

## Supplementary Information

### S1. Life cycle inventory

#### S1.1 Banana at-the-farm-gate

**Table S1.** Inventory of inputs and outputs per functional unit (1Ton) Banana at-the-farm-gate.

Inputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Algae (Laminaria), dried, consumption mix	1.72E-02	1.73E-02	kg	Product flow	Ecoinvent [34] Algae (Laminaria), dried, consumption mix - FR
Alkyl sulphate (C12-14)	1.24E-03	3.11E-05	kg	Product flow	Ecoinvent [34] market for alkyl sulphate (C12-14)   alkyl sulphate (C12-14)   APOS, U - GLO
Aminopyridine	1.18E-02	8.30E-03	kg	Product flow	Ecoinvent [34] market for aminopyridine   aminopyridine   APOS, U - RoW
Ammonium nitrate, as N	2.56E+0 0	1.40E+0 0	kg	Product flow	Ecoinvent [34] market for ammonium nitrate, as N   ammonium nitrate, as N   APOS, U - GLO
Ammonium sulfate, as N	9.85E-01	7.63E-01	kg	Product flow	Ecoinvent [34] market for ammonium sulfate, as N   ammonium sulfate, as N   APOS, U - GLO
Benzoic acid	1.06E-03	6.47E-02	kg	Product flow	Ecoinvent [34] market for benzoic acid   benzoic acid   APOS, U - RoW
Bipyridylium-compound	1.79E-02	6.68E-03	kg	Product flow	Ecoinvent [34] market for bipyridylium-compound   bipyridylium-compound   APOS, U - GLO
Butyrolactone	1.24E-03	1.57E-03	kg	Product flow	Ecoinvent [34] market for butyrolactone   butyrolactone   APOS, U - RoW

Calcium carbonate	4.12E-02	1.33E-02	kg	Product flow	Ecoinvent [34] market for calcium carbonate, precipitated   calcium carbonate, precipitated   APOS, U - RoW
Calcium nitrate	1.12E-04	7.56E-05	kg	Product flow	Ecoinvent [34] market for calcium nitrate   calcium nitrate   APOS, U - GLO
Chlorothalonil	1.22E-02	6.21E-03	kg	Product flow	Ecoinvent [34] market for chlorothalonil   chlorothalonil   APOS, U - GLO
Diammonium phosphate (DAP) (with 18% N, 46% P2O5)	1.80E+0 0	2.55E+0 0	kg	Product flow	Ecoinvent [34] Diammonium phosphate (18% N 46% P2O5), at plant (WFLDB 3.5) - RER
Dithiocarbamated-compound	1.33E-03	6.63E-03	kg	Product flow	Ecoinvent [34] market for dithiocarbamate-compound   dithiocarbamate-compound   APOS, U - GLO
Esters of versatic acid	2.13E-03	1.29E-01	kg	Product flow	Ecoinvent [34] market for esters of versatic acid   esters of versatic acid   APOS, U - RoW
Ethylene glycol	0.00E+0 0	2.00E-03	kg	Product flow	Ecoinvent [34] market for ethylene glycol   ethylene glycol   APOS, U - GLO
Fruit tree seedling, for planting	2.27E+0 0	2.84E+0 0	item	Product flow	Ecoinvent [34] market for fruit tree seedling, for planting   fruit tree seedling, for planting   APOS, U - GLO
Glyphosate	1.01E-02	9.76E-03	kg	Product flow	Ecoinvent [34] market for glyphosate   glyphosate   APOS, U - GLO
Limestone, crushed, for mill	1.49E+0 0	4.43E-01	kg	Product flow	Ecoinvent [34] market for limestone, crushed, for mill   limestone, crushed, for mill   APOS, U - RoW
Lubricant oil	5.37E-02	7.00E-02	kg	Product flow	Ecoinvent [34] market for lubricating oil   lubricating oil   APOS, U - RoW
Magnesium	1.77E-09	1.07E-09	kg	Product flow	Ecoinvent [34] market for magnesium   magnesium   APOS, U - GLO
Magnesium sulfate	3.15E-01	2.30E-01	kg	Product flow	Ecoinvent [34] market for magnesium sulfate   magnesium sulfate   APOS, U - GLO
Mancozeb	4.06E-02	3.92E-02	kg	Product flow	Ecoinvent [34] market for mancozeb   mancozeb   APOS, U - GLO

Nitrogen fertiliser, as N	1.20E-01	3.52E-01	kg	Product flow	Ecoinvent [34] market for nitrogen fertiliser, as N   nitrogen fertiliser, as N   APOS, U - GLO
Occupation, agriculture	2.42E+0 2	2.67E+0 2	m <sup>2</sup> *a	Elementary flow	-
Organic fertiliser, 3-2-3, granulate, packaged	2.28E+0 0	6.69E+0 0	kg	Product flow	Ecoinvent [34] Organic fertiliser, 3-2-3, granulate, packaged
Organophosphorus-compound, unspecified	6.64E-02	6.29E-02	kg	Product flow	Ecoinvent [34] market for organophosphorus-compound, unspecified   organophosphorus-compound, unspecified   APOS, U - GLO
Packaging film, low density polyethylene	1.18E+0 0	1.29E+0 0	kg	Product flow	Ecoinvent [34] market for packaging film, low density polyethylene - GLO
Pesticide, unspecified	1.43E-02	6.29E-03	kg	Product flow	Ecoinvent [34] market for pesticide, unspecified   pesticide, unspecified   APOS, U - GLO
Petrol, unleaded, burned in machinery	5.65E+0 0	5.49E+0 0	MJ	Product flow	Ecoinvent [34] market for petrol, unleaded, burned in machinery   petrol, unleaded, burned in machinery   APOS, U - GLO
Petrol, unleaded, burned in machinery	1.77E+0 1	1.83E+0 1	MJ	Product flow	Ecoinvent [34] market for petrol, unleaded, burned in machinery   petrol, unleaded, burned in machinery   APOS, U - GLO
Phosphate fertiliser, as P2O5	2.79E-04	4.80E-04	kg	Product flow	Ecoinvent [34] market for phosphate fertiliser, as P2O5   phosphate fertiliser, as P2O5   APOS, U - GLO
Piperidine	2.36E-02	1.53E-02	kg	Product flow	Ecoinvent [34] market for piperidine   piperidine   APOS, U - GLO
Plastic cork stopper, PA, at plant	9.95E-01	6.23E-01	kg	Product flow	Ecoinvent [34] Bag, LDPE, at plant   Plastic cork stopper, at plant - RER
Plastic film, PA, at plant	3.75E-01	4.20E-01	kg	Product flow	Ecoinvent [34] Plastic film, PA, at plant (ACYVIA) - RER
Plastic film, PA, at plant	1.30E-02	1.61E-02	kg	Product flow	Ecoinvent [34] Plastic film, PA, at plant (ACYVIA) - RER
Polypropylene, granulate	2.00E-01	7.47E-01	kg	Product flow	Ecoinvent [34] market for polypropylene, granulate   polypropylene, granulate   APOS, U - GLO

Polypropylene, granulate	1.55E-02	2.90E-02	kg	Product flow	Ecoinvent [34] market for polypropylene, granulate   polypropylene, granulate   APOS, U - GLO
Potassium chloride (with 60% K2O)	1.81E+0 1	1.79E+0 1	kg	Product flow	Ecoinvent [34] Potassium chloride (60% K2O), at plant (WFLDB 3.5) - RER
Potassium fertiliser, as K2O	1.91E-03	2.58E-03	kg	Product flow	Ecoinvent [34] market for potassium fertiliser, as K2O   potassium fertiliser, as K2O   APOS, U - GLO
Urea, as N	2.70E+0 0	4.77E+0 0	kg	Product flow	Ecoinvent [34] market for urea, as N   urea, as N   APOS, U - GLO
Water pump operation, diesel	3.50E+0 2	4.35E+0 2	MJ	Product flow	Ecoinvent [34] water pump operation, diesel   water pump operation, diesel   APOS, U - PE
Water, river	9.02E+0 1	1.25E+0 2	m <sup>3</sup>	Elementary flow	-

Outputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Ammonia	6,87E-01	1,06E+0 0	kg	Elementary flow	-
Banana at the farm gate	1,00E+0 0	1,00E+0 0	Mg	<b>Product flow</b>	-
Carbon dioxide	4,98E+0 0	7,80E+0 0	kg	Elementary flow	-
Chlorothalonil	5,05E-04	2,57E-04	kg	Elementary flow	-
Chlorothalonil	9,46E-04	4,81E-04	kg	Elementary flow	-
Chlorothalonil	5,28E-07	2,68E-07	kg	Elementary flow	-

Dinitrogen monoxide	3,46E-01	3,99E-01	kg	Elementary flow	-
Diquat	1,83E-04	6,60E-05	kg	Elementary flow	-
Diquat	5,76E-03	2,08E-03	kg	Elementary flow	-
Diquat	1,53E-10	5,51E-11	kg	Elementary flow	-
Fenpropidin	2,35E-02	1,53E-02	kg	Elementary flow	-
Glufosinate-ammonium	1,28E-03	1,15E-03	kg	Elementary flow	-
Glufosinate-ammonium	1,78E-05	1,59E-05	kg	Elementary flow	-
Glufosinate-ammonium	2,94E-06	2,64E-06	kg	Elementary flow	-
Glyphosate	1,83E-04	1,77E-04	kg	Elementary flow	-
Glyphosate	3,13E-03	3,03E-03	kg	Elementary flow	-
Glyphosate	4,35E-06	4,21E-06	kg	Elementary flow	-
Imidacloprid	3,27E-05	3,26E-05	kg	Elementary flow	-
Imidacloprid	1,02E-03	1,02E-03	kg	Elementary flow	-
Imidacloprid	2,08E-07	2,08E-07	kg	Elementary flow	-
Mancozeb	7,28E-04	7,05E-04	kg	Elementary flow	-

Mancozeb	2,86E-14	2,77E-14	kg	Elementary flow	-
Mancozeb	4,90E-15	4,76E-15	kg	Elementary flow	-
Metiram	2,38E-05	1,19E-04	kg	Elementary flow	-
Metiram	1,16E-10	5,77E-10	kg	Elementary flow	-
Metiram	2,12E-11	1,05E-10	kg	Elementary flow	-
Nitrate	4,81E+0 1	5,73E+0 1	kg	Elementary flow	-
Nitrogen oxides	7,26E-02	8,39E-02	kg	Elementary flow	-
Paraquat	1,58E-04	6,14E-05	kg	Elementary flow	-
Paraquat	4,97E-03	1,93E-03	kg	Elementary flow	-
Paraquat	1,32E-10	5,00E-11	kg	Elementary flow	-
Phosphate	1,60E-04	2,20E-04	kg	Elementary flow	-
Pyrimethanil	2,30E-04	1,62E-04	kg	Elementary flow	-
Pyrimethanil	9,55E-07	6,71E-07	kg	Elementary flow	-
Pyrimethanil	1,33E-07	9,35E-08	kg	Elementary flow	-
Spiroxamine	1,22E-02	3,41E-03	kg	Elementary flow	-

Terbufos	5,57E-05	3,43E-05	kg	Elementary flow	-
Terbufos	3,29E-04	2,03E-04	kg	Elementary flow	-
Terbufos	5,41E-08	3,33E-08	kg	Elementary flow	-
Thiamethoxam	5,73E-05	3,48E-03	kg	Elementary flow	-
Thiamethoxam	1,03E-03	6,27E-02	kg	Elementary flow	-
Triflusulfuron-methyl	3,22E-06	1,42E-05	kg	Elementary flow	-
Triflusulfuron-methyl	2,36E-06	1,04E-05	kg	Elementary flow	-
Triflusulfuron-methyl	1,49E-08	6,54E-08	kg	Elementary flow	-
waste polyethylene	1,08E+00	7,85E-01	kg	Waste flow	Ecoinvent [34] treatment of waste polyethylene, open dump, dry infiltration class (100mm)   waste polyethylene   APOS, U - GLO

S1.2 Banana at-the-packaging-stage-gate

**Table S2.** Inventory of inputs and outputs per functional unit (1Ton) Banana at-the-packaging-stage-gate

Inputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Alkylbenzene sulfonate, linear, petrochemical	8.11E-02	7.71E-02	kg	Product flow	Ecoinvent [34] market for alkylbenzene sulfonate, linear, petrochemical   alkylbenzene sulfonate, linear, petrochemical   APOS, U - GLO
Aluminium sulfate, powder	4.90E-02	4.76E-02	kg	Product flow	Ecoinvent [34] market for aluminium sulfate, powder   aluminium sulfate, powder   APOS, U - RoW
Ammonium chloride	5.71E-02	1.35E-02	Kg	Product flow	Ecoinvent [34] market for ammonium chloride   ammonium chloride   APOS, U - GLO
Banana at the farm gate	1.05E+0 0	1.05E+0 0	ton	Product flow	-
Benzimidazole-compound	1.24E-02	1.09E-02	kg	Product flow	Ecoinvent [34] market for benzimidazole-compound   benzimidazole-compound   APOS, U - GLO
Carton board box production	7.08E+0 1	8.12E+0 1	kg	Product flow	Ecoinvent [34] market for carton board box production, with gravure printing   carton board box production, with gravure printing   APOS, U - GLO
Chlorinated alkaline detergent, with gravure printing	1.68E-03	9.48E-03	kg	Product flow	Ecoinvent [34] Chlorinated alkaline detergent, for the meat industry, at plant - RER
Citric acid	1.56E-03	1.00E-03	kg	Product flow	Ecoinvent [34] market for citric acid   citric acid   APOS, U - GLO
Electricity, low voltage	1.59E+0 1	1.66E+0 1	kWh	Product flow	Ramirez, et al. [37] Electricity, at supply, 2018 mix - EC
Generic detergent-disinfectant	1.24E-02	4.17E-02	kg	Product flow	Ecoinvent [34] Generic detergent-disinfectant, at plant - RER

Hydrogen peroxide	4.55E-02	4.35E-03	kg	Product flow	Ecoinvent [34] market for hydrogen peroxide, without water, in 50% solution state   hydrogen peroxide, without water, in 50% solution state   APOS, U - RoW
Imidazole	4.13E-03	1.52E-03	kg	Product flow	Ecoinvent [34] market for imidazole   imidazole   APOS, U - GLO
Monochlorobenzene		2.62E-03	kg	Product flow	Ecoinvent [34] market for monochlorobenzene   monochlorobenzene   APOS, U - RoW
Non-ionic surfactant	2.57E-04	1.87E-02	kg	Product flow	Ecoinvent [34] market for non-ionic surfactant   non-ionic surfactant   APOS, U - GLO
Packaging film, low density polyethylene	2.00E+00	2.30E+00	kg	Product flow	Ecoinvent [34] market for packaging film, low density polyethylene   packaging film, low density polyethylene   APOS, U - GLO
Soybean oil, crude	2.41E-02	2.60E-02	kg	Product flow	Ecoinvent [34] market for soybean oil, crude   soybean oil, crude   APOS, U - GLO
Sulfuric acid	1.25E-01	9.26E+00	kg	Product flow	Ecoinvent [34] market for sulfuric acid   sulfuric acid   APOS, U - RoW
Tap water	4.04E+02	4.45E+02	kg	Product flow	Ecoinvent [34] market for tap water   tap water   APOS, U - PE
Vinyl acetate		1.10E-02	kg	Product flow	Ecoinvent [34] market for vinyl acetate   vinyl acetate   APOS, U - GLO

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Outputs

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Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Azoxystrobin		4,82E-05	kg	Elementary flow	-
Azoxystrobin		1,15E-03	kg	Elementary flow	-

Azoxystrobin		1,34E-07	kg	Elementary flow	-
Banana at the packaging stage gate	1,00E+00	1,00E+00	Mg	<b>Product flow</b>	-
Prochloraz	2,58E-04	1,93E-04	kg	Elementary flow	-
Prochloraz	8,92E-03	6,70E-03	kg	Elementary flow	-
Prochloraz	9,65E-07	7,24E-07	kg	Elementary flow	-
Rachis, after banana packaging	4,78E+02	3,27E+02	kg	Waste flow	(This study) Banana_Rachis disposal - EC

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S2. Final disposition of the rachis at the “Banana Packaging Stage”

For describe the three scenarios of the final disposal of the rachis, table S3 shows the inventory analysis of the "Rachis, after banana packaging".

**Table S3.** Inventory of inputs and outputs per 1 kg of “Rachis, after banana packaging”, for the RM0 scenario.

Inputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Rachis, after banana packaging	1	1	kg	Waste flow	(This study) Banana_Rachis disposal - EC
Outputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Dinitrogen monoxide	4,69E-4	3,21E-4	kg	Elementary flow	
Nitrogen oxides	9,85E-5	6,74E-5	kg	Elementary flow	
Waste wood, untreated	1	1	kg	Waste flow	Ecoinvent [34] treatment of waste wood, untreated, open dump, moist infiltration class (300mm)   waste wood, untreated   APOS, U

**Table S4.** Inventory of inputs and outputs per 1 kg of “Rachis, after banana packaging”, for the RM1 scenario.

Inputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Rachis, after banana packaging	1	1	kg	Waste flow	(This study) Banana_Rachis disposal - EC
Outputs					
Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Dinitrogen monoxide	4,69E-4	3,21E-4	kg	Elementary flow	
Nitrogen oxides	9,85E-5	6,74E-5	kg	Elementary flow	

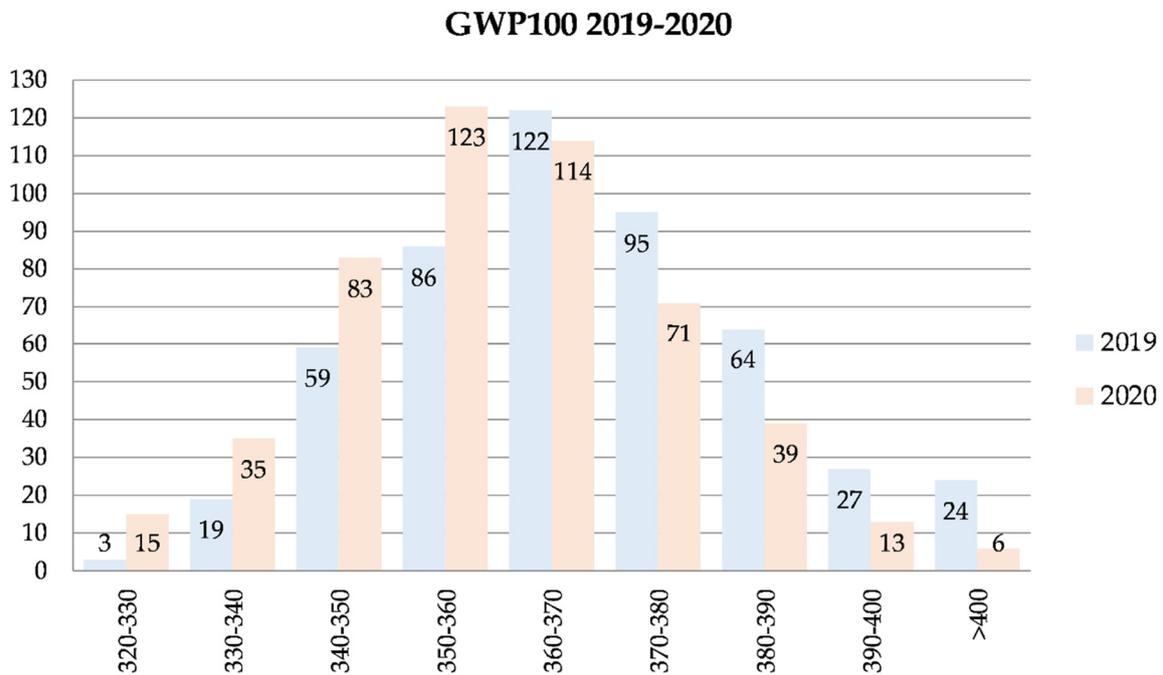
**Table S5.** Inventory of inputs and outputs per 1 kg of “Rachis, after banana packaging”, for the RM2 scenario.

Flow	Amount		Unit	Flow type	Life cycle inventory source
	2019	2020			
Rachis, after banana packaging	1	1	kg	Waste flow	(This study) Banana_Rachis disposal - EC

The first scenario (RM0) considered all inputs and outputs, including nitrogen emissions from the spine (dinitrogen monoxide and nitrogen oxides) and treatment (wood residues, untreated). The second scenario (RM1) considers all the inputs and outputs, and the nitrogen emissions from the spine. The third scenario (RM2) only includes all inputs and outputs, not counting the rachis. In the column of considered scenarios, indicate the scenario where the flow was used.

### S3. Uncertainty analysis

Figure S1 shows the results obtained in the uncertainty analysis, applying the Monte Carlo model. Performing 500 iterations, using OpenLCA software.



**Figure S1.** Histogram of the uncertainty analysis 2019-2020.

The uncertainty analysis was carried out for the Global Warming Potential (GWP100) category, at the "Banana Packaging Stage", for the RM0 scenario. The largest amount of iterations results are located in the range of 350-370 kg CO<sub>2</sub>-Eq/Ton banana. In 2019, an average of 367,85 kg CO<sub>2</sub>-Eq/Ton banana was obtained with a standard deviation of 17,77 kg CO<sub>2</sub>-Eq/Ton banana. In 2020, an average of 360,17 kg CO<sub>2</sub>-Eq/Ton banana was obtained with a standard deviation of 16,26 kg CO<sub>2</sub>-Eq/Ton banana.

According to the results of this study in 2019 (352 kg CO<sub>2</sub>-Eq/Ton banana), this is in the range of the uncertainty analysis (350.08-385.62 kg CO<sub>2</sub>-Eq/Ton banana). For the year 2020 (342 kg CO<sub>2</sub>-Eq/Ton banana), this is below the range of the uncertainty analysis (343.91-376.43 kg CO<sub>2</sub>-Eq/Ton banana).

### References

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37. Ramirez, A.D.; Boero, A.; Rivela, B.; Melendres, A.M.; Espinoza, S.; Salas, D.A. Life Cycle Methods to Analyze the Environmental Sustainability of Electricity Generation in Ecuador: Is Decarbonization the Right Path? *Renew. Sustain. Energy Rev.* **2020**, *134*, 110373, doi:10.1016/j.rser.2020.110373.