



Consumer awareness and willingness to pay for blockchain-based traceability systems in the forest nursery sector: lessons learnt in the Italian context

Stefano Bruzzese^a, Simone Blanc^{a,*}, Corrado Costa^b, Simona Violino^b, Andrea Rosario Proto^c, Filippo Brun^a

^a Department of Agricultural, Forest and Food Sciences (DISAFA), University of Torino, Largo Paolo Braccini 2, 10095 Grugliasco, Italy

^b Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), Research Centre for Engineering and Agro-Food Processing, Via della Pascolare 16, 00015 Monterotondo, Italy

^c Department of AGRARIA, Mediterranean University of Reggio Calabria, Feo di Vito, 89122 Reggio Calabria, Italy

ARTICLE INFO

Keywords:

Infotracings
Distributed ledger
Supply chain
Consumer knowledge
Semi-structured questionnaire
Ordered logit regression

ABSTRACT

Blockchain technologies due to their inherent characteristics of immutability, transparency, distribution, and programmability can aid in the traceability of forest nursery chains. In this context, the present research investigates consumers' awareness and willingness to pay (WTP) a premium price (PP) for forest materials tracked with a blockchain-based traceability system. A semi-structured questionnaire was administered across selected forest nurseries nationwide between August 2021 and May 2023, collecting 259 valid responses. Three econometric ordered logit models were developed to assess three product attributes: sustainability, origin, and quality. The main findings reveal that most consumers are not aware of blockchain (62.6%), but those who are aware generally perceive them useful for traceability (71.4%). The attribute "origin" emerged as the most significant factor influencing WTP, while it is "quality" for which consumers are willing to pay more PP (28.9%). At the socio-demographic level, education was the most influential factor, followed by gender, age, and household size. The research indicates an embryonic demand for these technologies in the forest nursery sector, further analysis is required to determine whether this level of development is attributable to natural life cycle of an innovation or other constraining factors. Finally, this study highlights key elements for developing communication and marketing campaigns to foster the adoption of these new traceability systems.

1. Introduction

The current Italian forest nursery sector is heavily influenced by the reforestation policies of the previous century, rather than by recent cultural and silvicultural developments in forestry practices (Martini et al., 2022). Since the post-World War II period, there has been an increase in the number of public forest nurseries - sometimes even temporary ones - that supplied forest materials free of charge under a state-run management system which controlled both supply and demand, driven by the need to reforest vast areas of the national territory (Martini et al., 2022). Subsequently, with the transfer of forestry responsibilities from the State to the Regional governments, there has been a progressive abandonment of public forest nurseries. This decline has

not been offset by private forest nurseries, which, from a business and profit-oriented perspective, have focused more on the production and sale of ornamental and fruit plants rather than forest species (Mariotti et al., 2022).

This has led over time to a series of challenges that the forest nursery sector is currently facing, such as the lack of: a dedicated research and development sector for product and process innovation; a sector governance that would support the creation of an interregional centre for seed collection and conservation; an active partnerships with the private sector; a specialised personnel training; and an effective communication - both internal and external - regarding the role of public forest nurseries (Mariotti et al., 2022). Additionally, there is a growing need for a monitoring and control system for reforestation interventions

* Corresponding author.

E-mail addresses: stefano.bruzzese@unito.it (S. Bruzzese), simone.blanc@unito.it (S. Blanc), corrado.costa@crea.gov.it (C. Costa), simona.violino@crea.gov.it (S. Violino), andrea.proto@unirc.it (A.R. Proto), filippo.brun@unito.it (F. Brun).

<https://doi.org/10.1016/j.tfp.2025.101018>

carried out using nursery material, which could be integrated into a certification system. Such a system could also trace additional information, such as the genetic and cultivation quality of the nursery material, and ensure transparency in the communication of quantitative and qualitative data related to the forest nursery sector (Mariotti et al., 2022).

In the forestry field, the role of traceability has become increasingly significant over the years (Malek and Abdul Rahim, 2022). This is evident, for instance, in the chain of custody of forest certification systems aimed at tracing the origin of certified products (So and Laforteza, 2022), as well as the European due diligence system, understood as a set of procedures for reducing environmental risk from the production and import/export of certain raw materials and related products (Florian et al., 2012). In particular, the EUTR 2010 (Timber Regulation) imposed a due diligence requirement on companies placing wood and wood products on the single market. This regulation represents the first EU application of due diligence in the environmental field and aims to prevent the marketing of illegal wood and its derivatives. Under the regulation, information on the origin of the wood, i.e., where, how and when the trees were cut, must first be acquired and checked for actual compliance. If not compliant, the raw material would be illegal and consequently so would all products derived from it (Apeti et al., 2023).

1.1. Theoretical framework

“Traceability” is defined as the ability to follow the movement of a product at every stage, from production to distribution, by monitoring the history, origin of materials and components, and processing stages (Violino et al., 2020; ISO, 2015). The set of means employed to ensure traceability is defined as a “traceability system” (Khan et al., 2018). “Infotracing” is the traceability system that integrates information related to the quality of a product with those related to its traceability (Costa et al., 2013).

To identify and trace the history of products and processes, a variety of technologies can be employed, such as Radio Frequency Identification (RFID) and Near Field Communication (NFC), which are capable of encoding information to facilitate efficient reading and retrieval of digital data (Cromwell et al., 2025). It is precisely in relation to due diligence that blockchain technology, which allows reliable and truthful information to be stored about the origin of raw materials, acquires considerable importance (Figorilli et al., 2018). “Blockchain” is an online information system in which steps (transactions) are protected to prevent any alterations. The first blockchain was introduced in 2008 by Satoshi Nakamoto (2008), a pseudonym for an author whose identity remains unknown, and was implemented the following year with the goal of serving as a “ledger” (a record of all transactions) for the emerging digital currency, Bitcoin. Blockchain is organised as a distributed ledger of records in the form of encrypted blocks (smaller datasets) or a public record of all transactions or digital events shared among participating parties, which can be verified at any time in the future (Nakamoto, 2008). To prevent tampering and data falsification, transactions entered into the ledger are validated through consensus mechanisms that vary according to the blockchain used (e.g., Proof of Work, Proof of Stake, and Proof of Authority). Once entered, information in the blockchain can be edited only with difficulty. The blockchain contains a verifiable record of every single transaction and its blocks can be used to coordinate an action or verify an event (Figorilli et al., 2018).

This technology ensures data authenticity and could therefore serve as a valuable tool in combating illegal logging, enhancing the global timber trade, and improving forestry practices by offering benefits such as data immutability and transaction verifiability (Sheng and Wicha, 2024).

1.2. Literature review

Blockchain technology has demonstrated its potential to transform

the food, agriculture, and fisheries sectors by improving transparency, traceability, and sustainability. For example, Tian (2016) developed a traceability system for China’s agri-food supply chain that uses RFID and blockchain technology to ensure tamper-proof records and enable real-time product tracking. The FAO (Sylvester, 2018) has reported on global case studies in which blockchain has verified organic certifications, managed land titles and enabled smart contracts for financing farmers. In the fishing industry, a start-up company, launched a blockchain-based pilot scheme in Indonesia to track tuna from catch to consumer, thereby reducing illegal fishing through transparent data logging (<https://legacy.provenance.org/tracking-tuna-on-the-blockchain>). Kim and Laskowski (2018) proposed an ontology-driven blockchain model to structure supply chain provenance and help machines to interpret and verify data across logistics networks. These initiatives demonstrate how blockchain can improve food safety, support small-holder farmers, and combat fraud. The use of immutable ledgers builds trust among stakeholders, while smart contracts automate transactions and reduce inefficiencies across supply chains.

In the forestry sector, the most common applications of blockchain are related to forest management, traceability, and wildfire control (He and Turner, 2022). According to He and Turner (2022), one of the primary applications of this technology is the prevention of illegal logging. Indeed, thanks to blockchain, all actors in the supply chain can monitor and ensure the authenticity of the information entered. Using this platform, authorities can verify the origin and legality of imported timber. Transactions on the blockchain can be linked to the wood’s DNA, represented as a cryptographic hash. Companies in the timber industry can also confirm the certification of composite wood products through blockchain. Düdler & Ross (2017) developed a blockchain-based digital logging system to address the illegal timber trade between countries, enabling authorities to control imported timber and verify its legal status in blockchain-based systems. Research has also explored wood volume traceability; For instance, Munoz et al. (2021) demonstrated blockchain’s competitive potential in these areas. Monitoring felled timber volumes is crucial to prevent illegal trading; for this reason, Mechik & Hauff (2021) proposed a blockchain technology to administer permits and documents across the entire timber supply chain, including logging licenses, timber cutting volumes, storage documents, sales, payments, and woodworking records.

Some studies highlight that blockchain is also useful for identifying the type of wood, such as teak, by tracking its journey from agricultural production to end-users (Sheng and Wicha, 2021; Sun et al., 2021). Another use of blockchain involves the protection of forest species and biodiversity. Images of species are captured by drones and uploaded to an application that, using an algorithm, identifies the type and quantity of trees. Information on felled trees is then recorded in smart contracts, making details such as the number of trees cut, their type, age, size, location, and date of felling accessible to all actors in the supply chain (Nandhini et al., 2021).

Blockchain-based systems can also be used as advanced wildfire surveillance tools. By employing IoT sensors placed in forests, such as temperature, smoke, and humidity sensors, data can be collected and analysed in real-time to predict and monitor the spread of wildfires (Datta et al., 2022).

In general, blockchain technologies applied to forestry product traceability systems enable the retrieval of information on each product and identify the parties involved in the wood supply chain. Stakeholders may be forest owners and managers, suppliers, logistic companies, and customers. The various actors can access supply chain data at any time, supplementing it or requesting changes if accepted through the underlying consensus mechanism of the blockchain, thus guaranteeing data integrity (Stopfer et al., 2024). Blockchain offer investment opportunities in the forestry sector, attracting investors due to its transparency. Global investors can easily access information on transactions in the sector, which increases trust in blockchain and its reliability. Blockchain’s transparency and traceability can attract investors from various

sectors (He and Turner, 2022). However, at present, practical applications of this technology in the forestry sector are still limited, likely due to its innovative nature and the need for wider adoption.

Originally developed to track the origin and path of timber, forest traceability has been adapted for the nursery sector to ensure the controlled origin of plants, responsible nursery management, and compliance with environmental regulations (Sortino et al., 2023). Forestry traceability system makes it possible to track every stage of the production cycle, from cultivation to distribution, thereby promoting transparency and sustainability in the plant market (Stopfer et al., 2024). Traceability in the forestry sector promotes sustainability through transparency, legality and responsible management of natural resources. Providing traceability means being able to verify the origin and path of every forest product, ensuring that it comes from sustainable forest management practices and complies with environmental and social regulations (Russo, 2019). A significant example is the CloudWood project, which uses blockchain technology to digitally track the wood supply chain, improving the transparency and sustainability of local supply chains (<https://www.rivistasherwood.it/webdoc/cloud-wood.html#:~:text=IL%20PROGETTO&text=CloudWood%20è%20un%20progetto%20più,questa%20preziosa%20materia%20prima%20rinovabile.>). This approach not only facilitates the monitoring of forestry practices, but also strengthens local supply chains and raises awareness among end consumers of the importance of individual choices for the legality and sustainability of wood supply chains. In addition, sustainable forest management and chain-of-custody certification is critical to ensure the traceability and sustainability of forest products. Schemes such as PEFC and FSC certify that products come from responsibly managed forests, meeting environmental, social and economic criteria, and that traceability is maintained throughout the supply chain. Therefore, traceability in the forestry sector not only facilitates verification of sustainability, but is also a key element in promoting responsible and transparent management of forest resources (Russo, 2019).

Nursery traceability is particularly relevant following the European Parliament's approval of the New EU Biodiversity Strategy for 2030 (European Commission, 2021) which includes the 3 billion Tree Planting Pledge for 2030. In Europe, several planting plans have been financed by the EU, involving 58 organisations with a total of over 22.6 million trees planted (MapMyTree, 2022). In Italy, among the different initiatives, there was the measure "Protection and enhancement of urban and peri-urban greenery" under the National Recovery and Resilience Plan (NRRP, M2C4 3.1), which aimed to plant 6.6 million trees in 14 metropolitan cities between 2022 and 2026. This target was later reduced to 4.5 million trees due to delays in some regions. Following the limited success of the previous measure, the Ministry of the Environment and Energy Security (MASE), in collaboration with private partners, recently launched a new project entitled "RiforestAzione", also within the framework of the same NRRP mission (M2 – "Green Revolution and Ecological Transition") (MASE, 2025). In addition to urban and peri-urban planting/afforestation projects, forest nurseries also play a key role for other purposes, such as reforestation efforts aimed at addressing consequences of major natural disturbances, including wildfires and storms. In Italy, the case of storm Vaia in October 2018 is emblematic (Cavaleri et al., 2019). In Figorilli et al. (2021), a blockchain-based web application was used for managing forest nurseries, implementing a traceability system using electronic tagging technologies such as RFID and NFC technologies. This application enabled real-time tracking of individual forest plants in nurseries, allowing for continuous monitoring and providing customers with information on attributes such as origin, sustainability and plant quality. To the best of the authors' knowledge, Figorilli et al. (2021) is the only study on the management of forest nurseries via blockchain, while economic studies examining consumer awareness and willingness to pay (WTP) a premium price (PP) for blockchain-tracked products are absent.

1.3. Research questions

Despite the growing attention to blockchain as a tool for ensuring transparency and traceability in forest supply chains, the economic literature appears lacking regarding the WTP for such technologies. Existing studies focus mainly on technological and regulatory aspects, neglecting the economic analysis of consumer perception of value. This knowledge gap prevents understanding the real impact of such technologies on market demand and business profitability, limiting the development of effective strategies for their integration into the forestry sector. The absence of in-depth research on WTP for forest products tracked through blockchain makes it difficult to assess whether consumers are really willing to pay a higher price for greater transparency and sustainability. Without hard data, companies in the industry may hesitate to invest in this technology, fearing an uncertain economic return. In addition, the lack of comparative studies with other forest certification instruments limits understanding of actual consumer preferences. Therefore, it is critical to fill this gap with detailed economic analyses to facilitate an informed and strategic transition to more sustainable and digitised production models.

In this context, before addressing these gaps in the scientific literature, our study aimed to explore consumers' familiarity with traceability systems by asking:

- 1) What is the level of consumer knowledge about traceability systems?
Subsequently, specific research questions regarding blockchain technologies were investigated:
- 2) Does the consumer know about blockchain technologies and believe they are useful for traceability in the nursery supply chain?
- 3) What factors affect the WTP a PP for blockchain-tracked nursery products?

To do this, a semi-structured questionnaire was designed to capture consumer knowledge and attitudes on traceability, and three ordered logit econometric models were developed to analyse WTP for the attributes under evaluation (sustainability, origin, and quality).

The study of consumer awareness and knowledge is essential to better understand their purchasing behaviour and, consequently, the decisions and actions they undertake, as reported by several authors (Firoozzare et al., 2024; Ishak and Zabil, 2012; Hartlieb and Jones, 2009), and to support informed decision-making on the supply side.

This research comes at a time of strategic importance. Forests are globally recognised as critical by various policies and related strategies aiming to tackle the triple planetary crisis (climate, environment, and pollution), necessitating reforestation and afforestation programmes that encourage a revival of the forest nursery sector. In this context, Italy has launched the RI-VIVA-FOR manifesto to promote new governance and enhance the value of regional forest nurseries, fostering collaborations among public and private sector actors (Alberitalia et al., 2022). Given the distribution, security, programmability, data immutability and verifiability, and transparency characteristics of blockchain, understanding whether market demand finds them useful for traceability purposes and whether it is able to sustain a WTP a PP for these innovations is essential to enable their appropriate adoption by companies. The rest of this work is structured as follows: Section 2 describes data collection and the development of the econometric models; Sections 3 and 4 present and discuss the main results; while the final section is dedicated to research implications, limitations, and future developments.

2. Materials & methods

2.1. Data collection

A semi-structured questionnaire was designed to address the research questions, specifically exploring end consumer knowledge and

WTP a PP for supply chain traceability and the adoption of new blockchain-based traceability systems. The first version of the questionnaire was pre-tested with scholars specialised in forest and rural economics and forestry nursery staff, to ensure clarity and comprehensibility. The revised version consisted of 18 questions, including open-ended, closed, multiple-choice and 5-point Likert scales, divided into five thematic sections (Appendix A). The first section was not included in the results of this study, as it was of secondary importance with respect to the research questions addressed. This section focused on understanding consumers' knowledge of traceability and their search for traceability elements in various sectors (e.g., food, industrial, and chemical). The second section examined knowledge of technologies used for traceability. The third section focused on assessing consumers' knowledge of blockchain technologies and their perceived usefulness in enhancing traceability systems. The fourth section, focused on economic factors, asked consumers about the importance of traceability in relation to certain product attributes and their WTP a PP to have these attributes tracked via a blockchain-based traceability system. The question on the WTP for a PP was structured on a three-level scale: 0%, up to 20%, and more than 20%, considering a base price of the forest material set at €3.30. This value is an average price derived from the price lists of the nurseries involved in the study and refers to the unit price of a potted field tree. The last section was dedicated to socio-demographic data collection. The questionnaire was administered by nursery staff, previously trained by university scholars, after the consumer had purchased forest material at the nursery. The data collection lasted nearly two years (August 2021 to May 2023) with a seasonal frequency, as spring and autumn are the busiest periods for nurseries. A total of 307 questionnaires were collected, of which 259 were considered valid for further analysis.

2.2. Data analysis

To analyse multiple response patterns, an ordered logistic econometric model was employed. This model (Equation 1) was chosen because it appropriately manages dependent variables (Table 1), such as the WTP, which are structured in ordered categories (Greene, 2011), representing a sequence of latent variables across the three levels of WTP: 0%, up to 20%, more than 20% (Merlino et al., 2020).

$$WTP^*_{i,j,k} = \mathbf{x}'_{i,j,k}\beta + \varepsilon_{i,j,k} \tag{1}$$

The WTP* is modelled as a continuous latent variable, ranging from $-\infty$ to $+\infty$. Here, $\mathbf{x}'_{i,j,k}$ is the vector that includes socio-economic characteristics contributing to WTP a PP for forest products tracked with blockchain technologies: *i*, origin; *j*, sustainability; *k*, quality. The parameter β represents the coefficients of the covariates and is calculated using the Maximum Likelihood Estimation method, with the overall fit of the Ordered Logistic (OL) model typically assessed via

Table 1
List of explanatory variables used in the model.

Variables	Scale
Gender	0, Male 1, Female
Age	18-84
Family size	1-6
Educational level	1, Elementary and middle school 2, High school (general diploma) 3, University (BA, MSc) 4, Higher education (PhD)
Monthly household income (€)	1 if Up to 1,000 2 if 1,001-2,000 3 if 2,001-3,000 4 if 3,001-4,000 5 if 4,001-5,000 6 if 5,001-6,000

Nagelkerke's R². The ϵ represents the error term across the sample observations (Long and Freese, 2014).

The model outcomes are presented as odds ratios (OR) with 95% confidence intervals, p-values, and predicted probabilities. An OR less than 1 (with p-value <0.05) indicates a negative relationship between the explanatory variable and the dependent variable, while an OR greater than 1 (with p-value <0.05) indicates a positive relationship (Hosmer Jr et al., 2013).

Finally, the predicted probabilities and marginal effects estimate the likelihood (McFadden, 1972) that a consumer would pay a PP for a product guaranteeing origin, sustainability, or quality.

The statistical analysis was carried out using Stata software, version 17.1.

2.3. Definition of product attributes

The attributes of forest material investigated in relation to consumers' WTP a PP for a blockchain-based traceability system are "Origin", "Sustainability", and "Quality". "Origin" is defined in accordance with Council Directive 1999/105/EC on the marketing of forest reproductive material, as the source of the material, considering both its legality and country of origin (Fady and Scotti-Saintagne, 2025). "Sustainability" refers to the production methods adopted in the nursery, with an awareness of their impact on climate change and the need to conserve natural resources (Gallegos-Cedillo et al., 2024). "Quality" is defined according to the morphological characteristics of the forest material, as described by Mataruga et al. (2023), including characteristics such as age, shoot height, imbalances between root size and shoot, and potential damage.

3. Results

3.1. Characteristics of respondents

Table 2 shows the socio-demographic profile of the interviewed sample. It consists mainly of male individuals (64.5%), with medium-high education (64.1%, high school or university) and medium-low income (48.6% of the sample earning less than 30,000€). The age distribution of the respondents is based on the classification used by Pippinato et al. (2022) and Brosdahl and Carpenter (2011), and falls mainly within

Table 2
Characteristics of respondents (n=259).

Variables	Categories	Frequency (n)	Percentage (%)
Gender	Male	167	64.5
	Female	81	31.3
	N/A	11	4.2
Age group	Younger generations	93	35.9
	Generation X	115	44.4
	Older generations	36	13.9
	N/A	15	5.8
Family size	<3	59	22.8
	3-4	118	45.6
	>4	43	16.6
Education	N/A	39	15
	Elementary and middle school	49	18.9
	High school	92	35.5
Monthly net household income	University	74	28.6
	Higher education	32	12.4
	N/A	12	4.6
	Up to 1,000	13	5
	1,001-2,000	58	22.4
	2,001-3,000	55	21.2
	3,001-4,000	18	7
	4,001-5,000	10	3.9
	5,001-6,000	26	10
	N/A	79	30.5

the Younger generation (35.9% born after 1980) and Generation X (44.4% born between 1965 and 1980). Households mainly consist of 3-4 persons (45.6%), with a significant portion also represented by small households (1-2 persons, 22.8%).

3.2. Consumers' knowledge of technologies for traceability

Table 3 presents the level of consumer knowledge regarding technologies used for traceability. The results show good recognition of the historical technologies, such as barcodes (73.4%) and transport documents (56.4%), but limited recognition of more innovative digital ones, such as RFID (32.4%) and NFC (36.7%). Moreover, more than half of consumers mistakenly attribute a traceability function for invoices (55.2%), possibly due to their role in payment tracking.

3.3. Consumers' awareness of blockchain technologies

Table 4 reports both consumers' knowledge of blockchain technologies and their perception of the usefulness of such technologies in improving the functioning of traceability systems. The results reveal that about two-thirds of the respondents have not heard of blockchain technologies (62.6%). However, almost three quarters of those who have heard of blockchains consider them useful for traceability, thanks to their inherent properties (71.4%).

3.4. Consumers' willingness to pay for forest products tracked with blockchain technologies

Table 5 shows the factors contributing to WTP a PP for nursery products tracked with blockchain technologies, when there are guarantees for sustainability, origin, or product quality. Significant attributes were observed across all three models, except for sustainability attribute in the origin-based WTP model. Each attribute exhibits a positive correlation with its respective model and a negative correlation with other attributes, indicating that as the importance attributed to these attributes increases, consumers tend to have a greater WTP. An exception is observed in the positive correlation between the origin attribute and the sustainability model, denoted by a coefficient of 0.205. This suggests a potential link between knowledge of the forest material's origin and its perceived environmental sustainability.

When examining odds ratios, the origin attribute has the most

Table 3
Consumers' knowledge of technologies used for traceability (n=259).

Variables	Categories	Frequency (n)	Percentage (%)
RFID	Yes	84	32.4
	No	36	13.9
	I don't know	124	47.9
	N/A	15	5.8
Sales receipt	Yes	82	31.7
	No	117	45.1
	I don't know	49	18.9
	N/A	11	4.3
Barcode	Yes	190	73.4
	No	27	10.4
	I don't know	36	13.9
	N/A	6	2.3
Invoice	Yes	143	55.2
	No	64	24.7
	I don't know	45	17.4
	N/A	7	2.7
Transport document	Yes	146	56.4
	No	60	23.1
	I don't know	43	16.6
	N/A	10	3.9
NFC	Yes	95	36.7
	No	12	4.6
	I don't know	130	50.2
	N/A	22	8.5

Table 4

Consumers' awareness of blockchain technologies and their perceived usefulness in improving traceability systems.

Variables	Categories	Frequency (n)	Percentage (%)
Blockchain knowledge (n=259)	Yes	84	32.4
	No	162	62.6
	N/A	13	5
Usefulness of blockchain for traceability (n=84)	Yes	60	71.4
	No	4	4.8
	Doesn't know	14	16.7
	N/A	6	7.1

substantial influence on the WTP of the corresponding model, showing a 2.85-fold increase as the attribute's importance escalates. This is followed by quality (2.73 times) and sustainability (1.56 times).

Turning to sociodemographic factors, all variables were significant in the three models, except for monthly household income, which only held significance for the origin model, displaying a negative correlation of -0.106. Educational level emerged as the sociodemographic factor with the most pronounced impact on WTP, exhibiting increases of 2.48, 2.58, and 1.93 for sustainability, origin, and quality models respectively, as education level advanced. Gender follows, with females being 1.50 times more inclined to pay a PP for sustainability, while for origin and quality, males show a higher likelihood. Lastly, age and family size exert a negative effect on WTP across all models, particularly for larger households and older individuals, whose WTP a PP tends to diminish.

Table 6 reports the predicted probabilities and marginal effects of the independent variables across the three classes of WTP. In terms of probability, despite the strong importance ascribed to the origin attribute in WTP, it appears that consumers are willing to pay a PP of over 20% of the base price for the quality (28.9%), more so than for the sustainability (15.7%) and origin (9.6%). The factors influencing this inclination include the importance attached to each attribute and a high level of education. A higher level of education influences WTP a PP of more than 20%, and in the origin model, this influence is even greater for a WTP of less than 20%. For sustainability, the importance of origin also influences the WTP by more than 20%.

Age has a minor effect; however, older individuals have a maximum reservation price of 20% of the base price, and they are not willing to pay a PP for the origin attribute. Females are willing to pay more than 20% for sustainability, up to 20% for quality, and nothing for origin. As family size increases, individuals are willing to pay up to 20% for both sustainability and quality, but not for origin. Lastly, concerning the origin WTP, individuals with the highest income are generally unwilling to pay a PP.

4. Discussion

Blockchain technologies, as reported by some authors (Li and Dou-nas, 2024; Shahzad et al., 2024; Vilkov and Tian, 2023; Park and Li, 2021), exhibit intrinsic characteristics that enhance supply chains, such as data immutability, decentralisation and distribution of the ledger, transparency, and consensus democratisation among network participants. According to the reviews of Stopfer et al. (2024) and He & Turner (2022), these technologies are applied in the forestry sector in various ways, including traceability, forest management, carbon markets, early detection of wildfires, and nursery production.

In this context, understanding consumers' WTP a PP for such innovation is of vital importance to justify its implementation and economic viability from the supply side. In light of our findings within the forest nursery sector, two main results emerge:

- About two-thirds of respondents are unaware of blockchain technologies, however, most of those who are aware consider them useful

Table 5
Ordered logit econometric model results.

Covariates	Sustainability			Origin			Quality		
	Coeff.	Odds ratio		Coeff.	Odds ratio		Coeff.	Odds ratio	
Sustainability importance	0.448	1.564	***	-	-		-0.591	0.554	***
Origin importance	0.205	1.227	***	1.046	2.848	***	-0.105	0.901	**
Quality importance	-0.342	0.710	***	-0.549	0.577	***	1.004	2.730	***
Age	-0.012	0.988	***	-0.016	0.984	*	-0.016	0.984	***
Gender	0.403	1.496	***	-0.184	0.832	***	-0.203	0.816	**
Family size	-0.398	0.672	***	-0.324	0.723	***	-0.280	0.756	***
Educational level	0.907	2.476	***	0.946	2.576	***	0.657	1.928	***
Monthly household income	-	-		-0.106	0.899	***	-	-	
Cut-point 1	0.792	1.227		1.664	1.227		-0.001	0.554	
Cut-point 2	4.196	1.564		5.007	1.564		2.830	2.730	
Log-pseudolikelihood	-3,128.09			-3,064.19			-3,336.63		
Chi-square	926.69			1,279.42			992.70		
Prob. Chi-square	0.000			0.000			0.000		
Pseudo R ²	0.129			0.173			0.130		

Note: The p-value refers to the level of statistical significance: *** < 0.001; ** < 0.01; * < 0.05.

Table 6
Predicted probabilities and marginal effects from the estimated ordered logit model.

Sustainability	WTP=0%	WTP≤20%	WTP>20%
Predicted probability	0.151	0.692	0.157
Sustainability importance	-0.057	-0.002	0.059
Origin importance	-0.026	-0.001	0.027
Quality importance	0.044	0.001	-0.045
Age	0.001	0.000	-0.002
Gender	-0.049	-0.007	0.056
Family size	0.051	0.002	-0.053
Education	-0.116	-0.004	0.120
Monthly net household income	-	-	-
Origin	WTP=0%	WTP≤20%	WTP>20%
Predicted probability	0.250	0.654	0.096
Sustainability importance	-	-	-
Origin importance	-0.196	0.105	0.091
Quality importance	0.103	-0.055	-0.048
Age	0.003	-0.002	-0.002
Gender	0.035	-0.020	-0.020
Family size	0.061	-0.033	-0.028
Education	-0.177	0.095	0.082
Monthly net household income	0.020	-0.011	-0.009
Quality	WTP=0%	WTP≤20%	WTP>20%
Predicted probability	0.127	0.584	0.289
Sustainability importance	0.065	0.056	-0.022
Origin importance	0.012	0.010	-0.121
Quality importance	-0.111	-0.095	0.206
Age	0.002	0.002	-0.003
Gender	0.023	0.018	-0.041
Family size	0.031	0.027	-0.058
Education	-0.073	-0.062	0.135
Monthly net household income	-	-	-

for traceability purposes. This result suggests that, on the one hand, this innovation in the forest nursery sector is, according to [Rogers' diffusion curve \(1962\)](#) and as argued by [Shahzad et al. \(2024\)](#), in the early stages of its dissemination, thus explaining the low level of awareness and adoption. On the other hand, it may indicate a lack of interest in, or scepticism about these technologies, potentially linked to the cost of accessing additional information about the tracked product, as noted by [Füzesi et al. \(2020\)](#), or to concerns about data privacy and confidentiality, as highlighted by [Pearson \(2019\)](#). Furthermore, even if we consider the hypothesis that the innovation is in its initial diffusion stage, this does not necessarily imply that it will achieve significant market maturity. This outcome may occur, for example, if consumers find a more affordable alternative or if, as reported by [Fan et al. \(2022\)](#), adoption by suppliers is hindered by implementation costs and consumer awareness of traceability.

Blockchain adoption could reduce information asymmetries among supply chain actors, enhancing the credibility and quality of transmitted information, as well as supporting traceability and transparency, as argued by [Liu et al. \(2021\)](#) and [ElMessiry & ElMessiry \(2018\)](#). These characteristics also align well with mechanisms such as forest certifications (Forest Stewardship Council – FSC – and Programme for the Endorsement of Forest Certification – PEFC), where signalling one's activities is a key motivation for companies to adopt them, as noted in studies by [So and Laforzezza \(2022\)](#) and [Bruzzese et al. \(2025\)](#) in the Italian context. In addition to reducing information asymmetries, blockchains may indirectly lower transaction costs, as reported by several authors ([Chen et al., 2022](#); [Schmidt and Wagner, 2019](#); [Tapscott and Tapscott, 2018](#); [Iansiti and Lakhani, 2017](#)). This effect occurs both during initial contact between supply chain actors and in the application and monitoring of processes compliance, as information on the distributed ledger can be verified at any time. Finally, blockchain adoption may have positive rebound effects, such as promoting sustainable and responsible practices downstream in the supply chain, as reported by [Kafi et al. \(2023\)](#), [Benstead et al. \(2022\)](#), and [Park & Li \(2021\)](#). As a result of these considerations, blockchain technologies could also have added value for forest nursery products ([Calvano et al., 2025](#)). However, it could also have negative environmental impacts for blockchains based on energy-intensive consensus mechanisms (e.g., Proof of Work), as reported by [Mougayar et al. \(2016\)](#).

■ Consumers place significant importance on attributes such as origin, sustainability, and quality, which also positively influence their WTP a PP for blockchain-based traceability. Interestingly, a positive correlation between the attribute "origin" and the sustainability model suggest a link between the perception of a product's sustainability and its place of origin, as reported by [Lazzarini et al. \(2017\)](#), particularly when this origin is local or near the point of sale, as supported by [Groth et al. \(2023\)](#) and [van Bussel et al. \(2022\)](#). However, despite "origin" being the attribute declared as most important, consumers are willing to pay a higher PP for the "quality" attribute. This finding could indicate, on one hand, a social desirability bias ([Nazari et al., 2024](#)), whereby respondents tend to answer in a way that is socially accepted rather than fully reflecting their actual intentions, as defined by [Edwards \(1953\)](#). On the other hand, it may imply that consumers, according to [Holopainen et al. \(2017\)](#), attribute greater weight in their purchasing behaviour to tangible attributes, such as quality or price, over intangible ones, like origin or sustainability. In terms of sociodemographic variables, all were significant in the three models, except for income, which negatively influenced only the origin model to a small extent. This result suggests that other values, such as ethics and morality, may play a more crucial role in purchasing decision than purely economic

considerations. A higher level of education positively impacted WTP, whereas increased age and family size had a negative effect. These findings align with other studies on WTP a PP for traceability, such as the review by [Poratelli et al. \(2022\)](#) and the work by [Wu et al. \(2015\)](#). This trend is likely because a higher education level corresponds to increased awareness and capability in understanding new technologies, while older consumers and larger families may have lower disposable income and less inclination to adopt such innovations. Finally, as observed in the studies by [Pippinato et al. \(2022\)](#) and [Zhang and Dong et al. \(2020\)](#), women showed particular sensitivity and WTP a PP for sustainability-related product attributes.

5. Conclusions

Consumer awareness of blockchain technologies, particularly in the context of traceability systems for the Italian forest nursery sector, remains relatively limited but has significant potential for growth. A total of 62.6% of respondents were not aware of blockchain technologies, although 71.4% of those who were aware attributed usefulness to them for traceability purposes. Blockchain offers a transparent, secure, and immutable record of transactions, which can significantly increase trust in the supply chain, especially in sectors where sustainability and origin verification are critical. The attribute “origin” was found to have the greatest influence on consumers’ WTP, although they were primarily willing to pay a premium of more than 20% for the attribute “quality” (28.9%), followed by “sustainability” (15.7%) and, lastly, “origin” (9.6%).

5.1. Implications

The study aligns well with the current interests of blockchain applications in forestry, providing a valuable contribution to the traceability of forest nurseries. Focusing on the utility of blockchain in consumer traceability, the paper adds innovative insights relevant to sustainability and transparency, and offers actionable recommendations to enhance the market potential of blockchain through targeted consumer awareness and education, with suggestions for leveraging blockchain attributes in marketing.

However, widespread adoption will require both increased education and infrastructure development. Consumers need to better understand how blockchain can benefit them, particularly in terms of ensuring product authenticity and sustainability. Public awareness campaigns, industry collaboration and policy support can all play an important role in bridging this knowledge gap. Additionally, forest nurseries themselves need to adapt to new technologies and demonstrate their value to customers. Blockchain could become a powerful tool for transparency, but without proper consumer engagement, its potential may remain untapped. Moreover, in the coming years, the demand for new plants to be planted will increase and a system for controlling production processes may represent an important guarantee tool.

5.2. Limitations

There are two main limitations to this study. First, the sample size is small (259 valid responses), making it difficult to generalise and infer

results at the population level (i.e., all buyers from Italian forest nurseries), although the analyses benefit from statistical robustness. Second, the sampling method is based on convenience, as the questionnaire was administered only in a selection of forest nurseries across the national territory. To mitigate potential sampling biases, such as self-selection bias, the questionnaire began with a screening question regarding the purchase of forest plants in nurseries. These limitations underscore the exploratory nature of this research and the preliminary use of its results in future developments as a source of lessons learnt.

5.3. Future developments

In conclusion, this study aims to serve as a starting point for a more extensive and detailed analysis of the potential, challenges, and risks associated with the use of blockchain-based traceability systems in the nursery sector. Further research is needed to understand the underlying reasons and causes of the early-stage adoption of such technologies in this context, as well as to analyse whether other product attributes could or should be tracked using blockchain and the perceived utility of this tracking among consumers. In this regard, a longitudinal study could be useful for monitoring changes in awareness of blockchain technology, as well as its perceived importance and interest in nursery traceability over a specific period. Finally, a more comprehensive discussion of blockchain limitations, such as scalability, energy consumption, and privacy concerns, would provide a more balanced perspective and contribute to identifying practical strategies for improving adoption.

Funding source

This study was supported by the Italian Ministry of Agriculture, Ministry of Agriculture, Food Sovereignty and Forestry (MASAF), National program sub project Precision Forestry (AgriDigit program) (DM 36509.7305.2018 of 20/12/2018).

CRediT authorship contribution statement

Stefano Bruzzese: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Blanc:** Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Corrado Costa:** Writing – original draft, Investigation. **Simona Violino:** Writing – original draft, Investigation. **Andrea Rosario Proto:** Writing – original draft. **Filippo Brun:** Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Authors would like to acknowledge the nursery operators for helping us with the collection of questionnaires and the consumers who participated in the research.

Appendix A

Questions, thematic sections, and evaluation scales of the questionnaire.

Index	Thematic sections	Questions	Scale
Q1	-	Are you a buyer of forest nursery products?	Closed
Q2	Knowledge of traceability	For which products do you look for traceability tags?	Closed
Q3		If you answered yes to the Other option, specify what is meant	Open-ended
Q4		For which products do you find traceability tags?	Likert
Q5		If you answered yes to the Other option, specify what is meant	Open-ended
Q6	Knowledge of traceability systems	The traceability systems are: "aimed at the automatic identification of the different production and processing phases that contribute to the creation of a product". Which of these systems do you think can guarantee the traceability of a product?	Closed
Q7		If you answered yes to Other, please specify what you mean	Open-ended
Q8	Knowledge of blockchain technologies	Have you ever heard of blockchain technologies?	Closed
Q9		If so, what do you associate blockchain technologies with?	Open-ended
Q10		If so, do you think they could be useful tracking technologies?	Closed
Q11	WTP	How important do you think the following attributes are for the purchase of a maple seedling?	Likert
Q12		How much would you be willing to pay extra for the following attributes to purchase a 3,30€ potted maple plant?	Scale
Q13	Sociodemographic	Age	Open-ended
Q14		Sex	Closed
Q15		Number of household members?	Multiple-choice
Q16		What is your education level?	Multiple-choice
Q17		Profession	Open-ended
Q18		Which of the following monthly net family income bands do you return to?	Multiple-choice

Data availability

Data will be made available on request.

References

- Alberitalia, SISEF, 2022. RI-VIVA-FOR Manifesto for the revitalisation of forest nursery activities. Original version: RI-VIVA-FOR Manifesto per il rilancio delle attività vivaistiche forestali [WWW Document]. SISEF. URL: <https://sisef.org/2022/07/27/ri-viva-for-manifesto-per-il-rilancio-delle-attivita-vivaistiche-forestali/>.
- Apeti, A.E., N'doua, B.D., 2023. The impact of timber regulations on timber and timber product trade. *Ecol. Econ* 213, 107943. <https://doi.org/10.1016/j.ecolecon.2023.107943>.
- Benstead, A., Mwesumbe, D., Moradlou, Hamid, Boffelli, A., 2022. Entering the world behind the clothes that we wear: practical applications of blockchain technology. *Prod. Plan. Control*. <https://doi.org/10.1080/09537287.2022.2063173>.
- Brosdahl, D.J.C., Carpenter, J.M., 2011. Shopping orientations of US males: a generational cohort comparison. *J. Retail. Consum. v* 18, 548–554. <https://doi.org/10.1016/j.jretconser.2011.07.005>.
- Bruzzese, S., Brun, F., Galati, A., Borsellino, V., Mirabella, C., Brunori, A., Blanc, S., 2025. Examining the adoption of PEFC chain of custody certification in the Italian forest-based industry: an empirical study on motivations and impacts. *For. Policy. Econ* 170, 103385. <https://doi.org/10.1016/j.fopol.2024.103385>.
- Calvano, S., Negro, F., Blanc, S., Bruzzese, S., Brun, F., Zanuttini, R., 2025. Adding value to wood-based products: a systematic literature review on drivers. *Forests* 16, 590. <https://doi.org/10.3390/f16040590>.
- Cavaleri, L., Bajo, M., Barbariol, F., Bastianini, M., Benetazzo, A., Bertotti, L., Chiggiato, J., Davolio, S., Ferrarin, C., Magnusson, L., Papa, A., Pezzutto, P., Pomaro, A., Umgiesser, G., 2019. The October 29, 2018 storm in Northern Italy – an exceptional event and its modeling. *Prog. Ocean* 178, 102178. <https://doi.org/10.1016/j.pocean.2019.102178>.
- Chen, W., Botchie, D., Braganza, A., Han, H., 2022. A transaction cost perspective on blockchain governance in global value chains. *Strateg. Change* 31, 75–87. <https://doi.org/10.1002/jsc.2487>.
- Costa, C., Antonucci, F., Pallottino, F., Aguzzi, J., Sarriá, D., Menesatti, P., 2013. A review on agri-food supply chain traceability by means of RFID technology. *Food. Bioprocess. Technol* 6, 353–366. <https://doi.org/10.1007/s11947-012-0958-7>.
- Cromwell, J., Turkson, C., Dora, M., Yamoah, F.A., 2025. Digital technologies for traceability and transparency in the global fish supply chains: a systematic review and future directions. *Mar. Policy* 178, 106700. <https://doi.org/10.1016/j.marpol.2025.106700>.
- Datta, S., Kumar, S., Sinha, D., Das, A.K., 2022. BSSFFS: blockchain-based sybil-secured smart forest fire surveillance. *J. Ambient. Intell. Hum. Comput* 13, 2479–2510. <https://doi.org/10.1007/s12652-021-03591-1>.
- Düdder, B., Ross, O., 2017. Timber tracking: reducing complexity of due diligence by using blockchain technology (SSRN Scholarly Paper No. ID 3015219). *Soc. Sci. Res. Netw.* <https://doi.org/10.2139/ssrn.3015219>.
- Edwards, A.L., 1953. The relationship between the judged desirability of a trait and the probability that the trait will be endorsed. *J. Appl. Psychol* 37, 90–93. <https://doi.org/10.1037/h0058073>.
- ElMessiry, M., ElMessiry, A., 2018. Blockchain framework for textile supply chain management. In: Chen, S., Wang, H., Zhang, L.-J. (Eds.), *Blockchain – ICBC 2018*. Springer International Publishing, Cham, pp. 213–227. https://doi.org/10.1007/978-3-319-94478-4_15.
- European Commission, 2021. Commission staff working document. The 3 billion tree planting pledge for 2030. Accompanying the New EU Forest Strategy for 2030, SWD.
- Fady, B., Scotti-Saintagne, C., 2025. Why conserve genetic diversity? A perspective based on a case study with a European conifer. *Ann. Bot. mcaf041*. <https://doi.org/10.1093/aob/mcaf041>.
- Fan, Z.P., Wu, X.Y., Cao, B.B., 2022. Considering the traceability awareness of consumers: should the supply chain adopt the blockchain technology? *Ann. Oper. Res* 309, 837–860. <https://doi.org/10.1007/s10479-020-03729-y>.
- Figorilli, S., Antonucci, F., Costa, C., Pallottino, F., Raso, L., Castiglione, M., Pinci, E., Del Vecchio, D., Colle, G., Proto, A.R., Sperandio, G., Menesatti, P., 2018. A blockchain implementation prototype for the electronic open source traceability of wood along the whole supply chain. *Sens. (Basel)* 18. <https://doi.org/10.3390/s18093133>.
- Figorilli, S., Bruzzese, S., Proto, A.R., Costa, C., Moscovini, L., Blanc, S., Brun, F., 2021. A Blockchain implemented app for forestry nursery management, in: 2021 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor). Presented at the 2021 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), pp. 396–400. <https://doi.org/10.1109/MetroAgriFor52389.2021.9628715>.
- Firoozzare, A., Boccia, F., Yousefian, N., Ghazanfari, S., Pakoos, S., 2024. Understanding the role of awareness and trust in consumer purchase decisions for healthy food and products. *Food. Qual. Prefer* 121, 105275. <https://doi.org/10.1016/j.foodqual.2024.105275>.
- Florian, D., Masiero, M., Mavsar, R., Pettenella, D., 2012. How to support the implementation of due diligence systems through the EU Rural Development Programme: problems and potentials. *Ital. for. mont* 67 (2), 191–201. <https://doi.org/10.4129/ifm.2012.2.07>.
- Füzesi, I., Csordás, A., Shkodra, R., Felföldi, J., 2020. Consumer acceptance of blockchain-based traceability systems in food supply chains. *J. Agric. Inf.* 11, 9–23. <https://doi.org/10.17700/jai.2020.11.1.562>.
- Gallegos-Cedillo, V.M., Nájera, C., Gruda, N.S., Signore, A., Gallegos, J., Rodríguez, R., Ochoa, J., Egea-Gilabert, C., Fernández, J.A., 2024. An in-depth analysis of sustainable practices in vegetable seedlings nurseries: a review. *Sci. Hortic* 334, 113342. <https://doi.org/10.1016/j.scienta.2024.113342>.
- Greene, W. H., 2011. *Econometric analysis*, 7th edition. ed. Pearson, London, United Kingdom.
- Groth, C., Wegmann, C., Meyerding, S.G.H., 2023. Perception of product sustainability: the case of processed tomatoes – a qualitative study in Germany. *J. Retail. Consum. v* 71, 103214. <https://doi.org/10.1016/j.jretconser.2022.103214>.
- Hartlieb, S., Jones, B., 2009. Humanising business through ethical labelling: progress and paradoxes in the UK. *J. Bus. Ethics* 88 (3), 583–600. <https://doi.org/10.1007/s10551-009-0125-x>.
- He, Z., Turner, P., 2022. Blockchain applications in forestry: a systematic literature review. *Appl. Sci* 12, 3723. <https://doi.org/10.3390/app12083723>.
- Holopainen, J., Toppinen, A., Lähinen, K., Rekola, M., 2017. Forest certification and country of origin: choice experiment analysis of outdoor decking material selection in E-commerce market in Finland. *Forests* 8, 431. <https://doi.org/10.3390/f8110431>.
- Hosmer Jr, D. W., Lemeshow, S., Sturdivant, R. X., 2013. *Applied Logistic Regression*, 3rd edition. ed. John Wiley & Sons, New Jersey, United States.
- Iansiti, M., Lakhani, K.R., 2017. *The truth about blockchain*. Harv. Bus. Rev.

- ISO, 2015. ISO 9000:2015 quality management systems — fundamentals and vocabulary, 4th edition. ed. International Organization for Standardization, Geneva, Switzerland.
- Ishak, S., Zabil, N.F.M., 2012. Impact of consumer awareness and knowledge to consumer effective behavior. *Asian. Soc. Sci* 8 (13), 108. <https://doi.org/10.5539/ass.v8n13p108>.
- Kafi, A., Zainuddin, N., Saifudin, A.M., Shahron, S.A., Razalli, M.R., Musa, S., Ahmi, A., 2023. Meta-analysis of food supply chain: pre, during and post COVID-19 pandemic. *Agric. Food. Secur* 12, 27. <https://doi.org/10.1186/s40066-023-00425-5>.
- Khan, S., Haleem, A., Khan, M.I., Abidi, M.H., Al-Ahmari, A., 2018. Implementing traceability systems in specific supply chain management (SCM) through critical success factors (CSFs). *Sustainability* 10 (1), 204. <https://doi.org/10.3390/su10010204>.
- Kim, H.M., Laskowski, M., 2018. Toward an ontology-driven blockchain design for supply-chain provenance. *Intelligent systems in accounting. Fin. Manag* 25 (1), 18–27. <https://doi.org/10.1002/isaf.1424>.
- Lazzarini, G.A., Visschers, V.H.M., Siegrist, M., 2017. Our own country is best: factors influencing consumers' sustainability perceptions of plant-based foods. *Food. Qual. Prefer* 60, 165–177. <https://doi.org/10.1016/j.foodqual.2017.04.008>.
- Li, J., Dounas, T., 2024. Directions for research on incentivising and governing the increase of biodiversity in cities with blockchain technologies, in: *Computing in Construction*. Presented at the EC3 Conference 2024, European Council on Computing in Construction, p. 8. <https://doi.org/10.35490/EC3.2024.239>.
- Liu, L., Zhang, J.Z., He, W., Li, W., 2021. Mitigating information asymmetry in inventory pledge financing through the Internet of things and blockchain. *J. Enterp. Inf. Manag* 34, 1429–1451. <https://doi.org/10.1108/JEIM-12-2020-0510>.
- Long, J.S., Freese, J., 2014. Regression models for categorical dependent variables using stata, 3rd edition. ed. Stata Press, College Station, USA.
- Malek, E. J., Abdul Rahim, A.R., 2022. A thematic review of forest certification publications from 2017 to 2021: analysis of pattern and trends for future studies. *Trees. For. People* 10, 100331. <https://doi.org/10.1016/j.tfp.2022.100331>.
- MapMyTree, 2022. [WWW Document]. MapMyTree. URL <https://mapmytree.eea.europa.eu/> (accessed 9.9.25).
- Mariotti, B., Mezzalana, G., Allasia, E., Fazio, F., Fiorentin, R., Maltoni, A., Marchetti, M., Matteucci, G., Mori, P., Motta, R., Piotti, A., Rositi, A., Sabatti, M., Tognetti, R., Salbitano, F., 2022. The Italian forest nursery sector at the crossroads: challenges and strategies (Original version: La vivaistica forestale in Italia al bivio: sfide e strategie). *For. @. - J. Silv. For. Ecol* 19, 85. <https://doi.org/10.3832/efor4193-019>.
- Martini, S., Maltoni, A., Monteverdi, M., De Dato, G., Salbitano, F., Marchetti, M., Mariotti, B., 2022. A survey on public forest seedling production in Italy (Original version: Indagine sulla produzione vivaistica forestale pubblica in Italia). *For. @. - J. Silv. For. Ecol* 19 (18). <https://doi.org/10.3832/efor4083-019>.
- MASE, 2025. Environment, MASE launches the “RiforestAzione” project to protect and enhance urban and extra-urban greenery in 13 metropolitan cities in Italy (Original version: Ambiente, il MASE lancia il progetto “RiforestAzione” a tutela e per la valorizzazione del verde urbano ed extraurbano in 13 città metropolitane d'Italia | Ministero dell'Ambiente e della Sicurezza Energetica) [WWW Document]. Ministry of the Environment and Energy Security. URL <https://www.mase.gov.it/notizie/ambiente-il-mase-lancia-il-progetto-riforestazione-tutela-e-la-valorizzazione-del-verde> (accessed 4.15.25).
- Mataruga, M., Cvjetković, B., De Cuyper, B., Aneva, I., Zhelev, P., Cudlín, P., Metslaid, M., Kankaanhuhta, V., Collet, C., Annighöfer, P., Mathes, T., Marianthi, T., Despoina, P., Jónsdóttir, R.J., Cristina Monteverdi, M., de Dato, G., Mariotti, B., Dina Kolevska, D., Lazarević, J., Sundheim Fløistad, I., Klisz, M., Gil, W., Paiva, V., Fonseca, T., Nicolescu, V.N., Popović, V., Devetaković, J., Repáč, I., Božić, G., Kraigher, H., Andivia, E., Diez, J.J., Böhlenius, H., Löf, M., Bilir, N., Villar-Salvador, P., 2023. Monitoring and control of forest seedling quality in Europe. *For. Ecol. Manag* 546, 121308. <https://doi.org/10.1016/j.foreco.2023.121308>.
- McFadden, D., 1972. Conditional logit analysis of qualitative choice behavior. *Front. Econ.* 105–142.
- Mechik, E., Hauff, M., Von, 2021. The fight against deforestation of tropical forests — the contribution of the blockchain-based contract management method to minimize illegal logging. *World. Sci. Book. Chapt* 439–463.
- Merlino, V.M., Brun, F., Versino, A., Blanc, S., 2020. Milk packaging innovation: consumer perception and willingness to pay. *AIMS. Agric. Food* 5, 307–326. <https://doi.org/10.3934/agrfood.2020.2.307>.
- Mougayar, W., 2016. The business blockchain: promise, practice, and application of the next internet technology, 1st edition. ed. John Wiley & Sons, New Jersey, United States.
- Munoz, M. F., Zhang, K., Shahzad, A., Ouhimmou, M., 2021. LogLog: a blockchain solution for tracking and certifying wood volumes, in: 2021 IEEE International Conference on Blockchain and Cryptocurrency (ICBC). Presented at the 2021 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), pp. 1–9. <https://doi.org/10.1109/ICBC51069.2021.9461153>.
- Nakamoto, S., 2008. Bitcoin: a peer-to-peer electronic cash System.
- Nandhini, J. M., Anuratha, K., Sangeetha, K., Jaswant, K. A., 2021. Smart tree management with biodiversity preservation using image processing and blockchain technology, in: 2021 International Conference on System, Computation, Automation and Networking (ICSCAN). Presented at the 2021 International Conference on System, Computation, Automation and Networking (ICSCAN), pp. 1–6. <https://doi.org/10.1109/ICSCAN53069.2021.9526540>.
- Nazari, S., Leite, W.L., Huggins-Manley, A.C., 2024. Enhancing the detection of social desirability bias using machine learning: a novel application of person-fit indices. *Educ. Psychol. Meas.* <https://doi.org/10.1177/00131644241255109>, 00131644241255109.
- Park, A., Li, H., 2021. The effect of blockchain technology on supply chain sustainability performances. *Sustainability* 13, 1726. <https://doi.org/10.3390/su13041726>.
- Pearson, S., May, D., Leontidis, G., Swainson, M., Brewer, S., Bidaute, L., Frey, J.G., Parr, G., Maull, R., Zisman, A., 2019. Are distributed ledger technologies the panacea for food traceability? *Glob. Food. Secur* 20, 145–149. <https://doi.org/10.1016/j.gfs.2019.02.002>.
- Pippinato, L., Bruzzese, S., Zanchini, R., Poratelli, F., Blanc, S., Brun, F., 2022. Econometric analysis of choice drivers and willingness to pay for certified forest biomasses for energy. *Ital. Rev. Agric. Econ. (REA)* 77, 41–53. <https://doi.org/10.36253/rea-13655>.
- Poratelli, F., Blanc, S., Pippinato, L., Zanchini, R., Bruzzese, S., Brun, F., 2022. Willingness to pay for certified wooden products: a critical literature review. *For. Stud* 76, 46–63. <https://doi.org/10.2478/fsmu-2022-0003>.
- Rogers, E.M., 1962. Diffusion of innovations. Free Press, Illinois, United States.
- Russo, L., 2019. Voluntary certification of sustainable forest management and traceability of forest products. In *Commentary on the Consolidated Law on Forests and Forest Supply Chains (Legislative Decree 3 April 2018, No. 34)* (Original version: La certificazione volontaria della gestione forestale sostenibile e la tracciabilità dei prodotti forestali. In *Commentario al Testo Unico in materia di foreste e filiere forestali* (d. lgs. 3 aprile 2018, n. 34)), pp. 249–266. Wolters Kluwer. <https://hdl.handle.net/11392/2415708>.
- Schmidt, C.G., Wagner, S.M., 2019. Blockchain and supply chain relations: a transaction cost theory perspective. *J. Purch. Supply. Manag* 25, 100552. <https://doi.org/10.1016/j.pursup.2019.100552>.
- Shahzad, K., Helo, P., Ranta, M., Nousiainen, E., 2024. Blockchain technology for operational excellence and supply chain resilience: a framework based on use cases and an architecture demonstration. *Technol. Anal. Strateg. Manag* 1–18. <https://doi.org/10.1080/09537325.2024.2304698>.
- Sheng, S.W., Wicha, S., 2024. Blockchain-based traceability for teak identity: a transformational approach. *J. Mob. Multimed* 267–306. <https://doi.org/10.13052/jmm1550-4646.2022>.
- Sheng, S. W., Wicha, S., 2021. The proposed of a smart traceability system for teak supply chain based on blockchain technology, in: 2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering. Presented at the 2021 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering, pp. 59–64. <https://doi.org/10.1109/ECTIDAMTNC51128.2021.9425780>.
- Sylvester, G., 2018. E-agriculture in action: drones for agriculture. *FAO* 112. <https://openknowledge.fao.org/handle/20.500.14283/i8494en>.
- So, H.W., Lafortezza, R., 2022. Reviewing the impacts of eco-labelling of forest products on different dimensions of sustainability in Europe. *For. Policy. Econ* 145, 102851. <https://doi.org/10.1016/j.forpol.2022.102851>.
- Stopfer, L., Kaulen, A., Purfürst, T., 2024. Potential of blockchain technology in wood supply chains. *Comput. Electron. Agric* 216, 108496. <https://doi.org/10.1016/j.compag.2023.108496>.
- Sortino, A., De Leo, G., Andò, A., Caruso, T., Zinnai, A., & Beltrame, F., 2023. The importance of standardization in nursery management and production: a blockchain approach. In *1 International Symposium on Plant Propagation, Nursery Organization and Management for the Production of Certified Fruit Trees* 1413, 219–224. <https://doi.org/10.17660/ActaHortic.2024.1413.26>.
- Sun, Y., Du, G., Cao, Y., Lin, Q., Zhong, L., Qiu, J., 2021. Wood product tracking using an improved AKAZE method in wood traceability system. *IEEE. Access* 9, 88552–88563. <https://doi.org/10.1109/ACCESS.2021.3088236>.
- Tapscott, D., Tapscott, A., 2018. How blockchain will change organizations. MIT Sloan Management Review.
- Tian, F., 2016. An agri-food supply chain traceability system for China based on RFID & blockchain technology. In 2016 13th international conference on service systems and service management (ICSSSM), 1–6. IEEE. <https://doi.org/10.1109/ICSSSM.2016.7538424>.
- van Bussel, L.M., Kuijsten, A., Mars, M., van 't Veer, P., 2022. Consumers' perceptions on food-related sustainability: a systematic review. *J. Clean. Prod* 341, 130904. <https://doi.org/10.1016/j.jclepro.2022.130904>.
- Vilkov, A., Tian, G., 2023. Blockchain's scope and purpose in Carbon markets: a systematic literature review. *Sustainability* 15, 8495. <https://doi.org/10.3390/su15118495>.
- Violino, S., Pallottino, F., Sperandio, G., Figorilli, S., Ortenzi, L., Tocci, F., Vasta, S., Imperi, G., Costa, C., 2020. A full technological traceability system for extra virgin olive oil. *Foods* 9, 624. <https://doi.org/10.3390/foods9050624>.
- Wu, L., Wang, S., Zhu, D., Hu, W., Wang, H., 2015. Chinese consumers' preferences and willingness to pay for traceable food quality and safety attributes: The case of pork. *China. Econ. Rev* 35, 121–136. <https://doi.org/10.1016/j.chieco.2015.07.001>.
- Zhang, X., Dong, F., 2020. Why do consumers make green purchase decisions? Insights from a systematic review. *Int. J. Env. Res. Public. Health* 17, 6607. <https://doi.org/10.3390/ijerph17186607>.