, Dickinson, and Menominee counties in Upper Michigan, habitat type was collected together with the soil series. For the combinations of soil series and habitat type observed in the surveys, the combined productivity estimates were developed and are given in Tables 3 and 4. These combined estimates can be regarded as the best available unbiased estimates of red pine plantation site index and mean annual increment for these sites in the absence of stand information.

The combined estimate always falls between the estimates from the habitat classification field guide and the soil/site equations and is closer to the estimate which has the smallest variance. The confidence interval on the combined estimate is also narrower than the interval for either of the independent estimates. For some combinations of soil series and habitat type there is very good agreement between the two productivity estimates. For example, site index on the Grayling series is estimated to be 53 ± 5.1 and on the QAE habitat type it is estimated at 54 ± 9.4. The combined estimate in this case is 53 ± 4.6. On the other hand, there are combinations of soil series and habitat type where there is no agreement between the two estimates. The estimated site index on the Zimmerman series is 53 ± 5.3 while the estimate for the TMV habitat type is 75 ± 6.2. The combined estimate in this case is 63 ± 4.3. All combinations of soil series and habitat type given in Tables 3 and 4 were observed to occur in the soil surveys for Baraga, Dickinson, and Menominee counties in Michigan.

Table 3. Combined red pine plantation site index estimates (feet at age 50) for selected soil series and habitat types in Baraga, Dickinson, and Menominee Counties, Michigan.

Series	Habitat Type							
	AQVac	AQVib	ATD	AVO	PVD	QAE	TM	TMV
Amasa	-	75 (4.9) [a/]	79 (4.0)	-	-	-	79 (4.0)	74 (5.7)
Channing	-	-	-	-	-	-	-	76 (5.8)
Karlin	-	-	-	-	-	-	74 (3.4)	69 (4.2)
Kinross	-	-	-	-	-	59 (7.7)	- -	- -
Grayling	61 (3.3)	-	-	-	49 (4.1)	53 (4.6)	-	-
Mancelona	66 (3.7)	73 (4.4)	-	-	-	-	77 (3.7)	-
Nadeau	-	76 (4.9)	80 (4.0)	80 (4.0)	-	-	80 (4.0)	75 (5.7)
Ocqueoc	-	-	74 (3.5)	-	-	-	74 (3.5)	-
Onaway	-	-	80 (4.0)	80 (4.0)	-	-	80 (4.0)	76 (5.9)
Pemene	-	74 (4.5)	78 (3.8)	-	-	-	78 (3.8)	73 (5.1)
Pence	-	-	-	-	-	-	79 (3.9)	74 (5.6)
Peshekee	-	-	80 (4.0)	80 (4.0)	-	-	-	74 (5.9)
Rousseau	64 (3.5)	-	74 (3.5)	-	-	-	74 (3.5)	67 (4.5)
Rubicon	60 (3.2)	63 (3.6)	-	-	-	-	-	61 (3.8)
Vilas	63 (3.2)	-	-	-	-	-	-	65 (3.9)
Zimmerman	61 (3.4)	-	-	-	-	-	-	63 (4.3)

[a/] The value plus or minus the number in parenthesis gives a 95 percent confidence interval for the combined estimate of site index.

Table 4. Combined estimates of red pine plantation mean annual increment (feet per acre per year to a 3-inch top) for selected soil series and habitat types in Baraga, Dickinson, and Menominee Counties, Michigan.

Series	Habitat Type							
	AQVac	AQVib	ATD	AVO	PVD	QAE	TM	TMV
Amasa	-	140.4 (24.8)[a/]	164.4 (24.8)	-	-	-	164.4 (24.8)	127.1 (33.7)
Channing	-	-	-	-	-	-	-	129.9 (34.3)
Karlin	-	-	-	-	-	-	146.6 (21.5)	116.1 (26.3)
Kinross	-	-	-	-	-	75.2 (20.0)	-	-
Grayling	86.2 (18.0)	-	-	-	-	67.9 (18.0)	-	-
Mancelona	99.5 (19.3)	132.5 (23.3)	-	-	-	-	153.2 (23.3)	-
Nadeau	-	141.6 (24.9)	165.7 (24.9)	165.7 (24.9)	-	-	165.7 (24.9)	129.0 (33.9)
Ocqueoc	-	-	137.6 (22.3)	-	-	-	137.6 (22.3)	-
Onaway	-	-	168.4 (25.1)	168.4 (25.1)	-	-	168.4 (25.1)	132.1 (34.6)
Pemene	-	137.9 (23.6)	159.2 (23.6)	-	-	-	159.2 (23.6)	125.4 (30.8)
Pence	-	-	-	-	-	-	162.3 (24.5)	124.9 (33.1)
Peshekee	-	-	165.3 (25.2)	165.3 (25.2)	-	-	-	125.9 (34.7)
Rousseau	91.4 (18.7)	-	137.0 (22.3)	-	-	-	137.0 (22.3)	97.3 (27.9)
Rubicon	85.7 (17.5)	105.5 (20.2)	-	-	-	-	-	85.1 (23.9)
Vilas	96.6 (17.7)	-	-	-	-	-	-	105.8 (24.5)
Zimmerman	88.4 (18.3)	-	-	-	-	-	-	90.5 (26.5)

[a/] The value plus or minus the number in parenthesis gives a 95 percent confidence interval for the combined estimate of mean annual increment.

One should note that the validity of these combined estimates depends in part on the correctness of the information given in the habitat classification field guide, especially regarding the standard errors of the estimates as well as the appropriateness of the regression equations developed by Bottenfield. This study merely provides a means of combining independent estimates and requires the discretion of the user in choosing which estimates to apply.

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