A Study of the Visual Physical Characteristics and Psychological Images of Select Taiwanese Hardwoods

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Abstract

This study investigated the relationship between visual images of wood color and wood grains of wood products manufactured from select Taiwanese commercial hardwoods. The Taiwan Forestry Research Institute provided samples for 23 species of commercially available woods, each with tangential and radial sections (46 samples total). Wood color parameters were measured, followed by a survey using a Semantic Differential scaling method to discern the consumers' mental perception toward the wood products. Finally, factors involved in constructing different images underwent statistical analysis to offer designers and consumers a reference for designing a product or wood product selections. Among Taiwan's commercial woods, *Swietenia mahogoni* was perceived to be advanced, elegant, and exquisite in the tangential section and warm, soft, and possessive of a natural image in the radial section. The tangential section of *Paulownia taiwaniana* was perceived to possess a common image; meretricious and rough images were associated with the tangential section of *Cassia siamea*. Cold and hard images were associated with the tangential and radial sections of *Actinodaphne nantoensis,* and *Cyclobalanopsis longinux* was perceived to possess an artificial image. In terms of color (Commission Internationale d'Eclairage L*a*b*), the relative images of advanced and common, elegant and meretricious, and warm and cold were closely related to L* and a*; the relative images of exquisite and rough and of soft and hard were related to a*. In terms of grains, the relative images of soft and hard and of natural and artificial are closely related to thickness of the wood lines.

Use of wood products in design (product design or space design) has become more fashionable. Designers can use shape, color, and material type to achieve a given impression, but consumers may feel differently. Therefore, understanding what impressions are conveyed by different species and design offerings should facilitate designers' communication with their consumers and result in production of products that are psychologically appealing to consumers. Thus, if designers have knowledge regarding the physical characteristics of wood and know how those characteristics influence a consumer emotionally, they can design a product or space that meets the user's psychological needs.

A number of in-depth studies have examined the relationship between product design and human emotions and senses. Hsu et al. (2004) investigated the differences in product form and perception between designers and users. Those authors used the Semantic Differential scaling method to measure the relationship between the subjects' evaluation of telephones and design form elements. Alcantara (2005) applied the Semantic Differential method to structure the semantic space of footwear. Hsiao and Huang (2002) applied a back-propagation neural network to establish between product–form parameters and adjective-based image words; those authors used a chair design for a case study. Lai et al. (2006) used Type I Theory and neural networks of user-oriented design for transforming consumers' perceptions into product element design, and Horiguchi and Suetomi (1995) used the Kansei engineering method to evaluate the interior images of vehicles.

The literature regarding wood textures include Yamada and Shiraishi (2006), who suggested that the grain direction of wood texture could influence the visual perception of the spatial dimension. Takahashi et al. (1995) emphasized, in accordance with the five-senses analysis of wood materials, that the affinity of wood grain image as well as the warmness of colors influence wood fiber visual reflection in a painting. Those authors also investigated whether the amount of wood vessels affects the visual brightness of a

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painting. Kobayashi et al. (2006) proposed that specialists have different viewpoints on the visual image of wood textures from those of average consumers. Their premise was that specialists undertake the visual analysis by a method of physical measurement, so their perception of the wood texture visual image is more consistent. The analysis by Shiraishi et al. (2006) indicated that generic processed materials were similar in visual and tactile aspects. In Nakatsuka and Aoyama (2006), the results indicated that the use of naturally occurring patterns and images on man-made materials can be used successfully to manufacture a product that is perceived as natural. Furthermore, Masuda (1985a, 1985b) utilized artificial wood grain printed on paper to conduct a visual–psychological experiment, the results of which indicated that different wood species have different psychological characteristics, mainly from the color of the wood grain and daily usage. Nordvik et al. (2009) used the Kansei engineering methodology to evaluate the visual cognition of human response toward wood flooring. Iniguez et al. (2007) conducted an in-depth study of visual grades for a large volume of structural sawn timber from Spanish coniferous species.

Currently, many countries are endeavoring to protect their local culture as well as promote and develop ways to utilize indigenous materials. Countries with unique indigenous materials can market the uniqueness of the local products using cultural linkages. Further research and development of products from different regions may boost trade and cooperation. Along these lines, the present study used a systematic investigation and analysis of wood products manufactured from commercial hardwoods found in Taiwan. The results will provide a reference for application and research of related designs and for evaluating the relationships between visual image, color, and grain by correlation analysis.

Materials and Methods

The samples used in the present study were composed of 23 commercial hardwood species found in Taiwan (Table 1). In total, 46 samples, which included one sample each from the tangential and radial sections for each tree species, were evaluated. Samples were supplied by the Taiwan Forestry Research Institute. The tangential section was sawn parallel to the trunk and cut longitudinally without passing through the pith of the tree; the rings had either a U- or a V-shaped pattern (Fig. 1A). The radial section was sawn parallel to the trunk and cut longitudinally through the pith of a tree, which yielded a straight grain pattern (Fig. 1B).

The physical characteristics of color as well as grain characteristics were measured. For color, a spectral colorimeter (SCM-108) was used to measure the physical characteristics of hue and brightness on each sample. The lighting was a D65 standard light source; the correlated color temperature was 6,504 K. The geometrical angle of the lighting and observation was 0/d (normal incident/diffuse reflection) at 10°, and the measurement range was Φ25mm.The color parameters were the average of a multipoint test (five points) on the tangential and radial sections of each species. The study of wood color was presented in a Commission Internationale d'Eclairage (CIE) L*a*b* color space, where $L^* = 0$ is black, $L^* = 100$ is white, a negative a* is green, a positive a* is red, a negative b* is blue, and a positive b* is yellow. Also, I had characterized the grains for each sample by having experts from the Taiwan Forestry Research Institute classify the grain characteristics as to grain orientation.

Table 1.—Species of hardwoods in Taiwan.

No.	Species
1	*Michelia compressa*
2	*Trochodendron aralioides*
3	*Cinnamomum camphora*
4	*C. micranthum*
5	*Machilus kusanoi*
6	*Litsea acuminate*
7	*Sasafras randaiense*
8	*Cassia siamea*
9	*Acacia confuse*
10	*Schefflera octophylla*
11	*Alnus formosana*
12	*Cyclobalanopsis gilva*
13	*C. longinux*
14	*Castanopsis carlesii*
15	*Lithocarpus amygdalifolius*
16	*Pasania brevicaudata*
17	*P. ternaticupula*
18	*Zelkova serrata*
19	*Trema orientalis*
20	*Schima superba*
21	*Fraxinus formosana*
22	*Paulownia taiwaniana*
23	*Swietenia mahogoni*

A Semantic Differential questionnaire uses adjectives to measure the subjects' assessment of the samples. In all, 116 adjectives were collected regarding the wood materials, and from these, six experts selected 26 adjectives, which were then compiled into a Semantic Differential questionnaire. The questionnaires were statistically analyzed. In consultation with experts, I reduced the adjectives to six groups: advanced ↔ common, elegant ↔ meretricious, exquisite ↔ rough, warm ↔ cold, soft ↔ hard, and natural ↔ artificial. The questions were designed on a 5-point scale from ''in complete agreement'' to ''no opinion.'' For each question, the center point was 0, indicating ''no opinion,'' with 2 and –2 indicating ''in complete agreement.'' The participants were placed in an environment where the color temperature was 6,000 K as the experimental items were placed in a standard color-temperature box. The subjects reviewed and

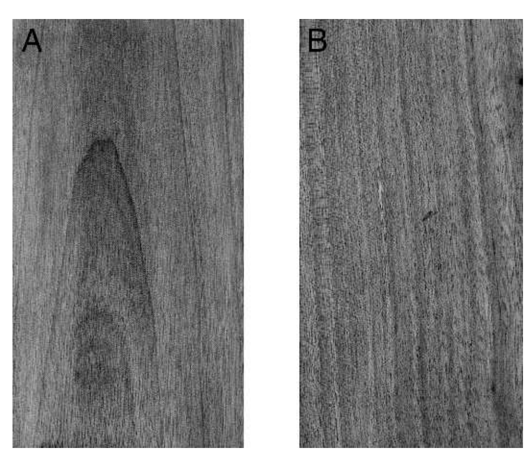

Figure 1.—(A) Tangential and (B) radial sections of Machilus kusanoi.

assessed one sample after another and immediately completed the questionnaire. The number of questionnaires distributed and completed totaled 72 (100% response rate).

For each sample, an average rating value was computed. To represent the results numerically, I transformed the values from ordinal to interval—for example, transforming the scale ordinal numbers (−2, −1, 0, 1, 2) into scale interval numbers (1, 2, 3, 4, 5). Thus, when the average is less than 3, the perception is closer to the left side, and the smaller the number, the stronger the perception. When the average is greater than 3 the perception is closer to the right side, and the larger the number, the stronger the opinion. For example, when the average interval is 4.36 (>3), it indicates that the perception is quite strong. In addition, a one-sample t test was used to contrast the average of the population and the specified constant. In addition, biserial correlation was used to study the relationship between the images and L*, a*, and b*, and the I had used tetrachoric correlation analysis to assess the relationship between the images and grain patterns.

Results and Discussion

Table 2 presents the parameters for wood color in a CIE L*a*b* color space. The measured value of color can be presented as a plane projection (as presented in Fig. 2). The scatter diagram represents the projection position of the measured value at the a*–L* plane (x axis, a*; y axis, L*) and the b*–L* plane (x axis, b*; y axis, L*), respectively. Figure 2 presents the range of the 46 samples. Brightness L* is between 34 and 75, colorfulness a* between 4 and 16, and colorfulness b* between 15 and 26.

From Table 3, which presents the results of the one-sample t test, I concluded that each descriptor adjective ($P < 0.05$) corresponds to a discrete species. In the first group, I examined advanced ↔ common. From this, the sample with the most advanced image was the tangential section of *Swietenia mahogoni,* and the sample with the most common image was the tangential section of *Paulownia taiwaniana*. In the second group, I assessed elegant ↔ meretricious. From this selection, the sample with the most elegant image was the tangential section of *S. mahogoni,* and the sample with the most meretricious image was the tangential section of *Cassia siamea*. In the third group, I measured exquisite ↔ rough. From this section, the sample with the most exquisite image was the tangential section of *S. mahogoni,* and the sample with the roughest image was the tangential section of *C. siamea*. In the fourth group, I assessed warm ↔ cold. The results indicated that the sample with the warmest image was the tangential section of *S. mahogoni,* and the sample with the coldest image was the tangential section of *Litsea acuminate*. In the fifth group, soft ↔ hard, the sample with the softest image was the radial section of *S. mahogoni,* and the sample with the hardest image was the radial section of *L. acuminate*. In the sixth group, natural ↔ artificial, the sample with the most natural image was the radial section of *Michelia compressa,* and the sample with the most artificial image was the radial section of *Cyclobalanopsis longinux*.

In the analysis of visual physical characteristics and cognitive psychology of materials, I used biserial correlation analysis to study the relationship between the images and L*, a*, and b*. Quarter correlation analysis was also used to see the relationship between image and grains. The adjectives were treated as binary variables, with advanced, elegant, exquisite, warm, soft, and natural set as 1 and their counterparts (i.e., common, meretricious, rough, cold, hard, and artificial, respectively) set as 0. In correlation analysis of colors of hardwoods using the images of our samples, I found that some adjectives and their counterparts were highly related to wood color. As presented in Table 4,

Table 2.—Measured color parameters of hardwoods.[a]

Species	Tangential section			Radial section		
	L*	a*	b*	L*	a*	b*
Michelia compressa	42.06	6.07	22.91	53.68	6.68	25.16
Trochodendron aralioides	65.50	10.49	23.77	66.40	11.56	25.13
Cinnamomum camphora	65.63	10.30	21.77	63.11	10.46	21.90
C. micranthum	53.01	11.44	22.08	55.82	10.75	21.47
Machilus kusanoi	60.40	7.56	18.72	60.22	7.88	22.29
Litsea acuminate	59.02	5.13	19.00	59.05	4.44	18.87
Sasafras randaiense	38.79	7.72	15.14	40.96	6.98	15.64
Cassia siamea	61.46	7.37	24.34	51.31	8.60	23.77
Acacia confuse	44.87	11.37	17.41	45.79	11.26	17.17
Schefflera octophylla	74.62	5.13	18.74	75.00	4.86	16.08
Alnus formosana	69.33	8.46	22.10	70.94	8.99	22.53
Cyclobalanopsis gilva	46.88	13.05	19.89	34.98	10.28	15.75
C. longinux	45.32	13.55	21.62	40.00	10.88	17.21
Castanopsis carlesii	68.45	7.60	21.16	71.82	6.58	20.61
Lithocarpus amygdalifolius	42.14	8.29	15.79	48.17	6.83	16.90
Pasania brevicaudata	59.60	10.13	21.51	52.10	9.03	18.45
P. ternaticupula	50.38	8.95	17.99	52.08	11.69	20.77
Zelkova serrata	47.54	14.52	24.72	40.50	15.70	20.74
Trema orientalis	52.05	7.76	17.14	59.27	11.53	23.15
Schima superb	60.82	9.56	19.68	61.29	10.46	20.36
Fraxinus formosana	69.61	8.91	24.65	69.04	7.56	21.53
Paulownia taiwaniana	70.32	6.34	20.61	69.20	6.37	19.14
Swietenia mahogoni	51.59	15.27	23.48	50.85	15.14	23.42

[a] L* = brightness; a* = colorfulness index (red–green axis); b* = colorfulness index (yellow–blue axis).

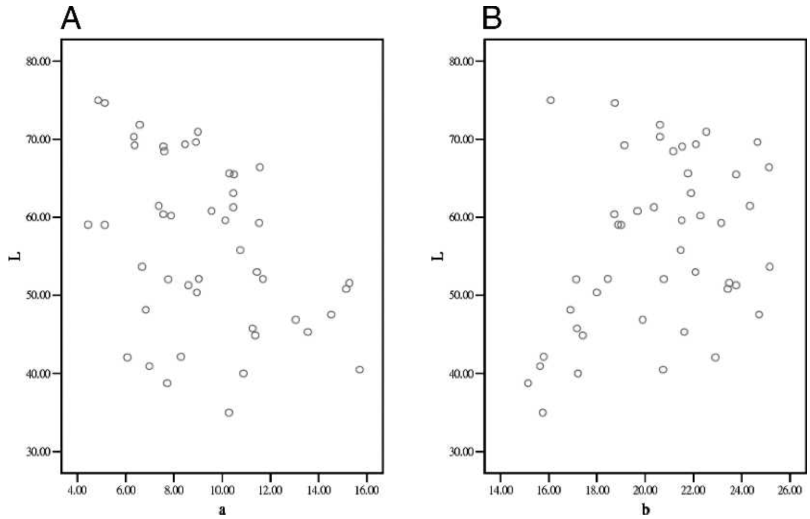

Figure 2.—Projection diagram of material-color space. Material-color distribution along the (A) a–L* axis and the (B) b*–L* axis.*

advanced and common, elegant and meretricious, and warm and cold are highly correlated to L*. Exquisite and rough as well as soft and hard are correlated to a*. Natural and artificial are not correlated to L*, a*, or b*.

Advanced ↔ common image analysis

The relative image of advanced and common, as shown in Table 4, achieves the significance level of 0.01 (for color L*, $r = -0.468$ and $P < 0.01$), so it can be concluded that advanced and common are negatively correlated to L*. In color a*, $r = 0.665$ and $P < 0.01$. Thus, it achieves the significance level of 0.01, so it can be concluded that advanced and common are positively correlated to a*. In other words, in hardwoods, the species with a perception of advanced image has a low L* and a high a*, and the species with a perception of a common image has a high L* and a low a*. Accordingly, once the lightness of the hardwood turns low, the hue turns toward reddish, such as the radial section of *S. mahogoni* (L* = 51.59, a* = 15.27), which gives the impression of advanced, whereas when the lightness turns high, the hue turns toward greenish, such as the tangential section of *P. taiwaniana* (L* = 70.32, a* = 6.34), which gives the impression of common in the image analysis.

Elegant ↔ meretricious image analysis

The relative image of elegant and meretricious, as shown in Table 4, achieves the significance level of 0.05 (in color L*, $r = -0.392$ and $P < 0.01$), so it can be concluded that elegant and meretricious are negatively correlated to L*. In color a*, $r = 0.710$ and $P < 0.01$. Thus, it reaches the standard of 0.01, and it can be concluded that elegant and meretricious are positively correlated to a*. In other words, in a broad-leaved tree, the species with the perception of elegant image has a low L* and a high a*, and the species with the perception of meretricious image has a high L* and a low a*. Accordingly, when the lightness is low, the hue of hardwood turns toward reddish, such as the tangential section of *S. mahogoni* (L* = 51.59, a* = 15.27), which gives an impression of elegant, whereas when the lightness is high, hardwood turns greenish, such as the tangential section of *Cassia siamea* (L* = 61.46, a* = 7.37), which gives an impression of meretricious in the image analysis.

Warm ↔ cold image analysis

The relative image of warm and cold, as shown in Table 4, achieves the significance level of 0.01 (in color L*, $r = -0.593$, $P < 0.01$), so it can be concluded that warm and cold are negatively correlated to L*. In color a*, $r = 0.768$ and $P < 0.01$. Thus, it achieves the significance level of 0.01, and it can be concluded that warm and cold are positively correlated to a*. In other words, in hardwoods, a species with the perception of warm image has a low L* and a high a*, whereas the species with a perception of cold image has a high L* and a low a*. Thus, among hardwoods, when the lightness is low and the hue is toward reddish, such as the tangential section of *S. mahogoni* (L* = 50.85, a* = 15.14), this tends to give a warm feeling, whereas when the lightness is high and the hue is toward greenish, such as the tangential section of *L. acuminate* (L* = 59.02, a* = 5.13), this tends to give the impression of a cold feeling.

Exquisite ↔ rough image analysis

The relative image of exquisite and rough, as shown in Table 4, achieves the significance level of 0.01 (in color a*, $r = 0.696$ and $P < 0.01$), and it can be concluded that exquisite and rough are positively correlated to a*. In other words, in hardwoods, the species with a perception of exquisite image has high a*, and the species with a perception of rough image has a low a* value. Accordingly, once the hue turns toward reddish, such as the tangential section of *S. mahogoni* (a* = 15.27), it is exquisite, whereas once the hue turns toward greenish, such as the tangential section of *Cassia siamea* (a* = 7.37), it becomes rough.

Soft ↔ hard image analysis

The relative image of soft and hard, as shown in Table 4, achieves the significance level of 0.01 (in color a*, $r = 0.694$ and $P < 0.01$), so it can be concluded that soft and hard are positively correlated to a*. In other words, in hardwoods, the species with the perception of a soft image has a high a*, and the species with a perception of a hard image has a low a*. Accordingly, once the hue turns toward reddish, such as

Table 3.—One-sample t *test of species.*[a]

		Tangential section			Radial section		
(Group) Imagery	Species	Mean	*t* value	SD	Mean	*t* value	SD
(1) Advanced	*Cinnamomun micranthum*	—	—	—	2.625	−2.813**	1.131
	Acacia confuse	2.403	−4.420***	1.146	2.611	−3.014**	1.095
	Cyclobalanopsis longinux	2.708	−2.119*	1.168	—	—	—
	Schima superba	2.361	−4.554***	1.190	—	—	—
	Swietenia mahogoni	1.931	−9.984***	0.909	1.944	−8.670***	1.033
(1) Common	*Michelia formosana*	—	—	—	3.417	3.017**	1.172
	Cinnamomum camphora	3.542	4.040***	1.138	3.389	2.765**	1.193
	C. micranthum	3.361	2.391*	1.282	—	—	—
	Machilus kusanoi	3.611	4.578***	1.133	3.764	6.393***	1.014
	Actinodaphne nantoensis	3.764	6.307***	1.028	3.778	6.822***	0.967
	Cassia siamea	3.847	6.018***	1.195	3.528	4.388***	1.021
	Schefflera actophylla	3.542	3.629***	1.266	3.577	3.894***	1.250
	Alnus formosana	—	—	—	3.347	2.736**	1.077
	Cyclobalanopsis longinux	—	—	—	3.292	2.264*	1.093
	Castanopsis carlesii hay	3.750	5.668***	1.123	—	—	—
	Pasania brevicaudata	3.375	2.782**	1.144	3.278	2.187*	1.078
	P. ternaticupula	3.500	3.409***	1.245	—	—	—
	Trema orientalis	3.806	6.237***	1.096	3.278	2.112*	1.116
	Fraxinus formosana	—	—	—	3.347	2.612*	1.128
	Paulownia taiwaniana	3.887	8.927***	0.838	3.375	3.149**	1.013
(2) Elegant	*Cinnamomun micranthum*	—	—	—	2.625	−2.877**	1.106
	Acacia confuse	2.458	−3.875***	1.186	2.597	−3.318**	1.030
	Cyclobalanopsis gilva	2.681	−2.412*	1.124	—	—	—
	C. longinux	2.569	−3.288**	1.111	—	—	—
	Zelkova formosana	2.681	−2.311*	1.173	—	—	—
	Schima superba	2.208	−6.414***	1.047	2.667	−2.699**	1.048
	Fraxinus formosana	2.611	−2.979**	1.108	—	—	—
	Swietenia mahogoni	1.944	−10.105***	0.886	1.986	−8.262***	1.041
(2) Meretricious	*Michelia formosana*	—	—	—	3.292	2.188*	1.131
	Cinnamomum camphora	3.458	3.457***	1.125	3.306	2.454*	1.057
	Machilus kusanoi	3.333	2.272*	1.245	3.556	4.504***	1.047
	Actinodaphne nantoensis	3.583	4.511***	1.097	3.556	4.755***	0.991
	Cassia siamea	3.889	7.145***	1.056	3.472	4.096***	0.978
	Schefflera actophylla	3.306	2.000*	1.296	3.394	2.664*	1.248
	Cyclobalanopsis longinux	—	—	—	3.389	2.638*	1.251
	Castanopsis carlesii hay	3.667	5.697***	0.993	—	—	—
	Pasania ternaticupula	3.486	3.408**	1.210	3.292	2.164*	1.144
	Trema orientalis	3.736	5.317***	1.175	—	—	—
	Paulownia taiwaniana	3.817	6.853***	1.004	—	—	—
(3) Exquisite	*Cinnamomun micranthum*	—	—	—	2.569	−3.326**	1.098
	Acacia confuse	2.458	−4.568***	1.006	2.556	−3.979***	0.948
	Cyclobalanopsis gilva	2.708	−2.119*	1.168	—	—	—
	C. longinux	2.681	−2.265*	1.197	—	—	—
	Zelkova formosana	—	—	—	2.681	−2.106***	1.287
	Schima superba	2.069	−9.000***	0.877	2.423	−4.170***	1.167
	Fraxinus formosana	2.333	−5.397***	1.048	—	—	—
	Swietenia mahogoni	2.014	−9.028***	0.927	2.056	−7.378***	1.086
(3) Rough	*Cinnamomum camphora*	3.306	2.2867*	1.134	—	—	—
	Machilus kusanoi	—	—	—	3.417	3.260**	1.084
	Actinodaphne nantoensis	3.486	3.839***	1.075	3.639	4.799***	1.130
	Sasafras randaiense	3.361	2.654*	1.154	—	—	—
	Cassia siamea	4.000	7.994***	1.061	3.528	4.274***	1.048
	Schefflera actophylla	3.306	2.035*	1.274	3.423	3.263**	1.091
	Cyclobalanopsis gilva	—	—	—	3.403	2.513*	1.360
	C. longinux	—	—	—	3.333	2.408*	1.175
	Castanopsis carlesii hay	3.472	3.447**	1.162	—	—	—
	Lithocarpus amygdalifolius	—	—	—	3.444	2.979**	1.266
	Pasania brevicaudata	3.431	3.251**	1.124	—	—	—
	P. ternaticupula	3.722	5.757***	1.064	3.333	2.632*	1.075
	Trema orientalis	3.903	7.294***	1.050	—	—	—
	Paulownia taiwaniana	3.831	6.811***	1.028	—	—	—

Table 3.—Continued.

(Group) Imagery	Species	Tangential section Mean	Tangential section *t* value	Tangential section SD	Radial section Mean	Radial section *t* value	Radial section SD
(4) Warm	*Cinnamomun micranthum*	—	—	—	2.583	−3.260**	1.084
	Sasafras randaiense	2.736	−2.035*	1.100	—	—	—
	Acacia confuse	2.264	−5.676***	1.100	2.569	−3.251**	1.124
	Cyclobalanopsis gilva	2.521	−3.138**	1.286	—	—	—
	C. longinux	2.306	−5.965***	0.988	—	—	—
	Zelkova formosana	2.282	−5.795***	1.044	1.986	−8.992***	0.957
	Schima superba	2.625	−2.644*	1.204	2.653	−2.704**	1.090
	Fraxinus formosana	2.528	−3.344**	1.198	—	—	—
	Swietenia mahogoni	1.917	−8.687***	1.058	1.833	−9.212***	1.075
(4) Cold	*Michelia formosana*	—	—	—	3.347	2.504*	1.177
	Trochodendron aralioides	3.431	3.053**	1.197	—	—	—
	Machilus kusanoi	3.458	3.044**	1.278	3.625	4.588***	1.156
	Actinodaphne nantoensis	3.625	4.851***	1.093	3.458	3.622***	1.074
	Schefflera actophylla	3.583	3.848***	1.286	3.507	3.732***	1.145
	Castanopsis carlesii hay	3.389	2.527*	1.306	—	—	—
	Pasania ternaticupula	3.319	2.142*	1.265	—	—	—
	Trema orientalis	3.319	2.592*	1.046	—	—	—
	Fraxinus formosana	—	—	—	3.264	2.084*	1.075
	Paulownia taiwaniana	3.443	3.646***	1.016	—	—	—
(5) Soft	*Cinnamomun micranthum*	—	—	—	2.625	−2.877**	1.106
	Acacia confuse	2.444	−4.447***	1.060	—	—	—
	Cyclobalanopsis longinux	2.625	−2.753**	1.156	—	—	—
	Zelkova formosana	2.583	−3.149**	1.123	2.486	−3.790***	1.151
	Trema orientalis	—	—	—	2.486	−4.331***	1.007
	Schima superba	2.153	−6.078***	1.183	2.639	−2.433*	1.259
	Fraxinus formosana	2.319	−5.522***	1.046	—	—	—
	Swietenia mahogoni	2.097	−6.792***	1.128	1.986	−8.055***	1.068
(5) Hard	*Michelia formosana*	—	—	—	3.403	2.730**	1.252
	Trochodendron aralioides	3.361	2.524*	1.214	—	—	—
	Machilus kusanoi	—	—	—	3.417	2.900**	1.219
	Actinodaphne nantoensis	3.403	2.730**	1.252	3.542	4.179***	1.100
	Cassia siamea	3.431	3.084**	1.213	—	—	—
	Cyclobalanopsis gilva	—	—	—	3.472	3.058**	1.251
	C. longinux	—	—	—	3.514	4.108***	1.184
	Lithocarpus amygdalifolius	—	—	—	3.458	3.667***	1.061
	Pasania brevicaudata	—	—	—	3.458	3.578***	1.087
	P. ternaticupula	3.472	3.824***	1.048	3.514	4.523***	1.047
	Trema orientalis	3.389	2.765**	1.193	—	—	—
	Paulownia taiwaniana	3.451	3.395**	1.119	—	—	—
(6) Natural	*Michelia formosana*	2.556	−2.904**	1.299	—	—	—
	Acacia confuse	2.458	−3.837***	1.198	2.486	−4.009***	1.088
	Zelkova formosana	—	—	—	2.583	−2.703**	1.308
	Trema orientalis	—	—	—	2.292	−5.497***	1.093
	Schima superba	2.222	−5.663***	1.165	2.528	−3.600***	1.113
	Fraxinus formosana	2.681	−2.142*	1.265	—	—	—
	Swietenia mahogoni	2.292	−5.199***	1.156	2.167	−5.843***	1.210
(6) Artificial	*Michelia formosana*	—	—	—	3.375	2.724**	1.168
	Cyclobalanopsis gilva	—	—	—	3.361	2.063*	1.485
	C. longinux	—	—	—	3.514	3.383**	1.289
	Lithocarpus amygdalifolius	—	—	—	3.375	2.594*	1.227

[a] * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Table 4.—Correlation analysis of color and each image.

Adjectives and their counterparts	Color coefficient[a] L*	a*	b*
Advanced ↔ common	−0.468**	0.665**	0.006
Elegant ↔ meretricious	−0.392**	0.710**	0.113
Exquisite ↔ rough	0.205	0.696**	0.275
Warm ↔ cold	−0.593**	0.678**	0.124
Soft ↔ hard	0.046	0.694**	0.358
Natural ↔ artificial	0.403	0.433	0.367

[a] ** = $P < 0.01$.

the radial section of *S. mahogoni* (a* = 15.14), it becomes soft, whereas once the hue turns toward greenish, such as the radial section of *L. acuminate* (a* = 4.44), it is considered to be hard.

Natural ↔ artificial image analysis

The relative image of natural and artificial is not related to L* (brightness), a* (red–green), or b* (yellow–blue). This indicates that neither lightness nor hue creates a difference in perception between natural or artificial.

Grain analysis

In correlation analysis of grains of hardwoods and images, the relationship between the grain and images was investigated using tetrachoric correlation. The adjectives were treated as binary variables, and the grain characteristics of growth rings (clear/ring porous or unclear/diffuse porous), section (tangential or radial), and rays (thick or thin) were also treated as binary variables. As a result, no correlation between images and veins (clear or unclear) and sections (tangential or radial) was found. However, the thickness of rays, which is a feature of hardwoods, was found to be correlated with the soft/hard and natural/artificial look. These results are presented in Table 5.

Summary and Conclusions

From the study of the attributes that constitute the visual images of wood materials, conducted by assessing wood color (L*, a*, and b*), analysis of grain characteristics, utilization of a Semantic Differential questionnaire to explore consumers' perception toward wood materials, and statistical analysis of the images of different woods, the following was discerned:

1. The grain appearance of hardwoods can be generally divided into clear and unclear types. The variance range of brightness L* was between 34 and 75, colorfulness a* between 4 and 16, and colorfulness b* between 15 and 26. Thus, samples of Taiwanese commercial timbers in the present study tended more toward yellowish and reddish.
2. The advanced, elegant, and exquisite findings for Taiwan's commercial broad-leaved trees were from the tangential sections of *S. mahogoni*. The warm, soft, and natural images were found in the radial sections of *S. mahogoni*. In addition, the common image was discerned in the tangential section of *P. taiwaniana*. Meretricious and rough perceptions were associated with the tangential sections of *Cassia siamea* and cold and hard perceptions with the tangential/radial sections of *L. acuminate*. Lastly, the artificial image was discerned in *C. longinux*. These results indicate that *S. mahogoni* has a particularly high value-added potential based on consumer preferences and, as such, should be targeted for future commercial timber plantations/production.
3. Through correlation analysis, I found that in hardwoods, the relative perception of advanced and common, elegant and meretricious, and warm and cold were highly correlated to L* and a*. The more advanced, elegant, or warm the perception was, the lower the L* and the higher the a* (i.e., lower brightness and more red); the more common, meretricious, or cold the image was, the higher the L* and lower the a* (i.e., higher brightness and lower red). The relative images of exquisite and meretricious as well as soft and hard were related to colorfulness a*. The more exquisite and soft the perception was, the higher the a* (colorfulness) and the more red the color. The more meretricious and hard the perception rating was, the lower the a* and the less red the color. Regarding the clarity of the growth rings, the tangential/radial section was not related to images of the species. For the thickness of rays, which is a prominent feature of broad-leaved trees, the rays related to soft and hard and to natural and artificial. The sample with soft and natural images had thinner rays, whereas the sample with hard and artificial images had thicker rays. Based on the materials used, wood colors that tend toward reddish and less brightness, such as *S. mahogoni,* are more frequently perceived as advanced, elegant, and warm, whereas the reverse are perceived as common, meretricious, and cold. Materials with thin rays easily generate soft and natural images.

Table 5.—Correlation analysis of grains and each image.

Adjectives and their counterparts	Grain coefficient[a]		
	Growth ring	Section	Rays
Advanced ↔ common	0.255	−0.079	0.304
Elegant ↔ meretricious	0.211	−0.016	0.127
Exquisite ↔ rough	0.223	−0.044	0.268
Warm ↔ cold	0.087	0.000	0.183
Soft ↔ hard	0.363	−0.116	0.435*
Natural ↔ artificial	0.471	−0.471	0.826**

[a] * = $P < 0.05$; ** = $P < 0.01$.

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