Code: SFM-001

Circular Bioeconomy as a Contribution to Forest Conservation: Insights from Italy's Wood-Based Industries

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Politiche di riduzione della CO_2

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Outline

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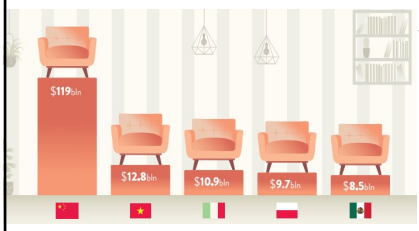
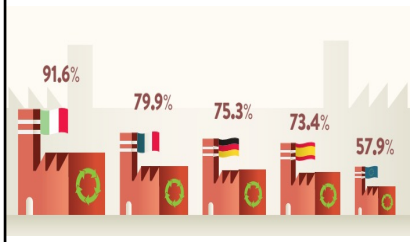
1. Introduction and background

- ✓ Forest cover in Italy: ca. **12 mln ha** (ca. **40%** of the total national area)
- ✓ **Continuous forest expansion** in the last 70 years
- ✓ **Limited active management and removals** (morphological, structural, socioeconomic and demographic factors)
- ✓ **Highly developed and competitive wood-processing industry** (e.g., leading furniture producer)

1. Introduction and background





- ✓ Third-largest **global trade balance in furniture**: $10.9 billion (after China and Vietnam).
- ✓ **Leading EU furniture turnover**: 27.2 billion Euros
- ✓ Highest **recycling rate** in Europe: 91.6% (compared to the EU average of 57.9%)
- ✓ **First in Europe to produce 100% recycled panels.**

→ Research question: feeding industrial processes while ensuring forests integrity: how?

SOURCE: Fondazione Symbola and Unioncamere, Greenitaly 2024

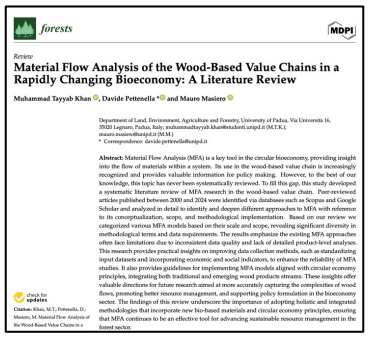
2. Research objectives

- Assess the role of **recycled wood and paper** in promoting a **circular forest-based bioeconomy in Italy**
- Identify and address challenges in the **recycling process**, including **collected inefficiencies** and material quality constraints
- Evaluate policy framework and recommend strategies for **integrating circular bioeconomy** approaches with **sustainable forest management**

3. Methodology Aspects

The research consists of **two main blocks:**

1. Data and Literature Review ⟷
2. Modeling of the forest-wood supply chain


forests
MDPI
Review
Material Flow Analysis of the Wood-Based Value Chains in a Rapidly Changing Bioeconomy: A Literature Review
Muhammad Tayyab Khan, Davide Pettenella * and Mauro Masiero
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* Correspondence: davide.pettenella@unipd.it
Abstract: Material Flow Analysis (MFA) is a key tool in the circular bioeconomy, providing insight into the flow of materials within a system. Its use in the wood-based value chain is increasingly recognized and provides valuable information for policy making. However, to the best of our knowledge, this topic has never been systematically reviewed. To fill this gap, this study developed a systematic literature review of MFA research in the wood-based value chain. Peer-reviewed articles published between 2000 and 2024 were identified via databases such as Scopus and Google Scholar and analyzed in detail to identify and deepen different approaches to MFA with reference to its conceptualization, scope, and methodological implementation. Based on our review we categorized various MFA models based on their scale and scope, revealing significant diversity in methodological terms and data requirements. The results emphasize the existing MFA approaches often face limitations due to inconsistent data quality and lack of detailed product-level analyses. This research provides practical insights on improving data collection methods, such as standardizing input datasets and incorporating economic and social indicators, to enhance the reliability of MFA studies. It also provides guidelines for implementing MFA models aligned with circular economy principles, integrating both traditional and emerging wood products streams. These insights offer valuable directions for future research aimed at more accurately capturing the complexities of wood flows, promoting better resource management, and supporting policy formulation in the bioeconomy sector. The findings of this review underscore the importance of adopting holistic and integrated methodologies that incorporate new bio-based materials and circular economy principles, ensuring that MFA continues to be an effective tool for advancing sustainable resource management in the forest sector.
check for updates
Citation: Khan, M.T.; Pettenella, D.; Masiero, M. Material Flow Analysis of the Wood-Based Value Chains in a

3.1. Data sources

Main secondary sources:

- FAOSTAT (FAO)
- Eurostat (European Commission)
- Italian Forest and Carbon Inventory (INFC-2015 for base-year 2018)

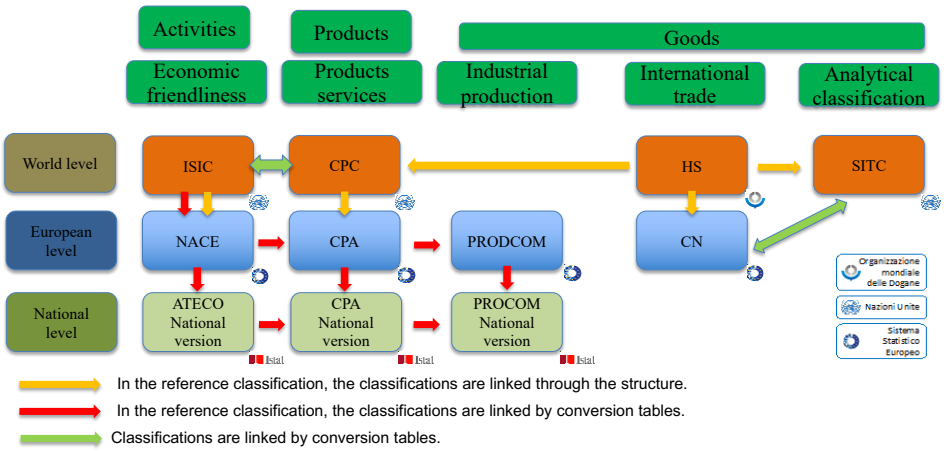
Additional secondary sources:

- ISTAT for economic data
- ORBIS DB

Primary data and sources:

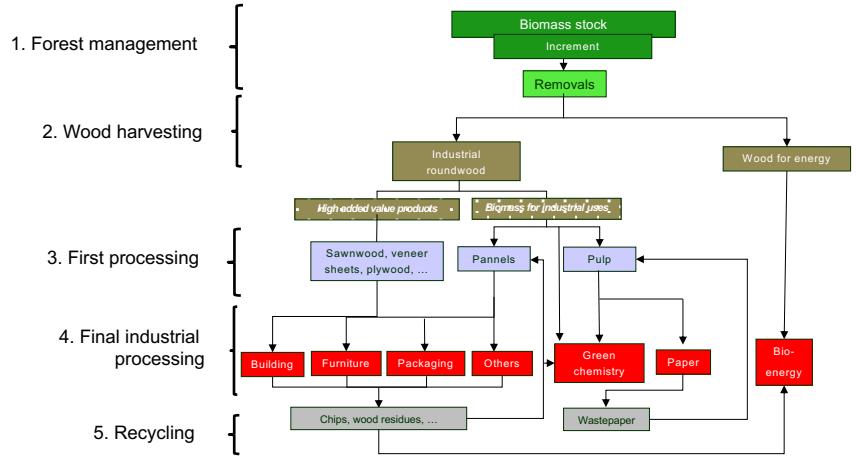
- Sawmills: DB analysis + survey
- Shadow flows, technical coefficients and consumption distribution: Delphi method approach

Data sources: Different classifications



- A new aggregation of variables and a new classification with **7 final sectors**: Building, Furniture, Packaging, Paper, Bioeconomy new products (“Green Chemistry”), Bioenergy, Others

3.2. Model structure



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System Dynamic Modeling

- **Vensim Software** for system dynamic modeling.

Why Vensim?

- **Ease of Use:** User-friendly interface for building and analyzing complex dynamic models.
- **Flexibility:** Ability to handle nonlinear systems and feedback loops effectively.
- **Visualization:** Offer clear causal loop diagrams and stock-and-flow structures.
- **Validation Tools:** Built-in features to test and validate model assumptions and behavior.
- **Efficiency:** Allows rapid prototyping and scenario testing for decision-making support.

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Methodology details

Conversion to wood fibre equivalent:

- **Semi-Products (m^3 or tons)** were converted to **wood fibre equivalent (m^3)** to estimate the **wood content** in first- and second processing semi-finished products.
- **Coefficients** were derived and assigned based on **literature, industry reports** to know the composition of the products, and **expert knowledge** (Delphi approach).
- All data and coefficients were linked in the **Vensim model** to analyse wood by-products and material flows across industries.

4. Preliminary Results

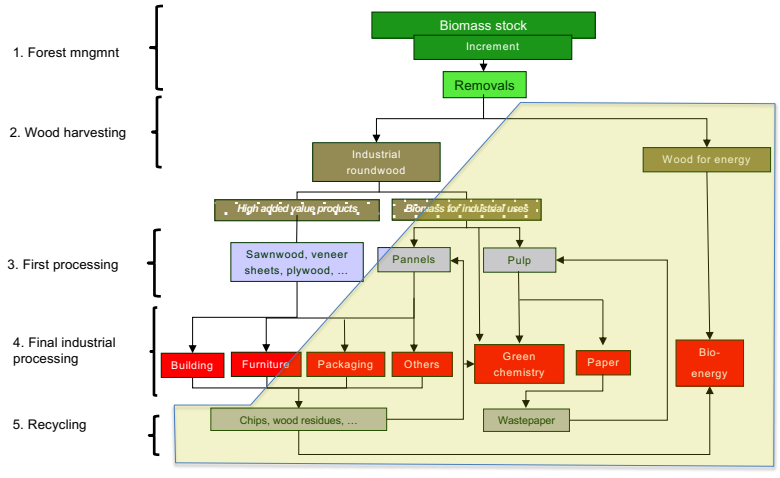
Italy: production and trade of wood products
(1,000 m^3 or tonnes; 2018)

2018	Conversion factor	Import	Export	Production	Apparent consumption
Fuelwood, coniferous	1.00	206	1	1,180	1,385
Fuelwood, non-coniferous	1.00	805	22	9,659	10,442
Industrial roundwood, coniferous	1.00	2,047	67	1,317	3,298
Industrial roundwood, non-coniferous	1.00	1,812	26	889	2,676
Roundwood, coniferous	1.00	2,254	68	2,497	4,683
Roundwood, non-coniferous	1.00	2,617	48	10,348	13,118
Roundwood TOT	**1.00**	**4,871**	**116**	**13,046**	**17,801**
Recovered post-consumer wood	2.37		0	4579	4579
Recovered paper	1.67	401	1903	6646	5,144
Recovered fiber pulp	1.9	8	1	0	7
Total recycling		**409**	**1904**	**11225**	**9,730**
Wood charcoal	2.86	177	0	29	205
Wood chips and particles	2.43	907	38	5280	6149
Wood residues	2.37	540	5	0	534
Wood pellets				450	2624
Other agglomerates				45	204
Sawnwood, coniferous				1004	4694
Sawnwood, non-coniferous all				550	1221
Veneer sheets				117	241
Plywood				320	637
Particle board				2978	3537
OSB				130	304
Hardboard				16	141
MDF/HDF	2.12	806	309	1006	1502
Other fibreboard	1.54	69	4	3	67
Chemical wood pulp	4.46	151	25	22	147
Mechanical and semi-chemical wood pulp	2.66	3348	170	348	3525
Dissolving wood pulp		1	0	0	1

Recycling is 2 times bigger than the domestic removals of industrial roundwood

Source: FAOSTAT data, except for the production of recycled wood products (source: Rilegno)

The relevant role of products from low-quality wood raw material



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Veneer sheets				117	241
Plywood	2.30	527	211	320	637
Particle board	1.54	1095	536	2978	3537
OSB	1.68	211	38	130	304
Hardboard	1.60	143	18	16	141
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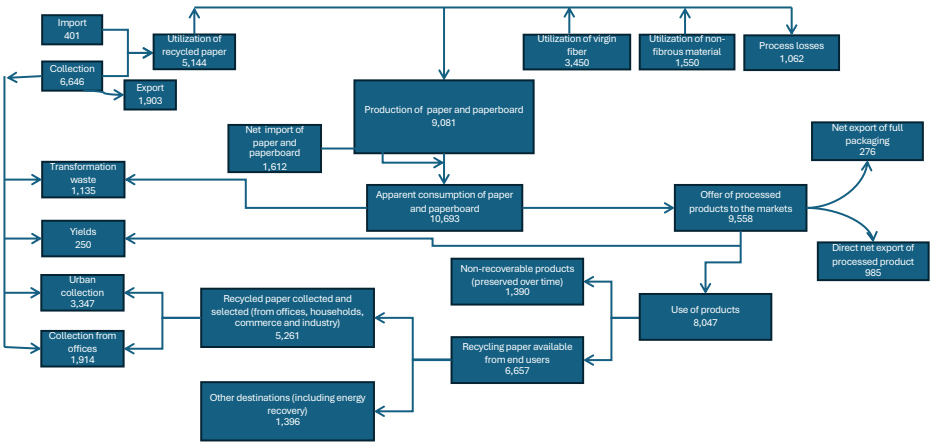
79.5% of the apparent consumption of semifinished products and bioenergy is based on low quality biomass

Source: FAOSTAT and Rilegno

Key recycling statistics:

- **Paper production:** **45.9%** of paper production relies on recycled paper (*Assocarta, 2019*)
- **Particleboard production:** **95-97%** made from reycled wood (*European panel Federation*).

Paper flow model for the 2018 (1000 t)



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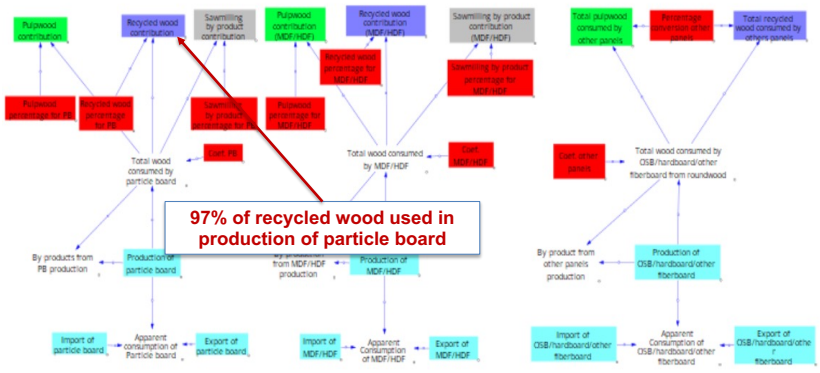
Panels model for the 2018 using Vensim



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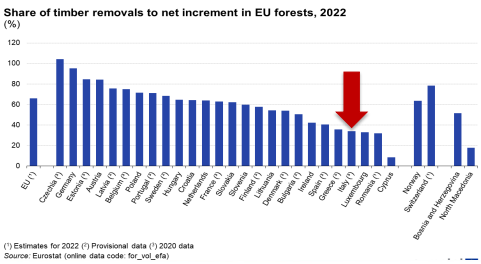
5. Discussion, conclusion and future directions

- **Exploratory nature** of the research.
- Results serve as groundwood for **future model refinement.**
- **Forest management insights:**
  - Italy removes approx. **30% of its net annual increment**, among the lowest in EU.



- **Increasing potential** for balanced, **sustainable utilization** → opportunities for **socioeconomic development** in marginal/mountain areas,
- **Improved forests = less vulnerable** to climate change impacts.

Future Directions:

- **Improving the model** to make it more precise and dynamic.
- Testing **policy scenarios** and developing **industry strategies.**

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One final consideration

The importance of synergies

Istat → Sinfor ← INFC

Sinfor → Modello FiLI (Filiere Legno Italia???) ← GRINS FOUNDATION

Modello FiLI (Filiere Legno Italia???) → ItaliaForestaLegno cluster nazionale

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