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EAAP + WAAP + Interbull Congress 2023

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Aligning carbon footprint estimates from different tools across Europe

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Sheep production in EUROPE: needs for mitigation policies

- **Sheep Production:** High potential for methane reduction due to low production levels and eterogenous farming systems worlwide compared to cattle

- **Emission quantification** can be performed with LCA (time consuming, only possible for few sample farms per area)

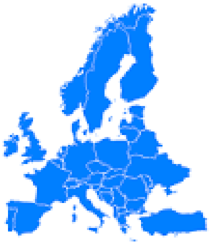
- **Policies for emission mitigation require:**
  - Broad inventories but performed at farm level
  - List of mitigation practices quantifying mitigation potentials and effectiveness

- **Policies at European Level require:**

  Alignement of tools to estimate impact at farm level across countries and farming systems

  Shared priorities across countries and farming systems for mitigation practices

Green Sheep objectives for emission quantification in sheep



Launch a national and European dynamic progress initiative to reduce greenhouse gas emissions while ensuring sustainability of sheep farms

Create the basis for an European observatory of environmental and sustainable performances of sheep production systems

Train technical staff on the use of the tools and environmental indicators

Today's Objective

To show how different tools available at country level and developed for specific regions can be aligned to perform comparable estimates

SIMPLIFIED LCA!!

CAP2ER
(Institute De L'elevage)

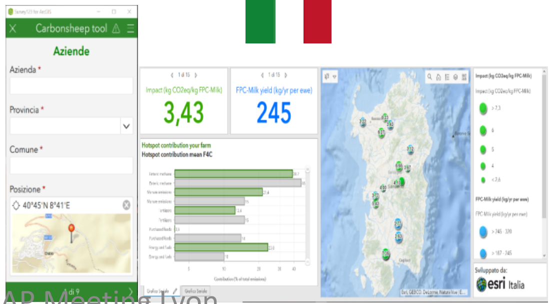
ARDI CARBON
(Batalla et al., 2015)

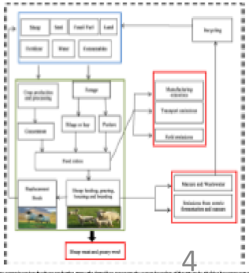
CarbonSHEEP
(Atzori et al., 2021)

SheepLCA
(O'Brien et al.,2015)

Figure 1.1. CAP'2ER registration widget.

Figure 1.5 Ardicarbon excel interface.





THE TOOLS: qualitative description (Atzori et al., 2021)

	Country	Production	Inputs (LCI), n	Detail Flock profile	Output Impact Categories	Approach IPCC	Crops and GHG coeficiencies	OUTCOMES
CAP2'ER (Institute elevage)	FRANCE	Milk/meat	82	Annual	ALL Imp. Cat. including Cseq.	Tier 2, IPCC 2019	Detailled	Software dashboard
ARDI CARBON (Batalla et al., 2014)	Spain	Milk/meat	83	Annual	ALL Imp. Cat. including Cseq.	Tier 2, IPCC 2019	Detailled	Spreadsheet
CARBON SHEEP (Atzori et al., 2017)	Italy	Dairy only	**25**	Annual	Only CFP	Tier 2, IPCC 2019	Generic	Webapp and GIS online
SHEEP LCA (O'Brien et al., 2015)	Ireland	Meat Only	100	Monthly	ALL Imp. Cat.	Tier 2, IPCC 2006	Medium choice	Spreadsheet

All the tools perform simplified LCA

TOOL COMPARISON: data collection and analysis

Tool	Farms
France	3 milk/3 meat
Italy	3 milk/3 meat
Spain	3 milk/3 meat
Ireland	n.a. /3 meat
Romania	3 milk/ n.a.

Farms	Runs (each farm x 4 tools)
12 dairy	48 dairy
12 meat	48 meat
24 total	96 total

Assumptions:

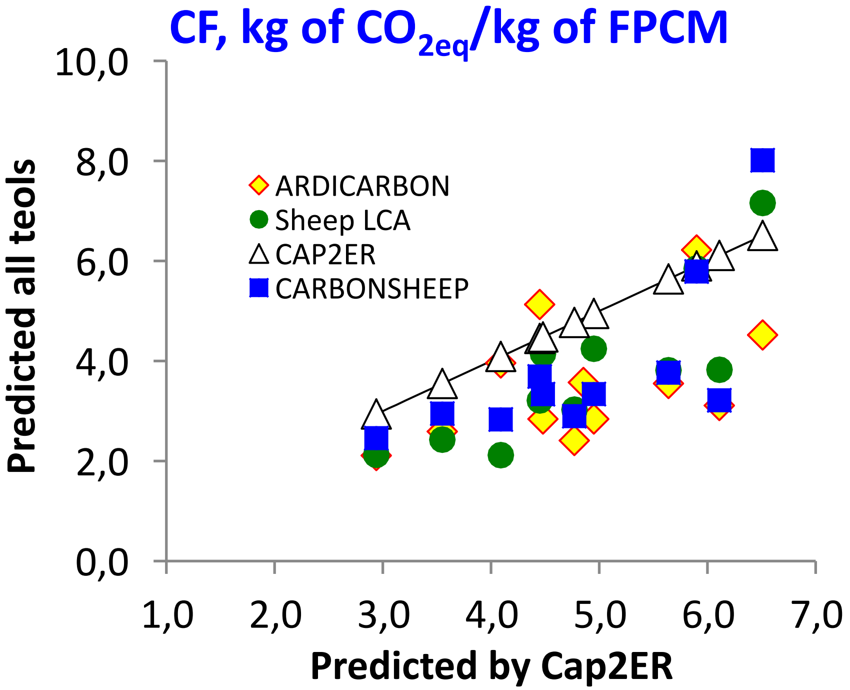
- ✓ Mixed and Specialized farming systems both in milk and meat farms
- ✓ Farms were randomly selected, not country average
- ✓ Comparison w/out a reference values, no complete LCA
- ✓ Equal input and outputs in all tools

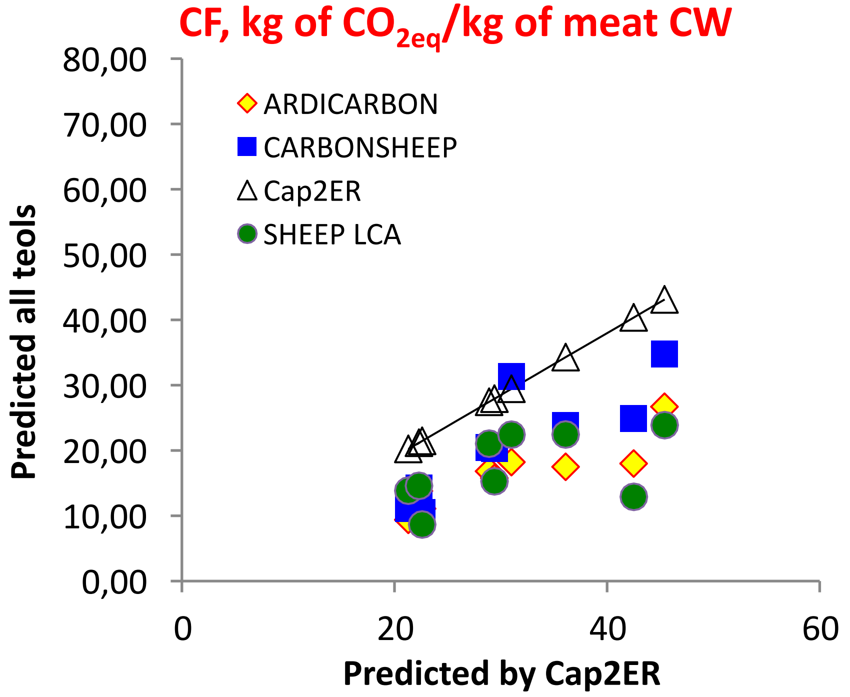
DATASET DESCRIPTION

		Ewes n°	Land ha	Milk/ewe L/yr	Stock rate ewe/ha	Purch. feeds kg/ewe	Fertilizers kg/ha	Fuel Kg/ha	Eletricity Kwh/yr
DAIRY FARMS (n=12)	Mean	497	185	202	6.1	137	78	101	10640
	SD	444	426	131	3.0	45	78	120	8850
	Max	1900	1600	479	12.9	205	352	432	27600
	Min	132	14	16	1.2	58	0	1	420
				Meat per ewe, kg/yr					
MEAT FARMS (n=12)	Mean	746	89	33	8.4	112	67	76	2265
	SD	692	56	12	5.4	79	142	122	2743
	Max	2214	172	51	21.1	263	114	136	8925
	Min	104	15	17	1.1	27	0	26	0

Before alignment: Carbon Footprint (GW) estimates, Meat Farms

CAP2'ER was assumed as equivalence line





RMSPE: 28-35% of CF for C2ER vs others

Main differences:

- Methane emissions
- Manure estimates
- Feed purchased and emission coefficients

RESULTS: Comparison of estimates per each hotspot,

	Kg of CO_2eq/kg of FPCM		Kg of CO_2eq/kg of Carcass Weight	
	Country*	**Tool***	**Country***	**Tool***
CF	<0.001	**0.01**	<0.001	**<0.001**
Allocation	NS	**<0.001**	-	-
Enteric methane	0.05	**NS**	<0.001	**<0.001**
Manure emiss.	**NS**	**<0.001**	**<0.01**	**<0.001**
Crop& fertilizers	NS	<0.01	<0.01	0.03
Feed purchased	**<0.01**	**0.01**	**NS**	**NS**
Electricity	0.05	<0.001	0.01	NS
Fuel	0.06	NS	<0.001	NS

*Interaction Country x tool: not significative

Relevant Differences for approach

Small Differences due to emission coefficients

DIFFERENCES: Methane and manure emissions

	CAP2ER	ARDI CARBON	CARBON SHEEP	SHEEP LCA
Methane GEI x Ym	Sauvant and Noziere (2013) Intake Level and PCO; dairy data	Geographical approach (Fedna, Cambra Lopez et al., 2008)	IPCC, 2019; Vermorel (2008)	IPCC 2019
Intake	Forage intake + Purchased concentrates	NE req/NE diet value	Pulina et al., 1991	INRA, 1989

Alignment proposal

Tool building phase (Task 2) for improvement:

- **Input:** combined input collection from each tool

- **Enteric and Manure**: align intake algorithms → estimation of CH_4 and N emissions
- **Manure**: check for excretion and align emission coefficients
- **Fuel**: align emission coefficients
- **Crops**: align land type and emission coefficients
- **Fertilizers:** align fertilizers choice
- **Purchased feed**: align inventories of emission coefficients

- **Electricity**: consider electric mix, not possible align emission coefficients

Align equations for FPCM and allocations .

Functional units and Allocation

GWP Conversion:

Methane: 27.9 CO_{2eq} and N_2O: 273 CO_{2eq} (IPCC, 2021)

Functional units:

Meat: Carcass weight: (breed coefficients of carcass yield)

Milk: Fat and protein corrected milk from Pulina and Nudda (2005) or INRA (2018)

Allocation method for milk:

- Biophysical based on nutritional requirements

- IDF (2015) → All, % 1-6.04 *(meat/milk)

Methane emissions: 2 options

- IPCC dairy cattle approach
- GEI = DMI intake X 18.45 MJ/kg of DM X Ym (6.7% sheep)

DMI =

Pulina 2013; or INRA 2018;

Adoption of Ym that varies with Digestibility like cattle?

Methane from Intake level:
(Sauvant and Noziere 2013)
(CAP2ER)

CH_4 (g/kg Digestible Organic Matter) =

$45,2 – 6,66*IL + 0,75*IL^2$

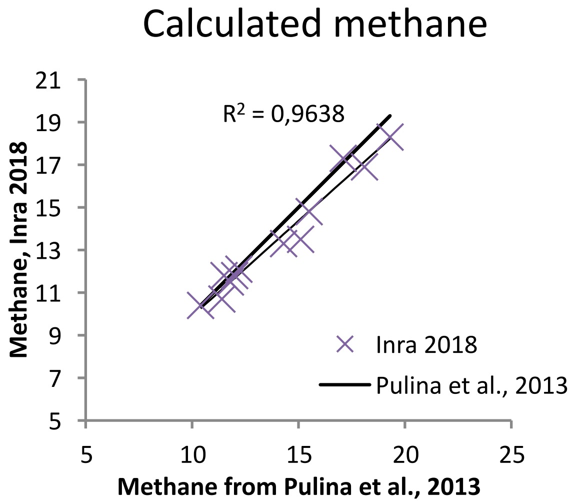
$+ 19,65*Con\% – 35*Con\%$

$- 2,69*IL*Con\%$

Consistent also with Vermorel (2008)

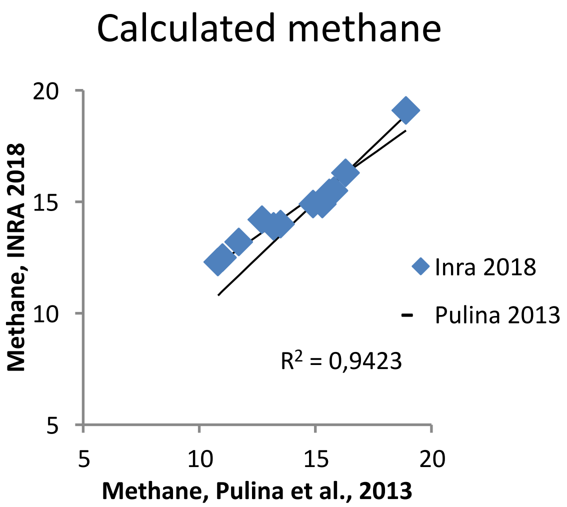
Dairy farm intake and methane emission comparison

Farm Name	Pulina et al., 2013				INRA 2018			
	Ewes DMI	**Ewes CH4**	**Rams CH4**	**Replacem. sheep CH4**	**Ewes DMI**	**Ewes CH4**	**Rams CH4**	**Replacem. sheep CH4**
	kgMS/year	kgCH4/year	kgCH4/year	kgCH4/year	kgMS/year	kgCH4/year	kgCH4/year	kgCH4/year
FR_Cas-type OL PA04	720.9	15.5	9.1	8.3	675.1	14.8	9.7	10.5
FR_Cas-type OL ROQ02	923.5	19.3	14.8	9.9	863.4	18.3	14.6	12.3
FR_Cas-type OL ROQ03	848.5	18.1	15.0	10.0	772.0	16.9	14.7	12.3
IT Arca Farm	573.3	12.2	14.3	5.8	567.3	12.1	13.1	8.5
ITCugusi Farm	558.6	12.0	14.5	6.6	548.0	11.8	13.5	9.0
IT_Farm Manconi	544.5	11.5	13.2	3.8	561.9	11.8	13.5	7.2
IT_ Farm Riu	545.8	11.8	14.5	6.3	530.6	11.5	13.6	8.8
RO_Chicos	511.4	11.4	17.0	9.2	463.3	10.7	14.9	11.4
RO_Dambovita	462.8	10.4	13.4	0.0	461.8	10.4	12.5	0.0
RO_Ovis	685.3	15.1	21.9	11.8	582.6	13.5	18.9	14.2
SP_CL1	768.0	0.0	0.9	0.0	924.6	0.0	7.2	0.0
SP_CL3	971.9	17.1	18.6	6.6	980.7	17.3	18.0	10.1
SP_PV1	650.1	14.3	16.3	7.4	586.9	13.3	14.6	9.6
Average	**674.2**	**13.0**	**14.1**	**6.6**	**655.3**	**12.5**	**13.7**	**8.8**



Meat farms intake and methane comparison

	Pulina et al., 2013		INRA 2018	
Farm name	DMI kgMS/ewe/year	Sheep CH4 kg CH4/ewe/year	DMI kgMS/ewe/year	Sheep CH4 kg CH4/ewe/year
FR_Céréalier Ovin fourrager intensif	885	18.9	898	19.1
FR_Préalpin spécialisé sédentaire	682	14.9	687	14.9
FR_Spécialisé Semi-extensif zone défavorisée	750	16.3	754	16.3
IR_13512	701	15.3	676	14.9
IR_21121	717	15.6	702	15.4
IR_26270	739	15.8	721	15.5
SP_MP	618	13.5	651	14.0
SP_PZ	632	12.7	717	14.2
SP_SI S.C.	606	13.2	646	13.9
IT D'agostino	556	11.7	651	13.2
IT MACRINI	526	11.0	618	12.5
IT FARINDOLAGRI	521	10.8	609	12.3
Average	**661.1**	**14.1**	**694.1**	**14.7**



Manure emissions:

Methane: equation 10.23 IPCC 2019:

$EF = (VS \times 365) \times (B0 \times 0{,}67 \times \sum MCF/100 \times \%\ MS\ (\text{management system}))$

Nitrogen balance

- Excreted = Intake - requirements
- Decandia et al. (2013)
- Fixed values of Nitrogen excretion per head

IPCC, 2019

Emission factors

Based on manure management system

Detailed as much as possible!

Other emission coefficients

Fertilizers:

Direct: 1% N losses as $N\text{-}N_2O$ + Nvol + Nres + N leach → Ipcc, 2019;
Indirect: 3.22 kg of CO2 eq/ kg of N, P, K.

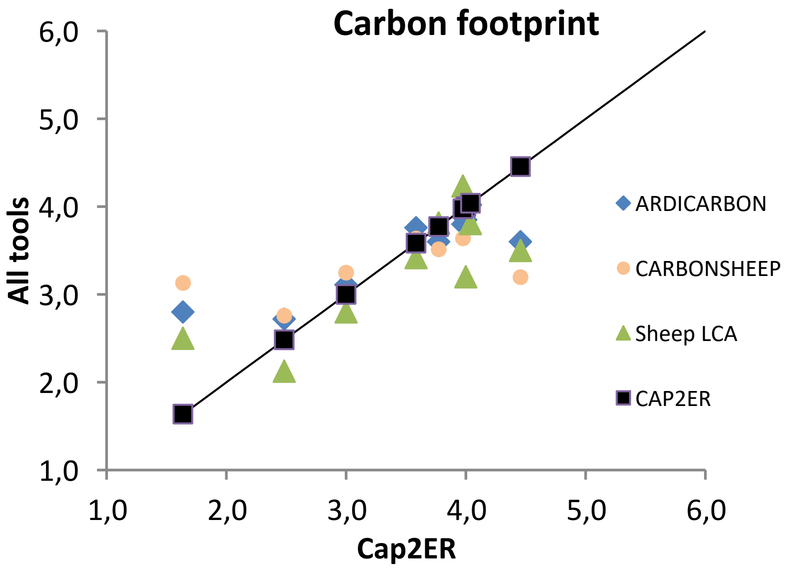
Purchased feeds: aligned to AgriBalyse 3.1 or Ecoinvent

Diesel: 3.25 kg CO_{2eq}/kg fuel

Energy kg CO_2/kWh: España: 0,3278, France: 0,0855; Italy : 0,3745, Rumanía: 0,4505

Plastic, Machinery, facilites : not considered, cut-off 1%

Simulation with aligned tools for dairy farms



	CAP2ER	ARDICARBON	CARBONSHEEP	SHEEP LCA
CF_kgFPCM	**4.21**	**4.24**	**4.14**	**3.99**
ENTERIC	2.35	1.68	2.35	2.11
MANUR	0.54	0.37	0.52	0.37
CRP&fer	0.50	0.58	0.34	0.44
FEEDpurch	0.83	0.45	0.60	0.27
Electricity	0.0044	0.04	0.04	0.04
Fuel	0.22	0.30	0.27	0.28

Differences in CF: 1 - 5%

Conclusions

- Alignment can include IPCC (2019) values and equations specifically developed for sheep in European countries
- Alignment would allow reducing differences in estimates among countries
- More evaluations need to be done at territorial level to fit all the production systems and cases
- For the use of software within countries the original more flexible models can be still used
- Is needed a broad agreement amogn institutions to agree on equation changes in order to proceed in common way (

Join Life Green Sheep for networking or follow up projects!

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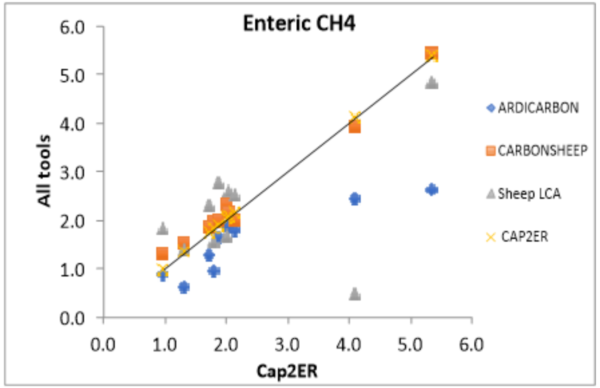
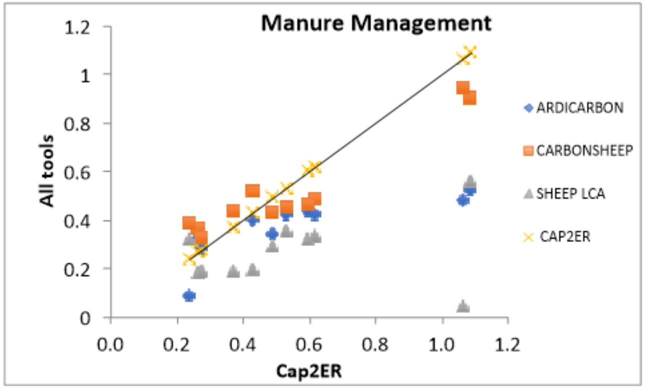
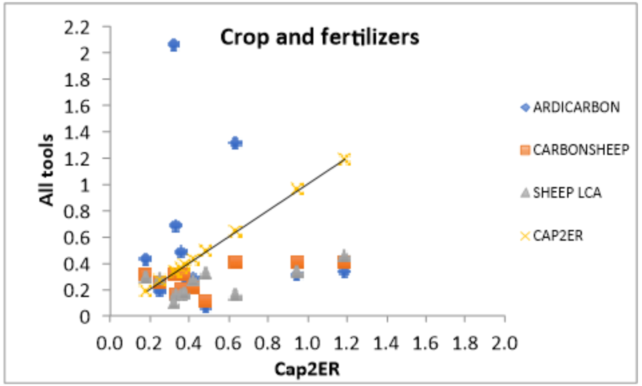
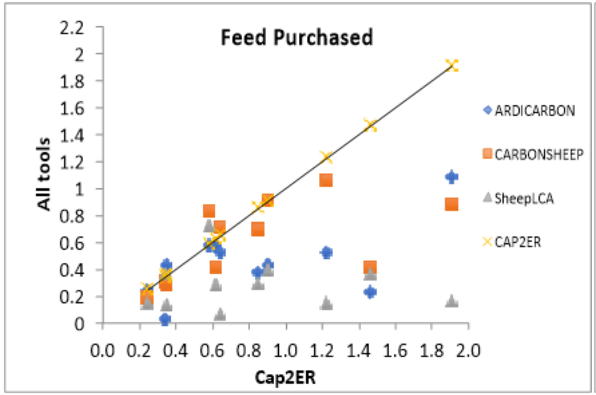
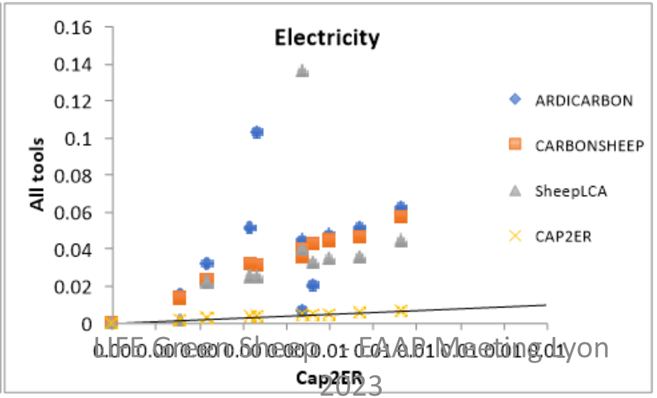
Simulation aligned Dairy Farms

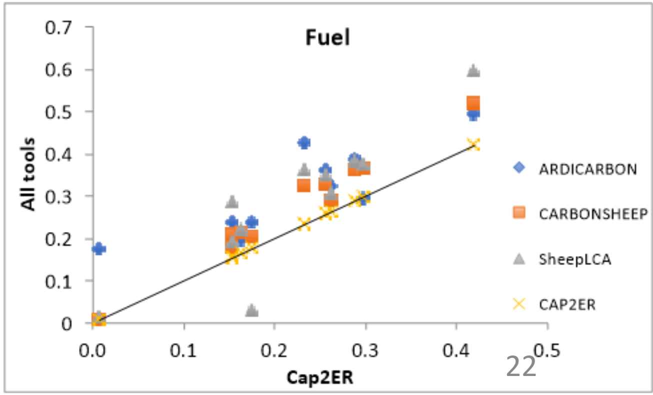












NEXT: Tool building phase for improvement

Input: → Combine input collection

Animal: → Align intake algorithms → N excretion

Fuel, **Crops**, **Fertilizers**, **Purchased feed**, **Energy** → Align type and emission coefficients

Implications for territorial application (demonstration) and Environmental plan

- ✓ Alingned tools → comparable estimates across countries with different tools for territorial inventories with farm level inputs
- ✓ Common estimation approach (tools?) in sheep supply chains
- ✓ Put the basis for environmental observatory on good practices, flexible tools at European level → Territorial inventories → planning for effective mitigation.

RESULTS: Comparison of estimates per each hotspot, Dairy Farms

Kg of CO_2eq/kg of Carcass Weight

	France	Italy	Spain	Cap2 Er	ARDI Carbon	Carbon Sheep	Sheep LCA	SEM	Country	Tool	TxC	Rom*
CF	**2.85 b**	**3.90a**	**4.15a**	**4.69 a**	**3.20 b**	**3.43 ab**	**3.34 b**	0.19	**<0.001**	**0.01**	**NS**	**10.96**
Allocation	0.84	0.86	0.84	0.89 b	0.69 c	0.95 a	0.86 b	0.02	0.39	**<0.001**	NS	0.75
Enteric methane	1.46 b	2.06 a	1.84 ab	1.87	1.50	2.04	1.84	0.11	0.05	**NS**	NS	5.65
Manure emiss.	0.49 b	0.68 a	0.58 ab	1.32 a	0.32 b	0.48 b	0.24 b	0.08	NS	**<0.001**	NS	1.28
Crop& fertilizers	0.31	0.29	0.34	0.43 ab	0.54 a	0.05 b	0.22 ab	0.05	NS	**<0.01**	NS	0.62
Feed purchased	0.30 b	0.52 ab	0.74 a	0.86 a	0.41 bc	0.58 ab	0.23 c	0.06	<0.01	**0.01**	NS	3.23
Electricity	0.03 b	0.05 a	0.03 b	0.004 b	0.044 a	0.043 a	0.044 a	0.00	0.05	**<0.001**	NS	0.00
Fuel	0.27	0.28	0.18	0.22	0.26	0.25	0.25	0.02	0.06	NS	NS	0.25

Tool evaluation

CARBON FOOTPRINT

P-O	C2E-AC	C2E-CS	AC-CS	C2E-SLCA	AC-SLCA	CS-SLCA
RMSPE	1.71	1.49	1.23	1.44	1.34	0.60
	35%	31%	25%	30%	28%	12%

Main differences in:
- Manure estimates
- Emission coeff.

*Romania: excluded from statistics, errated estimates

RESULTS: Comparison of estimates per each hotspot, meat farms

Kg of CO_2eq/kg of Carcass Weight

	France	Ireland	Spain	CAP2 ER	ARDI Carbon	Carbon Sheep	Sheep LCA	SEM	Country	Tool	C x Tool
CARBON FOOTPRINT	27.4 a	22.6 b	14.5 c	31.1a	16.4b	21.3b	17.2 b	1.50	<0.001	**<0.001**	**NS**
Enteric methane	16.7	13.0	8.8	17.3 a	9.2 b	13.9 ab	11.1 b	0.33	<0.001	**<0.001**	**NS**
Manure emissions	4.5	2.7	3.1	6.6 a	2.4 bc	3.6 b	1.2 c	0.01	<0.01	**<0.001**	**NS**
Crop& fertilizers	2.2 a	2.6a	0.41 b	2.6 a	2.3 ab	0.4 b	1.7 ab	0.96	<0.01	0.03	NS
Feed purchased	2.1	1.6	1.3	1.3	1.6	2.0	1.8	0.15	NS	NS	NS
Electricity	0.07 ab	0.10 a	0.004 b	0.1	0.0	0.1	0.1	0.12	0.01	**NS**	**NS**
Fuel	1.9 a	0.7 b	0.8 b	0.9	1.1	1.2	1.3	0.44	<0.001	0.49	NS

	P-O	C2E-AC	C2E-CS	AC-CS	C2E-SLCA	AC-SLCA	CS-SLCA
CARBON FOOTPRINT	RMSPE, Kg of CO2eq	**14.8**	**10.8**	**4.6**	**15.7**	**3.7**	**6.5**

Difference similar to dairy (30% of CF)

LIFE19 CCM/FR/001245 - LIFE GREEN SHEEP

LIFE Green Sheep

Demonstration and dissemination actions to reduce the carbon footprint in sheep farming

Coordinated by: Institute de L'elevage, Paris (P.I.: Dr. S. THROUDE)

https://www./life.green.sheep/

INSTITUT DE L'ELEVAGE idele

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Life

uniss UNIVERSITÀ DEGLI STUDI DI SASSARI agraria DIPARTIMENTO DI AGRARIA

Demonstration and dissemination actions to reduce the carbon footprint in sheep farming

Coordinated by: Institute de L'elevage, Paris (P.I.: Dr. S THROUDE)

https://www./life.green.sheep/

LIFE GREEN SHEEP IS:

5 years
European project, from October 2020 to September 2025

€ 4,6 M
budget

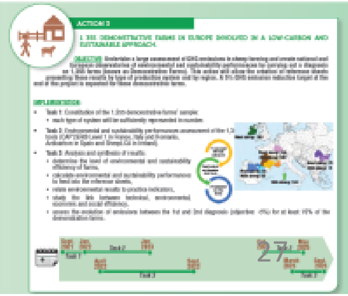
1 355
demonstrative farms involved

40 partners from
5 European countries

Reduce by **12 %**
GHG emissions while maintaining farms' sustainability

282
innovative farms involved in the implementation of action levers

France, Spain, Italy, Romania, Ireland



Before alignment: Carbon Footprint (GW) estimates, Meat Farms

	CAP2 ER	ARDI Carbon	Carbon Sheep	Sheep LCA
Carbon footprint	31.1 a	16.4 b	21.3 b	17.2 b
SD	8.8	5.0	8.5	5.3

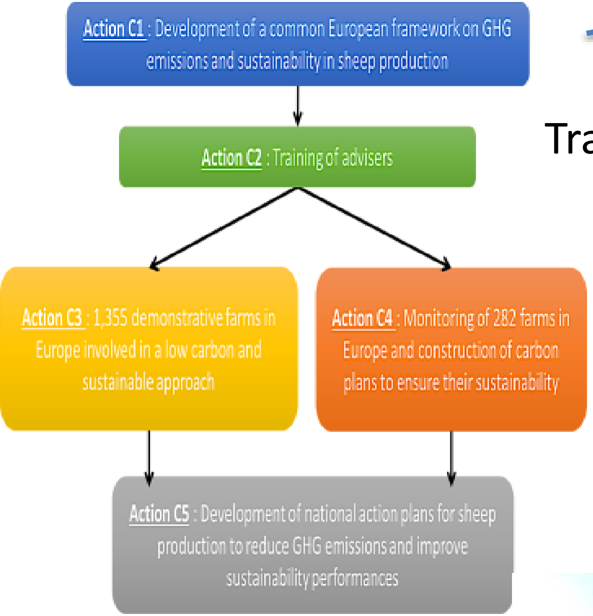
P =<0.001

RMSPE: 28-35% of CF C2ER vs others

Main differences:

- Methane emissions
- Manure estimates
- Feed purchased coefficients

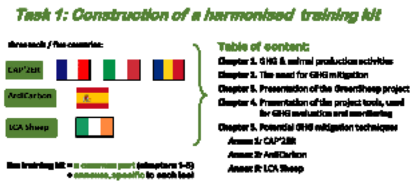
Green Sheep project's actions



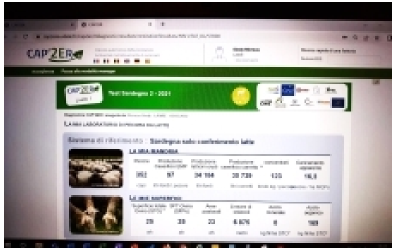
This work

Set up comparable tools

Training of technical staff (> 300)



Good practices:
Demonstration 1355 farms
Monitoring 282 farms



Action plans,
National,
European

Aligned
monitoring and
mitigation policies

Action C	Tasks
C1 : Development of a common European framework on GHG emissions and sustainability in sheep production	1-Development of a common carbon footprint assessment methodology
	2-Development of a common sustainability assessment
	3-Tools update and building up
	4-Common GHG mitigation synthesis

Objectives of the action

- This action will allow to perform farms assessment and development of a common framework composed of innovative practices aiming at reducing GHG emissions and increasing carbon sequestration while ensuring farms sustainability.
- Develop :
  - Task 1: build a common methodology on carbon footprint (task 1),
  - Task 2: environmental impacts and socio-economic indicators assessment (task 2),
  - Task 3 and propose specific tool updates to fit production context in France, Ireland, Italy, Romania and Spain
  - Task 4: identify list of promising mitigation practices

Deliverable 1: Methodology assessment: completed, to be checked with all partners

Deliverable 2: Common methodology: on draft (Task 2, 3 and 4) to be completed by en

Main Objective

To compare different tools available at country level and developed for specific regions:

- Qualitative features of tools
- Quantitative estimates

SIMPLIFIED LCA!!

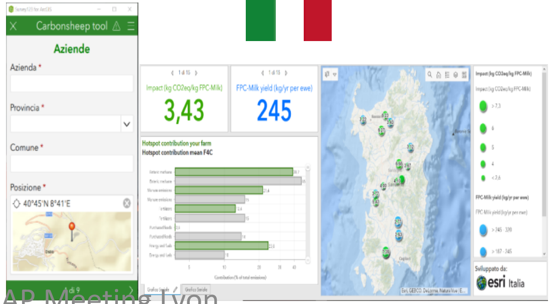
CAP2ER
(Institute De L'elevage)

Figure 1.1. CAP'2ER registration widget.

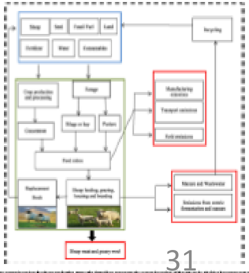
ARDI CARBON
(Batalla et al., 2015)

Figure 1.5 Ardicarbon excel interface.

CarbonSHEEP
(Atzori et al., 2021)



SheepLCA
(O'Brien et al.,2015)



TOOL COMPARISON: data collection

Tool	Farms
France	3 milk/3 meat
Italy	3 milk/3 meat
Spain	3 milk/3 meat
Ireland	n.a. /3 meat
Romania	3 milk/ n.a.

Farms	Runs (each farm x 4 tools)
12 dairy	48 dairy
12 meat	48 meat
21 total	96 total

Assumptions:

- ✓ Farms were randomly selected, not country average
- ✓ Comparison w/out a reference values, no complete LCA
- ✓ Equal input and outputs in all tools

DATASET DESCRIPTION

DAIRY FARMS (n=12)

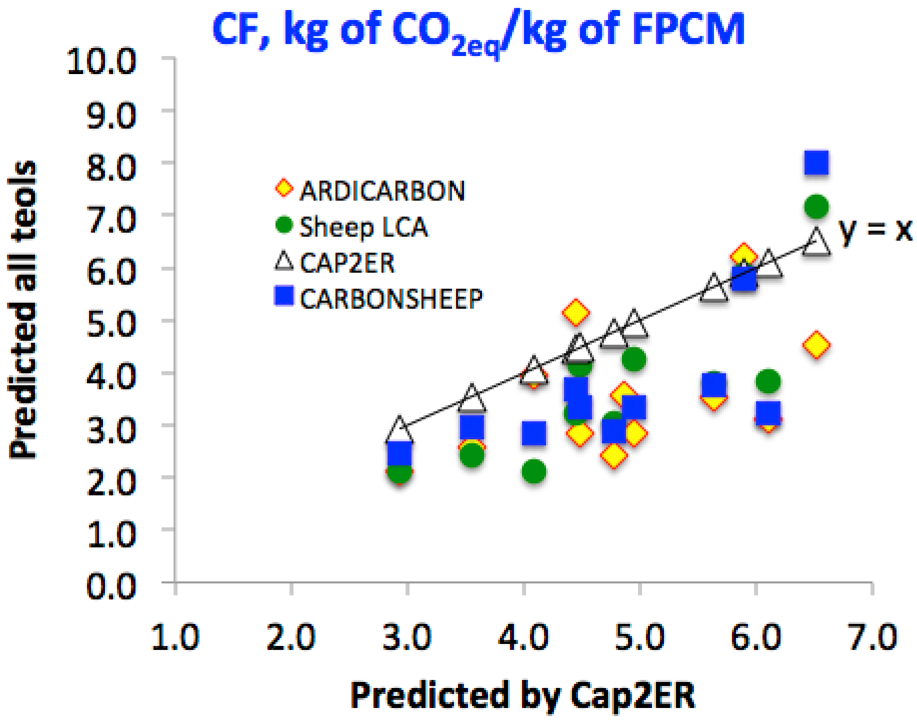
	Ewes n°	Land ha	Milk/ewe L/yr	Stock rate ewe/ha	Purch. feeds kg/ewe	Fertilizers kg/ha	Fuel Kg/ha	Eletricity Kwh/yr
Mean	497	185	202	6.1	137	78	101	10640
SD	444	426	131	3.0	45	78	120	8850
Max	1900	1600	479	12.9	205	352	432	27600
Min	132	14	16	1.2	58	0	1	420

MEAT FARMS (n=12)

			Meat per ewe, kg/yr					
Mean	746	89	33	8.4	112	67	76	2265
SD	692	56	12	5.4	79	142	122	2743
Max	2214	172	51	21.1	263	114	136	8925
Min	104	15	17	1.1	27	0	26	0

Mixed and Specialized farming systems both in milk and meat farms

RESULTS: Comparison of Carbon Footprint (GW) estimates, Dairy Farms



TOOL	CAP2 ER	ARDI CARBON	CARBON SHEEP	Sheep LCA
Carbon footprint	4.85 a	3.57 ab	3.84 b	3.69 b
SD	1.11	1.27	1.64	1.58

P =0.01

Main differences:

Manure estimates higher in CAP2ER

Feed purchased

CAP2'ER was assumed as equivalence line

RESULTS: Comparison of estimates per each hotspot, Dairy Farms

Kg of CO_2eq/kg of Carcass Weight

	France	Italy	Spain	Cap2 Er	ARDI Carbon	Carbon Sheep	Sheep LCA	SEM	Country	Tool	TxC	Rom*
CF	**2.85 b**	**3.90a**	**4.15a**	**4.69 a**	**3.20 b**	**3.43 ab**	**3.34 b**	0.19	**<0.001**	**0.01**	**NS**	**10.96**
Allocation	0.84	0.86	0.84	0.89 b	0.69 c	0.95 a	0.86 b	0.02	0.39	**<0.001**	NS	0.75
Enteric methane	1.46 b	2.06 a	1.84 ab	1.87	1.50	2.04	1.84	0.11	0.05	**NS**	NS	5.65
Manure emiss.	0.49 b	0.68 a	0.58 ab	1.32 a	0.32 b	0.48 b	0.24 b	0.08	NS	**<0.001**	NS	1.28
Crop& fertilizers	0.31	0.29	0.34	0.43 ab	0.54 a	0.05 b	0.22 ab	0.05	NS	**<0.01**	NS	0.62
Feed purchased	0.30 b	0.52 ab	0.74 a	0.86 a	0.41 bc	0.58 ab	0.23 c	0.06	<0.01	**0.01**	NS	3.23
Electricity	0.03 b	0.05 a	0.03 b	0.004 b	0.044 a	0.043 a	0.044 a	0.00	0.05	**<0.001**	NS	0.00
Fuel	0.27	0.28	0.18	0.22	0.26	0.25	0.25	0.02	0.06	NS	NS	0.25

Tool evaluation

CARBON FOOTPRINT

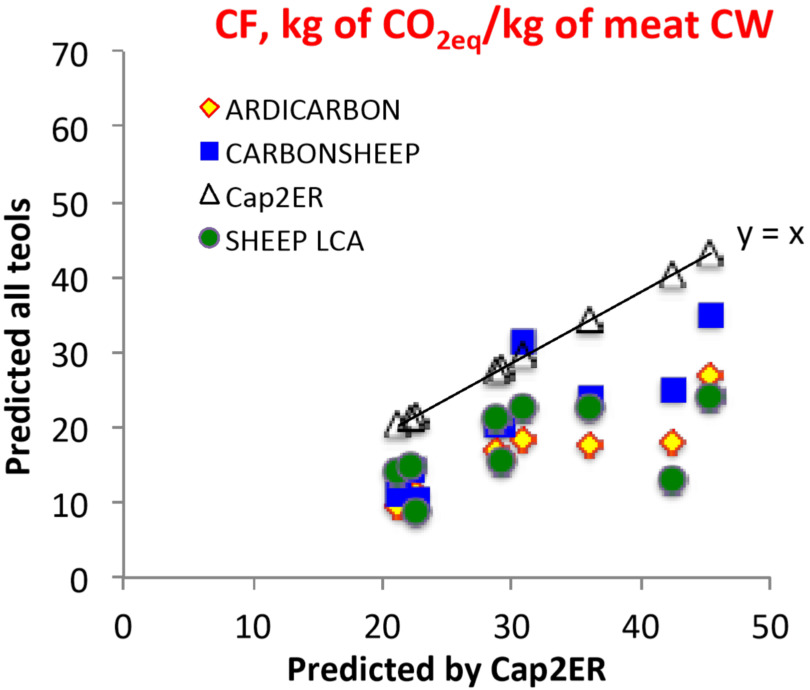
	P-O	C2E-AC	C2E-CS	AC-CS	C2E-SLCA	AC-SLCA	CS-SLCA
	RMSPE	1.71	1.49	1.23	1.44	1.34	0.60
		35%	31%	25%	30%	28%	12%

Main differences in:

- Manure estimates
- Emission coeff.

*Romania: excluded fro

RESULTS: Comparison of Carbon Footprint (GW) estimates, Meat Farms



	CAP2 ER	ARDI Carbon	Carbon Sheep	Sheep LCA
Carbon footprint	31.1 a	16.4 b	21.3 b	17.2 b
SD	8.8	5.0	8.5	5.3

P =<0.001

Mainly methane

Manure emissions

CAP2'ER was assumed as equivalence line

RESULTS: Comparison of estimates per each hotspot, meat farms

Kg of CO_2eq/kg of Carcass Weight

	France	Ireland	Spain	CAP2ER	ARDI Carbon	Carbon Sheep	Sheep LCA	SEM	Country	Tool	C x Tool
CARBON FOOTPRINT	27.4 a	22.6 b	14.5 c	31.1a	16.4b	21.3b	17.2 b	1.50	<0.001	**<0.001**	**NS**
Enteric methane	16.7	13.0	8.8	17.3 a	9.2 b	13.9 ab	11.1 b	0.33	<0.001	**<0.001**	**NS**
Manure emissions	4.5	2.7	3.1	6.6 a	2.4 bc	3.6 b	1.2 c	0.01	<0.01	**<0.001**	**NS**
Crop& fertilizers	2.2 a	2.6a	0.41 b	2.6 a	2.3 ab	0.4 b	1.7 ab	0.96	<0.01	0.03	NS
Feed purchased	2.1	1.6	1.3	1.3	1.6	2.0	1.8	0.15	NS	NS	NS
Electricity	0.07 ab	0.10 a	0.004 b	0.1	0.0	0.1	0.1	0.12	0.01	**NS**	**NS**
Fuel	1.9 a	0.7 b	0.8 b	0.9	1.1	1.2	1.3	0.44	<0.001	0.49	NS

CARBON FOOTPRINT

P-O	C2E-AC	C2E-CS	AC-CS	C2E-SLCA	AC-SLCA	CS-SLCA
RMSPE, Kg of CO2eq	**14.8**	**10.8**	**4.6**	**15.7**	**3.7**	**6.5**
% of x	35%	25%	11%	37%	9%	15%

DIFFERENCES: Methane emissions

	CAP2ER	ARDI CARBON	CARBON SHEEP	SHEEP LCA
Methane GEI x Ym	Sauvant and Noziere (2013) Intake Level and PCO ….. dairy	Geographical approach (Fedna, Cambra Lopez et al., 2008)	IPCC, 2019; Vermorel (2008°).	IPCC 2019
Intake	Forage intake + Purchased concentrates	NE req/NE diet value	Pulina et al., 1991	INRA, 1989

Action C1 : Development of a common European framework

- Task 3: Tools update and building up (impact assessment formulas)

Action C	Tasks
C1 : Development of a common European framework on GHG emissions and sustainability... sheep product...	1-Development of a common carbon footprint assessment methodology
	2-Development of a common sustainability assessment
	3-Tools update and building up
	4-Common GHG mitigation synthesis

Proposal for building up

Hotspot	CF	Set of equation/coefficient	Note	reference	WHy
Functional unit	FPCM	FPCM(6.5; 5.8) = L(0.25 + 0.085F + 0.035P) (reference value kcal/kg = 1.047)		Pulina et al., 2005	Already used by the tools
	Carcass weight	Country/farm input values, default			
Allocation	Phisical/Mass			IDF 2015	Already used by the tools
Enteric methane	GE intake	Maintenance requirements per kg of BW Lactation requirements Digestibility/ 0.82/0.64	Requirements	(INRA, 2018)	international standard
	Digestibility Ym	From forage to concentrate ratio? Fixed? Regression from IPCC (Ym vs DIG) or Vermorel et al., 2008? Others?	Diet info	INRA 2018 French system or IPCC 2019	international standard Consistency among system
Manure emissions	Methane + Nitrogen management	complete list and emission coefficients		IPCC, 2019	Already used by the tools
Crop& fertilizers	Nitrogen	Same Emission coefficients of N fertilizer + Fertilizers Dropdown list		IPCC, 2019	Already used by Ardicarbon, Sheep LCA
Feed purchased		Ecoinvent dropdown list (other free?)		Ardicarbon	Broad list and largely accepted.
Energy	Electricity	Country values for energy mix?	0.29, 0.31, 0.06?		Already used by tootls
	Fuel	Equal value for all =	Which value?		Select one from tools

We set the assumption of level 1 within these inputs

Example:
N Fertilizers = 33% of N

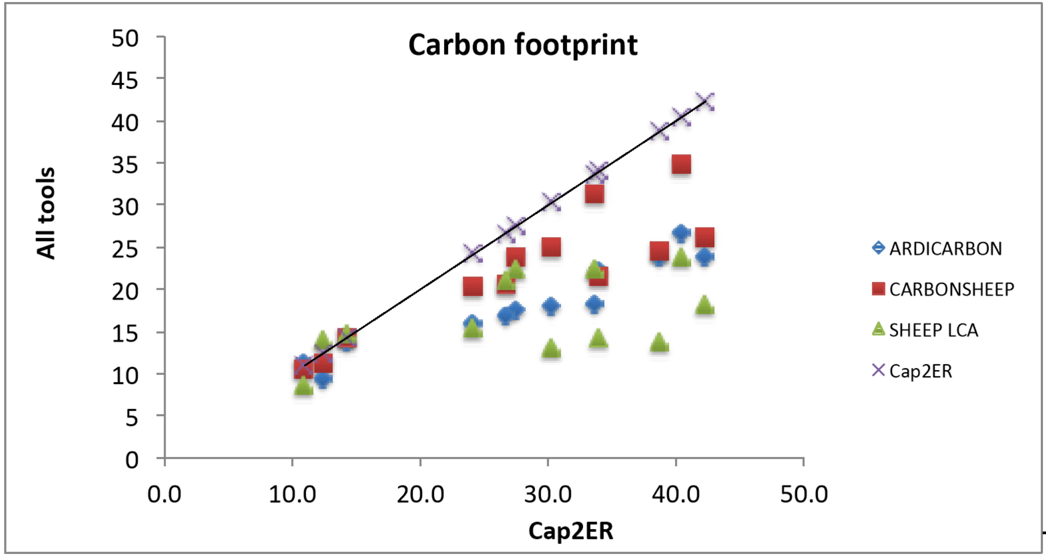
Dairy farm intake and methane check

	CAP'2ER				CARBONSHEEP				INRA			
Farm Name	Ewes DMI (kgMS/year)	Ewes Enteric CH4 (kgCH4/year)	Rams Enteric CH4 (kgCH4/year)	Replacement sheep Enteric CH4 (kgCH4/year)	Ewes DMI (kgMS/year)	Ewes Enteric CH4 (kgCH4/year)	Rams Enteric CH4 (kgCH4/year)	Replacement sheep Enteric CH4 (kgCH4/year)	Ewes DMI (kgMS/year)	Ewes Enteric CH4 (kgCH4/year)	Rams Enteric CH4 (kgCH4/year)	Replacement sheep Enteric CH4 (kgCH4/year)
FR_Cas-type OL PA04	722.8	15.5	14.7	5.8	720.9	15.5	9.1	8.3	675.1	14.8	9.7	10.5
FR_Cas-type OL ROQ02	939.1	19.5	20.5	6.7	923.5	19.3	14.8	9.9	863.4	18.3	14.6	12.3
FR_Cas-type OL ROQ03	915.7	19.2	20.3	6.6	848.5	18.1	15.0	10.0	772.0	16.9	14.7	12.3
Sheeptoship Arca Farm	688.0	14.0	13.9	5.9	573.3	12.2	14.3	5.8	567.3	12.1	13.1	8.5
Sheeptoship Cugusi Farm	677.6	13.9	14.7	5.7	558.6	12.0	14.5	6.6	548.0	11.8	13.5	9.0
IT_Sheeptoship Farm Manconi	733.8	14.6	17.2	5.8	544.5	11.5	13.2	3.8	561.9	11.8	13.5	7.2
IT_Sheeptoship Farm Riu	667.4	13.7	14.8	5.8	545.8	11.8	14.5	6.3	530.6	11.5	13.6	8.8
RO_Chicos	619.1	13.1	13.8	5.5	511.4	11.4	17.0	9.2	463.3	10.7	14.9	11.4
RO_Dambovita	738.1	14.9	14.7	10.8	462.8	10.4	13.4	0.0	461.8	10.4	12.5	0.0
RO_Ovis	828.0	17.4	19.2	7.1	685.3	15.1	21.9	11.8	582.6	13.5	18.9	14.2
SP_CL1	1825.1	32.9	24.8	6.5	768.0	0.0	0.9	0.0	924.6	0.0	7.2	0.0
SP_CL3	1231.6	22.1	23.7	7.6	971.9	17.1	18.6	6.6	980.7	17.3	18.0	10.1
SP_PV1	634.9	14.0	14.4	5.3	650.1	14.3	16.3	7.4	586.9	13.3	14.6	9.6
Average	**863.2**	**17.3**	**17.4**	**6.5**	**674.2**	**13.0**	**14.1**	**6.6**	**655.3**	**12.5**	**13.7**	**8.8**

Meat farms intake and methane check

Farm name	CAP'2ER		CARBONSHEEP		INRA	
	DMI (kgMS/ewe/year)	Enteric CH4 (kg CH4/ewe/year)	DMI (kgMS/ewe/year)	Enteric CH4 (kg CH4/ewe/year)	DMI (kgMS/ewe/year)	Enteric CH4 (kg CH4/ewe/year)
FR_Céréalier Ovin fourrager intensif	1011	20.9	885	18.9	898	19.1
FR_Préalpin spécialisé sédentaire	799	16.7	682	14.9	687	14.9
FR_Spécialisé Semi-extensif zone défavorisée	973	19.8	750	16.3	754	16.3
IR_13512	965	19.5	701	15.3	676	14.9
IR_21121	963	19.5	717	15.6	702	15.4
IR_26270	795	16.7	739	15.8	721	15.5
SP_MP	883	17.8	618	13.5	651	14.0
SP_PZ	1012	19.5	632	12.7	717	14.2
SP_SI S.C.	820	16.6	606	13.2	646	13.9
D'agostino	875	17.3	556	11.7	651	13.2
MACRINI	909	17.9	526	11.0	618	12.5
FARINDOLAGRI	912	17.9	521	10.8	609	12.3
Average	**909.7**	**18.3**	**661.1**	**14.1**	**694.1**	**14.7**

Task 3: Building up phase Meat Farms

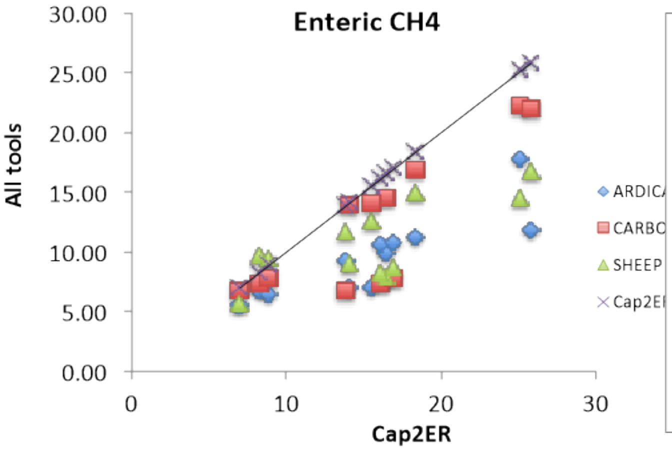


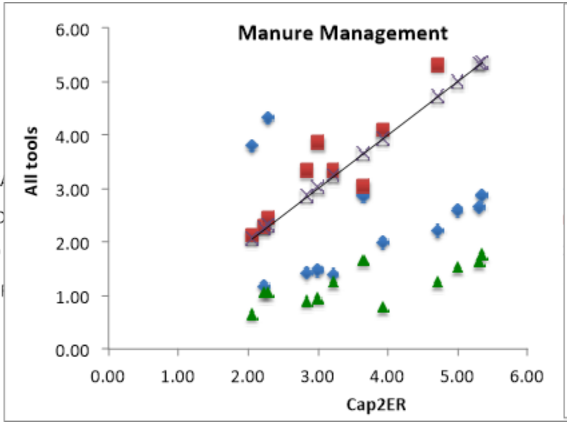
Statistics will be executed after final check

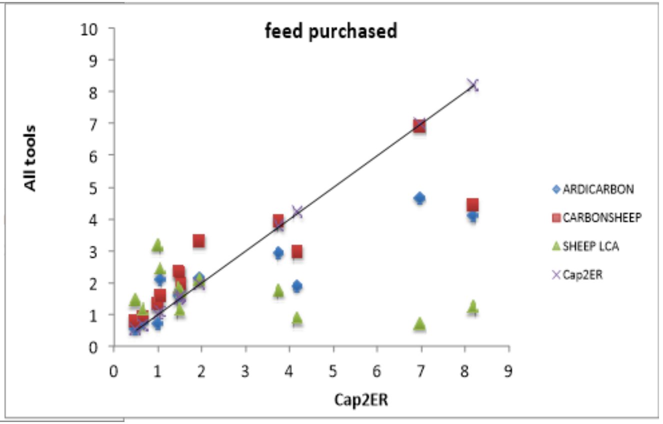
	CAP2ER	ARDICARBON	CARBONSHEEP	SHEEP LCA
CF_kgmeat	**28.0**	**18.1**	**21.9**	**16.7**
Enteric	**15.5**	**9.4**	**12.2**	**10.7**
Manure	**3.3**	**2.4**	**3.6**	**1.2**
Purchased feeds	**2.7**	**2.1**	**2.7**	**1.6**
Crop and fertilizers	**3.6**	**2.2**	**1.0**	**1.7**
Electrcity	**0.017**	**0.086**	**0.137**	**0.081**
Fuel	**1.6**	**1.4**	**1.7**	**1.5**

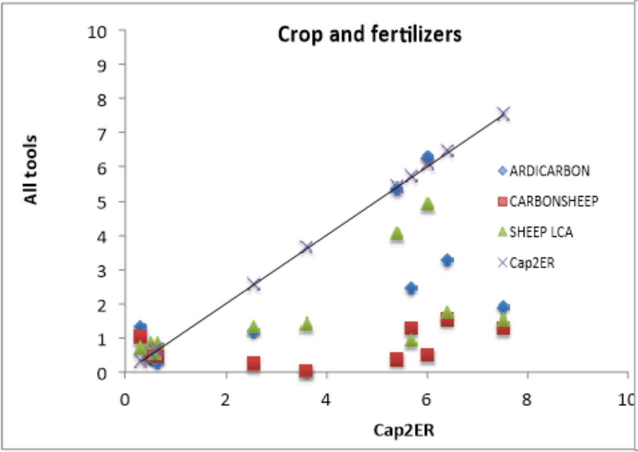
Task 3: Building up phase Meat Farms

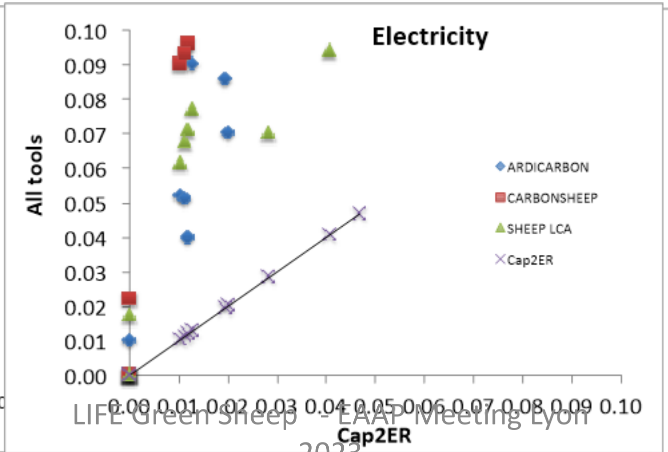
Statistics will be executed after final check

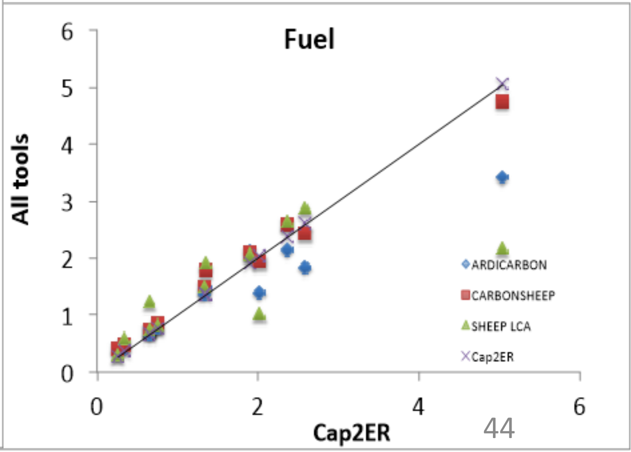












To be decided:

Feed purchased

Cereals for meat sheep (=triticale) = 0.376

Cereals for dairy sheep (= winter barley) = 0.389

Soybean meal = 1.371

Dairy sheep concentrate - PC<=20% = 1.046

Dairy sheep concentrate - PC >20% = 0.655

Meat sheep concentrate - PC <=25% = 0.512

Meat sheep concentrate - PC >25% = 0.684

Dehydrated concentrates (alfalfa) = 1.25

Milk powder = 4.279

minerals =0.518

Hay = 0.306

Dehydrated forages (=alfalfa) = 1.25

Straw = 0.072

Crops and fertilizers

List of fertilizers (Ardicarbon, Sheep LCA, CA

Simplified coefficients (Cap2ER L1 and Carbo

Final check of formulas per each tool

Key on-farm emission and energy factors applied in a cradle to farm-gate life cycle assessment sheep model.

Emission or energy source	Emission or energy factor	Unit	Reference(s)
Carbon dioxide (CO_2)			
Lime	0.44 × lime application	kg/kg lime	IPCC (2006)
Urea	0.73 × urea application	kg/kg urea	IPCC (2006)
Diesel	2.63 × diesel use	kg/l	IPCC (2006)
Gasoline	2.30 × gasoline use	kg/l	IPCC (2006)
Kerosene	2.52 × kerosene use	kg/l	IPCC (2006)
Grassland carbon sequestration	0.57–0.89[a] × grassland area	t/ha	Leip et al. (2010), Schulte et al. (2013)
Methane (CH_4)			
Enteric fermentation			
Ewes, hoggets and rams	0.065 × GEI[b]	MJ/d	Duffy et al. (2014)
Lambs	0.06 × GEI	MJ/d	Duffy et al. (2014)
Manure storage and excretion on pasture	Manure VS[c] excreted × 0.19 × 0.67 × MS[d] × MCFe	kg/year	Duffy et al. (2014)
Nitrous oxide (N_2O-N)			
Solid manure storage	0.005 × solid manure N stored	kg/kg N	Duffy et al. (2014)
Manure excreted on pasture	0.01 × N excreted on pasture	kg/kg N	Duffy et al. (2014)
Synthetic N fertilizer	0.01 × N fertilizer applied	kg/kg N	Duffy et al. (2014)
Solid manure application	0.01 × N in manure spread	kg/kg N	Duffy et al. (2014)
Crop residues	0.01 × N crop residues	kg/kg N	Duffy et al. (2014)
Nitrate leaching	0.0075 × N leached	kg/kg NO_3^--N	Duffy et al. (2014)
Ammonia (NH_3) re-deposition	0.01 × sum of NH_3 loss	kg/kg NH_3-N	Duffy et al. (2014)
Nitrogen oxides (NO_x)			
Solid manure storage	0.01 × solid manure TAN[f] stored	kg/kg TAN	Duffy et al. (2015)
Solid manure application	0.002 × N in manure spread	kg/kg N	Duffy et al. (2015)
Manure excreted on pasture	0.0035 × TAN excreted on pasture	kg/kg TAN	Duffy et al. (2015)
Synthetic N fertilizer	0.002 × N fertilizer applied	kg/kg N	Duffy et al. (2015)
Diesel	0.025 × diesel use	kg/l	Nemecek and Kägi (2007)
Gasoline	0.030 × gasoline use	kg/l	Nemecek and Kägi (2007)
Kerosene	0.001 × kerosene use	kg/l	Nemecek and Kägi (2007)
Ammonia (NH_3-N)			
Housing	0.22 × manure TAN stored	kg/kg TAN	Duffy et al. (2015)
Solid manure storage	0.35 × solid manure TAN stored	kg/kg TAN	Duffy et al. (2015)
Solid manure application	0.68–0.004 × TAN in solid manure spread	kg/kg TAN	Duffy et al. (2015)
Manure excreted on pasture	0.06 × TAN excreted on pasture	kg/kg TAN	Duffy et al. (2015)
Synthetic N fertilizer	(0.01–0.13)[g] × N fertilizer applied	kg/kg N	Duffy et al. (2015)
Nitrate (NO_3^--N)			

O'Brien et al., 2016

Proposal for task 3: Building up phase

- Deliverable 1: completed with results of comparison as presented in previous conferences. Highligth diffrences and errors

Next step

Updated dataset with modified Ardicarbon (and Sheep LCA? Coefficient for adjusted estimates?)

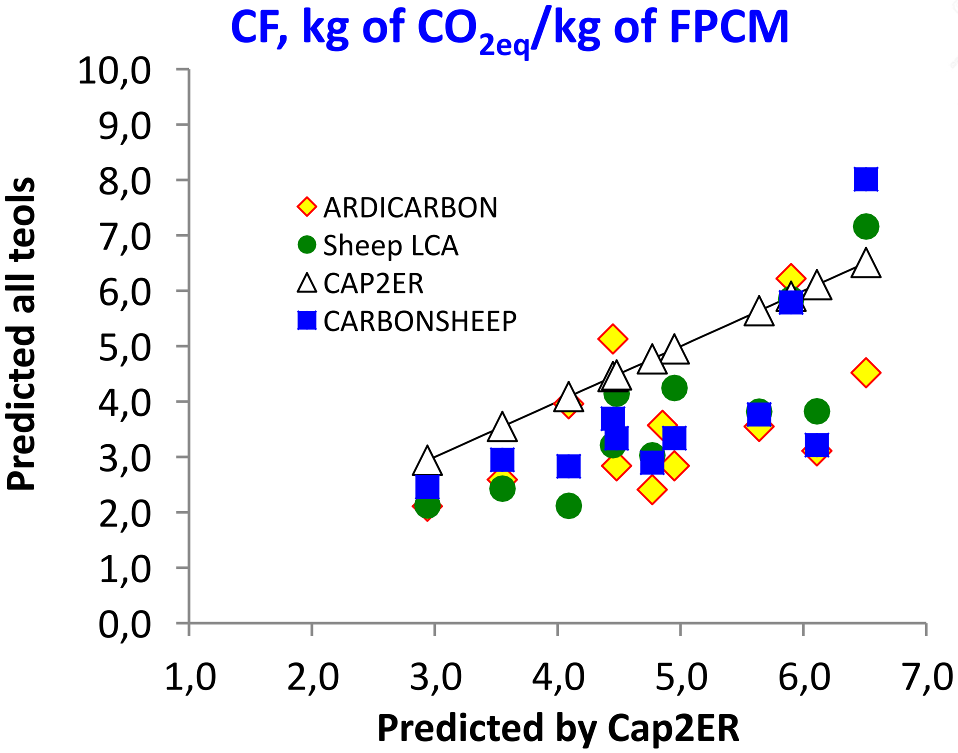
Paper on Tools alignement:

- Description of the tools and methodological differences, results of comparisons in the text without graphs.
- Building up phase in methods for alignment
- Results of final alignment (Bias, statistics, RMSPE etc)
- Table and graphs for dairy and meat farms.

Deliverable 2:

- The paper has the same structure of the deliverable 2.
- Deliverable 2 includes the report on good practices (Already Completed)

Before aligment: Comparison of Carbon Footprint (GW) estimates, Dairy Farms



TOOL	CAP2 ER	ARDI CARBON	CARBON SHEEP	Sheep LCA
Carbon footprint	4.85 a	3.57 ab	3.84 b	3.69 b
SD	1.11	1.27	1.64	1.58

P =0.01

RMSPE: 28-35% of CF among all tools

Except: vs.

Main differences:

- Manure estimates
- Feed purchased coefficients

CAP2'ER was assumed as equivalence line