EUTR implementation in the Italian wood-energy sector: role and impact of (ongoing) digitalisation

Stefano Ciliberti[1,2+*], Fabio Bartolini[3], Antonio Brunori[4], Eleonora Mariano[4], Matteo Metta[1], Gianluca Brunori[1], Angelo Frascarelli[2]

[1] Pisa Agricultural Economics Group (PAGE), University of Pisa, Department of Agriculture, Food and Agri-Environmental Sciences, Via del Borghetto 80, 56124, Pisa, Italy

[2] Department of Agricultural, Food and Environmental Sciences, University of Perugia, Via Borgo xx giugno, 74, 06121 Perugia, Italy

[3] Department of Chemical, Pharmaceutical and Agricultural Sciences, University of Ferrara, Borsari 46, 44121 Ferrara, Italy

[4] Programme for the Endorsement of Forest Certification (PEFC) schemes, Italian Secretariat, Via Pietro Cestellini, 17, 06135 Perugia, Italy

*c.a. email: stefano.ciliberti@unipg.it

[+] Present address

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

We are very grateful to all Living Lab members and interviewees for sharing their knowledge and experience.

1. Introduction

Widespread illegal logging and wood trading have resulted in rapid and catastrophic deterioration of the environment (Trishkin et al., 2015). In particular, illegal logging has been regarded as a chronic problem throughout the world, and this fact has spurred major international efforts to control its associated trade (Maryudi et al., 2020). Moreover, illegal logging is seen as one of the key drivers of deforestation and forest degradation, and it accounts for up to 10-30% of global logging (FAO/UNEP, 2020; Leipold, 2017). Illegal activities usually include a wide array of practices: incorrect estimations of wood volume and quality, overestimating the age of trees (permitting an earlier harvest), altering the stand density to apply clearcutting, initiating paid afforestation which never materialises, or performing salvage cuttings applied to healthy and vigorous trees as well as illegal harvesting and illegal transport and export of logs (Gavrilut et al., 2016). Illegally sourced timber is estimated to cost, on average, 16% less than legal wood~~, so that it creates unfair competition for legally operating businesses, as~~ since illegal operators sidestep duties and taxes, contribut~~e~~ing to unfair competition and significant ~~losses of~~ government ~~revenues and they have no obligation to invest in proper management of forests~~losses as well (Maryudi et al., 2020). Thus, illegal logging not only impacts some of the world's most vulnerable and threatened forests but also affects state revenue, global market prices for timber and wood products, and local livelihood (Moser and Leipold, 2021).

The EU is one of the world's largest timber importers, even if there is a considerable cross-country variation across Member States. It account~~s~~ed for more than 35% of total world imports of timber and timber products in 2017, and between 2012 and 2017 the imports from non-EU countries registered a cumulative annual growth rate of 5~~%.~~% (Moral-Pajares et al., 2020; United Nations International Trade Statistics Database, 2017). Although almost three-quarters of these trade flows are within the EU, part of this trade between EU members is in timber or timber products initially purchased from outside the EU (Moral-Pajares et al., 2020). As far as wood-energy is concerned, it is currently the most important renewable energy source for heating, but a large part of this wood is sourced from uncertified forests (Sikkema et al., 2017).

Public and private concerns about the impacts of illegal logging were addressed at the EU level by adopting the European Timber Regulation n.995/2010 (EUTR) in 2010 (Sotirov et al., 2017). It has been part of a suite of initiatives to promote sustainable forestry by removing illegal timber from global supply chains (McDermott and Sotirov, 2018). The EUTR approach, in particular, has been expected to yield substantial environmental and social stewardship in the forest sector (Moser and Leipold, 2021). However, matching both environmental and socio-economic objectives, the EUTR has lacked one coherent policy goal, with implementation problems as a consequence (Leipold et al., 2016). Each Member State is responsible for determining how to control the legality of its imports and how sanctions are applied if necessary (Ituarte-Lima et al., 2019; Moser and Leipold, 2021). In some ~~European countries~~EU member states, the formal implementation of the EUTR has proven to be a slower process than in others. The EU Commission concluded that implementation and compliance by operators have been uneven across the Member States. Numerous challenges still exist depending on enterprise size, the complexity of traded products and sourcing countries (Acheampong and Maryudi, 2020). Therefore, it is not surprising that the EU Member States have performed relatively low rates of compliance checks among importing operators (Köthke, 2020).

According to Eurostat (2021), over the period 2011-2020, Italy~~, despite~~ imported on average 1.02 million cubic meters of fuelwood (including wood for charcoal) and 1.32 million cubic meters of wood chips. Despite being one of the largest worldwide importers of firewood and the fourth largest importer of ~~wood residues, particles and chips, and the first European importer of pellets for residential use (Crivellaro and Ruffinatto, 2020; Secco et al., 2017),~~these products, Italy has not been particularly proactive ~~on~~in the domestic implementation of the EUTR to establish both penalties and a system of checks to encourage legal behaviour among economic operators ~~effectively (~~(Crivellaro and Ruffinatto, 2020; McDermott and Sotirov, 2018; Secco et al., 2017).

As the entire procedure of EUTR enforcement is mainly based on traceability verification following a "paper-based" approach aimed to assess risks and introduce mitigating measures (UNEP-WCMC, 2020), operators are encouraged to produce adequate documentation as proof of legally sourced timber (Cashore and Stone, 2012). However, traceability represents an interesting application scenario for digital technologies (Rolandi et al., 2021), since emerging digital solutions could make the massive exchange of data and information more effective and efficient, lowering policy-related transaction and costs associated with EUTR implementation.

~~This policy paper aims to stimulate the debate on the impact of digitalisation in implementing EUTR in the wood-energy sector, a traditionally low tech sector with a limited importance in terms of value-added creation, where administrative burden may hinder the achievement of traceability goals. To this purpose, the paper presents the main findings of participatory activities conducted in a Living Lab composed by 25 stakeholders with different expertise from September 2020 to April 2021, aimed to assess the impact of digitalisation on EUTR implementation and traceability in the Italian wood-energy sector. A Living Lab is defined as a 'research methodology aimed at co-creating innovation through the involvement of aware users in a real-life setting' (Dietrich et al., 2021). It has received extensive political support as part of regional development policies and, most recently, as a potential tool for analysing and supporting the local transition towards more sustainable agri-food systems (Gamache et al., 2020). In a Living Lab, user-needs are central, and collaborative learning is undertaken by users, stakeholders and researchers in a real-life environment. In fostering the interaction between science and society, Living Labs are also of scientific value since they provide a unique setting for collective innovation in the context of societal challenges involving heterogeneous stakeholders (such as but not limited to citizens, customers, policy-makers, researchers, educators, businesses and universities) to significantly contribute to the development of sustainable public policy (Kalinauskaite et al., 2021).~~

Against this backdrop, this paper aims to assess the impacts of the uptake of digital technologies on the EUTR enforcement and implementation in the wood-energy sector, so as to stimulate a debate between stakeholders and policymakers about possible future interventions in this field. Even if this is a traditionally low tech sector with a limited importance in terms of value-added creation, our research hypothesis is that digitalisation is able to generate both positive and negative impacts on the implementation of the EUTR, respectively fostering or hindering the achievement of traceability goals in the wood-energy sector.

The paper is organised as follows. ~~Next~~The next section reviews the implementation of the EUTR at a national level, highlighting issues and opportunities at stake. Then, material and methods are described before the impacts~~ of the application~~ of digital technologies on traceability and EUTR implementation are analysed~~.~~ and discussed. Lastly, final policy recommendations are provided.

2. EUTR enforcement at the national level: issues and opportunities

According to a growing body of literature, EUTR incurs in some degree of bureaucracy and places disproportionate burdens on specific actors along with production networks (Maryudi et al., 2020). Traceability obligations and due diligence requirements for European operators (entailing access to information on imported timber, risk assessment procedures, risk mitigation measures and procedures) are not only tedious but also costly since they imply an extra workload introducing accurate documentation (Brusselaers and Buysse, 2021; Giurca and Jonsson, 2015). It follows that implementing timber traceability, due diligence systems, and corresponding sanctions certainly requires appropriate capacity and resources in terms of finances, personnel, expertise and technical equipment, both for target groups (operators, traders) and for Competent Authorities (Gavrilut et al., 2016).

~~Operators and stakeholders~~Stakeholders (including also operators) have expressed concern and complained about the complicated documentation requirements and the burdensome nature of the EUTR due diligence process that has increased the cost of trading timber (Giurca et al., 2013; Masiero et al., 2015). The number of required documents included certificate of business registration, tax identification number, tax clearance certificate, social security and national insurance trust clearance certificate, timber utilisation contract, proof of payment of forest levies, tree information form, log information form, export contract, export permit, log measurement and conveyance certificate, phytosanitary certificate, among others (Acheampong and Maryudi, 2020; Sikkema et al., 2017). Some authors argued that such a "paper-based" approach is not expensive but manually intensive, leading to errors and delays (Appelhanz et al., 2016). Due to technical, organisational, and financial barriers, some smallholders and industries struggle to engage in legality verification. In contrast, large industries and exporters accumulate more benefits due to their scale and pre-existing capacity (Maryudi et al., 2020).

Since the volume of information and documentation rises as much as the distance between production and consumption increases, attention is increasingly focused on digital technologies to enhance transparency in the global supply chains (Ebinger and Omondi, 2020; Ehlers et al., 2021). Since each Member State is responsible for determining how to control timber legality (McDermott and Sotirov, 2018), in countries dominated by a strongly differentiated administrative landscape, Governments and public administrations might take advantage of digital and innovative solutions to improve policies enforcement (Carstens, 2021). As a whole, the application of digital solutions for traceability of forest resources, from origin to end-use, may offer enormous potential to support the sector and further contribute to global sustainability, enhancing European value chains, and fighting corrupt practices associated with illegal imports (Brunori et al., 2021). Digital solutions, in fact, include computer-based information systems for recognition, traceability, log tracking and monitoring, including barcodes, Quick Response (QR) codes, microchips, fingerprints, isotopes, Radio Frequency Identification (RFID) transponders and blockchain (Corona et al., 2017; Tzoulis et al., 2014). For instance, a QR code can be marked in a tree log by lasers and then it can be read using a smart phone application, whereas very durable RFID tags can be planted inside a wood log and transmit data to receivers contributing to traceability (Sperandio et al., 2017).

However, these innovative and digital log-tracking solutions are not particularly practical and tend to be high cost, also because sometimes they require high-level specialists and then are difficult to apply on a large scale, if not for large companies able to process high volumes of biomass for energy purposes (Schraml et al., 2020; Watkinson et al., 2020).

~~The~~A relevant research question for policymakers and stakeholders is then the following: how to activate a pathway for digitalisation of the forestry sector that can address the problems of illegal logging in different contexts? Our case study, based on the results of the work of a Living Lab (LL) in Italy constituted within the H2020 project DESIRA, ~~addresses~~is aimed to offer an answer to this ~~question~~demand.

3. Traceability and EUTR implementation in the Italian wood-energy sector: ~~context and~~ assessing the impacts of digitalisation

3.1 Materials and methods

The paper develops an inclusive approach to formulating agenda-setting digitalisation on EUTR implementation and traceability in the Italian wood-energy sector. The participatory approach was based on Living Lab activities, which took place from September 2020 to April 2021. A Living Lab is defined as a 'research methodology aimed at co-creating innovation through the involvement of aware users in a real-life setting' (Dietrich et al., 2021). It has received extensive recognition in academic and political areas as a potential tool for analysing and supporting the local transition towards more sustainable agri-food and forestry systems (Arnould et al., 2022; Gamache et al., 2020). In a Living Lab, user-needs are central, and collaborative learning is undertaken by users, stakeholders and researchers in a real-life environment. In fostering the interaction between science and society, Living Labs are also of scientific value since they provide a unique setting for collective innovation in the context of societal challenges involving heterogeneous stakeholders (such as but not limited to citizens, customers, policy-makers, researchers, educators, businesses and universities) to significantly contribute to the development of sustainable public policy (Kalinauskaite et al., 2021).

In more detail, the Living Lab mobilised knowledge from 25 stakeholders, which were preliminarily identified from a mapping activity and then formally invited. This exercise allowed to cover main categories of stakeholders, as follows: forest owners, operators and their associations (4 participants), public administrations (2), non-government organizations (4), private industrial companies (4), universities (2) and research centres (2), practitioners and consultants (5), certification and control body (1), and journalists (1). After a preliminary desk analysis aimed to review both scientific and grey literature on the topic under investigation, two online workshops were organised in October and December 2020 (participation rates were, respectively, 92% and 80%) aimed to assess needs, expectations and impacts related to the uptake of digital technologies in the wood-energy sector. The first workshop was organised in two sessions. After an introductory speech, stakeholders were first asked to analyze the context under analysis, elaborating a SWOT analysis and identifying the main needs related to the uptake of digital technologies to achieve traceability goals. Afterwards, they participated in identifying main (social, physical and digital) entities, activities and relationships at stake in the wood-energy sector. The second workshop was also split into three sessions. First, a follow-up session allowed stakeholders to validate the results of the first workshops. Then, after a short introduction, participants were asked to identify main digital technologies at stake in the wood-energy sector for traceability purposes. Lastly, based on a template containing a list of items and structured questions elaborated and provided by the DESIRA project research team (see Annex), participatory activities revolved around identifying and evaluating impacts of the digitalisation process on traceability and EUTR implementation in the wood-energy sector. Likewise, determinants of these impacts were identified and assessed.

As a rule of thumb, after an introductory presentation of the topic, participation in each session was stimulated by a group of moderators. Therefore, stakeholders were continuously asked to intervene in chat and take part in an open debate. Moreover, online participatory tools such as interactive boards and online surveys were largely used, both in plenary and working group sessions. The latter were organised and managed using specific digital breakout rooms with at least one moderator for the group, in order to allow a higher level of analysis of specific topics.

3.~~1~~2 Context analysis

According to the National Forest and Carbon Sink Inventory (CREA and Carabinieri Forestali, 2015), there are 10.9 million hectares of forest in Italy, which is 37% of the national land area. Italian forest area has constantly increased in the last decades (+4.9% in the decade 2005-2015), mainly because of the abandonment of agricultural activities in the mountain and hilly areas~~.~~ (Agnoletti et al., 2022; Pallotta et al., 2022). However, due to several reasons (mainly depopulation and ageing in mountain and remote areas, ISTAT 2020a), the Italian forestry sector has been largely affected by a continuous decrease in forestry activities. Consequently, only ~~a small percentage~~18% of Italian forests is actively managed by means of forestry plans, and only 852,000 forest hectares ~~(ISTAT, 2020b)~~ are certified according to existing certification schemes~~.~~ (Corona and Gismondi, 2019; ISTAT, 2020b).

Thus, even if wood biomass for energy purposes (i.e. firewood, pellet and woodchips) represents the first renewable energy source for heating in Italy (Pra and Pettenella, 2016), it mainly comes from abroad. According to the United Nations International Trade Statistics Database (2017), Italy in 2015 was the first world importer of firewood, the fourth importer of pellet and among the first ten importers of woodchips. ~~Some structural characteristics of the Italian wood-energy market (such as the prevalence of an informal economy based on unrecorded and unregulated transactions, a~~A wide presence of micro and small enterprises ~~operating in local value chains, and the relevant role of self-consumption), all~~ contributes to the lack of traceability of imported wood biomass for energy purposes and to the prevalence of informal economic activities in forestry areas (Pra and Pettenella, 2016). In the case of firewood, it is estimated that 14 out of 20 million tons consumed annually are not registered (and therefore tracked) at all (Legambiente, 2016). Notwithstanding, the low priority given to the EUTR in the national political agenda, the complexity of the legislative system, a highly fragmented and decentralised institutional framework, and the economic crisis have been cited as the main reasons for the delay in the formal domestic implementation of the EUTR in Italy since its entered into force (Secco et al., 2017). Although the national Competent Authority (i.e. the Ministry of ~~Agriculture~~Agricultural, Food and Forest~~s~~ry Policies) has increased the number of checks aimed to fine non-compliant operators (from 21 in 2015 to 577 in the second semester of 2018), there is still a large room for manoeuvre to make this procedure more effective.

Moreover, it must be considered that more than 80% of forest areas (representing the 'backbone' of the Italian wood-energy sector) is located in the so-called 'inner areas', which correspond to the 'areas with development issues' according to the EAFRD classification (Storti, 2016). In these areas, where wood and biomass for energy purposes is largely produced, factors like ageing, low digital literacy, scarce attitudes to embrace newness and changes, lack of digital infrastructure and connectivity greatly affect the low uptake of digital technologies (Rete Rurale Nazionale, 2017).

3.~~2~~3 Impacts of digitalisation and its determinants

Implementing digitally~~–~~-enabled traceability systems requires a relevant set of socio-technical conditions that may enable or limit their uptake. Therefore, a deep understanding of the socio-economic, environmental and technological context is needed to investigate the impacts of these digital solutions in a given application scenario, such as the wood-energy sector. Henceforth, we report the main evidences that emerged from participatory activities conducted during our Living Lab.

In the workshops organised within the Living Lab, stakeholders recognised that two technologies could be considered key enablers of digitalisation: digital payments (e.g. e-invoicing, point of sales) and digital platforms. As for digital payments, Appelhanz et al. (2016) observed that electronic traceability of transactions enables automatic data import, simple data accumulation, and information provision to internal and external data processing. About digital forest innovation platforms (as called by Pynnönen et al., 2021), they provide operational tools for forest data sharing, decision-support, e-government operations, and connecting forest owners and service providers. Ebinger and Omondi (2020, p.8) recognised that '*the commonality among emerging digital approaches in supply chains management is a trend towards 'datafication' that is increasingly leading to the translation of the physical world into data, which could then be used to support decision-making in a dynamic, problem-oriented, and tailor-made way by combining data from various supply chain actors*'. For example, such a 'datification' could help companies and Competent Authorities to reliably record, check and measure traceability performances to strengthen the implementation of the EUTR. Examples are the Intrastat portal of the Customs and Monopolies Agency, where data and information related to import and/or sale of biomass for energy purposes are stored in digital format within digital portals, as well as the implementation of an upcoming public data warehouse implemented by the Ministry of Agricultur~~e~~al, Food and Forestry Policies to manage the enforcement of the EUTR regulation. Another interesting example is the Monitoring Organisation "Conlegno" portal, named "LegnOKweb", a tool that allows to perform the Due Diligence System in three steps (Access to Information, Risk Analysis, any Risk Mitigation).

~~Such~~According to the Living Lab, such a switch from hard copy to digital solutions aimed to foster information exchange between competent authorities and forestry companies and speed up the enforcement of verification and inspection activities related to the EUTR is ongoing. The Living Lab recognised that the uptake of digital payments and invoices, on the one hand, and digital platforms and portals, on the other hand, ~~-~~impacts on traceability and EUTR enforcement, since they both affect activities and relationships in the wood-energy sector~~ (table 1).~~. As a result of this participatory activity, table 1 was elaborated to capture and describe the main positive and negative impacts of each technology under analysis.

Table 1: Main impacts of digitalisation on EUTR implementation in the wood-energy sector in Italy

Digital technology	Positive impact	Negative impact

Payments for wood for energy have been increasingly digitalised. The main technologies involved in digital payments are a point of sale (POS) and e-invoicing. However, even if growing, the process is still minimal.	• Reinforced traceability of payments • Deployed safer and simpler solutions for payments • Enhanced transparency in business relationships • Increased responsibility of the woman in managing administrative and management tasks within family companies • Lessened opportunities for tax avoidance/evasion • Increased availability of reliable data on wood-energy production • Limited socio-economic dumping (unfair price competition)	• Increased costs for SMEs (e-invoicing services, devices) • Arisen difficulty for SMEs to address the increasing need for digital skills (for instance: to hire/to train skilled employees for managing software and similar). • Marginalised forest companies in areas with low broadband coverage • Increased technical and practical difficulties in using tools and software for digital payments.
Authorisation of cut wood and administrative controls related to the EUTR enforcement rely on information and data that are being (slowly) digitised. Such an ongoing process relies on online portals and digital platforms.	• Accelerated communications between EUTR managing authorities, public administrations and forest companies involved in the production of biomass for energy use • Speeded up documentary checks related to compliance with EUTR • Increased availability of data for policy planning, public research, final users • Enhanced transparency in administrative decisions	• Increased administrative and managerial costs for the digital transition of public administrations • Proliferation of web services with different characteristics (not interoperable and not fully reliable) • Induced reluctance to accept, use and manage new digital tools and portals in managing authorities • Arisen risks for data protection (and reluctance to share information)

Source: our elaboration from Living Lab activities

What emerges is that digital solutions, building a structured data infrastructure and converting the most important transactions into digital format, may contribute to speeding up documentary checks and communication ~~between~~ among public administrations, EUTR Competent Authorities and forest companies producing wood biomass for energy use. This fact, in turn, improves the availability and reliability of data on wood biomasses production and sales, accelerate~~s~~ both authorisation and control activities related to the EUTR enforcement. Therefore, in line with Rolandi et al. (2021) and Ebinger and Omondi (2020), digital technologies mediating processes, tasks and a massive exchange of data and information lead to more efficient traceability and tracking activities in global supply chains.

The other side of the coin related to this digitalisation process is that it may entailentails additional costs for companies and public authorities (due to the need for digital upskilling and reskilling and new managerial and organisational patterns. In line with Appelhanz et al. (2016), this phenomenon brings to further marginalisation of (especially small or medium-sized) forest companies in absence of broadband coverage, connectivity and proper digital skills (as revealed by Appelhanz et al., 2016)..

All these impacts of digital tools on traceability and EUTR implementation strongly depends on three contribution mechanisms, such as technology design, access to digitalisation and system complexity. Table 2 synthetically reports and describes how The Living Lab was asked to analyze and evaluate these latter are able tomechanisms, so as to describe whether and how they can generate impacts on EUTR implementantion in the wood-energy sector. Table 2 highlights the results of this participatory activity.

Table 2: Impact pathways of digitalisation in the Italian wood-energy sector.

Contribution mechanisms	Description
Digital technology design	• Interoperability among platforms and information and communication technologies (ICT) services for e-invoicing, that affects time losses and administrative burden for forest companies and public administrations • Integration of digital devices with software packages for control and management of forest operations • Standardisation of information required and procedures affecting the use of platforms and ICT services • Adaptability of digital tools and easiness to carry out multiple tasks and transactions (e.g. e-payment, document scanning using photo camera, file sharing via an online messaging platform like WhatsApp, file storing via an online cloud, etc.) • Possibility to use different technological devices (tablet, smartphones, smartwatches) to speed up and facilitate the uptake of technologies for digital payments and administrative tasks • Availability of offline use of digital devices for payments and other administrative tasks in mountain areas
Access to digitalisation	• Lack of new skills and abilities towards the use of digital technologies among forest companies and consumers • Lack of digital skills among civil servants, also due to the reduction of employees' turnover in the Italian public administrations • Presence of entrance costs (subscription, membership, fees) for digital payments solutions and digital services
System complexity	• Level and quality of public investments in broadband coverage in mountain areas • COVID 19 lockdown triggered online, and digital payments and social distancing fostered the use of digital tools

	• Conflicts related to the use of digital technologies for traceability purposes • Issues related to property, privacy and personal data.

Source: our elaboration from Living Lab activities

What emerges is that the impact related to the uptake of digital ~~payments, databases and portals in~~ tools in the wood-energy sector largely depends on ~~whether and~~ how ~~these technologies~~they are designed in order to ensure~~:~~ high interoperability~~, use of~~ among different software, devices and ~~supports,~~platforms, as well as offline access in the absence of fast broadband coverage~~, and possible integration with software for forestry control and management~~. Likewise, accessibility greatly matters. On the one hand, entrance costs for digital services affect the affordability for forest companies. On the other hand, the need for specific digital skills influences the uptake ~~to~~of digital tools among forest entrepreneurs and civil servants responsible for implementing the EUTR at the national level. Furthermore, some other relevant system conditions are able to drive the impacts of digital solutions in the wood-energy sector. For instance, the level of (public and private) investments for enhancing broadband coverage and connectivity in the mountain and remote areas, enabling or disabling the diffusion of digital payments, as well as conflicting uses of digital tools, such as digital payments and digital platforms, for traceability purposes and potential issues in terms of property, privacy and personal data.

Unlike Schroeder et al. (2021), these results somehow contradict the fact that digitally-enabled traceability offers automatic advantages such as efficiency through low cost and ease of use. What emerges is that, in line with Ferrari et al. (2022), socio-economic barriers related to lack of competence (i.e. ICT skills) and training as well as lack of funding could hinder the adoption of digital tools and their impacts on wood-energy traceability. Scarce connectivity and lack of interoperability are also key elements that often negatively affect the digitalisation process and distorce its impact in rural and mountain economies (Rijswijk et al., 2021).

All things considered, if supported by holistic attitudes, applications and evaluations, the uptake of digital payments and platforms may help stakeholders of the wood-energy sector to familiarizing with pros and cons related to digital solutions and possibly overcoming issues related to bad design, low accessibility and high system complexity. In this regard, these basic digital applications can represent a first important step along the road towards a creation of a digital ecosystem, that – thanks to a wider access to open data and services of technical assistance, improved digital skills, etc. – is able to support and sustain further digitalisation steps in favour of EUTR implementation and traceability in the wood-energy sector. This fact, in turn, paves the road to future applications of more advanced digital solutions in this sector, still largely neglected and unexplored because of poor digital education, high costs of use and wide diffidence and anxiety related to data privacy and cybersecurity.

4 Conclusions and policy recommendations

The present paper delivered some interesting insights on the role of digital technologies for traceability in the wood-energy sector in Italy. Empirical evidence highlighted that impacts of digital tools on the implementation of the EUTR in Italy are multifaceted and still not able to fully overcome traditional issues at stake, so as to boost traceability in the wood-energy sector.

Our analysis contributed in revealing that, in the last years, the actual impact of the incoming digitalisation in this sector has been mainly related to the application of some basic digital tools in public administrations and business activities (such as online portals, databeses and e-payment tools), that are involved at different stages in the implementation of the EUTR. As of now, the uptake of more advanced digital applications is still lagging behind in the Italian wood-energy sector, being mainly limited to scattered projects and initiatives related to RFID and blockchain solutions.

Results contribute also to filling and preliminary framing the cognitive gap related to the analysis of possible effects related to the adoption of digital technologies to enforce traceability policies in the wood-energy sector. As a consequence, recommendations for policymakers follow.

First and foremost, the 'low-tech' nature of the wood-energy sector shall not prevent the identification of (even basic) digital tools, able to contribute to overcoming endemic sectoral, institutional and administrative weaknesses related to the slow implementation of a policy aimed to foster traceability, in a framework characterised by lack of transparency and presence of illegal activities.

Second, we recognised that any kind of analysis on the state of digitalisation in the wood-energy sector shall carefully take into account the geographical dimension and physyical location of forest activities in Italy, so as to properly consider longstanding socio-demographic, environmental and economic issues at stake in these inner and mountain areas. Depopulation, ageing, lack of physical and digital infrastructures are all elements that have certainly affected the deployment of digital technologies and their impacts on the implementation of traceability policies, such as the EUTR, is still far from an end.

Moreover, in presence of such a 'low-tech' sector the social element is certainly crucial, since digitalisation is largely expected to change, modify or substitute consolidated relationships in administrative and business activities (for instance, dematerialising, replacing or accelerating certain tasks). In more details, the upcoming deployment of digital solutions aimed to enhance the level of transparency and traceability in the wood-energy sector and facilitate the implementation of the EUTR is expecting not only to generate winners, but also losers and opponents.

As a consequence – and this is another recommendation – any possibility of a positive and inclusive impact of digitalisation in the wood-energy sector strongly depends on a massive diffusion of a digital culture among stakeholders, from forest owners and companies to final consumers passing through public administrations and Competent Authorities.

All that said and considered, we urge policymakers to foster a shift from a traditional technology-driven narrative around the interaction between digitalisation and traceability towards a more olistic approach, so as to carefully analyse and overcome potential issues related to technology design and accessibility, taking also into account the complexity of the application context. To this end, in the medium and short run, open and participatory approaches involving stakeholders may contribute to co-design viable and successful policy measures at national and regional level (such as, open access and interoperable digital platforms and portals). In this time span, rather than sporadic disruptive innovations, these measures shall incentivise a large-scale, incremental and more aware use of (basic) digital technologies for traceability in the wood-energy sector, able to relly match their long-lasting needs and expectations among producers, civil servants and consumers and overcome their scepticism.

A last reflection concerns the method of the Living Lab we used. The method allows researchers to better understand the system where technology is supposed to be incorporated, the needs of the stakeholders, the potential barriers and constraints to technology diffusion. In early stages of digitalisation, understanding these aspects is key to define clear policy objectives and set or revise policy priorities and tools. From the scientific point of view, Living Labs help researchers to develop conceptual models closer to real contexts, and to identify the key empirical variables to take into consideration when designing (or reforming) policies and assessing their implementations.

However, even if Living Lab technique allowed to provide a participatory assessment taking into account and comparing relevant stakeholders' point of views related to the impact of digital technologies on traceability and EUTR implementation in Italy, this methodology reveals at least two potential weaknesses. First, as some relevant stakeholders could be omitted (or could decide to not participate) their evaluations are missing with negative consequences on impact evaluations. Moreover, techniques for online participatory activities could be less effective than those held in presence in terms of stimulating debate, ideas sharing. In conclusion and looking forward, since the digitalisation process aimed to boost EUTR implementation and traceability in the wood-energy sector is at its early stages, policymakers are expected to periodically ask for (and rely on) updated, thorough and holistic evaluations of impacts also related to the most advanced digital tools, still scarcely diffused. To this aim, they shall consider that inclusive and thematic Living Labs could represent a form of governing digital transitions fostering co-creation of solutions in order to better enforce traceability policies and limit illegal logging, contributing to socio-economic and environmental sustainability goals.

Funding

This document was produced under the terms and conditions of Grant Agreement No. 818194 for the European Commission. It does not necessarily reflect the view of the European Union and in no way anticipates the Commission's future policy in this area.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

This work was supported by the European Union's Horizon 2020 program [grant numbers 818194 (DESIRA project)].

We are also very grateful to all Living Lab members and interviewees for sharing their knowledge and experience.

References

Acheampong, E., Maryudi, A., 2020. Avoiding legality: Timber producers' strategies and motivations under FLEGT in Ghana and Indonesia. For. Policy Econ. 111, 102047. https://doi.org/10.1016/j.forpol.2019.102047

Agnoletti, M., Piras, F., Venturi, M., Santoro, A., 2022. Cultural values and forest dynamics: The Italian forests in the last 150 years, Forest Ecology and Management 503, 119655. https://doi.org/10.1016/j.foreco.2021.119655.

Appelhanz, S., Osburg, V.S., Toporowski, W., Schumann, M., 2016. Traceability system for capturing, processing and providing consumer-relevant information about wood products: System solution and its economic feasibility. J. Clean. Prod. 110, 132–148. https://doi.org/10.1016/j.jclepro.2015.02.034

Arnould, M., Morel, L., Fournier, M., 2022. Embedding non-industrial private forest owners in forest policy and bioeconomy issues using a Living Lab concept, Forest Policy and Economics, 139, 102716, https://doi.org/10.1016/j.forpol.2022.102716.

Brunori, A., Brunori, G., Casares, B., Nieto, E., 2021. Key digital game changers shaping the future of forestry in 2040 views from DESIRA’s rural digitalisation forum experts. Available at: https://enrd.ec.europa.eu/sites/default/files/2_desira_ltvra_forestry.pdf Last accessed: July 28, 2021

Brusselaers, J., Buysse, J., 2021. Legality requirements for wood import in the EU: Who wins, who loses? For. Policy Econ. 123, 102338. https://doi.org/10.1016/j.forpol.2020.102338

Carstens, N., 2021. Digitalisation Labs: A New Arena for Policy Design in German Multilevel Governance. Ger. Polit. 0, 1–18. https://doi.org/10.1080/09644008.2021.1887851

Cashore, B., Stone, M.W., 2012. Can legality verification rescue global forest governance?. Analyzing the potential of public and private policy intersection to ameliorate forest challenges in Southeast Asia. For. Policy Econ. 18, 13–22. https://doi.org/10.1016/j.forpol.2011.12.005

Corona, P., Chianucci, F., Quatrini, V., Civitarese, V., Clementel, F., Costa, C., Floris, A., Menesatti, P., Puletti, N., Sperandio, G., Verani, S., Turco, R., Bernardini, V., Plutino, M., Scrinzi, G., 2017. Precision forestry: concepts, tools and perspectives in Italy. For. - Riv. di Selvic. ed Ecol. For. 14, 1–12. https://doi.org/10.3832/efor2285-014

Corona, P., Gismondi, R., 2019. Gestione e tutela delle foreste, in Direzione generale delle foreste del Mipaaft (Ed.), RAF Italia: Rapporto sullo stato delle foreste e del settore forestale in Italia. Compagnia delle Foreste, Arezzo, pp. 98-99. Available at: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/19231 Last accessed: March 22, 2022

CREA and Carabinieri Forestali, 20~~0~~15. Inventario nazionale delle foreste e dei serbatoi di carbonio. Available at: https://www.sian.it/inventarioforestale/ Last accessed: November 24, 2021.

Crivellaro, A., Ruffinatto, F., 2020. Wood identification to combat illegal timber trade: the situation in Italy. For. - Riv. di Selvic. ed Ecol. For. 17, 88–91. https://doi.org/10.3832/efor3678-017

Dietrich, T., Guldager, J.D., Lyk, P., Vallentin-holbech, L., Rundle-thiele, S., Majgaard, G., Stock, C., 2021. Co-creating Virtual Reality Interventions for Alcohol Prevention : Living Lab vs . Co-design 9, 1–6. https://doi.org/10.3389/fpubh.2021.634102

Ebinger, F., Omondi, B., 2020. Leveraging digital approaches for transparency in sustainable supply chains: A conceptual paper. Sustain. 12. https://doi.org/10.3390/su12156129

Ehlers, M.H., Huber, R., Finger, R., 2021. Agricultural policy in the era of digitalisation. Food Policy 102019. https://doi.org/10.1016/j.foodpol.2020.102019

Eurostat (2021). Database. Available at: https://ec.europa.eu/eurostat/data/database Last accessed:

March 23, 2022.

FAO/UNEP, 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Food and Agriculture Organization of the United Nations, Rome. Available at: http://www.fao.org/3/ca8642en/online/ca8642en.htmlLast accessed: November 15, 2021.

Ferrari, A., Bacco, M., Gaber, K., Jedlitschka, A., Hess, S., Kaipainen, J., Koltsida, P., Toli, E., Brunori, G., 2022. Drivers, barriers and impacts of digitalisation in rural areas from the viewpoint of experts, Information and Software Technology, 145, 2022, 106816. https://doi.org/10.1016/j.infsof.2021.106816.

Gamache, G., Anglade, J., Feche, R., Barataud, F., Mignolet, C., Coquil, X., 2020. Can living labs offer a pathway to support local agri-food sustainability transitions? Environ. Innov. Soc. Transitions 37, 93–107. https://doi.org/10.1016/j.eist.2020.08.002

Gavrilut, I., Halalisan, A.F., Giurca, A., Sotirov, M., 2016. The interaction between FSC certification and the implementation of the EU timber regulation in Romania. Forests 7, 1–13. https://doi.org/10.3390/f7010003

Giurca, A., Jonsson, R., 2015. The opinions of some stakeholders on the European union timber regulation (EUTR): An analysis of secondary sources. IForest 8, 681–686. https://doi.org/10.3832/ifor1271-008

Giurca, A., Jonsson, R., Rinaldi, F., Priyadi, H., 2013. Ambiguity in timber trade regarding efforts to combat illegal logging: Potential impacts on trade between south-east Asia and Europe. Forests 4, 730–750. https://doi.org/10.3390/f4040730

Istat, 2020a. Rapporto sul territorio 2020: ambiente, economia e società. Available at: https://www.istat.it/it/archivio/240989 Last accessed: October 29, 2021.

Istat, 2020b. Rapporto SDGs 2019. Informazioni statistiche per l'agenda 2030 in Italia. Available at: https://www.istat.it/it/archivio/229565 Last accessed: October 29, 2021.

Ituarte-Lima, C., Dupraz-Ardiot, A., McDermott, C.L., 2019. Incorporating international biodiversity law principles and rights perspective into the European Union Timber Regulation. Int. Environ. Agreements Polit. Law Econ. 19, 255–272. https://doi.org/10.1007/s10784-019-09439-6

Kalinauskaite, I., Brankaert, R., Lu, Y., Bekker, T., Brombacher, A., 2021. Facing Societal Challenges in Living Labs : Towards a Conceptual Framework to Facilitate Transdisciplinary Collaborations 1–14.

Köthke, M., 2020. Implementation of the European Timber Regulation by German importing operators: An empirical investigation. For. Policy Econ. 111, 102028. https://doi.org/10.1016/j.forpol.2019.102028

Legambiente, 2016. Rapporto Ecomafia 2016 – Le storie e I numeri della criminalità ambientale in Italia – Ed. Ambiente

Leipold, S., 2017. How to move companies to source responsibly? German implementation of the European Timber Regulation between persuasion and coercion. For. Policy Econ. 82, 41–51. https://doi.org/10.1016/j.forpol.2016.11.009

Leipold, S., Sotirov, M., Frei, T., Winkel, G., 2016. Protecting "First world" markets and "Third world" nature: The politics of illegal logging in Australia, the European Union and the United States. Glob. Environ. Chang. 39, 294–304. https://doi.org/10.1016/j.gloenvcha.2016.06.005

~~Luisi, D., 2018. Aree interne e il problema delle distanze: le proposte della SNAI. Forum disuguaglianze e diversità. Available at: https://www.forumdisuguaglianzediversita.org/aree-interne-distanze-proposte-snai Last accessed: November 26, 2021~~

Maryudi, A., Acheampong, E., Rutt, R.L., Myers, R., Dermott, C.L., 2020. "A Level Playing Field?"–What an Environmental Justice Lens Can Tell us about Who Gets Leveled in the Forest Law Enforcement, Governance and Trade Action Plan. Soc. Nat. Resour. 33, 859–875. https://doi.org/10.1080/08941920.2020.1725201

Masiero, M., Pettenella, D., Cerutti, P.O., 2015. Legality constraints: The emergence of a dual market for tropical timber products? Forests 6, 3452–3482. https://doi.org/10.3390/f6103452

McDermott, C.L., Sotirov, M., 2018. A political economy of the European Union's timber regulation: Which member states would, should or could support and implement EU rules on the import of illegal wood? For. Policy Econ. 90, 180–190. https://doi.org/10.1016/j.forpol.2017.12.015

Moral-Pajares, E., Martínez-Alcalá, C., Gallego-Valero, L., Caviedes-Conde, Á.A., 2020. Transparency index of the supplying countries' institutions and tree cover loss: Determining factors of EU timber imports? Forests 11, 1–16. https://doi.org/10.3390/F11091009

Moser, C., Leipold, S., 2021. Toward "hardened" accountability? Analyzing the European Union's hybrid transnational governance in timber and biofuel supply chains. Regul. Gov. 15, 115–132. https://doi.org/10.1111/rego.12268

Pallotta, E., Boccia, L., Rossi, C.M., Ripa, M.N., 2022. Forest Dynamic in the Italian Apennines. Appl. Sci. 12, 2474. https://doi.org/10.3390/app12052474

Pra, A., Pettenella, D., 2016. Consumption of wood biomass for energy in Italy: a strategic role based on weak knowledge. L'Italia For. E Mont. 2010, 49–62. https://doi.org/10.4129/ifm.2016.1.03

Pynnönen, S., Haltia, E., Hujala, T., 2021. Digital forest information platform as service innovation: Finnish Metsaan.fi service use, users and utilisation. For. Policy Econ. 125. https://doi.org/10.1016/j.forpol.2021.102404

Rete rurale nazionale, 2017. Forestry in Italy: state of health and management. A challenge for the future. Available at: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/16437 Last accessed: March 24, 2021

Rolandi, S., Brunori, G., Bacco, M., Scotti, I., 2021. The digitalization of agriculture and rural areas: Towards a taxonomy of the impacts. Sustain. 13, 1–16. https://doi.org/10.3390/su13095172

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., Brunori, G., 2021. Digital transformation of agriculture and rural areas : A socio-cyber-physical system framework to support responsibilisation. J. Rural Stud. https://doi.org/10.1016/j.jrurstud.2021.05.003

Schraml, R., Entacher, K., Petutschnigg, A., Young, T., Uhl, A., 2020. Matching score models for hyperspectral range analysis to improve wood log traceability by fingerprint methods. Mathematics 8. https://doi.org/10.3390/MATH8071071

Schroeder, K., Lampietti, J., Elabed, G., 2021. What's Cooking : Digital Transformation of the Agrifood System. Agriculture and Food Series;. Washington, DC: World Bank. Available at: https://openknowledge.worldbank.org/handle/10986/35216 Last accessed: July 25, 2021

Secco, L., Favero, M., Masiero, M., Pettenella, D.M., 2017. Failures of political decentralization in promoting network governance in the forest sector: Observations from Italy. Land use policy 62, 79–100. https://doi.org/10.1016/j.landusepol.2016.11.013

Sikkema, R., Dallemand, J.F., Matos, C.T., van der Velde, M., San-Miguel-Ayanz, J., 2017. How can the ambitious goals for the EU's future bioeconomy be supported by sustainable and efficient wood sourcing practices? Scand. J. For. Res. 32, 551–558. https://doi.org/10.1080/02827581.2016.1240228

Sotirov, M., Stelter, M., Winkel, G., 2017. The emergence of the European Union Timber Regulation: How Baptists, Bootleggers, devil shifting and moral legitimacy drive change in the environmental governance of global timber trade. For. Policy Econ. 81, 69–81. https://doi.org/10.1016/j.forpol.2017.05.001

Sperandio, G., Costa, C., Figorilli, S., Pallottino, F., Scrinzi, G., Colle, G., Proto, A., Macrì, G., Antonucci, F., Menesatti, P., 2017. Economic assessment of RFID coupled with open source technologies for wood traceability in Calabria. For. - Riv. di Selvic. ed Ecol. For. 14, 124–134. https://doi.org/10.3832/efor2267-014

Storti, D., 2016. Aree Interne e sviluppo rurale: prime riflessioni sulle implicazioni di policy Agriregionieuropa, 45. Available at: https://agriregionieuropa.univpm.it/it/content/article/31/45/aree-interne-e-sviluppo-rurale-prime-riflessioni-sulle-implicazioni-di-policy Last accessed: February 12, 2021

Trishkin, M., Lopatin, E., Karjalainen, T., 2015. Exploratory assessment of a company's due diligence system against the EU timber regulation: A case study from Northwestern Russia. Forests 6, 1380–1396. https://doi.org/10.3390/f6041380

Tzoulis, I.K., Andreopoulou, Z.S., Voulgaridis, E., 2014. Wood Tracking Information Systems To Confront Illegal Logging. J. Agric. Informatics 5, 9–17. https://doi.org/10.17700/jai.2014.5.1.130

UNEP-WCMC, 2020. Brazil relaxes its timber export regulations, weakening its ability to control the legality of shipments. Briefing Note for the Competent Authorities (CA) implementing the EU Timber Regulation February. Available at: https://ec.europa.eu/environment/forests/pdf/EUTR%20Briefing%20note%20February-May%202020.pdf Last accessed: March 30, 2021

United Nations International Trade Statistics Database, 2017. UN Comtrade Database. Available at: https://comtrade.un.org/ Last accessed: November 4, 2021

Watkinson, C.J., Gasson, P., Rees, G.O., Boner, M., 2020. The development and use of isoscapes to determine the geographical origin of Quercus spp. in the United States. Forests 11, 1–21. https://doi.org/10.3390/f11080862

ANNEX

Template for the evaluation of impacts of digitalisation

What has been digitalised? Which digital technologies are involved?	**Impacts (Socio-economic-environmental)**	
Impact 1	Direct	Negative impact
		Positive impact
	Indirect	Negative impact
		Positive impact
Impact n	Direct	Negative impact
		Positive impact
	Indirect	Negative impact
		Positive impact

Template for the evaluation of the determinants of the impacts of digitalisation

Impact pathways	**How? (*Some questions to bear in mind for the facilitation)***
Digital technology design	• Which aspects of the technology are highly relevant for the observed effects?
Access to digitalisation	• How are the observed effects mitigated or exacerbated by the access (or lack thereof) to digitalisation? • How human digital skills, access costs, or private ownership of data network are influencing the observed impacts?
System complexity	• What kind of contextual factors influence the effects observed in the socio-cyber and physicial system? • How do external forces play a role in the type of effects observed in your focal?

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

We are very grateful to all Living Lab members and interviewees for sharing their knowledge and experience.

CRediT authorship contribution statement

SC - conceptualisation, investigation, methodology, visualisation, data curation, writing - original draft.

FB - conceptualisation, methodology, visualisation, supervision, writing - review & editing

AB - conceptualisation, investigation, funding acquisition, supervision, investigation, writing - review & editing

EM – conceptualisation, investigation, methodology, visualisation, data curation, project administration, writing - review & editing

MM - conceptualisation, methodology, writing - review & editing

GB - conceptualisation, funding acquisition, supervision, writing - review & editing.

AF - conceptualisation, investigation, funding acquisition, supervision, project administration, writing - review & editing.