UNIVERSITY OF FORESTRY

International Conference
FORESTRY
BRIDGE TO THE FUTURE

5-8 MAY 2021

Park hotel Moskva
Sofia • Bulgaria

ECONOMIC AND ENVIRONMENTAL PERFORMANCES OF FORESTRY MECHANIZATION: AN INNOVATIVE APPROACH

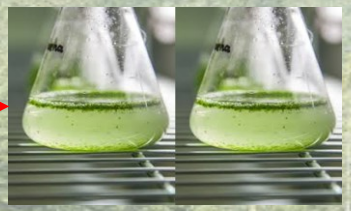
Luca NONINI([1]*), Daniele CAVICCHIOLI[(2)], Marco FIALA[(1)]

Department of Agricultural and Environmental Science. Production, Landscape, Agroenergy (DiSAA), University of Milan. Via G. Celoria 2, 20133 Milan, Italy.
Department of Environmental Science and Policy (ESP), University of Milan. Via G. Celoria 2, 20133, Milan, Italy.

*Corresponding author: luca.nonini@unimi.it

INTRODUCTION AND AIM OF THE WORK – 1









INTRODUCTION AND AIM OF THE WORK– 2

Regardless of the final utilization of wood

SELECTION OF MACHINES FOR FORESTRY OPERATIONS

APPROCHES AT DIFFERENT SCALES

- National
- Regional
- Local (Forest stand)

CRUCIAL FOR

- Quantification of economic and environmental performances of the whole chain;
- Increase operations' productivity and efficiency;
- Improvement safety conditions of operators at work.

Forest Management Plans (FMPs)

TOGETHER WITH

Information on forestry mechanization

Improvement of forest management at the local scale

INTRODUCTION AND AIM OF THE WORK – 3

Problems

Several approaches available but:

- definition of machines according to few parameters (e.g., slope);
- usable machines defined as input by the user and not as output;
- calculation of economic costs generally performed for single operations and not for the whole chain;
- environmental performances: for single operations and often based on literature data.

Solution

GENERALIZED APPROACHES IN ORDER TO:

- indentify forestry machinery chain (FMC) for specific forest stands;
- calculate economic costs and environmental performances

AIM OF THE WORK

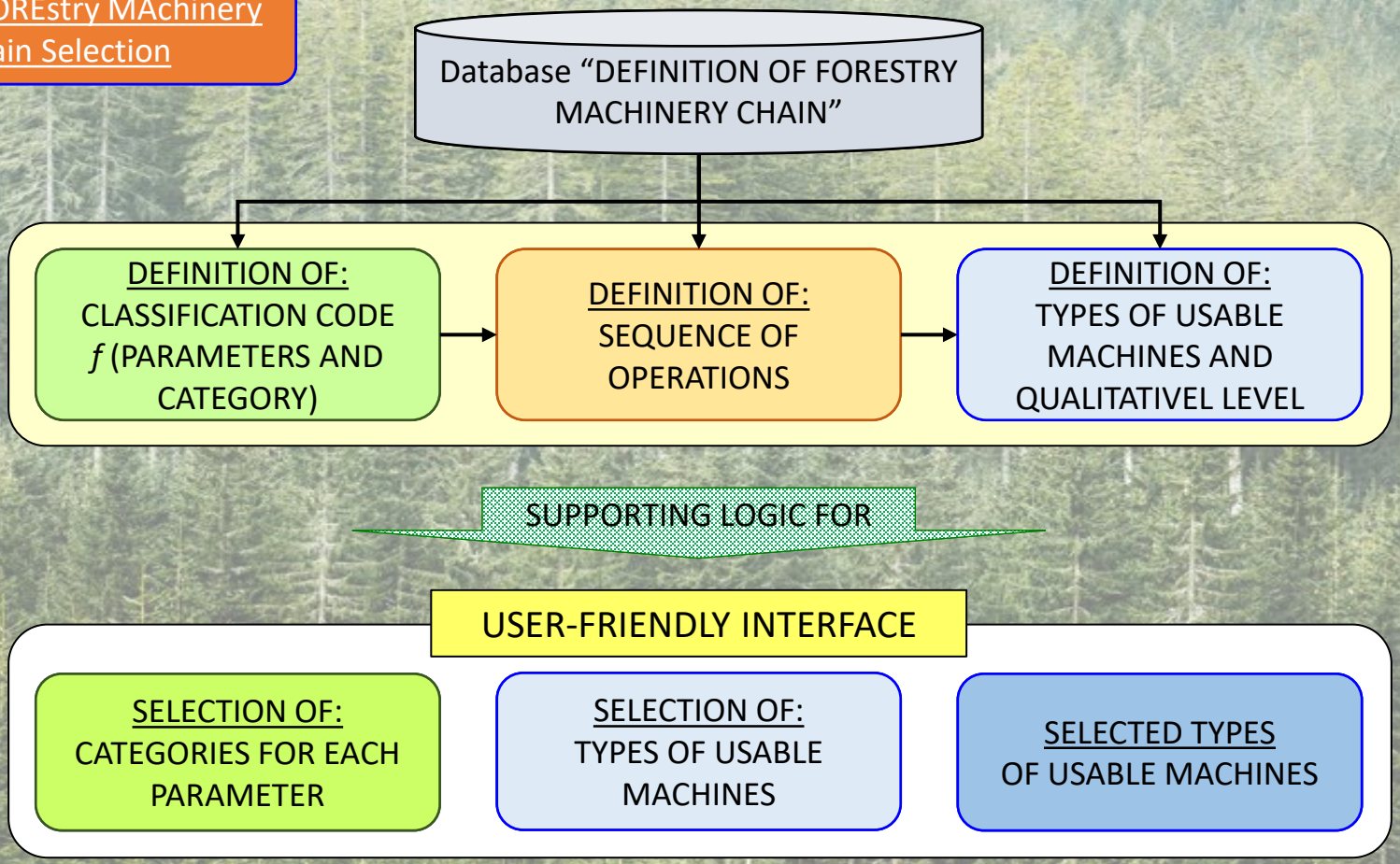
TO DEVELOP AN INNOVATIVE APPROACH BASED ON TWO STAND-LEVEL MODELS TO SELECT THE FORESTRY MACHINERY CHAINS ACCORDING TO FORESTRY AND OPERATING CONDITIONS AND TO CALCULATE ECONOMIC COSTS AND ENVIRONMENTAL PERFORMANCES.

BENEFIT

Strategic support for Local Administrations (public subsidies) and logging companies (tariffs for operations).

MATERIALS AND METHODS: THE MODEL *«FOREMA»* – 1

Model: FOREstry MAchinery Chain Selection



MATERIALS AND METHODS: THE MODEL *«FOREMA»* – 2

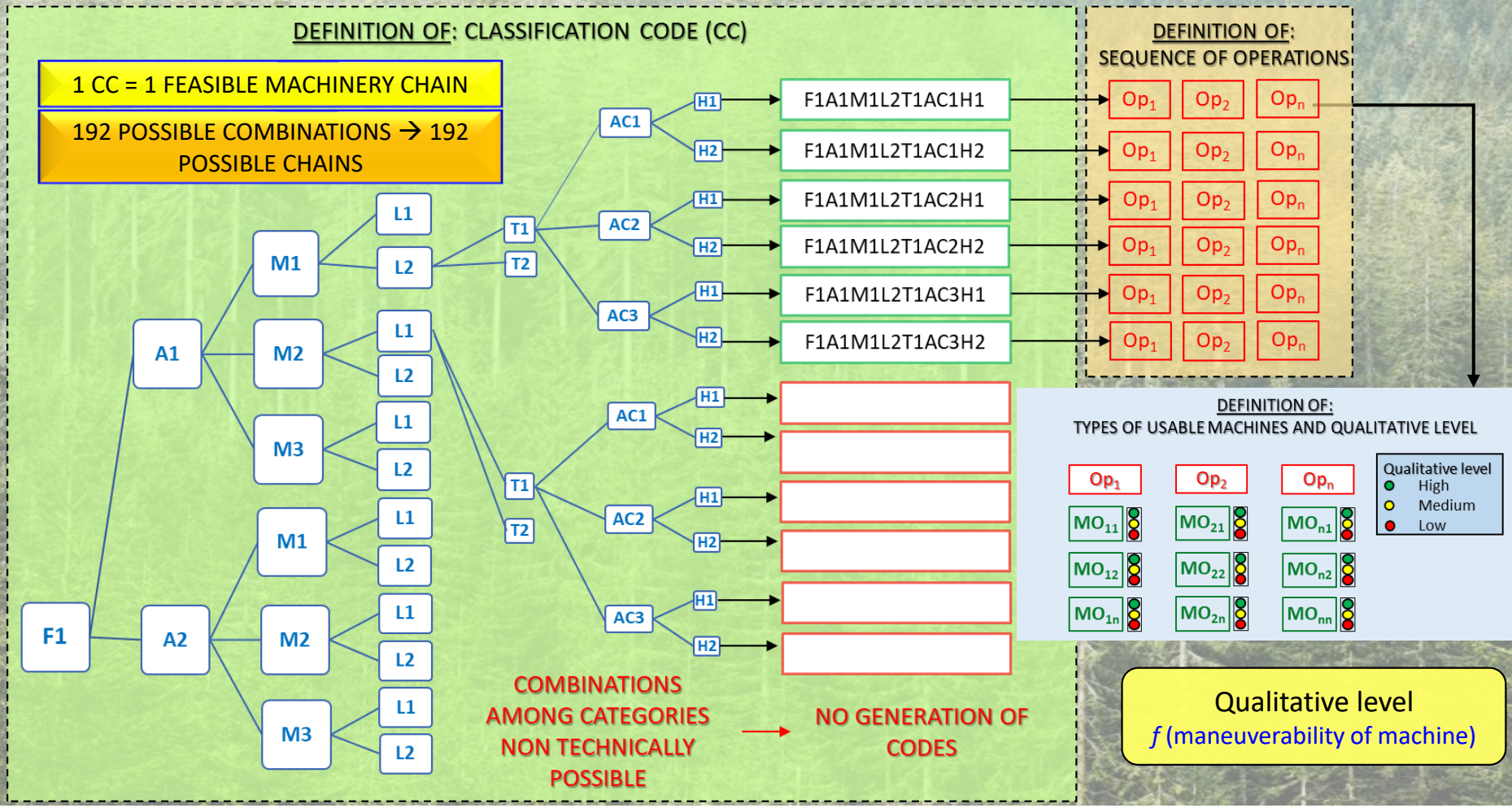
Database "DEFINITION OF FORESTRY MACHINERY CHAIN"

Stands classified according to

Limiting factor		Technical Parameter			
N°	Name	N°	Name	Category	Sub-Code
1	Characteristics of the forest	1	Management System	Coppice	F1
				High forest	F2
2	Characteristics of the production system	2	Wood Assortment	Firewood	A1
				Beams/poles	A2
				Woodchips	A3
		3	Harvesting Method	Cut-to-length	M1
				Tree length	M2
				Full tree	M3
		4	Level of Mechanization	Low	L1
				Medium-high	L2
3	Site-specific operating conditions	5	Forest roads' Transitability	Medium-high	T1
				Medium-low	T2
		6	Forest stand's Accessibility	High (AC I)	AC1
				Medium (AC II)	AC2
				Low (AC III)	AC3
		7	Harvested Merchantable Mass	≤ 16 t·ha^{-1} DM	H1
				> 16 t·ha^{-1} DM	H2

PARAMETERS AND CATEGORIES: HIERARCHICAL TREE STRUCTURE

MATERIALS AND METHODS: THE MODEL «*FOREMA*» – 3



MATERIALS AND METHODS: THE MODEL «*FOREMA*» – 4

USER-FRIENDLY INTERFACE

SELECTION OF: CATEGORIES FOR EACH PARAMETERS

Management System		Wood Assortment		Harvesting Method		Level of Mechanization		Forest roads' Transitability		Stand's Accessibility		Harvested Mass	
Coppice	F1	Firewood	A1	Cut-to-length	M1	Low	L1	Medium-high	T1	High	AC1	≤ 16 t·ha^{-1}	H1
High forest	F2	Beams/poles	A2	Tree length	M2	Medium-high	L2	Medium-low	T2	Medium	AC2	> 16 t·ha^{-1}	H2
		Woodchips	A3	Full tree	M3					Low	AC3		

CLASSIFICATION COCE (CC)

Searching…

DATABASE: DEFINITION OF FORESTRY MACHINERY CHAIN

CC LIST

CC_1 Op_1 Op_2 Op_3 Op_n

CC_2 Op_1 Op_2 Op_3 Op_n

CC_3 Op_1 Op_2 Op_3 Op_n

CC_n Op_1 Op_2 Op_3 Op_n

Op_1 Op_2 Op_3 Op_n

MO_{11} MO_{21} MO_{31} MO_{n1}

MO_{12} MO_{22} MO_{32} MO_{n2}

MO_{1n} MO_{2n} MO_{3n} MO_{nn}

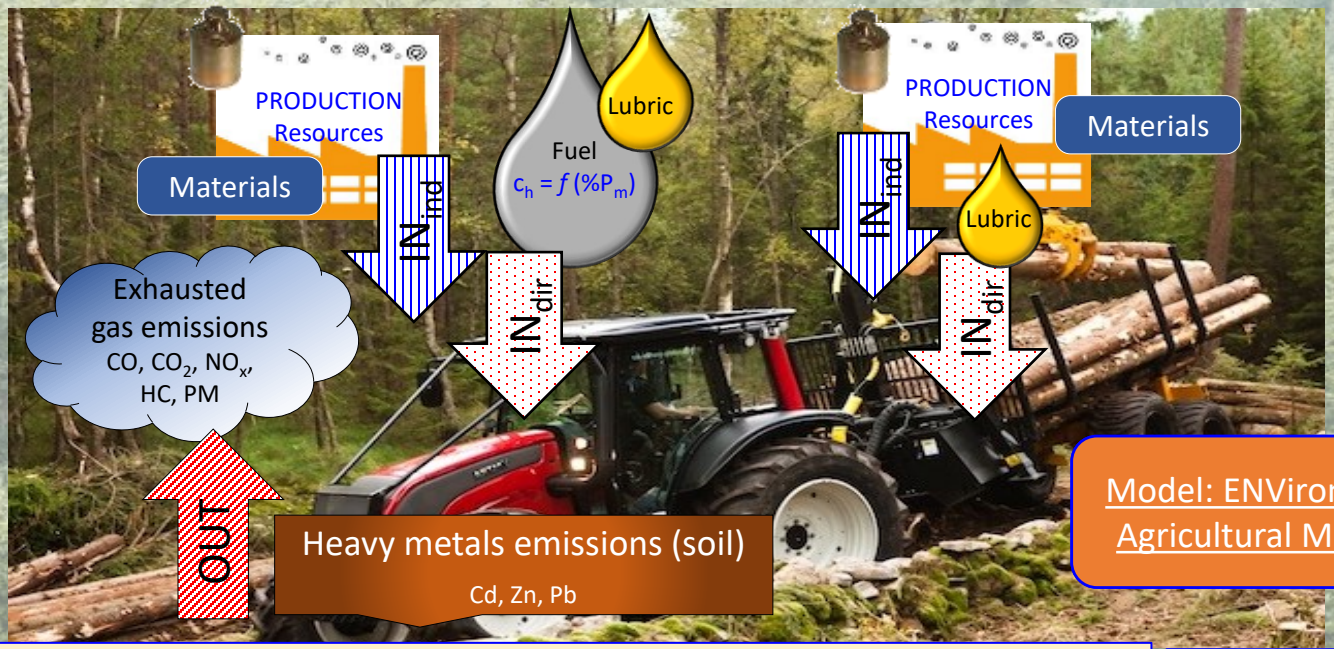
SELECTION OF: TYPES OF USABLE MACHINES

Op_1	Op_2	Op_3	Op_n
MO_{11}	MO_{21}	MO_{31}	MO_{n1}
MO_{12}	MO_{22}	MO_{32}	MO_{n2}
MO_{1n}	MO_{2n}	MO_{3n}	MO_{nn}

USER

SELECTED TYPES OF USABLE MACHINES (for each operations according to the qualitative level)

MATERIALS AND METHODS: THE MODEL «*ENVIAM*» – 1



Model: ENVironmental Inventory of Agricultural Machinery operations

How the machines (TR&IM) are manufactured (different materials' mass, energy flows) → MANUFACTURERS

How the machines are used (different consumable materials' mass, working time, etc.) → LOGGING COMPANIES

INFORMATION FOR

ENVIRONMENTAL AND ECONOMIC PERFORMANCES ASSESSMENT

MATERIALS AND METHODS: THE MODEL «*ENVIAM*» – 2

MECHANICAL PARAMETERS

SELECTION

According to local working conditions

Adherence&rolling coefficients
Power surplus coefficient
Global power tractor efficiency
….

DATABASE IMPLEMENT/MACHINE

SELECTION

Mass & dimension
Type of coupling with TR
Service life
Effective Field Capacity
…

DATABASE TRACTOR

SELECTION

According to implement requirement

Type (2WD-4WD, crawler)
Max engine power
Mass & dimension
Service life
…

SELECTED OPERATION

Mechanization Calculation

Power required by IM
(Required TR engine power)
Engine load (λ_{TEF}) during "Effective Work"

Working times & engine load (λ) definition

Division in 13 working times (CIOSTA Methodology)
λ choice for each working time

MATERIALS AND METHODS: THE SECOND MODEL «*ENVIAM*» – 3

ENGINE LOADS

TRACTOR and IMPLEMENT CHARACTERISTICS (mass, service life)

OPERATION WORKING TIMES

SPECIFIC FUEL CONSUMPTION (g/kWh)

Manufacturing process + repairing&maintenance

TR&IM Materials' (mass) Consumption Calculation

Tires Abrasion Calculation

Fuel Consumption Calculation

Lubricant & AdBlue® Consumption Calculation

Metals emissions into soil

Engine emissions into atmosphere

Steel/Iron; Copper; Aluminium; Lead; Glass; Polimeric materials & rubber; Tyres; Fluids, oils & chemicals

Cadmium; Zinc; Lead

CO; HC; NO_x; PM; CO_2

ENVIRONMENTAL PERFORMANCES ASSESSMENT

MATERIALS AND METHODS: THE SECOND MODEL *«ENVIAM»* – 4

ECONOMIC PERFORMANCES ASSESSMENT

ECONOMIC PARAMETERS DEFINITION

Fixed costs

Purchase price
Salvage value rate
Tax, supervision& management rate
Interest rate
Recovery per unit of area

Variable costs

Repairing&maintenance rate
Fuel price
Lubricant price
N. of operators, net wage, social charges
Productivity parameters (working days, n. of shift/day, scheduled hours/shift, …)

Preliminary calculations

Annual use, Economic life
N. of required machines&productivity
N. of required workers, …

COSTS CALCULATION

Fixed costs

Financial Depreciation
Tax, supervision& management
Recovery

Variable costs

Repairing&maintenance
Fuel and lubricant
Labor

TOTAL COSTS OF THE OPERATION (TC_{OPi}) €/h, €/t DM, €

TOTAL COST FORESTRY MACHINERY CHAIN

(«n» operations; €·h^{-1}; €·t^{-1} SS; €)

$$TC_{FMC} = \sum_{i \to 1}^{n} TC_{Op_i}$$

CONCLUSIONS AND FUTURE PERSPECTIVES

An innovative approach based on two linked stand-level models was developed:

- the FOREMA model support the user in selecting the forestry machinery chain to use, by taking into account seven technical parameters that "classify" the stand;
- for a given machinery chain, FOREMA defines the sequence of operations and the types of usable machines;
- in the ENVIAM model environmental performances assessment based on calculation of fuel/lubricant, materials and emissions of each operation (relations between engine load and working times);
- economic costs of each operation computed as the sum of fixed and variable costs;
- simultaneous calculation of economic costs and environmental performances crucial to better define the sustainability of the whole machinery chain.

PERSPECTIVES

- Model validation (experimental tests);
- Improvement of FOREMA model with:
  - Parameters currently not included: soil conditions, average tree diameters;
  - Selection of different wood assortment at the same time;
- use of a programming language and integration of FOREMA and ENVIAM models.