EAAP – September 2024

Nitrogen flows in the development of organic agriculture: two scenarios for the future of organic and conventional livestock in France

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Context

- The European Green Deal targets 25% of land under organic agriculture (OA) by 2030

- Several studies have explored scenarios of complete conversion to OA or agroecology (*Muller et al. 2017, Barbieri et al. 2021, Billen et al. 2021*):

→ N is the main factor limiting OA expansion : biological nitrogen fixation (BNF)

- The EU aiming to eventually abolish derogations (Annex II Regulation (EU) (2018/848)) for the use of conventional manure in OA for a self-sufficient OA

- Growing pressure to reduce livestock numbers:

→ Decline in EU livestock numbers for all species over the last decade (*Eurostat, 2023*)

→ Agri-food scenarios at different scales also provide a reduction in animal numbers (*Van Zanten et al. 2018*, *Springmann et al. 2018, van Selm et al. 2022)*

Research question

What would be the consequences for the large-scale development of OA in France in terms of the functioning of nitrogen flows (self-sufficiency, productivity)?

(i) To model N flows in organic and conventional agriculture in France in a 25% OA development scenario, including different changes in organic and conventional livestock numbers (ruminants and monogastrics)

(ii) To identify the impact of these changes on the functioning of the N flows by means of efficiency indicators

→ Focused on metropolitan France, which has the largest area of OA among countries in Europe

Materials and methods

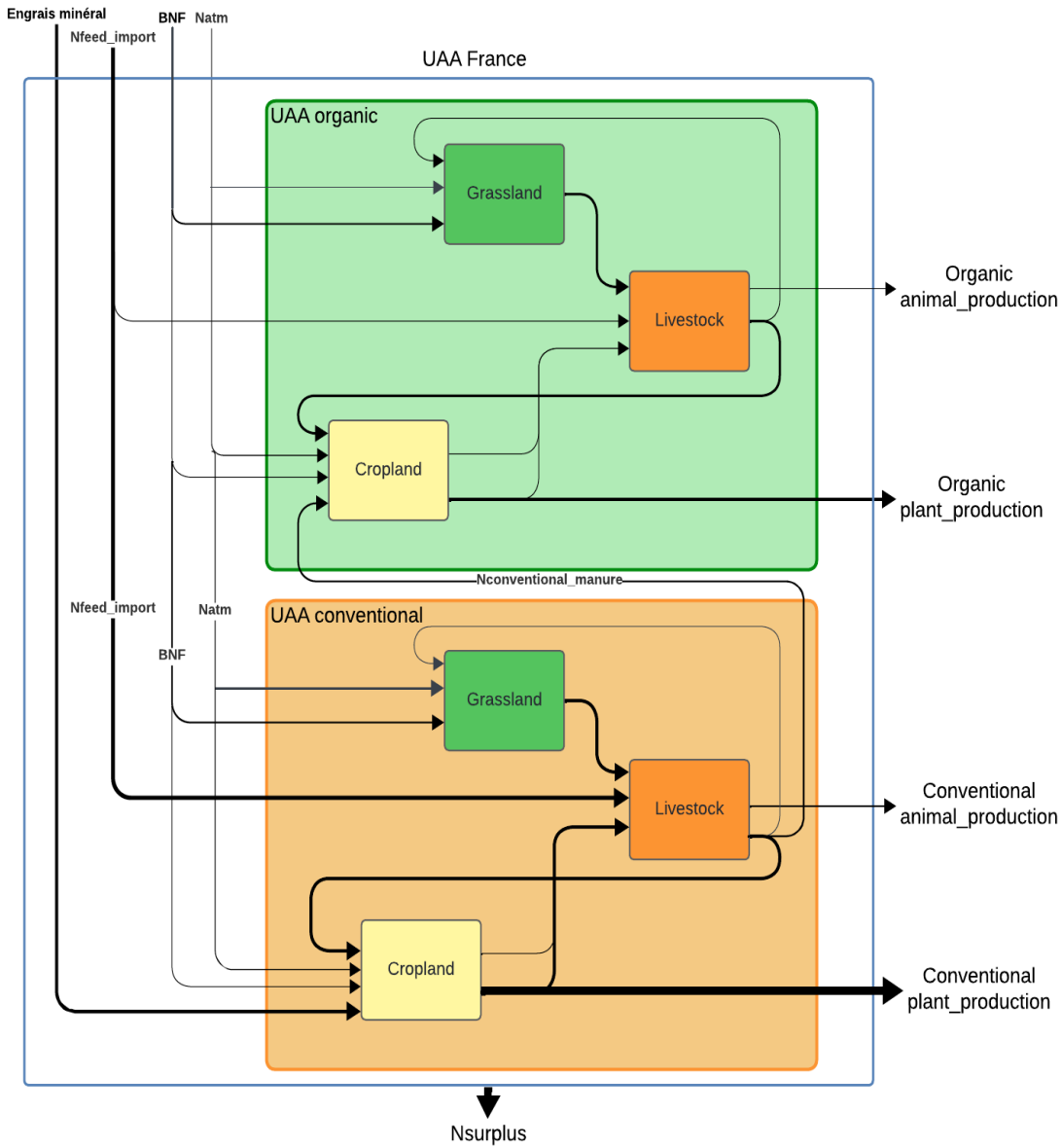
- N flows represented in the ALPHA-national model for organic and conventional agriculture in France

- Calibrates a model over 2021 (*Vergely et al, 2024)*

- Identified indicators:
- Y_{crop} (kgN ha^{-1} yr^{-1})
- N_{output} (kgN ha^{-1} yr^{-1})
- NUE_{tot} (%)
- $N_{self\_sufficiency}$ (%)
- $Animal_{production}$ (%)

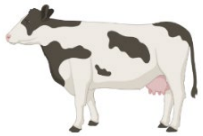
- Mains assumptions :
- Soil and surpluses : no annual variations in soil N stocks (equilibrium model)
- Grasslands : NUE_{grass} set at 75% for OA and 75% for conventional
- Crops : NUE_{crop} set at 65% for OA and 70% for conventional
- Livestock : NCE for organic livestock (*Puech and Stark, 2023; Rouillé et al., 2023 and Garnier et al., 2023*) and conventional livestock (*Laisse et al 2019*)

- Projected 2 development scenarios for OA in France in 2030

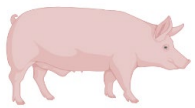


Adapted from *Chatzimpiros and Harchaoui (2023)*

Materials and methods



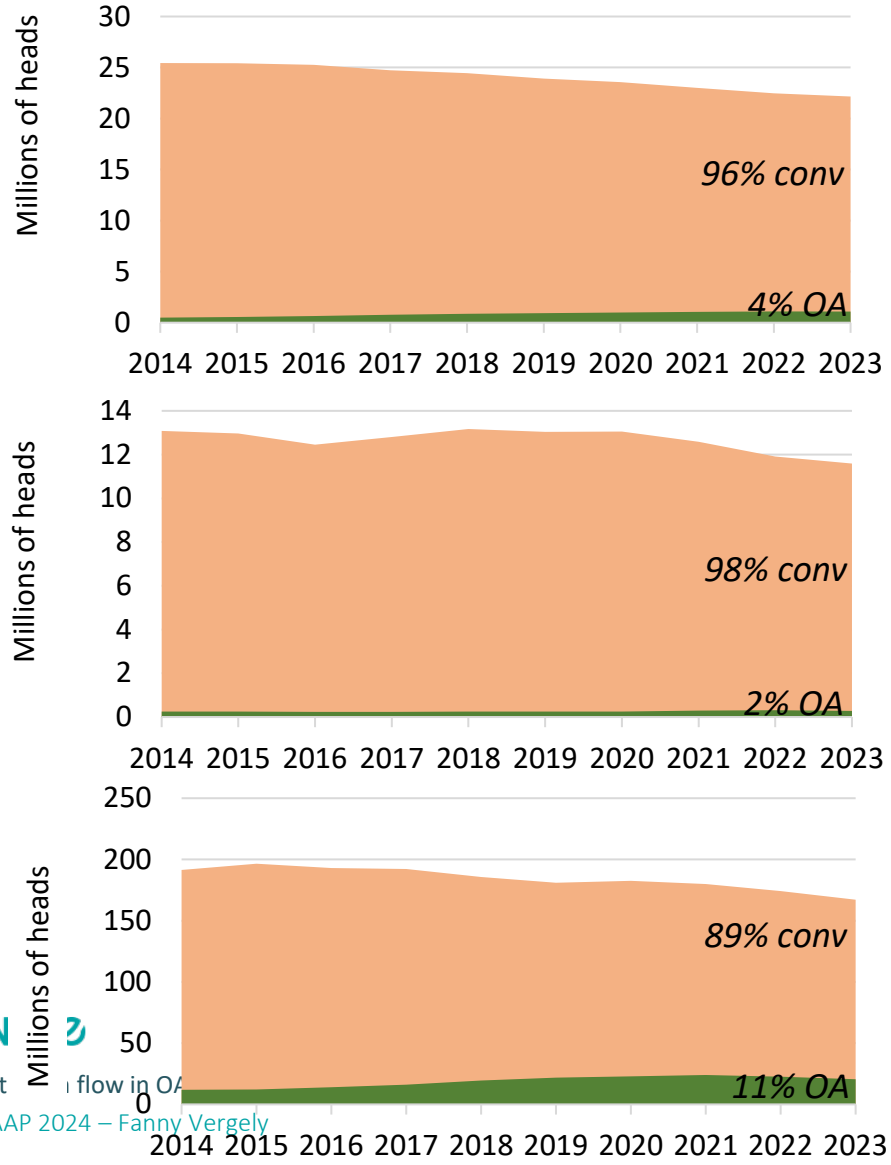
Ruminants (dairy cow, beef, dairy ewes, meat ewes, dairy goats)



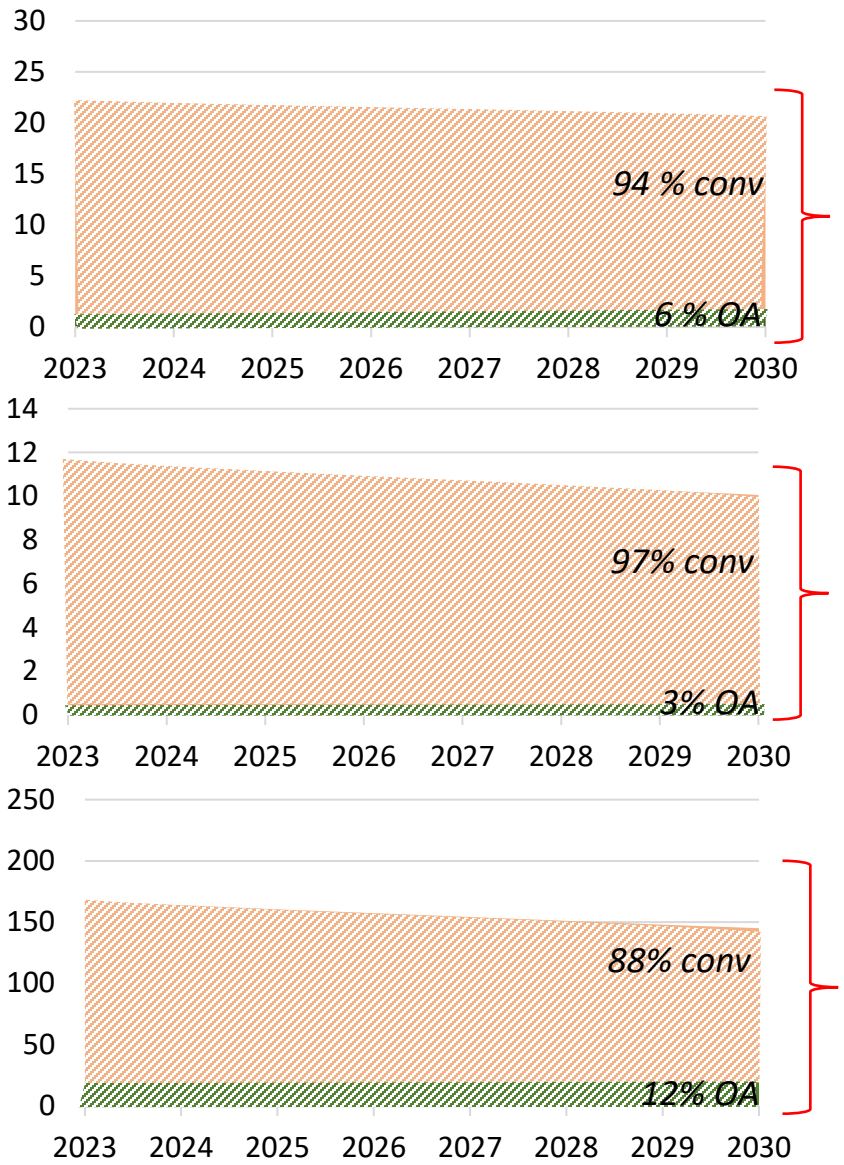
Pigs

Broiler chickens and laying hens

Historical trends in organic and conventional livestock 2014-2023 (Agreste 2024)



Projection in organic and conventional livestock 2023-2030 (assuming the trend over the last 5 years)



-1,5% / year in conventional
+3,6% / year in organic

-2,2% / year in conventional
+1,8% / year in organic

-1,5% / year in conventional
-1,2% / year in organic

Materials and methods

Scenarios construction

Current situation 2021 (UAA 24,5 millions ha)
9% of total UAA under OA (2,2 millions ha)
Ruminants : 4% OA / 96% conventional
Monogastrics : 11% OA / 89% conventional

Constraints
25% of UAA to be organic by 2030 (6,1 millions ha) + regulations on the use of conventional manure in OA

Scenario 1-2030 : trend

in organic and conventional livestock numbers since 2019 (UAA 24,5 millions ha)

↑ in organic livestock (except for poultry)
↓ in conventional livestock

Ruminants : 6% OA / 94% conventional 

Monogastric : 12% OA / 88% conventional 

(-15%) of total livestock numbers in France

Scenario 2-2030 : proportional

growth in organic and conventional livestock in proportion to the organic UAA growth (UAA 24,5 millions ha)

↑ in organic livestock
↓ in conventional ruminants

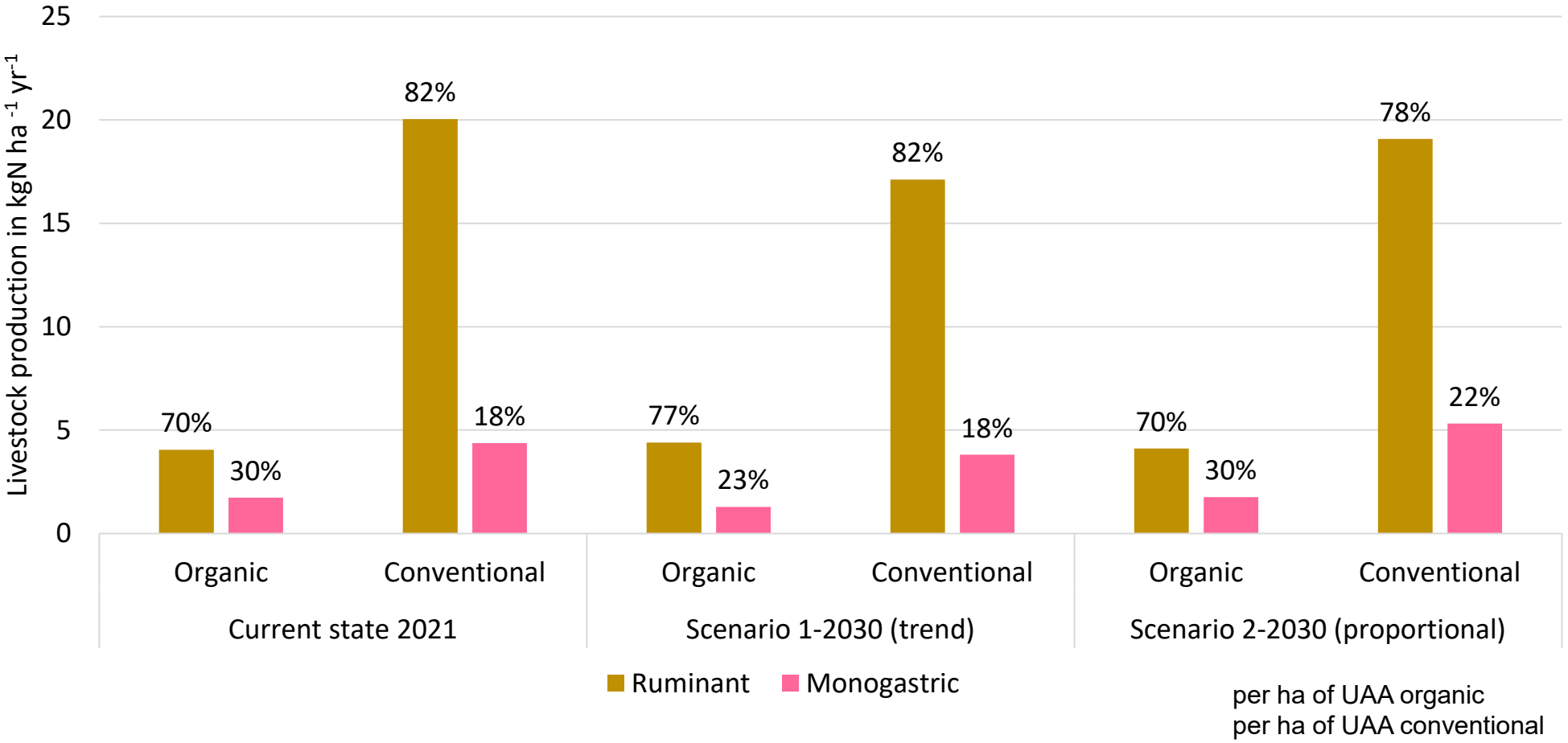
Ruminants : 12% OA / 88% conventional 

Monogastric : 26% OA / 74% conventional 

(+16%) of total livestock numbers in France

Results

Monogastric and ruminant production as a proportion of total livestock production in France



→ Overall, even though there are more organic animals in scenarios 1 and 2, in both scenarios total nitrogen meat production per ha in the agricultural system decreases

Results

Current situation in 2021

Indicators	Organic agriculture	Conventional agriculture	Total agriculture*	Unit
Y_{crop}	52	139	129	kgN ha^{-1} yr^{-1}
N_{output}	19	67	62	kgN ha^{-1} yr^{-1}
NUE_{tot}	43	42	42	%
$N_{self\_sufficiency}$	80	19	26	%
$Animal_{production}$	31	36	36	%

Vergely et al, 2024

**Total agriculture = 2.2 million ha (UAA AB) + 22.3 million ha (UAA conventional)*

Results

Scenario 1-2030: trend in livestock numbers since 2019

Decrease / Increase / Similar (compared to current state 2021)

Indicators	Organic agriculture	Conventional agriculture	Total agriculture	Unit
Y_{crop}	45	133	114	kgN ha^{-1} yr^{-1}
N_{output}	17	66	55	
NUE_{tot}	42	45	45	%
$N_{self\_sufficiency}$	87	21	37	
$Animal_{production}$	33	32	31	% of output

**Total agriculture = 6.1 million ha (UAA AB) + 18.4 million ha (UAA conventional)*

- OA system had a better $N_{self\text{-}sufficiency}$ but lower N_{output} because fewer monogastric animals
- Conventional system had a better $N_{self\text{-}sufficiency}$ but lower N_{output} because lower livestock share in production

→ Overall, the livestock share of production is reduced, as its productivity, but the system is more efficient and self-sufficient

Results

Scenario 2-2030: proportional evolution

Decrease / Increase / Similar (compared to current state 2021)

Indicators	Organic agriculture	Conventional agriculture	Total agriculture*	Unit
Y_{crop}	47	139	115	kgN ha^{-1} yr^{-1}
N_{output}	18	67	54	
NUE_{tot}	42	42	42	%
$N_{self\_sufficiency}$	84	19	36	
$Animal_{production}$	33	36	36	% of output

**Total agriculture = 6.1 million ha (UAA AB) + 18.4 million ha (UAA conventional)*

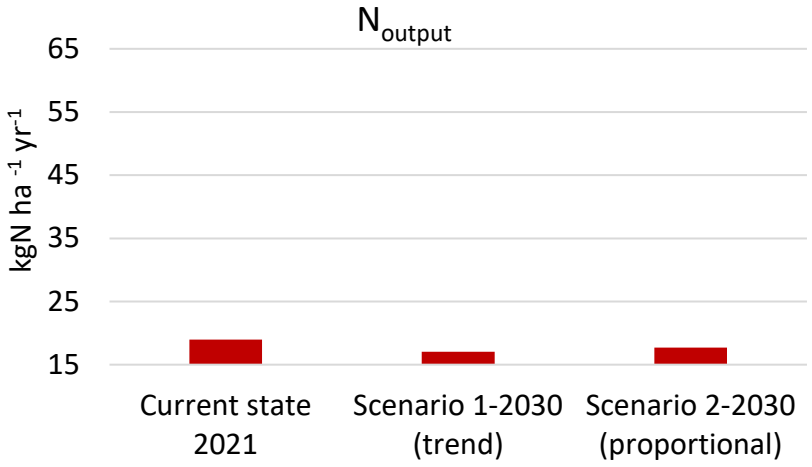
- OA system had a better $N_{self\text{-}sufficiency}$ but lower N_{output} with lower NUE_{tot}
- Conventional system remains similar because moderate decrease in ruminant numbers proportional to the decrease in conventional area

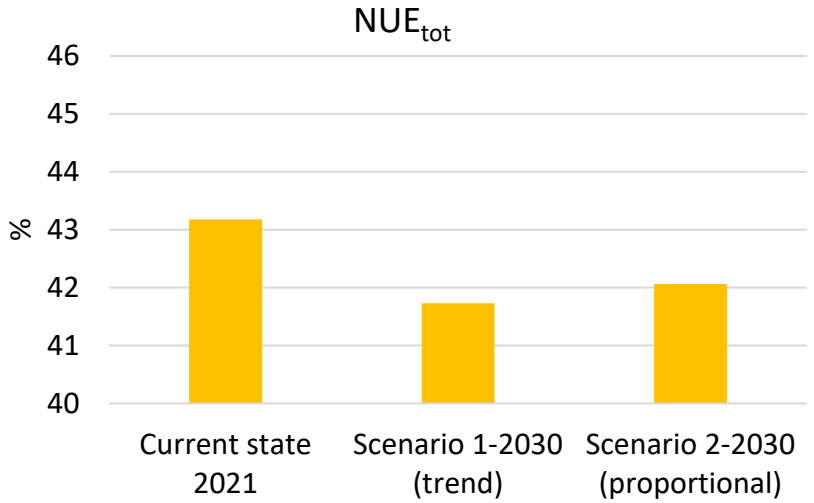
→ Overall, more organic animals and fewer conventional animals = total system more self-sufficient but less productive (as organic animals are less productive)

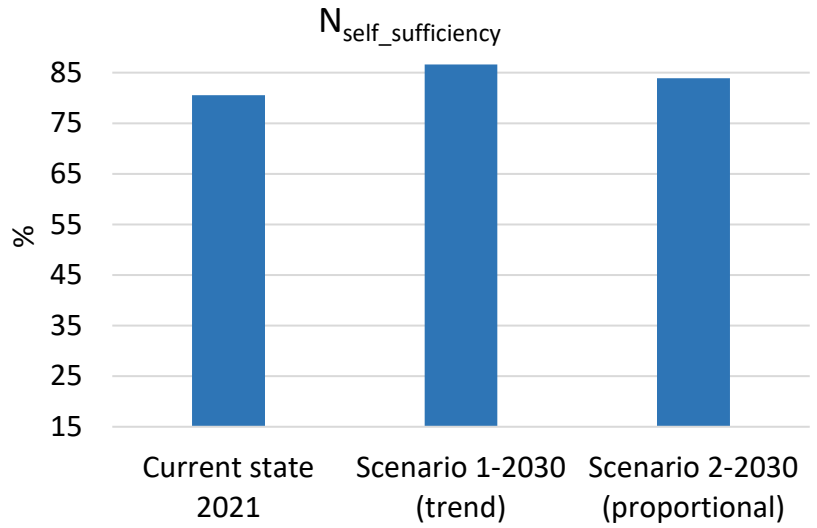
Results

Trends in indicators for organic and conventional agriculture

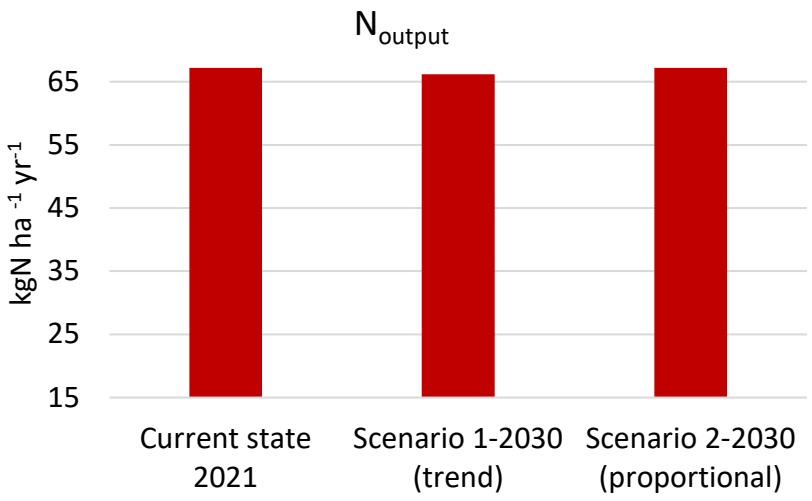
Organic agriculture

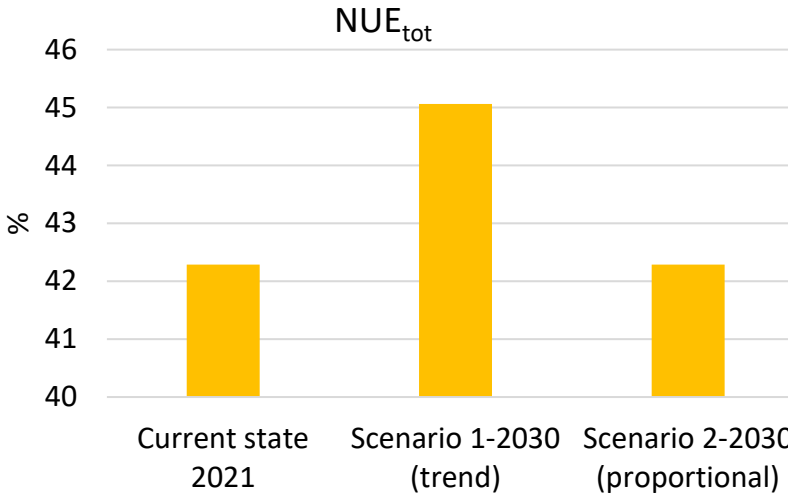


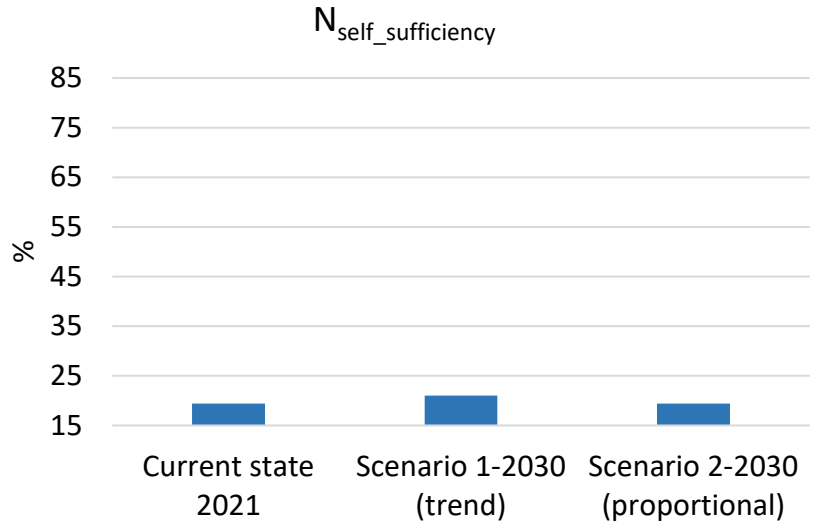




Conventional agriculture







Conclusion

Total agriculture France	Scenario 1-2030 (trend)	Scenario 2-2030 (proportional)
Organic UAA (25% of UAA to be organic by 2030)	↑	↑
Number of organic ruminants	↑	↑
Number of organic monogastrics animals	↑ Pig ↓ Poultry	↑
Number of conventional ruminants	↓	↓
Number of conventional monogastrics animals	↓	=
$N_{self\_sufficiency}$	↑	↑
N_{output}	↓	↓

- Both scenarios show a decline in conventional livestock in favour of organic livestock
- Increase in the number of organic livestock but lower productivity of the total system is lower than the current state, and self-sufficiency is higher
- Both scenarios of a reduction in livestock production are compatible with a reduction in meat consumption

Perspectives

- Provides a basis for comparison with other scenarios for the development of OA in European countries
- Can be adapted to assess potential for expanding OA
- Can be fine-tuned at a smaller scale
- Data collection and modelling approaches can be adapted to examine phosphorus flows

Thank you for your attention

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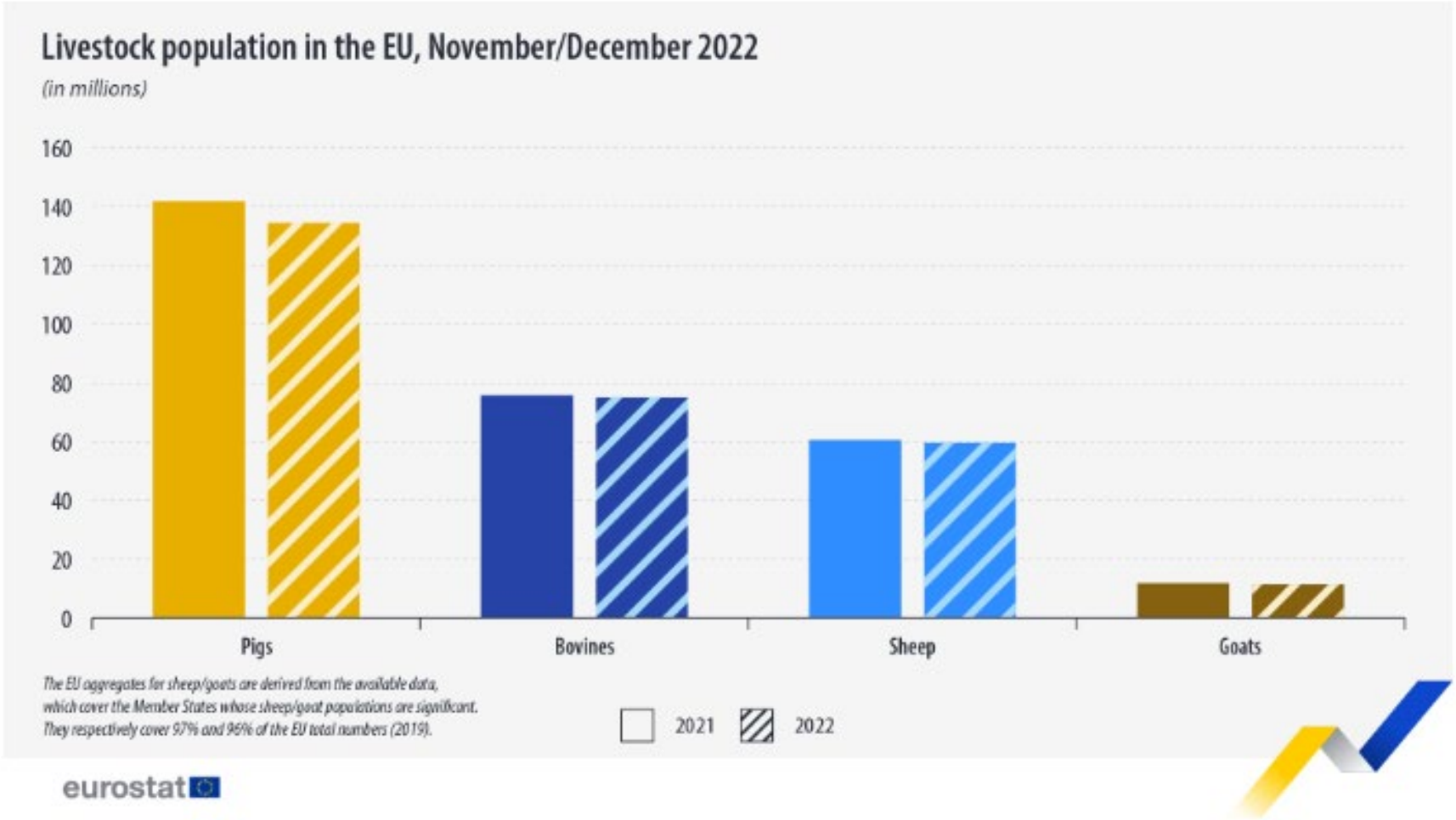
Annexes


Livestock population in the EU, November/December 2022
(in millions)
160
140
120
100
80
60
40
20
0
Pigs
Bovines
Sheep
Goats
The EU aggregates for sheep/goats are derived from the available data, which cover the Member States whose sheep/goat populations are significant. They respectively cover 97% and 96% of the EU total numbers (2019).
2021
2022
eurostat

Bibliographie

Noélie Borghino « Organic farming expansion and food security: A review of foresight modeling studies" 2024

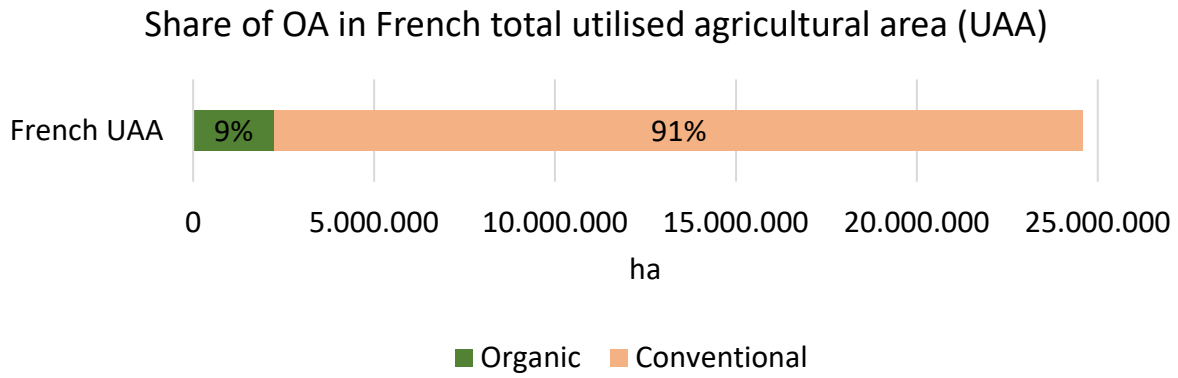
	Spatial scope	Simulated year	Highest % UAA under organic farming *(brackets: number and name of variant, if applicable)*	Model	Reference unit for food supply/ demand
Studies at the global scale					
Erb et al. (2016)	World	2050	100 (130)	BioBaM (B)	Energy
Muller et al. (2017)	World	2050	100 (27)	SOL (B)	Energy
Theurl et al. (2020)	World	2050	100 (130)	BioBaM-GHG (B)	Energy
Barbieri et al. (2021)	World	2015	100 (12)	GOANIM (B)	Energy/Protein
Morais et al. (2021)	World	2050	100 (65)	BioBaM-GHG (B)	Energy
Studies at continental/group of countries scale					
Karlsson et al. (2018)	Denmark, Finland, Norway and Sweden	2030	100	Biomass-flow model (B)	Mass
Poux and Aubert (2018)	EU-28	2050	100	TYFAm (B)	Energy/Mass
Smith et al. (2018)	England and Wales	ca 2018	100	OLUM (B)	Energy
Aubert et al. (2019)	EU-28	2050	100	TYFAm (B)	Energy/Mass
Karlsson and Röös (2019)	Denmark, Finland, Norway and Sweden	2030	100 (2: SY and EY)	Biomass-flow model (B)	Energy
Billen et al. (2021)	EU27 + United Kingdom, Norway, Switzerland, Albania, Serbia, Montenegro, and North Macedonia	2050	100	GRAFS model (B)	Protein
Kalt et al. (2021); Röös et al. (2021)	EU-28	2050	50 (1: LAESyst)	BioBaM-GHG 2.0 (B)	Mass
Schiavo et al. (2021)	EU-28	2050	100 (1: TYFA-Alone)	GlobAgri-Agt (B)	Energy
Studies at country scale					
Kumm (2001)	Sweden	2021	100 (1: FOb)	Swedish agricultural sector	Energy
Risku-Norja and Mäenpää (2007)	Finland				
Couturier et al. (2016)	France	2050	90 (1: BHF)	MOSUT (B)	Energy/Protein/ Mass
Billen et al. (2018)	France	2040	100 (1: ARD)	GRAFS model (B)	Protein
Feuerbacher et al. (2018)	Bhutan	ca 2018	100	STAGE2 (E)	Economic value
Kuczuk and Widera (2021)	Poland			)	Energy
Studies at sub-national scale					
Kratochvil et al. (2004)	Mostviertel-Eisenwurzen (Austria)	ca 2004	100 (2)	Biomass flow model (B)	Energy
Thieu et al. (2011)	Somme-Seine-Scheldt Watersheds (France, Belgium, Netherlands)	ca 2011	100 (2: OA 3 mg and 6 mg)	Seneque–Riverstrahler model (B)	Protein
Buschbeck et al. (2020)	Baden-Württemberg (Germany)	ca 2018	44,54,77 (3)	Multi-objective optimization model (B)	Land
Lombardi et al. (2021)	Toscany (Italy)	ca 2021	100 (4)	Biophysical Land food footprint model (B)	Land

Ne modélise pas l'azote

Ne regarde pas l'AB spécifiquement

Context

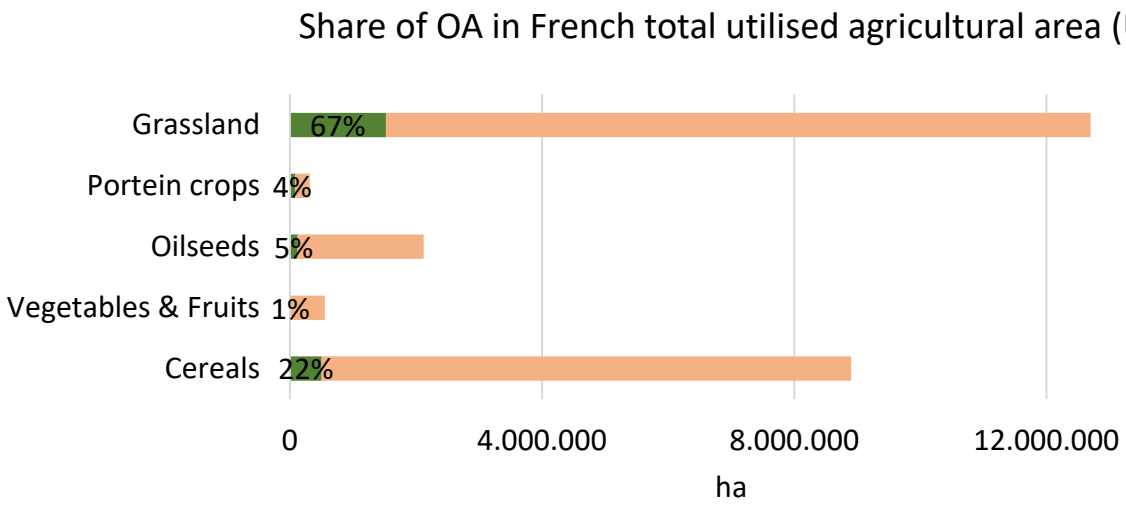
Current state of organic agriculture in France in 2021

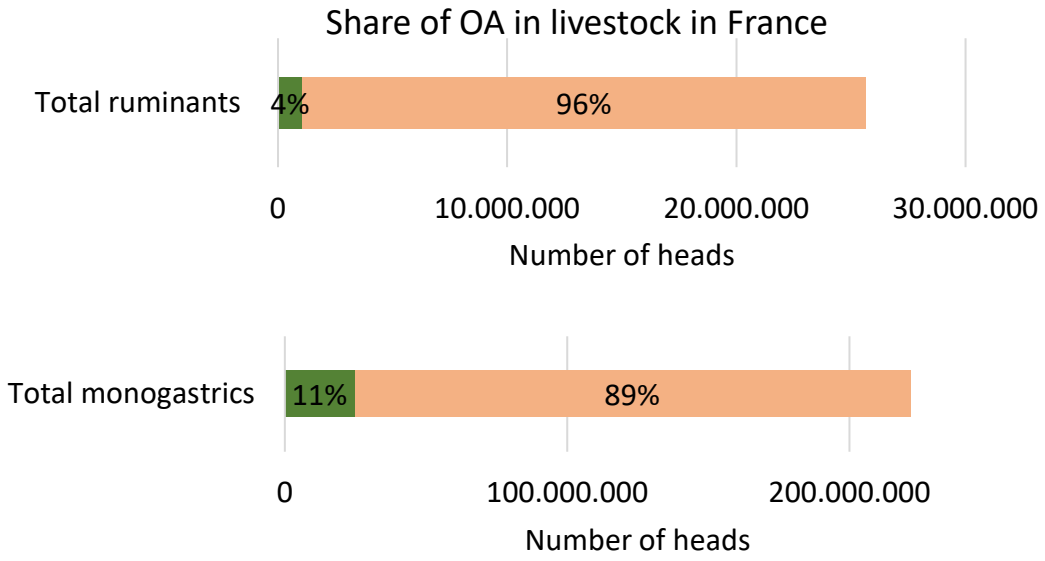


Focused on **metropolitan France**, which has the largest area of OA among countries in Europe :

- Total UAA France considered = 24,5 millions ha of which 2,2 millions ha are organic (9%) (vines, perfume and aromatic plants and other crops are excluded)

Austria is well ahead of France, with 26% of its agricultural land under OA in 2021





→ **The organic share is lower in livestock production than in crop production**

Bibliographie

Grandes tendances dans les scénarios de développement de l'AB

Nombre d'animaux d'élevage :

- 10 scénarios ont rapporté une baisse globale de - 28 % en moyenne des animaux d'élevage lors d'une expansion de l'AB
- En moyenne, la population de ruminants a diminué de - 13 %, tandis que les monogastriques ont diminué de - 51 %

Rotations de cultures :

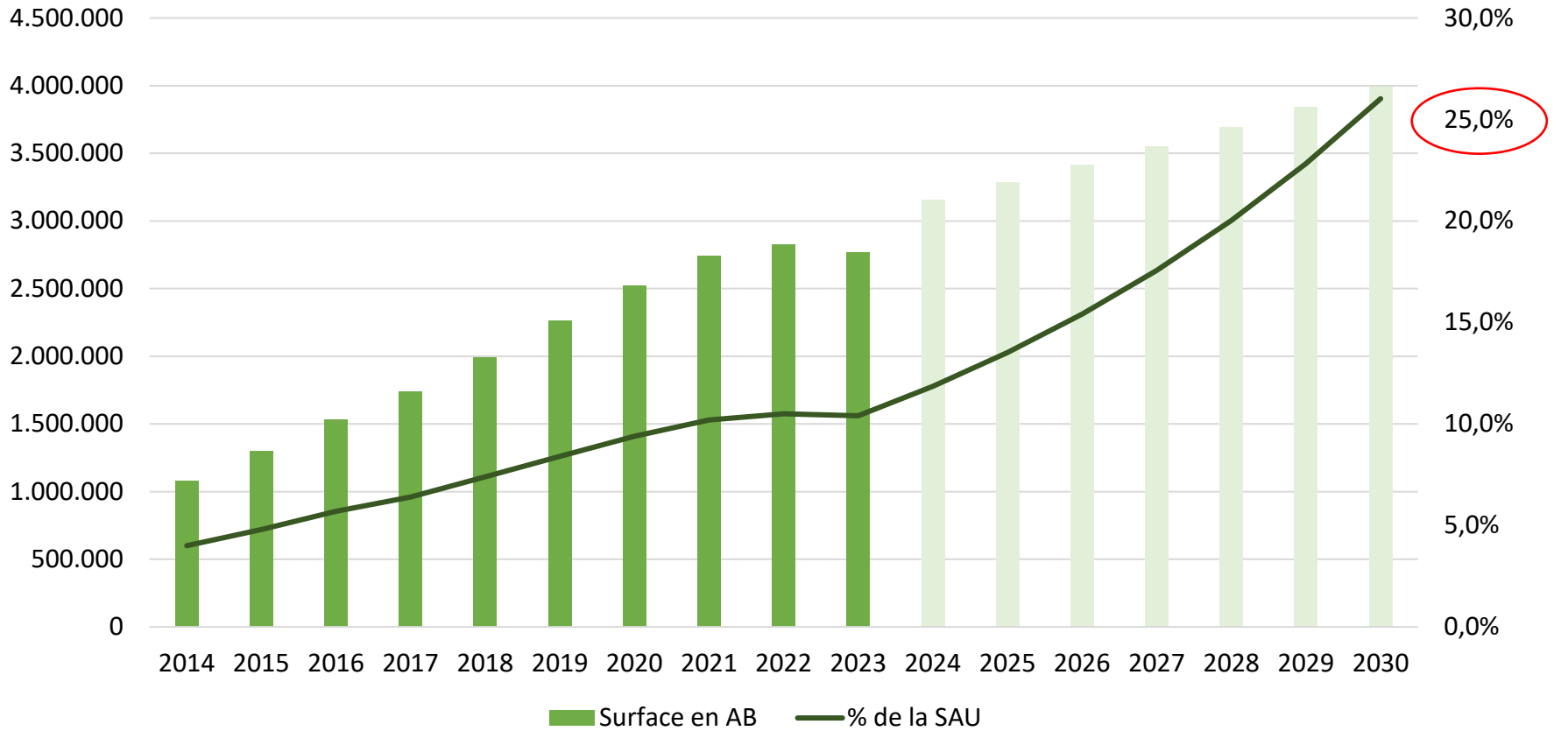
- 19 scénarios incluaient des espèces fixatrices d'azote en tant que mesure autonome
- Contraintes de rotation pour la prévention des mauvaises herbes, des ravageurs et des maladies
- Les rotations de cultures biologiques ont généralement une composition différente de celle des rotations de cultures conventionnelles, avec notamment une plus grande fréquence de légumineuses

Part de protéine animale dans l'alimentation :

- La plupart des simulations dans lesquelles l'autosuffisance alimentaire n'a pas été atteinte correspondent aux régimes alimentaires actuels ou prévus
- Le maintien des tendances actuelles de nos régimes alimentaires - vers un apport calorique élevé et une part importante d'aliments d'origine animale - est difficilement compatible avec la montée en puissance de l'agriculture biologique

Contexte

Part de la SAU utilisée pour l'AB en France au cours de la période 2014-2023 et l'évolution pour atteindre 25% de la SAU en 2030

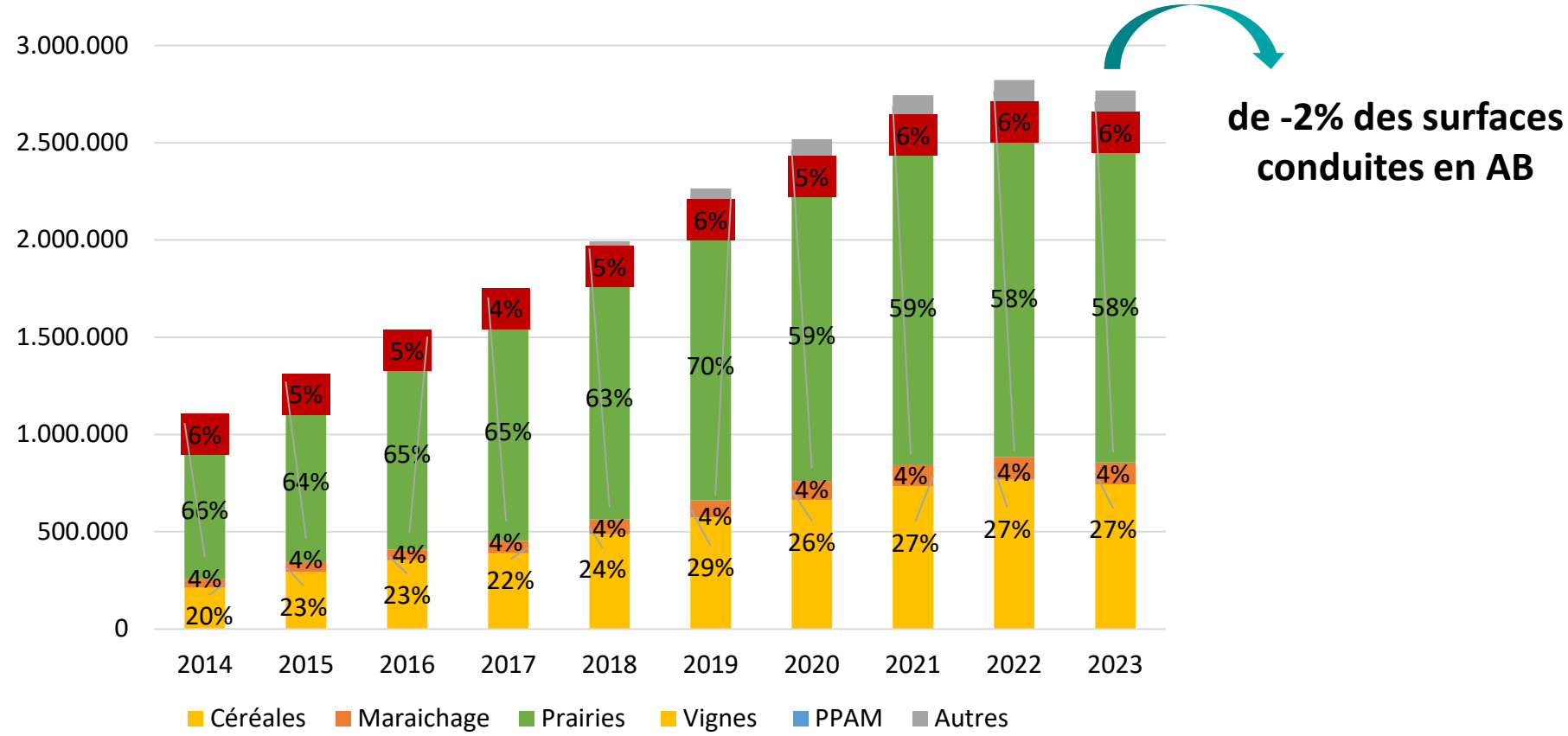


Source Agence Bio 2024

Pour atteindre 25% de la SAU il faudrait une augmentation de +14% par an, or nous sommes autour de +4% ces dernières années (2019-2023)

Contexte

Evolution des surfaces en AB en France

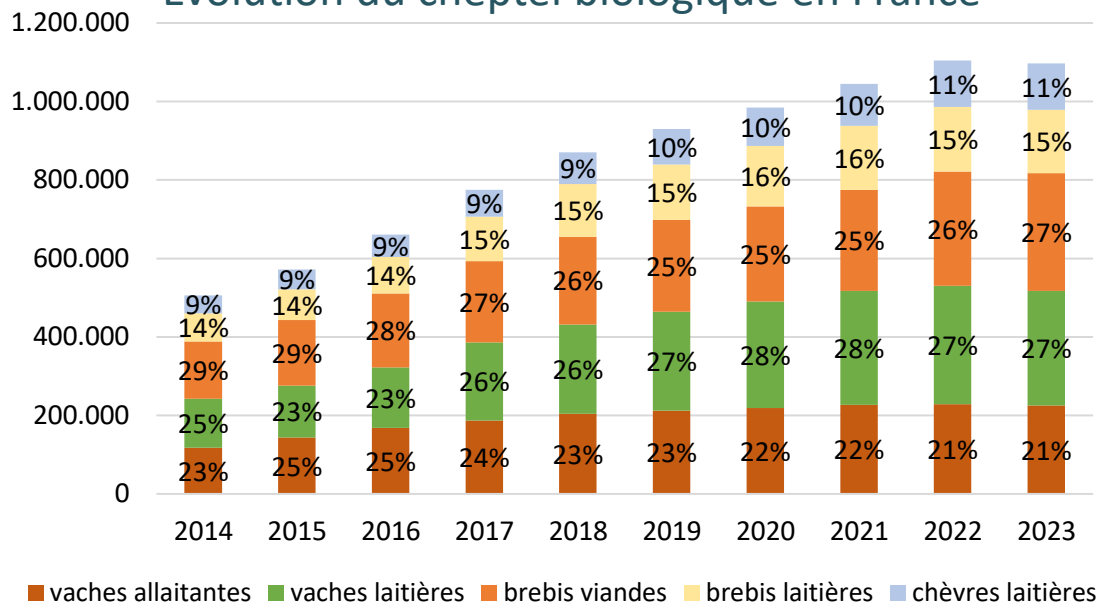


Source Agence Bio 2024

La part des prairies dans la SAU en AB ne croit pas aussi vite que les autres surfaces ces dernières années en France - à l'inverse des grandes cultures qui augmentent
La part de maraichage, PPAM, vignes et autres sont stables dans la SAU en AB

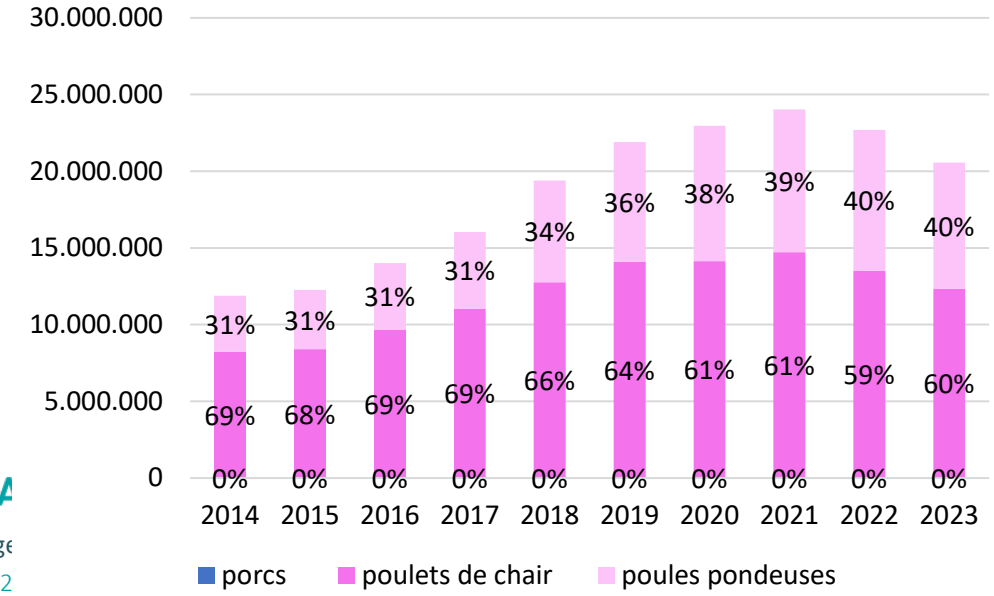
Contexte

Evolution du cheptel biologique en France

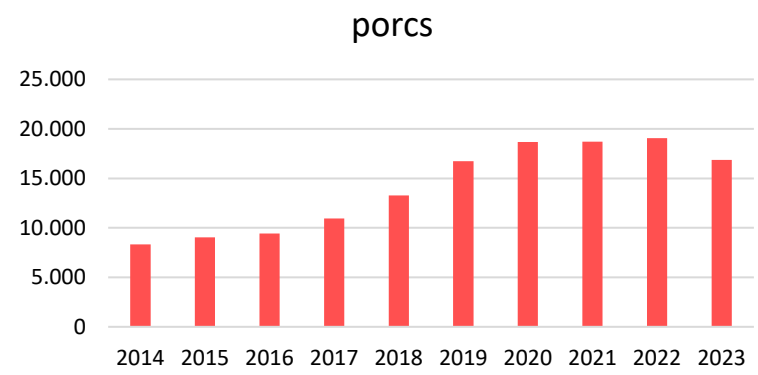


La part des vaches allaitantes et des brebis viandes baisse légèrement
La part des vaches laitières et des chèvres augmente légèrement
La part des brebis laitières reste stable

2022/2023 baisse de -1% pour les ruminants et -9% pour les monogastriques → facteurs limitants est le manque d'alimentation animale bio, et la consommation de produit bio



La part des poulet de chair baisse
La part des poules pondeuses augmente
La part des porcs reste stable mais très faible



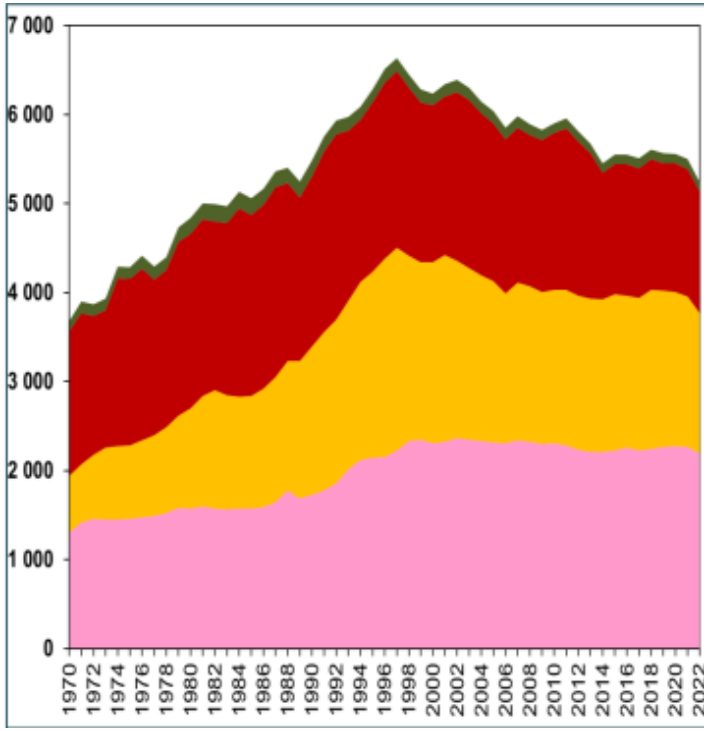
Source Agence Bio 2024

Context

Current meat consumption and production in France

Thousands of tonnes between 1970-2022

Production of meat in France



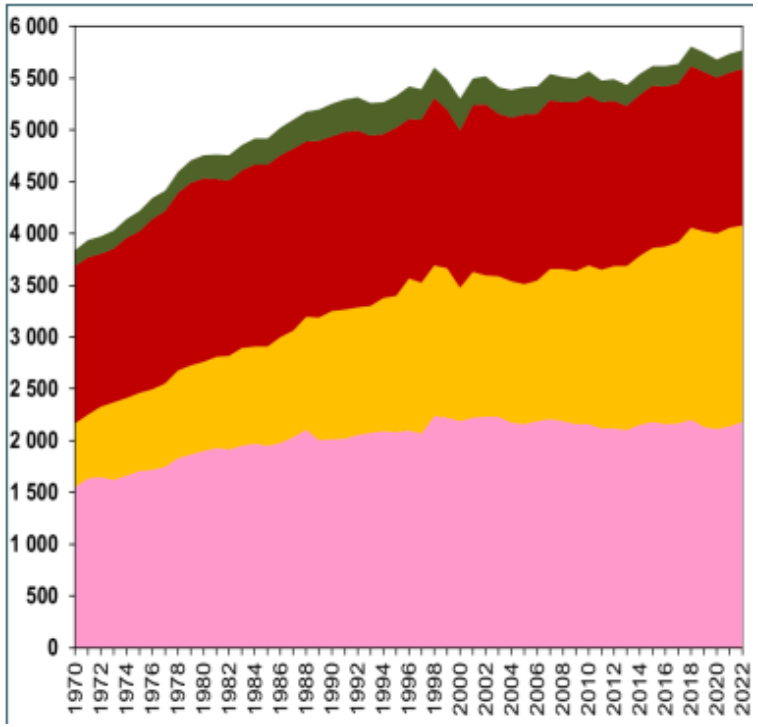
Sheepmeat & goatmeat

Beef meat

Poultry meat

Pork meat

Consumption of meat in France

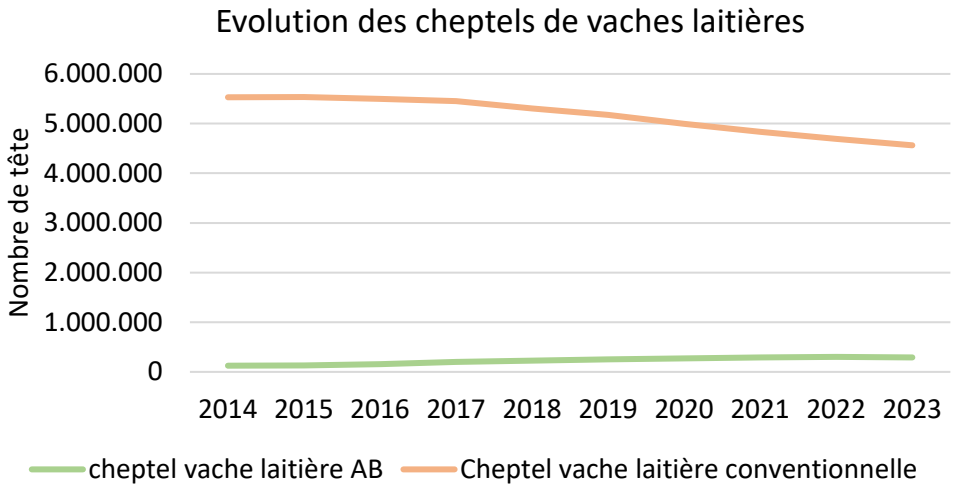


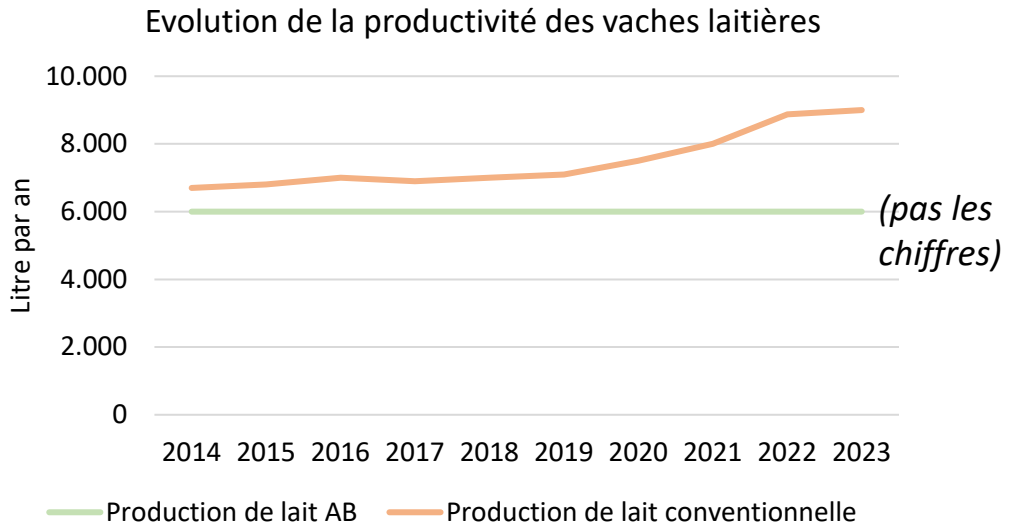
Disconnect between meat production and consumption in France (*Chatellier, 2024*):

- decline in poultry and pork production
- rise in consumption of poultry and pork meat
- major exports and imports of poultry and pork meat

Contexte

Rapport cheptels et productivité





Source : GEB/Idele/Eurostat

Baisse du cheptel de vache laitière conventionnelle mais progression des rendements par vache important et régulier (modernisation/intensification /spécialisation des exploitations)

→ Moins de vache mais produit autant de lait

→ Faut-il adopter un raisonnement sur le cheptel ou sur la part de production ?

(pas les chiffres)

Matériel et méthode

Calibration du modèle pour l'agriculture conventionnelle (2021)

Variable	Abbrev.	Type (Input, Output)	Value	Unit
Crop yield	Y_{crop}	I	139	kg N ha^{-1} yr^{-1} of cropland
Grass yield	Y_{grass}	O	50	kg N ha^{-1} yr^{-1} of grassland
Livestock N-conversion efficiency	NCE	I	19	%
Percentage of crop residues used for feed	$\alpha_{residues}$	I	30	%
Percentage of grassland	τ	I	50	%
Percentage of crop production used for feed	α_{crop}	I	40	%
Atmospheric deposition rate in cropland	r_{atm_crop}	I	12	kg N ha^{-1} yr^{-1} of cropland
Atmospheric deposition rate in grassland	r_{atm_grass}	I	12	kg N ha^{-1} yr^{-1} of grassland
Biological N fixation rate in cropland	r_{BNF_crop}	I	13,9	kg N ha^{-1} yr^{-1} of cropland
Biological N fixation rate in grassland	r_{BNF_grass}	I	23,8	kg N ha^{-1} yr^{-1} of grassland
NUE in cropland	NUE_{crop}	I	70	%
NUE in grassland	NUE_{grass}	I	78	%
N harvest index of crops	NHI	I	70	%
Percentage of N excreted on grassland	γ	I	47	%
Percentage of manure N recovered for cropland	β	I	63	%
Exported manure	$N_{exported\_manure}$	I	49	%
N industrial fertiliser	N_{ind}	I	60	kg N ha^{-1} yr^{-1} of cropland
N in imported feed	N_{import_feed}	I	68	kg N ha^{-1} yr^{-1}
Food yield	Y_{food}	O	67	kg N ha^{-1} yr^{-1} of total agric. area
Total agricultural conventional land	CL	I	24 165 501	ha
Percentage of animal-based food	$Animal_{production}$	O	36	%
N surplus rate	$N_{surplus}$	O	92	kg N ha^{-1} yr^{-1} of total agric. area
Total NUE	NUE_{tot}	O	42	%

Matériel et méthode

Définition des termes et hypothèses

Termes :

$SAU_{tot} = SAU_{AB} + SAU_{conv}$

$Eff_{AB}^{2021} = Rum_{AB}^{2021} + Mono_{AB}^{2021}$

$Eff_{conv}^{2021} = Rum_{conv}^{2021} + Mono_{conv}^{2021}$

$Share\_N_{mono} = N_{output\_mono} / N_{output\_livestock}$

$Conv\_{manure}$ = N dans l'importation d'effluent conventionnel en AB

α_{crop} = part des cultures destiné à l'alimentation animale

État actuel 2021 :

SAU_{tot}^{2021} = 24 589 715 ha

SAU_{AB}^{2021} = 2 253 516 ha

SAU_{conv}^{2021} = 24 165 501 ha

Hypothèses :

Cheptel monogastrique conventionnel n'est pas diminué dans le scénario proportionnel car on observe une hausse de la consommation de viande blanche en France + 46% des exploitations hors sol sont élevages volailles et 18% élevages porcin (Agreste, 2024)

Dans la SAU AB et la SAU conventionnelle sont exclus les cultures de vignes, PPAM, et autres

SAU totale France ne change pas

L'alimentation du cheptel en AB :

- Ruminant : $feed_{grass}$ 90%, $feed_{import}$ 6% et $feed_{residues}$ 3%
- Monogastrique : $feed_{crop}$ 50%, $feed_{import}$ 37% et $feed_{residues}$ 13%

Materials and methods

Scenario construction

Current situation 2021 (UAA 24,5 millions ha)
9% of total UAA under OA
4% of total ruminant on OA
11% of total monogastric on OA

Constraints
25% of UAA to be organic by 2030 + regulations on the use of conventional manure in OA

+36 % organic ruminants
-12% organic poultry
+18% organic pigs
+3% feed import
+3% part destined for animal feed

-15 % conventional ruminants
-15% conventional poultry
-22% conventional pigs
-15% feed import
-15% part destined for animal feed

+173 % organic ruminants
+173% organic monogastrics
+28% feed import

-17 % conventional ruminants
= conventional monogastrics

Scenario 1-2030 : trend in organic and conventional livestock numbers since 2019 (UAA 24,5 millions ha)
25% of total UAA under OA
6% of total ruminant on OA
12% of total monogastric on OA
-15% of total livestock numbers in France

Scenario 2-2030 : proportional change in organic and conventional livestock in organic UAA (UAA 24,5 millions ha)
25% of total UAA under OA
12% of total ruminant on OA
26% of total monogastric on OA
+16% of total livestock numbers in France

Materials and methods

Current situation in 2021

Input variables	Organic agriculture	Conventional agriculture	Total agriculture*	Unit
N_{conv_manure}	3	0	0	kg N ha^{-1} yr^{-1}
$N_{imported\_feed}$	5	68	62	kg N ha^{-1} yr^{-1}

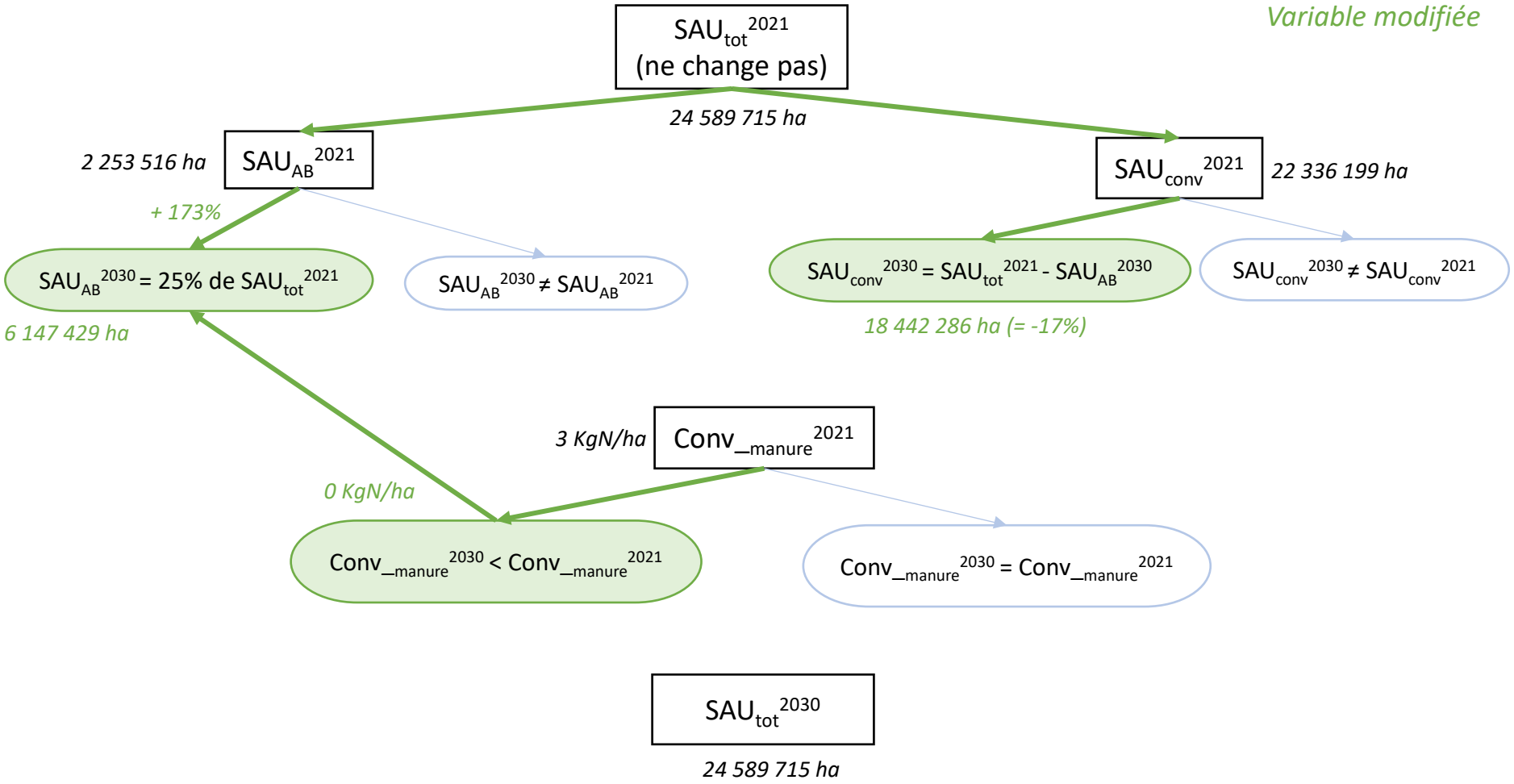
Indicators	Organic agriculture	Conventional agriculture	Total agriculture	Unit
Y_{crop}	52	139	129	kg N ha^{-1} yr^{-1}
N_{output}	19	67	62	kg N ha^{-1} yr^{-1}
NUE_{tot}	43	42	42	%
$N_{self\_sufficiency}$	80	19	26	%
$Animal_{production}$	31	36	36	%

**Total agriculture = 2.2 million ha (UAA AB) + 22.3 million ha (UAA conventional)*

Vergely et al, 2024

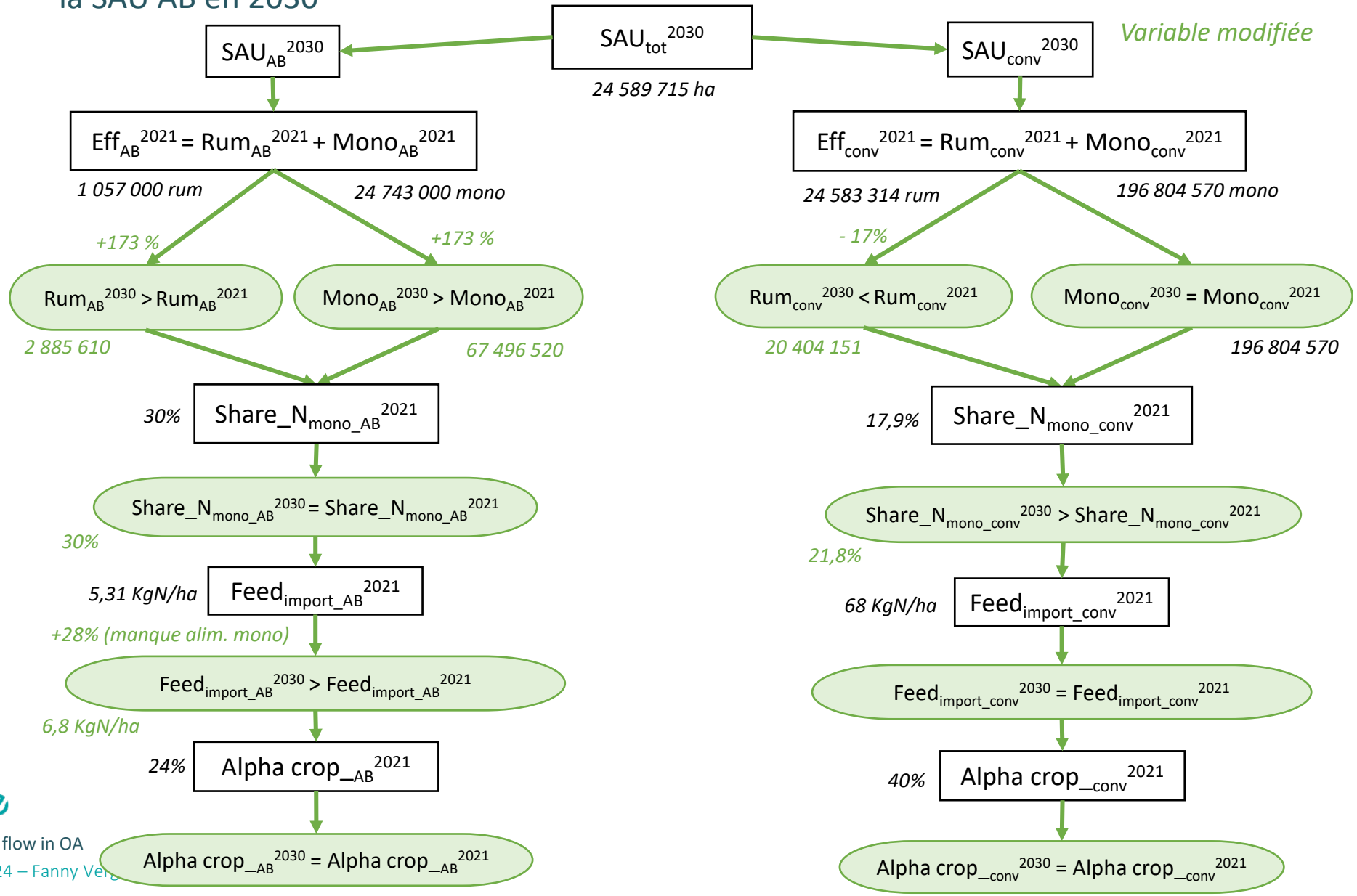
Matériel et méthode

Contraintes : 25% SAU en AB en 2030 et réglementation effluent conventionnel



Matériel et méthode

Scénario 1-2030 : évolution proportionnelle des cheptels biologiques et conventionnels à la SAU AB en 2030



Matériel et méthode

Scénario 2-2030 : évolution tendancielle des cheptels biologiques et conventionnels depuis 2014

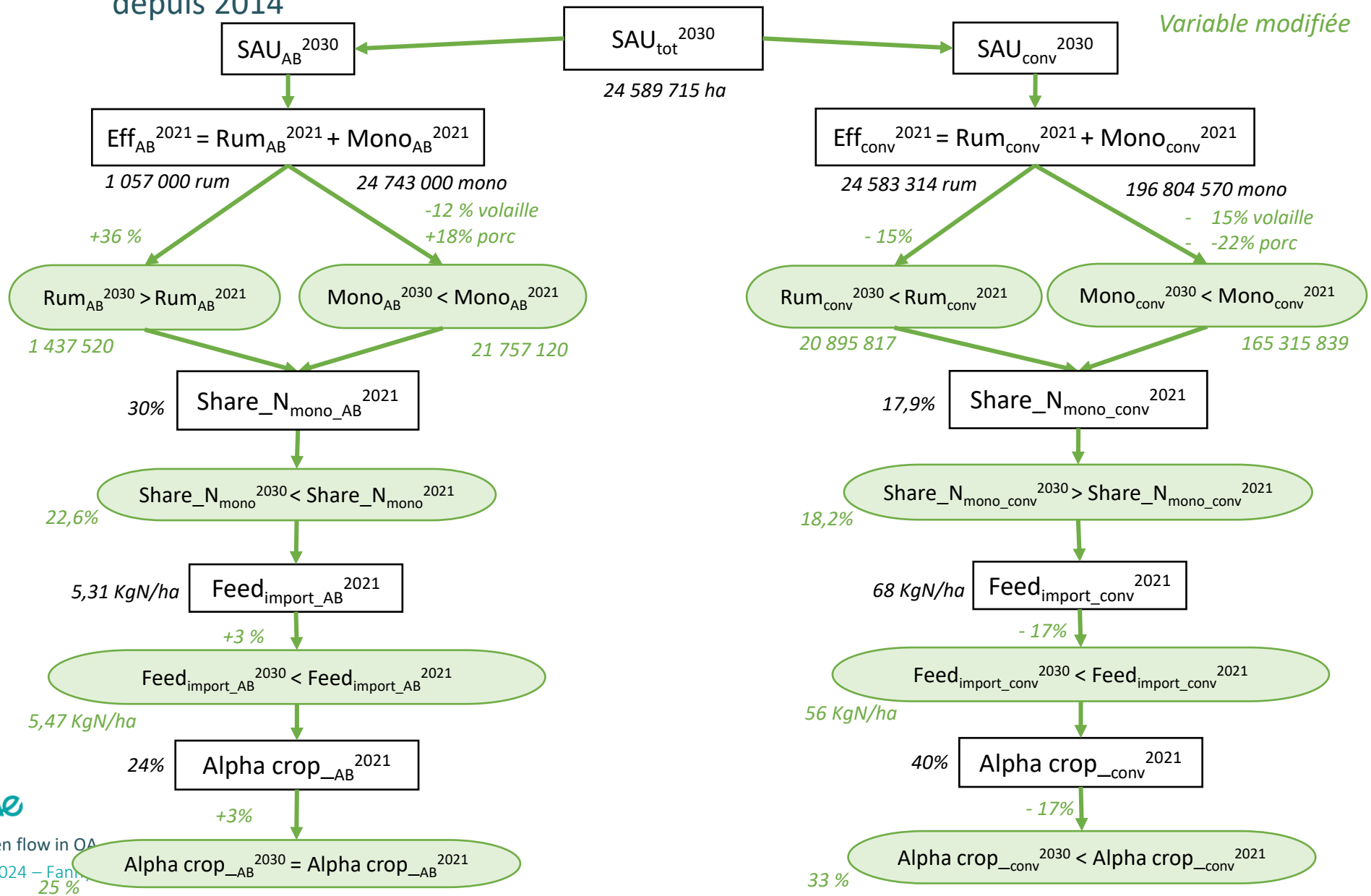
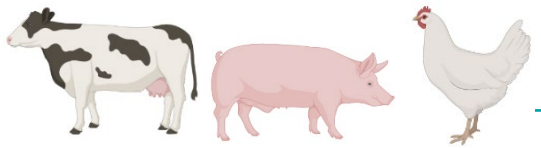


Figure article

Increase livestock numbers



- In OA the second largest potential N input is the recycling of N flows from grassland to cropland by livestock (Berry et al., 2002; Peyraud et al., 2012; Dumont et al., 2016)

→ Improve nutrient circularity in OA

→ BUT possibility to found other nitrogen ressource like household bio-waste, green waste compost, biogas, incorporate legume

- role in global warming (greenhouse gas emissions, such as methane)

- deforestation it causes in Latin America

- pollution for which it is responsible through the potential surplus of manure in relation to the areas where it is spread and via the pesticides used by the crops grown for it

- impact on human health of excessive consumption of animal by-products.

→ Several agri-food scenarios at multiple scales indicate that livestock numbers must decrease greatly to maintain the availability of sustainably produced food (Van Zanten et al., 2018), increase nutrient circularity and reduce greenhouse gas emissions (van Selm et al., 2022) or to maintain the agri-food system within environmental limits (Springmann et al., 2018)

→ BUT may change land use, lack of manure, for fertilizing organic crops, decrease grassland area

Decrease livestock numbers