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Reliability of Height Estimates of Some Teak Plantations Using Existing Aerial Photographs

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Abstract

The concept of estimating quantitative stand characteristics from aerial photography is not new, but rarely put into practice. The use of aerial photographs to supplement costly field work is a continuing interest among inventory researchers. This paper is an attempt to find out how reliable are the height measurements of teak plantations as estimated from aerial photographs of 1 : 25, 000 scale against ground measurement for stand height estimation.

ကျွန်းစိုက်ခင်းများ၏ အမြင့်ကို ကောင်းကင်ဓါတ်ပုံများ အသုံးပြု၍ တိုင်းတာခန့်မှန်းခြင်း

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အကြီးတန်းသုတေသနမှူး၊ သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

ကောင်းကင်ဓါတ်ပုံများကို အသုံးပြုခြင်းအားဖြင့်၊ သစ်ပင် သစ်တောများနှင့် ဆက်စပ် လျက်ရှိသည့် အချက်အလက် များကို တိုင်းတာခန့်မှန်းနိုင်သော်လည်း အလွန်အသုံးနည်းလှပေသည်။ သစ်တောများကို စာရင်းကောက်ယူရာတွင် ကွင်းဆင်း၍ တိုင်းတာခြင်း နည်းစနစ်မှာ ငွေကုန်ကြေးကျ များလှသဖြင့် ကောင်းကင်ဓါတ်ပုံကို အသုံးပြု၍၊ ခန့်မှန်းရန် စိတ်ဝင်စားမှု ရှိလာကြပါသည်။ ယခု စာတမ်းမှာ မြန်မာနိုင်ငံရှိ ကျွန်းစိုက်ခင်းများ၏ စိုက်ခင်းအမြင့်ကို လက်ရှိ ၁း၂၅၀၀၀ စကေး ကောင်းကင် ဓါတ်ပုံများ အသုံးပြု၍၊ ခန့်မှန်းရာတွင် တိကျမှုကို ကွင်းဆင်းတိုင်းတာခန့်မှန်းခြင်းဖြင့် နှိုင်းယှဉ် ဆန်းစစ် လေ့လာထားခြင်းဖြစ်ပါသည်။

Contents

1. Introduction

Burma is one of the early users of aerial surveys and aerial photointerpretation. The earliest aerial photography in Burma was made in February 1924, over 1,000 square miles of forest areas in the Delta region, the southern part of Burma (Myint, 1956). Since then, subsequent aerial photographic missions were conducted, covering almost the entire region of the country (Aggrawal, 1980). The recent and most updated one being the aerial photographs at a scale of 1:25,000, taken by the National Forest Inventory and Survey project, covering some priority forested areas during 1981 and 1985 (Allen, 1985).

The major use of these aerial photographs for forestry purposes in Burma were for the production of stock maps and photointerpretation of forest types and other land use. These aerial photographs were also used for stratification of forested areas into homogenous zones, based on height, density and association, in forest surveys and inventory works (Myint, 1967). Though interpretation, mapping and compilation of photointerpretation keys were complied and used in forestry operation, photomensuration assignments were very rarely in use. This may be due to the very complex nature of the broad leaved forests of Burma, where there are very numerous tree species of differing crown sizes and shapes. Moreover, the multi-storied nature of the natural forest stands and dense canopy inhibits the visibility of the ground line, rendering the application of the photomensuration technique rather doubtful.

Unlike the natural stands, man-made forest plantations can easily be discernable on conventional black and white aerial photographs due to the typical characteristics of uniform texture, tone and a well defined boundary along with the evenly distribution of trees (Myint, 1955). This is an attempt to estimate the height of teak stands, of different age classes on the aerial photographs and compared with the height measurements made on actual ground conditions to find out the reliability of photoestimates in stand height estimation which is one of the most important variable in volume determination and guaging the performance of the plantation.

2. Literature Review

The use of aerial photographs to supplement or eliminate costly field work is a continuing interest of inventory researchers. Tree height has been shown to be the most valuable photovariable for estimating tree diameters and volume (Aldred and Sayn-Wittgenstien, 1972) and is also one of the few tree characteristics that can be measured directly on aerial photographs.

In a scientific study of the comparison of tree height measurements made from large scale photomeasurements with field measurements for 502 lodge pole pine trees in Yukon territory (Canada), it was found that photo and field height measurements were not significantly different from felled heights. The standard deviation of field and photo height errors were 0.95 m and 1.17 m respectively, about 6% of the felled height (16.3 m). Variability in errors due to image type (contact print or transparency) and image enlargement scale (1x, 2x, 4x) was not significant (Titus, 1985).

In order to find out the feasibility of forest cover type interpretation using small scale aerial photographs, Joseph J. Ulliman and Merle P. Meyer (1971), conducted a research project using various scales of aerial photographs. The objective was to determine if there are any significant differences in interpreters ability to classify forest cover types (i.e, species, size, and density class) between medium and small scale aerial photographs in the lake states. The small scale (1:31680, 1:63360, 1:90000) photographs were compared against those of the medium scale (1: 15840).

Height measurements were also made in which a limited samples of five trees were measured on the ground by two independent observers using abney level. One photointerpreter, who had advanced training used a parallax bar, made at least three independent readings of the same tree or group of trees, on each of three scales of photography (1:15840, 1:63660, 1:90000).

The results of this limited sample of tree height measurements (see appendix 1) show that there was no increased accuracy with the medium scale. Although theoretical considerations would indicate otherwise, simplified studies have borne the same conclusion for scales ranging between 1:2500 to 1:3380 (Axleson, 1956; Johnson, 1958; Moessner, 1955, Pope, 1957).

Concerning with the characterisation of photo measurement errors, several researchers have learned that the size and structure of the errors is dependent on several factors, such as the scale of photography, skill of the interpreter and the types of forest stand being examined (Spurr and Brown, 1964).

Typical errors in height measurements and crown closure estimates are of particular importance because most aerial plot volume tables uses these two variables (Paine, 1981). Paine (1981) estimated errors in height to be 10 to 20 percent of average stand height and to be relatively independent of photo-scale. Spurr and Brown (1946) reported three foot errors in the average height of 20 Southern pine plantations.

3. Materials and Methods

The study area comprises differing age classes of Teak (and a commercial tree species) plantations in Kaing and Ngalaik forest reserves in Pyinmana and Takon townships. Altogether thirty four trees or tree groups were measured on 1:25000 scale black and white prints and also measured on the ground by three independent observes. Measurement on aerial photographs were made by two trained personnels with a parallax bar, taking three independent readings of the same tree or tree group.

Of the three basic methods of height measurement on aerial photographs, such as, direct measurement of displacement on single photographs of trees viewed on the oblique, measurement of shadows and measurement of parallax differences on stereo pairs of photographs, the parallax methods was applied in this study.

3.3 The Parallax Methods

This is the most practical methods for the determination of tree heights as it is applicable to a greater variety of topographical and forest conditions. The technique is based on the parallax measurements on a properly oriented pair of photographs.

The general parallax formula used is

$$H = \frac{Zr \times dp}{Pr + dp}$$

where,

H = the height (meter or foot) of the tree top above the reference plane through the tree foot

Zr = the flying height (also meter or foot) above the reference plane

Pr = the sterescopic parallax (millimeter) of the reference plane

dp = the difference in sterescopic parallax (millimeters) between the top of the tree and the horizontal plane through the foot of the tree

Zr, for this experiment, is obtained from the photo-scale at reference level and the principal distance.

$$S\ (\text{photo}) = \frac{L\ (\text{map}) \times S\ (\text{map})}{L\ (\text{photo})}$$

where,

S (photo) = the scale factor of the photograph at reference level

S (map) = the scale factor of the map (Here the topographic map with a scale of 1:63360 is used).

L (photo) = length between two identifiable objects on the photo

L (map) = corresponding length between the two objects on the map

The average scale is obtained by means of length measurements on two diagonals; first the scale factor is worked out for each diagonal and then the mean of the two is calculated.

Zr, is thus calculated from the expression

$$Zr = \frac{C \times S}{1000}$$

where,

C = the principal distance, or the focal length of the camera lens (mm). (214.07 mm for the whole of this measurement)

S = the scale factor of the photo at reference level

Pr, being the stereoscopic parallax of the left photo, is measured with a ruler (to 0.1 mm) on the right photo of the stereo pair as the distance between the principle point and the conjugate principle point.

dp, is obtained from the photo pair by measuring the image seperation of the top and the foot, or rather the plane through the foot of the tree. As a ruler is not precise enough, these measurements are taken to 0.01 mm with the parallax bar in combination with a mirror stereoscope.

The terrain in all the four stereo pairs are not exactly flat, but according to the contours in the topographic map the elevation difference between each tree measured and the reference plain is less than 300 feet. This is less than 2% of the lowest flying height calculated. Therefore, the general formula for the flat terrain is directly applied with Zr and Pr referring to the reference plain and not to the foot of the tree measured.

On aerial photographs tree height measurements always refer to the total tree height. There are several factors which influence the accuracy of the measurements and errors may occur due to one or more of the following factors (Spurr, 1948).

(1) Sharply pointed conical crowns may show insufficient photographic resolution resulting in an underestimation while flat broad crowns allow rather accurate parallax readings of the top.

(2) Undergrowth obscuring the soil is responsible for an under estimation of the tree height.

(3) Sloping terrain may cause an under or overestimation of the tree height.

(4) High crown closure makes readings near the foot of the trees impossible or unreliable.

(5) Height measurements of dense forest stands can only take place near the edge of the stand where ground is visible. It is thus assumed that the trees along the perifery show the same growth pattern as the trees inside the stand.

(6) The photo scale. A small scale means smaller images and less ground resolution.

(7) The principle distance of the camera lens. The influence depends on the applied method of height measurement.

(8) The position of the tree within the photo frame has influence on the amount of image displacement.

(9) The time and season of photography have influence on the presence and density of the foliage. Defoliated trees are difficult or impossible to see.

4. Results and Discussions

The results of measurements of trees or tree groups on aerial photographs using the parallax method and that of the ground measurements are shown in the following tables.

<u>Reserve</u> Kaing <u>Age</u> Over 80 Years

photo estimate (height ft.)	Ground estimate (height ft.)	Difference	% Difference
87.8	91.32	-3.54	-3.88
84.60	76.12	8.48	11.14
78.13	85.30	-7.17	-8.40
103.99	100.61	3.38	3.36
105.68	100.07	5.61	5.60
81.00	89.67	-8.67	-9.67
82.70	81.47	1.23	1.51
102.91	103.89	-0.98	-0.94

T - tests ; degrees of freedom =7 calculated t value = .097 tabular t.05 with 7 df = 2.36. As calculated t does not exceed tabular value, the two height measurements are not shown to be significantly different.

<u>Reserve</u> Kaing <u>Age</u> About 25 Years

photo estimate (height ft.)	Ground estimate (height ft.)	Difference	% Difference
73.44	74.90	-1.46	-1.95
62.53	56.32	6.21	11.03
69.26	65.62	3.64	5.55
67.89	74.91	-7.02	-9.37
38.34	51.40	-13.06	-25.41
35.49	42.65	-7.16	-16.79
53.07	49.50	3.57	7.21

T - tests ; degrees of freedom 7 calculated t value 0.407 tabular t.05 with 7 df 2.36 N.S

<u>Reserve</u> Ngalaik <u>Age</u> About 20 Years

photo estimate (height ft.)	Ground estimate (height ft.)	Difference	% Difference
57.75	63.98	-6.23	-9.73
51.96	56.86	-4.90	-8.62
44.62	54.69	-10.07	-18.41
37.84	41.00	-3.16	-7.70
47.81	54.69	-6.89	-12.54

T - tests ; degrees of freedom 4 calculated t value 5.442 tabular t.05 with 4 df 2.78. As calculated t exceeds tabular value, the two height measurements are significantly different.

Reserve Ngalaik		Age 17 Years	
photo estimate (height ft.)	Ground estimate (height ft.)	Difference	% Difference
39.65	47.57	-7.92	-16.65
37.84	48.12	-10.23	-21.26
39.65	50.85	-11.20	-22.03
42.51	47.96	-7.25	-14.57
39.65	50.85	-6.56	-14.20
44.95	53.05	-8.10	-15.27

T - tests ; degrees of freedoms 5 calculated t value 9.56 tabular t.05 2.57. As calculated t exceeds tabular value, the two height measurements are significant different.

Reserve Ngalaik	Age About 6 Years or Less		
photo estimate (height ft.)	Ground estimate (height ft.)	Difference	% Difference
24.8	31.7	-6.34	-20.44
24.48	30.62	-6.14	-20.05
38.67	44.02	-5.35	-12.15
38.27	42.10	-3.83	-9.10
35.41	38.27	-2.86	-7.47
17.18*	28.70	-11.52	-40.00
14.92	25.70	-10.78	-41.95

T - tests ; degrees of freedom 6 calculated t value 5.44 tabular t.05 with 6 df 2.45 Measurements are significantly different.

It is quite evident from looking at the above tables that there exist some discrepancies among the measurements made in this study. In general, there is more variation in height estimates of younger age stands than in older ones, and the degree of uncertainty becomes quite pronounced with the stands of less than five years of age as experienced from the last two tree groups.

The percentage errors in this study is within 10 to 20 percent of the average stand height as mentioned by Paine (1981), except in a few cases where the estimated error exceeds more than 20 percent.

The ensure whether there is any statistical significance between photo measurements and the ground truth data, t- tests were tried besed on grouping of measurements by age among the 34 sets of measurements.

Results indicated that photoestimates were not appreciably different from that of the ground height measurements for the stands over 25 years of age. Other than that, in the younger age classes there were significant differences with the ground truth data. This may have arisen from the fact that in the older age stands the crown is well developed and the tip of the tree or group of trees are quite easily to resolve than in the case of younger age stands where the crown has not yet properly developed. The results becomes even poorer with the shedding of the foliage as experiences from one particular case with two different sets of photography over the same area. The earlier print gave better resolution because of the presence of foliage while it was very hard to depict the other one in which the tree had shed the leaves, so that the placing of the parallax dot allows for more variation.

The print quality of the photographs is also one of the important factors in stand height determination, especially in younger age stands where difference in tonal contrast may obscure the tree line, and a small shift in the position of the parallax dot causes a relatively large shift in the ground distance.

The significance difference in the younger age stands may be due also to the difference between the time of photography and the actual ground check. In this study, a time difference of two years could be one of the reasons for having estimates significantly different from ground measurements in the younger age classes. The actual fact is that a patch which had been under site preparation in the photograph appears to be a young teak stand of about 8 feet high during the actual ground checking. Hence, an allowable factor should have been taken into account in the case of younger age stands, as teak is a very fast growing species at its early stages of development, whereas in the older stands the growth is not as pronounced as at the early stages (Laurie and Ram, 1942).

To find out whether there is any relationship between photoestimates and ground measurements, regression analyses were made using single variable regression analyses.

Four different types of single variable regression analyses were tried. The four types were:

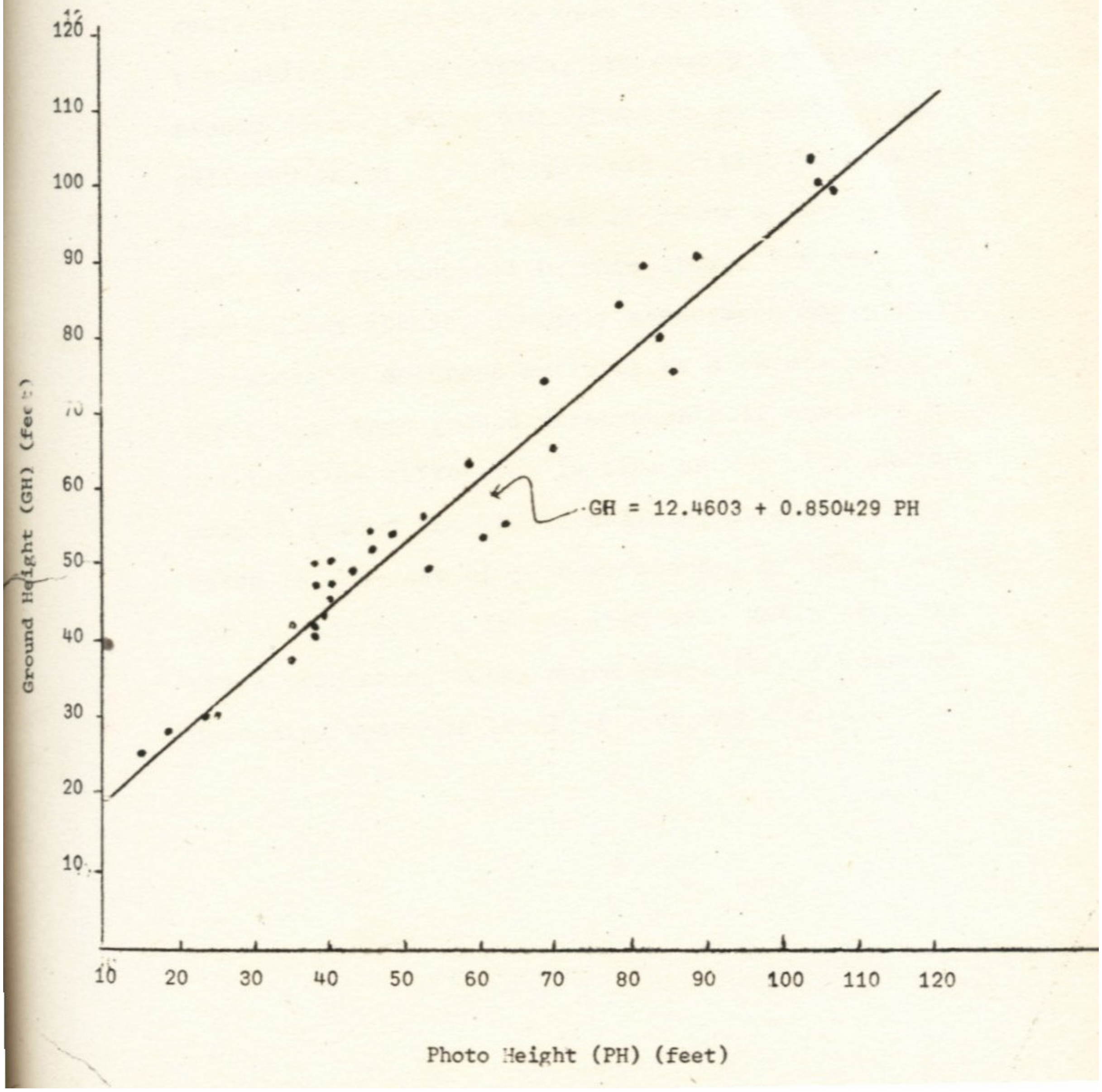
Regression types	Coefficient of determination
1. GH = a + b (PH)	0.95
2. GH = a + exp (b.PH)	0.92
3. $GH = aPH^b$	0.87
4. $GH = aPH^b$	0.94

Of the four, the first type gives the best fit, where ground height (GH) is expressed in terms of photo height (PH) as ;

$$GH = 12.4603 + 0.850429\ PH$$

where, GH = ground height in feet
PH = photo height in feet

Figure I. Relationship between Photo height and Ground height measurements.



5. Conclusion

With an adequate training and good quality photographs, the existing aerial photographs with a scale of 1:25,000 can be used for stand height estimation of teak stands, preferably for those stands over 25 years old. There is no statistical differences in the interpreters ability to estimate stand heights for teak over 25 years of age under conditions encountered in this study. For the younger age stands, a timely assessment may produce a reasonable accurate estimate at a relatively short time than ground measurements. If there is a considerable difference in time between the photographic period and its actual use, care should be taken in the case of younger stands, or else, worked out the correction factor that will match with research depending upon the level of accuracy desired.

Appendix -1 Relationship between actual height measurement and height estimated from different scales of photography in Northern Minnesots

		1:15840		1:63,360		1:90.000	
	Actual	Error		Error		Error	
Species	height (ft.)	Ft. Ft.	(%)	Ft. Ft.	(%)	Ft. Ft.	(%)
Red Pine	65	52-13	(20)	56-9	(14)	50-15	(23)
Blue spruce group	34	32-2	(6)	26-8	(24)	36 2	(6)
Red pine stand	53	34-19	(36)	42-11	(21)	72 19	(30)
Norway spruce	50	38.12	(24)	34-16	(32)	51 1	(2)
Paper birch	53	38.15	(28)	54 1	(2)	64 11	(21)
		-12.2	(23)	-9.0	(19)	9.6	(18)

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