Tree traits that define timber ideotypes of *Gmelina arborea* Roxb.

S F Vallesteros

Department of Forestry and Agroforestry, College of Forestry Nueva Vizcaya State University, Bayombong, Nueva Vizcaya, Philippines

E-mail: sfvallesteros@gmail.com

**Abstract.** Gmelina (*Gmelina arborea* Roxb.) is the most widely planted tree species in the province of Nueva Vizcaya, Philippines. Its role in local wood supply becomes more important as a consequence of the ban on harvesting naturally growing timber. More than 90% of the wood supply, based on reported transactions in 2013, is gmelina. Wood is coming from different planting configurations such as solitary trees, home gardens, road sides, riparian strips, small stands, and large plantations. While gmelina appears to be the most important tree in meeting local demand for wood, the yield per hectare is low due to poor tree management and mismatch between species and site. Results indicate great potentials for tree improvement with effort coming from the tree owners themselves and supported by scientific approach in tree improvement. Research on ideotype, or conceptual model of an ideal plant, promises to play a key role. The study worked on gmelina timber ideotype. Between-tree-trait relationships were investigated in order to see what traits might be subjected for simultaneous improvement. Significant relationships came out that would lead to defining the desired tree forms. Not a single form shall come out as combination of traits may result in increased in wood yield in tree or stand.

1. Introduction

Government policies banning harvesting of naturally growing timber from both private and public lands have resulted in shortage of wood supply in most part of the Philippines [1]. Fortunately, Nueva Vizcaya is endowed with vast tract of lands planted to trees, predominantly fast growing exotic species such as *Gmelina arborea* and *Swietenia macrophylla*. Trees planted on roadsides, farms, house surroundings, home gardens, pastures, parks, and land property boundaries have become the lifeblood of wood-based businesses. Planted trees are cut chiefly for furniture, fixtures, general construction, and fuel wood [2].

Gmelina gets the lion’s share of the local wood supply volume constituting around 70% of the total local wood supply [3]. In the province, gmelina wood can be seen everywhere as furniture, fixtures, panel board, construction lumber, form lumber, house structural members, fencing material, and firewood. The phenomenal planting of the species in the past in both private and public lands, across wide range of geographical condition, contributed to the dominance of the species in terms of land cover and wood yield. However, whether supply will last or not for a long period of time remains uncertain.

In the next few years, supply of gmelina wood may decline as the rate of harvesting is faster than the rate of regeneration. People see gmelina as the major source of wood particularly for furniture and general construction purposes. People easily gets permit for cutting gmelina and other exotic fast growing timber species. However, young trees are also cut because of high demand for wood triggered...
by the increasing number of furniture shops and lumber traders dedicated to gmelina and mahogany and coupled with the absence of regulation on cutting concerning timber maturity and wood quality.

Tree traits such as tolerance to a wide range of field situations, fast growth [4], ease of cultivation [5] and ability of the stand to regenerate through seeding and coppice [6], prompt tree owners to minimize maintenance activities for trees and stands. As a result, investment is focused on land preparation and planting.

Despite of bole defects, low yield of unmanaged trees and stands, and environmental issues against the species, gmelina remains to be the top choices of farmers and tree owners [7]. Tree owners aiming to cut timber in less than 10 years, regenerate the stand or plantation easily through natural seeding and coppice, and enjoy relaxed government regulation on tree cutting and harvesting, pick gmelina as the top species choice.

Ideotype development shall be part of the tree improvement and tree management approaches [8]. Ideotype refers to the conceptual model which explicitly describes plant phenotypic characteristics that are hypothesized to produce greater yield [9]. Ideotype is mostly based on morphological characteristics but may also include biochemical, physiological, or other attributes of desirable phenotypes. Many tree improvement programs begin with selection of promising phenotypes from natural populations [9].

The study captures a number of relationships between tree traits hence, providing idea of what traits could be improved simultaneously. The improvement is focused on wood or lumber volume in bole, which is related to bole length, straightness and circularity, and number of stems in a tree. This paper provides information on the relationships between tree traits.

2. Research Methods

2.1. Study area

Thirty-four sites located within five adjoining municipalities of the province of Nueva Vizcaya were selected. The sites are within 121°4’ and 121°20’ east longitudes; and within 16°26’ and 16°38’ north latitudes. The area is experiencing Type 3 climate described as relatively dry from November to April and relatively wet during the rest of the year. The average annual rainfall is around 1,900 mm. Average monthly temperature ranges from 22 to 28°C. Slope ranges from 1.89% (nearly level) to 53.87% (very steep). Elevation also varies considerably ranging from 243 to 725 m asl. with a mean of 340 m asl.

2.2. Field measurements and observations

Plots, having a dimension of 20m x 20m, were established in all tree planting configurations including hedges and scattered trees. The number of which per site depends on the size of the plantation, farm or area of interest. The minimum number of plots per site was three. Plots were distributed in the area of interest such that differences in stand and site attributes were captured by sampling. All plots have the same orientation: the sides are along the compass cardinal directions, i.e., N-S, E-W. The location of the plot is defined by the coordinates of its lower-left corner. Adjacent plots must be separated by at least 40 meters, center to center. All gmelina trees 10 cm in DBH and larger were measured.

Standards were followed in the measurement of DBH, MH and TH. Measurements of these commonly observed tree dimensions were based on the Philippine National Forest Inventory Field Manual [10]. However, particular attention was made on MH such that the upper limit of the MH was not necessarily the first major branch. The MH can be extended to include at least 1-m section after the first major branch.

Straightness of the bole was defined in terms of absence and amount of sweeps and crooks along the bole. Crown height and width were estimated visually or with the aid of height pole. In order to increase accuracy and consistency of estimates, crew members’ estimates were calibrated. Subjectivity in measurement was expected in the course of observations and measurements except for DBH, short MH and lean. Use of sample photographs and line drawings greatly increased precession among observations.
3. Results and Discussion

3.1. Stand dimensions
The average tree height of the stands was 12.63 m while the mean merchantable height was 6.49 m. The average DBH was 22.66 cm, which is proportional to the total height. Most of the trees tend to have circular stem at DBH point. They also tend to have thick stems relative to their merchantable height.

As regards crown, most of the trees have crown that is longer than wide. Most trees assume this proportion whether the crown is fully illuminated or shaded, or whether the bole is long or short. Most of the crowns are compact suggesting vigorous growth of branches.

The closeness of the means and the medians of the datasets suggests normal distribution of values. Minimum and maximum values are governed by the scope of the data collected in the field, hence, particularly useful for describing the tree form models or the gmelina ideotypes.

3.2. Forking and lean
Occurrence of forking is not common among the stands averaging only around 15%, of which around 13% is categorized as double splits. Fork is classified as a defect because it causes reduction in volume or yield of any product. However, the survey crew noted that most of the forked stems exceeded 1 m, hence, the logs can be cut into short sections suitable for different uses. Likewise, occurrence of lean is not widespread. Less than 22% of the trees in a stand is leaning based on the definition that a tree is considered leaning if it deviates more than 10° from its natural vertical position. Lean is principally associated to stem movement in order for it to position its foliage for maximum light interception as well as to the effect of wind blow.

3.3. Basal bend
Basal bend refers to the bend, whether gradual or abrupt, within one-meter section of the main trunk. Majority of the stands contain trees with basal crook although the percentage of trees containing basal bend in each stand hardly exceeded 20%.

3.4. Bole Straightness
The stands taken collectively, an average of 24.44% occurrence of sweep and crook was recorded. It implies higher chance of getting straight logs from each tree. In fact, 65.56% of the trees in a stand contain log section that is equal or longer than 3-m log. In order to better visualize the straightness of the bole, the bole is sectioned into 3 m logs and rated as straight, sweep or crook. Only the first two sections were considered because many trees had less than 6 m merchantable height.

Straight logs were more common in the first 3-m and second 3-m sections, with 60% and 48% occurrences, respectively. The amount of sweep logs (45%) in the second section is close to that of straight logs. Crook logs were uncommon among trees in the stands.

3.5. Upright branches or shoots
Formation of upright branches is common in gmelina. This upright branches, operationally defined here as stem inclined by less than 20° from the vertical, are important in increasing timber volume. Upright branches may emanate from the main trunk or from horizontally oriented first order branches. Formation of these branches is associated to reduction in apical dominance. When they grow vigorously, they grow into size that contributes wood volume, hence, sometimes referred here as “extra log”. Trees whose main crown is cut or heavily disturbed commonly develop upright branches close to the point of cutting or disturbance.

One hundred percent of the stands contain “extra logs” ranging from 1 to 2.67 pieces. The average number of upright branches was 1.68 while the average length was 1.71 m. The average was low because many trees had no such kind of branches. The maximum length computed for the stands was 2.5 m.
3.6. Bole straightness and merchantable height

It was clear that bole straightness is positively and significantly correlated with merchantable height. Longer MH is associated with higher number of 3-m straight bole sections anywhere along the main stem. It must be mentioned, however, that in this study the bole is sectioned into 3-m sections. It is the percentage occurrence of straight 3-m sections that is correlated with MH, which ranges from less than 3 m to 18 m. Nonetheless, the correlation coefficients decrease as the log section gets further from the tree base (0.7126 for the first section, 0.6988 for the second, 0.3778 for the third), which means that bending occurs more often at higher position in the stem. Contributing to this situation is the crowding of branches at the canopy level causing bending of the main trunk at that level.

3.7. Bole straightness and crown traits

The straightness of the first bole section is moderately correlated with other tree traits such as crown compactness \( r = -0.4893 \), branch angle \( r = 0.3569 \), and upright branches \( r = 0.4001 \). As supported by correlation between crown compactness and bole straightness, it appears that compact crown, which is usually heavy, promotes bending of the bole particularly within the first \( r = -0.4893 \) and second sections \( r = -0.3471 \).

Compact crown is associated with shorter trees and larger diameter. Compact crown, which means larger volume of foliage, produces more photosynthesize. Production of large volume of photosynthesize encourages diameter growth throughout the length of the main stem [11]. Conversely, thin crown with loose foliage is commonly associated with tall trees as tree with small crown has its energy concentrated to elongation of the main stem [11]. In addition, crown asymmetry, especially at young age, is known to be associated with bole bending. Branches tend to move towards larger space and higher amount of sunlight, and so does the main bole.

As regard upright branches, thick and straight stem tends to produce long vertically oriented shoots emanating from the point where branches split. Straight main stem or bole, an indication of tree vigour throughout the growing period, tends to produce branches that assume the behaviour of the main bole, which is to elongate upward. Trees of this kind may produce more timber volume than a tall, thin diameter tree of the same age.

Bole straightness appears to be affected by branch angle, or it is the other way around. The straightness of the first two bole sections is positively correlated to branch angle. Trees with vertically oriented first order branches tend to be more straight not only in the first section \( r = 0.3569 \) but also in the second section \( r = 0.3564 \). Formation of horizontally oriented branches, or flatter-angled branches [12], which may droop when foliage is heavy, is a common manifestation of poor tree vigour and disturbance sustained by the tree [13]. It was observed that trees growing in difficult sites and those disturbed by fire often have drooping branches. When lateral growth tends to grow past the height growth, much plant energy is channelled to branch development. However, plagiotropic branching tends to produce large crown thus putting increased more pressure to the bole resulting in higher occurrence of sweep and crook logs.

3.8. Sweep, crook and bending

While it was discussed earlier that straight bole up to the third log section is common in trees with longer merchantable height, it was found out that formation of sweep logs is likewise common in longer bole, i.e., logs exceeding 9 m long \( r = 0.9015 \) for 10-12 m section; and \( r = 0.8662 \) for 13-15 m section). Tree vigour diminishes with ages, hence, upper log sections are often sweep or even crook. Another thing is that slower height growth tends to encourage formation of larger branches that tend to persist in contrast to small branches that tend to die off shortly.

Consistent with merchantable height is the total height. Taller trees tend to contain sweep logs in the upper section of the bole \( r = 0.6557 \) for third bole section (9-12 m).
Forked trees tend to have sweep in the first 3-m bole section \( (r = -0.6149) \), 1 is assigned to stem that is not fork). This is an expected condition because the stems tend to push each other out. However, when the stem has found its place, it tends to straighten. The formation of sweep in the 1-3 m and 7-9 m bole sections was not predicted by the occurrence of forked stem.

Boles containing crooks within 1-3 m section have short bole \( (r = -0.3529) \) or much shorter in proportion to total height \( (r = -0.5955) \). Abrupt bending in gmelina appears to be associated with growth disturbance resulting in underdevelopment in terms of bole length and height. Majority of the trees with crooked stems are stunted.

What is true for the first bole section is true for the second bole section \( (4-6 \text{ m}) \). Occurrence of crook stems is significantly but negatively correlated with total height \( (r = -0.3529) \), number of logs greater than 3 m \( (r = -0.3689) \), and occurrence of long boles \( (r = -0.3679) \). In addition, the occurrence of both sweep and crook defects in individual tree is likely.

In terms of amount of bending, the study found out that lean induces bending \( (r = -0.3495) \) on the main stem. Young trees are more sensitive to bending due to disturbance. They easily succumb to load and stress such as when they are used as pole to secure animals, cloth line, and similar uses. Further, the correlation coefficient suggests that bending at the butt section is more likely. However, sweep in the first 3-m section is also associated with higher amount of bend \( (r = 0.3675) \).

Basal bend occurrence in stands tends to be directly proportional to the stand’s merchantable height \( (r = 0.4434) \) although not significantly correlated to total height. The occurrence of basal bend does not lead to shortness of bole. It is, in fact, positively correlated to the higher number of sections greater than 3 m \( (r = 0.4268) \) and to maximum bole length \( (r = 0.5180) \). Moreover, basal bending seems to encourage formation of straight bole at the second 3-m section \( (r = 0.5042) \). Bending at the base may be interpreted as quick response of young plant to lack of sunlight. Upon positioning the crown, the tree tends to form straight bole. As trees with basal bending tend to have larger base, it is interesting to know whether these trees tend to possess larger root volume as well.

3.9. **Bole roundness**

Bole roundness seems to be independent of any other tree or stand characteristics except for the number of logs greater than 3 m \( (r = 0.4050) \) and crown compactness \( (r = -0.4967) \). Bole roundness and long straight log combination is highly desirable for saw log production \[14\]. Trees possessing both traits yield timber that converts well to lumber.

Even distribution of branches or branch symmetry implies even distribution of nutrients elaborated in the crown to the other parts of the tree \[11\]. Even distribution would mean higher chance that bole would be circular.

3.10. **DBH and height**

The ratio between DBH and TH of the tree provides a glance of the general architecture of the tree, i.e., how the tree would look like from a far. As expected, correlation between DBH and TH yields a positive value and significant \( (r = 0.3690) \). In order to support the weight of the crown, DBH must be proportional to height \[15\]. However, DBH does not correlate with MH \( (r = -0.0032) \) suggesting wide variation in DBH and MH relationship.

DBH-MH ratio is an indicator of the volume of the crown or crown spread \[16\]. Chances are the higher the ratio, the larger the crown \( (r = 0.5668) \). In other words, short-bole trees often possess large crowns \[17\], assuming the correct proportion of bole strength and weight of the crown. In fact, the correlation coefficient between MH-DBH ratio and maximum length of straight bole is \(-0.4947\). Similarly, DBH-MH ratio is positively correlated with the compactness of the crown \( (r = 0.3517) \), albeit weak.

Trees that form branches positioned low on stem at relatively young age often possess short stems that contain bends, either sweep or crook as indicated by the \( r \) value of \(-0.6693 \) between DBH-MH ratio and Straight_1-3, between DBH-MH ratio and Crook_1-3 \( (r = 0.4164) \), and between TH-MH ratio and Straight_1-3 \( (r = -0.4945) \). This observation is based on a number of young trees, aged between 3 and
5 years, in the field possessing such trait and on the examination of branch scars on the bole of mature
trees. Branches persist for a number of years and grow together with the main trunk.

3.11. Crown traits
The correlation coefficient of 0.7442 between crown depth and crown diameter suggests that crown
diameter enlarges with crown depth. As to what shape the crown may assume, the relationship between
crown diameter and total height ($r = 0.4698$) and crown depth and total height ($0.6884$), the latter having
larger $r$ value, suggests that a crown longer than wide is more likely; hence, in most cases, gmelina trees
possess more or less ovate crown.

In general, most of the first order branches assume near horizontal orientation rather than incline in
small angle from the longitudinal axis of the stem. The branches are clustered towards the tip of the
main stem and the bole is rather slender and devoid of branches. Trees normally give priority to height
growth [11], and when height growth is fast lateral expansion of the crown becomes slow. Branch
growth may be limited by crowding [18]. In addition, crown recession reduces crown size [19].

Crown that is wider than tall tends to be associated with bole that is sweep ($r = 0.4296$) particularly
within the first 3-m section, or crook in the upper section (7-9-m section, 0.3839). In like manner, the
amount of bending based on the actual number of curvature in the bole seems to be positively correlated
with higher crown diameter-crown depth ratio.

Crown is also affected by tree lean. Leaning trees tend to have broader crown ($r = -0.3993$). To
assume the upright position, vertically oriented branches are developed on the upper side of the lean
while on the lower side, horizontally oriented branches tend to elongate and sometimes droop.

3.12. Upright branches or “extra logs”
Results of correlation analysis indicates that trees forming these stems tend to be associated with tall
trees ($r = 0.3471$). The apical dominance appears to be revitalized as the stems shoot up long. In general,
merchantable height is also long ($r = 0.3939$) and the stems are commonly straight.

The stems normally develop into relatively long and clear bole that are used or harvested in the same
way as the main bole. Tall trees also tend to develop more of these branches ($r = 0.5224$). These branches
may arise singly from a branch node or in group, ranging from two to five pieces based on the data.

In the point of view of timber production, formation of vertically oriented branches or upright
branches in gmelina may be a desirable characteristic. These branches usually develop into timber-size
(or 15 cm diameter, ≥ 1 m in length) trunks that can be harvested to produce lumber. Presence of these
secondary main stems and vertically oriented branches increases the lumber yield of the tree. The
branches arise from the main trunk, often at the point where the main trunk terminates to give rise to
two or more branches of almost equal size.

Because of the position of the vertically oriented branches along the main trunk and their variation
in length, the crown of the tree that has several vertically oriented branches tend to be elongated ($r =
0.4631$). However, the crown tends to be loose ($r = -0.4669$) probably due to generally small number of
horizontal branches (second order branches) as plant nutrient tends to be channeled to elongating the
main branch rather than the secondary ones.

Correlation analysis found several notable relationships involving “extra log”. One is that the
umber of stems is positively correlated with straightness of first bole section. It appears that straight,
more stable bole, tend to often possess more of these “extra logs” than a sweep or crook trunk.

4. Conclusions
Analysis of the different relationships resulted in describing several tree models, which were grouped
into three categories. The models or ideotypes include highly desirable forms plus those that can be
considered as second choices. The first category is expected for well-managed stands located in good
sites. This ideotype is described as a tree with straight bole that is branchless within at least five m
section of bole. If there are branches, they must be small and would die out causing no significant knot
defect in lumber. Trees possessing such quality of bole are often associated with small crown where first order branches are inclined more than 45° from the vertical axis of the stem. Most of the trees have crowns that are taller than wide.

The second-choice ideotypes are recommended in situations where control of stand characteristics is less optimal such as in coppice and wide-spacing situations. For example, the practice of coppice is characterized by lack of sprout management and irregular spacing. On the other hand, wide-spacing situations are associated with shorter bole and large branches, but improvement is likely by way of inducing the development of branches that assume the role of the main stem or bole.

The study contains rich information vital to tree improvement process. The status that gmelina enjoys, that is being the primary source of wood for large number of uses, shall inspire efforts in revitalizing attention to the species so that sustained wood supply is achieved.

References
[1] Guiang E S 2001 Impacts and effectiveness of logging bans in natural forests: Philippines Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Chapter 8 pp. 103-137.
[2] Briones M B, Vallessteros A P 2004 The phenomenal planting and utilization of Gmelina arborea Roxb. in Bayombong Nueva Vizcaya Meristem 4 30-39.
[3] FMB 2013 Philippine Forestry Statistics Forest Management Bureau - Department of Environment and Natural Resources Quezon City.
[4] Ajayi O C, Place F 2012 Policy support for large-scale adoption of agroforestry practices: experience from Africa and Asia In Nair P K, Garrity D (Eds.) Agroforestry: The Future of Global Land Use Springer pp. 175–201.
[5] Roshetko J M, Mulawarman P 2003 Gmelina arborea – aviable species for smallholder tree farming in Indonesia? Recent advances with Gmelina arborea CAMCORE.
[6] Alipon M A, Bondad E O 2011 Comparative strength and related properties of Yemane (Gmelina arborea Roxb.) coppice and planted stand Phil. J. Sci. 140 2 231-238.
[7] Vallessteros A P 2015 Management of planted trees: a discussion paper for FRM 200 Advanced Forest Management College of Forestry Phillipines.
[8] Vallessteros S F 2009 Development of oil ideotype in selected provenances of Jatropha curcas L. University of the Philippines Los Baños Los Baños.
[9] Martin T A, Johnsen K H, White T L 2001 Ideotype development in southern pines: Rationale and strategies for overcoming scale-related obstacles Forest Sci. 47 1 21-28.
[10] Branthomme A 2002 National forest inventory Philippines In Field Manual Forestry Department Philppines.
[11] Larsen D R, Bliss L C 1998. An analysis of structure of tree seedling populations on a Lahar Landscape Ecol. 13 307-322.
[12] Madgwick H A I 1994 Pinus radiata biomass, form and growth Madgwick Rotorua.
[13] Zimmermann M H, Brown C L 1971 Trees structure and function Springer-Verlag.
[14] Ahuja M R, Libby W J 1993 Clonal forestry II conservation and application Springer-Verlag.
[15] Bartelink H H 1996 Allometric relationships on biomass and needle area of Douglas-fir Forest Ecol. Manage. 86 1–3 193–203.
[16] Dhillon G P S, Singh A, Sidhu D S, Brar H S 2013 Variation among poplar clones for growth and crown traits under field conditions at two sites of North-western India J. Forest Res. 24 1 61-67.
[17] Echereme C B, Mbaekwe E I, Ekweelor K U 2015 Tree crown architecture: approach to tree form, structure and performance: a review Int. J. Sci. Res. Pub. 5 9 1-6.
[18] Mäkine H, Colin D F 1998 Predicting branch angle and branch diameter of Scots pine from usual tree measurements and stand structural information Canadian J. Forest Res. 28 11 1686-1696.
[19] Garber M S, Monsrud R A, Maguire D A 2008 Modelling crown recession in three conifer species of the Northern Rocky Mountains forest growth and timber quality Forest Sci. 54 6 633-646.