Reanalysis of Production Statistics on Wood-based Materials and Wood Adhesives in Japan By Data Reconciliation Method

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INTRODUCTION

The IPCC inventory guidelines (IPCC 2006 and IPCC 2019) have not yet provided emission factors for wood-based materials that contain synthetic adhesives. Moreover, statistics on adhesives do not differentiate plywood, particleboard (PB), and medium-density fiberboard (MDF) as demand sectors. To overcome this limitation, we developed a dynamic material flow model and applied a data reconciliation method to estimate the unit amount of adhesives used in the wood-based materials.

MATERIALS AND METHODS

The material flow model describes the production of three types of wood-based materials and the consumption of three types of adhesives: urea-, melamine-, and phenol-resin adhesives from 1990 to 2018 in Japan. Eq. 1 and Eq. 2 show the relationship between adhesives consumption and wood-based materials production volume. $A(w,a)$ was assumed to be a product of $B(w)$ and $s(a)$ (Eq. 3). The $r(y,w,a)$ was assumed to follow a softmax function with a quadratic polynomial (Eq. 4, Eq. 5). The proportions of different types of adhesives used in PB and MDF were assumed to be equal.

$$AT(y,a) = \sum_w AC(y,w,a) \quad \text{(Eq. 1)}$$

$$AC(y,w,a) = \frac{VT(y,w) \times r(y,w,a) \times A(w,a)}{1000} \quad \text{(Eq. 2)}$$

$$A(w,a) = B(w) \times s(a) \quad \text{(Eq. 3)}$$

$$r(y,w,a) = \frac{\exp\{f(y,w,a)\}}{\sum_i \exp\{f(y,w,i)\}} \quad \text{(Eq. 4)}$$

$$f(y,w,a) = k_{aw0} + k_{aw1}y + k_{aw2}y^2 \quad \text{(Eq. 5)}$$

$AT(y,a)$ [tonne]: Amount of adhesive type *a* used in wood-based materials in year *y*.
$AC(y,w,a)$ [tonne]: Amount of adhesive type *a* used in wood-based material type *w* in year *y*.
$VT(y,w)$ [m^3]: Production volume of wood-based material type *w* in year *y*.
$r(y,w,a)$ [m^3/m^3]: Share of wood-based material *w* with adhesive *a* among the wood-based material *w* in year *y*.
$A(w,a)$ [kg/m^3]: Amount of adhesive type a per unit volume of wood-based material type *w*.
$B(w)$ [kg/m^3]: Amount of urea-resin per unit volume of wood-based material type *w*.
$s(a)$ [$-$]: Relative amount of adhesive type a compared to urea-resin. $s(urea) = 1$

We estimated the parameter that minimizes the sum of squares of the residuals between the statistical values (JAIA 1990-2018) and the estimated consumption of the adhesives used for wood materials $AT(y,a)$ using

data reconciliation method. Since the estimated values cannot be determined only by comparing the amount of adhesive production, data obtained from other statistics and existing literature (METI 1990-2001, JPIC 2015-2018, Nakano et al. 2018) were used as observed values.

RESULTS AND DISCUSSION

Table 1 shows the estimation results of consumption of adhesives per unit volume of wood-based materials $A(w, a)$. It was found that plywood consumes fewer adhesives than PB and MDF, and MDF consumes the most adhesives among the three. The consumption level of urea-resin and melamine-resin was similar, while that of phenol-resin was about half of them. Figure 1 shows the gradual shifts from urea-resin to phenol-resin used in wood-based materials from 1990 to 2018.

Table 1 Estimation results of $A(w, a)$ [kg/m^3]

	Plywood	PB	MDF
Urea- resin	50	98	196
Melamine- resin	52	103	204
Phenol- resin	27	53	106

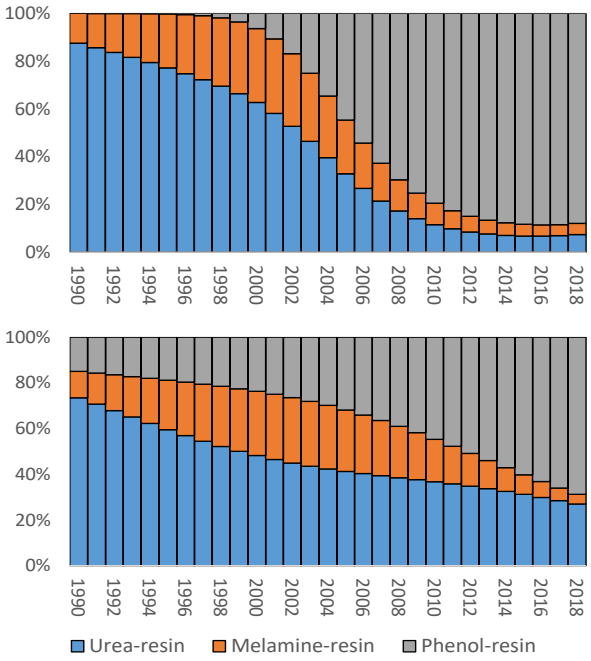

Figure 1 Market share of wood-based materials by adhesive type from 1990 to 2018 in Japan. Top: plywood, bottom: PB and MDF

CONCLUSION

This study aimed to estimate the unit amount of adhesives used in the wood-based materials. The dynamic material flow model and the data reconciliation method successfully revealed the data not directly available from the statistics. We are now improving the estimation by incorporating more observation and planning to verify this approach by comparing them with other methods such as elemental analysis.

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