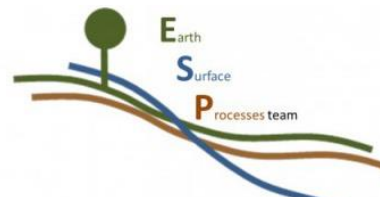


How can organic matter improve soil-based ecosystem services?

Frank Verheijen & Jacob Keizer



The bottom line

Soil-based Ecosystem Services

Agricultural goods	Soil-based delivery processes
Food and fibre	Nutrient capture and cycling
	OM input decomposition
	SOM dynamics
	Soil structure maintenance
	Biological population regulation

How can we push this one?

C sequestration for climate change mitigation

Non-agricultural services	Soil-based delivery processes
Water quality and supply	Soil structure maintenance
	Nutrient cycling
Erosion control	Soil structure maintenance
Atmospheric composition and climate regulation	SOM dynamics
Pollutant attenuation and degradation	Decomposition
	Nutrient cycling
Non-agricultural pest and disease control	Biological population regulation
Biodiversity conservation	Habitat provision
	Biological population regulation

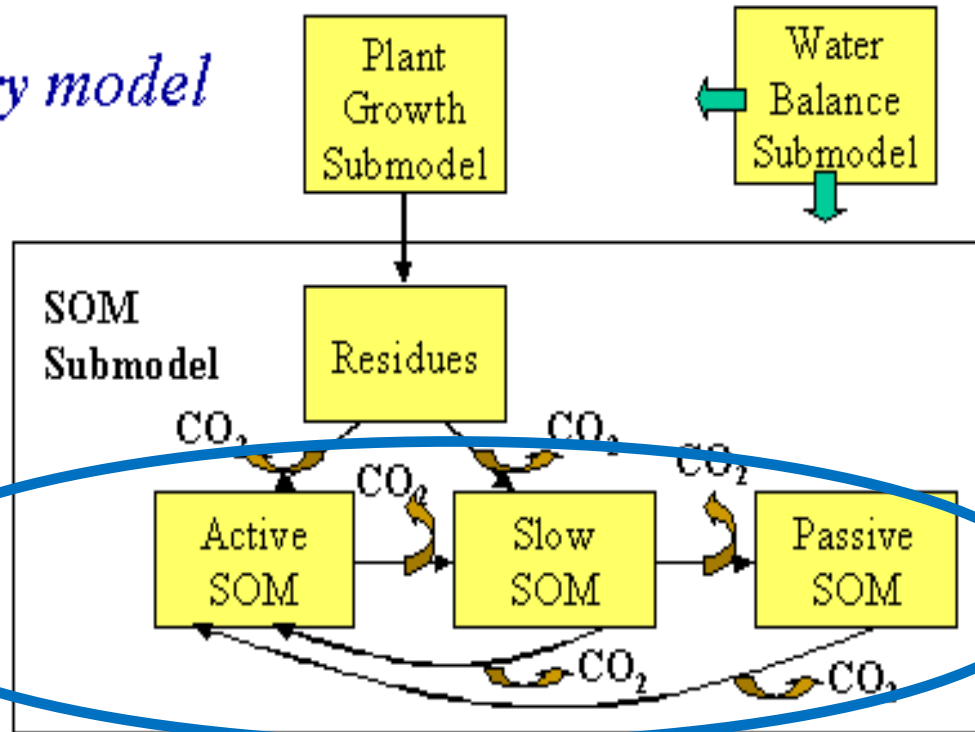
While either improving, or not causing undesired side-effects, on all these ones?

Kibblewhite et al. (2008)

Philosophical transactions of the Royal Society B

There is a practical upper limit to SOC

Century model



The dynamic equilibrium between inputs (residues) and outputs (CO₂) is not linear.

For example, to maintain SOC:

- at **2%** it requires **10 t/ha** of residue inputs.
- at **3%** it requires **150 t/ha**.

=
SOM

What else can we do to slow down the flux of CO₂ back to the atmosphere?

SOC sequestration?

1. Disturb the soil less (minimum tillage)
2. Use more recalcitrant residue inputs: **biochar**
 - Historically done on small scale only
 - And with wood char mostly

Amazonian dark earth - *terra preta*



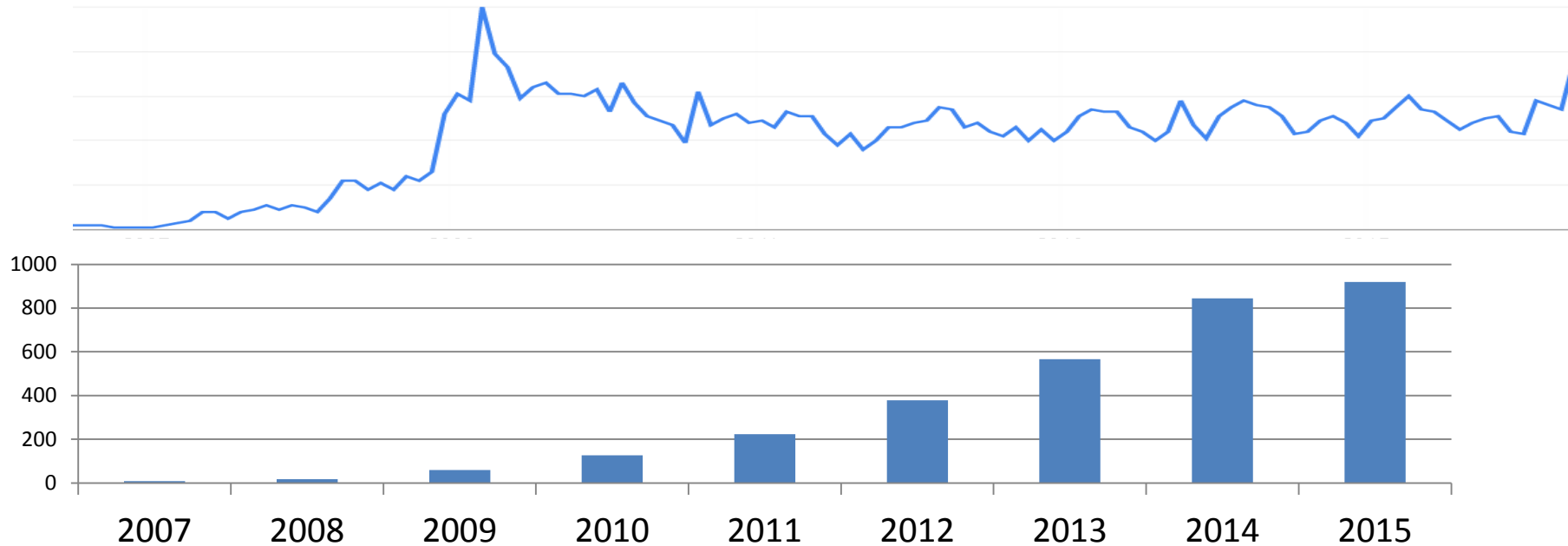
Left a nutrient-poor *oxisol*; right an *oxisol* transformed into fertile *terra preta* - photo courtesy of Bruno Glaser

European plaggic anthrosol



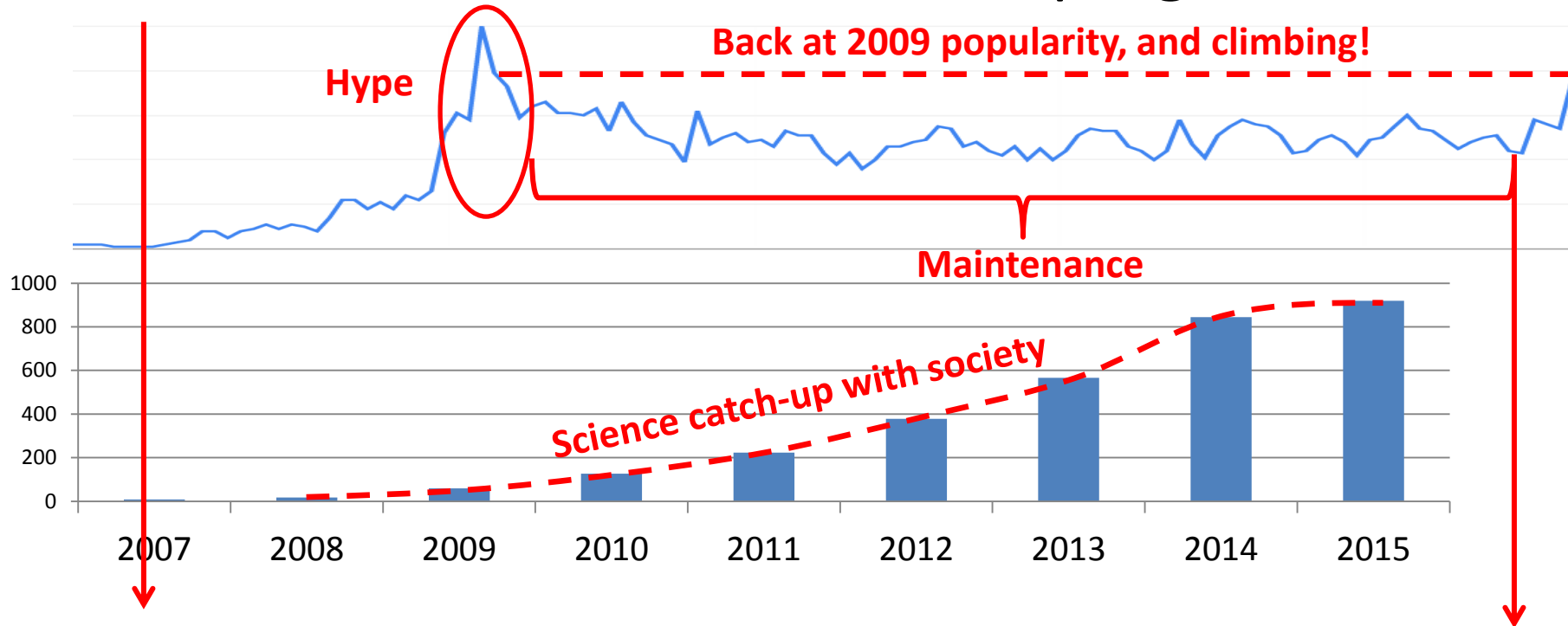
Timeline of seminal biochar progress

Global Internet traffic on the search term
'biochar' (GoogleTrends)



Biochar publications in peer-reviewed int. journals
(SCOPUS)

Timeline of seminal biochar progress



‘Invention’ of biochar

Johannes Lehmann’s Nature paper
(concept)

COMMENTARY

A handful of carbon

Locking carbon up in soil makes more sense than storing it in plants and trees that eventually decompose, argues Johannes Lehmann. Can this idea work on a large scale?



“A 0.4% annual growth of SOC stock (agricultural soils, grasslands, and forest soils) to improve agricultural production and to contribute to achieving the long-term objective of limiting the temperature increase to +1,5/2°C.”

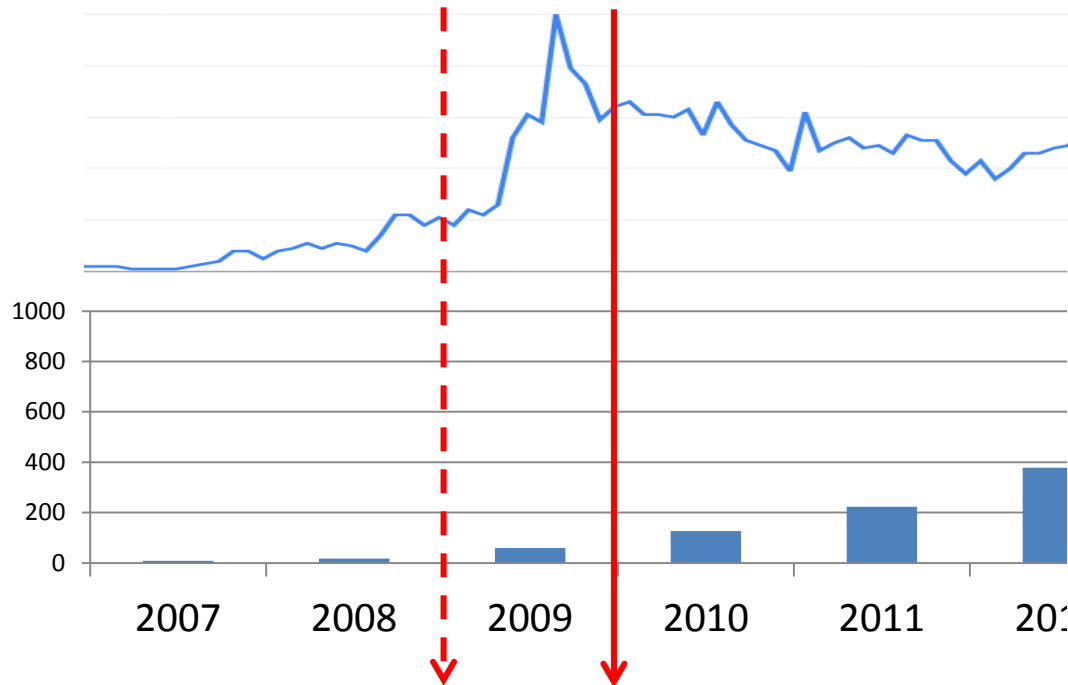
COP21

4/1000 initiative.

Now backed by

UNFCCC

Timeline of seminal biochar progress



Start and finish of major EC JRC report published after period of hype

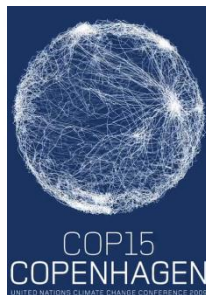
- Broadened biochar science (166 pages)
- First balanced publication
 - Positive effects
 - Negative effects
 - **Unknowns!**



Biochar Application to Soils
A Critical Scientific Review
of Effects on Soil Properties, Processes and Functions
F. Verheijen, S. Jefferly, A.C. Bastos, M. van der Velde, I. Dias

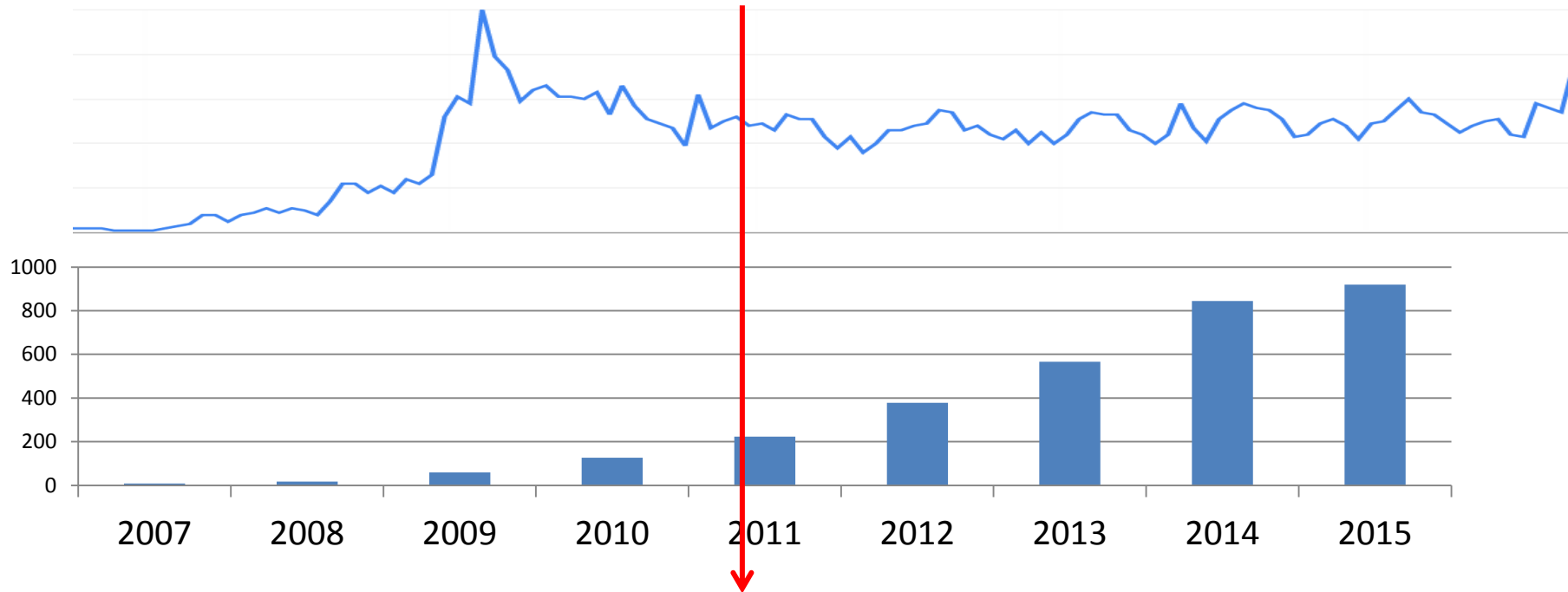


EUR 24100 EN - 2010



POSITIVES	NEGATIVES	UNKNOWNNS
Empirical evidence of charcoal in soils exists (long term)	The use of biochar analogues for assessing effects of modern biochars is very limited	Empirical evidence is extremely scarce for many modern biochars in soils
The principle of improving soils has been tried successfully in the past	Soil loss by erosion. Top-dressing biochar to soil is likely to increase water erosion	C Negativity
Plant production has been found to increase significantly after biochar addition to soils	Soil compaction during application	Effects on N cycle
Liming effect	Risk of contamination	Biochar dose-effect
High sorption affinity for HOC may enhance the overall sorption capacity of soils towards these trace contaminants	Residue removal. Removal of crop residues for use as a feedstock for biochar production can forego active SOM	Environmental behaviour, mobility and fate
Microbial habitat and provision of refugia for microbes whereby they are protected from grazing	Health (e.g. dust exposure) and fire hazards associated to the production, transport, application and storage of biochar	Distribution and availability of contaminants (e.g. heavy metals, PAHs) within biochar
Increases in mycorrhizal abundance which is linked to observed increases in plant yield	Reduction in earthworm survival rates (limited number of cases). pH or salt levels	Effect on soil organic matter dynamics
Increases in earthworm abundance		Pore size and connectivity
		Soil water retention/availability
		Priming effect
		Effects on soil meso-megafauna
		Soil hydrophobicity
		Upscaling (time & space)
		Soil CEC
		Soil albedo
		Wind erosion
Requires reproducibility experiments (industry funding)	Needs innovative experiments (research funding)	

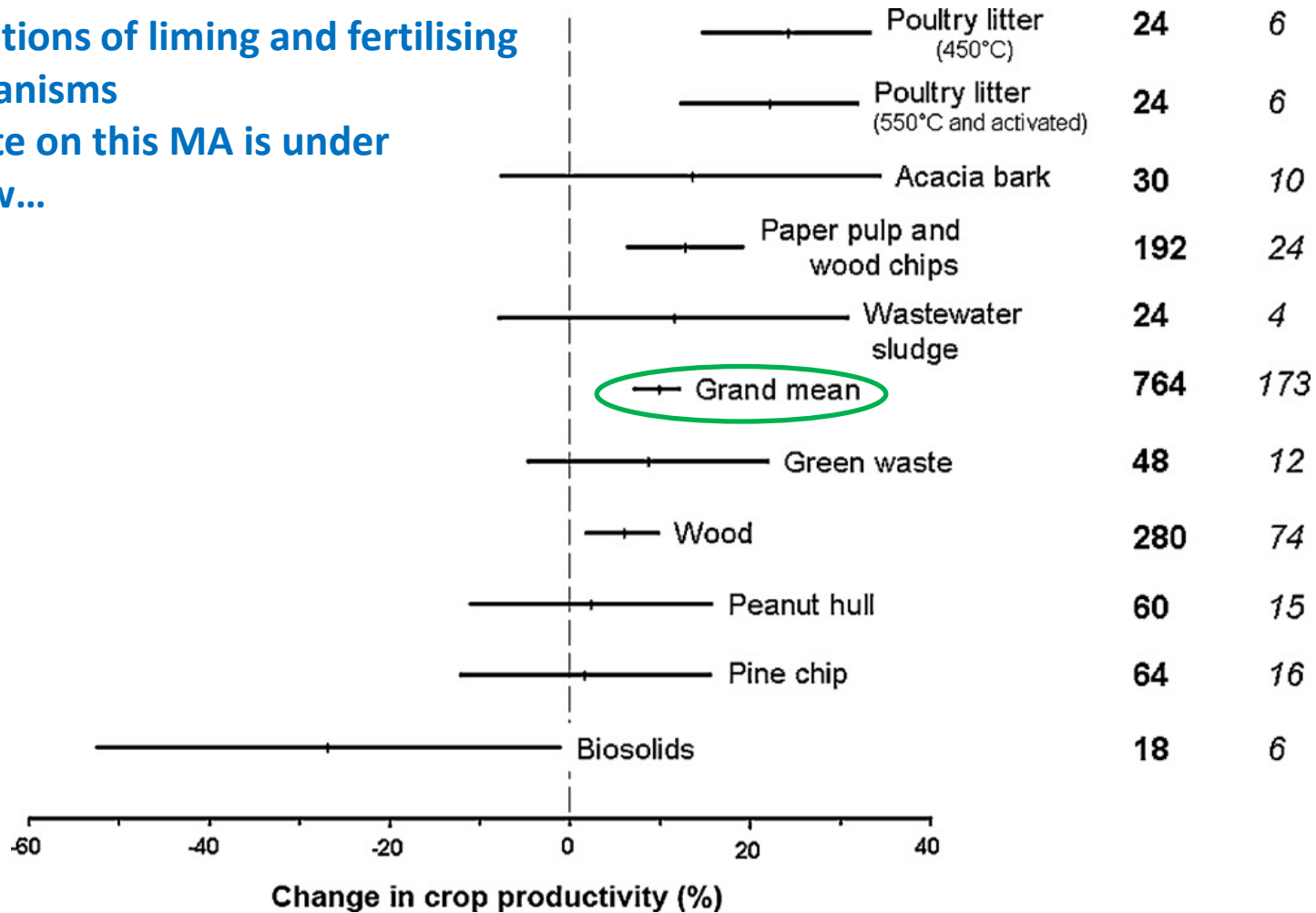
Timeline of seminal biochar progress



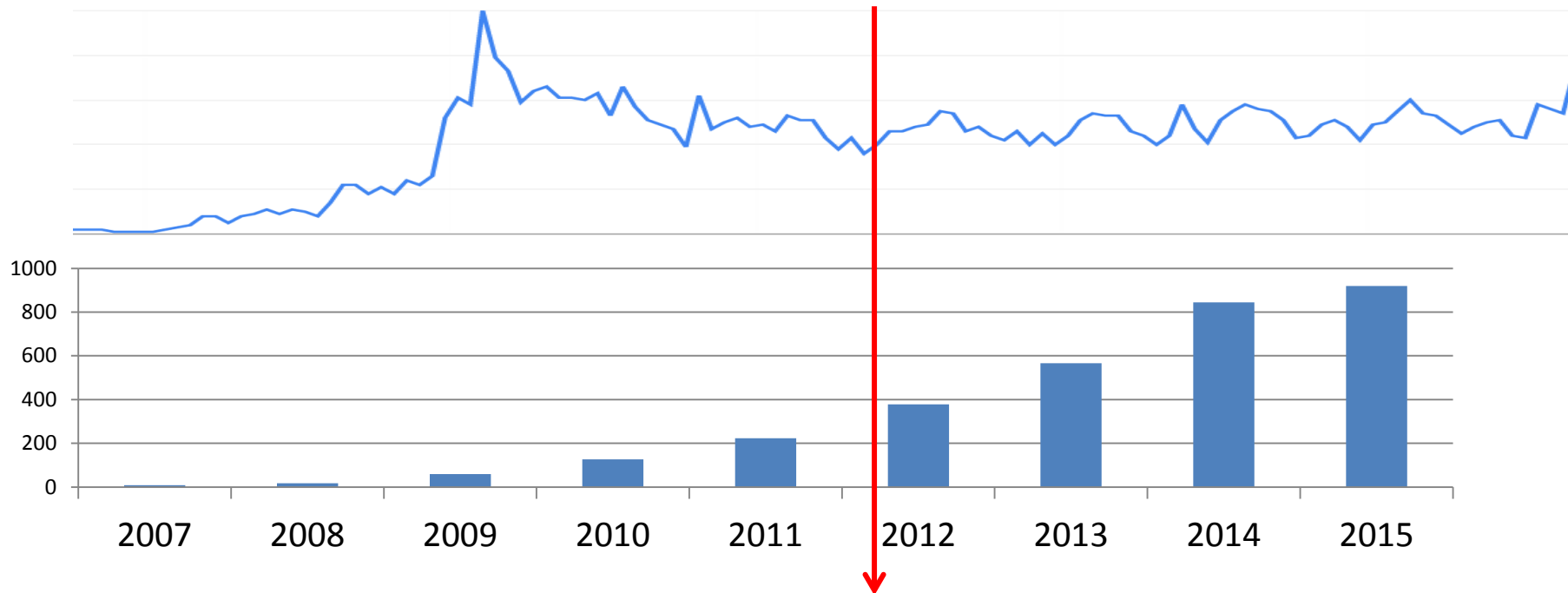
First biochar-crop yield meta-analysis

- Most cited article in **Agriculture, Ecosystems & Environment** since 2011!
- 291 citations (Scopus)

1. 10% increase globally
2. Large variation by biochars, soils, and plants
3. Indications of liming and fertilising mechanisms
4. Update on this MA is under review...



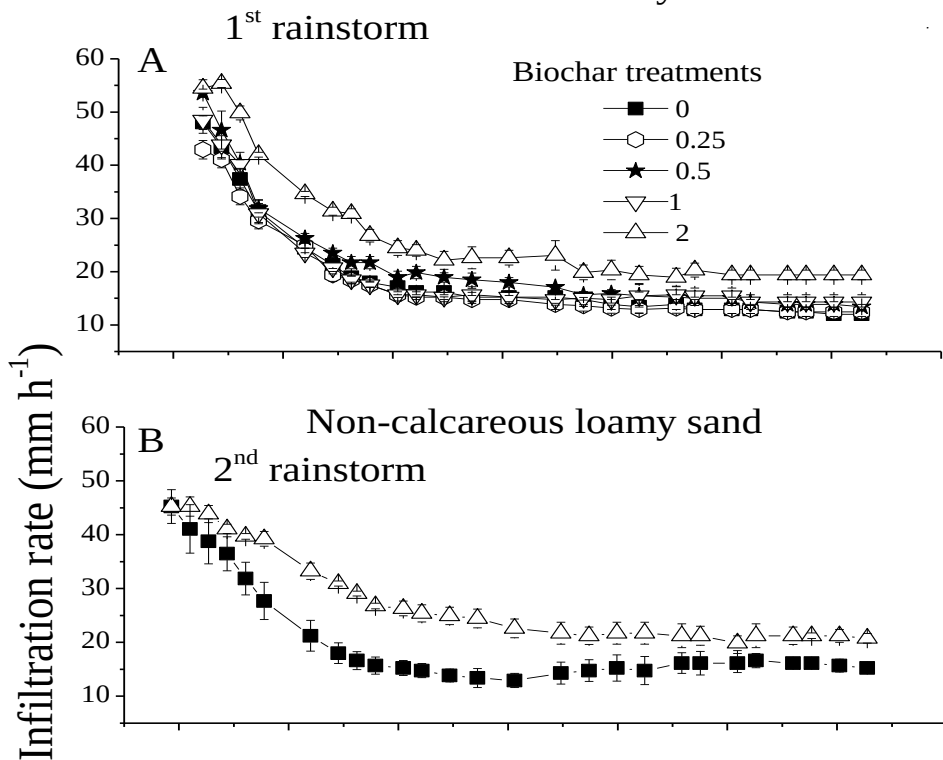
Timeline of seminal biochar progress



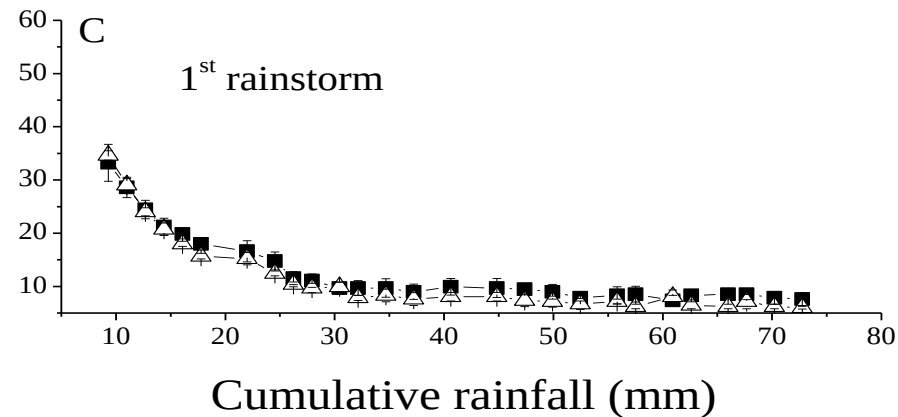
Biochar COST Action starts

- Leader of WG2: Land Use Management
- Two erosion STSMs between ESP and Volcani Centre (Israel)

Infiltration rate increased in non-calcareous loamy sand



No effect in calcareous loam

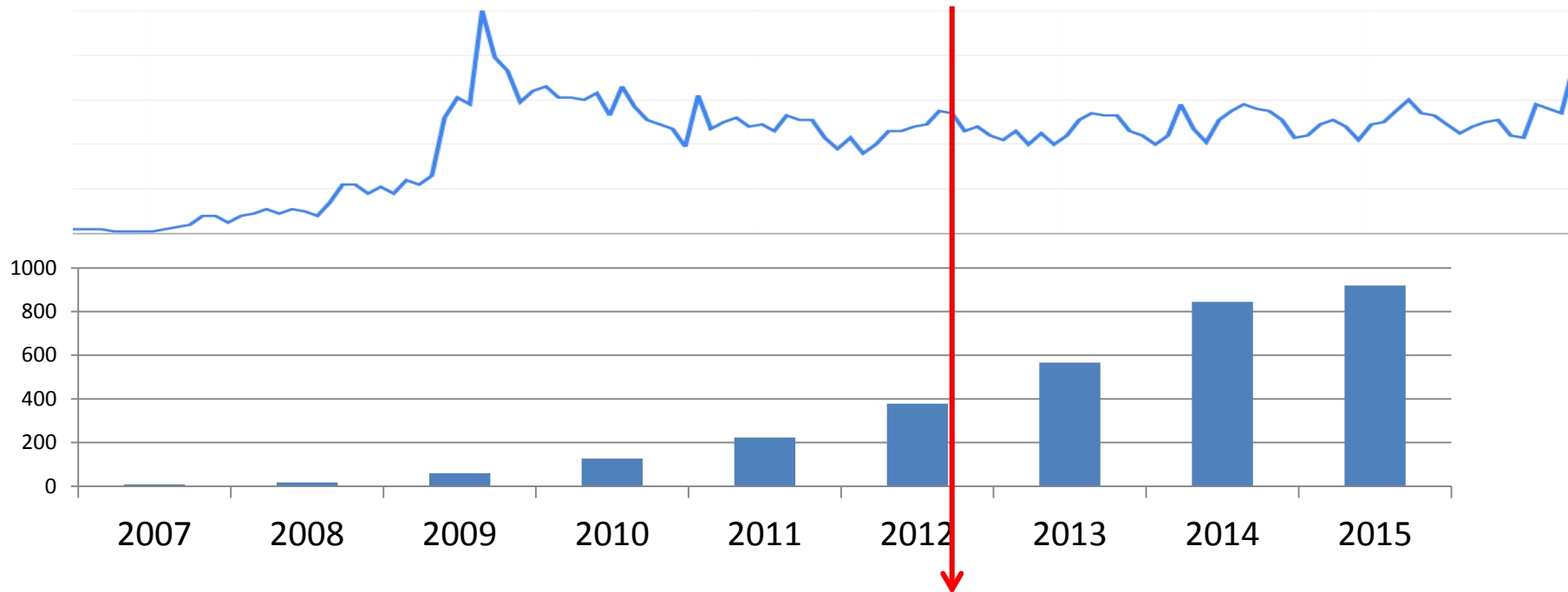


Soil loss reduced by 1.3 times

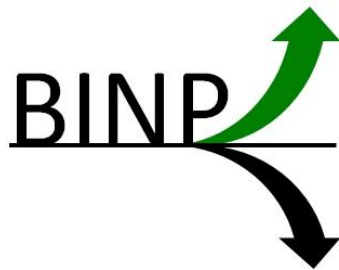
Soil loss reduced by 3.6 times!



Timeline of seminal biochar progress



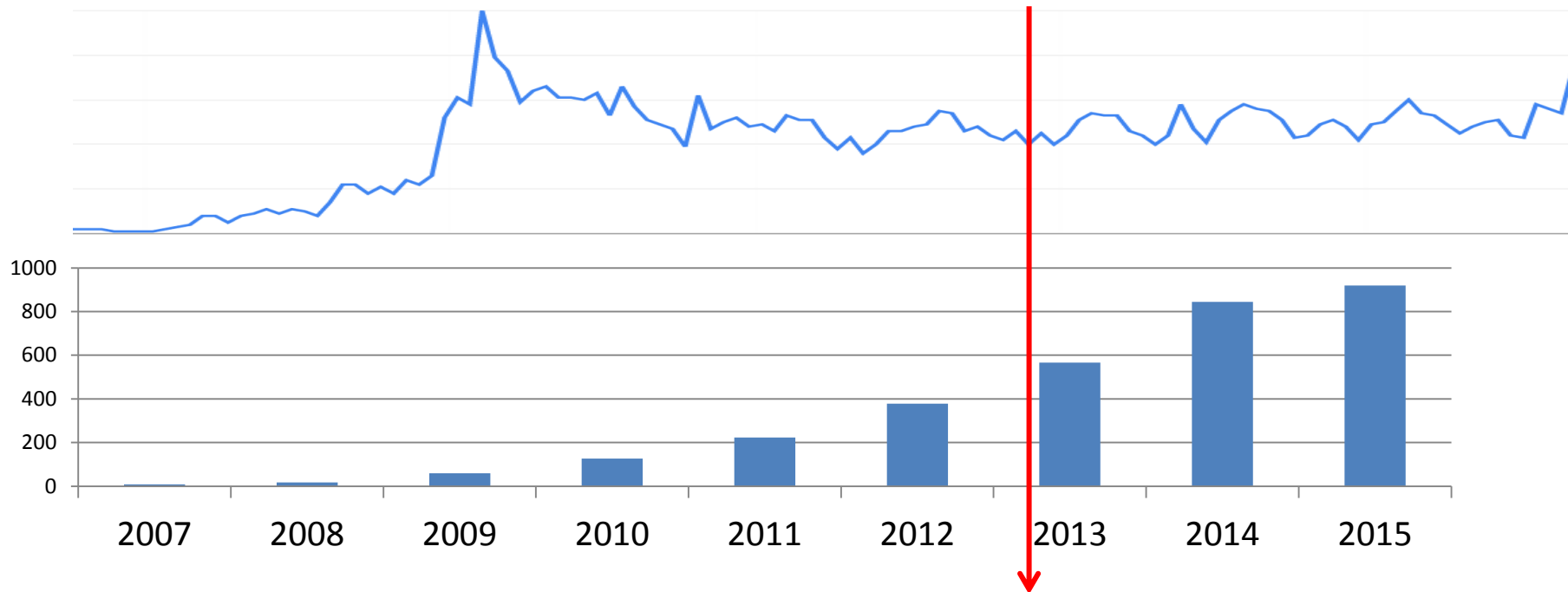
Biochar Investigation Network of Portugal (BINP) starts



www.cesam.ua.pt/binp

Mission: to bring together people involved in biochar research and production in Portugal, to facilitate collaborations by providing a platform for networking, to disseminate national and international biochar news, funding opportunities, conferences and workshops.

Timeline of seminal biochar progress



First biochar-crop field study of Portugal (Vitichar) starts

In collaborations with EVB, DRAPC

Objectives:

1. Can biochar affect grapes?
2. Are there any undesired side effects?





- No reduction in plant drought stress (deep roots!)
- No effect on grape yield
- No effect on grape quality
- No negative effects on soil invertebrates

Now iSCAPER project field site

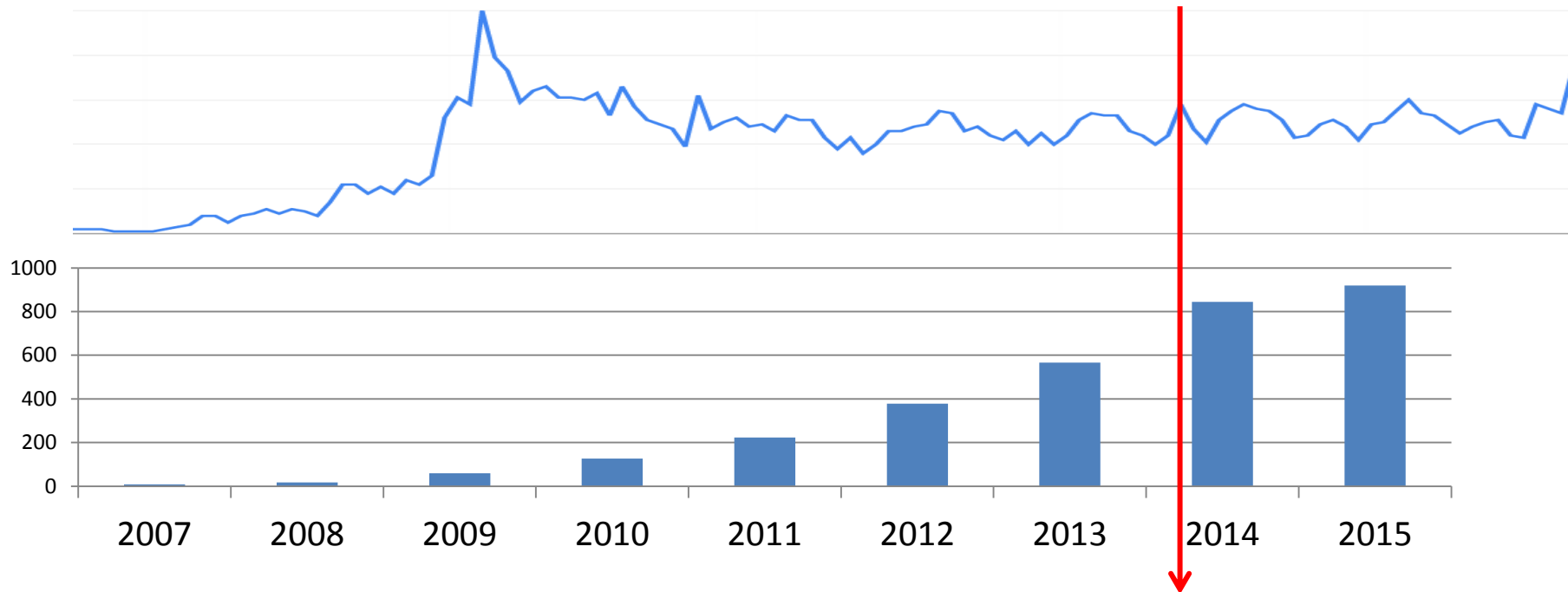
Interactive Soil Quality
Assessment in Europe and China
for agricultural Productivity and
Environmental Resilience



Future work:

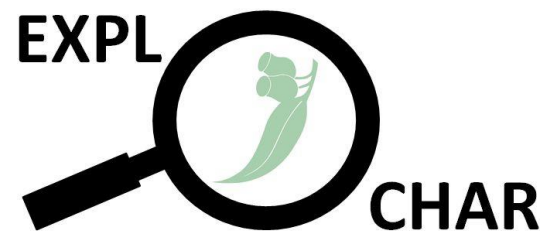
Biochar to help reduce
erosion of vineyard soil
MASCC project:
Mediterranean
Agricultural Soils
Conservation under global
Change

Timeline of seminal biochar progress

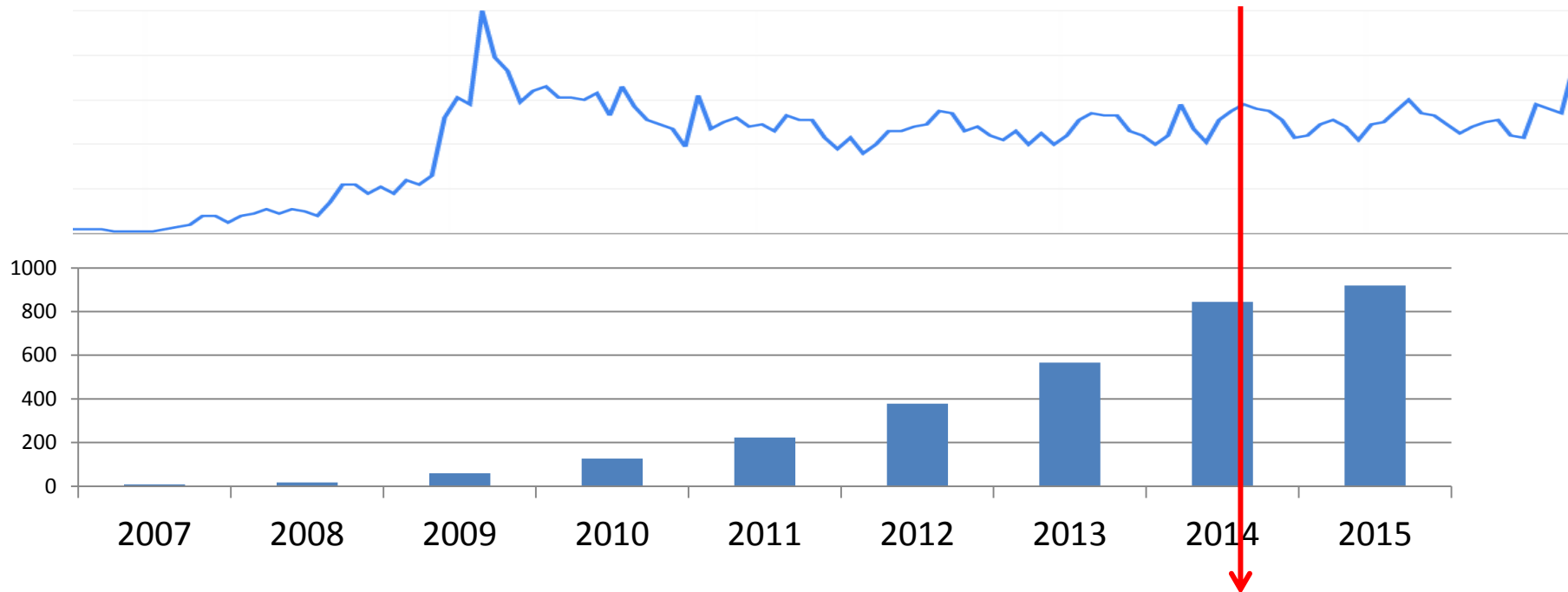


First FCT biochar project starts: EXPLOCHAR

Exploring mechanisms of reducing drought and disease stress in eucalypt plants by applying biochar to soils



Timeline of seminal biochar progress



Welcome biochar experts!

An expert knowledge workshop...

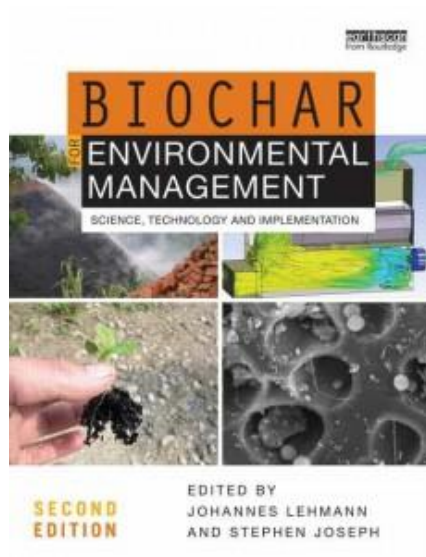
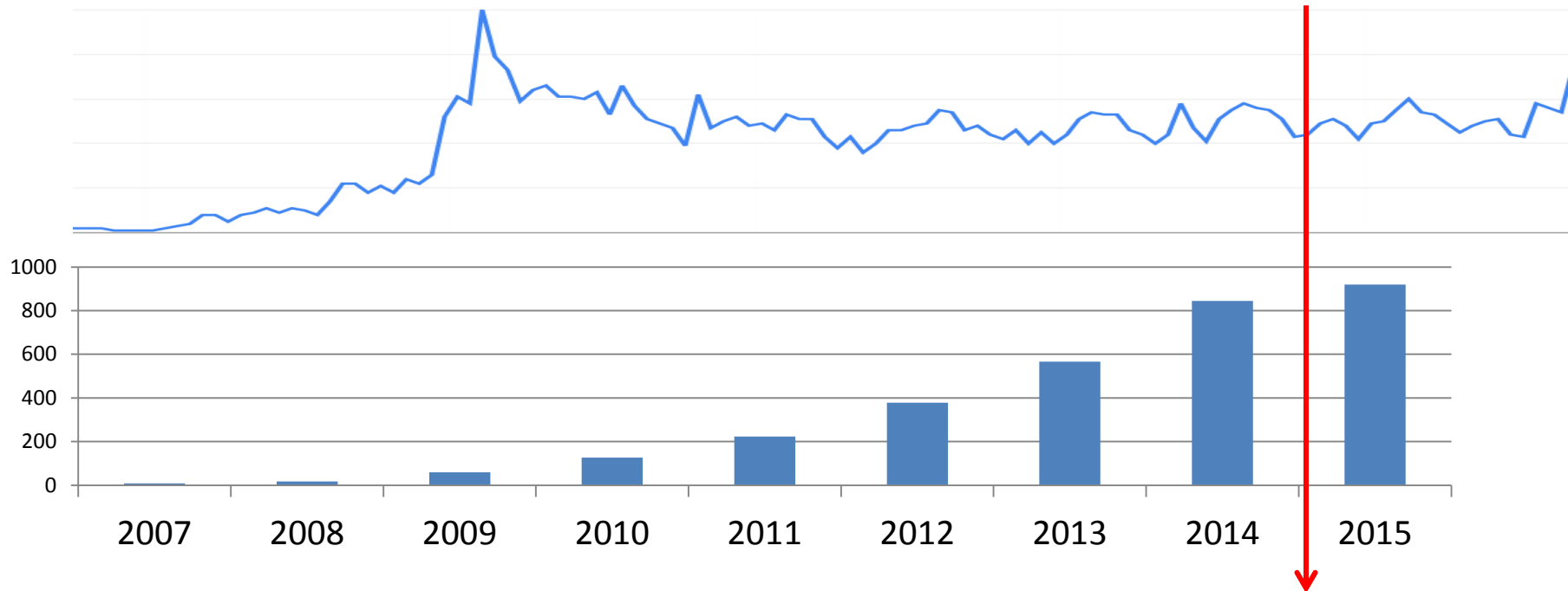


- 40 experts (incl. Brazil, USA, Israel)
- Research priorities
- Will be published in SI in summer 2016

Major meeting in Aveiro of international biochar experts

Biochar in soils: on the path to the required level of scientific understanding (LOSU)...for sustainable policy development!

Timeline of seminal biochar progress

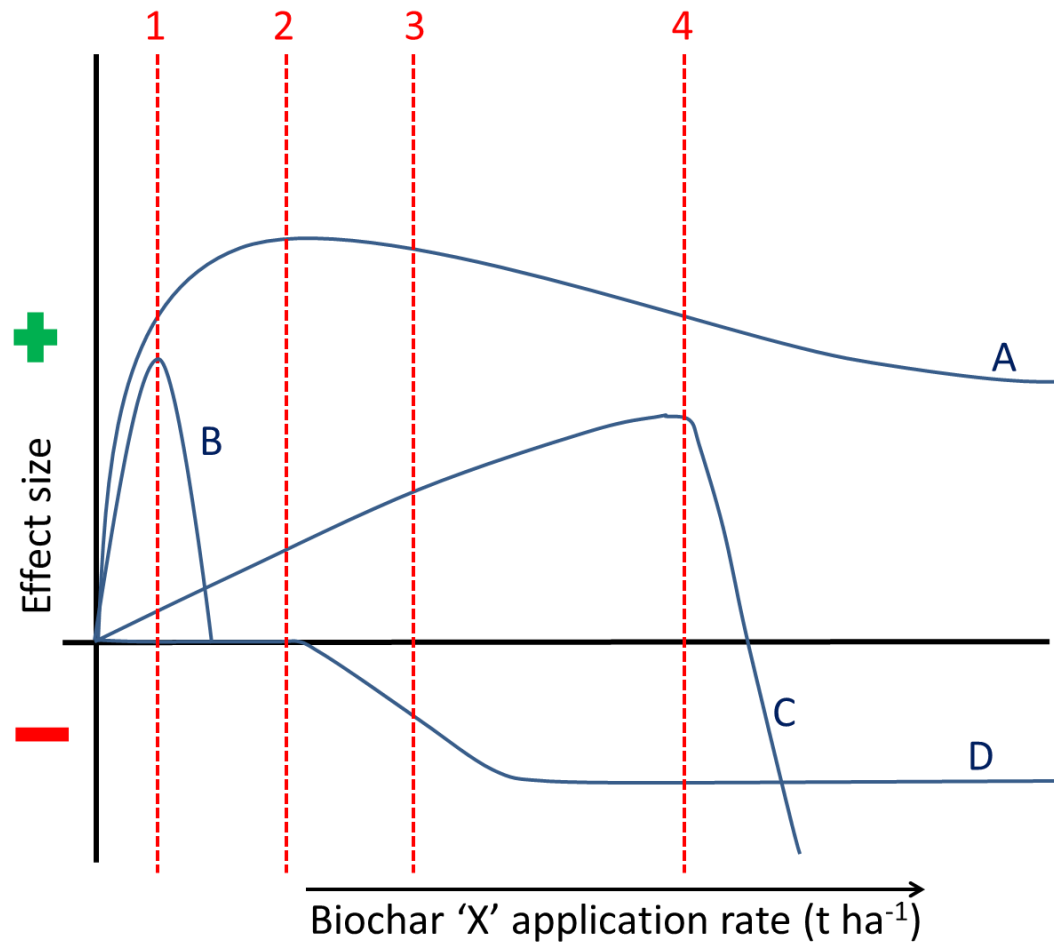


Book chapter in 'Biochar Bible' 2nd edition

Biochar Sustainability and Certification

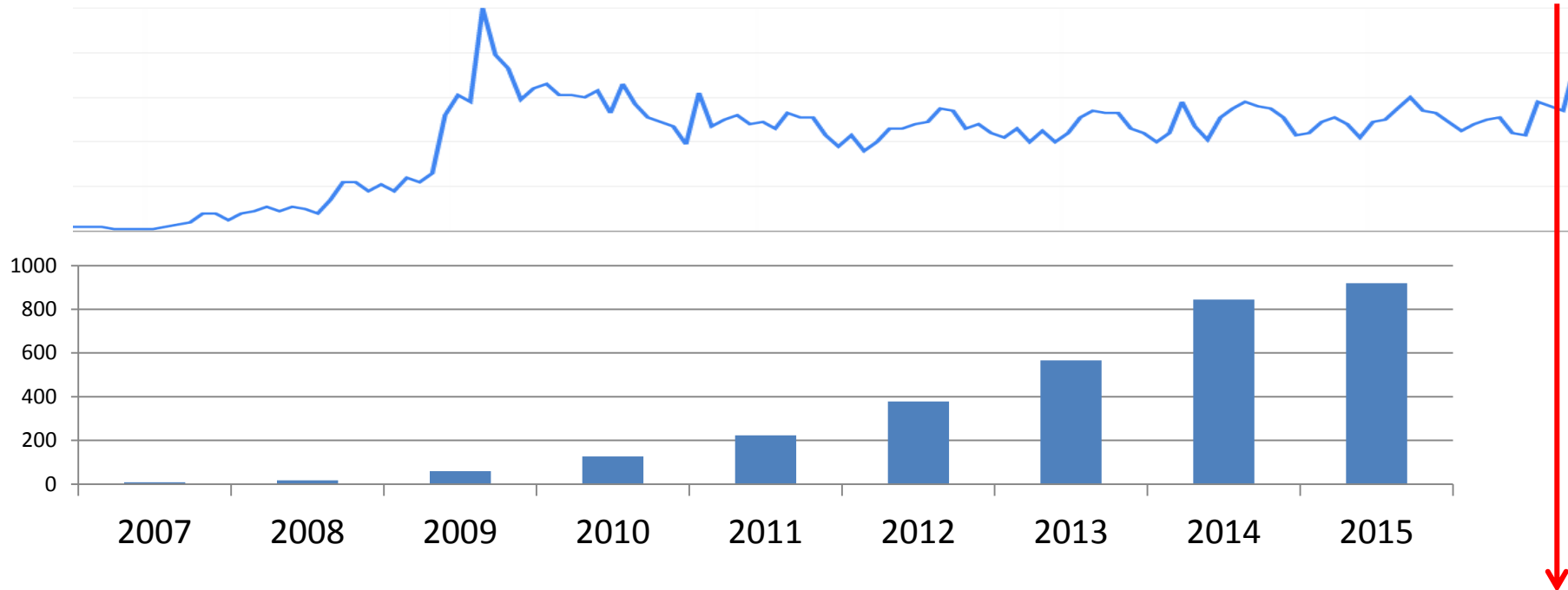
“Sustainable production and sustainable application are two sides of the same coin. One cannot succeed without the other!”

Optimum dose-effect



What biochar application rate do we choose?
Trade-offs!

Timeline of seminal biochar progress



First biochar forestry field site in Portugal

Collaboration led by Associação Florestal Baixa Vouga

To improve growth and survival of eucalypt plants



Take-home messages

1. Different biochar applications for different Ecosystem Services
2. Trade-offs need careful consideration
3. Biochar sustainability needs interdisciplinary research!
4. A lot more work is needed on the unknowns!

Some of our collaborators!



Thank you!

Any Questions?

