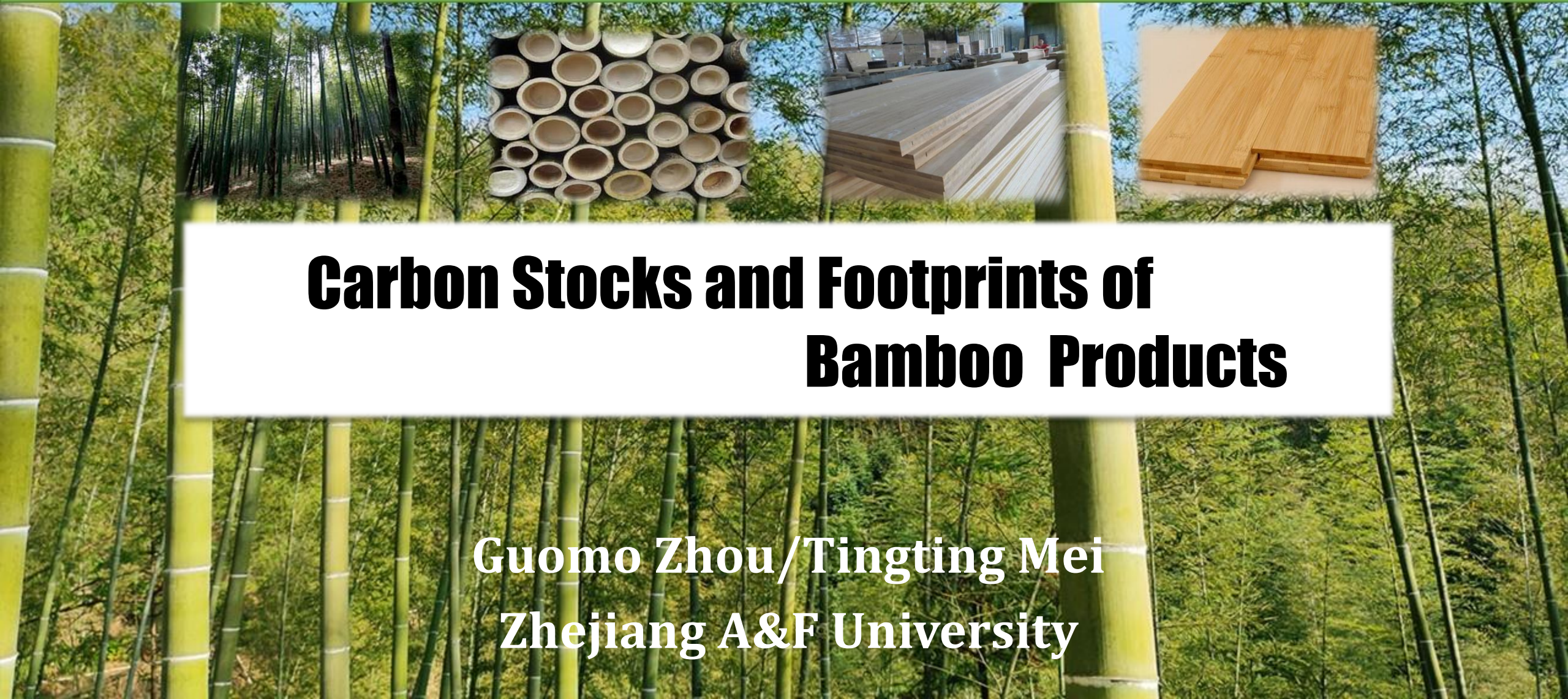


Engineered Bamboo for Sustainable Construction

May 17 – 19, 2022



Carbon Stocks and Footprints of Bamboo Products

Guomo Zhou/Tingting Mei
Zhejiang A&F University

Bamboo products: various usages

Bamboo production:

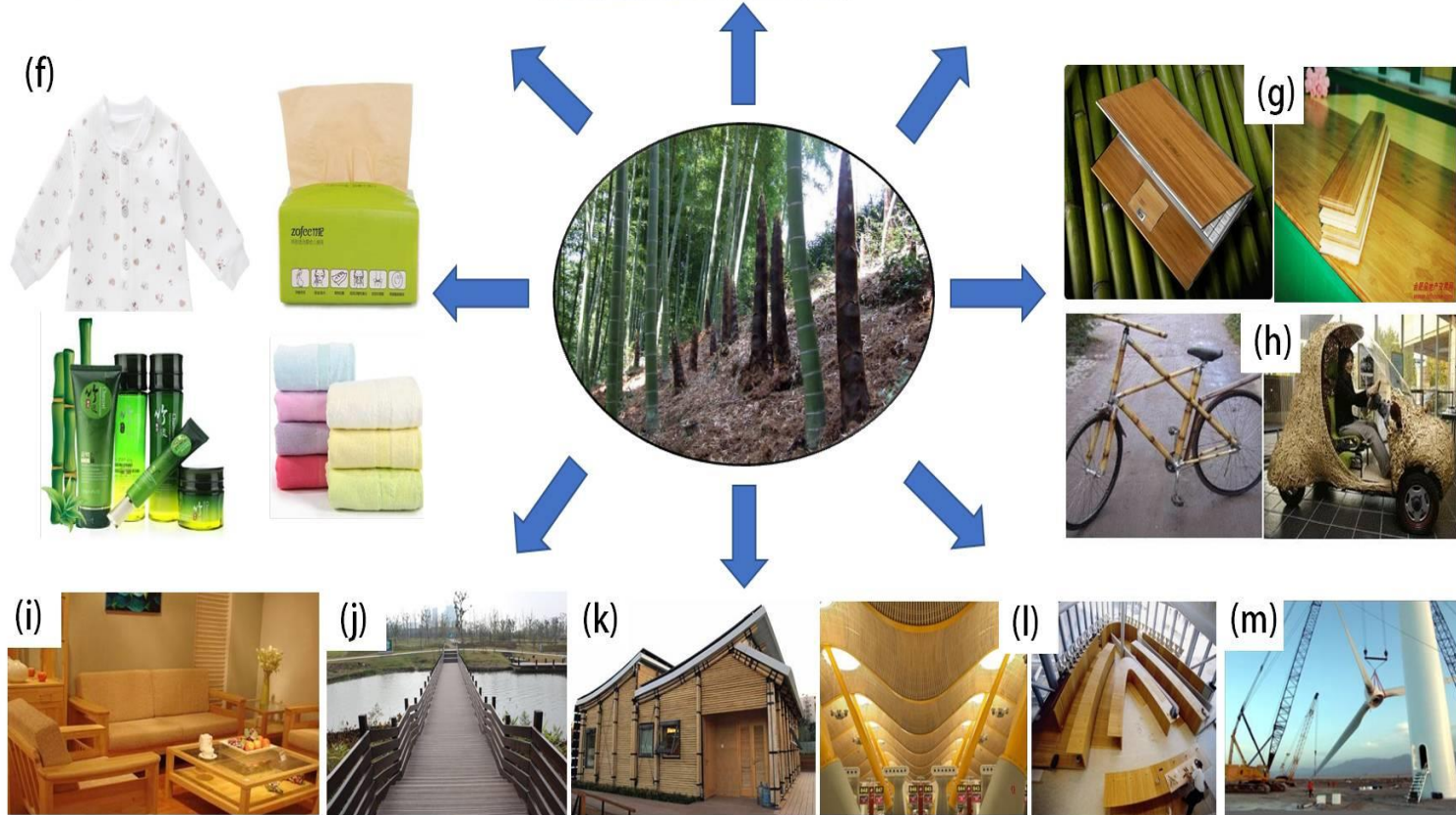
10 billion dollars per year

Bamboo products:

more than 2000 varieties



- (a) bamboo shoots;
- (b) bamboo weaving;
- (c) bamboo slabs;
- (d) bamboo mats;
- (e) bamboo biochar;
- (f) bamboo-fiber fabric, facial tissues, and makeup;
- (g) bamboo decorative material;
- (h) bamboo vehicle;
- (i) bamboo furniture;
- (j) bamboo floor;
- (k) bamboo buildings;
- (l) bamboo waiting hall;
- (m) bamboo wind turbine blades.



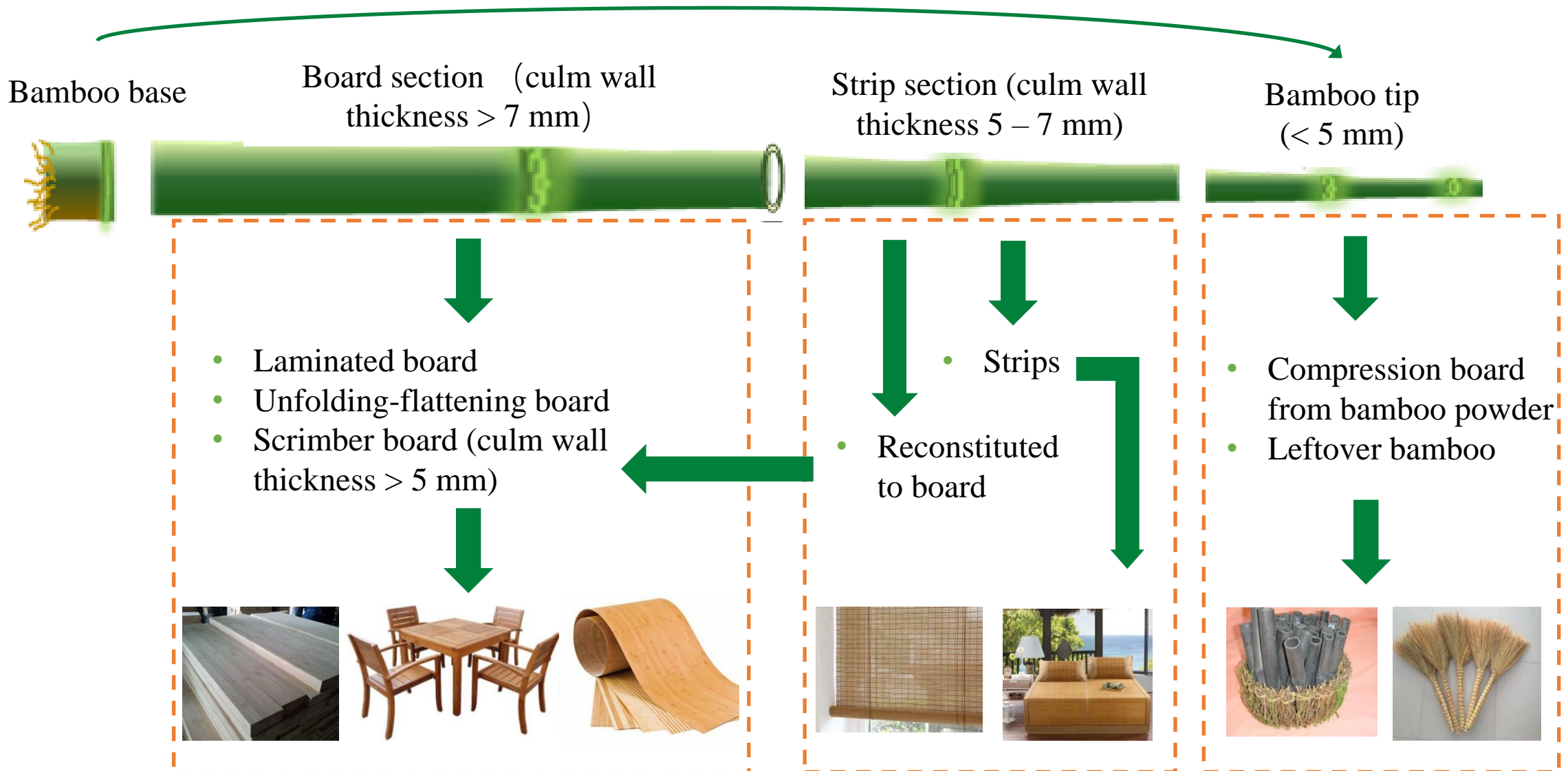
Carbon footprints of bamboo products



From 2011 to 2016, we:

- investigated **105** bamboo manufacturers in 4 provinces in China (Zhejiang, Fujian, Jiangxi, Sichuan)
- measured **1098** logged bamboo culms
- traced and measured the **whole** technological processes of bamboo production
- measured carbon footprints of **9** bamboo products in **5** categories.

From a standing bamboo culm to products



3 main technologies

Laminated

Unfolding-flattening

Reconstituted



5 bamboo product categories

Laminated board

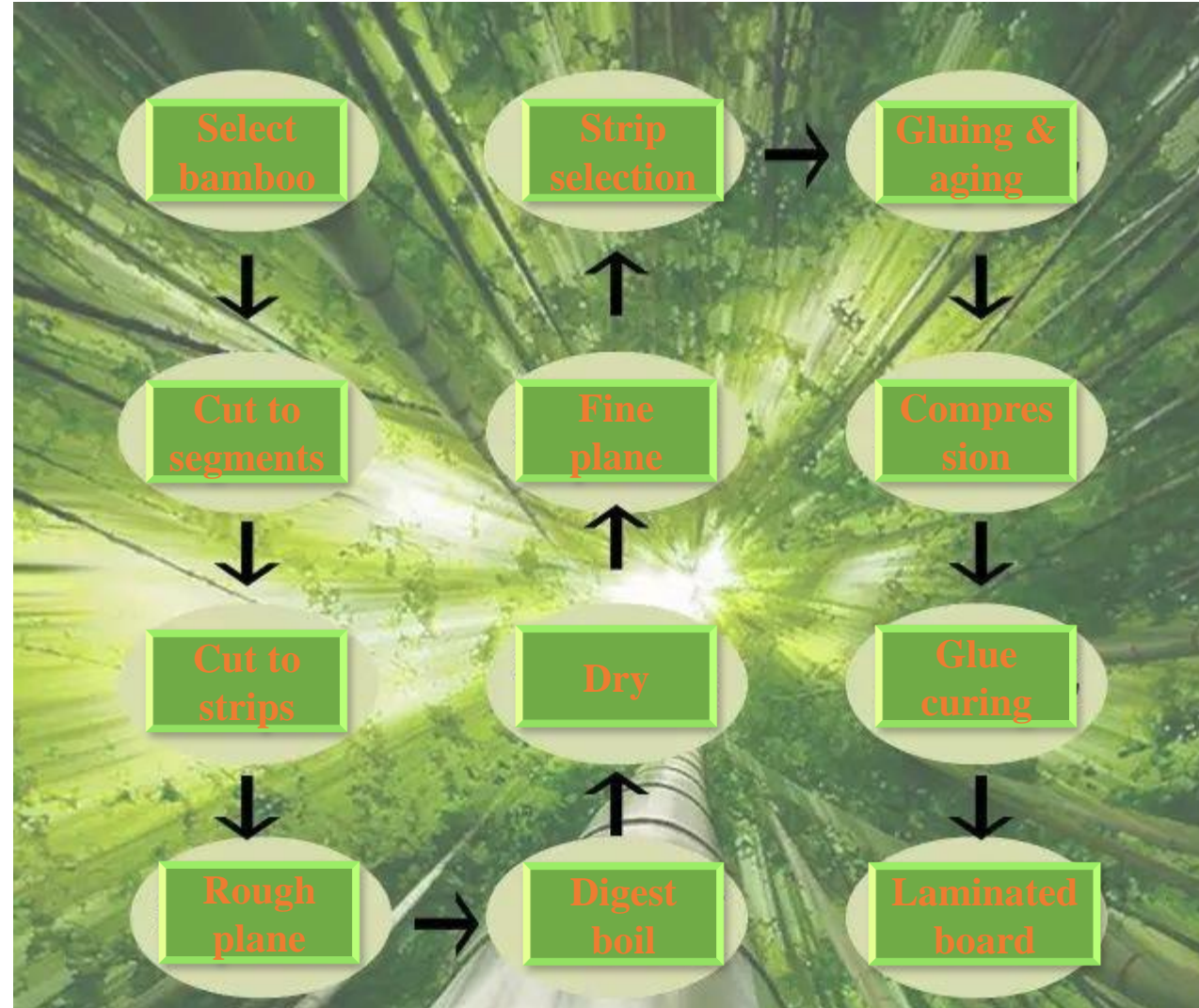
Unfolding-flattening board

Scrimber board

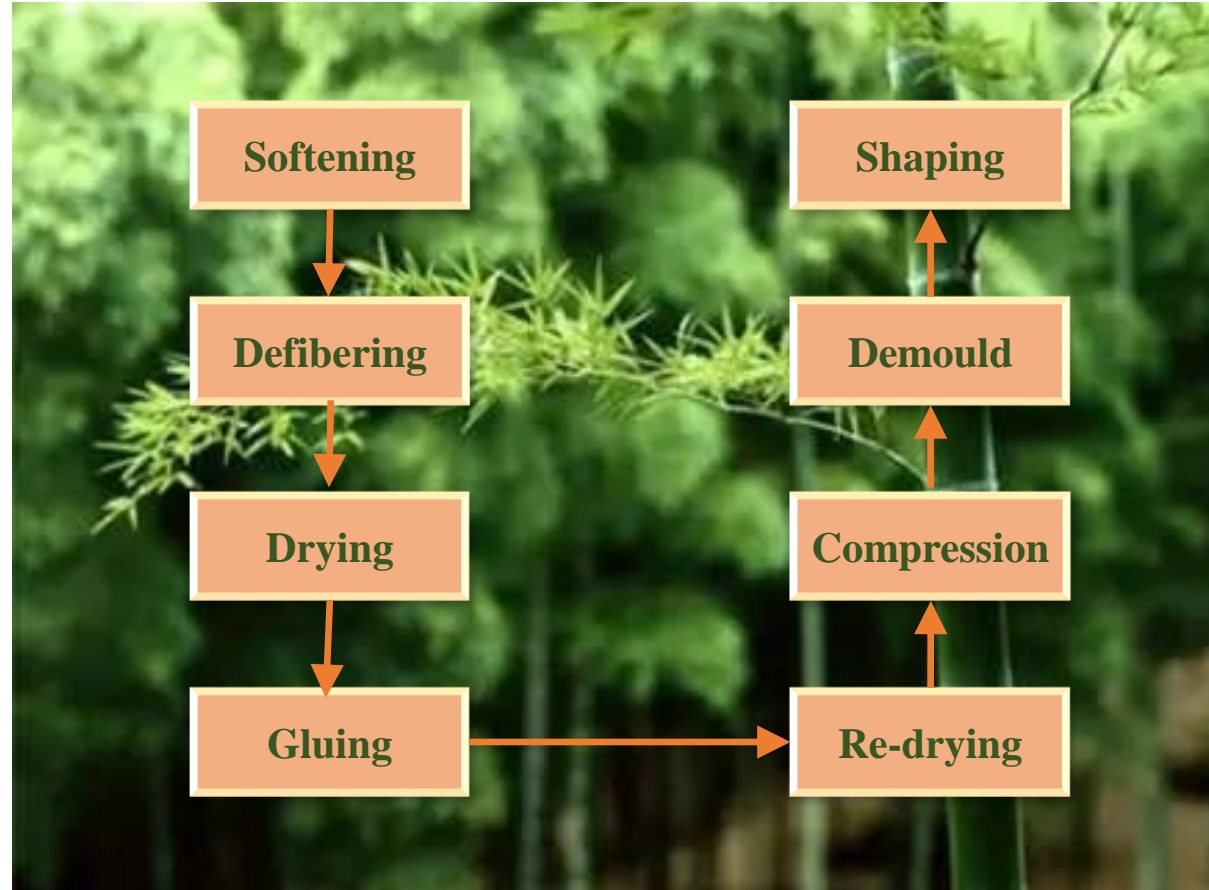
Drawn bamboo threads

Sliced bamboo board

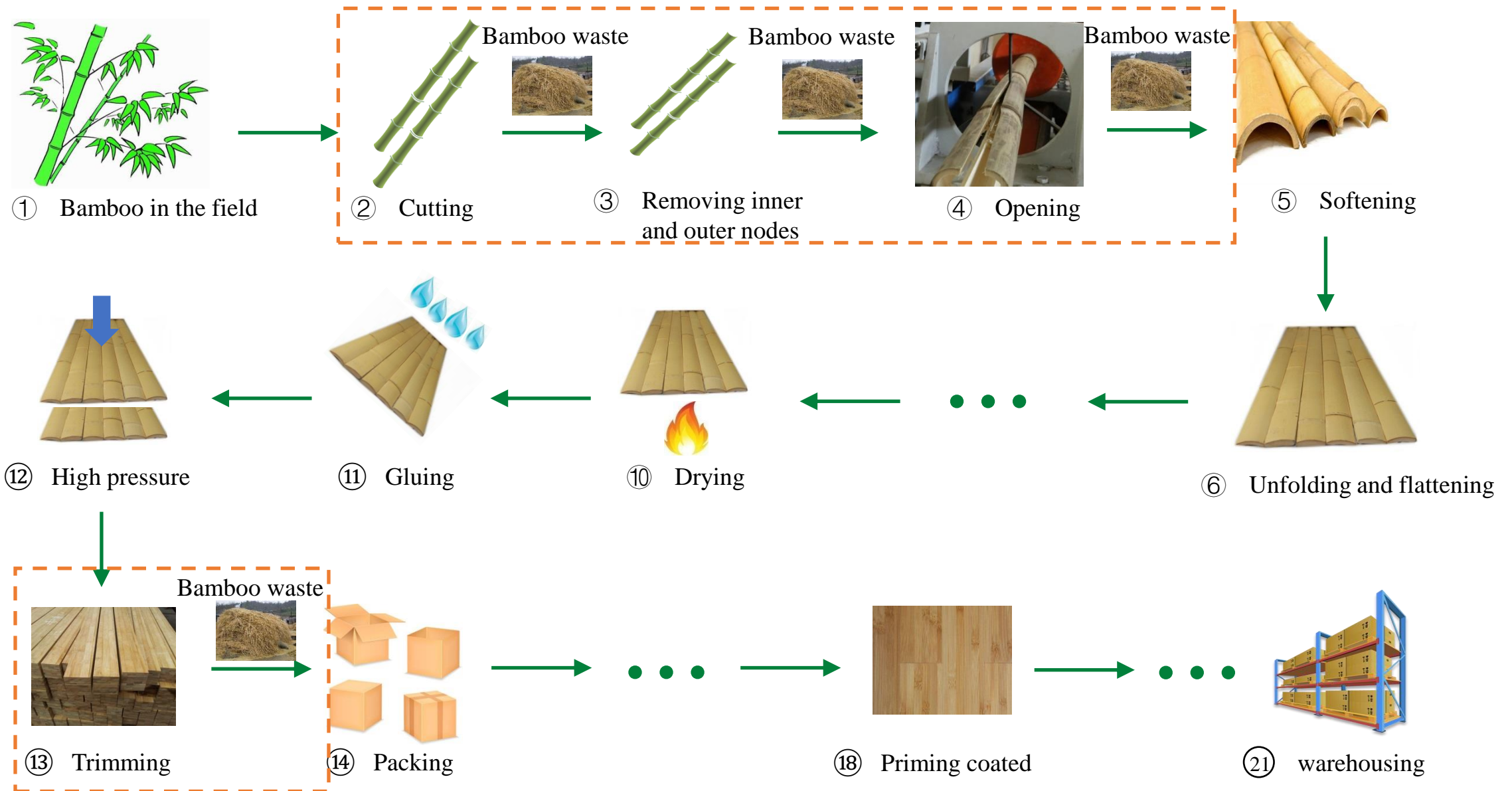
1st Main technology: Laminated technology



2nd Main technology: Reconstituted technology



3rd Main technology: **unfolding-flattening (bamboo floor with green bark)**

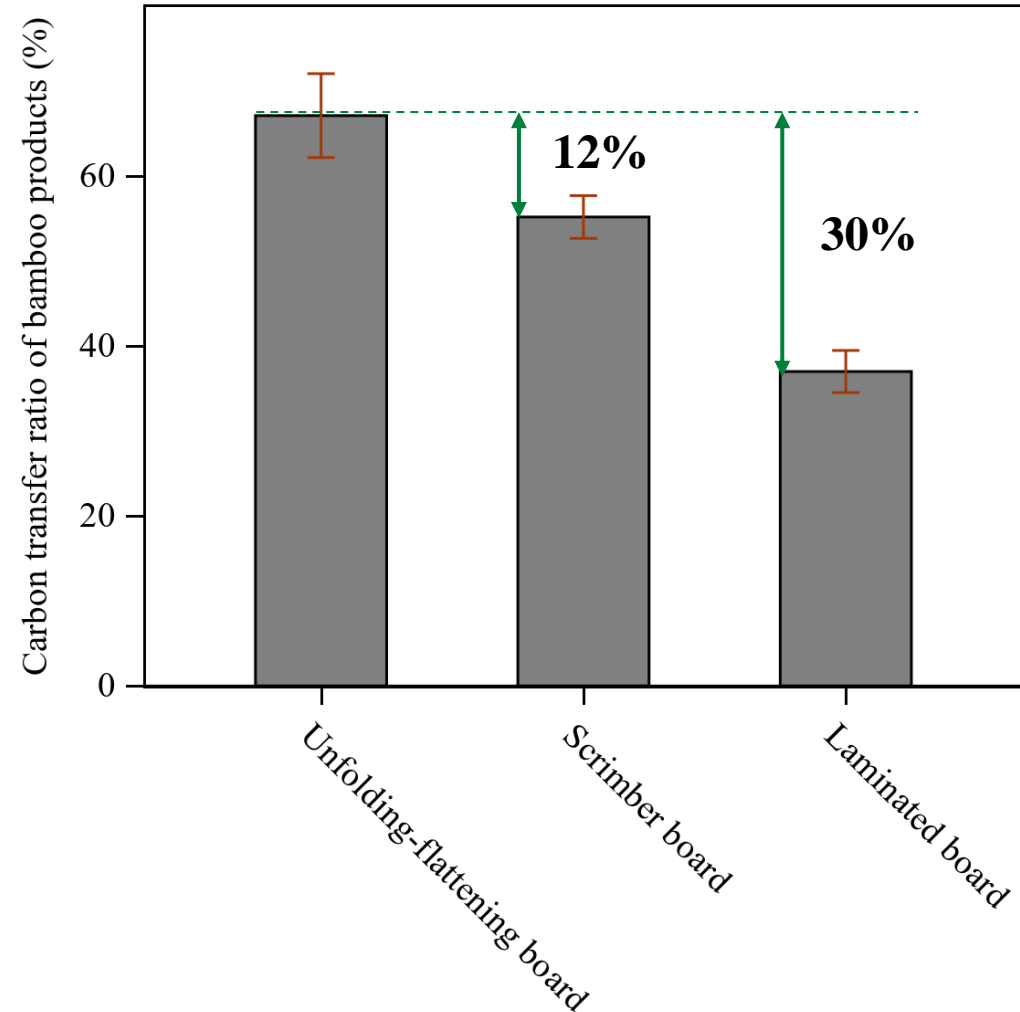
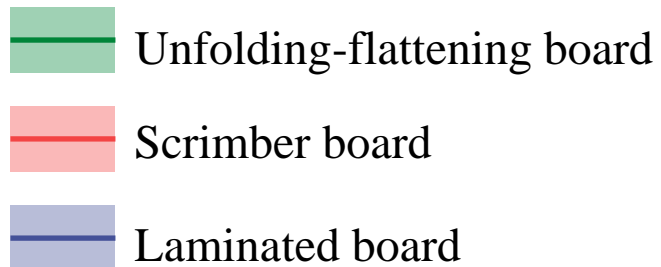
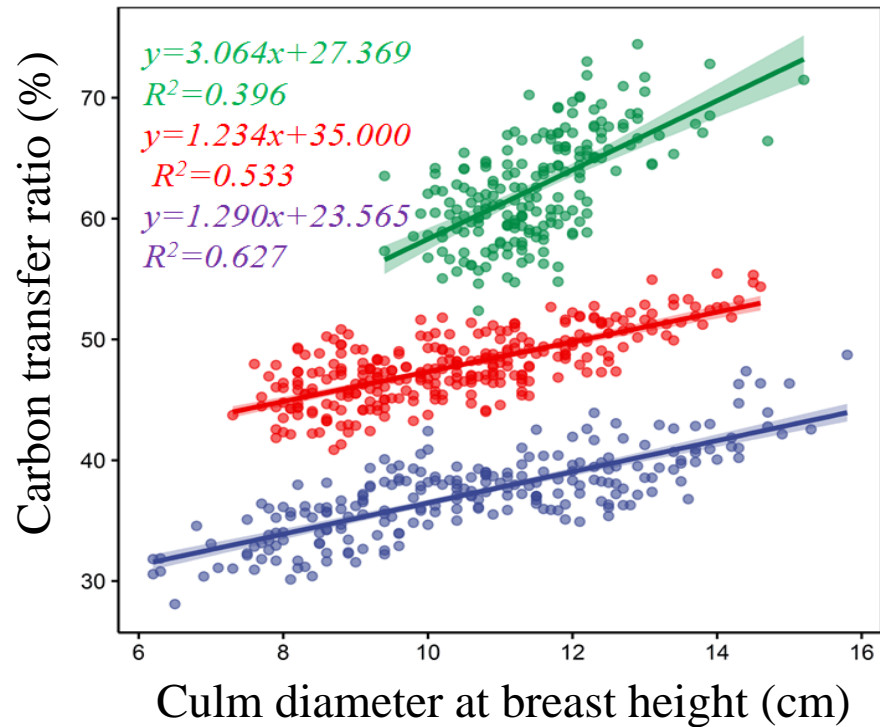


Carbon emission: unfolding-flattening bamboo floor

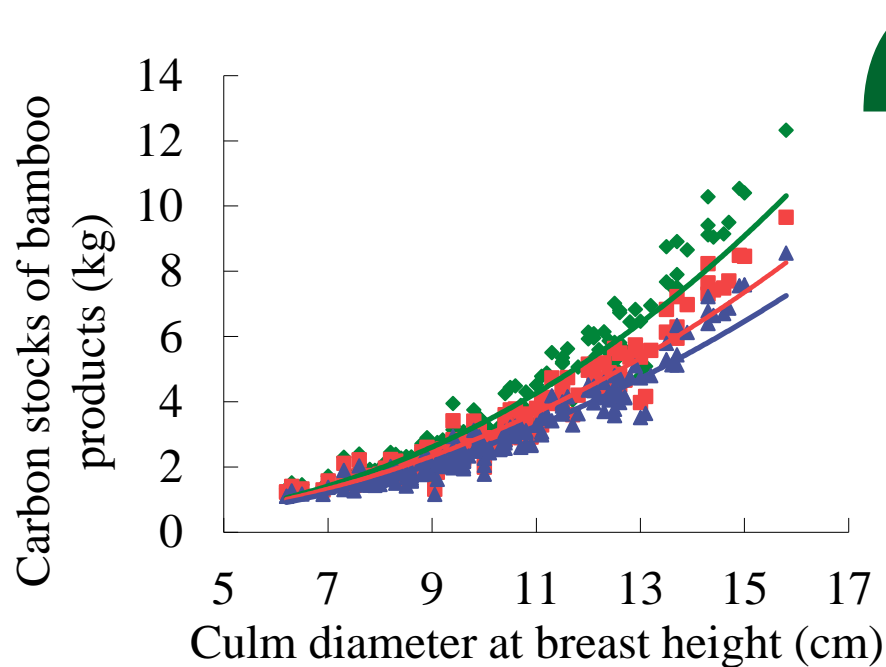
Process	Power consumption	Operation time of machine	Idle operation of machine	Carbon transfer	Carbon emission for producing 1 m ³ board	Percentage emission
Unit	Kw h ⁻¹	s	s	%	kg	%
① Cutting	4.5	4	10	100	0.88	1.01
④ Open	3	16 <i>6 times</i>	100	100	0.38	1.18
⑤ Softening	1.5	60 <i>2 times</i>	120	100	0.29	0.33
⑥ Unfolding/flattening	14	47	20	100	4.32	4.92
⑧ Remove color	35.1	48	12	81.54	10.59	12.06
⑩ Drying	1.5	432000	0	100	0.42	0.48
⑬ Trimming	4.5	4	10	100	1,24	1.41
⑮ Rough-plane	19.5	20	3	54.02	33.46	38.1
⑰ Fine-plane	15	17	3	67.1	22.02	25.08
⑱ Primary coated	1.5	0.5	3	100	0.12	0.13
...						
Summary					87.8	100

Carbon transfer ratio of bamboo products:

effects of culm diameters and Technological types



Upscaling carbon stocks of bamboo products to national level



- ◆ Unfolding-flattening board (high-tech)
- Scrimber board (traditional)
- ▲ Laminated board (traditional)

Step 1: Carbon stocks of bamboo products from 3 technologies:

$$\text{◆ } C_i = 0.0123 \times D_i^{2.4584}$$

$$\text{■ } C_i = 0.0169 \times D_i^{2.2445}$$

$$\text{▲ } C_i = 0.0161 \times D_i^{2.2146}$$

Step 2: Weibull distribution of bamboo culm diameter:

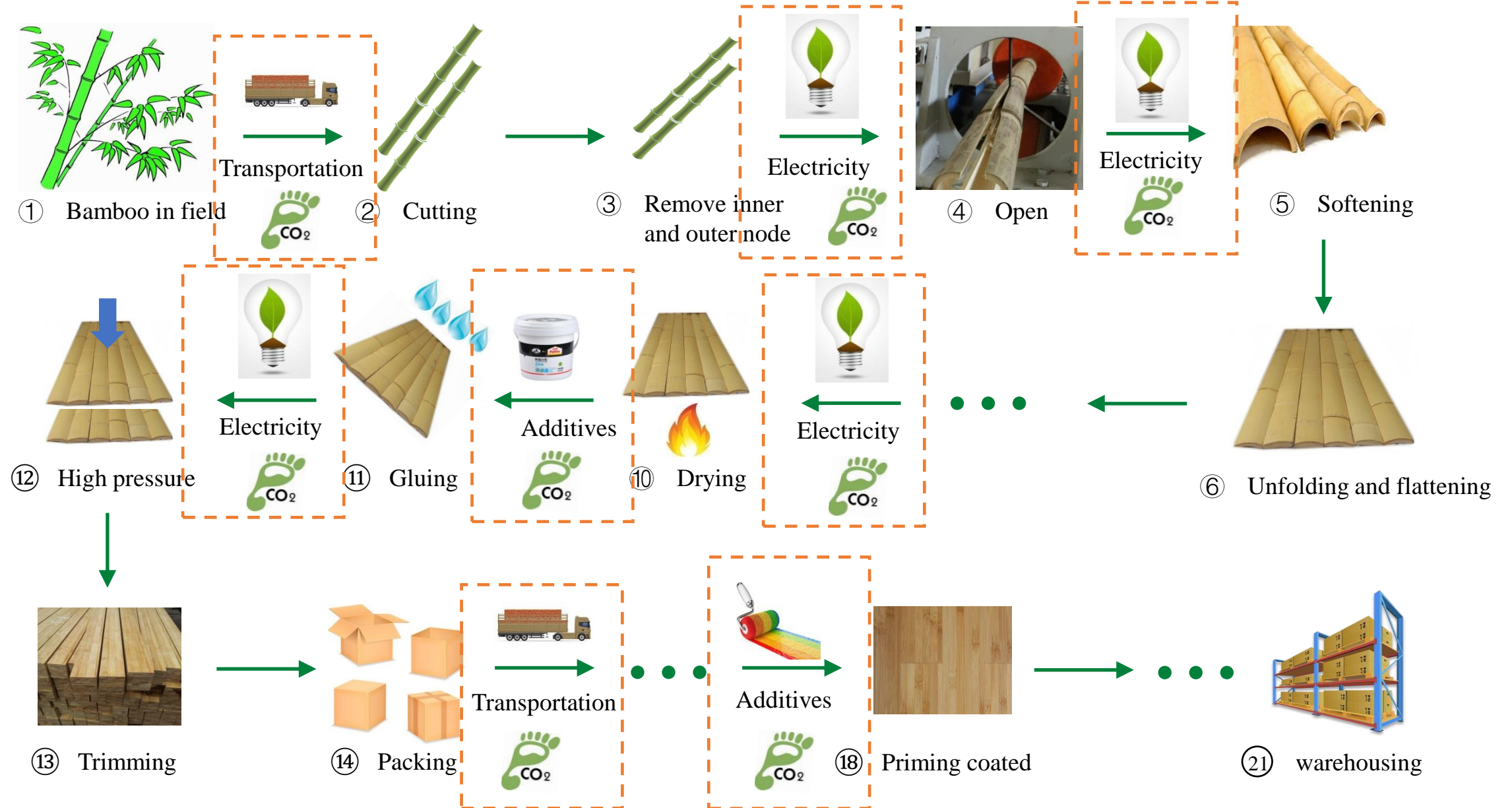
$$f(D, \theta) = \left(\frac{D - 1.3367}{7.442} \right)^{3.606} \frac{3.606}{D - 1.3367} e^{-\left(\frac{D - 1.3367}{7.442} \right)^{3.606}}$$

Step 3: Cumulated carbon stocks of bamboo products derived from bamboo culms with diameter range of 5 to 15 cm:

$$C_{product} = \sum_{i=5}^{15} (N \times f(D_i, \theta) \times c_i)$$

Results: based upon **1.9 billion** bamboo removals in **2015**, we predicted that a national level of carbon flux into bamboo products is **319,200 ton C year⁻¹**.

Technological processes: unfolding-flattening bamboo floor with green bark









Carbon emission of unfolding-flattening bamboo floor with green bark

(Additives)

Process	Additives	Carbon emission factor	Amount of additive for 1 m ³ board	Carbon emission for producing 1 m ³ board	Ratio of emission
Unit	-	kg kg ⁻¹	kg	kg	%
Gluing	Adhesive	0.6	27.44	16.47	51.75
Primary coated	Oil paint	0.6	0.41	0.25	0.78
Waxing	Paraffin	0.2	0.41	0.08	0.25
Packing	Carton	0.9	16.69	15.03	47.22
Summary				31.82	100

Carbon footprints of unfolding-flattening bamboo floor with green bark

	Item	Carbon footprint (kg)*	Footprint count
	Transportation	31.2	yes
	Electricity	87.8	yes
	Additives	31.8	yes
	Bamboo waste	232.2	no
Carbon stock (assumed 20 years of usage)		168.8	
Carbon footprint		-17.9	 Carbon uptake product

* The amount of carbon footprint for 1 m³ bamboo floor.

Carbon footprints of 9 investigated products

Bamboo products	Specification	Theoretical life span	Carbon footprint
	mm*mm*mm	Year	kg m ⁻³
Unfolding-flattening floor with green bark	1200*137*18	20	-17.91
Unfolding-flattening chopping board	360*240*17	8	114.55
Unfolding-flattening chopping board	380*280*18	8	130.38
Bamboo scrimber flooring for outdoor use	1860*137*20	20	3.83
Bamboo scrimber flooring for indoor use	910*127*14	20	51.58
Sliced bamboo veneer	2500*450*0.6	20	152.60
Bamboo curtain	1500*3.5*1.5	15	118.06
Bamboo mat	1500*2.5*2.5	15	152.27
Bamboo carpet	1500*4.5*2.0	15	112.22

Conclusions

- **Culm diameter** and **production technology** are two main factors influencing carbon transfer ratio.



Dendrocalamus giganteus,
Bogor Botanical Garden, Indonesia



Unfolding-Flattening floor

- A predicted large amount of national level of carbon stocks in bamboo products based on carbon transfer ratio and Weibull distribution of bamboo diameters, which implied a **potentially huge carbon pool of bamboo products**.



Ecosystem carbon flux of Moso bamboo monitored by the eddy covariance tower in Anji, Zhejiang

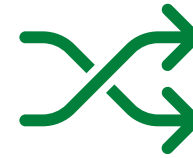


Photo by Jinhe Fu, INBAR

Guomo Zhou (contact: zhougm@zafu.edu.cn)

Professor of ZAFU

Director of

- **State Key Laboratory of Subtropical Silviculture**
- **Key Laboratory of Carbon Cycling in Forest Ecosystems and Carbon Sequestration of Zhejiang Province**
- **Engineering Research Center of Bamboo Carbon Sequestration for State Forestry and Grassland Administration**

Thank you for your attention!



浙江农林大学
ZHEJIANG A&F UNIVERSITY