Average Yarding Distance for Row Thinning of Plantations

F.E. Greulich[1]
University of Washington
Seattle, USA

ABSTRACT

An average yarding distance model for rectilinear skidtrail layout from a centralized landing is given. The model is appropriate to the evaluation of some row thinning designs in plantations. The theoretical basis for formulas used in the model is briefly described. The model was coded for computer solution and applied to a hypothetical example the results of which are presented.

Keywords: _forest harvesting, centralized landings, logging engineering, turn location parameters, average skidding distance._

INTRODUCTION

Commercial thinning activity in forest plantations can result in a rectilinear pattern of skidtrails leading to a centralized landing. A rectilinear skidtrail pattern typically develops when row thinning is conducted on ground that is either flat or of uniform slope. Under these conditions skidtrails are generally laid out in straight, parallel lines separated by rows of residual trees. A single connecting skidtrail that leads directly to the landing will often cross the rows at approximately right angles (Figure 1). Not infrequently this connecting skidtrail is also a truck road that predates the plantation, which was planted at right angles to it. The landing may then be located on the road at some convenient point more or less central to the thinned area [2].

The usual model for average yarding distance (AYD) assumes straight line travel between the landing and the location of the turn in the plantation [1]. Where rectilinear rather than straight line travel occurs, some adjustment is required. One alternative is to multiply the usual straight line AYD estimate by a wander factor. A better solution, however,
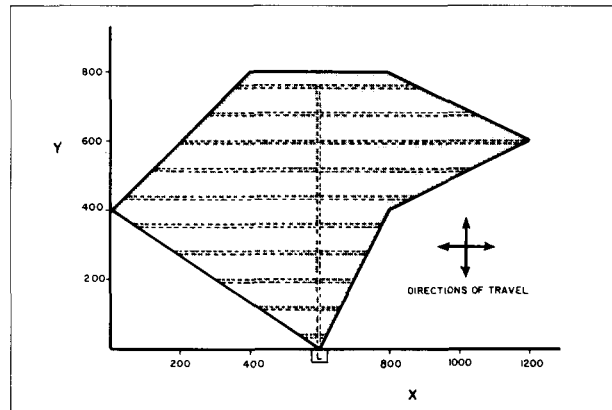
Figure 1. Traverse plot of a plantation showing one possible skidtrail/landing location design.
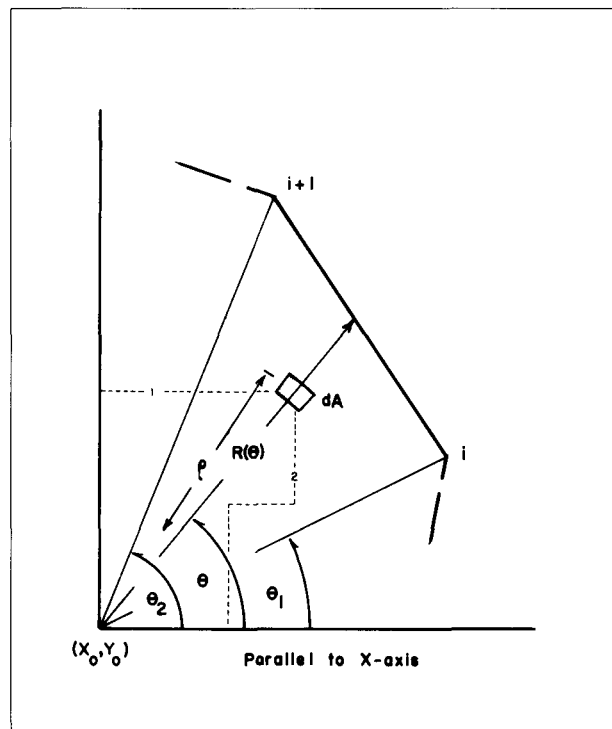

Figure 2. A triangular element showing variables for the calculation of the average rectilinear distance.

is to directly incorporate the rectilinear yarding pattern assumption into the model.

THE RECTILINEAR MODEL

Following standard procedure for models of this type, the AYD for a single triangular element (Figure 2) is first developed. The AYD for a composite area can then be found by using this
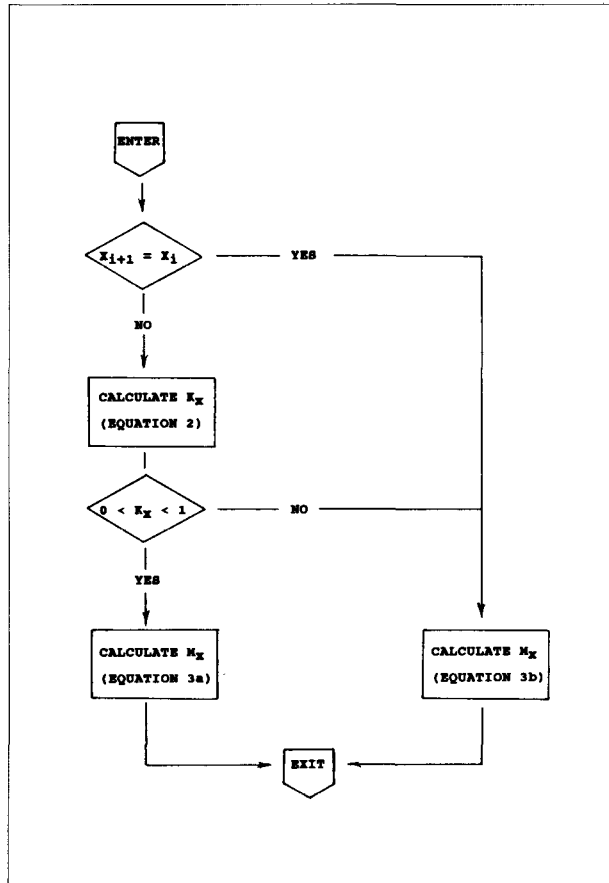
Figure 3. Flow chart for the calculation of expected travel distance parallel to the x-axis.

triangle result in conjunction with the coordinate area formula.

Key assumptions are uniform turn distribution, rectilinear travel to a centralized landing, and flat ground. Under these assumptions the expected, or average, rectilinear yarding distance for turns distributed across the triangular element shown in Figure 2 is given by equation 1 (Table 1). Continuing with respect to Figure 2, the local reference system shown in this figure is centred on the landing location (x_0, y_0) and has a horizontal axis parallel to the x-axis. The base of the triangle opposite the landing vertex is the traverse course from turning point (TP) i to TP $i+1$. All turns are yarded to the landing vertex at (x_0, y_0). The yarding direction at any point always parallels either the x-axis or the y-axis (a rectilinear travel pattern). During the yarding process the distance of the turn from the landing is constantly decreasing. Two possible paths that meet these two criteria are shown with dashed lines for a turn falling within infinitesimal area dA of the figure. Path

number 1 first runs horizontally as far as permitted; it then proceeds vertically down to the landing. Path number 2, a distinctly different route, contains two additional jogs; note however that it has the same total length as the first path.

Integration of equation 1 leads to results that are best illustrated using a flow chart. Accordingly, in Figure 3 the calculating procedure for expected travel distance parallel to the x-axis, M_x, is given. By substituting y wherever x appears in equations 2, 3a and 3b of Table 1 and by doing the same universal substitution of y for x in Figure 3 a similar result for expected travel distance parallel to the y-axis, M_y, is obtained. The total expected rectilinear distance travelled is the sum of these two components, M_x and M_y, as shown in equation 4.

In order to calculate the rectilinear AYD for a composite region, the weight to be applied to each triangle is calculated using the coordinate area formula (equation 5). The positive or negative sign associated with each weight must be retained. Note here that if the weight, W_i, of any triangle were to be zero then that triangle makes no contribution to the composite result and the calculation of M_x and M_y is not carried out. The total horizontal area of the region is calculated using equation 6 and the AYD for the composite region is then obtained via equation 7.

A NUMERICAL EXAMPLE

The procedure described in the previous section is easily implemented on a computer. A short FORTRAN program was written and used to analyse a yarding pattern for the region illustrated in Figure 1. The first step in the analysis is to rotate the x-y coordinate system so that the coordinate axes parallel the proposed skidtrail system. This step has already been done in Figure 1. The coordinates of the landing, (x_0, y_0), are then specified; in this case they are (600,0). From an arbitrarily selected starting point the TP coordinates, (x_i, y_i), are identified in counterclockwise order; viz., (600,0), (800,400), (1200,600), (800,800), (400,800) and (0,400). The starting TP, (600,0), is then repeated as the closing point for the traverse. These seven sequential TPs yield six traverse courses. Each of these six traverse courses which define the boundary of the region are evaluated in turn using the previously described process.

The horizontal area, A, of this region is found to be 480,000 square units. The average rectilinear

Table 1. Equations for the calculations of average rectilinear distance.

(1)
$$M_i = \frac{\displaystyle\int_{\theta_1}^{\theta_2}\int_0^{R(\theta)}\left[\rho\left|\cos\theta\right| + \rho\left|\sin\theta\right|\right]\rho\,d\rho\,d\theta}{\displaystyle\int_{\theta_1}^{\theta_2}\int_0^{R(\theta)}\rho\,d\rho\,d\theta}$$

(2)
$$K_{x,i} = -\frac{(x_i - x_o)}{(x_{i+1} - x_i)}$$

(3a)
$$M_{x,i} = \left|\left[\frac{1}{3}\right]\left[(x_i - x_o)(4K_{x,i} - 2K_{x,i}^2 - 1) + (x_{i+1} - x_o)(2K_{x,i}^2 - 1)\right]\right|$$

(3b)
$$M_{x,i} = \left|\left[\frac{1}{3}\right]\left[(x_i - x_o) + (x_{i+1} - x_o)\right]\right|$$

(4)
$$M_i = M_{x,i} + M_{y,i}$$

(5)
$$W_i = \left[\frac{1}{2}\right]\left[(x_i - x_o)(y_{i+1} - y_o) - (x_{i+1} - x_o)(y_i - y_o)\right]$$

(6)
$$A = \sum W_i$$

(7)
$$M = \left[\frac{1}{A}\right]\sum W_i M_i$$

yarding distance, M, for the illustrated skidtrail/landing design is calculated to be 677.78 units. Parenthetically, use of the standard straight line model [1] yields an expected travel distance of 535.31 units. This substantial difference in the two estimates is not unusual.

Alternative designs can be quickly examined. For example, a landing location more central to the thinned region might be under consideration. If the landing were to be moved to coordinate location (600,400) the average rectilinear yarding distance could be reduced to 366.67 units.

CONCLUSIONS

The rectilinear yarding distance model presented here greatly facilitates design evaluation of some row thinning operations. Contemporary analytical procedures are employed in this model giving it some distinct advantages: the model is quite general and extremely accurate; it is easily computer programmed, and manual procedures for its application are readily understood and implemented. Program developers should find the model useful within many existing program packages. The forest engineer engaged in the design of commercial thinning units should seriously consider the addition of this model to his or her repertoire of analytical tools. For thinning layouts of the type described here both speed and accuracy of design assessment are greatly enhanced by this model.

REFERENCES

[1] Greulich, F.E. 1992 Estimation of turn location parameters for cable settings J. For. Eng. 3(2):29-35.

[2] McNeel, Joseph F. 1993. Personal Communication. Research Engineer, USDA, FS. AR-10, University of Washington, Seattle, WA.

NOTE

A copy of the FORTRAN source code may be obtained from the author either via INTERNET at greulich@u.washington.edu or by posting a formatted high density (1.44 Mbyte) 3 1/2" diskette together with a self-addressed pre-paid mailer to the author.