ACTA FACULTATIS XYLOLOGIAE ZVOLEN, 64(1): 99−111, 2022
Zvolen, Technická univerzita vo Zvolene
DOI: 10.17423/afx.2022.64.1.09

TIMBER FOREST PRODUCTS: A WAY TO INTENSIFY GLOBAL BIOECONOMY FROM BIO-MATERIALS

Victor De Araujo – **Juliano Vasconcelos** – **Francisco Lahr** – **André Christoforo**

ABSTRACT

Bioresources are converted into greener products with multiple applications, which present elementary or complex characteristics, and perishable or durable purposes. Forests are leading matrices of sustainable inputs, as they convert environmental energy into renewable materials. Whether from intensive silviculture or native forest management, wood became a valuable bio-material for the industry. Boosted by high industrialization and marked by versatile uses, woody products have been designed to replace unsustainable solutions. In response to the sustainable needs of recent sanitary and environmental crises, this paper seeks to clarify the potentials of timber forest products. From the literature review, global plans revealed neglected obstacles faced by less developed nations. Recommendations and actions were suggested to promote sustainable goods as the main engine for the bio-economic development of nations. As mineralized solutions still dominate markets worldwide, a turnaround attitude may address regional and global obstacles through more sustainable practices and goods.

Key words: bio-based resources, lignocellulosic products, sustainability, bio-development

INTRODUCTION

Trees arose on Earth before humans. As a result, forests have been supplying different solutions throughout the human evolution. Using good practices of sustainable managements and efficient silvicultural activities, forest resources can be virtually illimitable.

Following roughly a century serving as a massive carbon sink, JIN *et al.* (2017) asserted that forests can become carbon neutral or carbon source. Even in hot and dry environments, forests achieve efficient carbon storage, essentially due to mechanisms related to plant activity and photosynthesis (SCHIMEL 2010). About wood applications, DE ARAUJO *et al.* (2020) have confirmed relevant outcomes for timber construction, both in native and exotic species.

Large forests are more efficient in carbon storage when compared to other ecosystems. This fact corroborates the preservation and managed uses of native forests as real instrument for a healthier livelihood. Therefore, affirmative thoughts of change in our habits have sought sustainable paths in our lifestyles towards protocols driven for better attitudes.

Solutions for urban planning and actions have been sought by different governments in response to negative and positive externalities provoked by urban growth (CEPEDA 2019). Forest resources are easily renewable and wherefore ensure a sustainable path indeed.

Forests and forestry sectors provide essential services and products to support health, livelihoods and a green recovery during times of crisis, whereas this aspiration symbolizes a strategic way to get sustainable forest ecosystems and resilient forest-dependent communities (SEN and SINGER 2020). In the sustainable scope towards a greater renewability vision, timber acts as a natural forestry resource with relevant potential for society (SPURR and VAUX 1976).

Wood has been utilized for multitude functions, because unique features and visible abundance have afforded this natural raw material for numerous buildings, houses, vehicles, tools, objects, furnishings, instruments, and others (WIEMANN 2010, DE ARAUJO *et al.* 2017).

Rare nations do not have the wood as an input easily obtained in their domains. The values of forest chain perceptibly increase in sustainable times toward renewable sources.

For example, native wood was the first raw material of notable economic importance in Brazil, as it was collected and exported to Europe, to be converted into several products (DE ARAUJO *et al.* 2017). In parallel, European timber has competitive characteristics, although conifer-based manufactured products have reached greater market predominance in the last decades (CARBONE *et al.* 2020). As such, wood consumption is economically important for any nation, above all, for regions with reasonable presence of forests.

Yet, illegal logging is a complex problem in forests as the Amazon, where regulatory efforts have improved the detection of illegal activities such as overestimated volumes of high-value timber species in the logging permits (BRANCALLION *et al.* 2018). Since 2010s, Amazon basin is being affected by increased deforestations and fiercer fires (AMIGO 2020).

Despite uncontrolled situations and wood misuses of native forests, the silviculture has become popular in the Northern Hemisphere and is growing visibly in Latin America and Africa. According to GUSTAFSSON *et al.* (2012), mitigation of environmental impacts of clear-cuts has been efficiently satisfied by silviculture towards timber harvesting and biodiversity preservation in forests. Responsible practices ensure that forest products are manufactured in tune with the highest ecological, social and ethical standards (PEFC 2018). Thus, certifications rely on the forest management and chain of custody to enable a sustainable behavior in forests for the sustainable development of wood-processing industry (MIKULKOVÁ *et al.* 2015).

Developed nations have utilized, progressively and successfully, silvicultural practices to get certified materials for industrial purposes. D'AMATO *et al.* (2009) stated that, over the last years, the context of forest management in the United States has gone through one of its most dynamic periods in history. In 2020, 54% of global forests hold long-term management plans, where Europe and Asia have participated with 96% and 64% of their areas (FAO 2020).

Throughout the progress of societies, forests have become indispensable sources for the conversion of bioresources into timber forest products. The broad longevities and purposes of many existing buildings, furnishings and musical instruments prove the secular uses of wood. Thus, new discussions are completely convenient to explain and promote these solutions.

In line with this introductory perspective, the paper explored timber forest products as viable alternatives to develop the global bioeconomy in this moment with demands for more sustainable solutions. Theoretical foundations were used to conceptualize theory and practices related to the current strategies and policies. From literature arguments and author's remarks, this review seeks to analyze the convenience of timber forest products from their features to encourage bioeconomy. Sections were organized to approach bioproducts and related topics.

EXPERIMENTAL

Literature-based research is a plural route, whose aim includes the exposition of views and arguments from different authors, correlation of distinct scenarios, and the establishment of discussions and suggestions to advance any specific topic. According to LIN (2009), this method is to read through, analyze and sort literatures in order to identify essential attributes.

From this literature method, this study regarded a research prospection through different databases: DOAJ, Scopus, Web of Science, SciELO, Taylor&Francis Online, SpringerOpen, Elsevier's ScienceDirect, and Google Scholar. Other documents were used to complete views.Multiple keywords were used: 'timber', 'wood', 'wood market', 'timber forest product', 'timber product market', 'engineered wood product', 'bioproduct', 'wood industry', 'timber industry', 'bioresources', 'bioeconomy', 'native forest', 'forestry', 'silviculture' 'and 'forest policy'. Sections were guided according to the contents from citations and authors' remarks.

RESULTS AND DISCUSSION

'Bio-based' materials, products, technology and economy

People realize agriculture practice as food and fiber sources. But output materials from agroforestry activities are so-called "bio-based" and renewable through primary production from solar energy, atmospheric carbon-dioxide and terrestrial nutrients (SINGH *et al.* 2003). Agriculture can be efficient to feed the world's demands with less arable land available and, therefore, it may be sustainable, organic and able to produce bio-products (CHOJNACKA 2015). So, bio-based materials are naturally produced from renewable resources.

Biotechnology is a contemporary biological approach to a great range of industries, whose term was stated by the Hungarian agro-economist 'Károly Ereky' for lines of work by which products are produced from raw materials with the support of living organisms (BUD 1989). From crops to woods and their residues, a broader agricultural role is boosting markets for renewable energy and industrialized goods from bio-based feedstock (SINGH *et al.* 2003). Industrial biotechnology utilizes enzymes and microorganisms to make bio-based products for multiple sectors (chemicals, detergents, textiles, food, bioenergy, paper and pulp, *etc.*), using sustainable processes from biomass to encourage the reduction of our dependence on coal, oil and gas (EUROPABIO 2012). The relief on non-renewable sources through biological resources for sustainable production is the core idea of bio-based economy (PRIEFER *et al.* 2017).

Bioeconomy combines the production of renewable bioresources and their conversions into bio-based products, food, and energy, whose activities include cleaner energy, forestry, agriculture, fishery, pulp and paper, biotechnology and biochemistry (EUROPEAN COMMISSION 2012). Transition from linear economy to bioeconomy is argued by literature as playing a key role in targeting challenges such as health, industry restructuring, energy and food securities, and mitigation of climate change (BIANCOLILLO *et al.* 2020). The transition will depend on the implementation of circular economy into the industry to promote sustainable goods (HOSSAIN *et al.* 2020). Bioeconomy is ensured by bio-based product markets, whose input-to-product conversion involves renewable resources to feed biotechnology-based productions. Future of bioeconomy is a joint vision with the importance of sustainability (PFAU *et al.* 2014). Forest material private firm and industry may pay part of their profits to support forest regeneration programs (IBRAHIM *et al.* 2020). Despite the difficulties to measure sustainable progresses of institutions, the use of timber

products is essential to modern societies, as sustainable features are assured by their renewable and recyclable materials (DASGUPTA *et al.* 2015, DE ARAUJO *et al.* 2017). Wood materials and chemicals, fiber textiles, and non-timber forest products may satisfy the growing consumer's demand in times of environmental valuation (EUROPEAN COMMISSION 2013). These goods drive the forest bioeconomy, whose activities use resources from forests or side streams of biomass from harvesting and refining (KARVONEN *et al.* 2017).

This outlook harmonizes with WOLFSLEHNER *et al.* (2016) and SEN and SINGER (2020), as forests and forest industry play great roles in the bioeconomy, providing materials, bioenergy, regulatory and cultural ecosystem income, service, and livelihood. Value-added wood solutions have contributed a higher share of income to forest owners than lower-end products as paper and fuel (WHERRY and BUEHLMANN, 2014). Full bioeconomy of food, feed and bioproducts is expected to grow globally from 10.3 billion dollars in 2018 to 12.8 in 2030 (WBCSD 2020).

Timber forest products: definitions and exemplifications

Forest production represents transformation of raw materials into consumer goods given by solutions with timber and non-timber features – that is, according to ligneous features.

Non-timber forest products are biological materials extracted from natural ecosystems and planted forests to be used within the household, be marketed, or have certain significance (WICKENS 1991). Non-timber forest products (NTFPs) are diversified, being classified into categories about the parts of plants extracted (leaf, fruit, *etc.*), purposes (food, medicine, fuel, *etc.*) and levels of utilization (commercial and self-supporting) (PANDEY *et al.* 2016). Non-timber forest products are literally any forestry resource, except woody materials (NEUMANN and HIRSCH 2000). They include plants used for food (fruits, nuts, mushrooms, and honeys), fodder for livestock, fuel, medicine herbs, biochemicals, gums, ornamental plants, textiles, fibers, seeds, and environmental and social services for extraction and protection (MCLAIN and JONES 2005, SULEIMAN *et al.* 2017).

Timber Forest Products are the woody materials processed and utilized as firewood and energy biofuels, roundwood, sawnwood, value-added wood products, paper- and fiber-based products, and engineered composite panels and beams (FALK 1958, SHMUKSKY and JONES 2011, MARCILLE *et al.* 2020, UNECE/FAO 2020a). They are ligneous goods, which are naturally and biologically produced from woody-character plants. Due to multiple uses (Table 1), timber forest products can properly support markets toward bioeconomy, as they add value to wood, above all, due to its polyvalent, renewable, reusable and sustainable vocations.

Panels and engineered products (Table 1), such as composite solutions, have improved wood performance. Glued wood products are structurally used in construction and furniture as stated by FARES *et al.* (2015), SANTIAGO *et al.* (2018), BIAZZON *et al.* (2019), VAŇOVÁ and ŠTEFKO (2021) and others. Yet, contributions have been developing sustainable value-added manufactured products from silvicultural species and low-emission glues, for example, GAVA *et al.* (2015), CHEN and TAI (2018), AQUINO *et al.* (2019), SILVA *et al.* (2021), and others.

Tab. 1 Timber forest products examples.

Category	Application Example
Agriculture	Fences, stakes, poles, braces, and straws
Arts, weaving and sports	Easels, canvas, sculptures, looms, needles, bows, and clubs
Construction	Lumber, engineered wooden products, panels, beams, floors, doors, and decks
Clothing and vesture	Watches, clogs, jewelry, shoe soles, and shoe heels
Culinary utensils	Cables, spatulas, pestles, bowls, barrels, vats, and corottes
Furniture	Tables, chairs, beds, bookcases, cabinets, and chests

Medicine instruments	Crutches, walking sticks, and physiotherapy supplies
Musical instruments	Guitars, basses, violins, flutes, harps, sticks, and drums
Nautical	Boats, crafts, canoes, oars, piers, and masts
Objects	Clocks, bins, holders, folding screens, pencils, and sticks
Packaging	Pallets, containers, crates, boxes, and covers
Toys	Miniatures, board games, whipping-tops, and dollhouses

Source: adapted from DE ARAUJO *et al.* (2017).

Current markets of timber forest products

The increment of urbanization and working age of people drives the increase in demand of wood-based products used in construction and furnishing (BRACK 2018). Yet, other timber-forest-based solutions may have high growth potential as our society develops, for example, decoration, instruments and goods typified in Table 1. In recent years, the leading markets, more specifically in Europe and North-America, are showing fluctuations in consumption and production of timber forest products through reliable data forecasted by UNECE/FAO (2020b). In Table 2, different performances are observed in the main available manufactured solutions.

Tab. 2 Market volumes per timber forest product in the Europe and North-America.

Product volumes (million cubic meter)	2019*		2020**		2021**	
	C	P	C	P	C	P
Softwood logs	430.40	449.36	430.31	447.69	432.19	448.10
Softwood lumber	183.17	209.52	180.25	204.20	181.47	205.98
Hardwood logs	79.61	81.10	79.82	81.60	79.58	81.55
Hardwood lumber	32.84	34.71	31.66	34.24	31.53	34.39
Veneer sheets	15.64	15.47	15.91	15.75	15.63	15.48
Plywoods	23.42	15.59	22.92	15.43	22.56	15.39
Particleboards	62.81	50.36	62.94	49.45	63.41	50.05
Fiberboards	28.70	28.89	28.38	27.89	29.04	28.60

* Real values; **Forecasted values; C: apparent consumption; P: production
Source: adapted from UNECE/FAO (2020b).

In most cases, product volumes decreased between 2019 and 2020, although a possible resumption is already expected for 2021 at similar or even better levels than 2019 period; in fact, this triennium has been severely marked by global socioeconomic effects from a sanitary crisis, as reported by studies such as AKBULAEV *et al.* (2020), CUTLER and SUMMERS (2020), HANUSHEK and WOESSMANN (2020), WORLD BANK GROUP (2020), and other authors.

Contrastingly, wood-based panels showed antagonistic scenarios in this period (Table 2). As in logs and lumber, fiberboards also had a parabolic behavior in production and consumption volumes. However, other panels showed distinct ways, as particleboards were increasingly consumed and plywood market was slightly reduced.

Log and lumber indexes are increasing with respect to pricing due to lower levels of production and raw materials exports from several countries as confirmed by ITTO (2021a, b). On a similar route, prices of wooden panels are rising in many regions in the present stage marked by a sanitary crisis as analyzed by REPKO (2020), DELBERT (2021), LOGAN (2021), SANCHIS (2021), and others. Yet, GILBERTIE (2021) claims that "price of physical lumber seems like it still has to rise a bit more because mills are at capacity and unable to meet current demand". Some regions, as Northern America, are seeing a downward movement in softwood lumber and panel prices as ensured by MADISON'S LUMBER REPORTER (2021) and LAMBERT (2021), though market and environmental circumstances may add uncertainty over the remainder of 2021. As a result, Brazil is exporting significant volumes of lumber, panels and furniture as cited by ZAFALON (2021) and LAURINDO (2021). This supply will be easily reduced if silvicultural production does not keep up with existing demands of international

and local markets. ROSNER (2020), KEELEY (2021), MADISON'S LUMBER REPORTER (2021), Sugden (2021) and other authors declare that the world's forests are being devastating by pests, insects, and wildfires. BELEDELI (2021) completes that reforestation activity is being affected by the expansion of food crops in Southern and Midwest Brazil.

The possible resumption of silviculture activities will improve material supplies, though a global intensification of forestry activities is necessary to continuously provide inputs and, therefore, contribute to cost reduction. Synchronously, industries must be part of the process. SUJOVÁ and SIMANOVÁ (2021) cited that wood processing industry needs booster changes in customer requirements and increased pressures from competitors. Excluding food and feed, the global market of bioproducts already exceeds 3.4 billion dollars, with just under a third referring to lumber, wood-based goods, pulp and paper, panels, and bioenergy (WBCSD 2020).

Current perspectives and challenges about bioeconomy toward timber forest products

Bioeconomy leads to sustainable economic growth and green opportunities for job and income (BIANCOLILLO *et al.* 2020). So, policies and plans must account for the trade-offs of forests to store carbon, adapt to climate change and yield wood products (FARES *et al.* 2015).

Governments may reduce uncertainties and commit to global climate action of forest sector, applying carbon taxes to products with higher global warming emissions, and creating programs to reduce barriers on cultural, educational and technological scopes in relation the use of sustainable products (HOWARD *et al.* 2021). In China, the carbon emission trading has offered co-benefits by improving pollution reduction (KOU *et al.* 2021). Bioeconomy policy is already present in Austria, France, Ireland, Italy, Latvia, Nordic countries, Spain, and United Kingdom, whose more habitual goal has prioritized forest sources (TEITELBAUM *et al.* 2020). Due to advantages and benefits of timber forest products, their markets may be intensified by affirmative strategies to reduce the use of unsustainable goods from non-renewable sources.

Substitutions are really effective if an increase in wood product consumption implies verifiably a global reduction in non-timber productions as wood-based fuels (LETURCQ 2020). Also, wooden products accept efficient retro-designs, which impact customers' satisfactions incorporating attractive changes and desirable functions (LOUČANOVÁ and OLŠIAKOVÁ 2020). These products can stimulate a green recovery in times of crises, while sustainable goods are produced and opportunities are created by forestry (SEN and SINGER 2020). Mixed production with timbered and non-timbered goods may form a multiple way to utilize potentials from silviculture and managed areas. Plural strategy for industry development is globally required.

For this, the resource efficiency can minimize impacts on the environment and climate through intense use of forests to obtain higher added-value outputs in cascade (EUROPEAN COMMISSION 2013). In a single-stage cascade, the wood is processed into a product and it can be applied again for energy, but a multi-stage strategy offers the same initial processing with a further use in material before disposal or energy purpose (THONEMANN and SCHUMANN 2018).

EUROPABIO (2012) already suggested actions to stimulate bio-based alternatives such as creation of policies to improve sustainably productivity and management of forests, utilization of green biotechnology for industrial ends, development of lignocellulosic and energy crops alongside traditional examples, and investments in infrastructure to improve biomass uses.

Thenceforward, a large global share tries out these strategies although a small portion works towards a greener reality. While conscientious and concerned countries have succeeded in developing bio-based economies and goods, other nations still slip into projects

and uses of green solutions. In effect, multiple changes must be globally performed for a healthier future.

Actions to stimulate bioeconomy using biomaterial-based products and suggestions to promote timber forest products as valuable sustainable options

As a result of cited antagonistic scenario and the strategies developed under Eurocentric views on more favorable realities, global actions are required to reduce all contrasts among developed and underdeveloped regions. VAUHKONEN *et al.* (2019) mentioned that constraints for wood availability greatly differ between countries, demanding a harmonious globalized policy; our perception corroborates this view, as we exclaim the reduction of all inequalities.

Nations have chosen to make use of their domestic advantages by specializing in certain aspects toward sustainable activities (TEITELBAUM *et al.* 2020). Bioeconomy has plural ways to seek resources, whether green materials from forests and blue resources from aquatic life.

In this perspective, contrasts have been linked to different developmental ambitions and stages to convert fossil-based economy into a bio-based economy toward renewable sources (DELBRÜCK *et al.* 2018). Under cascade principle, wood is efficiently utilized in the following order of priorities: production of wood-based products, re-use, recycling, bio-energy, and disposal (EUROPEAN COMMISSION 2013). On a synchronous route, efforts may be 'inclusive' by the expressive participation of global nations, 'innovative' by the consideration of cleaner productions, 'complete' by the intense use of bioresources in a wide bioproduct cascade, and 'affirmative' by the inclusion of bioeconomy-oriented activities aimed at sustainable goods.

Strategically, Europe leads a plan developed in 2012 and updated in 2018 to accelerate the deployment of a sustainable European bioeconomy so as to cooperate with the sustainable development goals of 2030 Agenda and the Paris Agreement (EUROPEAN COMMISSION 2018). The prioritization of policy strategies has been more intense in Austria, Japan, Great Britain and Nordic countries, as they consider multiple fields described by Table 3.

Tab. 3 Countries with considerable engagement about bioeconomy policy and their main priority fields.

	AT	CR	DE	ES	FR	GB	IT	JP	LT	MY	ND	TH	US	ZA
Forestry activities	X					X		X			X			
Biotechnology						X		X			X		X	X
Biorefinery	X	X	X	X	X	X	X		X		X	X		
New biomaterials	X					X		X		X			X	
Bioproducts	X	X	X	X	X	X			X		X	X		
Bio-plastics	X					X		X		X				
Fiber products	X										X			
Wooden buildings	X	X						X			X			

AT: Austria; CR: Costa Rica; DE: Germany; ES: Spain; FR: France; GB: Great Britain (England, Scotland, Northern Ireland, Wales, and Ireland); IT: Italy; JP: Japan; LT: Latvia; MY: Malaysia; ND: Nordics (Denmark, Finland, Norway, Sweden, Iceland and Faroe); TH: Thailand; US: United States; ZA: South Africa.

Source: table built using information from TEITELBAUM *et al.* (2020).

Despite numerous efforts and plans, the bioeconomy is practically not a complete global reality. TÖLLER *et al*. (2021) recognize the bioeconomy policy as a conceptual coalition for available policies, so far with little tangible effect, as it is limitedly institutionalized and lacks actors linked to bio-economic activities and specific instruments in place. This fact is justified by DELBRÜCK *et al*. (2018), as they forecast that, for the next two decades, bioeconomy will succeed in the agriculture, forestry, energy, food and feed

sectors. But, the obstacles of less developed regions are not regarded by these paths, since they were designed and developed by leading nations for, particularly, mature societies in reference to technological, economic, social and political levels. So, specific strategies are proposed to satisfy pluralities (Table 4).

Tab. 4 Challenges to develop forestry chain towards bio-based products and economies.

Obstacles	Main Reasons	Assertive Actions
Deforestation	a) Expansion of agriculture b) Fires c) Criminality	a) Stimulus for permanent protection areas b) Dry season plans, and arsonist penalty c) Penalty to recover degraded areas
Illegal logging	a) Unfamiliar forest laws b) Unfamiliar protected wood c) Criminality	a) Clarification campaign in rural areas b) Creation of timber inspection offices c) Penalty to recover degraded areas
Low uses of silviculture timber	a) Ignorance of benefits b) Irregular wood supplies c) Misuse and low quality	a) Clarification campaign about features b) Economic incentives for planted forests c) Innovation using planted woods
High generation of wood waste	a) Low industry technology b) Improper maintenance c) Expensive machinery	a) Promotion of advanced processing b) Clarification of maintenance benefits c) Incentives to import high technology
Small market of forest products	a) More regionalized markets b) Limited exportation c) Low export of products	a) Promotion to open markets and public procurements b) Product adequacies to global sustainable demands c) New products and market prospections
Forestry chain troubles	a) Sectoral disarticulation b) Other dominant sectors c) Illegality and pollution	a) Resource and industry synergies b) Prioritization of cleaner forest sectors c) Activity regulations, and penalties
Weak control and regional promotion	a) Disjointed national actions b) Lack of global controls c) Divestment in poor region	a) Global plans with regional features b) Global alliance with multiple offices c) Loans prioritized for sustainable aims

From the frequent obstacles experienced by countries outside this main developed axis, individual actions were suggested to correct limiting barriers, as those raised by DE ARAUJO *et al.* (2018), to intensify bio-product consumption and bioeconomy development in poor and development aspirant regions. This suggestion was inspired by a statement from ODDONE and PADILLA-PÉREZ (2016), as 'there is a space for policies aimed at supporting convenient value chains for society'. This fact is duly valid, as many sectors are not even developed regionally.

Hence, we propose multiple recommendations to intensify global markets and industries of timber forest products under bioeconomy aspects, where actors and key-people may:

- Prioritize certified native resources collected exclusively in legalized managed areas to preserve biodiversity of protected forests located in Africa, Asia and Latin America;
- Eradicate illegal activities and unfriendly practices using the global establishment of green-commodities from cleaner bio-product industry and driven by licit bioresources;
- Boost mixed productions of non-timber and timber forest products in a broad chain of bio-investors, large-to-small-sized companies, artisans, and forest-linked livelihoods;
- Incentive well-run sectors toward bio-products, low impact activities and waste reuse;
- Educate governments as to public procurements under life-cycle bases driven by a fine association of risk, timeliness and cost as cited by SÖNNICHSEN and CLEMENT (2020);

- Encourage global suppliers, public procurers and consumers to prioritize bio-products;
- Design global policies on forest products with incentives for less developed producers;
- Mitigate obsolete views about wood as a sub-material or lower quality material, using the diffusion of benefits and features for nobler and added-value purposes;
- Increase the development of studies and forecasts about global and local timber forest product markets toward sector economy, product consumption and sales, and jobs.

CONCLUSIONS

Timber forest products have been developed to meet the needs of our societies and thus they have been materialized in multiple solutions, whose purposes can comprise construction, furniture, household items, objects, toys, instruments, boxes, tools, and other consumer goods. These bio-products can move diversified domestic economies, since any country with forests may produce them. Despite vocations, bio-products are still not effectively a leading choice, since global markets are dominated by solutions from non-renewable sources. Therefore, timber forest products still need to be more valued by governments through global policies and attentive public procurements, since such goods have multiple potentialities and functions to replace any traditional solutions in plastics, oils, and other minerals. The replacement may be ensured by benefits and practically inexhaustible sources of bio-materials, whose right uses may prioritize bio-products manufactured in clean industry powered by certified bioresources.

As assertive actions are required to stimulate this path, they were proposed to ensure the best sustainable practices, since regionalized obstacles had not been considered in the global plans led by the developed nations. Thereby, less developed nations in Africa, Asia and Latin America with forestry potentials will be able to form a multiple-continental alliance for the bio-development driven by policies with greater integration and adaptation to their realities.

If more sustainable conditions are broadly and really met through policies with regional values, timber forest products may be surely healthier than traditional mineral-based products. If native woods are correctly procured from well-managed areas and silviculture activities are properly inserted in suitable areas without native forests, timber forest products may become sustainable goods obtainable indefinitely. This way reinforces the deference of bioproducts, as they play a key role in responding to daily challenges of climate, health and livelihood.

REFERENCES

AKBULAEV, N., MAMMADOV, I., ALIYEV, V. 2020. Economic impact of Covid-19. In Sylwan 164, 113-126.

AMIGO, I. 2020. When will the Amazon hit a tipping point? In Nature 578, 505-507.

AQUINO, V.B.M., RODRIGUES, E.F.C., PIETROBON, I.M., CHRISTOFORO, A.L., LAHR, F.A.R., PANZERA, T.H. 2019. Determination of the adhesive content of medium density particle-boards produced with bio-based polymer. In Journal of Building Material Science 1, 20-24.

BELEDELI, M. 2021. Oferta de madeira no RS é afetada pela expansão das lavouras. URL https://www.jornaldocomercio.com/_conteudo/agro/2021/07/802121-oferta-de-madeira-no-rs-e-afetada-pela-expansao-das-lavouras.html.

BIANCOLILLO, I., PALETTO, A., BERSIER, J., KELLER, M., ROMAGNOLI, M. 2020.A literature review on forest bioeconomy with a bibliometric network analysis. In Journal of Forest Science 66, 265-279.
BIAZZON, J.C., DE ARAUJO, V.A., ALVES, P.R.G., MORALES, E.A.M., GONÇALVES, M.T.T., VALARELLI, I.D. 2019. Resistência mecânica à adesão em superfícies de madeira de pinus aplainadas e unidas por adesivos PVAc. In Matéria 24, 1-8.
BRACK, D. 2018. Sustainable consumption and production of forest products. New York: UN. pp.1-74.
BRANCALION, P.H.S., ALMEIDA, D.R.A., VIDAL, E., MOLIN, P.G., SONTAG, V.E., SOUZA, S.E.X.F., SCHULZE, M.D. 2018. Fake legal logging in the Brazilian Amazon. In Science Advances 4, 1-7.
BUD, R. 1989. History of 'biotechnology'. In Nature 337, 10-10.
CARBONE, F., MORONI, F., MATTIOLI, W., MAZZOCCHI, F., ROMAGNOLI, M., PORTOGHESI, L. 2020. Competitiveness and competitive advantages of chestnut timber laminated products. In Annals of Forest Science 77, 1-19.
CEPEDA, P. 2019. Ecobarrios en Quito: ¿existen modelos sustentables y sostenibles a nivel barrial en Quito? In Eidos 19, 21-31.
CHEN ,Y.C., TAI, W. 2018. Castor oil-based polyurethane resin for low-density composites with bamboo charcoal. In Polymers 10, 1-12.
CHOJNACKA, K. 2015.Innovative bio-products for agriculture. In Open Chemistry 13, 932-937.
CUTLER, D.M., SUMMERS, L.H. 2020. The COVID-19 pandemic and the $16 trillion virus. In JAMA 324, 1495-1496.
D'AMATO, A.W., JOKELA, E.J., O'HARA, K., LONG, J.N. 2018. Silviculture in the United States: an amazing period of change over the past 30 years. In Journal of Forestry 116, 55-67.
DASGUPTA, P., DURAIAPPAH, A., MANAGI, S., BARBIER, E., COLLINS, R., FRAUMENI, B., GUNDIMEDA, H., LIU, G., MUMFORD, K. 2015. How to measure sustainable progress. In Science 350, 748.
DE ARAUJO, V.A., GARCIA, J.N., CORTEZ-BARBOSA, J., GAVA, M., SAVI A.F., MORALES, E., LAHR, F.A.R., VASCONCELOS, J.S., CHRISTOFORO, A.L. 2017. Importância da madeira de florestas plantadas para a indústria de manufaturados. In Pesquisa Florestal Brasileira 37, 157-168.
DE ARAUJO, V.A., VASCONCELOS, J.S., MORALES, E.A.M., SAVI, A.F., HINDMAN, D.P., O'BRIEN M.J., NEGRÃO, J.H.J.O., CHRISTOFORO, A.L., LAHR, F.A.R., CORTEZ-BARBOSA, J., GAVA, M., GARCIA, J.N. 2018. Difficulties of wooden housing production sector in Brazil. In Wood Material Science and Engineering 15, 87-96.
DE ARAUJO, V., VASCONCELOS, J., CORTEZ-BARBOSA, J., MORALES, E., CHRISTOFORO, A., LAHR, F., GAVA, M., GARCIA, J. 2018. Wood consumption and fixations of carbon dioxide and carbon from timber housing techniques: a Brazilian panorama. In Energy and Buildings 216, 1-14.
DELBERT, C. 2021. Lumber is ridiculously expensive right now. Here's why-and what you should do. In Popular Mechanics. URL www.popularmechanics.com/home/outdoor-projects/a36166521/lumber-shortage-prices-2021-why-lumber-is-so-expensive/.
DELBRÜCK, S., GRIESTOP, L., HAMM, U. 2018. Future opportunities and developments in the bioeconomy - a global expert survey. Berlin: Bioökonomierat. pp.1-39.
EUROPABIO 2012. Building a bio-based economy for Europe in 2020. Brussels: EuropaBio.
EUROPEAN COMMISSION. 2013. A new EU forest strategy: for forests and the forest-based sector. Brussels: European Commission. pp.1-17.
EUROPEAN COMMISSION. 2018. Bioeconomy: the European way to use our natural resources: action plan 2018. Brussels: European Commission. pp.1-23.
EUROPEAN COMMISSION. 2012. Commission staff working document: accompanying the document. Brussels: European Commission. pp.1-51.
FALK, H.W. 1958. Timber and forest products law. Berkeley: Howell-North.
FAO. 2020. Global Forest Resources Assessment 2020 - Key findings. Rome: FAO. pp.1-12.
FARES, S., MUGNOZZA, G.S., CORONA, P., PALAHÍ, M. 2015. Five steps for managing Europe's forests. In Nature 519, 407-409.

GAVA, M., MÜZEL, S.D., LIMA, L.R., BARBOSA, J.C., GARCIA, J.N., FERREIRA, B.S., SERVOLO FILHO, H.J., BERNARDES, M.S., DE ARAUJO, V.A. 2015. Production of particleboards from *Hevea brasiliensis* clones and castor oil-based polyurethane resin. In BioResources 10, 6896-6905.
GILBERTIE, S. 2021. Lumber prices rocket higher as demand overwhelms supply. In Forbes. URL https://www.forbes.com/sites/salgilbertie/2021/04/17/lumber-prices-rocket-higher-as-demand-overwhelms-supply/?sh=1259532721f9.
GUSTAFSSON, L., BAKER, S.C., BAUHUS, J., BEESE, W.J., BRODIE, A., KOUKI, J., LINDENMAYER, D., LÕHMUS, A., MARTÍNEZPASTUR, G., MESSIER, C., NEYLAND, M., PALIK, B., SVERDRUP-THYGESON, A., VOLNEY, W.J.A., WAYNE, A., FRANKLIN, J.F. 2012. Retention forestry to maintain multifunctional forests: a world perspective. In BioScience 62, 633-645.
HANUSHEK, E.A., WOESSMANN, L. 2020. The economic impacts of learning losses. In Education Working Papers, n.225. Paris: OECD Publishing.
HOSSAIN, M.U., THOMAS NG, S., ANTWI-AFARI, P., AMOR, B. 2020. Circular economy and the construction industry: existing trends, challenges and prospective framework for sustainable construction. In Renewable and Sustainable Energy Reviews 130, 1-15.
HOWARD, C., DYMOND, C.C., GRIESS, V.C., TOLKIEN-SPURR, D.T., VAN KOOTEN, G.C. 2021. Wood product carbon substitution benefits: a critical review of assumptions. In Carbon Balance and Management 16, 1-11.
IBRAHIM, A.S., LANHUI, W., EKANAYAKE, E.M.B.P., OMIFOLAJI, J.K., KHAN, D., AREE, S. 2020. Analysis of the factors affecting the contribution of forest and forestry sector on the economy of Nigeria. In Journal of Sustainable Forestry 2020, 1-17.
ITTO. 2021a. Tropical Timber Market Report. Yokohama: ITTO. Vol. 25(4). pp.1-24.
ITTO. 2021b. Tropical Timber Market Report. Yokohama: ITTO. Vol. 25(10). pp.1-29.
JIN, W., HE, H.S., THOMPSON, F.R., WANG, W.J., FRASER, J.S., SHIFLEY, S.R., HANBERRY, B.B., DIJAK, W.D. 2017. Future forest aboveground carbon dynamics in the central United States: the importance of forest demographic processes. In Scientific Reports 7, 41821.
KARVONEN, J., HALDER, P., KANGAS, J., LESKINEN, L. 2017. Indicators and tools for assessing sustainability impacts of the forest bioeconomy. In Forest Ecosystems 4, 1-20.
KEELEY, J.E., GUZMAN-MORALES, J., GERSHUNOV, A., SYPHARD, A.D., CAYAN, D., PIERCE, D.W., FLANNIGAN, M., BROWN, T.J. 2021. Ignitions explain more than temperature or precipitation in driving Santa Ana wind fires. In Science Advances 7, 1-9.
KOU, P., HAN, Y., QI, X., LI, Y. 2021. Does China's policy of carbon emission trading deliver sulfur dioxide reduction co-benefits? In Environment, Development and Sustainability 2021, 1-22.
LAMBERT, L. 2021. Lumber prices are down 68% - but there's a catch. In Fortune. URL https://fortune.com/2021/08/02/lumber-prices-down-cash-market-wholesale-retail-home-depot-lowes/
LAURINDO, T. 2021. Painéis de madeira: consumo interno e exportação no 1º tri. URL https://setormoveleiro.com.br/industria/paineis-de-madeira-consumo-interno-e-exportacao-no-1o-tri/
LETURCQ, P. 2020. GHG displacement factors of harvested wood products: the myth of substitution. In Scientific Reports 10, 1-9.
LIN, G. 2009. Higher Education research methodology-literature method. In International Education Studies 2, 179-181.
LOGAN, D. 2021. Price of OSB up more than 500% since January 2020. In NAHB. URL https://eyeonhousing.org/2021/07/price-of-osb-up-more-than-500-since-january-2020/
LOUČANOVÁ, E., OLŠIAKOVÁ, M. 2020. Consumers' perception of retro-innovation of wood products. In Acta Facultatis Xylologiae Zvolen 62, 165-174.
MADISON'S LUMBER REPORTER. 2021. Lumber prices drop again even as customers step in to buy. URL madisonsreport.com/2021/08/04/lumber-prices-drop-again-even-as-customers-step-in-to-buy/
MARCILLE, K.C., MORGAN, T.A., MCIVER, C.P., CHRISTENSEN, G.A. 2020. California's Forest Products Industry and Timber Harvest, 2016. Portland: USDA. [WWW Document]. URL www.fs.fed.us/pnw/pubs/pnw_gtr994.pdf.

MCLAIN, R.J., JONES, E.T. 2005. Nontimber Forest Products - Management on National Forests in the United States. Portland: USDA. [WWW Document]. URL www.fs.fed.us/pnw/pubs/pnw_gtr655.pdf
MIKULKOVÁ, A. HÁJEK, M., ŠTĚPÁNKOVÁ, M., ŠEVČÍK, M. 2015. Forest certification as a tool to support sustainable development in forest management. In Journal of Forest Science, 61, 359-368.
NEUMANN, R.P., HIRSCH, E. 2000. Commercialisation of non-timber forest products: review and analysis of research. [WWW Document]. URL www.cifor.org/publications/pdf_files/mgntfp3.pdf.
ODDONE, N., PADILLA-PÉREZ, R. 2016. Economic and social upgrading through professional and supporting services: lessons from the shrimp value chain in El Salvador. In Reg.&Cohesion 6, 72-95.
PANDEY, A.K., TRIPATHI, Y.C., KUMAR, A. 2016. Non timber forest products (NTFPs) for sustained livelihood: challenges and strategies. In Research Journal of Forestry 10, 1-7.
PEFC. 2018. PEFC ST 1003:2018. Sustainable Forest Management – Requirements. Geneve: PEFC.
PFAU, S.F., HAGENS, J.E., DANKBAAR, B., SMITS, A.J.M. 2014. Visions of sustainability in bioeconomy research. In Sustainability 6, 1222-1249.
PRIEFER, C., JÖRISSEN, J., FRÖR, O. 2017. Pathways to shape the Bioeconomy. In Resources 6, 1-23.
REPKO, M. 2020. Pandemic-induced 'nesting' fuels Home Depot and Lowe's sales. In CNBC. URL cnbc.com/2020/11/20/home-depot-and-lowes-earnings-boosted-by-pandemic-induced-nesting.html.
ROSNER, H. 2020. A tiny pest helped stoke this year's devastating wildfires. In NatGeo. URL www.nationalgeographic.com/science/article/bark-beetles-helped-stoke-2020-devastating-wildfires.
SANCHIS, A. 2021. La gran fiebre de la madera: sus precios se han disparado y no hay suficiente para todo el mundo. URL https://magnet.xataka.com/en-diez-minutos/gran-fiebre-madera-sus-precios-se-han-disparado-no-hay-suficiente-para-todo-mundo.
SANTIAGO, S.B., GONÇALVES, F.G., LELIS, R.C., SEGUNDINHO, P.G.A., PAES, J.B., ARANTES, M.D.C. 2018. Colagem de madeira de eucalipto com adesivos naturais. In Matéria 23, 1-12.
SEN, M., SINGER, B. 2020. Forests: at the heart of a green recovery from the COVID-19 pandemic. Geneva, Switzerland: UN. pp.1-4.
SCHIMEL, D.S. 2010. Drylands in the Earth system. In Science 327, 418-419.
SHMULSKY, R., JONES, P. 2011. Forest products and wood science: an introduction. Chichester: Wiley.
SILVA, V.U., NASCIMENTO, M.F., OLIVEIRA, P.R., PANZERA, T.H., REZENDE, M.O., SILVA, D.A.L., AQUINO, V., LAHR, F.A.R., CHRISTOFORO, A. 2021. Circular vs. linear economy of building materials: A case study for particleboards made of recycled wood and biopolymer vs. conventional particleboards. In Construction and Building Materials 285, 1-17.
SINGH, S.P., EKANEN, E., WAKEFIELD JR, T., COMER, S. 2003. Emerging importance of bio-based products and bio-energy in the U.S. economy: information dissemination and training of students. In International Food and Agribusiness Management Review 5, 1-15.
SÖNNICHSEN, S.D., CLEMENT, J. 2020. Review of green and sustainable public procurement: Towards circular public procurement. In Journal of Cleaner Production, 245, 118901.
SPURR, S.H., VAUX, H.J. 1976. Timber: biological and economic potential. In Science 191, 752-756.
SUGDEN, A.M. 2021. Carbon cycling after boreal forest fire. In Science 372, 250.
SUJOVÁ, A., SIMANOVÁ, L. 2021. Influence of aspects of change management on the performance of enterprises in the wood processing industry. In Acta Facultatis Xylologiae Zvolen 63, 165-178.
SULEIMAN, M.S., WASONGA, V.O., MBAU, J.S., SULEIMAN, A., ELHADI, Y.A. 2017. Non-timber forest products and their contribution to households income around Falgore Game Reserve in Kano, Nigeria. In Ecological Process 6, 1-14.
TEITELBAUM, L., BOLDT, C., PATERMANN, C. 2020. Global Bioeconomy Policy Report (IV): A decade of bioeconomy policy development around the world. Berlin: IACGB. pp.1-165.
THONEMANN, N., SCHUMANN, M. 2018. Environmental impacts of wood-based products under consideration of cascade utilization: a systematic literature review. In Journal of Cleaner Production 172, 4181-4188.

TÖLLER, A.E., VOGELPOHL, T., BEER, K., BÖCHER, M. 2021. Is bioeconomy policy a policy field? A conceptual framework and findings on the European Union and Germany. In Journal of Environmental Policy and Planning 23, 152-164.
UNECE/FAO 2020a. Forest products - annual market review 2019-2020. [WWW Document]. URL https://unece.org/fileadmin/DAM/timber/publications/2020/SP-50.pdf.
UNECE/FAO 2020b. Timber forecasts: production and trade data for 2019-2021. [WWW Document]. URL https://unece.org/fileadmin/DAM/timber/statsdata/tb-73-6.pdf.
VAŇOVÁ, R., ŠTEFKO, J. 2021. Assessment of selected types of the structural engineered wood production from the environmental point of view. In Acta Facultatis Xylologiae Zvolen 63, 117-130.
VAUHKONEN, J., BERGER, A., GSCHWANTNER, T., SCHADAUER, K., LEJEUNE, P., PERIN, J., PITCHUGIN M., ADOLT, R., ZEMAN, M., JOHANNSEN, V.K., KEPFER-ROJAS, S., SIMS, A., BASTICK, C., MORNEAU, F., COLIN, A., BENDER, S., KOVÁCSEVICS, P., SOLTI, G., KOLOZS, L., NAGY, D., NAGY, K., TWOMEY, M., REDMOND, J., GASPARINI, P., NOTARANGELO, M., RIZZO, M., MAKOVSKIS, K., LAZDINS, A., LUPIKIS, A., KULBOKAS, G., ANTÓN-FERNÁNDEZ, C., REGO, F., NUNES, L., MARIN, G., CALOTA, C., PANTIĆ, D., BOROTA, D., ROESSIGER, J., BOSELA, M., ŠEBEŇ, V., SKUDNIK, M., ADAME, P., ALBERDI, I., CAÑELLAS, I., LIND, T., TRUBINS, R., THÜRIG, E., STADELMANN, G., DITCHBURN, B., ROSS, D., GILBERT, J., HALSALL, L., LIER, M., PACKALEN, T. 2019. Harmonised projections of future forest resources in Europe. In Annals of Forest Science 76, 1-12.
WBCSD. 2020. Circular bioeconomy: the business opportunity contributing to a sustainable world. In Geneve: WBCSD. pp.1-72.
WHERRY, G., BUEHLMANN, U. 2014. Product life cycle of the manufactured home industry. In BioResources 9, 6652-6668.
WICKENS, G.E. 1991. Management issues for development of non-timber forest products. In Unasylva 42, 3-8.
WIEMANN, M.C. 2010. Characteristics and availability of commercially important woods. In Forest Products Laboratory. Wood handbook: wood as an engineering material. Madison: FPL. pp.1-45.
WOLFSLEHNER, B., LINSER, S., PÜLZL, H., BASTRUP-BIRK, A., CAMIA, A., MARCHETTI, M. 2016. Forest bioeconomy - a new scope for sustainability indicators. [WWW Document]. URL www.efi.int/sites/default/files/files/publication-bank/2018/efi_fstp_4_2016.pdf.
WORLD BANK GROUP. 2020. The impact of the Covid-19 pandemic on education financing. [WWW Document]. URL https://thedocs.worldbank.org/en/doc/734541589314089887-0090022020/original/CovidandEdFinancefinal.pdf.
ZAFALON, M. 2021. Exportação de madeira bruta cresce 315% em dois meses. In Folha de São Paulo. URL https://www1.folha.uol.com.br/mercado/2021/06/exportacao-de-madeira-bruta-cresce-315-em-dois-meses.shtml.

AUTHORS ADDRESSES

Prof. Sci. doc. Ing. Victor Almeida De Araujo, D.Sc.
Research Group on Development of Lignocellulosic Products, São Paulo State University
Itapeva, Brazil; va.araujo@unesp.br / engim.victor@yahoo.de

Prof. Ing. Juliano Souza Vasconcelos, M.Sc.
Post-Graduation Program of Energy in Agriculture, São Paulo State University
Botucatu, Brazil; souza.vasconcelos@unesp.br

Full Prof. doc. Ing. Francisco Antonio Rocco Lahr, D.Sc.
Department of Structural Engineering, University of São Paulo
São Carlos, Brazil; frocco@sc.usp.br

Assoc. Prof. doc. Ing. André Luis Christoforo, D.Sc.
Department of Civil Engineering, Federal University of São Carlos
São Carlos, Brazil; christoforoal@yahoo.com.br