The future of agriculture

The agriculture of the future.

LOME

(Leguminous, Oleaginous
MEthanisation

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Agriculture is in crises!

Since when? At least 50 years!

What are the solutions?

Challenges of sustainable SOCIETAL development

1. GROWTH. **Gross Domestic Product / capita .year in Europe**

	west	east
	~€30 -40000 €	**~ 20000 €**
***The share of agriculture & IAA in GDP*:**	**0.7 - 2%**	**≥3% (Ro 4.3 Mo10.2)**

What challenges agriculture should face if its future development is to become a priority

2. L'ENVIRONMENT = major challenge for future development

New geological era: Anthropocene

Climate change, LCA, resources …

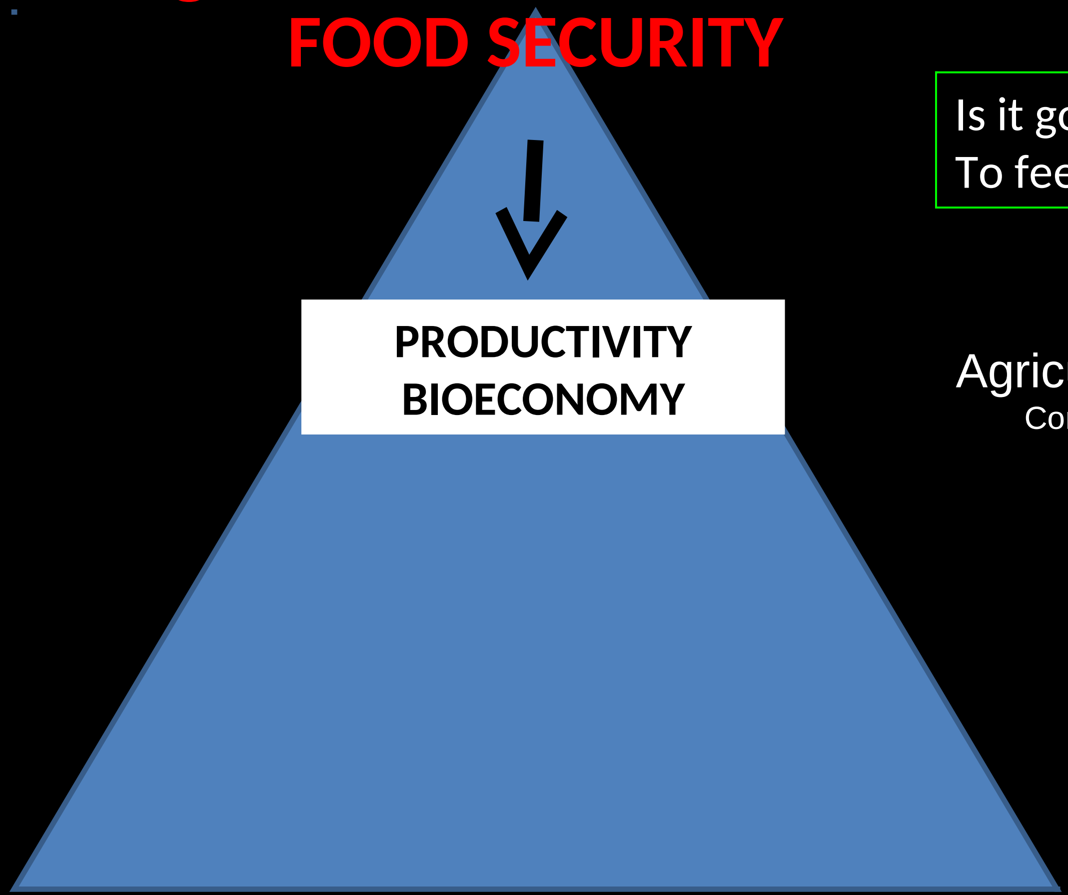
W. Nordhaus and P. Romer (Nobel prize 2018): combine long-term sustainable growth of the world economy and environment (climate change…)

3. ENERGY is/ will be the key to the future

the EU with high energy dependency → RENEWABLE ENERGIES

Sustainable development → capital & knowledge & environment

The 3 MAJOR CHALLENGES for future agriculture in future society



Is it going down?
To feed the world?

Agriculture and Food
Comments at the end

	Composition (%MS)					
	Amidon	Carbohydrate C5 C6...autres	Lipides	Total C	Protéines	Lignine
GRAINS						
Maïs	71	14	5	90	9	2
Blé	66	17	3	86	13	2
Soja	15	14	21	50	41	6
Petit Pois	55	18	2	76	25	6
Lupin	22	23	5	50	45	16
Fève	42	21	1	64	31	9
BIOMASSE AERIENNE						
Blé pailles	0	92	2	94	3	45
Pois résidus	0	81	2	83	7	41
Graminées & Trèfle	2	62	4	66	22	20
Luzerne (après flo)	2	72	3	75	20	31

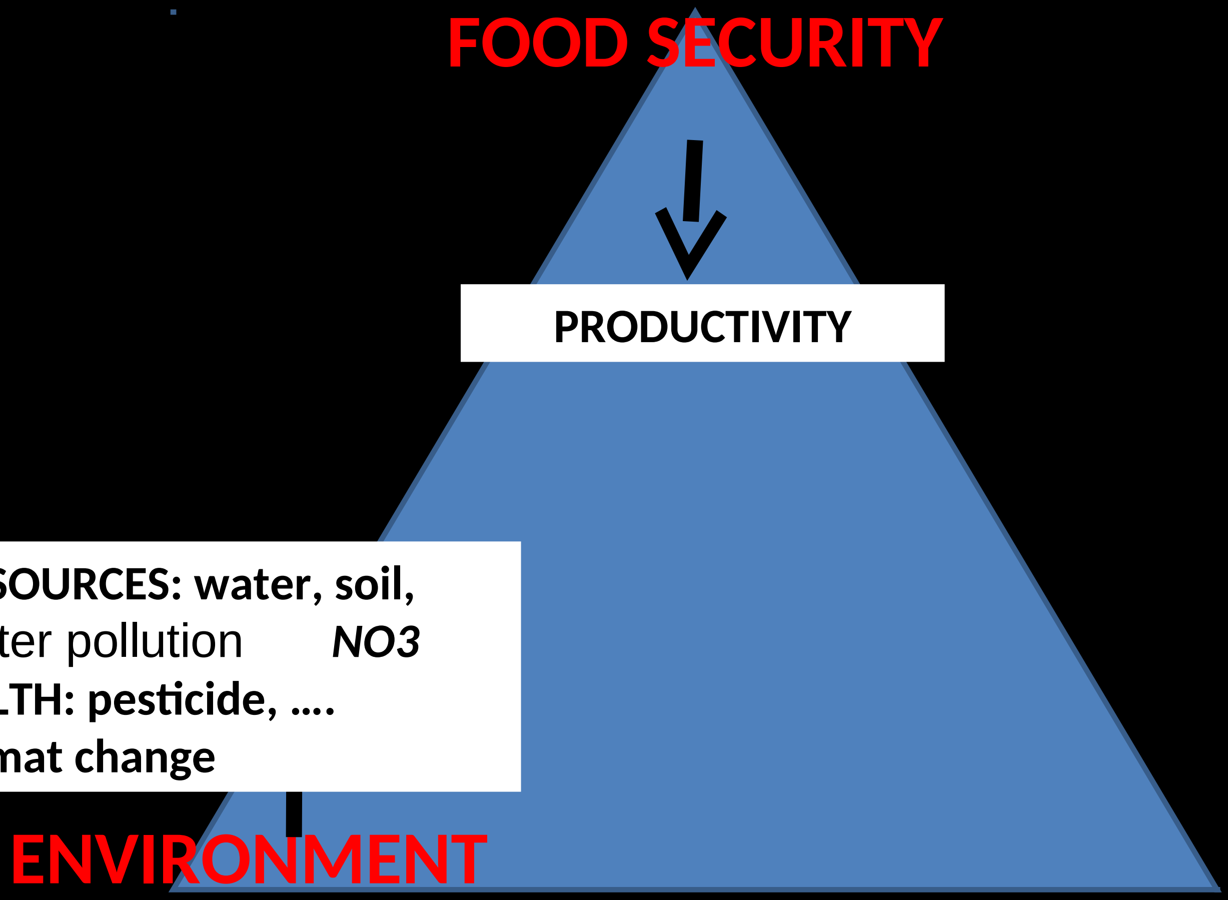
BIOMASS

CARBON (50 à 90%) + NITROGEN (10 à 50%)

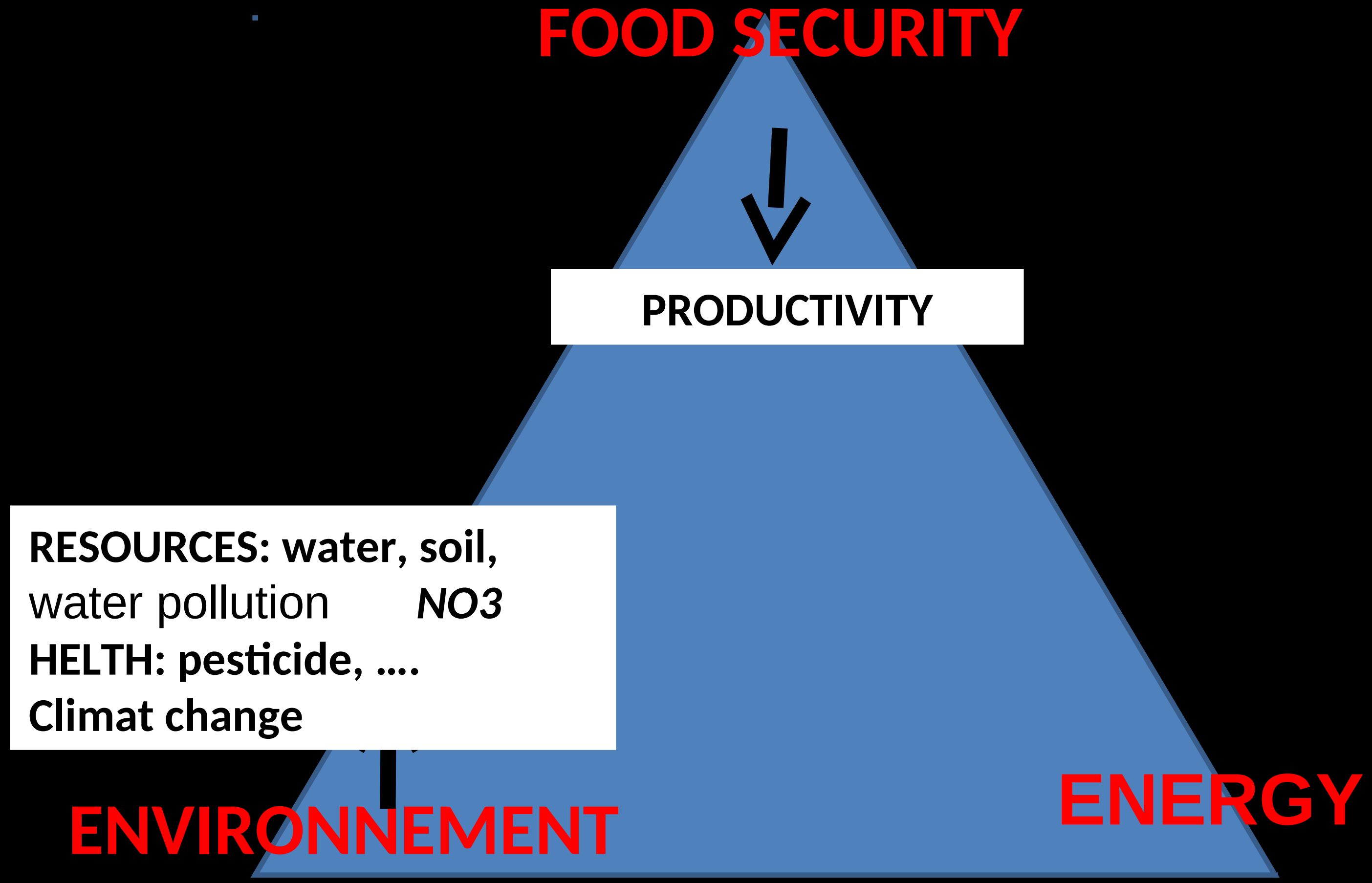
BIOECONOMY

_biomass production & processing

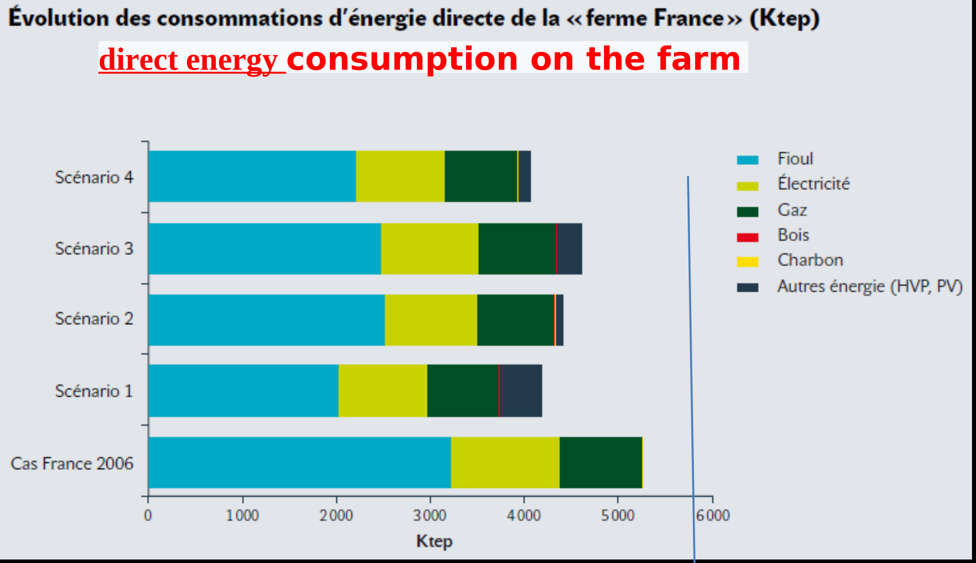
The 3 MAJOR CHALLENGES

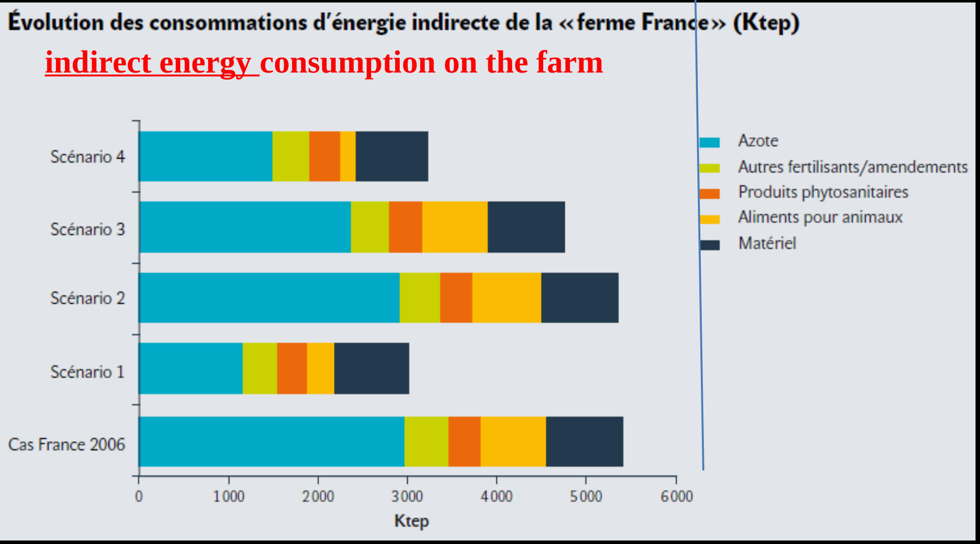


The 3 MAJOR CHALLENGES



Agriculture and Energy: 4 evolution scenarios Prospective 2030 France/2006





1•Territauriorisation Regionalisation, hight energy prices, autonomy, N-40%, yield -20%, methanisation >biofuels

2.Sustainable under energy realism, precision, intensive, multifunctional with environmental services, price volatility, globalization, CAP decreases, inputs increase, yield + 1% Extensive or intensive organic farming for export,

3.Health without major energy constraints, sector, local, intensive or bio-urban food, biofuels 2nd generation

4. Intensive ecology with energy control, CO2 prices ***56 € in 2020 and 100 € in 2030,*** strong CAP, legumes and oilseeds, high RTD, high methanisation and autonomy.

- *N=element inputs* (reduction of -61%, -15% and -40% under scenarios
- Soybean cake imports (protein autonomy in sc.4 versus increase in sc.2)

Agriculture Energie 2030Vert J., Portet F. (coord.), Prospective Agriculture Energie 2030. L'agriculture face aux défis énergétiques, Centre d'études et de prospective, MAAPRAT 2010.

Agriculture et Energie: 4 scénarios d'évolution
Prospective 2030 France/2006

Conclusion

1. A radical change in the production method could save fossil energy

~ 500ktep 10% direct +~ 1500ktep 30% indirect (N…)

2. The energy autonomy of agriculture contributes to the sustainable development of agriculture but it is not significant for the energy autonomy of the country

because the energy consumed by agriculture represents only about 4% of the total energy consumed in a country like France

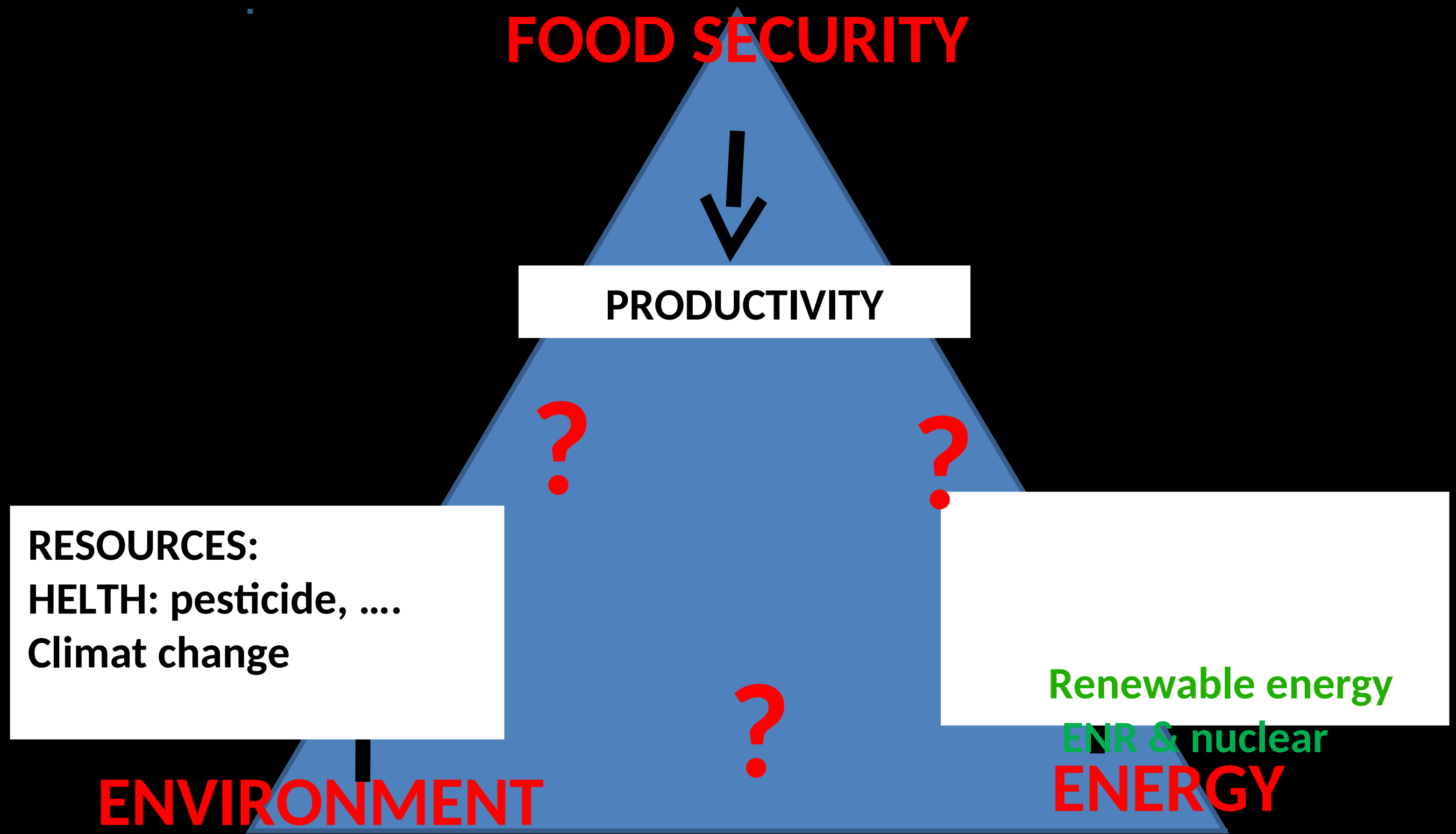
It could even be subsidized!

3.But the agriculture can participate significantly in the energy autonomy of the country by the production of renewable energy,

A major objective at country level.

Agriculture Energie 2030Vert J., Portet F. (coord.), Prospective Agriculture Energie 2030. L'agriculture face aux défis énergétiques, Centre d'études et de prospective, MAAPRAT 2010.

3 DEFIS MAJEURS



Do today's modes of production meet these criteria?

Are current knowledge sufficient to develop a new agriculture?

The fate of N in cropping systems → environment

Uncupled N and C

Management practices that alter inorganic fertilizer addition

Forme, rate application timing, methods…

Meta-analysis of 217 ^{15}N field Experiments

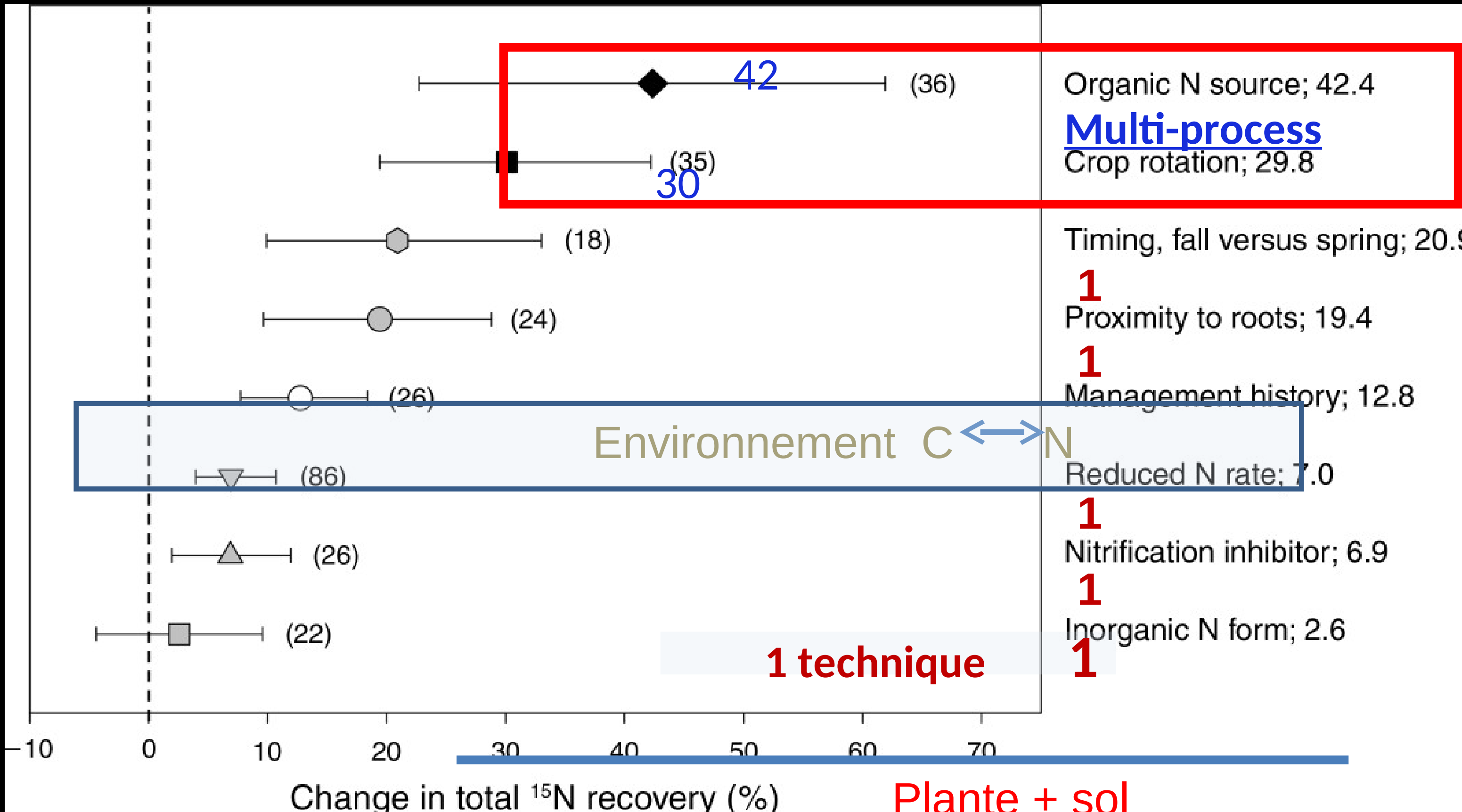
Short-Term studies

Cupled N and C

Complexed practices that coupled C and N

organic N sources, diversified crop rotation

JENNIFER B. GARDNER AND LAURIE E. DRINKWATER 2009. Ecological Applications Vol. 19, No. 8



Multi-process (30-42%)>> 1 technique réduction (2.6 -20.9%)

JENNIFER B. GARDNER AND LAURIE E. DRINKWATER 2009. Ecological Applications Vol. 19, No. 8

5 New complex agro-ecosystems producing
FOOD & FOODDER & BIOENERGY

1st approach

- ***1.8 TEP / t N*** *(NH4NO3) & 5.30 kg equivalent CO2/ kg N*

⇓

replacement of synthetic mineral nitrogen with nitrogen biologically fixed by legumes

⇓

comparison of conventional cropping systems without legumes with cropping systems with legumes in main crop and / or intercropping

First experiment: quantification

Long term experiment (30 years: 1969 – 2000), INRA Clermont-Ferrand

- 2 crops system of 6 years

  A: Wheat, Sugarbeet wheat, corn (rapeseed), wheat, barley (wheat)

  L: Alfalfa 2 years wheat, corn (rapeseed), wheat, barley (wheat)

- Mineral N: with or without Nmin on annual crops
- CI vetch: with or without EV behind a straw cereal
- R lignified culture residues: with or without

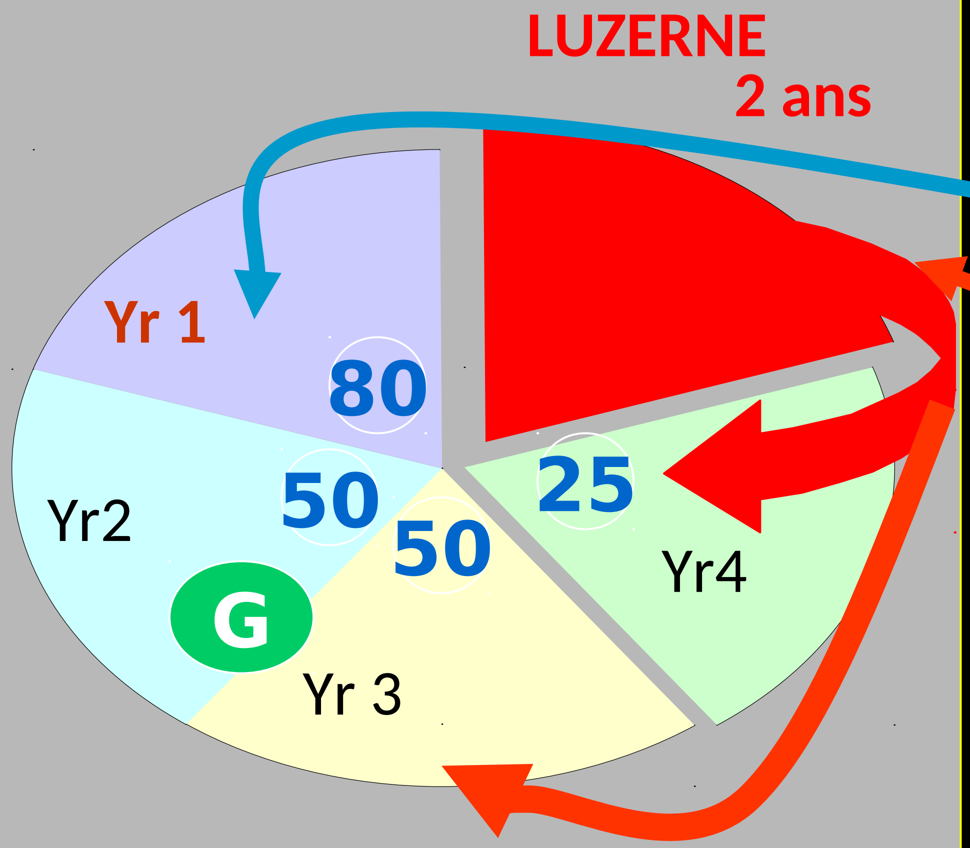
16 treatments = 2 CS * 2 Nmin * 2 CI * 2 R

A 2-year-old alfalfa produces about 1000 kgN,
± 800 in the aboveground biomass
± 200 in the soil

Can we satisfy the N requirements of a high productivity production system from legumes?

A second approach 2nd experiment:

N selfsufficiency crop system based on N brought by Legume



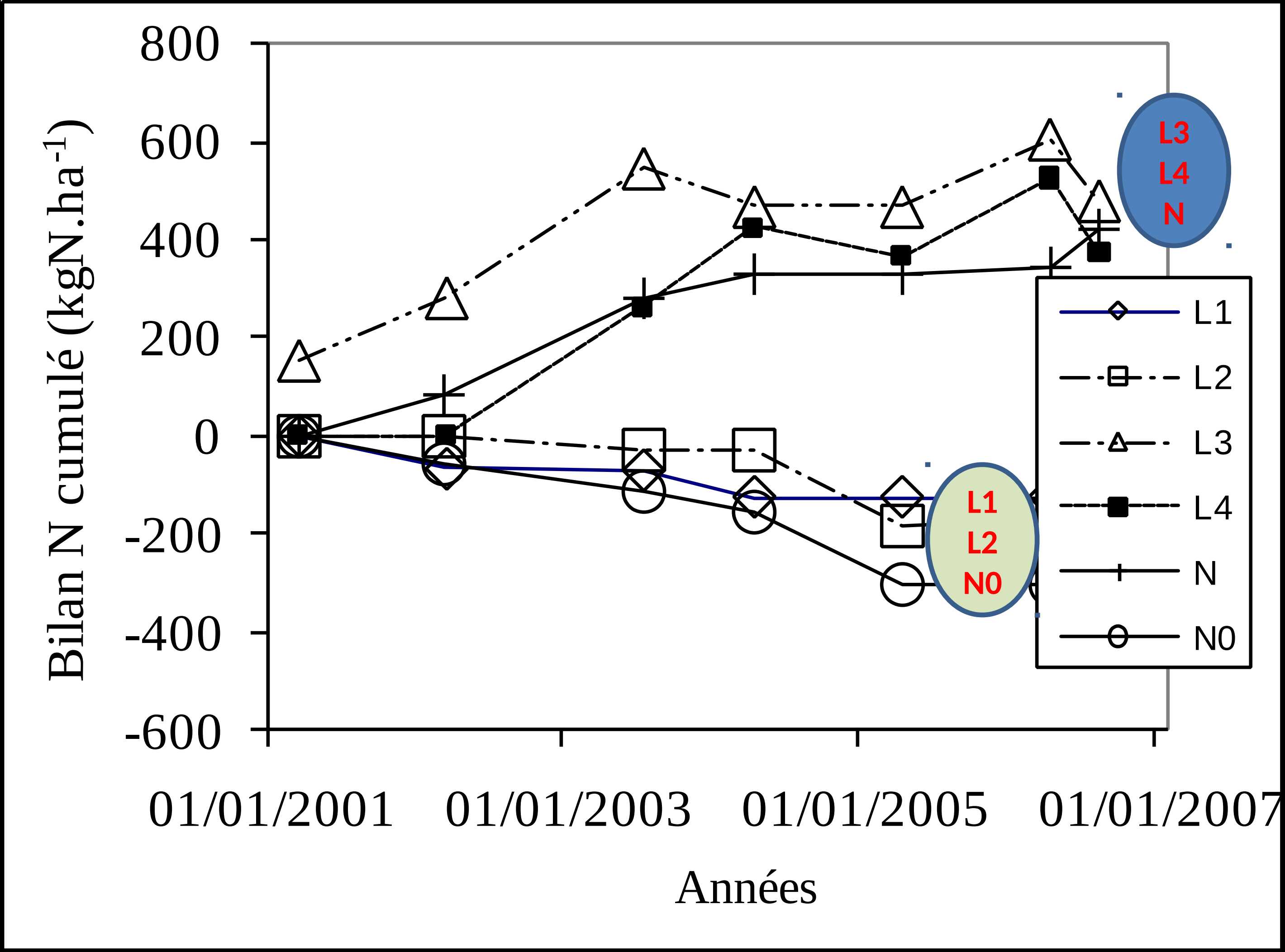
N-Sources

1. Luzerne > 1000 kgN

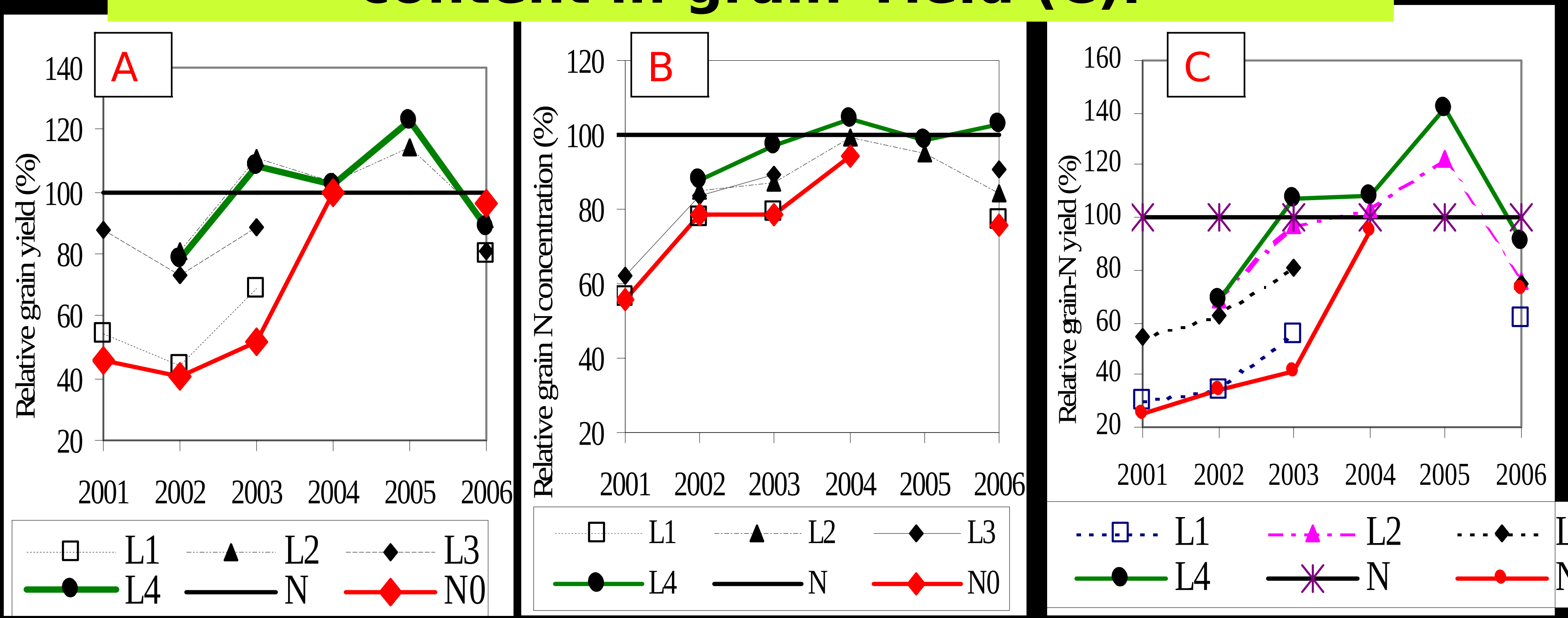
- **residual effet**
  - **200 kgN/4 years**
- **alfalfa biomass used as "organic fertilizer"**
  700 kgN/2 yrs
- **2. Legume Green Fertilizer**
  50 – 100 kgN/yr

Fig. 2. DYNAMIQUE DU BILAN D'AZOTE

N inputs by underground biomass of Lucerne are not included in balance.



Relative yield (A), relative N concentration of grain (B) and relative N content in grain-Yield (C).



N treatment (mineral fertilisation) was used as reference treatment (100%). L1 to L4 = organic N treatments as in Table 2; N0 = without N input.

Crop grown: Wheat 2001, 2002, 2003, 2006; Maize =2004; green pea =2005

The relative grain-N yield and the relative total-N yield are high

NOTE: *Based on these results ARVALIS (former ITCF) organized a network research- development to answer this question for organic agriculture*

CONCLUSIONS

1. The achievement of autonomous CSs in N is not a utopia
2. In animal-free production systems, pulse biomass can be used as a nitrogen source for self-sufficiency.
3. 10 to 20% of the surface area must be reserved for the production of this biomass

<u>3th approach</u>

In the conventional Intensive System
10 - 20% of the area is used for
energy crops: biofuels

<u>The production system is not improved</u> because biofuel is produced in centralized industrial facilities that control the price of biomass

4th approach

Crop systems with pulses in which 10 to 20% of the surface is reserved for the production of energy
produced and consumed on the farm.
The evaluation of the agro-system is carried out using criteria derived from the ecology of natural environments and agro-ecology

The Value of Producing Food, Energy, and Ecosystem Services within an Agro-Ecosystem

Combinated Food Energy (CFE) system was planted in May 1995 (11.1ha)

45% arable food (barley and wheat)%
45% pasture fodder crop (clover-grass) and
10% biofuels: four belts of fast-growing trees

J Porter et all, 2009, AMBIO A Journal of the Human Environment · July 2009

Ecosystem services (ES) : market and nonmarket ES

- = the benefits humans derive from ***ecological processes*** & ***ecosystem function***
- provide a significantly increased net crop, energy, and nonmarketed ES
- require markedly less fossil-based inputs.
- provide environmental value for money for farming and nonfarming communities
- at European scale, the value of nonmarket ES > European farm subsidy payments

ES associated with the CFE system were assessed by field monitoring and assessment methods in June 2006 (1995 -2006)

Field assessment of each ES in pasture, cereals, and wood biomass

Field process and/or state		Pasture 45%	Cereals 45%	Biomass 10%
Predation rate of aphids (% removal 24/hr)	ES1	20	53	0
Predation rate of eggs (% removal 24 hr_1)	ES1	45	38	0
N regulation: mineralization of plant nutrients (%)	ES2	14.5	16.7	17.1
Earthworm density (number m_2)	ES3	104	160	0
Food/fodder (t dry matter ha_1)	**ES4**	**6.1**	**4.1**	0
Yield of wood (t dry matter ha_1)	**ES5**	**0**	**0**	**10**
Carbon residue (t ha_1)	ES6	3.7	2.5	0.5
Water recharged into ground (mm ha_1)	ES7	382	432	212
Aesthetic (*USD ha_1*)	ES8	262	138	332
Pollination (hives)	ES9	0.5	0	0.5

** The ES value of the CFE system was calculated based on the ratio of 45 : 45 : 10*

J Porter et all, Ambio Vol. 38, No. 4, June 2009

The monetary value and field assessment of ES in pastures, cereals, biomass belts, and the CFE system.

ES value USD/ ha/1 y1*	PASTURE 45%	CEREALS 45%	BIOMASS 10%	CFE 100%
Biological control of pests	13	0	12	**7**
N regulation: fixation & mineralization	434	217	125	294
Soil formation	11	17	_	13
Food and fooder production	**216**	**515**	**0**	**329**
Row material (biomass) production	0	0	**600**	60
Carbon accumulation	37	25	60	34
Hydrological flow	76	86	42	77
Anesthetics	262	138	332	213
Pollinisation	85	0	85	**47**
Total economic value of ES	**1134**	**998**	**1146**	**1074**
Nonmarked ES value NMV	**918**	**483**	**546**	**685**
NMV/ES value	**0.81**	**0.48**	**0.48**	**0.64**
Ambio Vol. 38, No. 4, June 2009				

5th approach

LOME CONCEPT

FOOD & FIBER & ENERGY

CH_4

biofuel

wood

autonomy

D. The Future agriculture could be

L	= legumes
O	= oilseeds
Me	= methanisation

The 3 levers are interdependent because the L produce nitrogen (N) but also energy (Carbon), the O produce energy, and the two constitute a substrate for the production of energy by methanisation.

C-energy will be the main export

The other elements N, P, S, K, Ca, Mg, etc. will be returned to the ground with the digests of methanisation in an easily assimilable form par les plantes.

L

like Legumes

L like Legumes

- Disappearance of legumes in CS: Implications (French agriculture)

- **IF 3 400 000 ha was in 1959 et < 400 000ha acctually**, the loss of ~ 3,000,000 ha of legumes represents

N loss of 3,000,000 ha * 200NFB/ha = 600,000 tNla = **600 000 tN**

(corresponds to 6 000 000 ha at 100 kg N/ha) 1kgN= 1l fuel for its synthesis

Massive protein import: 80% of the requirements (soybeans):

Environment: excess – pollution: 835,000 tonnes of nitrogen per year

?

Will we be able to meet the N requirements of a high productivity crop system by N from leguminous crops?

ESSAI 1

Essai de longue durée (30 ans: 1969 – 2000), INRA Clermont-Ferrand

- 2 rotations de 6 ans:

A: *Blé, Betterave S,* blé, maïs (colza), blé, orge (blé)

L: LUZERNE 2 ans blé, maïs (colza), blé, orge (blé)

- N minéral : avec ou sans Nmin sur cultures annuelles
- EV vesce: avec ou sans EV derrière une céréale à paille
- R résidus de culture lignifiés: avec ou sans

16 traitements = 2 rot * 2 Nmin * 2 EV * 2 R

The alfalfa crop grown for two years about produced about 1000kg N of which 200 are in the soil.

O

OILSEED

ENERGY

Recovery of C

HVP

CAKES

Recycling of N, P, K, Mg, …

- Animals → manure
- Direct use as fertilizer
- Novel substrate for methanisation.

Me ⇨ METHANISATION

Définition
Avantage
Les substrats
Le digest : composition
Agronomie: utilisation digest//biomasse
fertilité du sol

Transformation of organic matter C to CH_4 by anaerobic fermentation by

mesophilic bacteria 30-35°C

thermophilic 50-60°C

This results in:

BIOGAS = 50 -70% CH_4 +35% CO_2 →*electricity + heat*

Purification

Biogas →Bio-methane → injected into the gas network

bio-CNG fuel

DIGESTAT: contains *a portion of unprocessed C

***other elements N, P, K, Ca, Mg…**

Biogaz et Légumineuses: potentiel CH4

Potentiel CH4 (m3/kg VS) ***VS=Solid volatiles = MS - ash (550°C))***	
Maïs **Rye gras**	**0.38** **037**
Lucerne **Trèfle** **Lupin** **Fève** **Pois** **Vesce**	**0.34** **0.35** **0.34** **0.36** **0.39** **0.28**
Maïs frais **Maïs ensilage** **Trèfle frais** **Trèfle ensilage** **Graminées** **Phleum Pr- Trèfle violet (10%)** **Trèfle violet** **Vesce (50%)-avoine** **Lupin (polyphyllus)** **Grainés-trèfle**	**0.43** **0.39** **0.38** **0.40** **0.40** **0.37** **0.29** **0.41** **034** **0.34**

Jensen, 2012

Agricultural methanisation and use of energy crops in co-digestion

December 2009 ADEME Page 47 of 130 Table 4: Crop Database Modified

	DM	OM	N	Yield	m^3CH_4		m^3CH_4/ha		kgN/ha
	%	%MS	%MS	*tMS/ha*	t/HM	t/MO	min	max	min _ max
Trèfle-ensilé	19	89	2.3	*6 à 8*	58	352	1880	2506	138_184
Trèfle vert	18	89	2.5	*6 à 8*	50	313	1669	2225	150_200
Luzerne ensilée	33	88	4.4	*11 à 16*	99	340	3291	4787	484_704
Luzerne verte	18	90	3	*11 à 16*					330_480
Prairie ensilée	21	92	1.5	*4 à 6*	53	272	1001	1501	60_90
RGIt ensilé	24	91	1.3	*6 à 8*	90	409	2233	2978	78_104
RGIt vert	24	91	0.8	*6 à 8*	89	409	2233	2978	48_64
Maïs ensilage	30	84	1.3	*12 à 18*	80	318	3203	4804	156_234
Blé vert	37	93	1.2	*12 à 16*	111	324	3616	4821	144_192
Orge verte	38	93	1.1	*9 à 13*	126	356	2980	4304	99_143
Corn stover	52	91	0.3	*6 à 9*	82	173	945	1417	20_30
Straw wheat	88	92	0.3	*8 à 10*	199	245	1803	2254	25_30
Top beets	13	63	1.4	*4 à 8*	31	353	960	1910	56_112

LOME Crop rotation // Energy crops (EC)

EC:	**Maïs**	**Maïs**	**wheat *+IC***	***oilseed***	*maïs*	*betterave*
LOME:	**Alfalfa 2 ans**		**wheat *+IC***	sunflower + rapeseed	**maïs**	**betterave**
100Ha =	***10***	***10***	***30***	***10+10***	***20***	***10***

Energy yield	Ha	MS t/ha	LOME (*20% alfalfa*)			
			Tota lt DM	CH4 m3	Total CH4	Total kg N
alfalfa 1 **Wheat straw**	10 10	7 5	70 50	335 190	24000 9500	X 750
alfalfa2 ***Rapes straw***	10 10	15 2	150 20	335 150	*50250* 3000	10000 100
TOTAL	100		670		206010	17300

200 000 m³ CH4 →2000MWh energy *thus*

~800 MWH electricity

(~100kw power)

800 * 0.15 = 120 000€

This potential could double if husbandry systems are taken into account!

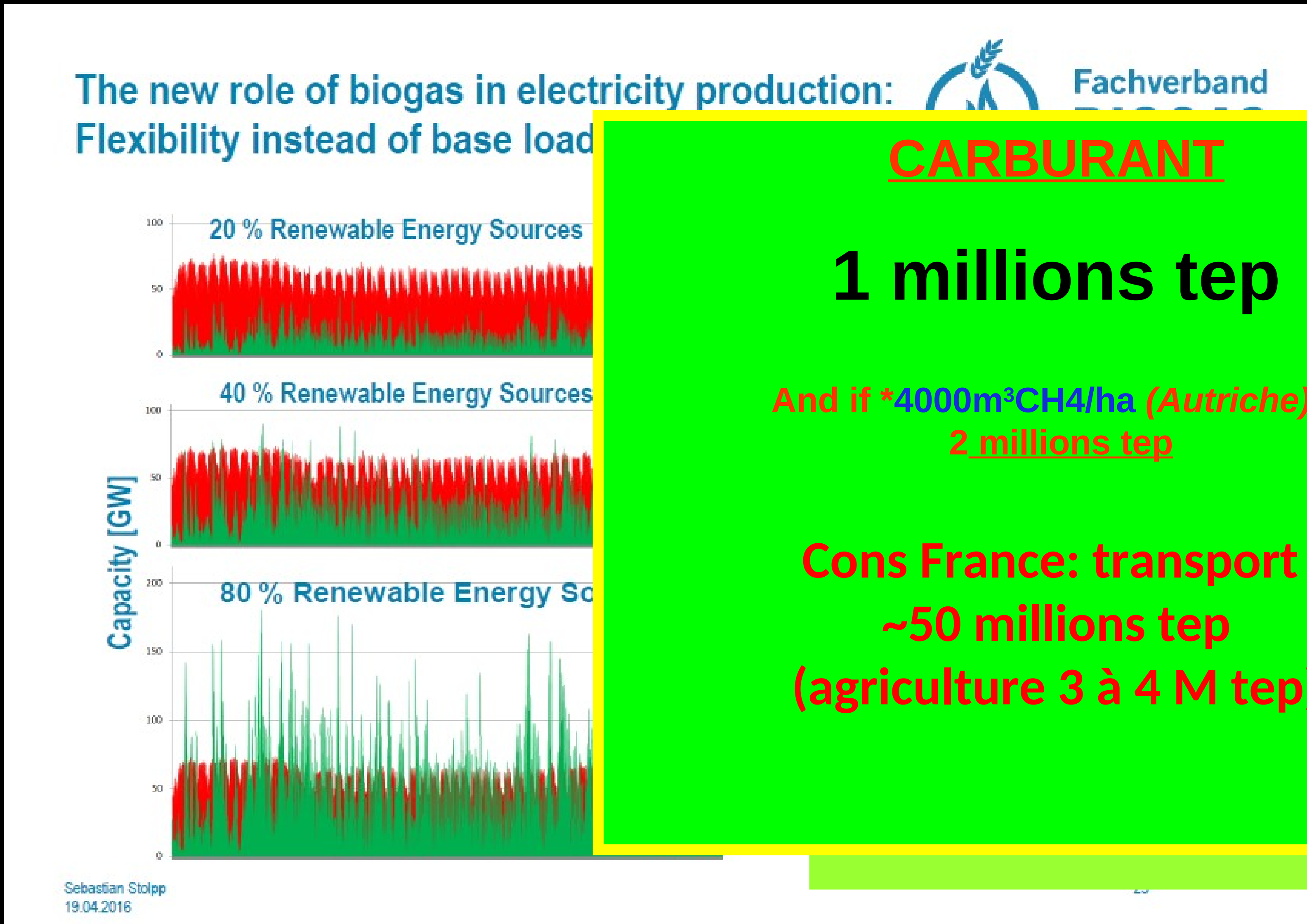
For ~ 100.000 ha energy crops (fuels, etc.)
energy production is
100.000 ha *6.000m3 CH4/ha = 600 millions m3 CH4

If the 100,000 ha are integrated into a LOME system
(rotation 5 years, 500,000 ha)
then energy production would be
500.000ha* 2000 m3 CH4/ha =

1 milliards m^3 CH4

Et si *4000m^3CH4/ha *(Autriche)* = 2 millions tep

Energy autonomy: 1milliards m³ CH4



CARBURANT

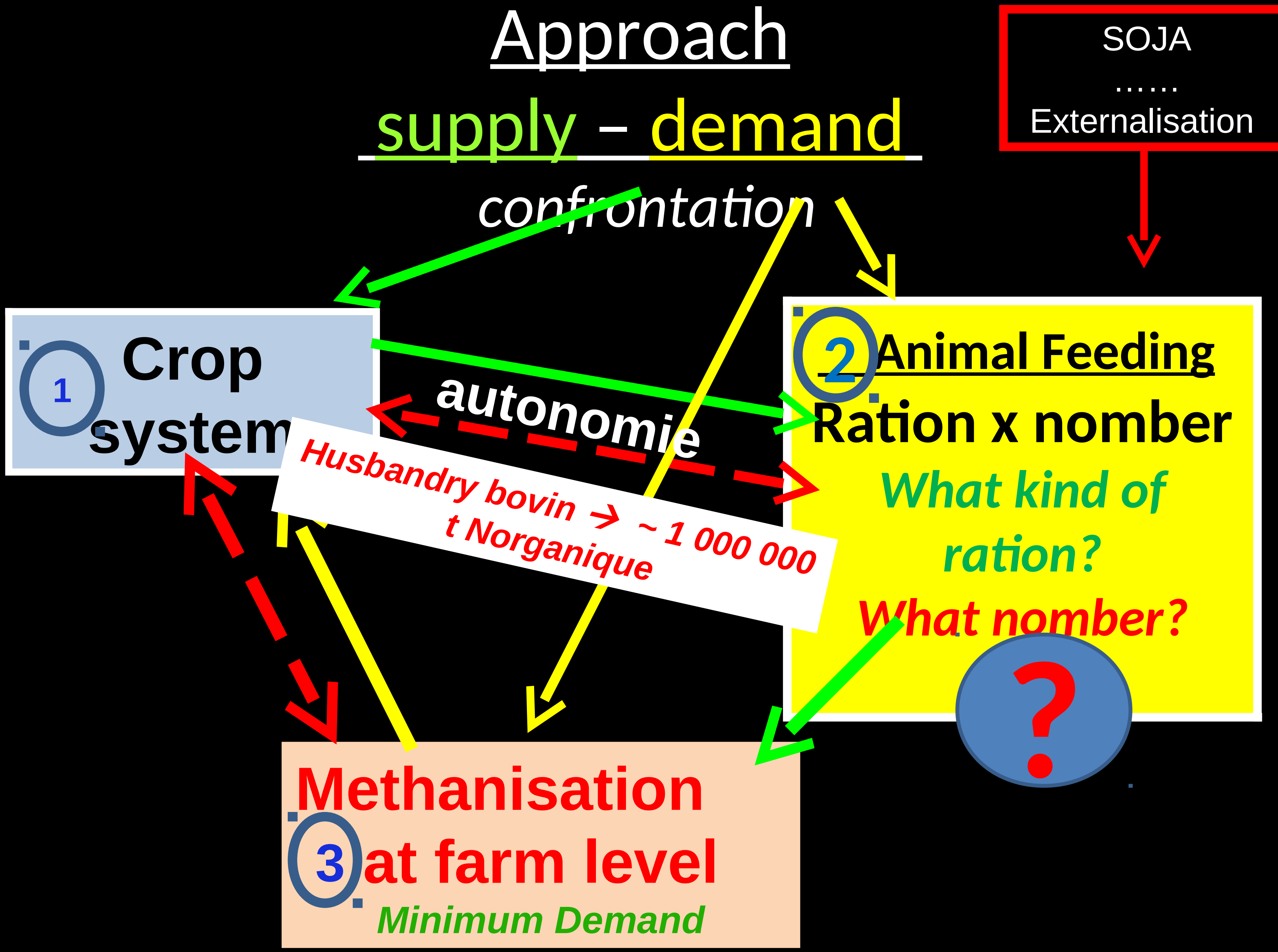
(100.000ha)

1 millions tep

And if *4000m³CH4/ha *(Autriche)* =
2 millions tep

Cons France: transport
~50 millions tep
(agriculture 3 à 4 M tep)

+ Heat


Approach
supply – demand
confrontation
SOJA
……
Externalisation
1 Crop system
autonomie
2 Animal Feeding
Ration x nomber
What kind of ration?
What nomber?
?
Husbandry bovin → ~ 1 000 000 t Norganique
Methanisation
3 at farm level
Minimum Demand

Manure supply and use

For 1000t MANURE

If 10t manure/UGB, than for 100UGB = 1000t manure

With 60m3 biogaz /t HM or 200m3/t DM
BIOGAZ yield =1000*60 =

60.000 m3 biogaz *(for 100ha> 185 000m3 biogaz)*

- The manure has a low methanogenic potency
- Need for complementary substrates richest in C→CI
- Association of several farms

- BUT is a source of micro-organisms and has an important buffer capacity

Composition of digests according to the origin of the substrate.
(GC=clover & grass; CC=vetch)
(CG&CC stored by silage; fermentation 2 steps, 4 to 10 days)

	Liquide	SOLIDE					
		CG&CC	Paille Pois	Paille blé	Maïs & CG ensilage	intervalle	*%MS*
MS%	2.5	18	17	18	20	18-20	
MS org%	52	74	89	89	83	74-89	
%N (MF)	**0.25**	**0.56**	**0.30**	**0.24**	**0.45**	**0.24-0.56**	***1.3-3.1%***
N-NH4 (MF)	0.18	0.15	0.02	0.02	0.081	0.02-0.81	*0.1-4.1*
NH4/Ntot	71	26	6	10	18	6-26	
C% (MS)	36	40	46	45	43	40-46	
C/N	**3.7**	**11**	**32**	**39**	**19**	**11-39**	
P% (MS)	0.62	0.40	0.24	0.15	0.39	0.15-0.40	*0.8-2.2*
K (MS)	18.5	2	1.22	1.42	1.68	1.2-2.0	*7.1-11.1*
Mg (MS)	0.72	0.36	0.25	0.16	0.25	0.16-0.36	*0.9-2.0*
pH	7.69						

Stinner, Möller, Leithold, EJA, 2008

Digest = the best fertilizer!

- **Méthanisation /?/ compostage**
- Allows for relative separation of cycles C and N
- Better distribution in time and in crop system.
- Better BNF because lower N content
- Reduction of N losses by leaching
- Higher N use
- Reduction of Greenhouse Gases Effects

Autonomy in nitrogen

- is no longer a utopia because the digestate would replace the N- mineral synthesis by biological N fixation and recycle the other elements P, K, Ca, Mg, etc.
- this concept is applicable even in organic farming where nitrogen is the main limiting factor.
- At present, Austrian, German, Dutch and Italian colleagues (the most advanced countries in this field) are insisting on this role of methanisation!

In the future in the evaluation of the various economic activities (including agriculture) the effect on the environment will be an important objective

- Agro-environmental analyses on GGE, pollution/contamination of the environment, life cycle analysis (energy, autonomy..) etc. ... will be generalized and incentives & coercive measures will be put in place (carbon tax…).

- LOME was an essential link in this process

C0NCLUSION 1

- The current policy is largely insufficient because LOME not only makes a major contribution to the energy autonomy of agriculture and the country, but also the radical transformation of agriculture because the integration of the methanisation process makes the increase in productivity compatible with the environment, including climate change.
(PV, wind turbine)

- Should we copy Germany?

  YES for efficiency and speed of development

  NO, for the concept, because to facilitate “industrial” efficiency our neighbours chose corn as a substrate and promoted industrial methanisation

Conclusion 2,

To put an end to the recurrent crisis in agriculture, the agriculture should challenge itself and develop its plan for a new agriculture that responds to the country's major challenges.

We have all the knowledge needed to change if Agroecology is complemented by the Bioeconomy, because we ensure the maximum use of solar energy through the production of biomass (renewable carbon) on the one hand, while preserving and even improving the environment, and optimizing the use of biomass according to the major interests of the country, between food and non-food such as energy production, fertilizers, etc. on the other hand.

.

This is a sine qua non for ending the recurrent crisis in agriculture and making it a priority again in the future.

It's time to act: SENECA Letters to Lucilius

…it is hours that we are taken away by force,
others by surprise,
Others are falling from our hands.
But the most shameful loss is that which comes from neglect; and, if you take heed of it,
the greater part of life
goes on to do wrong,
a great one to do nothing,
the whole to do something other than what we should.
... be completely in control of all your hours.
You will depend less on tomorrow, if you make sure of today.
As we adjourn, life passes.

…..everything else is borrowed, time alone is our good.

END

for INSTANT…..

Now it’s your turn to act !