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HARVESTING OF WOOD IN AN ITALIAN DISTRICT: A QUANTITATIVE STAND-LEVEL ANALYSIS

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INTRODUCTION – 1

FORESTS → ECOSYSTEM SERVICES

Supporting
- Soil formation
- Nutrient cycle
- Habitat formation

Regulation
- CO_2 sequestration
- Erosion control
- Particulate absorption

Cultural
- Recreational value
- Aesthetic value
- Spiritual value

Provisioning
- Air and water
- Food and fiber
- Wood biomass supply

QUANTIFICATION OF ECOSYSTEM SERVICES ESSENTIAL TO IDENTIFY THE EFFECTIVE ENVIRONMENTAL MANAGEMENT PRACTICES AND THE INSTITUTIONAL SCALE FOR DECISION-MAKING PROCESSES.

Wood removal affects forest C dynamic while ensuring availability of renewable materials

Logging residues
ENERGY GENERATION
Woodchips → Short C turnover; neutral C balance (combustion)

Merchantable stems
LONG LIFE-CYCLE PRODUCTS
Beams, poles → Long C turnover → positive C balance

INTRODUCTION – 3

Energy generation from residues: economic and environmental benefits without competing with other uses → termo-degradation of wood no additional CO_2 emissions into the atmosphere

PROBLEMS

- In the Alpine Region: at the local scale (stand-level) forest managed through Forest Management Plans → data only for the harvested merchantable stem → information on collected residues generally not provided;
- Residues availability often computed through biomass harvesting studies (site-specific experimental data);
- lack of approaches to compute forest biomass and C and predict logging residues availability at the stand level to use for energy generation starting from FMP data;

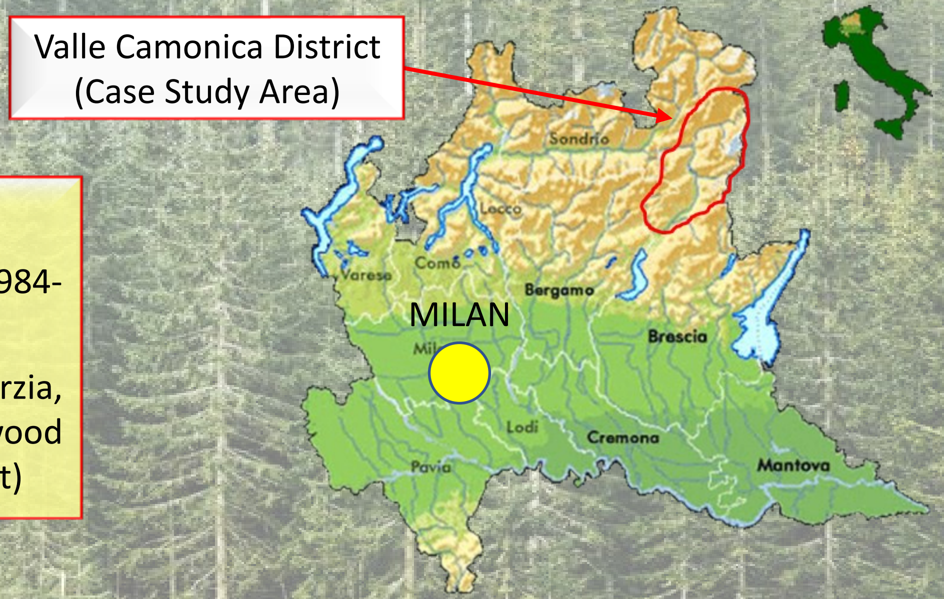
SOLUTION

MODELS TO CALCULATE FOREST BIOMASS AND C STOCK AND LOGGING RESIDUES AVAILABILITY FOR ENERGY.
BENEFIT: TO SUPPORT LOCAL FORESTRY AUTHORITIES AND SUPPLY CHAIN OPERATORS IN FOREST MANAGEMENT.

AIMS OF THE WORK

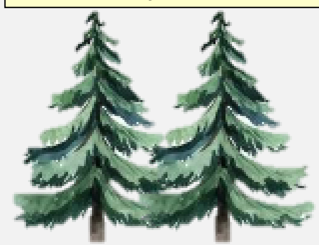
- To calculate the current average mass of logging residues (LR_A; t/yr dry matter, DM) potentially available for energy for Valle Camonica District (Northern Italy, Lombardy Region) starting from FMPs data;
- to quantify the potentially generated energy (heat, electricity; GJ/yr), potentially avoided natural gas consumption (m^3/yr standard conditions) and CO_2 emissions into the atmosphere (t/yr CO_2) for the final combustion process under the assumption that residues were used to feed the Organic Rankine Cycle Unit (ORC) of a local district heating plant.

- Public forests = 42000 ha (64% of total forest area);
- availability of forest stand level data (period 1984-2016);
- well developed forest-wood chain (6 forestry consorzia, 31 logging companies, 19 sawmills for primary wood processing, 1 centralized heating plant with ORC unit)

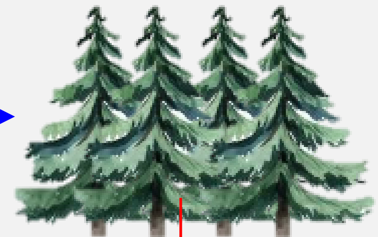


MATERIALS AND METHODS: THE MODEL «*WOODY BIOMASS AND CARBON ASSESSMENT*»

For each j-stand from the year in which the FMP entries into force until a predefined reference year



GAIN
(Gross annual increment)



LOSSES

SELF-THINNING
not available from FMPs

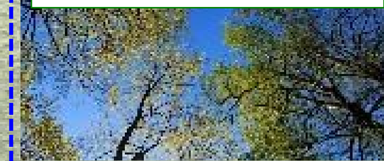
NATURAL DISTURBANCES
Possibly available from FMPs

HARVESTED MERCHANTABLE STEM VOLUME
available from FMPs

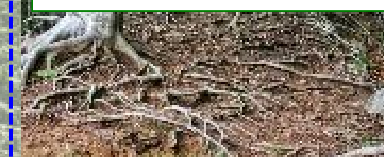
Gain-loss approach (IPCC Guidelines)

WOOD and C mass

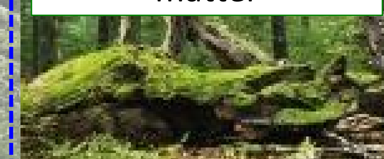
Aboveground biomass



Belowground biomass



Dead organic matter



MATERIALS AND METHODS: LOGGING RESIDUES CALCULATION – 1

For each stand: application of a recovery rate (η) to the past producible logging residues based on 6 availability factors

EACH FACTOR → CATEGORIES CLASSIFIED BY A QUALITATIVE LEVEL. EACH LEVEL DEFINED BY EMPIRICAL VALUE THAT REDUES THE MASS OF PRODUCIBLE RESIDUES THAT CAN BE AVAILABLE

Level	Value
Null	0.00
Low	0.25
Medium	0.50
High	0.75
Maximum	1.00

m	Availability factor	Category	Level	Weight
1	Stand's function	Recreation	0.00 (Null)	0÷1
		Protection	0.00 (Null)	
		Other	0.00 (Null)	
		Production	0.75 (High)	
2	Stand's management system	Coniferous high forest	0.25 (Low)	0÷1
		Mixed high forest	0.50 (Medium)	
		Broadleaves high forest	0.75 (High)	
		Coppice	1.00 (Maximum)	
3	Harvesting method	Tree Length	0.25 (Low)	0÷1
		Cut-to-length	0.50 (Medium)	
		Full Tree	1.00 (Maximum)	
4	Stand's accessibility	Insufficient (AC IV)	0.00 (Null)	0÷1
		Low (AC III)	0.25 (Low)	
		Medium-high (AC II)	0.75 (High)	
		Maximum (AC I)	1.00 (Maximum)	
5	Forest roads' transitability	Medium-low (TC III + IV)	0.25 (Low)	0÷1
		Medium-high (TC I + II)	0.75 (High)	
6	Energy market demand	Limited	0.25 (Low)	0÷1
		Good	0.50 (Medium)	
		Consistent	1.00 (Maximum)	

MATERIALS AND METHODS: LOGGING RESIDUES CALCULATION – 2

STAND'S ACCESSIBILITY *(Hippoliti and Piegai, 2000)*

	WOCAS v2 Accessibility class $AC_{(j)}$	Stand average slope $s_{(j)}$ (%)	Distance from road $d_{R(j)}$ (m) ≤ 1000	≤ 500	≤ 250	≤ 100	Altitude from road $d_{A(j)}$ (m)
HIGH	I	$s_{(j)} \leq 20$					-
MEDIUM	II	$20 < s_{(j)} \leq 40$	INSUFFICIENT				≤ 100
		$40 < s_{(j)} \leq 60$	INSUFFICIENT	INSUFFICIENT			≤ 100
LOW	III	$s_{(j)} > 60$	INSUFFICIENT	INSUFFICIENT	INSUFFICIENT		≤ 100

FOREST ROADS' TRANSITABILITY *(Lombardy Region, 2008)*

	Transitability class	Machines	Maximum load l_{max} (t)	Minimum width w_{min} (m)	Prevailing slope [a] s_p (%)	Maximum slope s_{max} (%) Natural bottom	Stabilized Bottom	Minimum turning radius tr (m)
MEDIUM-HIGH	I	Truck	25	3.5	≤ 10	12	16	9
	II	Tractors and trailers	20	2.5	≤ 12	14	20	8
MEDIUM-LOW	III	Small tractors	10	2.0	≤ 14	16	25	6
	IV	Small vehicles	4	1.8	> 14	> 16	> 25	< 6

Note: [a] not overcome for at least 70÷80% along the whole road.

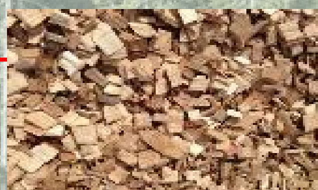
MATERIALS AND METHODS: LOGGING RESIDUES CALCULATION – 3

$$wv_{AVm} = v_{AVm} \cdot w_{AVm}$$

$$\eta = \sum_{m \to 1}^{6} wv_{AVm}$$

For each stand for each analyzed year

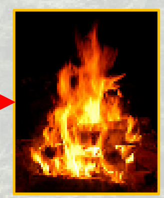
$$LR_A = LR_P \cdot \eta$$



ORC unit of a Local district heating plant

At the landscape level

ENERGY (GJ/yr)



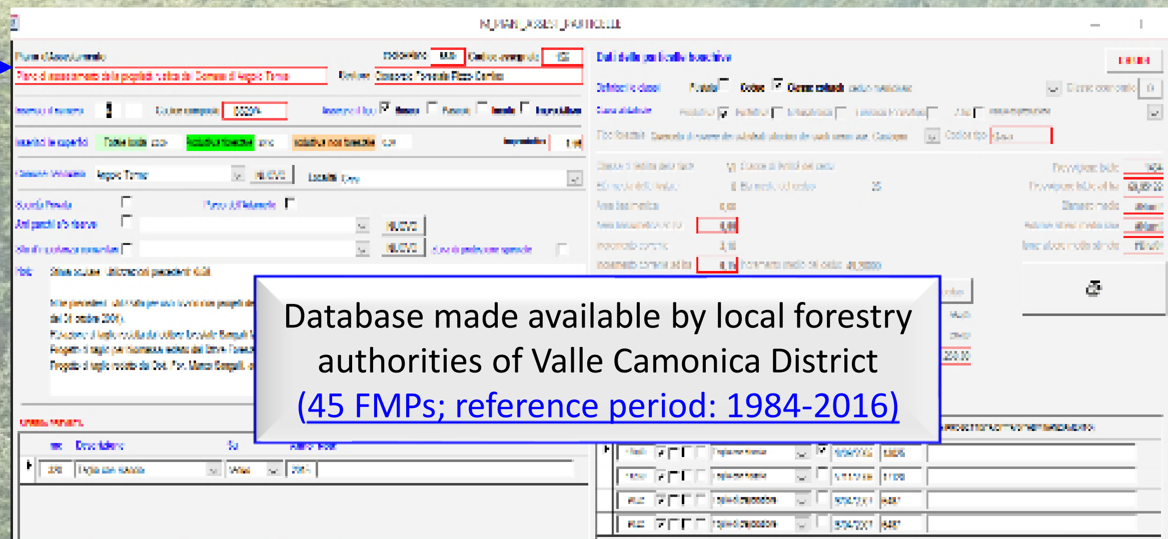
Substitution benefits

Avoided fossil fuel (m^3/yr Std cond.)

Avoided CO_2 emissions (t/yr CO_2)

FINAL COMBUSTION PROCESS ONLY

DATA COLLECTION AND ELABORATION – 1



Database made available by local forestry authorities of Valle Camonica District
(45 FMPs; reference period: 1984-2016)

DATA EXTRACTION

- stand's function;
- stand's management system;
- forest typology;
- forest area (ha);
- harvested merchantable stem volume (m^3) for each logging operation

Past scenario assessment

Current average mass of residues potentially available for energy

DATA COLLECTION AND ELABORATION – 2

Stand's accessibility and forest roads' transitability not available from FMPs

FMPs Data

Digital Elevation Model (SRTM-DEM 30 m)

Model WOCAS

GIS SOFTWARE

Stand annual producible residues

+

Stand elevation, slope, roads' characteristics

GIS GEOPROCESSING TOOLS

Subdivision of stands made up of different sub-stands (sub-polygons)

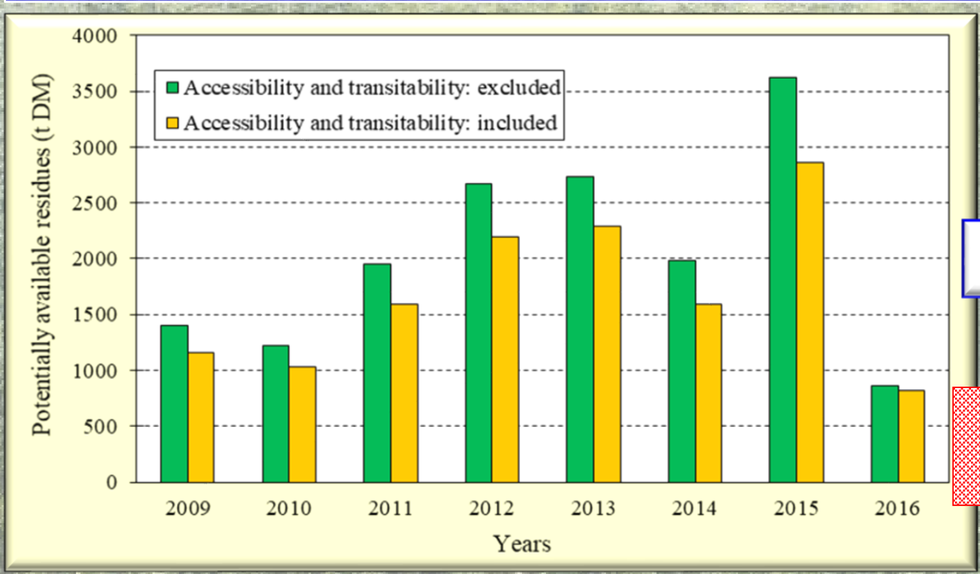
Calculation of producible residues, elevation, slope and roads' characteristics for each sub-polygon

Analysis of 2157 polygons (both stands and sub-stands)

Forest area: 36000 ha; analyzed period: 2009-2016 (data on forest roads not available before 2009)

RESULTS – 1

Past potentially available logging residues (annual cumulative values; landscape level)



Cumulative value for each year = sum of the value of potentially available residues of all the polygons

Harvesting method not considered (data not available)

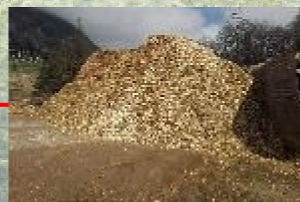
INCLUSION OF ACCESSIBILITY AND TRANSITABILITY: UNDERESTIMATION OF AVAILABLE RESIDUES (6-26%)

ASSUMPTIONS

1) Forests were sustainably managed; 2) forests have a specific age structure and mean tree volume

Current average mass of residues → Average value 2009-2015: $1.82 \cdot 10^3 \pm 6.61 \cdot 10^2$ t/yr DM

RESULTS – 2



Contribution of local residues on total energy generated by ORC unit only → Avoided natural gas consumption (m^3/yr std cond) → Avoided CO_2 emissions (t/yr CO_2)

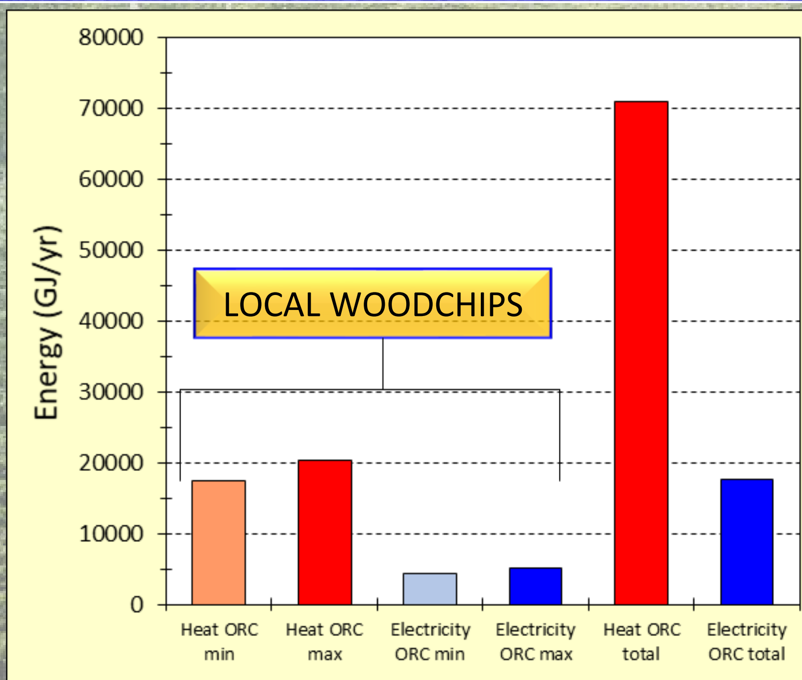
Current potentially generated energy *vs* plant generated energy (ORC unit only; ref. year 2019)

LOCAL WOODCHIPS (ORC unit Ponte di Legno Plant)

Type of energy	Potentially generated energy	Potentially avoided natural gas consumption	Potentially avoided CO_2 emissions into atmosphere
	($GJ \cdot yr^{-1}$)	($m^3 \cdot yr^{-1}$) (std. conditions)	($t \cdot yr^{-1}$ CO_2)
Heat	$1.74 \cdot 10^4 \div 2.04 \cdot 10^4$	$5.80 \cdot 10^5 \div 6.79 \cdot 10^5$	$1.14 \cdot 10^3 \div 1.34 \cdot 10^3$
Electricity	$4.30 \cdot 10^3 \div 5.03 \cdot 10^3$	$2.08 \cdot 10^5 \div 2.43 \cdot 10^5$	$4.22 \cdot 10^2 \div 4.94 \cdot 10^2$
Total	-	$7.88 \cdot 10^5 \div 9.22 \cdot 10^5$	$1.57 \cdot 10^3 \div 1.83 \cdot 10^3$

ORC nominal Thermal Power: 2.95 MW
ORC nominal Electric Power: 0.73 MW

IF ORC POWERED ONLY WITH LOCAL WOODCHIPS: AVERAGE POWER LOAD = 24%



CONCLUSIONS AND FUTURE PERSPECTIVES

- An innovative approach was presented to calculate the mass of available logging residues to use for energy generation (local scale) and tested for an Italian mountainous district;
- calculations performed by using the forest stand-level model WOCAS and GIS software to integrate FMPs data with information on landscape morphology;
- for the Case Study mass of available residues computed by considering a recovery rate based on 5 availability factor;
- mass of residues strongly depends on the value and weight of the availability factor: obtained results are the starting point for a more detailed analysis including also harvesting method;
- potentially avoided CO_2 emissions computed only for the final combustion process.

PERSPECTIVES

- Collection of data on the current harvested mass of residues and experimental tests to validate the results;
- definition of future potentially available mass of residues (different management scenarios).