# Measuring and assessing forest-based circular bioeconomy to implement the National Sustainable Development Strategy in Italy

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# Context

The implementation of **National Sustainable Development Strategy 2017/2030** (NSDS) in Italy in accordance with the strategic objective of UN Agenda 2030.

**11 of the 17 Sustainable Development Goals (SDGs)** directly align with the scope of circular bioeconomy aimed to promote and strength the economic growth by reducing the dependency on fossil resources, environmental impacts, creating new business and job opportunities.

# Project's aims

The Project *FOR.CIRCULAR* (*Decision Support System to improve the performance of forest-wood chain in a circular bioeconomy perspective*) – funded by the NSDS – is aimed to develop a DSS based on a set of indicators to assess circular bioeconomy in the forest sector.
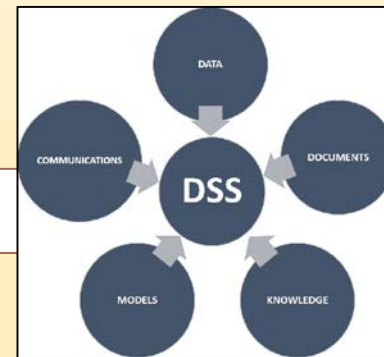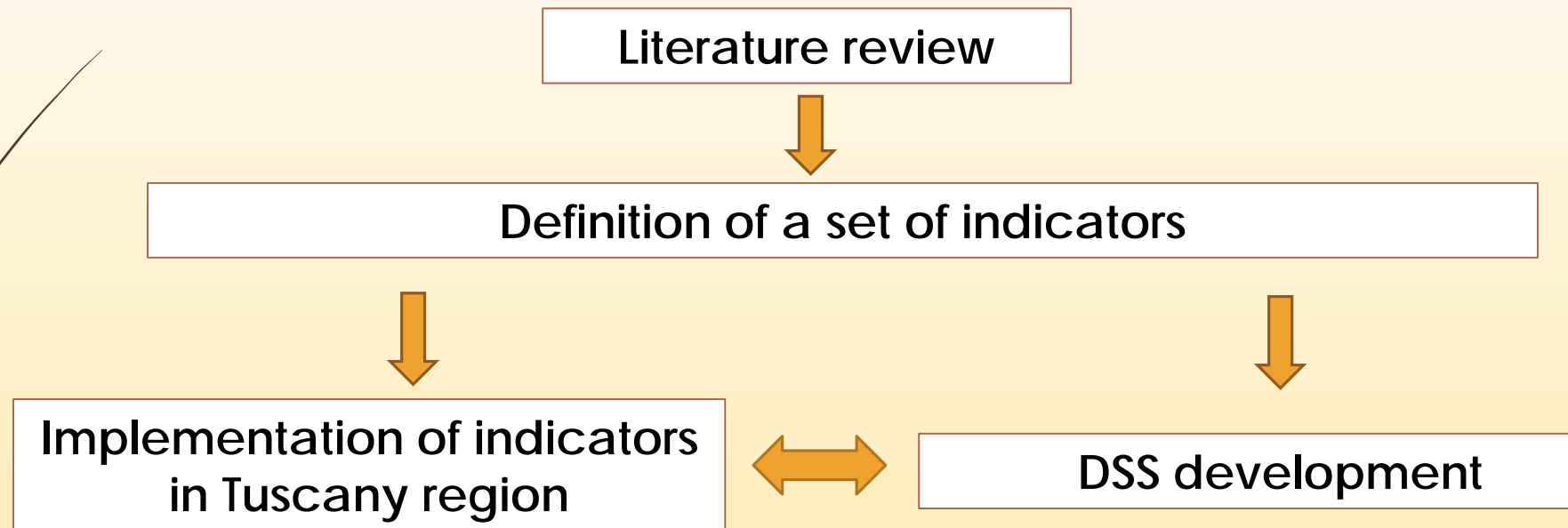
# Circular bioeconomy: definition and key aspects

## Definition

Circular bioeconomy can be defined as " *the sustainable, cascading processing of biological residues into bio-based products which can be shared/reused/remanufactured and recycled, or released safely to the biosphere via organic and nutrient cycles"* (Carus & Dammer 2018).

Cascading approach
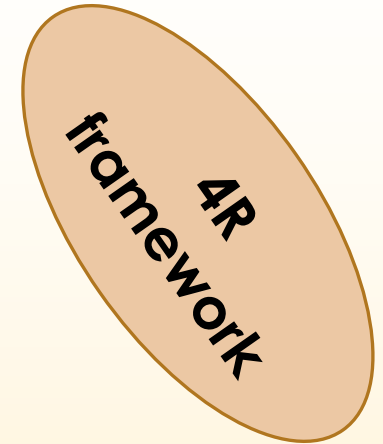
Circularity

Carbon neutrality

**REDUCE**

**REUSE**

**RECYCLE**

**RENEWABLE**

4R framework

# Literature review

The peer-reviewed publications were retrieved from Scopus database (https://www.scopus.com) using as keywords: "forest bioeconomy", "circular bioeconomy" + "forest", and so on (timeframe: 2003-2020).

All data were exported as .csv files and processed through a bibliometric network analysis using **VOSviewer software** (version 1.6.11).

The bibliometric network analysis is based on the combination of bibliometric approach and Social Network Analysis (SNA) approach.
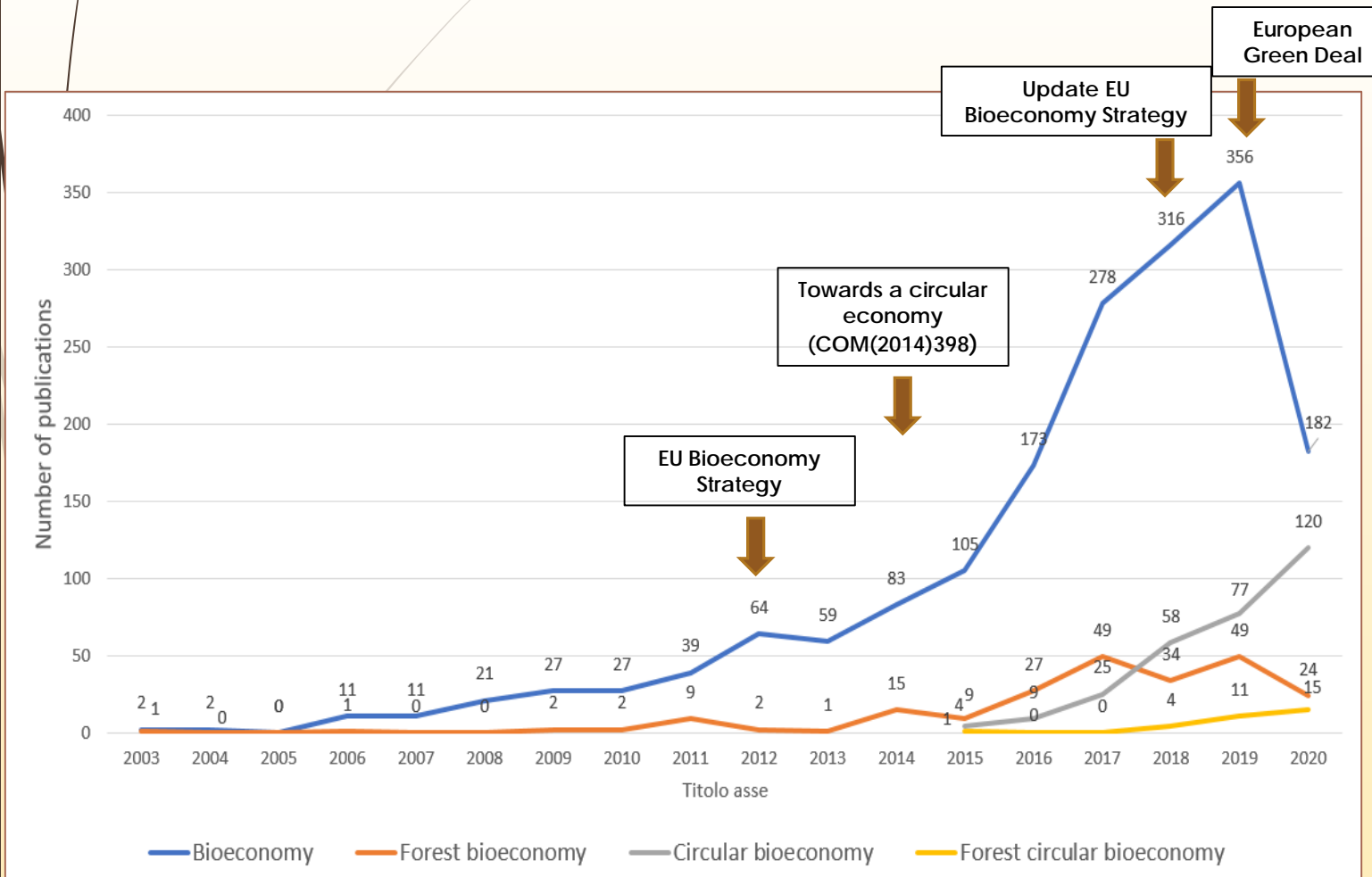
Co-authorship

Co-occurrence

# Trend – peer-review publications

The number of documents on the "bioeconomy" and "circular bioeconomy" shows an increasing trend in the investigated time-frame.



**Bioeconomy:** the trend of the scientific publications on "bioeconomy" is influenced by the publication of EU Bioeconomy Strategy (2012) with an increase in published documents since 2013.

**Circular bioeconomy:** in 2015 for the first time the two concepts of "bioeconomy" and "circular economy" have been conceptually combined.
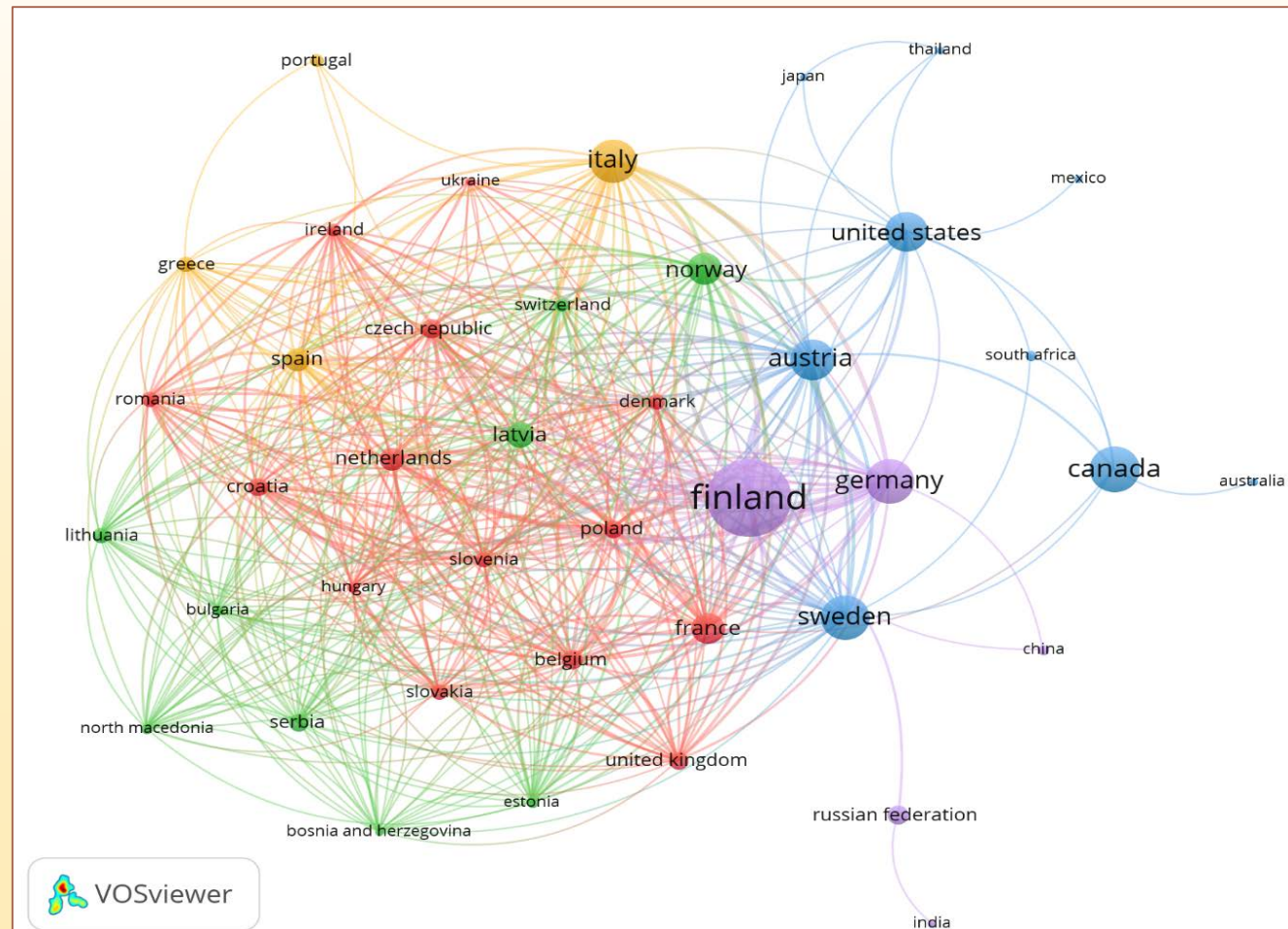
# Literature review – forest bioeconomy

The Scopus database search resulted in **225 forest bioeconomy publications** (2003-2020). On average 12.5 peer-reviewed publications on forest bioeconomy (SD =16.9; median = 2) have been published every year.

Finland is the most productive country with 72 publications (32.8% of the total documents), followed by Canada with 28 documents (12.7%).

**Clusters**:

✓ Green cluster among Eastern European countries (Bosnia and Herzegovina, Bulgaria, Estonia, Lithuania North Macedonia, Serbia).

✓ Yellow cluster among the Mediterranean countries (Portugal, Greece, Italy, Spain).
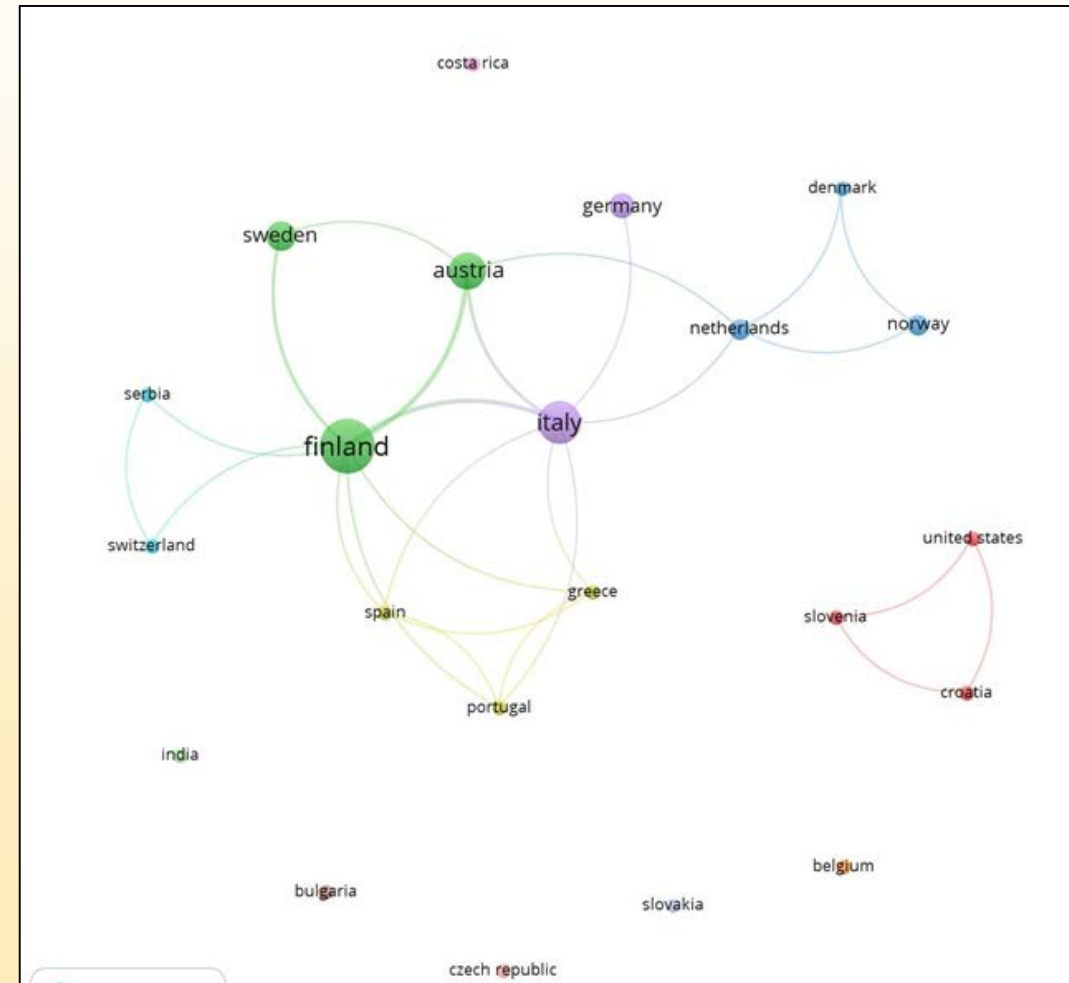
# Literature review – circular forest bioeconomy

The Scopus database search resulted only in **22 publications on circular bioeconomy in forest sector** (2003-2020). Finland and Italy are the two most productive countries.

**4 clusters of keywords** mainly related to the environmental, technical, economic and social aspects of circular economy concept.
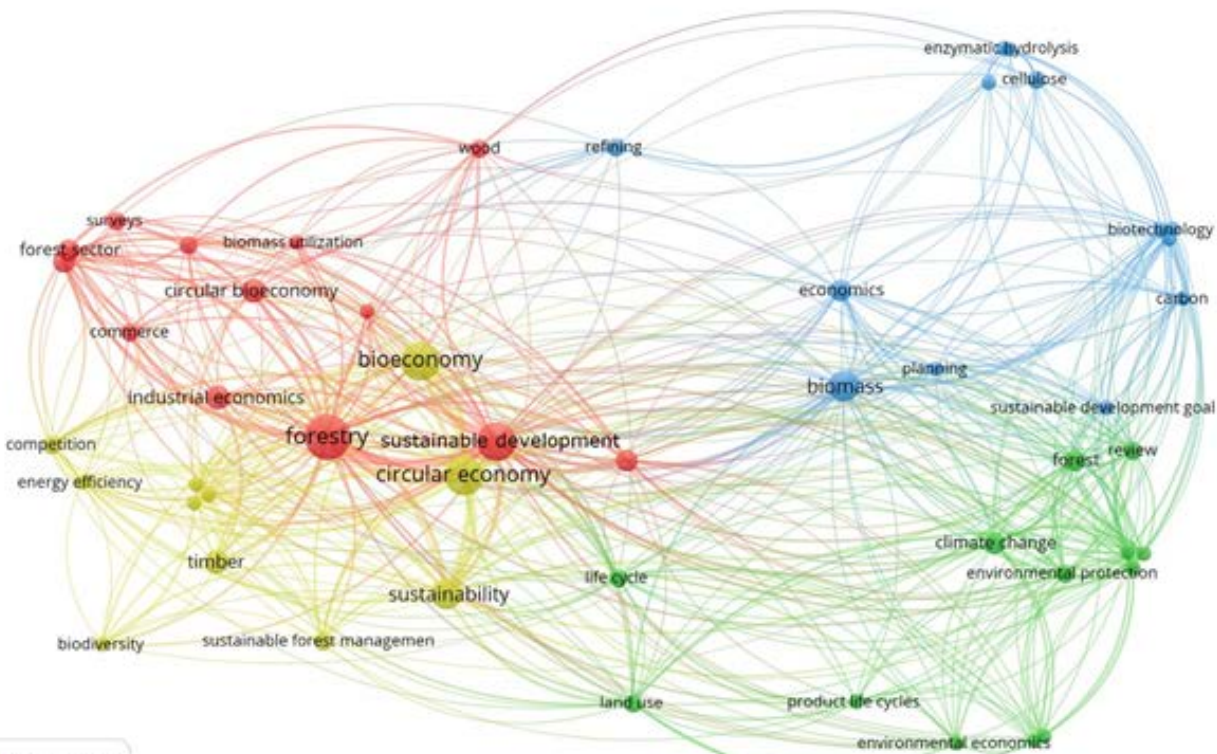


Co-occurrence



Co-authorship

# Literature review - indicators

During the literature review, the peer-review publications on indicators to assess the circular bioeconomy in the forest sector were selected and analyzed.

A preliminary set of 6 indicators was identified and tested in a case study in Central Italy.

## Assessing the forest-wood chain at local level: A Multi-Criteria Decision Analysis (MCDA) based on the circular bioeconomy principles

Elisa Pieratti[1], Alessandro Paletto[1§], Isabella De Meo[1], Claudio Fagarazzi[2], Matteo Rillo Migliorini Giovannini[2]

Abstract. In the last years, the circular bioeconomy has been recognized as key approach to increase the competitiveness of enterprises and economic growth in the European Union (EU) member countries. Forest-based sector plays a key role in the circular bioeconomy. The aim of the present study is to analyze the forest-wood chain at local level following the circular bioeconomy approach. A set of indicators to quantify the 4R ("Reduce", "Reuse", "Recycle", "Recover") of circular economy has been defined and tested in a study area in Italy (Monte Morello forest in Tuscany region). The indicators identified and tested are: improving production process efficiency; reuse and life-span of wood products; optimization of potential wood assortments and energy recover from the wood products. By means of the indicators and a Multi-Criteria Decision Analysis (MCDA), the current forest management strategy applied in the study area has been compared with other possible forest management scenarios in order to evaluate the optimum solution. The results show that the current forest management strategy did not optimize the productive function because the wood harvested is wholly allocated for bioenergy production. The economic value and the life-span of wood products can be increased by means of the wood harvested valorization. Anyway, the results show a favorable balance concerning the carbon dioxide ($CO_2$) emission – considering the fossil fuel substitution effect – and the bioenergy production from deadwood.
Keywords: circular bioeconomy indicators, forest management strategies, cascading approach, bioenergy, renewable energy policy

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**Table** Indicators based on the 4R framework of the circular bioeconomy

| 4R | Definition | Indicator defined for the forest sector |
|---|---|---|
| Reduce | Improving of the process efficiency reducing the utilization of natural resources | $I_1$ - ratio (on annual basis) between the economic value of the wood harvested per cubic meter and forest area (€ $m^{-3}$ $yr^{-1}$) <br> $I_2$ - $CO_2$ emissions of the phases of forest-wood chain (from the felling to the transport) for unit volume ($kgCO_2$ $m^{-3}$) |
| Reuse | Life span of products/Products re-utilization before its disposal | $I_3$ - product life span before to be used for energy generation (years) |
| Recycle | Level of recyclability of the products for other purpose/ objects (paper, animal bedding, chipboard panels) | $I_4$ - economical differential between the potential economic value of the wood assortment and the real value earned (%) |
| Recover | Energy production from the „end-of-life products" | $I_5$ - ratio between $CO_2$ emissions saved by the timber sold for energy production (respect to the diesel oil) and the total cubic meter collected ($kgCO_2$ $m^{-3}$) <br> $I_6$ - ratio between deadwood used for energy purpose and total deadwood in forest ($m^3$ $m^{-3}$) |

# Italian pilot area

The study site is the Monte Morello forest (43°51'20''N; 11°14'23''E) near the metropolitan area of Florence (Central Italy). Mixed conifer plantation established in 1960-68 for protection purpose, with never thinned stands.

Altitude between 55 m and 934 m a.s.l

Main tree species: Austrian black pine, Calabrian pine, cypress, Turkey oak and Downey oak

Degraded forest characterized by poor regeneration, marked susceptibility to adversities, huge quantity of deadwood

Mean tree density of 980 tree ha$^{-1}$, a basal area of 62.9 m$^2$ ha$^{-1}$ and a mean height of 17.1 m. Average growing stock is around 560 m$^3$ ha$^{-1}$, while the deadwood volume is equal to 75.1 m$^3$ ha$^{-1}$

*Monte Morello*

*Tuscany region*

# Implementation of indicators in the pilot area

The indicators were implemented in two field sites of the Monte Morello forest managed through two different silvicultural treatments:

1) **Thinning from below**: the choice of trees to be cut is based on a negative selection (thinned 15-20% of basal area). Small and leaned trees and standing dead trees are removed, while the lying deadwood is not removed during the silvicultural treatments.

2) **Selective thinning**: the choice of the trees to be cut is based on a positive selection (during cutting all crown-volume competitors trees are harvested). Thinned 30-40% of basal area. Standing dead trees and lying deadwood of first and second decay class with diameter at breast height (DBH) more than 20 cm are removed.

Implementation of indicators and creation of forest management scenarios

# Assessment of forest management scenarios

A Multiple-Criteria Decision Analysis (MCDA) has been performed to test the reliability and efficiency of the six circular bioeconomy indicators for forest sector.

The weights of circular bioeconomy indicators were assigned through a pairwise comparison considering the hierarchical position of the 4Rs ($I_1 = I_2 > I_3 > I_4 > I_5 = I_6$)

## Scenarios

Five alternative forest management scenarios have been defined changing **silvicultural treatments**(selective thinning and traditional thinning) and **wood outcomes** (woodchips and other wood products with a higher added value).



Structure of the criteria's tree
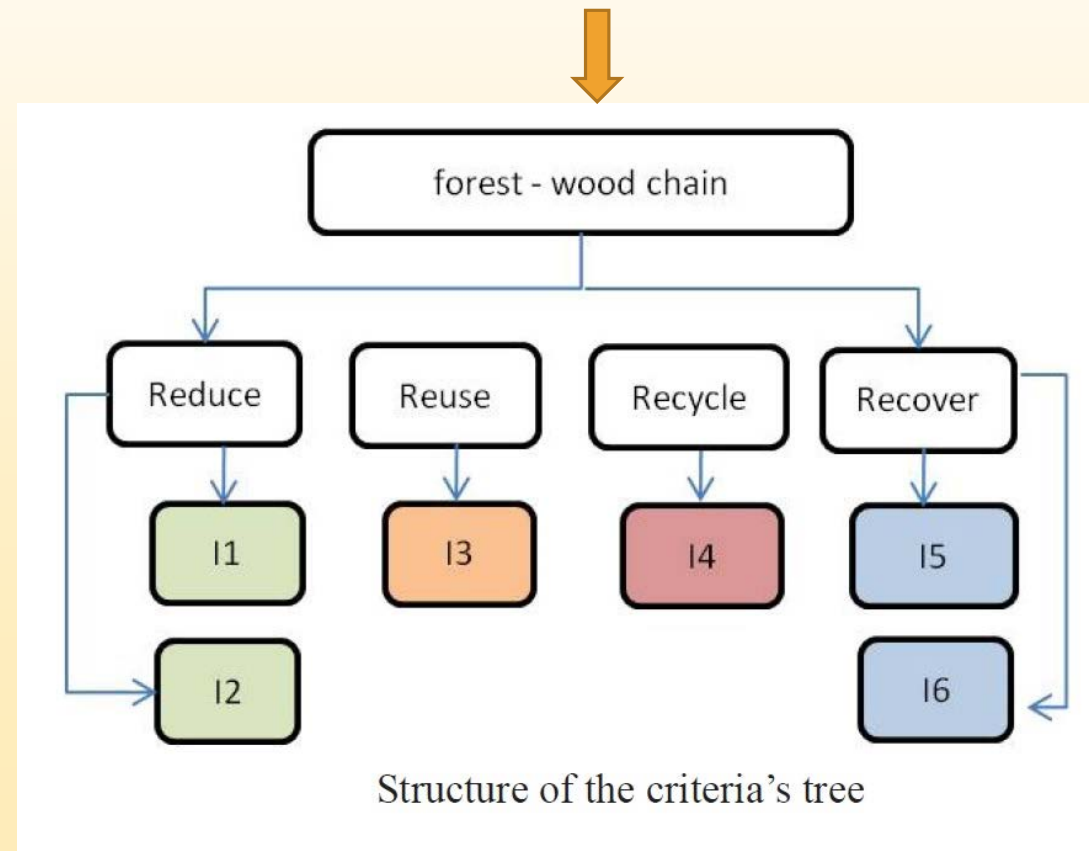
# Results

First of all, the results show the **applicability of the set of indicators** to the forest sector and the **replicability in other context**.
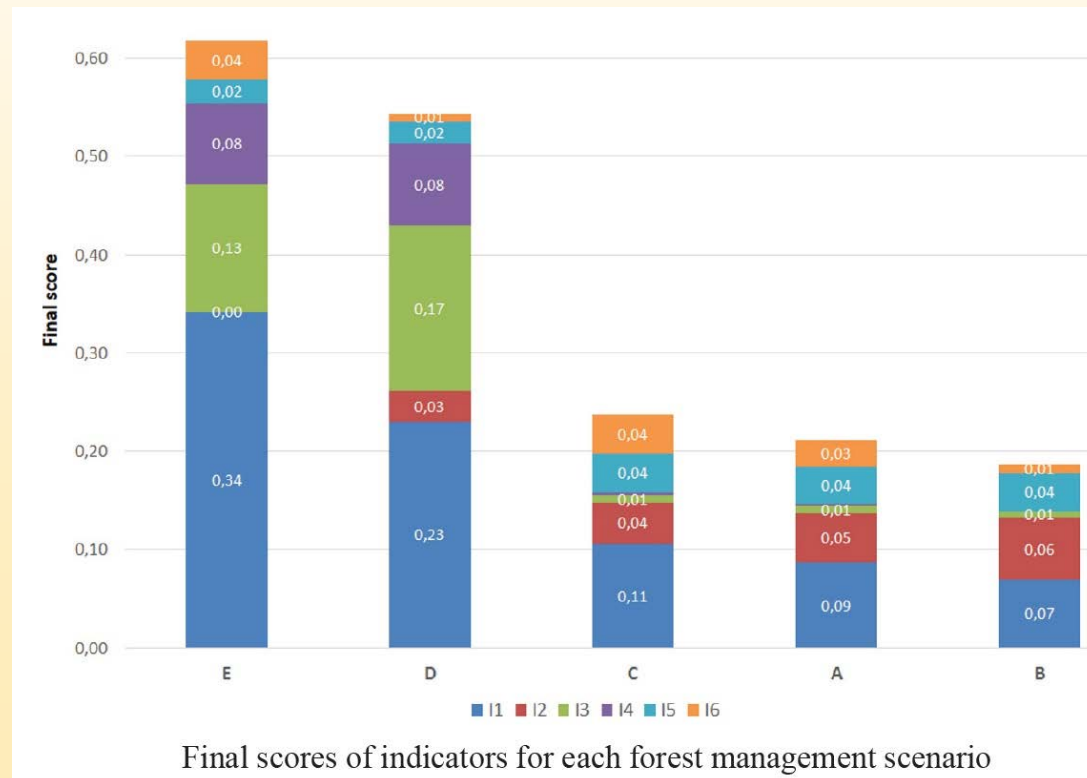
Regarding the pilot area, the results show that the Scenario "*selective thinning with economic valorization of the wood products*" is considered the optimum forest management solution according to the circular bioeconomy principles, based on the index priority order given by the 4R framework.

**Table**  Payoff matrix for each forest management scenario

| Scenario | $I_1$ (€ ha$^{-1}$) | $I_2$ (kgCO$_2$ m$^{-3}$) | $I_3$ (y) | $I_4$ (%) | $I_5$ (kgCO$_2$ m$^{-3}$) | $I_6$ (m$^3$ m$^{-3}$) |
|---|---|---|---|---|---|---|
| A | 2.34 | 7.80 | 0.50 | 0.30 | -634 | 0.37 |
| B | 2.34 | 7.50 | 0.50 | 0.30 | -634 | 0.10 |
| C | 2.34 | 8.00 | 0.50 | 0.20 | -634 | 0.50 |
| D | 7.80 | 8.30 | 11.60 | 0.00 | -371 | 0.10 |
| E | 7.57 | 8.40 | 8.90 | 0.00 | -359 | 0.50 |

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Final scores of indicators for each forest management scenario

# Conclusions

**Considerations on the preliminary results** of the project FOR.CIRCULAR:

- Application of indicators in many pilot areas could support an exhaustive quantification of the 4Rs of circular bioeconomy;

- DSS could be able to generate a complete set of efficient solutions to forest management and wood market problems helping the DMs to acquire a holistic view of the planning analysis problem;

- The DSS development will offer DMs the possibility to redirect their strategies improving the reuse and recycle of wood residues at local level;

- The use of wood residues for bioenergy or the production of added value products (bio-textiles, bio-plastics) will be the practical output at local level.

**Future steps** of the project FOR.CIRCULAR:

- Identification of additional indicators able to include all aspects of sustainability.

- Implementation of the indicators in a broader territorial context (Unione dei Comuni Valdarno e Valdisieve, Tuscany region)

# FOR.CIRCULAR communication tools

## Facebook Page
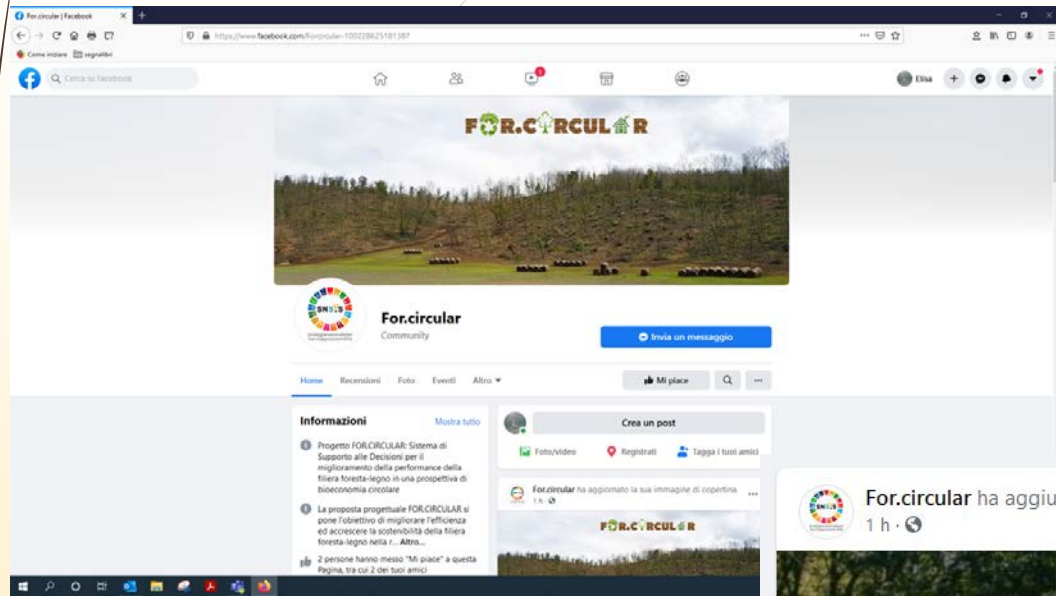
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