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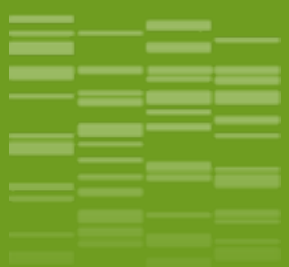
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Intensification in the context of bioeconomy and circular economy : status and foresight

Jean-François Dhôte, Catherine Bastien, Jean-Michel Carnus, Catherine Collet, Barry Gardiner, Myriam Legay, Laurent Saint-André



International Scientific Seminar, **Biarritz, June 13th 2016**
« Sustainable intensification of planted forests : how far can we go ? »

Objectives of the talk

- ❖ Background (trends & perspectives) :
 - ❖ world population & développement → demand of wood-products
 - ❖ forests : provide an increasing range of product/services, under stronger constraints, pressure by other land-uses (re-emerging)
 - ❖ bring an **integrated response to climate change** : adaptation, mitigation, regulation of ecosystem services, planning
 - ❖ need to **redesign production/management systems**
 - ❖ **imitation of nature** (Lorentz & Parade, 1837) → « *close-to-nature forestry* »
- ❖ 3 focus about nature/silviculture/intensification/ecology :
 - ➔ adaptive potential of close-to-nature forestry
 - ➔ options for diversification & planning
 - ➔ ecological intensification as **more efficient use of cycles**

Bioeconomy : consider wood in the *big picture*, supply new usages/production chains

Bio-based Economy: feedstocks, processes and products (without food & feed)



Many resources are forecasted to run out within a relatively short period, ...



<http://reports.weforum.org/toward-the-circular-economy-accelerating-the-scale-up-across-global-supply-chains/mounting-pressure-on-resources/>

Remaining years until depletion of known reserves (based on current rate of extraction)		5-50 years		50-100 years		100-500 years												
1	H											He						
3	Li	Be											B	C	N	O	F	Ne
11	Na	Mg											Al	Si	P	S	Cl	Ar
19	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	Fr	Ra	Ac†	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Lv	Uus	Uuo

Lanthanides *	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	140.9077	144.24	(145)	150.36	151.964	157.25	158.9253	158.9253	162.50	164.9303	173.04	174.967	175.04	174.967
Actinides †	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232.0381	231.0389	238.0289	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(257)	(259)	(260)

... while only few materials are recycled at scale

Current rates of recycling		<1%		1-10%		10-25%		25-50%		>50%		No data available						
1	H											He						
3	Li	Be											B	C	N	O	F	Ne
11	Na	Mg											Al	Si	P	S	Cl	Ar
19	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
87	Fr	Ra	Ac†	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Lv	Uus	Uuo

From linear to circular economy: complexity management and modelling

dominique.luzeaux@polytechnique.org | 5/11/2014

http://www.mosim2014.org/sites/mosim2014.org/files/pdf/Pleni%C3%A8re_D.Luzeaux.pdf

« Grey » renewables energies (wind, PV) consume lots of rare elements : unsustainable !

« la **dépendance des éoliennes au néodyme et au dysprosium**, deux métaux de la famille des terres rares qui constituent les aimants permanents actuellement nécessaires pour l'alternateur, illustrent bien cette question sensible des ressources minérales :

un déficit en dysprosium est prévisible à partir de 2020 compte tenu de l'augmentation de la demande actuelle.

Autre exemple avec des technologies **photovoltaïques** très prometteuses comme le CIGS (cuivre, indium, gallium, sélénium) qui sont confrontées aux mêmes enjeux :

on estime à 20 ans seulement le ratio « réserves sur production de l'indium »

Isabelle Blanc, 21 oct 2015, ParisTech Review.

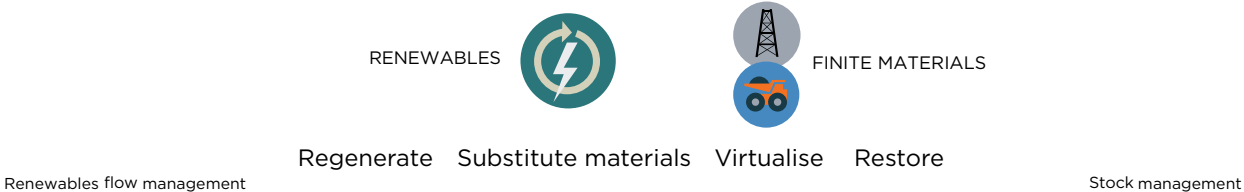
Comment calculer l'impact environnemental des énergies renouvelables ?

http://www.paristechreview.com/2015/10/21/impact-environnemental-renouvelables/?utm_campaign=NL%2052%20-%20112015%20-%20Global%20EN&utm_medium=email_eCircle&utm_source=Global%20FR

Circular economy - an industrial system that is restorative and regenerative by design

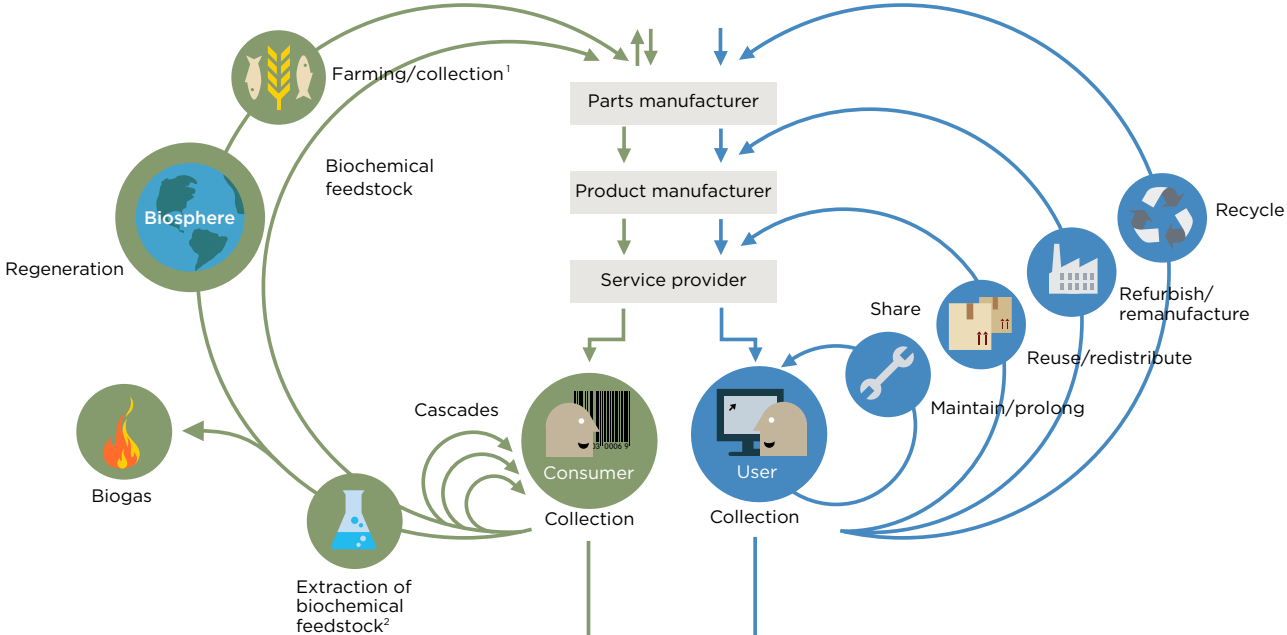
PRINCIPLE 1

Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows
ReSOLVE levers: regenerate, virtualise, exchange



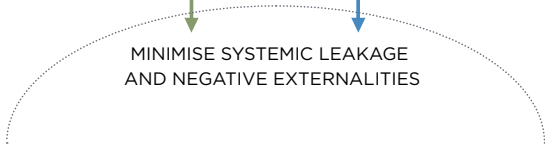
PRINCIPLE 2

Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles
ReSOLVE levers: regenerate, share, optimise, loop

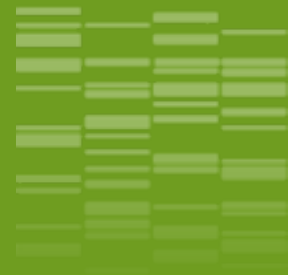


PRINCIPLE 3

Foster system effectiveness by revealing and designing out negative externalities
All ReSOLVE levers



¹ Hunting and fishing
² Can take both post-harvest and post-consumer waste as an input
 SOURCE: Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment, *Growth Within: A Circular Economy Vision for a Competitive Europe* (2015).
 Drawing from Braungart & McDonough, Cradle to Cradle (C2C).



1

**« Close-to-nature » forestry :
is it efficient as an adaptive strategy ?
what does it mean (ref Anthropocene) ?**

Extreme events such as storms, droughts, flooding, and heat waves are probably the **most important threats** in Temperate Oceanic regions [...]

2010

natural mechanisms of **inherent adaptive capacity** are diverse and **will support adaptation** of forests to climate change. However, **natural processes alone are too slow to cope with** the projected rates of environmental change [...]

from European biogeography it can be inferred that **adaptive capacity is smallest at the rear edge** of the forest biome, where only short-term adaptation and plasticity are able to counteract the threat of extirpation of forest species under less suitable climate conditions. There are **considerable differences in socio-economic adaptive capacity** within Europe and **it is worrying that this is smallest in the Mediterranean region where the largest potential impacts are expected**

Lindner, M., M. Maroschek, S. Netherer, A. Kremer, A. Barbat, J. Garcia-Gonzalo, R. Seidl, et al., 2010. « Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems ». Forest Ecology and Management 259(4): 698–709

2014

Review [Journal of Environmental Management 146 \(2014\) 69–83](#)

Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management?

Marcus Lindner ^a, Joanne B. Fitzgerald ^{a,*}, Niklaus E. Zimmermann ^b, Christopher Reyer ^{c,d}, Sylvain Delzon ^{e,f}, Ernst van der Maaten ^{g,h}, Mart-Jan Schelhaas ⁱ, Petra Lasch ^c, Jeannette Eggers ^{a,j}, Marieke van der Maaten-Theunissen ^{g,h}, Felicitas Suckow ^c, Achilleas Psomas ^b, Benjamin Poulter ^{b,k}, Marc Hanewinkel ^{b,l}



Adapting forests to extreme storm events is - outside Great Britain and Ireland with already existing particular storm adapted management strategies - an exception, and requires measures such as limiting tree height **that are unpopular** and **against the dominating “close-to-nature” forestry** with long rotation periods in Central Europe

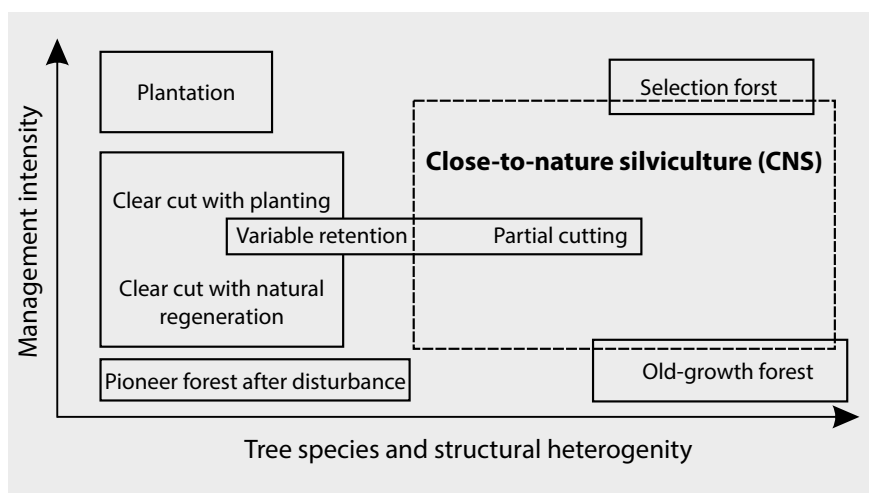


Figure 1
 Classification of CNS according to management intensity as well as tree species and structural diversity. Adapted after Puettmann et al. (2009).

Utiliser des processus naturels pour guider les écosystèmes avec **le moins possible d'apports en énergie (coûts)** :

- promotion d'espèces naturelles et/ou adaptées à la station (non-natives acceptées en mélange avec des natives)
- forêts mélangées et structurées
- **éviter les coupes rases** autant que possible
- promotion de la **régénération naturelle**
- sylviculture d'arbres individuels
- **intégration** des services écosystémiques (eau, récréation...) à **grain fin**

Pommerening & Murphy (2004), Johann (2006), Spathelf (1997)

« the restrictions of CNS for the use of natural regeneration and 'low impact' interventions and the focus of CNS systems on mid- and late-successional tree species **limit the options for human-induced assistance of adaptation**, e. g. by introducing non-native or specific drought-resistant tree species and provenances »

Is Close-to-Nature Silviculture (CNS) an adequate concept to adapt forests to climate change?

Landbauforsch · *Appl Agric Forestry Res* · 2015 · online first · 1-10

Peter Spathelf*, Andreas Bolte**, and Ernst van der Maaten***



Suitability of close-to-nature silviculture for adapting temperate European forests to climate change

Peter Brang^{1*}, Peter Spathelf², J. Bo Larsen³, Jürgen Bauhus⁴, Andrej Bončina⁵, Christophe Chauvin⁶, Lars Drössler⁷, Carlos García-Güemes⁸, Caroline Heiri¹, Gary Kerr⁹, Manfred J. Lexer¹⁰, Bill Mason¹¹, Frits Mohren¹², Urs Mühlethaler¹³, Susanna Nocentini¹⁴ and Miroslav Svoboda¹⁵

6 strategic principles (to increase adaptive capacities) :

- 1 Increase tree species richness (at the stand scale)
- 2 Increase structural diversity
- 3 Maintain and increase genetic variation within tree species
- 4 Increase resistance of individual trees to biotic and abiotic stress
- 5 Replace high-risk stands
- 6 Keep average growing stocks low

3 types of close-to-nature silviculture (CNS)

- 1 Single-tree selection, which also includes 'continuous forest'
- 2 Group selection
- 3 Shelterwood

Single-tree selection has limitations :

- very small gaps favour few shade-tolerant species, exacerbated if no tending
- enrichment planting often not used (browsing damage constraint)
- rarely uses non-native species with high adaptive capacity (Douglas fir)
- variant « target diameter harvesting » may decrease genetic variation (trees with higher heterozygosity)

The **uniform shelterwood system** :

- has the lowest structural diversity in the long term
- but is more suitable for increasing tree species richness in the next forest generation, by facilitating the introduction of new species or provenances with enrichment planting

Shortcomings of CNS : 'species richness', 'genetic variation', 'replace high-risk stands'

- ➔ employ a **larger variation in regeneration methods**
- ➔ integrate light-demanding tree species, **non-native species** and **non-local provenances**
- ➔ **apply** different CNS types **at the landscape level**
- ➔ *overcome restrictions aimed at conserving genetic diversity of local populations*

What is close-to-nature silviculture in a changing world?

Kevin L. O'Hara*

The **silviculture of the future** will be **highly varied** and highly **flexible**, [...] recognize the importance of adaptive or 'artificial' treatments such as tree **planting**, planting **non-native species**, **moving species beyond** their native range or **developing even-aged forests**. These are treatments that will **help forestry maintain productive** forest landscapes in a period of changing climate, conversion of forest land to other uses and expanding problems with invasive plants, insects and pathogens.

If the purpose of a close-to-nature forestry is to **persuade a doubtful public** that our intentions are good and our actions are sound, then **why risk alienation by using terms that are misleading** ? Why promote a suite of treatments that are artificially limited by **a selective interpretation of ecology** and truly unnatural ? [...]

Whereas our understanding of natural processes and stand dynamics has advanced, **rebranding forestry** with new labels that use the words 'nature', or 'balance', or 'holistic' **is really just advertising** or a form of 'buzzword creep' (e.g. Park 2011). **If existing scientific information is ignored** to pursue management strategies based on **tradition, beliefs or old science**, the label of close-to-nature is simply **misadvertising**

Silviculture in an uncertain world: utilizing multi-aged management systems to integrate disturbance[†]

Kevin L. O'Hara* and Benjamin S. Ramage

University of California, 137 Mulford Hall, Berkeley, CA 94720-3114, USA

Anthropocene : the distinction natural/artificial becomes less & less straightforward

« La caractéristique principale du naturalisme est son dualisme : s'il a permis, en objectivant la nature, d'en développer la connaissance scientifique, il est aussi ce qui permet d'opposer l'homme et la nature, alors même que **la distinction entre le naturel et l'artificiel, entre histoire humaine et histoire naturelle, est de plus en plus difficile à faire** »

Catherine Larrère, 2015. Pour une nouvelle approche de l'idée de « nature ». In « Guide des humanités environnementales » (éd. Aurélie Choné, Isabelle Hajek et Philippe Hamman), Presses universitaires du Septentrion

« Nous ne saurions penser et changer la société par les seules sciences. [...] En revanche, elles ne peuvent plus être tenues à l'écart de nos décisions politiques. [...] En ce seul sens, la nature entre résolument en politique.

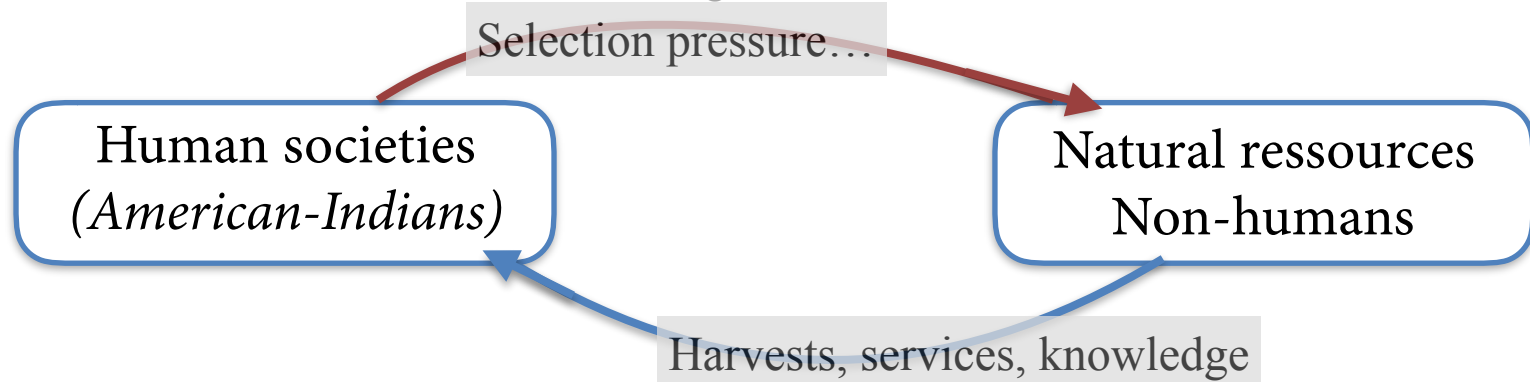
Et **les sciences de la nature constituent dès lors les organes sensoriels de la politique** »

Dominique Bourg, 2 janv. 2016. Les sciences naturelles sont-elles révolutionnaires ?
<http://sciences-critiques.fr/les-sciences-naturelles-sont-elles-revolutionnaires/>

Philippe Descola :

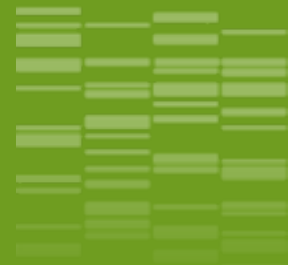
adaptation, co-evolution & Anthropocene

les humains participent évidemment de façon active à la production même des facteurs environnementaux qui affectent leur existence et, dans la très grande majorité des cas, sans en être conscients et dans la très longue durée



Avec l'**Anthropocène**, [...] ce qui s'était opéré de façon non intentionnelle, dans l'essentiel des cas, et sur une échelle de temps pluri-millénaire, nous apparaît soudain [...] comme **réclamant une action volontariste à mener dans des délais très courts**

notre destinée **ne se résume pas à un face-à-face**, plus ou moins hostile ou plus ou moins bienveillant, **entre l'homme et la nature**, ainsi que la tradition naturaliste nous avait portés à le croire, mais que cette destinée est entièrement dépendante des **milliards d'interactions et de rétroactions** par lesquelles **nous engendrons**, au quotidien, **les conditions environnementales nous permettant d'habiter** la Terre



2

Adaptation & mitigation : paths for diversification under uncertainty, looking for performance and flexibility

Plant reproduction material produced in seed-orchards may bring a better mixing of initial genetic diversity



Diversité allélique

Mode de régénération	Nb allèles SPAC 7.14	Nb allèles SPAC 12.5	déficit en hétérozygotes
Régénération naturelle (après tempête)	19 + 5	12 + 3	0,282
Verger à graines	27	18	0,074

**PSY-VG-003- Haguenau
4,3 ha**

**191 « arbres + » sélectionnés dans
les parcelles autochtones Haguenau
5 à 17 copies par géniteur
Répartition aléatoire**

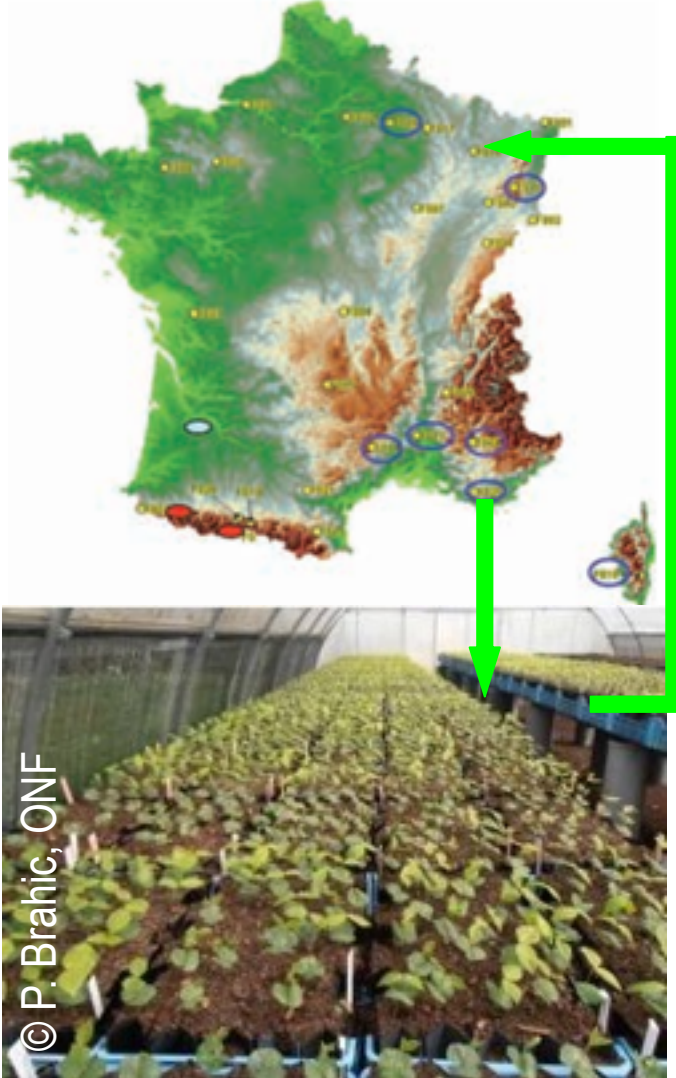
Diversité plus élevée en verger à graines

Réduction de l'apparement dans le matériel collecté en verger à graines

Pas d'organisation spatiale de la diversité en plantation

Source : Catherine Bastien

Change genetic resources : moving populations polewards



Projet GIONO

- **Vulnerability of populations at southernmost margin of distribution areas**
 - monitoring/identification of vulnerabilities
 - safeguarding in nurseries
 - planting on +northern locations
- **Applications :**
 - conservation of genetic resources
 - **strengthen local adaptation of autochthonous species**

Source : Brigitte Musch, Hervé Le Bouler, Olivier Forestier, Patrice Brahic, Myriam Legay (ONF)

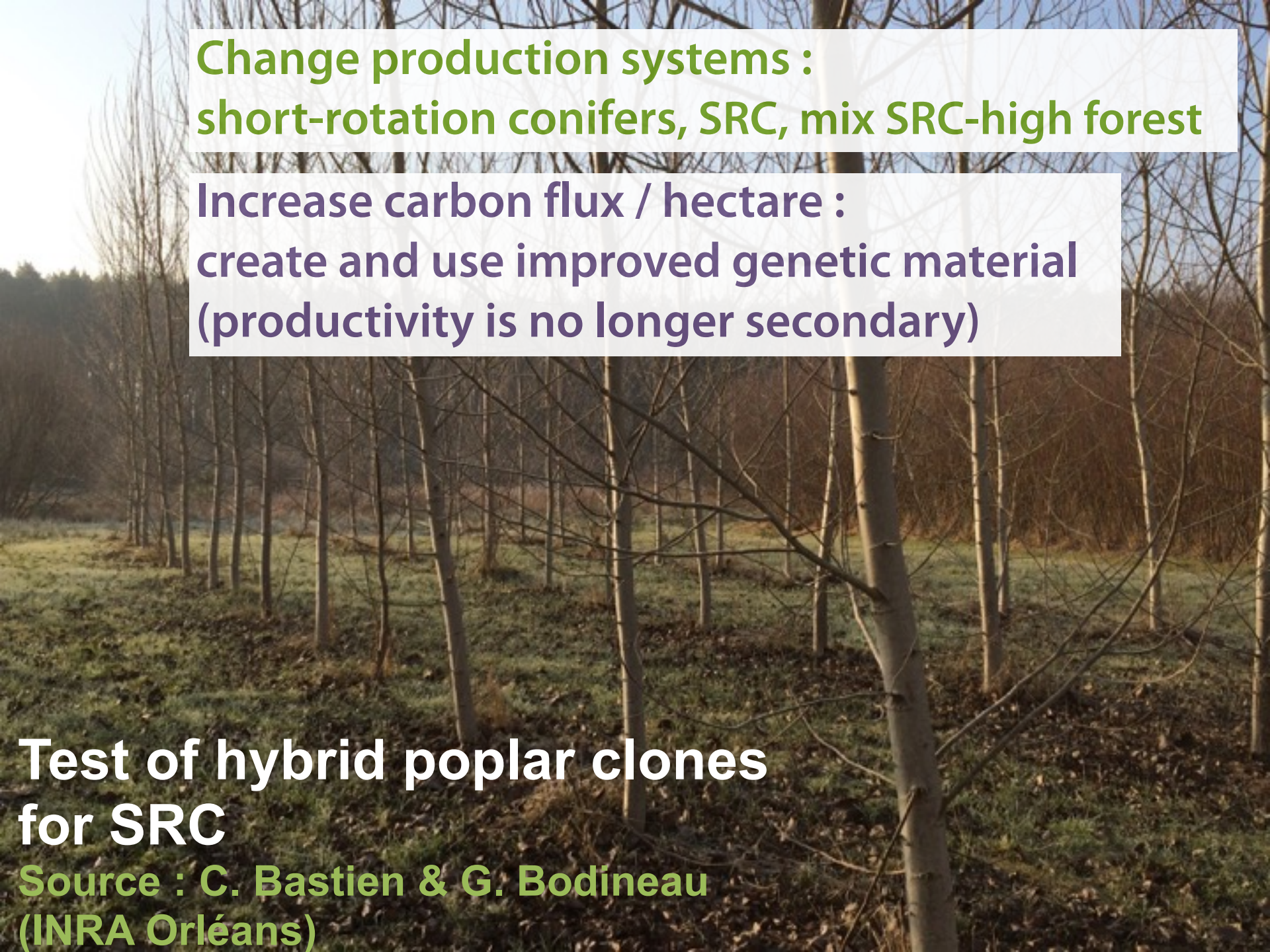


**Change genetic resources :
introducing thermophilous species**

**Performance of Eucalypts
under strong drought constraint**

(arboretum d'élimination de Caneiret, Estérel)

Source : ONF (T. Lamant & L. Blaison, 3/2012)



**Change production systems :
short-rotation conifers, SRC, mix SRC-high forest**

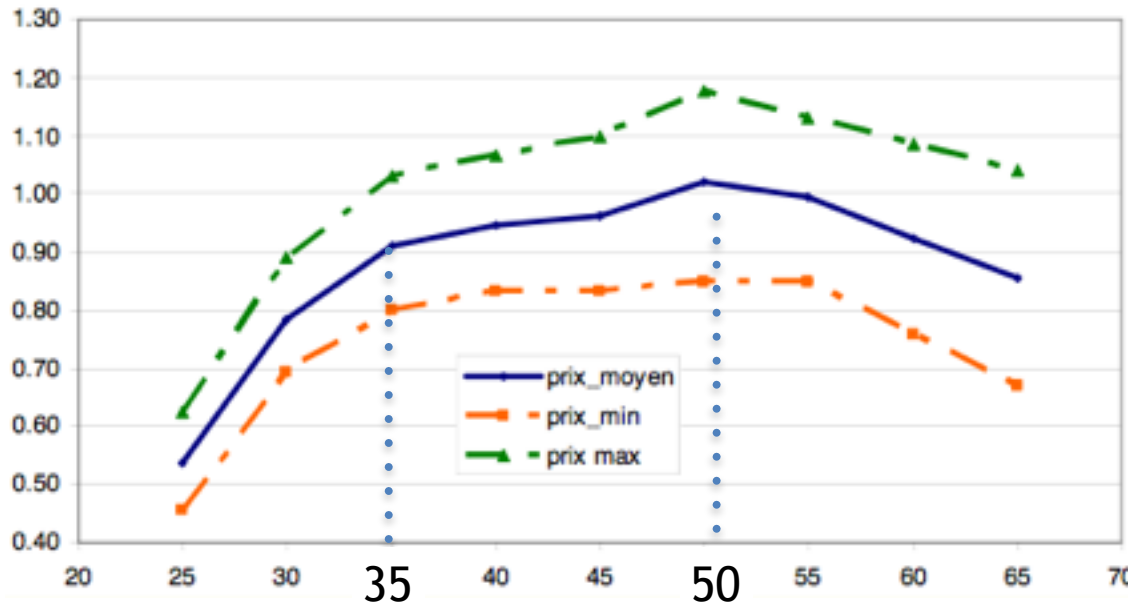
**Increase carbon flux / hectare :
create and use improved genetic material
(productivity is no longer secondary)**

**Test of hybrid poplar clones
for SRC**

**Source : C. Bastien & G. Bodineau
(INRA Orléans)**

Example of forest-industries co-adaptation : shortened rotations in conifers

Selling price/m³ (relative units)



Fir-Spruce - Vosges
mean (sept. 2009-sept. 2010)

Source : ONF
(Gamblin, 21/3/2011)

BH diameter (cm)

90%
of Max

Max

Opportunity of shorter rotations :

- ▶ *reduce abiotic risks*
- ▶ *supply closer to industrial demand*
- ▶ *increase fluxes and flexibility*

Need more management planning & integrated multi-scale management

Poplar (high forest)
SRC Poplar
Mix (HF-SRC)

Multi-purpose,
« mainstream »
management

National parks,
natural reserves,
recreation areas

Fast-growing conifers :
Douglas fir, hybrid larch

Specialization :
products

Land use planning, forest policy : specialize functions in space,
e.g. « Triad » (USA, UK)

Natural regeneration

Very short
cycle

Standard
rotation

Assisted
migration

Plant other
Oak spec.

Plant exotic
spec.

Example : diversify regeneration options in Oak management

Very short
cycle

Standard
rotation

Delayed
harvesting

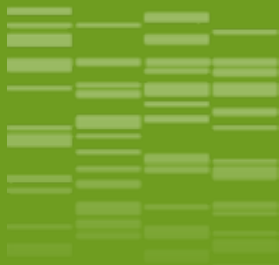
Natural
reserve

Example : diversify rotation ages in Beech management

Improve resilience
through :

...genetic
res. mgt

...prevent
abiotic
damages



« La bioéconomie suppose une *anthropisation réussie* de la biosphère »
(Michel Griffon, 5 mai 2015, restitution prospective UE SCAR-4)

≈ « Bioeconomy needs a *successful anthropisation* of biosphere »

3

Ecological intensification :
coupled cycles of matter/energy/information,
acknowledged effort to transform (manage, learn
by monitoring and science, improve)

Bioeconomy : circular processes/flows



LE PROJET FORÊT-BOIS pour la France

France Bois Forêt (FBF) et France Bois Industries Entreprises (FBIE) sont à l'initiative du

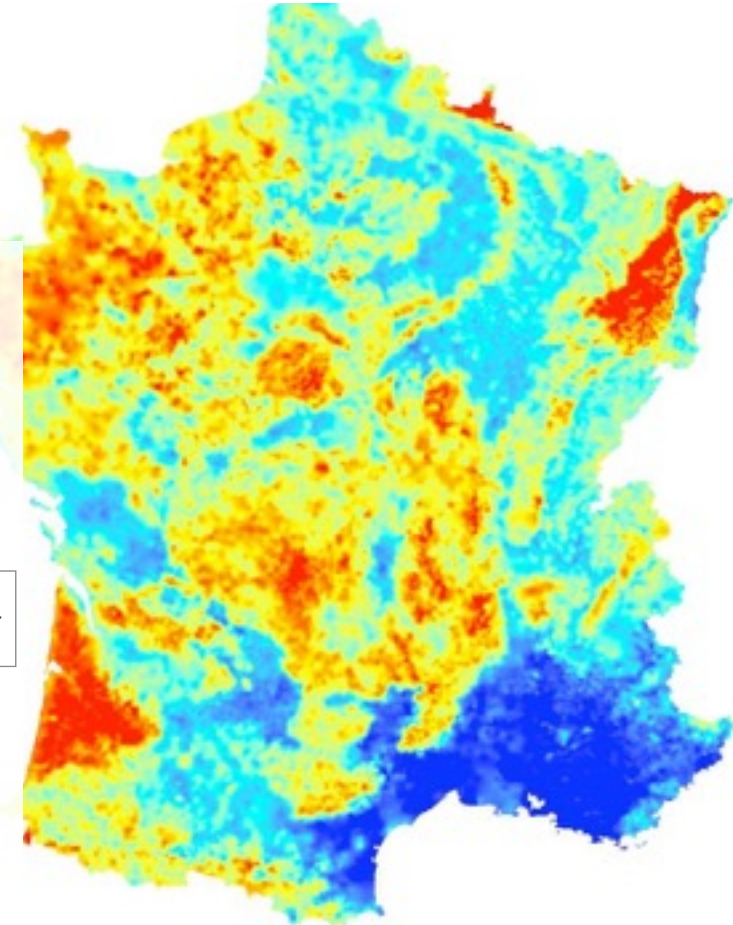
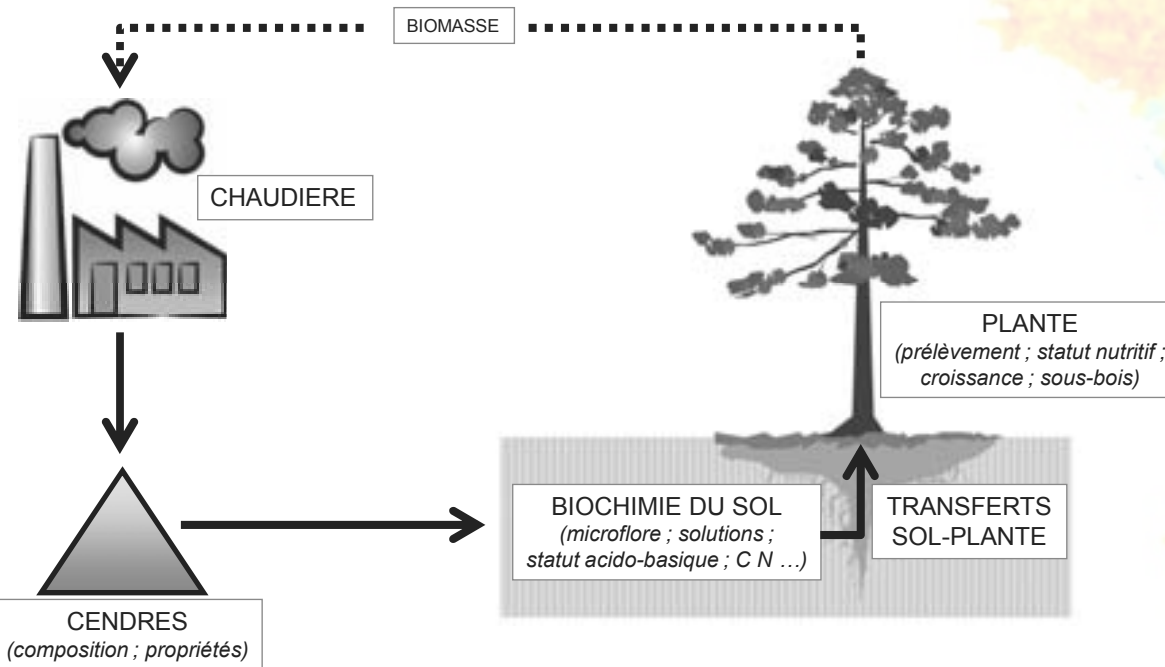


Optimized cycles of biomass :
 look for efficiency, reduce leakage,
 use the ≠ tissues at their best potential,
 re-use

Illustration: Kevin Jacquot

Recycle exported nutrients back to forests, possible strategies of flux limestones → acid soils

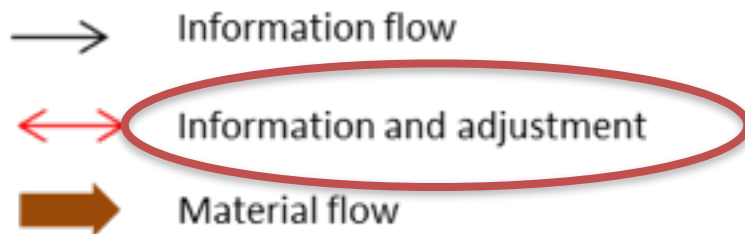
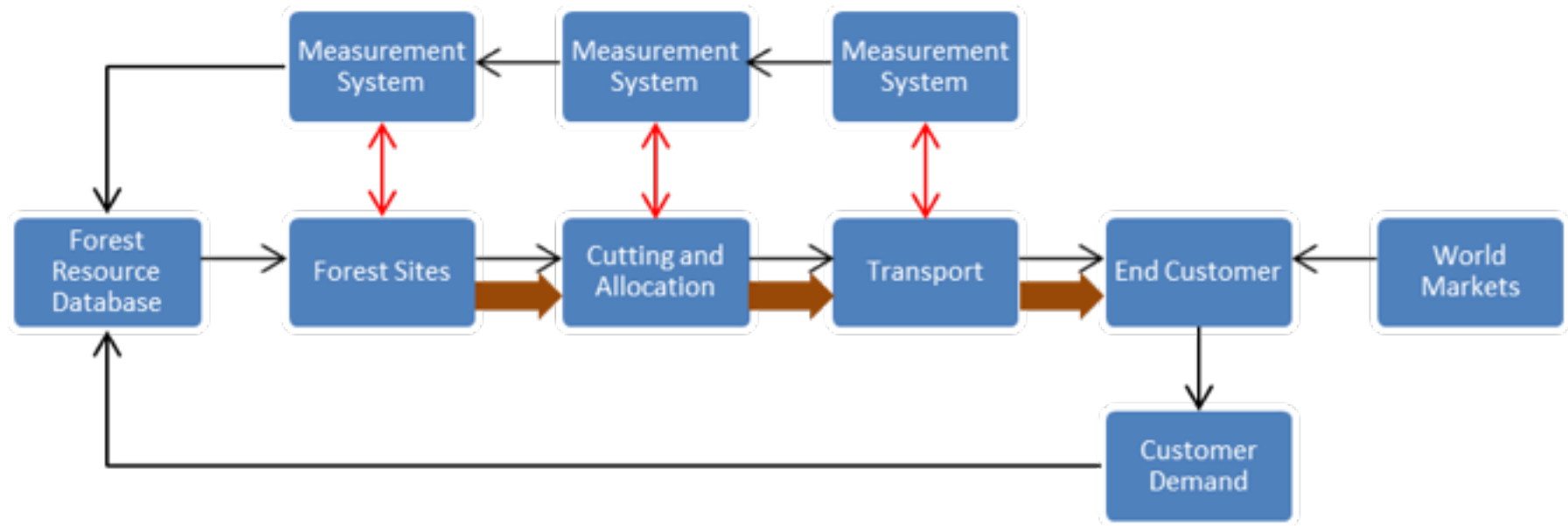
Restitution or recycling of firewood ashes



Carte de France du pH des sols forestiers,
échelle 1km, ©IFN, LERFoB

Source : Augusto et al. (2014) - Les intrants sont-ils nécessaires pour développer durablement la fonction de production ?

Integrated forest logistics : make a better use of information linked to production process



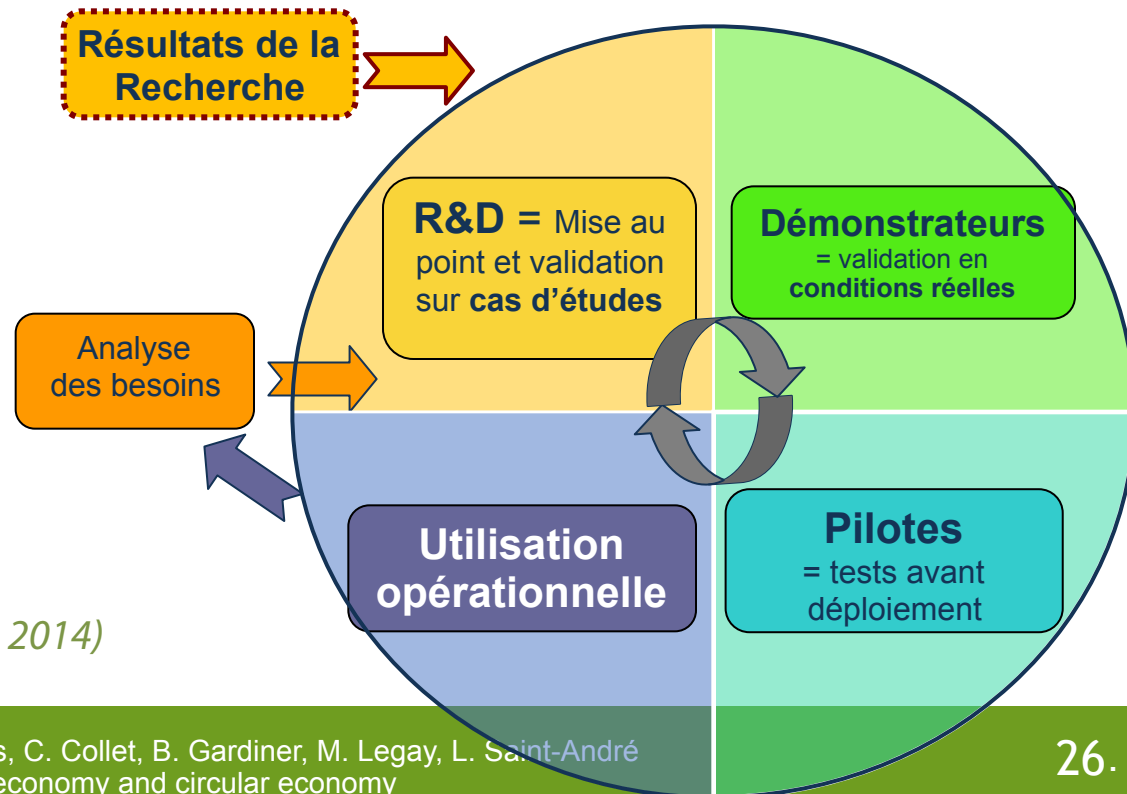
Adjustement-regulation : a major feature of ecological systems

Source : Barry Gardiner (25/1/2015)

Innovation through learning loops



- ❖ Make a step-forward beyond linear technology-transfer of platform CAPSIS :
 - Transfer methods, not only knowledge - case of remote sensing
 - Check robustness
 - Validate in industrial context
 - Handbooks, tools...




Source : ONF (Anne Jolly & Myriam Legay, 2014)



Conclusions

- ❖ Transition of sustainable management & climate challenges :
 - ❖ detect/analyze damages, anticipate large-scale **crises**
 - ❖ **use** existing forests (**more !**) and **plant**
 - ❖ reduce transaction costs (integration, **contracts**)
 - ❖ optimize the world's **use** of fibres and energy
 - ❖ forest soils : **+ targeted & + efficient use**
- ❖ Which questions arises ecological intensification ?
 - ❖ cycles embed ecosystems-human artifacts : **precaution**
 - ❖ **manage together** climate risks & impacts of practices
 - ❖ **information & planning** : monitor, control, correct, diversify, make explicit arbitrages ; optimization and viability
 - ❖ **combine** ecological/social/organisational **resiliences** (multi-scale)



谢谢你的关注

Obrigado

Gracias

Thank you

Merci

Forêt domaniale de Fontainebleau

nov. 2015

*« La bioéconomie suppose une anthropisation réussie de la biosphère »
(Michel Griffon, 5 mai 2015, restitution prospective UE SCAR-4)*