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ESTIMATION OF MOISTURE CONTENT IN BAMBOO FOR DERIVING THE WEIGHT AND PRICE CONVERSION FACTORS

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ABSTRACT

Bamboo (*Bambusa bambos*) from the forests in Kerala is allotted by the State Government to the Hindustan Newsprint Limited, a public sector newsprint factory in the State, for harvesting. Selling price of bamboo, known as notified price, is fixed annually by the government per metric tonne of standing weight of bamboo in the forests. Weight of the utilizable portion of the standing green mature bamboo culms in the forests is referred to as the standing weight, whereas the weight of the harvested bamboo when weighed at the factory gate is known as the net weight. Conversion factors are required to determine the equivalent standing weight from the weight of harvested bamboo and to derive the selling price of bamboo at 50% moisture content from the notified price.

For deriving the weight and price conversion factors, an estimate of the average moisture content in bamboo in the forests was necessary. To estimate the average moisture content, 312 sample culms were felled from 52 bamboo coupes during the harvesting period from October to May through a sample survey in the forest bamboo coupes in Kerala. As soon as the sample culms were felled from the sub-sample of two bamboo clumps in each of the selected coupes, sample discs of 5 cm length were prepared by cutting at different height levels of each culm without any change in the moisture content in the standing condition of the culm and the disc. Immediately after cutting, green weight of each disc was measured at the felling site in an electronic balance. Altogether 858 discs from nodes and 1,157 discs from mid-internodes were prepared and the oven-dry weight of each disc was determined in the laboratory. Based on the green and oven-dry weights of the sample discs, the average moisture content in bamboo in the forests was developed through ratio estimator.

Using the estimated average moisture content of 45.23%, the weight and price conversion factors were derived. The weight conversion factors for various values of the moisture content in harvested bamboo are calculated and presented. For converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of bamboo as in the forests, the weight figure has to be multiplied with the respective weight conversion factor. The derived price conversion factor is 0.9129. The selling price in a financial year per metric tonne of bamboo at 50% moisture content can be found out by simply multiplying the notified price in the same year with the price conversion factor of 0.9129. The price payable by the factory to the government for the net weight of harvested bamboo in a financial year can directly be arrived at by calculating its equivalent standing weight using the weight conversion factor and multiplying it with the notified price in the same year.

Key words: *Bambusa bambos*, moisture content, notified price, weight conversion factor, price conversion factor.

1. INTRODUCTION

Hindustan Newsprint Limited (HNL), a Government of India Enterprise, is currently the only pulp and paper factory in Kerala. Its major bamboo raw material requirement is being met from the bamboo forests in the State. Bamboo forests include plantations mixed with bamboo and those with bamboo as under-growth. For each financial year, specific coupes of bamboo forests are allotted by the State Government to HNL for harvesting. Almost all bamboo being harvested for the industrial use is *Bambusa bambos*, although there are species like *Dendrocalamus strictus* occurring sporadically in the forests. As per the Kerala Forest Produce (Fixation of Selling Price) Act, 1978, selling price of bamboo (*Bambusa* species) is fixed by the government for the standing crop in the forests. It is fixed for each financial year and timely notified in the Kerala Gazette. The selling price of bamboo, known as the notified price, is actually the price per metric tonne of standing weight which refers to the weight of utilizable portion of standing green mature bamboo culms in the forests.

Bamboo is harvested by HNL through contractors. Harvesting usually starts in October and ends by May in the next year. Bamboo culms are felled and the utilizable portion of the culms is cut into pieces suitable for transportation. The harvested bamboo pieces are then transported from the felling site to the factory yard by trucks. The bamboo reaching at the factory gate is weighed by the factory officials and the moisture content in bamboo is determined in the factory's laboratory using sample discs taken from the truck-load at the time of weighing. The weight of harvested bamboo when weighed at the factory gate is usually called as the net weight. Between the time of felling and reaching at the factory gate, there occurs a loss of moisture in the harvested bamboo due to drying. So, there is a difference between standing weight of bamboo culms and net weight of harvested bamboo pieces. Net weight of bamboo in each truck-load with varying levels of moisture content is converted by HNL to the weight at the standardized 50% moisture content. For calculating the cost of raw-material based on the weight at 50% moisture content and settling the payment with the government, the selling price of bamboo at 50% moisture content is required. In the absence of the price at 50% moisture content, it has to be derived from the notified price. Also for direct calculation of the cost using the notified price, it is required to determine the equivalent standing weight from the net weight of harvested bamboo.

Although selling price of bamboo is fixed by the government for standing weight, no information was available on the actual moisture content in bamboo in the forests. It was, therefore, necessary to estimate the average moisture content and thereby find out conversion factors to determine the equivalent standing weight from the net weight and derive the selling price of bamboo at 50% moisture content from the notified price. In this context, this study was taken up to derive the weight and price conversion factors for *Bambusa bambos*, as per G.O. (Rt) No. 355/05/WLD dated 23.06.2005 from the Government of Kerala. Weight

conversion factor is the multiplication factor for converting the net weight to the equivalent standing weight and price conversion factor is the multiplication factor for converting the notified price to the price of bamboo at 50% moisture content.

1.1 Objectives

The objectives of this study were (i) to estimate the average moisture content in mature bamboo in the forests in Kerala, (ii) to find out the weight conversion factors for determining the equivalent standing weight from the net weight of harvested bamboo and (iii) to arrive at a price conversion factor for deriving the selling price of bamboo at 50% moisture content from the notified price.

2. METHODOLOGY

For deriving the weight and price conversion factors, an estimate of the average moisture content was necessary. Sample bamboo discs were prepared by cutting culms felled through a sample survey in forest bamboo coupes in Kerala. The average moisture content was estimated based on the green and oven-dry weights of sample discs. Green weight refers to the fresh weight of the sample disc prepared by cutting green mature culms immediately after felling and measured in the shortest possible time without any change in the moisture content in the standing condition of the culm and in the disc. Oven-dry weight refers to the moisture less weight of the disc measured after drying it in an electric oven. As the moisture content in bamboo is the ratio of the weight of moisture contained in the culms to the green weight of the standing culms, the average moisture content was developed through ratio estimator. The methodology adopted is described below:

2.1 Sampling design

The sampling design adopted for the survey was a simple random sampling design. The sampling units were the bamboo coupes spread across the entire forests in Kerala. In the sampling plan, the observations on the sampling unit were the weight of moisture contained in the sample discs (the difference between the green and oven-dry weights) and the green weight of the sample discs. For the selection of coupes, the sampling frame was prepared as follows: Bamboo from the forests was exclusively used by the erstwhile Grasim Industries at Mavoor. Specific coupes were allotted to the factory for extraction in each year and the factory was harvesting bamboo for the last four decades. Based on the data available in the registers maintained by the factory and files of the Forest Department, the list of all coupes which were ever worked in the past was prepared for the study by Nair *et al.* (2001). From such an exhaustive list, the coupes worked in the past but now in protected areas which have been subsequently excluded from bamboo harvesting, were eliminated. Coupes, where

bamboo flowered within the last 10 years, were also excluded from the list as the seedlings emerged after flowering would take 10 to 15 years to become full sized culms. After the closure of Grasim Industries, the government has given HNL the right of harvesting bamboo from the forests. The list of coupes was updated using data on coupes worked in the past as well as currently being worked by HNL and information from knowledgeable bamboo felling contractors. The updated list of coupes was used as the sampling frame for the selection of sample coupes.

During the pilot field work carried out prior to the sample survey, it was observed that variation in moisture content in bamboo culms within a coupe was relatively low. But there may be variation in moisture content in coupes in different regions (Krishnankutty, 2003) due to climatic and edaphic factors. Variation in moisture content among coupes is more important than the variation within a coupe. So for a good representation of the whole bamboo forests in Kerala, it was decided to cover a larger sample of 52 coupes, 20 per cent of the total number of forest bamboo coupes in Kerala. To account the variation in moisture content due to weather and soil moisture, the bamboo harvesting period of eight months from October to May was divided into four sub-periods of two months each: October-November, December-January, February-March and April-May. For each of the four sub-periods, samples of 13 coupes each were selected independently from the total number of forest coupes in Kerala by the method of simple random sampling without replacement. The selected coupes belong to different Forest Divisions of Thiruvananthapuram, Punalur, Achencovil, KFDC Division Achencovil, Munnar, Malayattoor, Vazhachal, Thrissur, Nenmara, Nilambur South, Nilambur North, Mannarkkad, Wayanad South, Wayanad North, Kozhikode and Kannur.

2.2 Selection of bamboo culms for felling

From a selected bamboo coupe, a sub-sample of two typical bamboo clumps representing the coupe was identified for felling sample culms. Two clumps were sufficient due to the relatively low variation in moisture content among clumps within a coupe. From the two clumps identified, three green mature culms (three and above three years old culms) each were selected for preparing sample discs. It was also found during the pilot survey that the moisture content in bamboo culms within a clump varies with respect to the age of the culms. For accounting this variability, culms were selected in such a manner that each one belonged to the age-classes of 3-6, 7-10 and above 10 years old. All the culms by age-classes in a clump could easily be distinguished by the experienced bamboo cutters to select the culms for felling. Defective culms such as dry, broken, damaged and discoloured culms were excluded during selection of the culms for felling.

Selective felling of three representative culms from a bamboo clump was difficult when they were amidst the clump or intervened with other culms or trees nearby. For this survey, skilled workers experienced in cutting bamboo in forest

coups for contractors were recruited and the survey team consisted of specialist workers. Felling of culms was done mainly with two tools. The first was a bill-hook or *thotti* (a thin and strong bamboo pole fitted tightly with an appropriate sharp steel bill at the thicker end of the pole) and the second was a short hand-axe usually used by tree cutters for cutting branches of trees. For felling of a culm, the first operation was pruning off the thorny branches of the selected culm and those standing around it. The second intricate operation was cutting of the top half of the lengthy culm. Such a sturdy bill-hook was used for both operations. The base of the culm at the ground level was cut with a hand-axe. After felling of a culm, stumps of the thorny branches sticking out at the nodes of the culm were removed with the same tool. When the selected bamboo coupe was a currently working one, felling of culms was easier than from a coupe that was not being worked during the time of the field survey. In a working coupe, bamboo cutters were already at work and they could be directed to start working in a selected clump from the side that was best suited to reach the selected culms within the clump. Based on the instructions given to the bamboo cutters, the representative culms were felled and pruned by them. Then the role of the survey team started with marking on the felled culm and preparing the discs for green weight measurement. In the case of other coupes, the entire operation including felling and pruning was carried out by the survey team which consisted of experienced bamboo cutters.

2.3 Preparation of sample bamboo discs

After felling bamboo culms, it was necessary to collect sample discs from the predetermined positions of each culm. As density and hardness in a culm differ at different locations along the length and also between the nodal and internodal portions, the moisture content also varies accordingly. The moisture content in the nodal and internodal portions varies as the height level increases and that in the internodal portion is more than that at the nodes. As the weight of a culm is determined by the weight of moisture contained in both the nodal and internodal portions, both portions were considered in this study for the estimation of moisture content. This study is a pioneering one and no precedence on those aspects could be located in the literature or through discussion with industry people. Hence a small-scale experiment was conducted using the following method:

Bamboo discs of 5 cm length from different height positions in 18 culms felled in a bamboo coupe were prepared. Discs were taken by cutting from mid-internodes at the height of 1.5 m from the ground level of the standing culm and at every subsequent 3 m internodes. In the case of discs at nodes, the disc at the very first node was taken and subsequent nodes at every 10^{th} position along the length of the culm (see Appendix-1). Discs from both nodal and internodal portions were weighed for green weight at the felling site and marked with unique identification number. The discs were brought to KFRI and air dried. Afterwards, they were kept in an electric oven in the laboratory at a temperature of 103 ± 2^0 C for 48 hours

(Panshin and Carl de Zeeuw, 1980). After taking out the discs from the oven, the oven-dry weight of each disc was measured and recorded. Moisture content ***m*** in each disc was calculated using the formula $\boldsymbol{m = (g - d)/g}$, where ***g*** and ***d*** denote respectively the green and oven-dry weight (in gm) of the disc. The data regarding moisture content of discs at different positions in the culm were scrutinized. Then the weighted average moisture content of the entire culm and that in different sections of the culm was calculated. Using these data and observing the pattern of change in density and moisture content along the culm, it was decided to take mid-internode sample discs of 5 cm length at the midpoint of the first segment of 3 m and at the midpoint of every successive 6 m length along the culm. Likewise in the case of nodal portion, it was decided to take sample discs of 5 cm length at 10^{th}, 30^{th} and 50^{th} nodes from the base of the culm.

For preparing sample bamboo discs from the nodal and internodal portions of felled culms, experienced carpenters were included in the team. A special hack-saw with extra-wide and stronger blade was used to prepare the sample discs by cutting from the culms. Such a hack-saw was particularly useful to speed up the work of taking the discs by sawing in the shortest possible time after felling the culm. Electronic balance with a precision of one decimal to gm, with rechargeable batteries, was used in the felling site to measure the green weight of each disc immediately after felling of the culm and taking the discs by cutting with a hack-saw. The sample discs collected from each bamboo culm in the selected coupes were labeled with unique identification number.

2.4 Estimation of average moisture content

As explained earlier, sample discs of 5 cm length were prepared from nodes and mid-internodes at different height levels of 312 sample culms felled in the selected 52 coupes in Kerala during the period of eight months from April to May 2006 and October 2006 to March 2007. Immediately after cutting with hack-saw, green weight of each disc was measured at the site in an electronic balance and the green weight (in gm) was recorded. Number of sample discs prepared in various selected coupes ranged from 30 to 42 depending on the length of the felled culm. Altogether 2,015 discs were collected from 312 culms of which 858 were from nodal and 1,157 discs from internodal portions (see Appendix-2). As and when the discs were prepared from various selected coupes, they were brought to KFRI and kept in open place for air drying. The air-dried discs were then kept in the electric ovens in the laboratory at a temperature of 103 ± 2^0 C for 48 hours. After taking out the discs from the oven, the oven-dry weight (in gm) of each disc was measured and recorded. Caution was taken to prevent any change in the moisture content between removing the discs from the oven and weighing. With a weekly gap of time, the oven-dried discs were again kept in the oven at the same temperature for 48 hours and the oven-dry weight of each disc was re-measured and recorded. In most of the discs, the oven-dry weights were exactly the same

and in a few cases slightly different. In the case of a disc with different values, the lower figure was taken as the oven-dry weight of the disc.

As the sampling unit was a bamboo coupe, the green weights of all the sample discs prepared from the nodal and internodal portions of the six sample culms felled in each selected coupe were aggregated to arrive at the coupe-level green weight. Similarly, the respective oven-dry weights were also aggregated to arrive at the coupe-level oven-dry weight. The coupe-level green and oven-dry weights of the j^{th} selected coupe during the i^{th} felling sub-period were denoted by g_{ij} and d_{ij} respectively. Based on the coupe-level values of g_{ij} and d_{ij}, the ratio estimates of the moisture content for the four felling sub-periods were developed and then combined to arrive at the average moisture content during the harvesting period of eight months. That is; the average moisture content $\overline{M}$ (in percentage) in mature bamboo in the forests was estimated as $\overline{M} = 100\sum_{i,j}(g_{ij} - d_{ij})/\sum_{i,j} g_{ij}$.

2.5 Derivation of conversion factors

The weight and price conversion factors were derived as follows. The net weight (in metric tonne) of a specified quantity of harvested bamboo with known moisture content M_0 % is denoted by H and G its equivalent standing weight (in metric tonne) of green mature bamboo with an estimated average moisture content of $\overline{M}$ %. Then G is derived as $G = (100 - M_0)\ H\ /\ (100 - \overline{M})$, from which the weight conversion factors are given by $W_{CF} = (100 - M_0)\ /\ (100 - \overline{M})$, where $M_0 \leq \overline{M}$. The notified price and the price of bamboo at 50% moisture content (both in Rs per metric tonne) are denoted by P_N and P_{50} respectively. Then the price of bamboo at 50% moisture content is derived as $P_{50} = 50\ P_N\ /\ (100 - \overline{M})$. From this, the price conversion factor is given by $P_{CF} = 50\ /\ (100 - \overline{M})$. By substituting the value of the estimated average moisture content in the above formulae of W_{CF} and P_{CF}, the weight and price conversion factors were estimated.

3. CONVERSION FACTORS

Weight and price conversion factors were estimated using the average moisture content. Weight conversion factor is the multiplication factor for converting the net weight of a specified quantity of harvested bamboo with known moisture content to the equivalent standing weight of green culms as in the forests. Price conversion factor is the multiplication factor for converting the notified price in a financial year to the price of bamboo at 50% moisture content in the same year.

3.1 Average moisture content

The estimated average moisture content in the nodal and internodal portions in segments at different height levels from the base of a culm and average moisture

content in bamboo in the forests are presented in Table 1. Moisture content in the internodal portions ranges from 41.9% in the top segment to 48.2% in the bottom segment of the culm, whereas that in the nodal portions ranges from 43.1 % in the top segment to 44.3 % in the bottom segment of the culm. It can also be seen that the moisture content in the internodal portions is higher than that in the nodal portions. The estimated average moisture content in bamboo in the forests during the harvesting period from October to May is 45.23%.

Table 1 Average moisture content in bamboo in the forests in Kerala

(Moisture content in %)

Culm portions	Average moisture content in segments at different height levels from the base of a culm				Weighted average
	Bottom	Middle	Top	End	
Internodes*	48.19	45.67	43.99	41.85	46.38
Nodes#	44.31	44.37	43.13	-	44.19
Average moisture content in bamboo in the forests					45.23

* Mid- internodes at the height of 1.5 m (bottom), 6 m (middle), 12 m (top) and 18 m (end).

10^{th} node (bottom), 30^{th} node (middle), and 50^{th} node (top) from the base of the standing culm.

3.2 Weight conversion factors

The weight conversion factors are given by $\boldsymbol{W_{CF} = (100 - M_0) / 54.77,}$ where $\boldsymbol{M_0}$ is the known moisture content (in percentage) in the harvested bamboo such that $\boldsymbol{M_0 \leq \overline{M}}$. Weight conversion factors corresponding to different values of moisture content in harvested bamboo have been computed. The weight conversion factors corresponding to the integer values from 10% to 45% are presented in Table 2 and those for different values with one decimal from 10.0% to 45.23% are shown in Appendix-3. To convert the net weight of a specified quantity of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in the forests, the weight figure has to be multiplied with the respective weight conversion factor.

Net weight of harvested bamboo arriving at the factory and the moisture content of bamboo in each truck-load recorded at the factory gate are the only data available to HNL and also through them to the government. Using the weight conversion factor given in Table 2 or Appendix-3 corresponding to the moisture content recorded at the factory gate for each truck-load, the equivalent standing weight of bamboo in each truck-load can be calculated. For example, the net weight of 12.2 metric tonnes of harvested bamboo in a truck-load at the factory gate has a moisture content of 34%. The weight conversion factor corresponding to 34% moisture content is 1.205 from Table 2. The equivalent standing weight of bamboo in the same truck-load is calculated by multiplying the above weight of 12.2 metric tonnes with the conversion factor of 1.205 as 14.701 metric tonnes.

The notified price of bamboo during the year 2007-08 is Rs 850 per metric tonne of standing weight. Thus the material cost payable by HNL to the government, for 12.2 metric tonnes of harvested bamboo with moisture content of 34%, is the product of 14.701 and 850 which is equal to Rs 12,496.

Table 2 Weight conversion factors for different values of the moisture content in harvested bamboo

Moisture content (%)	Conversion factors*	Moisture content (%)	Conversion factors*	Moisture content (%)	Conversion factors*
10.0	1.6432	23.0	1.4059	36.0	1.1685
11.0	1.6250	24.0	1.3876	37.0	1.1503
12.0	1.6067	25.0	1.3694	38.0	1.1320
13.0	1.5885	26.0	1.3511	39.0	1.1137
14.0	1.5702	27.0	1.3328	40.0	1.0955
15.0	1.5519	28.0	1.3146	41.0	1.0772
16.0	1.5337	29.0	1.2963	42.0	1.0590
17.0	1.5154	30.0	1.2781	43.0	1.0407
18.0	1.4972	31.0	1.2598	44.0	1.0225
19.0	1.4789	32.0	1.2416	45.0	1.0042
20.0	1.4607	33.0	1.2233	45.1	1.0024
21.0	1.4424	34.0	1.2050	45.2	1.0005
22.0	1.4241	35.0	1.1868	45.23	1.0000

* Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in the forests.

3.3 Price conversion factor

The estimated price conversion factor is 0.9129. To calculate the selling price of bamboo at 50% moisture content, the government notified price has to be multiplied with the price conversion factor of 0.9129. For the notified price of bamboo during the financial years from 2001-01 to 2007-08 (Government of Kerala, 2000 to 2007), the selling price per metric tonne of bamboo at 50% moisture content is calculated and shown in Table 3. The selling price for the years prior to 2000-01 or after 2007-08 can be calculated by multiplying the respective notified prices with the price conversion factor of 0.9129.

Net weight of harvested bamboo recorded at the factory gate with varying levels of moisture content are usually converted to the standardized 50% moisture content and the total quantity at 50% moisture content is worked out. The cost

payable for the raw material by HNL to the government in a year can be calculated by simply multiplying the total quantity with the selling price per metric tonne of bamboo at 50% moisture content in the same year. Consider the earlier example of 12.2 metric tonnes net weight of harvested bamboo with 34% moisture content. When converted, the net weight of 12.2 metric tonnes of bamboo with 34% moisture content is equivalent to 16.104 metric tonnes of bamboo at 50% moisture content. From Table 3, the selling price of bamboo at 50% moisture content during the year 2007-08 is Rs 776 per metric tonne. The material cost payable by HNL to the government, for the above 12.2 metric tonnes net weight of harvested bamboo with 34% moisture content, is the product of 16.104 and 776 which is equal to Rs 12,496. It can be seen that the material cost of 12.2 metric tonnes net weight of bamboo with 34% moisture content worked out by the two methods: (i) converting to the equivalent standing weight and multiplying it with the notified price and (ii) converting to the weight at 50% moisture content and multiplying it with the selling price of bamboo at 50% moisture content, are the same.

Table 3 Selling price of bamboo at 50% moisture content corresponding to the government notified price in different years

(Rs / metric tonne)

Year	Notified price	Selling price at 50% *mc**	Year	Notified price	Selling price at 50% *mc**
2000-01	985	899	2004-05	1,055	963
2001-02	1,110	1,013	2005-06	850	776
2002-03	1,170	1,068	2006-07	800	730
2003-04	1,110	1,013	2007-08	850	776

*Selling price is obtained by multiplying the notified price with the price conversion factor of 0.9129.

As mentioned earlier, selling price of bamboo is notified for the standing weight of bamboo. In the absence of any facility to measure the standing weight at the felling site in the forests, the net weight of bamboo recorded at the factory gate is now converted by HNL to the equivalent standing weight by correcting the loss of weight after felling based on the following thump rule given in the government order: The weight of harvested bamboo recorded at the factory gate on or before the 30^{th} day of felling shall be treated as such; weight recorded after 30^{th} day but on or before the 75^{th} day of felling shall be multiplied by 10/6 and weight recorded after 75^{th} day of felling shall be doubled (Government of Kerala, 2007). The calculation of equivalent standing weight based on the above rule does not correctly account the change in the moisture content due to drying when the bamboo is brought to the factory after several days from the felling site. In this context, a new method in line with the spirit of the government order fixing the price of bamboo based on the weight of standing bamboo in the forests is suggested. If selling price of bamboo is fixed in a similar manner as that for the

standing weight of green mature bamboo in the forests, the price payable by HNL to the government for the net weight of harvested bamboo can directly be arrived at by calculating its equivalent standing weight using the weight conversion factor (given in Table 2 or Appendix-3) and multiplying it with the notified price.

4. CONCLUSIONS

The estimated average moisture content of 45.23% and conversion factors are new information to the government as well as scientific communities. The price conversion factor can be used for deriving the price of bamboo at 50% moisture content from the notified price in a financial year. Price payable by HNL in a financial year for each metric tonne of bamboo at 50% moisture content can be found out by simply multiplying the notified price in the same year with the price conversion factor of 0.9129. The weight conversion factor can be used for determining the equivalent standing weight of bamboo as in the forests from the weight of harvested bamboo with known moisture content. The price payable by HNL to the government for the net weight of harvested bamboo in a financial year can directly be arrived at by multiplying its equivalent standing weight with the notified price in the same year. The advantage of having the weight conversion factors which can readily be used is that the weight of standing bamboo in the forests, which is the basis of the government price notification, can easily be estimated from the weight of harvested bamboo. This is in line with the spirit of the government orders fixing the selling price of bamboo based on the weight of the standing crop in the forests.

REFERENCES

Government of Kerala (2007). Kerala Gazette (Extraordinary), Vol.52, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2006). Kerala Gazette (Extraordinary), Vol.51, No. 688, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2005). Kerala Gazette (Extraordinary), Vol.50, No. 697, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2004). Kerala Gazette (Extraordinary), Vol.49, No. 791, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2003). Kerala Gazette (Extraordinary), Vol.48, No. 523, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2002). Kerala Gazette (Extraordinary), Vol.47, No. 375, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2001). Kerala Gazette (Extraordinary), Vol.46, No. 490, Forest and Wildlife Department, Thiruvananthapuram.

Government of Kerala (2000). Kerala Gazette (Extraordinary), Vol.45, No. 584, Forest and Wildlife Department, Thiruvananthapuram.

Krishnankutty, C. N. (2003). Volume-weight relation of stacked bamboo and reed. *The Indian Forester*, 129 (11): 1339-1343.

Nair, P. V., Menon, A. R. R. and Krishnankutty, C. N. (2001). *Survey and estimation of bamboo resources of Kerala*. *KFRI Research Report No. 221*. Kerala Forest Research Institute, Peechi, India.

Panshin, A . J. and Carl de Zeeuw (1980). *Textbook of Wood Technology*. McGraw-Hill Book Company, USA.

Appendix-1 Green sample discs from nodes and mid-internodes at different height levels of bamboo culms

Appendix-2 Oven-dried sample bamboo discs

Appendix- 3
Weight conversion factors for different values of the moisture content in harvested bamboo

(Moisture content in %)

Moisture content	Conversion factors*	Moisture content	Conversion factors*	Moisture content	Conversion factors*
10.0	1.6432	12.4	1.5994	14.8	1.5556
10.1	1.6414	12.5	1.5976	14.9	1.5538
10.2	1.6396	12.6	1.5958	15.0	1.5519
10.3	1.6378	12.7	1.5939	15.1	1.5501
10.4	1.6359	12.8	1.5921	15.2	1.5483
10.5	1.6341	12.9	1.5903	15.3	1.5465
10.6	1.6323	13.0	1.5885	15.4	1.5446
10.7	1.6305	13.1	1.5866	15.5	1.5428
10.8	1.6286	13.2	1.5848	15.6	1.5410
10.9	1.6268	13.3	1.5830	15.7	1.5392
11.0	1.6250	13.4	1.5812	15.8	1.5373
11.1	1.6232	13.5	1.5793	15.9	1.5355
11.2	1.6213	13.6	1.5775	16.0	1.5337
11.3	1.6195	13.7	1.5757	16.1	1.5319
11.4	1.6177	13.8	1.5739	16.2	1.5300
11.5	1.6158	13.9	1.5720	16.3	1.5282
11.6	1.6140	14.0	1.5702	16.4	1.5264
11.7	1.6122	14.1	1.5684	16.5	1.5246
11.8	1.6104	14.2	1.5666	16.6	1.5227
11.9	1.6085	14.3	1.5647	16.7	1.5209
12.0	1.6067	14.4	1.5629	16.8	1.5191
12.1	1.6049	14.5	1.5611	16.9	1.5173
12.2	1.6031	14.6	1.5592	17.0	1.5154
12.3	1.6012	14.7	1.5574	17.1	1.5136

*Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in forests.

Appendix- 3 Continued…

Weight conversion factors for different values of the moisture content in harvested bamboo

(Moisture content in %)

Moisture content	Conversion factors*	Moisture content	Conversion factors*	Moisture content	Conversion factors*
17.2	1.5118	19.6	1.4680	22.0	1.4241
17.3	1.5100	19.7	1.4661	22.1	1.4223
17.4	1.5081	19.8	1.4643	22.2	1.4205
17.5	1.5063	19.9	1.4625	22.3	1.4187
17.6	1.5045	20.0	1.4607	22.4	1.4168
17.7	1.5026	20.1	1.4588	22.5	1.4150
17.8	1.5008	20.2	1.4570	22.6	1.4132
17.9	1.4990	20.3	1.4552	22.7	1.4114
18.0	1.4972	20.4	1.4534	22.8	1.4095
18.1	1.4953	20.5	1.4515	22.9	1.4077
18.2	1.4935	20.6	1.4497	23.0	1.4059
18.3	1.4917	20.7	1.4479	23.1	1.4041
18.4	1.4899	20.8	1.4460	23.2	1.4022
18.5	1.4880	20.9	1.4442	23.3	1.4004
18.6	1.4862	21.0	1.4424	23.4	1.3986
18.7	1.4844	21.1	1.4406	23.5	1.3968
18.8	1.4826	21.2	1.4387	23.6	1.3949
18.9	1.4807	21.3	1.4369	23.7	1.3931
19.0	1.4789	21.4	1.4351	23.8	1.3913
19.1	1.4771	21.5	1.4333	23.9	1.3894
19.2	1.4753	21.6	1.4314	24.0	1.3876
19.3	1.4734	21.7	1.4296	24.1	1.3858
19.4	1.4716	21.8	1.4278	24.2	1.3840
19.5	1.4698	21.9	1.4260	24.3	1.3821

*Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in forests.

Appendix- 3 Continued…

Weight conversion factors for different values of the moisture content in harvested bamboo

(Moisture content in %)

Moisture content	Conversion factors*	Moisture content	Conversion factors*	Moisture content	Conversion factors*
24.4	1.3803	26.8	1.3365	29.2	1.2927
24.5	1.3785	26.9	1.3347	29.3	1.2909
24.6	1.3767	27.0	1.3328	29.4	1.2890
24.7	1.3748	27.1	1.3310	29.5	1.2872
24.8	1.3730	27.2	1.3292	29.6	1.2854
24.9	1.3712	27.3	1.3274	29.7	1.2835
25.0	1.3694	27.4	1.3255	29.8	1.2817
25.1	1.3675	27.5	1.3237	29.9	1.2799
25.2	1.3657	27.6	1.3219	30.0	1.2781
25.3	1.3639	27.7	1.3201	30.1	1.2762
25.4	1.3621	27.8	1.3182	30.2	1.2744
25.5	1.3602	27.9	1.3164	30.3	1.2726
25.6	1.3584	28.0	1.3146	30.4	1.2708
25.7	1.3566	28.1	1.3128	30.5	1.2689
25.8	1.3548	28.2	1.3109	30.6	1.2671
25.9	1.3529	28.3	1.3091	30.7	1.2653
26.0	1.3511	28.4	1.3073	30.8	1.2635
26.1	1.3493	28.5	1.3055	30.9	1.2616
26.2	1.3475	28.6	1.3036	31.0	1.2598
26.3	1.3456	28.7	1.3018	31.1	1.2580
26.4	1.3438	28.8	1.3000	31.2	1.2562
26.5	1.3420	28.9	1.2982	31.3	1.2543
26.6	1.3401	29.0	1.2963	31.4	1.2525
26.7	1.3383	29.1	1.2945	31.5	1.2507

*Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in forests.

Appendix- 3 Continued…

Weight conversion factors for different values of the moisture content in harvested bamboo

(Moisture content in %)

Moisture content	Conversion factors*	Moisture content	Conversion factors*	Moisture content	Conversion factors*
31.6	1.2489	34.0	1.2050	36.4	1.1612
31.7	1.2470	34.1	1.2032	36.5	1.1594
31.8	1.2452	34.2	1.2014	36.6	1.1576
31.9	1.2434	34.3	1.1996	36.7	1.1557
32.0	1.2416	34.4	1.1977	36.8	1.1539
32.1	1.2397	34.5	1.1959	36.9	1.1521
32.2	1.2379	34.6	1.1941	37.0	1.1503
32.3	1.2361	34.7	1.1923	37.1	1.1484
32.4	1.2343	34.8	1.1904	37.2	1.1466
32.5	1.2324	34.9	1.1886	37.3	1.1448
32.6	1.2306	35.0	1.1868	37.4	1.1430
32.7	1.2288	35.1	1.1850	37.5	1.1411
32.8	1.2269	35.2	1.1831	37.6	1.1393
32.9	1.2251	35.3	1.1813	37.7	1.1375
33.0	1.2233	35.4	1.1795	37.8	1.1357
33.1	1.2215	35.5	1.1777	37.9	1.1338
33.2	1.2196	35.6	1.1758	38.0	1.1320
33.3	1.2178	35.7	1.1740	38.1	1.1302
33.4	1.2160	35.8	1.1722	38.2	1.1284
33.5	1.2142	35.9	1.1703	38.3	1.1265
33.6	1.2123	36.0	1.1685	38.4	1.1247
33.7	1.2105	36.1	1.1667	38.5	1.1229
33.8	1.2087	36.2	1.1649	38.6	1.1211
33.9	1.2069	36.3	1.1630	38.7	1.1192

*Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in forests.

Appendix- 3 Continued…

Weight conversion factors for different values of the moisture content in harvested bamboo

(Moisture content in %)

Moisture content	Conversion factors*	Moisture content	Conversion factors*	Moisture content	Conversion factors*
38.8	1.1174	41.0	1.0772	43.2	1.0371
38.9	1.1156	41.1	1.0754	43.3	1.0352
39.0	1.1137	41.2	1.0736	43.4	1.0334
39.1	1.1119	41.3	1.0718	43.5	1.0316
39.2	1.1101	41.4	1.0699	43.6	1.0298
39.3	1.1083	41.5	1.0681	43.7	1.0279
39.4	1.1064	41.6	1.0663	43.8	1.0261
39.5	1.1046	41.7	1.0645	43.9	1.0243
39.6	1.1028	41.8	1.0626	44.0	1.0225
39.7	1.1010	41.9	1.0608	44.1	1.0206
39.8	1.0991	42.0	1.0590	44.2	1.0188
39.9	1.0973	42.1	1.0571	44.3	1.0170
40.0	1.0955	42.2	1.0553	44.4	1.0152
40.1	1.0937	42.3	1.0535	44.5	1.0133
40.2	1.0918	42.4	1.0517	44.6	1.0115
40.3	1.0900	42.5	1.0498	44.7	1.0097
40.4	1.0882	42.6	1.0480	44.8	1.0079
40.5	1.0864	42.7	1.0462	44.9	1.0060
40.6	1.0845	42.8	1.0444	45.0	1.0042
40.7	1.0827	42.9	1.0425	45.1	1.0024
40.8	1.0809	43.0	1.0407	45.2	1.0005
40.9	1.0791	43.1	1.0389	45.23	1.0000

*Multiplication factors for converting the net weight of harvested bamboo with known moisture content to the equivalent standing weight of green mature bamboo as in forests.