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Abstract

Climate change and the recent financial crisis clearly show that humans have entered the anthropocene, an unprecedented era of fast and possibly dangerous changes. Unprecedented changes call for unprecedented thinking. Indeed, agriculture research has been too long driven solely by the need for higher yields using classical agrosciences, whatever adverse ecological effects. Agricultural research needs the input of other sciences such as ecological, economic, social and political sciences. Those uncommon sciences emerge in agricultural research since few decades, but there is actually no precise trends and data on the speed of emergence of specific topics. Therefore, here we report: 1) an analysis of the emergence of topics in the journal *Agronomy for Sustainable Development*, and 2) a review of selected articles published in 2009. First, to analyse topic emergence we studied three data sets: most-cited articles from 1999 to 2009, topic hits in article text from 1999 to 2009, and most downloaded articles in 2009. We found the following major points. Most-cited articles show that transgenic plants and biofuels are clearly emerging topics since 2007 whereas soil carbon and climate change are the major mainstream topics of the last 10 years. Topic hits analysis allows to rank topics by mean emergence date, e.g. 2008.3 for 'genetically modified' and 2005.3 for 'irrigation'. Accordingly the 10 most emerging topics over 1999-2009 are biofuels, genetically modified, conservation agriculture, urban agriculture, sociology, organic farming, carbon sequestration, phytoremediation, mulch, and biodiversity. Analysis of most downloaded articles in 2009 show the predominance of topics such as carbon, climate, biodiversity, biofuels, pollutants, beneficial microbes, transgenic plants, and organic farming. Second, we reviewed selected articles published in 2009 with emphasis on emerging topics. We find that sociology is clearly bringing novel and unexpected findings to design sustainable agriculture. Transgenic crops are highly innovative but show many unknowns that needs to be carefully studied using various disciplines. Climate change has many scientifically proven effects on terrestrial ecosystems and agriculture. Here, soil carbon loss should be of particular attention because it rules the long-term fate of many factors such as atmospheric CO_2, erosion, and water and nutrient supply. Biodiversity loss due to industrial monocropping is leading scientists to disclose alternative, more diverse cropping systems that optimize biodiversity, pest control and yield.

Keywords: agriculture; climate change; biofuel; transgenic plants; biodiversity; sociology; organic farming; conservation agriculture; urban agriculture; industrial agriculture; carbon sequestration; soil carbon; crop rotation; no tillage; beneficial microbes; citation analysis; topic emergence analysis; most-cited articles; most-downloaded articles.

1. Introduction

Climate change and the recent financial crisis clearly show that humans have entered an unprecedented era of fast and possibly dangerous changes. This era is the anthropocene, a term that was coined in 2000 by the Nobel Prize winning atmospheric chemist Paul Crutzen to point out that human activities have now a global impact on climate and ecosystems. Crutzen has explained, "I was at a conference where someone said something about the Holocene. I suddenly thought this was wrong. The world has changed too much. So I said: 'No, we are in the anthropocene.' I just made up the word on the spur of the moment. Everyone was shocked. But it seems to have stuck".

Unprecedented changes call for unprecedented adaptation. Unprecedented adaptation call for unprecedented thinking. For instance, a major issue is that agricultural research has been too long driven solely by the need for *higher yields* using monoculture, whatever adverse ecological effects such as food and drinking water pollution, biodiversity loss and pest resistance. Mainstream goals such as higher yields should be challenged and rethought to take into account other factors. Those factors should not be solely defined by classical agrosciences, e.g. plant and soil sciences, but should also include all other sciences that really rule agriculture, for instance ecological, economic, social and political sciences (De Bon et al. 2009, Wezel et al. 2009, Fleming and Vanclay, 2009, Lamine and Bellon, 2009, Lichtfouse et al. 2009a,b, Veldkamp et al. 2009). In other words agronomy should not be reduced as a science that improves crop yields but should answer all society issues because agriculture is the both the foundation and the future of society. Agronomists should rethink the role of agriculture in our society. For instance studies of farming systems should also include food systems (Gliessman, 2007).

Previous essays have attempted to define the core issues of the industrial agricultural society: technology without wisdom; and tragedy of the global commons: soil, water and air (Lal, 2009a,b); artificialisation and painkiller solutions; climate change and outdated society structures; and society dependence and sustainable agriculture (Lichtfouse, 2009a-c). In the book *Sustainable Agriculture* we have gathered 53 review articles that cover major advances in agrosciences (Lichtfouse et al., 2009a). Four recent books also report major contributions in emerging agrosciences (Lichtfouse, 2009d-g). Here we analyse recent topical trends in the journal *Agronomy for Sustainable Development*. Topical trends are assessed using three indicators: 1) most-cited articles 1999-2009, 2) topic hits on the journal website over 1999-2009, and 3) most downloaded articles in 2009. We then briefly review selected journal articles published in 2009.

2. Most-cited articles 1999-2009

A first means to assess topics in the journal is to look at most-cited articles in the *Journal Citation Reports*. Table 1 shows yearly top cited articles in the journal *Agronomy for Sustainable Development* from 1999 to 2009. Results indicate that major recent topics are transgenic plants, agroindicators, alternative crop management, beneficial microbes, and topics related to climate change such as biofuels and soil carbon. Whereas transgenic plants and biofuels are clearly emerging topics from 2007, soil carbon and climate are strikingly appearing as major topics through the whole 1999-2009 period. Soil carbon and climate are also topics of the 4 most-cited articles from 1999 to 2009. Other most-cited topics include agroindicators; alternative crop management, pest control and fertilisation; biodiversity; pollutants and pesticides. We conclude that transgenic plants and biofuels are clearly emerging topics whereas soil carbon and climate are major mainstream topics of the last 10 years.

3. Journal website hits

We studied also topics by counting hits over 1999-2009 using the search engine of the journal website (Table 2). As topics refer to queries found in the whole article text, topics do not necessarily represent article topic. We ranked topics by decreasing order of emergence using the mean emergence date calculated by averaging dates weighted by hits. Figure 1 and 2 shows examples of the evolution of topic hits with time. Four evolution types were identified: 1) a *plateau*, for instance 'irrigation' data shows a plateau with a mean emergence date of 2005.2. 2) A *regular increase* such as that for 'crop rotation' since 2003. 'Crop rotation' has thus a younger mean emergence date of 2006.2. 3) A *sharp increase* such as that for 'organic farming' after 2004. 'Organic farming' has thus an even younger

mean emergence date of 2007.1. 'Genetically modified' exhibits the youngest mean emergence date of 2008.3. 4) A *dive-rise* such as that for 'agroforestry' showing a decrease from 1999 to 2003 followed by an increase from 2003 to 2009, suggesting a renewed interest for this topic.

Table 2 shows that according to the mean emergence date the 10 most emerging topics are biofuels, genetically modified, conservation agriculture, urban agriculture, sociology, organic farming, carbon sequestration, phytoremediation, mulch, and biodiversity. This finding confirms biofuels and transgenic plants as emerging topics from citation data (Table 1). The predominance of soil carbon and climate is also apparent in most emerging topics.

Urban agriculture, ranking 3 in emergence, and sociology, ranking 4, are of special interest because those topics represent a clear change of thinking. Urban agriculture is challenging the common belief that crops should be cultivated in rural areas. Here the idea to produce food close to consumers to decrease transportation pollution and costs is clearly elegant to fight climate change. The emergence of sociology can be explained both by increased interest from agronomists and by the shift of journal topics from 2004 (Lichtfouse et al., 2004). Table 2 also shows printed in bold the 5 top topics according to hits in 2009. Here biodiversity is found in 55% of articles, crop rotation 49%, no tillage 43%, irrigation 40% and organic farming 38%. These data from one single year cannot be interpreted in terms of evolution, but they represent probably the major concerns of authors in 2009.

To conclude, the 10 most emerging topics according to mean emergence date are biofuels, genetically modified organisms, conservation agriculture, urban agriculture, sociology, organic farming, carbon sequestration, phytoremediation, mulch, and biodiversity. Those topics can be roughly classified into two streams of research aiming at a more sustainable agriculture. First, an *analytical stream* that develops technological innovations in plant science such as transgenic plants and biofuels. Second, a *systemic stream* that develops innovative farming practices such as organic farming and urban agriculture. Concepts of the systemic stream are given by Hill and MacRae (1996), Vandermeer et al. (1998), Papy (2001) and Dalgaard et al. (2003), Lichtfouse et al. (2009a), and references therein.

4. Most downloaded articles in 2009

Topics of interest for readers of the journal can be evaluated by topics of the most-downloaded articles on the journal website (Table 3). We observe three major categories of topics: 1) topics related to climate change, e.g. biofuels, drought and salt stress, biodiversity, and carbon sequestration in soils; 2) topics related to alternative management, e.g. agroindicators, fertilisation, beneficial microbes, intercropping, organic farming, and 3) topics related to food security, e.g. pollutants, alternative fertilisation and control, and organic farming. The predominance of topics such as carbon, climate, biodiversity, biofuels, pollutants, beneficial microbes, transgenic plants, and organic farming agrees with our previous results.

Table 1. Top 3 yearly most cited articles in the journal *Agronomy for Sustainable Development*. Number of citing articles, named cites, are from ISI-thompson on October 22, 2009. The top 5 highest cites are printed in bold. Full references are given in the reference list.

MOST-CITED ARTICLES

Year	Cites	Topics	First author - Title
2008	5	Transgenic plants	BONNY. Genetically modified glyphosate-tolerant soybean in the USA...
	5	Transgenic plants	DEVOS. Feasibility of isolation perimeters for genetically modified maize
	4	Agroindicators, N, pesticides	BOCKSTALLER. Agri-environmental indicators to assess cropping and farming...
2007	16	Transgenic plants	DEVOS. Implementing isolation perimeters around genetically modified...
	11	Alternative fertilisation, beneficial microbes	GARG. Symbiotic nitrogen fixation in legume nodules: process and signaling.
	10	Biofuels, climate, carbon	HILL. Environmental costs and benefits of transportation biofuel production...
2006	17	Alternative management, soil, carbon	BERNOUX. Cropping systems, carbon sequestration and erosion in Brazil.
	17	Alternative fertilisation, soil, carbon	HACHICHA. Compost of poultry manure and olive mill wastes as an alternative...
	8	Pollutants, food	GROVA. Effect of oral exposure to polycyclic aromatic hydrocarbons...
2005	19	Alternative management, soil, pesticides	LACAS. Using grassed strips to limit pesticide transfer to surface water.
	18	Agroindicators, biodiversity	CLERGUE. Biodiversity: function and assessment in agricultural areas.
	13	Transgenic plants	COLBACH. Spatial aspects of gene flow between rapeseed varieties and volunteers.
2004	25	Alternative management, biodiversity	MARRIOTT. Long-term impacts of extensification of grassland management...
	21	Alternative management, soil, erosion	LE BISSONNAIS. Grass strip effects on runoff and soil loss.
	17	Soil, carbon, compost	AMIR. Elemental analysis, FTIR and C-13-NMR of humic acids from sewage...
2003	**98**	Soil, carbon, roots	NGUYEN. Rhizodeposition of organic C by plants: mechanisms and controls.
	26	Soil, carbon, fungi	CASARIN. Quantification of oxalate ions and protons released by ectomycorrhizal...
	23	Pollutants, toxicity	ROUT. Effect of metal toxicity on plant growth and metabolism: I. Zinc.
2002	**146**	Alternative management, soil, carbon	SIX. Soil organic matter, biota and aggregation in temperate and tropical soils...
	50	Agroindicators, climate, soil	BRISSON. STICS: a generic model for simulating crops and their water...
	33	Climate, greenhouse	REICHRATH. Using CFD to model the internal climate of greenhouses...
2001	51	Climate, carbon, salt stress	DORAI. Influence of electric conductivity management on greenhouse tomato...
	35	Alternative control	EHRET. Disinfestation of recirculating nutrient solutions in greenhouse horticulture.
	32	Carbon, growth	GUICHARD. Tomato fruit quality in relation to water and carbon fluxes.
2000	**72**	Climate, canopy	WEISS. Investigation of a model inversion technique to estimate canopy...
	52	Alternative control, intercropping	FINCKH. Cereal variety and species mixtures in practice...
	37	Beneficial microbes	BOSSIS. The taxonomy of Pseudomonas fluorescens and Pseudomonas putida...
1999	**73**	Climate, remote sensing	CEROVIC. Ultraviolet-induced fluorescence for plant monitoring...
	44	Climate, canopy	FOURNIER. ADEL-maize: an L-system based model for the integration of growth...
	40	Plant architecture, model	GODIN. Exploration of a plant architecture database with the AMAPmod...

Table 2. Mean emergence date (MED) of topics in articles from the journal *Agronomy for Sustainable Development*. Topics were searched in all article text, and thus do not necessarily reflect the article topic. Topics that showed highest hits in 2009 are printed in bold. Hits in percent refer to the number of articles containing topics measured using the journal website search engine on October 22-23, 2009, versus total yearly published articles. Mean emergence date was calculated as the average of years weighed by hits : ∑(Hits.year)/ ∑Hits, thus allowing to sort topics by order of emergence in the journal. Most recent topics have thus most recent date (see figure 1). For queries having several words, e.g. genetically modified, we used double quotes operators ("...") to retrieve only answers from words appearing together. AD: Anno Domini.

TOPICS	MED	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999
	AD	%	%	%	%	%	%	%	%	%	%	%
Biofuels	2008.29	5.48	3.39	2.27	0	0	0	0	0	0	0	0
Genetically modified	2008.25	5.48	5.08	2.27	0	0	0	0	0	0	0	0
Conservation agriculture	2007.54	13.70	1.69	0	9.09	0	1.92	0	0	0	0	0
Urban agriculture	2007.22	2.74	1.69	0	0	0	1.92	0	0	0	0	0
Sociology	2007.11	10.96	0	2.27	0	1.59	3.85	1.27	0	0	0	0
Organic farming	2007.05	**38.36**	20.34	22.73	9.09	7.94	0	3.80	5.13	1.43	2.50	0
Carbon sequestration	2006.92	16.44	11.86	6.82	9.09	4.76	3.85	0	3.85	0	0	0
Phytoremediation	2006.87	1.37	6.78	2.27	0	3.17	0	1.27	0	0	0	0
Mulch	2006.62	21.92	28.81	15.91	15.15	3.17	9.62	1.27	5.13	1.43	1.25	1.79
Biodiversity	2006.55	**54.79**	25.42	25	12.12	12.7	7.69	5.06	6.41	5.71	2.50	5.36
Climate change	2006.54	31.51	18.64	9.09	9.09	6.35	9.62	2.53	5.13	2.86	1.25	1.79
Integrated pest management	2006.50	9.59	10.17	11.36	6.06	4.76	0	3.8	0	1.43	0	1.79
Allelopathy	2006.41	5.48	6.78	4.55	3.03	1.59	0	2.53	0	2.86	0	0
Soil erosion	2006.19	21.92	16.95	20.45	15.15	6.35	9.62	1.27	7.69	0	2.50	3.57
Crop rotation	2006.17	**49.32**	30.51	31.82	18.18	12.70	11.54	6.33	12.82	10	2.50	5.36
Transgenic	2006.15	13.70	13.56	13.64	0	4.76	1.92	6.33	0	0	1.25	5.36
Grass strips	2005.92	5.48	3.39	2.27	6.06	1.59	1.92	0	0	1.43	2.50	0
Biocontrol	2005.87	5.48	8.47	4.55	12.12	3.17	3.85	6.33	0	2.86	0	0
Cover crops	2005.76	17.81	16.95	15.91	6.06	9.52	7.69	3.80	14.1	2.86	1.25	1.79
Biological control	2005.70	10.96	10.17	18.18	12.12	7.94	7.69	7.59	0	7.14	2.50	0
No tillage	2005.59	**42.47**	35.59	34.09	18.18	20.63	28.85	18.99	20.51	5.71	3.75	8.93
Weed control	2005.35	27.40	27.12	18.18	24.24	20.63	19.23	13.92	8.97	14.29	2.50	7.14
Intercropping	2005.34	16.44	13.56	18.18	9.09	4.76	5.77	3.80	8.97	4.29	3.75	7.14
Irrigation	2005.21	**39.73**	42.37	43.18	39.39	39.68	51.92	37.97	32.05	28.57	0	0
Biological nitrogen fixation	2005.00	6.85	6.78	11.36	0	0	1.92	3.80	1.28	14.29	0	0
Agroforestry	2004.88	10.96	6.78	6.82	3.03	1.59	1.92	0	3.85	2.86	3.75	7.14
Decision support systems	2004.74	8.22	8.47	6.82	3.03	0	13.46	3.80	6.41	5.71	1.25	3.57
Precision agriculture	2004.06	4.11	3.39	2.27	0	1.59	9.62	1.27	6.41	2.86	0	3.57
Drought stress	2004.01	12.33	5.08	13.64	0	6.35	11.54	10.13	7.69	10	2.5	12.5

Table 3. Top 30 most downloaded articles from the website of the journal *Agronomy for Sustainable Development*. *Counts from January 1, 2009 to October 27, 2009. Year refers to year of publication. PDF refers to number of articles downloaded. PDF: portable document format. Full references are given in the reference list. E-first refers to articles online published but not yet issue published; those articles will be published in 2010.

MOST-DOWNLOADED ARTICLES 2009*

Year	PDF	Topics	First author - Title
2009	1975	Climate, drought stress	FAROOQ. Plant drought stress: effects, mechanisms and management.
2007	1421	Alternative fertilisation, beneficial microbes	KHAN. Role of phosphate-solubilizing microorganisms...
2009	1260	Agroecology	LICHTFOUSE. Agronomy for sustainable agriculture.
2003	970	Pollutants, toxicity	ROUT. Effect of metal toxicity on plant growth...
2006	931	Alternative fertilisation, beneficial microbes	HAFEEZ. Plant growth-promoting bacteria as biofertilizer
2009	786	Alternative management, intercropping	MALEZIEUX. Mixing plant species in cropping systems...
2007	647	Biofuel, climate, carbon	HILL. Environmental costs and benefits of transportation biofuel...
2001	641	Alternative fertilisation, beneficial microbes	IGUAL. Phosphate-solubilizing bacteria as inoculants...
2009	639	Soil, food security	LAL. Soils and food sufficiency.
2009	629	Alternative management, soil	LAL. Laws of sustainable soil management.
2009	628	Climate, biodiversity	FEEHAN. Climate change in Europe. 1. Impact on terrestrial...
2009	609	Climate, carbon, sequestration	BENBI. A 25-year record of carbon sequestration...
2001	522	Climate, carbon, salt stress	DORAI. Influence of electric conductivity management...
2009	497	Transgenic plants	DEVOS. Coexistence of genetically modified...
E-first	495	Organic farming, food security	LAIRON. Nutritional quality and safety of organic food.
2009	493	Organic farming, sociology	LAMINE. Conversion to organic farming...
2009	492	Agroindicators	BOCKSTALLER. Comparison of methods to assess the sustainability...
2009	473	Climate, agriculture	LAVALLE. Climate change in Europe. 3. Impact on agriculture...
2005	446	Climate, drought stress	SAMARAH. Effects of drought stress on growth and yield of barley.
2003	437	Climate, salt stress	BEN KHALED. Effet du stress salin en milieu hydroponique...
2009	436	Climate, soil	JONES. Climate change in Europe. 2. Impact on soil.
2008	427	Alternative control	DORDAS. Role of nutrients in controlling plant diseases...
2009	423	Agroecology	WEZEL. Agroecology as a science, a movement and a practice.
2007	422	Alternative fertilisation, beneficial microbes	GARG. Symbiotic nitrogen fixation in legume nodules...
2009	411	Alternative fertilisation, intercropping	ZUO. Iron and zinc biofortification strategies in dicot plants...
2003	392	Soil, carbon, roots	NGUYEN. Rhizodeposition of organic C by plants...
E-first	391	Alternative fertilisation, food security	SPIERTZ. Nitrogen, sustainable agriculture and food security.
E-first	366	Alternative management, urban agriculture	DE BON. Sustainable urban agriculture in developing countries.
2003	364	Pollutants, beneficial microbes	JONER. Phytoremediation of organic pollutants using mycorrhizal...
2003	341	Beneficial microbes, methods	GAMALERO. Methods for studying root colonization...

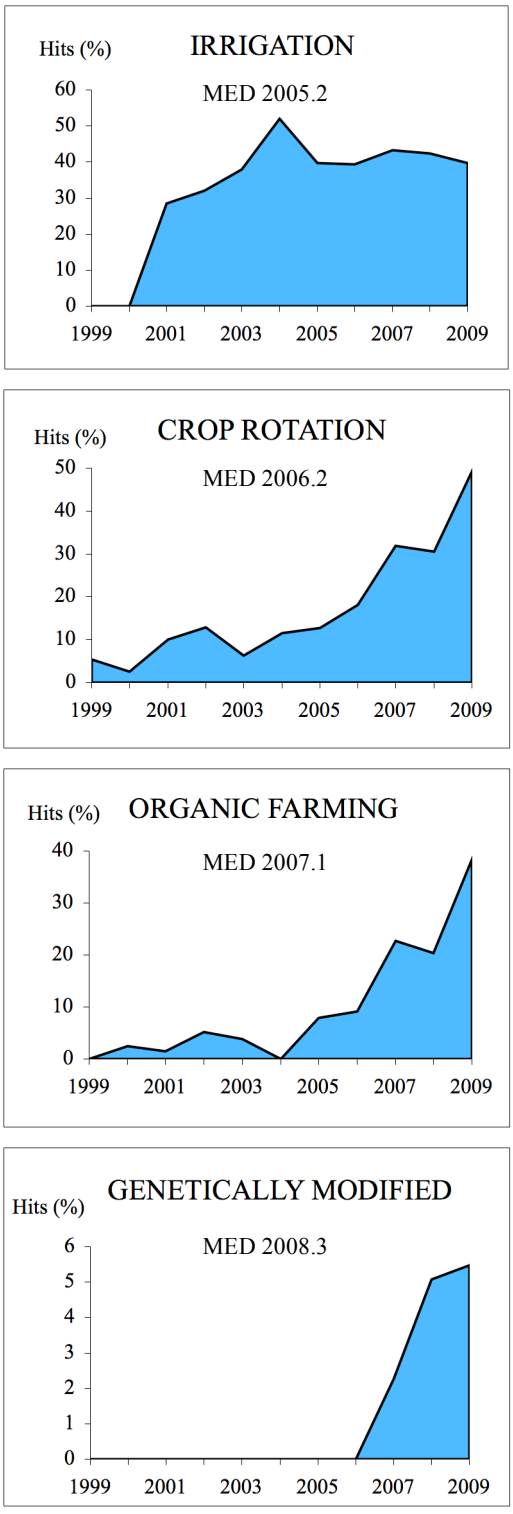

Figure 1. Emergence of topics in article text from the journal Agronomy for Sustainable Development. Note the shift to the right of most emerging topics in the journal. MED refers to mean emergence date (see Table 3 caption). Hits in percent refer to the number of articles containing topics measured using the journal website search engine (see Table 3 caption).

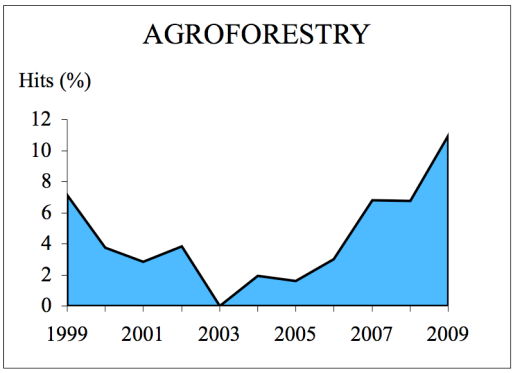

Figure 2. Evolution of the topic Agroforestry in article text from the journal Agronomy for Sustainable Development. Note the decrease until 2003 followed by an increase, suggesting a renewed interest. Hits in percent refer to the number of articles containing topics measured using the journal website search engine (see Table 3 caption).

5. Review of selected 2009 articles

Here we review selected articles published in 2009 in the journal *Agronomy for Sustainable Development*. The fast emergence of new disciplines such as social and economic sciences in agronomical research is underlined by Wezel et al. (2009), Lamine and Bellon (2009), and Lichtfouse et al. (2009a). Wezel et al. (2009) reconstruct the historical rising of agroecology following the decline of industrial agriculture. Noteworthy these authors observe that the meaning of agroecology changes from one country to another. For instance, in Germany agroecology is mainly a science, whereas in France and in Brazil agroecology is also a green movement that is borne by citizens.

5.1 Sociology

Sociology emergence in the journal *Agronomy for Sustainable Development* is nicely highlighted by Veldkamp et al. (2009) who design an innovative Dutch project that take into account the opinion of all stakeholders. The authors develop their ideas on the alternative principle that sustainable development requires a better balance of the triple P values - people, planet and prosperity. Another tantalizing example of bridging sociology and agronomy is given by Fleming and Vanclay (2009) who analyse the impact of climate change on farmer discourses. The core issue is nicely underlined by a farmer interview "What's sustainable? You've got to look at our world as we know it. We're not in a sustainable position at the moment. That's why I say 'what's sustainable?' – I don't know." The authors found that farmers have four main discourses that guide their decision: money, earth, human responsibility and questioning. Disclosing which discourses are at work in a specific farming system is clearly needed because, to put it simply farmers will not follow scientist advices if they are not convinced that those advices agree with their discourses. De Bon et al. (2009) show the social benefits of urban agriculture in developing countries. Lamine and Bellon (2009) review the conversion from intensive to organic farming using viewpoints from both agronomists and social scientists. They found that most publications report conversion effects and motivations, whereas few publications study transitions and trajectories. To conclude the use of sociological tools to study farming systems is bringing unexpected findings to design sustainable agriculture.

5.2 Transgenic crops

Transgenic crops is typically an emerging topic that has escaped the science sphere to be now a major social, economical and political issue. As a consequence, transgenic crops is therefore a well suited research topic for agronomists that use sociology and economics. Like all major science breakthroughs, e.g. nitro-glycerine and nuclear energy, there are many arguments in favour of genetically modified organisms and many arguments against their use. Devos et al. (2009) analyse policies ruling the coexistence of transgenic and non-transgenic maize in European nations. They found that actual isolation distances are excessive, difficult to implement, and not economically viable. Very interestingly they conclude that 'other scientific issues must be at play'. A such unknown may indeed be disclosed by the discourse approach of Fleming and Vanclay (2009).

Graef (2009) reviews possible adverse effects of introducing transgenic oilseed rape in Europe. He found that possible adverse effects to be monitored are persistence and spread of herbicide tolerant oilseed rape, transfer of tolerance to wild relatives, development of herbicide tolerance of weeds, decrease of biodiversity, herbicide pollution, and adverse impact on field organisms and biogeochemical cycles. Hart et al. (2009) demonstrate for the first time the persistence of transgenic crop DNA residues within a soil food web. They found the transgene for glyphosate tolerance in soil arthropods, nematodes and earthworms from a transgenic corn field. The potential of transgene flow from transgenic crops wild relatives is addressed by Loureiro et al. (2009) who found that hybrids of wheat and its wild relative *Aegilops biuncialis* are formed easily with 9-75% hybridization rates. To conclude, transgenic crops are highly innovative but show both benefits and drawbacks that needs to be carefully studied using various disciplines.

5.3 Climate change

Climate change effects in Europe are reviewed in three reprints from an European report. First, Feehan et al. (2009) analyse major effects on terrestrial ecosystems and biodiversity. Key trends include northward and uphill shift of plants, birds and mammals; earlier seasonal events such as flowering,

bird nesting and frog spawning. Second, Jones et al. (2009) report major effects of climate change on soils. Key observations include a decrease of soil C over the last 25 years, a higher risk of erosion and projected increases of CO_2 release in the atmosphere. It should be noted that there is much less evidence from soil studies because soil research is usually more difficult and needs more time - and funds - because most soil changes occur very slowly. Here the major issue is that once adverse changes have occurred, e.g. soil carbon depletion, they cannot be healed fast. Therefore management options that favour carbon sequestration and soil preservation should be applied (Doumbia et al. 2009, Benbi and Brar, 2009, Hazarika et al. 2009, Pleguezuelo et al. 2009, Tuttobene et al. 2009). Principles for sustainable soil management are given by Lal (2009c,d).

Third, Lavalle et al. (2009) review major effects of climate change on agriculture and forestry. Key trends include the shortening of the growing season in the south with higher risk of frost damage; flowering and maturity of crops occurring now about 2-3 weeks earlier; a higher yield variability due to extreme climate events such as the 2003 summer heat and the 2007 spring drought; a high increase of 50-70% of the water demand in Mediterranean areas; a faster forest growth; and a higher risk of forest fires. Tingem et al. (2009) simulate future crop yield in response to climate change in Cameroon. They found that developing later maturing cultivars could highly increase yields of maize, sorghum and bambara groundnut. Farooq et al. (2009) review effects of drought stress on plants. They also propose several solutions to counteract drought stress. To conclude, there are many scientific proofs of the effects of climate change on terrestrial ecosystems. Adverse, long-term effects such as soil carbon loss and erosion should be of particular attention by agronomists.

5.4 Biodiversity

Biodiversity loss due to adverse effects of industrial agriculture is a major threat to sustainable agriculture. A well-known example is the decrease of bees. Indeed bees and other insects carry pollen and thus are essential to the reproduction of some crops like blueberries. Higher biodiversity is also a means to control crop diseases because pathogens and natural antagonists are better balanced. De Cauwer and Reheul (2009) investigate the impact of grassland management on plant biodiversity and invasive species. They found that abundance of non-leguminous dicots decrease with higher intensity use and N supply. They identify several land uses that suppress invasive species and optimize plant biodiversity. Weed diversity and density is also investigated by Izquierdo et al. (2009) and Koocheki et al. (2009). Pelosi et al. (2009) studied earthworm biodiversity in conventional, organic and living-mulch cropping systems. They found that the Shannon-Wiener and equitability indexes were higher in the living-much system. To conclude, agronomists are designing alternative, cropping systems that optimize biodiversity, pest control and yield.

5.5 Alternative farming systems

Alternative management systems involving mixing plants, e.g. intercropping and agroforestry are reviewed by Malézieux et al. (2009). They found that potential benefits are higher overall productivity, better pest control, and better ecological services. Koocheki et al. (2009) analysed the effect of different cropping systems and various crop rotations on weeds. To reduce the weed seed bank they propose rotations that include crops with different life cycles such as winter wheat-maize and winter wheat-sugar beet. To design and evaluate innovative cropping systems on a medium- and long-term basis, new methods are required combining simulation and field experimentation. Here Debaeke et al. (2009) describe an iterative and rule-based approach to set up cropping systems in response to a drastic reduction of water, nitrogen and pesticide inputs.

6. Conclusion

Citation analysis shows that transgenic plants and biofuels are clearly emerging topics whereas soil carbon and climate change are major mainstream topics of the last 10 years. The 10 most emerging topics according to mean emergence date are biofuels, genetically modified, conservation agriculture, urban agriculture, sociology, organic farming, carbon sequestration, phytoremediation, mulch, and biodiversity. In 2009, the higher hits were found for biodiversity (55%), crop rotation (49%), no tillage (43%) and organic farming (38%). Analysis of most downloaded articles in 2009 show the predominance of topics such as carbon, climate, biodiversity, biofuels, pollutants, beneficial microbes,

transgenic plants, and organic farming. We find that sociology is clearly bringing novel and unexpected findings to design sustainable agriculture. Transgenic crops are highly innovative but show many unknowns that needs to be carefully studied using various disciplines. Climate change has many scientifically proven effects on terrestrial ecosystems and agriculture. Here, soil carbon loss should be of particular attention because it rules the long-term fate of many factors such as atmospheric CO_2, erosion, and water and nutrient supply. Biodiversity loss due to industrial agriculture is leading scientists to disclose alternative, more diverse cropping systems that optimize biodiversity, pest control and yield.

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