Supplementary materials

Manuscript: Eco-efficiency of pellet production from dedicated poplar plantations

Tables S1, S2 and S3 show the main technical and economic elements applied to determine the hourly costs of each machine and equipment to produce wood chips. Table S1 and Table S2 refer to the machines and equipment used in harvesting and extraction for the HS1/HS2 systems and HS3/HS4 systems respectively. Table S3 refers to the chipping and wood chip handling machines used in all harvesting systems.

Table S1. Main technical and economic data of the poplar cultivation stage employed in the study.

			Machine				Equipment		Technical input			Economic input	
Operation	**Period (years)**	**Opera-tion (n./ha)**	**Power (kW)**	**Weight (kg)**	**Work time (h/ha)**	**Fuel (L/ha)**	**Machine (N.)**	**Weight (kg)**	**Type**	**Type**	**Quantity (kg)**	**Rates (kg/ha)**	**Cost (€/h)**	**Cost (€/ha)**
- Deep scarification	1	1	199	8700	3,50	136	1	800	Ripper				85.49	299.22
- Light ploughing	1	1	199	8700	1,60	67	1	1100	Ploughshares				89.84	143.74
- Basal Fertilization	1	2	59	3100	0,60	5	2	200	Fertilizer spreader	N-P-K	800	500 KP; 300N	38.07	222.84
- Cover Fertilization	6 or 3	1	59	3100	0,60	5	2	200	Fertilizer spreader	N	300	300N	38.07	132.23
- Mechanized transplantation	1	1	73	3800	4,00	39	1	380	Transplanter	Cuttings	n. 7000		102.00	2158.00
- Chemical weeding post-planting	1	1	59	3100	0,80	6	1	250	Sprayer	Goal	2,00		39.43	97.54
- Irrigation	1	1	59	3100	7,00	56	1	300	Pump and sprinkler	Water	400000		43.98	307.86
- Hoeing	18	1	59	3100	3,00	8	2	380	hoeing machine				38.82	116,46
- Harrowing	18	1	80	4100	1,20	14	1	500	Harrow				46.82	56.18
- Stump grinding at the end cycle	1	1	199	8700	6,00	173	1	500	Stump grinder				90.46	542.76

Table S2. Main technical and economic elements for calculating the hourly cost of machines and equipment used in felling (chipping) and extraction operations for HS1 and HS2.

Description	HS1			HS2		
	Tractor (felling)	**Disc saw (felling)**	**Tractor with grapple (wood extraction)**	**Modified forage harvester**	**Tractor x 2**	**High-sided trailer x 2**
Purchase price (€)	35,000	10,000	50,000	340,000	60,000	10,000
Salvage value (€)	6,440	2,000	9,440	67,520	11,400	1,680
Lifetime (y)	10	12	10	10	10	12
Average Annual Investment (€/y)	20,608	6,333	30,208	216,064	36,480	5,320
Total time (h)	10,000	3,600	10,000	10,000	10,000	3,600
Scheduled hours (h/y)	1,120	960	1,120	1,120	1,120	1,120
Productive hours (h/y)	1,000	300	1,000	1,000	1,000	300
Machine utilization	0.89	0.31	0.89	0.89	0.89	0.27
Daily machine utilization (h/day)	7.14	2.50	7.14	7.14	7.14	2.14
Engine Power (kW)	59	-	75	350	84	-
Interest rate	0.05	0.05	0.05	0.05	0.05	0.05
Fuel consumption (L/h)	6.86	-	8.72	45.76	10.98	-
Lubricants consumption (L/h)	0.37	-	0.41	1.15	0.44	0.21
Fuel price (€/L)	1.23	1.23	1.23	1.23	1.23	1.23
Lubricant price (€/L)	9.00	9.00	9.00	9.00	9.00	9.00
hourly Labour cost (€/L)	15.00	-	15.00	21.00	15.00	-
Labour time per year (days/y)	140	120	140	140	140	140
Labour time per day (h/day)	8	8	8	8	8	8
Depreciation rate	0.20	0.20	0.20	0.20	0.20	0.20
Load factor	0.40	-	0.40	0.45	0.45	-

Table S3. Main technical and economic elements for calculating the hourly cost of machines and equipment used in felling and extraction operations of whole trees for HS3 and HS4.

Description	HS3			HS4		
	Chainsaw (Felling)	**Tractor (extraction)**	**Winch (extraction)**	**Excavator with forest shear (felling)**	**Shear head (felling)**	**Skidder with rear grapple (extraction)**
Purchase price (€)	1,000	36,000	2,700	110,000	20,000	150,000
Salvage value (€)	200	6,640	540	21,200	4,000	29,400
Lifetime (y)	3	10	10	10	12	10
Average Annual Investment (€/y)	733	21,248	1,728	67,840	12,667	94,080
Total time (h)	2,100	10,000	5,000	12,000	9,600	10,000
Scheduled hours (h/y)	1,040	1,120	960	1,600	1,000	1,120
Productive hours (h/y)	700	1,000	500	1,200	800	1,000
Machine utilization	0.67	0.89	0.52	0.75	0.80	0.89
Daily machine utilization (h/day)	5.38	7.14	4.17	6.00	6.40	7.14
Engine Power (kW)	3	70	-	69	-	90
Interest rate	0.05	0.05	0.05	0.05	0.05	0.05
Fuel consumption (L/h)	1.13	10.17	-	13.03	-	13.07
Lubricants consumption (L/h)	0.51	0.40	0.21	0.40	0.21	0.45
Fuel price (€/L)	1.23	1.23	1.23	1.23	1.23	1.23
Lubricant price (€/L)	9.00	9.00	9.00	9.00	9.00	9.00
hourly Labour cost (€/L)	15.00	15.00	-	21.00	-	21.00
Labour time per year (days/y)	130	140	120	140	140	140
Labour time per day (h/day)	8	8	8	8	8	8
Depreciation rate	0.20	0.20	0.20	0.20	0.20	0.20
Load factor	0.55	0.50	-	0.65	-	0.50

Table S4. Main technical and economic elements for calculating the hourly cost of machines and equipment used in chipping and handling operations for relevant harvesting systems.

Description	HS1, HS3 and HS4			HS2
	Tractor (Chipping)	**Chipper (Chipping)**	**Forest loader (Chipping)**	**Tractor with shovel (Handling)**
Purchase price (€)	120,000	80,000	70,000	50,000
Salvage value (€)	23,100	15,400	13,640	9,440
Lifetime (y)	10	12	10	10
Average Annual Investment (€/y)	73,920	48,767	43,648	30,208
Total time (h)	10,000	9,600	8,000	10,000
Scheduled hours (h/y)	1,120	1,120	1,040	1,120
Productive hours (h/y)	1,000	800	800	1,000
Machine utilization	0.89	0.71	0.77	0.89
Daily machine utilization (h/day)	7.14	5.71	6.15	7.14
Engine Power (kW)	177	-	75	74
Interest rate	0.05	0.05	0.05	0.05
Fuel consumption (L/h)	25.71	-	8.72	8.60
Lubricants consumption (L/h)	0.69	0.21	0,41	0,41
Fuel price (€/L)	1.23	1.23	1.23	1.23
Lubricant price (€/L)	9.00	9.00	9.00	9.00
hourly Labour cost (€/L)	15.00	15.00	15.00	15.00
Labour time per year (days/y)	140	140	130	140
Labour time per day (h/day)	8	8	8	8
Depreciation rate	0.20	0.20	0.20	0.20
Load factor	0.50	-	0.40	0.40

Table S5. Main technical and economic elements of the wood chip and pellet transportation.

Description	**Truck (load 10 Mg)**	**TIR (load 28 Mg)**	**Van (max load 3.4 Mg)**
Purchase price (€)	170.000	220.000	28.000
Salvage value (€)	32.600	42.000	3.600
Lifetime (y)	12	12	12
Average Annual Investment (€/y)	103.233	133.000	11.400
Total time (h)	24.000	24.000	24.000
Scheduled hours (h/y)	2.400	2.400	2.400
Productive hours (h/y)	2000	2000	2000
Machine utilization (%)	0,83	0,83	0,83
Daily machine utilization (h/day)	6,7	6,7	6,7
Engine Power (kW)	350	537	95
Interest rate (%)	5,0%	5,0%	5,0%
Fuel consumption (L/h)	12,71	17,16	4,14
Lubricants consumption (L/h)	1,26	1,82	0,50
Fuel price (€/L)	1,76	1,76	1,76

Table S6. Main technical and economic elements of the biomass pelletising process, divided into individual production phases.

Description	**Rotary dryer**	**Refiner (hammer shredder)**	**Pelletiser**	**Cooler/ Packager**
Purchase value and installation (€)	52,700	17,000	20,400	34,000
Salvage value (€)	5,270	1,700	2,040	3,400
Useful life (year)	18	18	18	18
Annual usage (h/year)	7,680	7,680	7,680	7,680
Daily usage (h/day)	24	24	24	24
Annual usage (day/year)	320	320	320	320
Hourly pellet production (Mg/h)	0.500	0.500	0.500	0.500
Annual pellet production (Mg/year)	3,840	3,840	3,840	3,840
Power (kW)	53	22	30	5