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ALLOMETRIC EQUATIONS FOR ESTIMATING THE LEAF AREA OF JARRAH TREES (*Eucalyptus marginata* Sm.)

by
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ALLOMETRIC[1] REGRESSIONS FOR DETERMINING THE LEAF AREA OF JARRAH (*Eucalyptus marginata* Donn ex Sm.)

1.Allometric Growth - A type of growth in which the size of a part is a constant exponential function of the whole.

1.0 Summary

Equations for estimating the single sided leaf area of individual jarrah (*Eucalyptus marginata* Donn ex Sm.) trees are developed and presented. This technique for measuring leaf area makes use of stem diameter, crown dimensions, and assessments of the crown size and leaf density within the crown outline. The destructive measurement of 93 trees on 6 sites over 3 seasons provided individual leaf areas that were related to these tree dimensions. The regressions provide an accurate but labor intensive method of determining the leaf area of individual jarrah trees and small plots.

Keywords: Crown dimensions, Crown assessment, Crown size, Crown position, Crown density, Crown width, Crown depth, Eucalyptus marginata, (5 only)

2.0 Introduction

Measurements of leaf area are essential to forest studies of photosynthesis and transpiration. In the northern jarrah forest of South West Western Australia, pressures from mining and disease, and the desire to actively manage water production in the states major water catchments create a need for a detailed understanding of leaf area index (LAI). Measurements of LAI are required for individual trees, small plots and whole catchments.

Techniques currently in use are either inaccurate or unproven. A method that would produce reliable estimates of leaf area on a variety of sites, was required for calibrating more efficient broad scale techniques.

The work of Carbon, Bartle and Murray (1979) had shown that, in jarrah, leaf area is correlated with stem diameter. Other researchers have shown relationships between sapwood area and leaf area in a variety of species. (Grier and Waring 1974, Whitehead 1978, and Kaufman and Troendle 1981.) Preliminary investigations in the jarrah forest showed that the leaf area of individual stems was correlated to both stem basal area and sapwood basal area (Whitford unpublished, Colqhoun unpublished). However, when comparing data for different sites and seasons, it was found that these regressions varied both in slope and intercept. Within species variations in sapwood area relationships have been observed by Whitehead (1978), Albrektson (1984), and Dean and Long (1986). Pook (1984) noted the seasonal variations in the relationship between leafarea and basal area in *Eucalyptus maculata* Hook. II. Various explanations have been proposed for these differences. The concept behind these relationships, that there is a relationship between the area of water conducting tissue and water consuming tissue is conceptually sound but simplistic. The variety of contributing and confounding factors are ignored. Regardless of the cause of this variation, it reduces the utility of leaf area estimates based on sapwood or basal areas alone.

Located in the South-west of Western Australia, the jarrah forest covers a wide range of site types across a rainfall gradient. Throughout these sites a 4 to 6 year seeding cycle produces annual variations in stand leaf area. Additionally, a regular annual cycle of leaf area produces a winter minimum and a summer maximum in LAI (Loneregan 1971). Along with bird damage and fire, these factors are seen to influence the leaf area of stands and individual trees. At present these variations in leaf area are observed but not quantified.

The inability of basal area relationships to account for site variations and the seasonal changes in leaf area that occur in the jarrah forest was seen as a major weakness in these simple predictive regressions. A more detailed model with better predictive ability was sort.

Individual tree's can accommidate changes in leaf area by altering one or all of the following:

the size of the crown
the leaf size
the leaf density within the crown outline

It was proposed, that quantifying the size of the crown and leaf density within the crown outline would account for these variations and refine the estimate of leaf area based on stem basal area.

If the range of these variables was covered, through the seasons and across a variety of sites, relationships that were independant of site and season could be developed. In practice, seperate measurement of leaf size and leaf density was found to be difficult. Consequently, both leaf size and crown leaf density were considered in one density assessment.

3.0 Method

The collection of each data point used in the regression model involved 5 steps.

1. Selection of tree for inclusion in data set.
2. Measurement of the trees dimensions.
3. Assessment of the tree crown.
4. Falling of the tree and leaf stripping.
5. Determination of the trees leaf area from leaf weight

3.1 SITES AND TREE SELECTION

Six sites were selected and trees were measured during two periods of the annual leaf area cycle. These periods were the relative maxima in Summer/Autumn and the minima in Winter/Spring.

The six sites chosen exhibited a wide range of the 3 principal crown characteristics listed above, ie. crown leaf density, crown size and leaf size.

Site no.	Site	Season	Number of trees
1	Banksiadale rd.	Spring (Oct)	18
2	Inglehope plots	Autumn (April)	34
3	Inglehope block	Spring (Oct)	17
4	Kennedy block	Spring (Nov)	8
5	Sandy dam	Summer (March)	13
6	Bush Pig rd.	Autumn (April)	24
		Total	114

note: A complete set of data was available only for 93 trees on 5 sites.

The initial sampling of trees was intended to randomly cover the range of diameters considered typical of a pile stand in the northern jarrah forest. Analysis of this data showed, that while the sampling had covered the range of basal areas well, the other variables had not been so thoroughly covered. As a strong basal area leaf area relationship was known to exist, subsequent tree selection covered the variation of leaf density and crown dimensions throughout the basal area range.

3.2 TREE ASSESSMENT

To describe the crown characteristics, two measurement techniques were used. These were the `box method' and the `Grimes method'. The `box method' confines the tree crown to a cubic shape. The Grimes method makes use of the Grimes crown assessments (Grimes 1978).

In the `box method', the crown volume was determined by defining the crown's occupation of an imagined box. This box was visualized so that the sides were in close contact with the extremities of the crown. The dimensions of the box, crown width and depth, were then measured. By viewing one vertical face of the box, the percentage of the box occupied by the crown was estimated using a graticule. The leaf density of this estimated volume was then determined by comparison to a density standard. In dense forest stands it is difficult to get a clear view of a tree crown against a clear sky. Often a single viewing point is all that is available. Consequently both this leaf density and crown occupation were assessed from only one angle and are two dimensional assessments.

The `Grimes method' used the same crown dimensions (ie. depth and width) as the box technique. However, here crown size and leaf density were determined using a modified version of the Grimes assessment. The Grimes assessment considers crown position, crown size, crown density and in this case seeding. Appendix 1 details the Grimes assessment as it was used in this experiment and should be read in conjunction with Grimes (1978).

3.21 VARIABLES MEASURED

The following variables were measured on all stems prior to falling:

dbhob, bark depth, tree height, height to base of crown, crown width

Subjective estimations were made of the following:

box occupation, crown density, crown position, crown size, Grimes crown density, seeding.

3.22 VARIABLES CALCULATED

From the above variables dbhub and crown depth were then calculated.

3.23 MEASUREMENT TECHNIQUE AND DEFINITIONS

Tree Dimensions

DBHOB (DBH)

The overbark diameter of the stem was measured with a diameter tape at breast height (1.3 metres).

Bark Depth (Bark)

The mean bark depth at breast height (1.3 m) was measured with a penetrometer. This was determined from the average of at least four measurements spread evenly around the circumference of the stem.

Tree Height (Top)

This is the distance from the base of the tree to the top of its uppermost green leaf clump. Using trigonometry this height was determined with a clinometer and tape measure.

Height to Base of Crown (Bot)

The distance from the base of the tree, to the lowest leaf clump that is considered to be part of the main crown structure.

Crown Width (Width)

A single measure of the width of the tree crown. This was determined using an observer with a plumb bob and a recorder with a tape measure. At a distance away from the stem, the observer with the plumb bob located one outer edge of the crown. From this point, the recorder measured the distance to the opposite edge of the crown identified by the observer.

Grimes Assessment

Crown Position (Pos)

This is the first of four subjective measures based on the Grimes crown assessment (Grimes 1978). The value used for all of these subjective assessments was the mean of the values from two observers.

Crown position is the position of the tree crown relative to adjacent crowns. It has a maximum score of five points. Five indicating a dominant stem, and one indicating a totally suppressed stem.

Crown Size (Siz)

Crown size is a subjective measure that ranks the depth, width and shape of the crown outline. The size classing system varies with the stem diameter. It is a comparison to an idealized crown proportion that relates the dimensions of the crown to the tree size. The perfect jarrah pole crown is egg shaped in outline and round in plan (score 5). In practice few trees attain this perfection. The size score attempts to describe the extent to which the tree departs from this imagined form.

This idealized pole crown shape, breaks down with pile and larger sized trees. In such trees, the score 5 crown becomes either wider or deeper than the egg shaped pole crown. The width and depth of the crown is considered in proportion to the trunk diameter and to a lesser extent the tree height. Crown size is considered from 2 views at right angles, or from beneath and at a distance where the crown can be seen clearly.

Crown Density (Den)

Crown density is a subjective measure of the density of leaves within the crown outline. The density and distribution of the foliage clumps determines the score. Crown density has a maximum score of nine points, but for simplicity it can be considered in five stages with interpolation between the stages ie. scores 1, 3, 5, 7, 9. These major levels are descriptively defined and can be related back to known objective standards.

Seeding (Seed)

The seeding score considers the amount of fruit carried by the tree and the affect this has on the leaf carrying capacity of the tree. A heavily seeding tree receives a score 5, while a tree that is not seeding is given a 1. This subjective score defines the visual contribution that seeding has on the percieved leaf density. Seeding is assessed using binoculars. This reduces the variation in this assessment caused by tree height. The crown is viewed first from beneath and then from a distance.

Box Assessments

Box Occupation (Boxcent)

This assessment estimates the percentage occupation of a box visualized about the tree crown. This was determined by viewing the crown from a position where it could be seen against a clear sky. A rectangular graticule was held up and the number of squares occupied by the crown was used to calculate a percentage occupation of the rectangular outline.

Crown Density (Crown)

This second assessment of the leaf density within the crown was based on comparisons made to a set of density standards. This set of standards consisted of random grid shadings of known density printed onto a clear plastic sheet.

3.3 LEAF STRIPPING FOR THE DETERMINATION OF LEAF AREA

After assessment the selected trees were fallen into an open space. Care was taken to minimize leaf loss during falling. Limbs were then removed and the leaves were stripped into plastic bags. The bags were then sealed to halt moisture loss. The total leaf mass for each bag of leaves was determined to $^{+}/_{-}$ 0.1gm. A sample of between 60gms (186 leaves) and 140gms (321 leaves) was removed from each bag and assessed to determine the mean specific area (the ratio of surface area to green weight) for that bag. A LiCor LI-3000 optical planimeter was used to determine the total area of this sample. From these measurements the total bagged leaf area could then be determined to better than +/_ 1.4%. The trees total leaf area was computed from the sum of the areas of all the bagged leaves

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4.0 Results

A complete set of data was available for 93 trees. This covered the tree diameter range of 3 cm to 78 cm and a range of leaf areas from 1 m^2 to 470 m^2.

TABLE 2. Variable names and units used in the discussion of results.

Name	Units	Description
Area	m2	The total tree single sided leaf area
DBH	cm	Tree diameter at 1.3 m over the bark
DBHUB	cm	Tree diameter at 1.3 m under the bark
Bark	cm	Average bark depth
Top	m	Tree height
Bot	m	Height to base of crown
Depth	m	Crown depth = Top - Bot
Width	m	Crown width
Boxcent	no units	Percentage occupation of box defined about the crown
Crown	no units	Percentage density of crown defined by compatison to standards sheet
Pos	no units	Grimes crown position variable
Siz	no units	Grimes crown size variable
Den	no units	Grimes crown density variable
Seed	no units	Grimes type crown seeding variable

4.1 CORRELATION BETWEEN VARIABLES

The intention of this data analysis was to produce equations for predicting the leaf area of individual trees. The development of these equations commenced with an inspection of the total correlation matrix and the subsequent selection of the most significant variables to use in describing the two leaf area attributes, crown size and leaf density.

The correlation matrix of the tree dimensional variables (table 3) provides an indication of the relationship between the variables that could be used to describe crown size. Included in this table are the natural logarithmic transformations of some variables.

Log transformations have been widely applied to the analysis of biological data. They are well known as a means of linearizing the simple bivariate curves

$$Y = aX^{b}$$

$$Y = be^{mX}$$

and $$Y = b + m \ln X$$

where b and m are constants, Y is the dependant variable and X the independant variable. These logrithmic transforms are less commonly applied in multiple regression analysis but are equally suited where similar conditions apply.

For least squares curve fitting to produce reliable estimates of the equation coefficients, the data set, transformed or otherwise, must meet certain criteria. These requirements, detailed by Zar (1974), are listed below.

1. For each value of X (the independant variable) a normal population of Y values must exist and this population should be sampled randomly.

2. The variances of these distributions of Y should be the same throughout the range of X ie. homoscedacity.

3. The errors in Y should be additive. ie. there is a linear relationship between X and Y.

4. The values of Y are independant from one another, ie. there is no relationship between the Y values.

5. Measurements of X must be obtained without error. In fact this is not possible but it is assumed they are smaller than the errors in Y

Scatter plots and analysis of the residuals of this data set showed that the (lnX, lnY) transformation was appropriate for regressions between leaf area and all of the tree dimensional measurements as well as Den. For identical reasons the (X, lnY) transformation was applied to the Grimes assessments Siz, Pos and Seed. For many of the relationships within this data set these log transformations improve the correlation.

From examination of the correlation matrix, the variables measured, can be seperated into 3 groups. These groups are:

1. The tree dimensional variables, DBH, width, top, bot, depth.
2. Grimes tree size variables, pos and siz.
3. and Density measures, crown and Grimes den and seed

Correlations exist within these groups and all groups are correlated with leaf area. However, correlation between these variable groupings is poor. Groups 1 & 2 contain variables that are measurements of tree size, group 1 containing actual dimensions and group 2 subjective estimations. Though there is some correlation between group 1 and 2, the sliding nature of the subjective measurement scale makes the group 2 Grimes measurements independant from the tree dimensions. As measurements of leaf density the variables in group 3 are completely independant of tree size.

Leaf area increases with tree size. Hence any of the size variables in group 1 and 2 provide a basic measurement that can be related to leaf area. However, some of these variables are more informative because they provide a measurement of the actual leaf bearing portion of the tree. Crown depth is the primary measure of crown size and is superior to the two related variables tree height and Bot in establishing this size. When combined with Depth, Width refines this estimate of crown size. Further refinement is obtained with the inclusion of Siz, which considers the crown fullness and proportions in 3 dimensions.

Dbh is a fundamental measurement of tree size and is well correlated with all of the variables that measure size. It can take the place of Depth as an initial estimator of crown size.

Once this crown size is defined by, for example, a combination of the variables

depth, width and siz

the estimate of leaf area may be further refined by consideration of the crown density. Both of the grimes variables Den and Seed are density measures as is the assessment Crown. While Den and Crown directly measure crown density, seed provides an indirect assessment of density because of the relationship between leaf loss and fruiting in jarrah. (When carrying a seed crop, jarrah shows marked leaf loss on branchlets adjacent to the fruit cluster). The inclusion of one of these variables completes the regression model so that the 2 factors of crown volume and leaf density within that volume have been described.

Correlation for tree dimensions and log transformed tree dimensions

CORR	BARK	DBH	DBHUB	WIDTH	TOP	BOT	DEPTH	LNWIDTH	LNDEPTH	LNAREA	LNDBHUB
BARK	1.00										
DBH	0.61	1.00									
DBHUB	0.58	1.00	1.00								
WIDTH	0.59	0.84	0.84	1.00							
TOP	0.38	0.82	0.83	0.55	1.00						
BOT	0.13	0.47	0.48	0.25	0.75	1.00					
DEPTH	0.45	0.79	0.79	0.59	0.79	0.20	1.00				
LNWIDTH	0.57	0.81	0.81	0.94	0.65	0.34	0.65	1.00			
LNDEPTH	0.44	0.74	0.74	0.59	0.82	0.32	0.93	0.71	1.00		
LNAREA	0.40	0.75	0.75	0.63	0.75	0.32	0.82	0.69	0.86	1.00	
LNDBHUB	0.51	0.91	0.92	0.76	0.90	0.59	0.80	0.84	0.86	0.81	1.00
AREA	0.31	0.65	0.65	0.58	0.49	0.03	0.71	0.55	0.60	0.77	0.59

TABLE 3. Correlation matrix of tree size variables measured on 93 trees.

Correlation coefficient r for:

	Bark	DBH	DBHUB	Width	Top	Bot	Depth
Bark	1.000						
DBH	0.613	1.000					
DBHUB	0.569	0.998	1.000				
Width	0.579	0.841	0.836	1.000			
Top	0.381	0.821	0.828	0.552	1.000		
Bot	0.127	0.468	0.478	0.251	0.753	1.000	
Depth	0.450	0.790	0.791	0.591	0.793	0.196	1.000
Area	0.315	0.650	0.655	0.580	0.492	0.030	0.706

4.2 REGRESSIONS

The models developed here all make use of these two variable groupings. Estimation of leaf area relies initially on determination of the crown size and secondarily on estimations of the crown leaf density.

The data was analyzed using the stepwise regression procedure available through the SAS statistical package (1985). Several variable combinations were used to determine the variety of regressions that could be produced. This procedure highlighted two points. Firstly, the log transformation of Area and the dimensional variables produced superior regressions, and secondly, the box based assessments of crown size and crown density were inferior to the subjective assessments of these same attributes. And thirdly linear combinations of the measured variables did not perform as well as the multiplicitive combinations produced by the regression procedure.

The multiplicitive combination of variables that results from this approach of combining transformed variables is conceptually suited to estimating leaf area. The additive combinations that would result from nonlinear regression of the untransformed variables are not consistent with determining an area which increases multiplicitively with density and volume.

With the number of variables available, a variety of regression combinations were produced. The following regressions for determining the leaf area of individual trees were produced.

$$\text{Area} = \text{DBHUB}^{1.739} \times 0.1414$$

$$N = 112 \quad r^2 = 0.71$$

$$Area = Depth^{1.95} \times 0.611$$

N = 94 $r^2 = 0.71$

$$Area = Depth^{1.560} \times Den^{1.431} \times 0.176$$

N = 96 $r^2 = 0.86$ C(p) = 148.85

$$Area = Depth^{0.820} \times Den^{1.611} \times Width^{0.936} \times 0.150$$

N = 96 $r^2 = 0.94$ C(p) = 17.50

$$Area = DBHUB^{0.831} \times Depth^{0.282} \times Width^{0.542} \times e^{0.162 \times Siz} \times Den^{1.288} \times e^{-0.113 \times Seed} \times 0.0793$$

N = 94 $r^2 = 0.96$ C(p) = 6.4

$$Area = DBHUB^{1.052} \times Den^{1.331} \times Width^{0.532} \times e^{-0.125 \times Seed} \times e^{0.171 \times Siz} \times 0.0678$$

N = 94 $r^2 = 0.96$ C(p) = 3.4

$$Area = DBHUB^{1.516} \times Den^{1.236} \times e^{0.317 \times Siz} \times e^{-0.115 \times pos} \times e^{-0.098 \times Seed} \times 0.035$$

N = 94 $r^2 = 0.95$ C(p) = 6.0

$$Area = Depth^{0.747} \times DBHUB^{0.541} \times e^{0.777 \times Siz} \times 0.117$$

N = 94 $r^2 = 0.86$ C(p) = 3.2

$$Area = Depth^{0.652} \times Den^{1.40} \times Width^{0.934} \times e^{0.176 \times pos} \times e^{-0.090 \times Seed} \times 0.207$$

N = 96 $r^2 = 0.95$ C(p) = 7.44

VARIABLE RANGES

N = 114

Variable	Minimum	Maximum	Mean	Std Dev
AREA	1.01	470.89	55.80	77.86
BARK	0.67	3.30	1.84	0.52
DBH	5.60	83.40	28.27	14.12
DBHUB	3.24	77.90	24.60	13.53
WIDTH	1.00	17.02	5.05	2.99
BOXCENT	26.00	93.00	73.02	10.16
CROWN	20.00	95.00	53.97	19.65
TOP	4.56	35.28	18.99	5.75
BOT	2.58	19.60	11.03	3.72
DEPTH	0.85	22.40	7.96	3.60
SEED	1.00	6.00	2.64	1.32
POS	1.00	5.00	3.13	1.07
SIZ	1.00	4.75	3.04	0.75
DEN	1.00	8.75	4.35	1.64
LNAREA	0.01	6.15	3.31	1.28
LNWIDTH	0.00	2.83	1.46	0.57
LNDEPTH	-0.16	3.11	1.95	0.56
LNDBHUB	1.18	4.36	3.04	0.62
LNSIZ	0.00	1.56	1.08	0.28
LNDEN	0.00	2.17	1.40	0.39

5.0 Discussion

Within a species, the leaf area of an individual tree is strongly related to the tree size. Therefore, any measurement that is a surrogate of tree size is capable of providing sufficient information to assess leaf area. More accurate determination requires some attempt at measuring the actual crown. In jarrah, DBHOB, tree height, and crown depth are reliable measures of tree size. These size measures show power curve relationships to leaf area. The addition of measurements of crown width, crown density, and crown size provide a more complete description of the leaf area. DBHUB is highly correlated to tree height across a variety of sites.

The assessments of crown size and crown density that were based on comparisons with standard sheets were not as usefull as the Grimes assesments of these characteristics. The Grimes assessments are subjective, and place a responsibility on the assesser to produce a reliable classification. The usefullness of these assessments is demonstrated by their significant contributions to the leaf area regressions. In the development of these regressions the grimes assessments provided more information than the comparitive assessments. However the use of any subjestive assessment requires a committment to the technique, regular practice and constant checking for deviation from the intended method. Without this discipline subjective assessments are inappropriate.

6.0 Conclusion

These regressions provide a labour intensive but accurate method of determining the leaf area of individual jarrah trees and small plots.

7.0 Acknowledgements

I would like to thank Geoff Stoneman for his advice throughout this project and the field staff who completed the leaf stripping.

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Correlation

CORR	BARK	DBH	DBHUB	WIDTH	BOXCENT	CROWN	TOP	BOT	CANDEPTH	SEED	POS	SIZ	DEN
BARK	1.000												
DBH	0.613	1.00											
DBHUB	0.569	0.998	1.000										
WIDTH	0.579	0.841	0.836	1.000									
BOXCENT	0.057	0.042	0.040	-0.033	1.000								
CROWN	-0.024	0.156	0.164	-0.000	0.141	1.000							
TOP	0.381	0.821	0.828	0.552	-0.038	0.205	1.000						
BOT	0.127	0.468	0.478	0.251	-0.032	-0.025	0.753	1.000					
CANDEPTH	0.450	0.790	0.791	0.591	-0.027	0.329	0.793	0.196	1.000				
SEED	0.295	0.323	0.316	0.399	-0.016	-0.544	0.189	0.251	0.049	1.000			
POS	0.437	0.755	0.756	0.567	-0.038	0.301	0.830	0.589	0.691	0.220	1.000		
SIZ	0.470	0.692	0.687	0.604	0.106	0.434	0.558	0.162	0.681	0.038	0.690	1.000	
DEN	-0.018	0.185	0.194	0.055	0.043	0.848	0.227	-0.101	0.431	-0.597	0.310	0.571	1.000
TTAREA	0.315	0.650	0.655	0.580	0.072	0.513	0.492	0.030	0.706	-0.182	0.504	0.654	0.600

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orrelation

CORR	BARK	DBH	DBHUB	WIDTH	BOXCENT	CROWN	TOP	BOT	CANDEPTH	SEED	POS	SIZ	DEN	LNWIDTH	LNDEPTH	LNTTAREA	LNDBHUB	LNSIZ	LNDEN
BARK	1.000																		
DBH	0.613	1.00																	
DBHUB	0.579	0.998	1.000																
WIDTH	0.589	0.841	0.836	1.000															
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BOT	0.127	0.468	0.478	0.251	-0.032	-0.025	0.753	1.000											
CANDEPTH	0.450	0.790	0.791	0.591	-0.027	0.329	0.793	0.196	1.000										
SEED	0.295	0.323	0.316	0.399	-0.016	-0.544	0.189	0.251	0.049	1.000									
POS	0.437	0.755	0.756	0.567	-0.038	0.301	0.830	0.589	0.691	0.220	1.000								
SIZ	0.470	0.692	0.687	0.604	0.106	0.434	0.558	0.162	0.681	0.038	0.690	1.000							
DEN	-0.018	0.185	0.194	0.055	0.043	0.848	0.227	-0.101	0.431	-0.597	0.310	0.571	1.000						
LNWIDTH	0.571	0.814	0.808	0.936	-0.172	0.018	0.646	0.341	0.647	0.397	0.653	0.612	0.077	1.000					
LNDEPTH	0.437	0.745	0.745	0.594	-0.139	0.292	0.821	0.316	0.930	0.054	0.738	0.657	0.403	0.706	1.000				
LNTTAREA	0.396	0.746	0.749	0.628	-0.042	0.562	0.749	0.318	0.822	-0.151	0.731	0.818	0.672	0.689	0.865	1.000			
LNDBHUB	0.514	0.915	0.917	0.762	-0.094	0.184	0.902	0.587	0.800	0.271	0.840	0.644	0.219	0.841	0.860	0.813	1.000		
LNSIZ	0.468	0.634	0.627	0.550	0.090	0.449	0.518	0.148	0.635	0.012	0.659	0.979	0.576	0.567	0.622	0.788	0.594	1.000	
LNDEN	0.022	0.193	0.200	0.055	0.060	0.796	0.245	-0.070	0.429	-0.588	0.311	0.604	0.957	0.063	0.411	0.677	0.213	0.629	1.000
TTAREA	0.315	0.650	0.655	0.580	0.072	0.513	0.492	0.030	0.706	-0.182	0.504	0.654	0.600	0.553	0.603	0.769	0.591	0.586	0.539