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INNOVATION SYSTEMS AND KNOWLEDGE COMMUNITIES IN THE AGRICULTURE AND AGRIFOOD SECTOR: A LITERATURE REVIEW[1]

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The concept of Innovation Systems (IS) exists not only in a significant amount of research on innovation since the late 1980s but also increasingly in the documents of public policies on innovation and of international development agencies (OECD, EU, World Bank, etc.). In general, this concept aims to understand how a set of institutions, organizations, networks and actors can interact to foster innovation in a given national, regional, or sectoral space, or in a space constructed by companies or around the development of a technology (Carlsson *et al.*, 2002). Originally used to study technological innovations in industry and the development of "*knowledge economies*" (Foray, 2009), the concept was extended to the analysis of agricultural and agrifood activities (World Bank, 2006). It seems to have

1. This article is a new version of a paper published in French in *Innovations* 43(1), 13-38 : Touzard, J.-M., Temple, L., Triomphe, B., Faure, G. (2014), Les Systèmes d'Innovation dans l'agriculture et l'agroalimentaire : une revue de la littérature.

found fertile ground in this domain because of the existence of specialized research and development institutions and a renewed interest in agricultural innovation in pursuit of sustainable development (McIntyre *et al.*, 2009). Adaptations of the concept of IS to this sector have been proposed, such as that of "Agricultural Innovation System" (EU SCAR, 2012), but since there seem to be a multiplicity of definitions and usages, a critical review is called for.

This article aims to analyse how different "*knowledge communities*" (Conein, 2004) use the concept of IS in agriculture or agrifood systems, and how these uses question the specifics of innovation in this sector: do these communities' scientific publications reflect a simple application of a general IS approach to a sector? Or do they instead give rise to more original proposals which include the conditions under which innovation can take place in the agriculture and agrifood sector? To answer these questions, we base our work on a literature review and a bibliometric study undertaken on a selection of international journals on agriculture and innovation.

In the first part, we review the evolution and diversity of studies on the concept of IS in order to propose an analytical framework based on three areas: the concept's theoretical and analytical frame of reference, its area of application, and its purposes and uses. In the second part, the results of the bibliometric work are presented in terms of indicators derived from the above framework. These results are discussed in the third part. They suggest that there exist four distinct knowledge communities, each of which questions in a different manner the specific character of the work mobilizing IS to study agricultural and/or agrifood innovation.

THE CONCEPT OF INNOVATION SYSTEM: THEORETICAL FOUNDATIONS, AREAS OF APPLICATION, USES

Origin and evolution of the concept of innovation system

The concept of Innovation System (IS) was created by authors who examined the history of several innovations and observed that their "successes" could be attributed to the existence of institutions and networks through which researchers and entrepreneurs from public and private sectors could collaborate, learn from each other, share resources and act to address economic and technical changes. Analysing the success of the Japanese economy in the 1970s and 1980s through this perspective, Freeman (1987) was the first to use the term "*national innovation system*" to describe government

institutions involved in defining and implementing research and innovation policies. Nelson (1993) and Lundvall (1992) then extended Freeman's definition to include all institutions and industrial actors undertaking research activities and promoting the dissemination of knowledge for technological innovation at the country level.

Research using the notion of IS that has followed this initial work has primarily developed around evolutionary approaches to innovation, gradually forming the "*Science Policy and Innovation Studies*" (Martin, 2012). The concept of IS has even been retained as one of the four pillars of this research community which, though dominated by economic approaches, also involves researchers from management science, history and sociology (Fagerberg, Verspagen, 2009). It is in this framework that most versions of the concept of IS have been developed (Edquist, 2004), going beyond the initial approaches whose scope was limited to the national innovation system: "*regional innovation systems*" in the vein of work on innovative clusters or districts (Cooke *et al.*, 1998); "*technological systems*" or "*Corporate Innovation Systems*" to take into account the interactions between institutions and firms outside of established political and administrative frameworks (Carlsson, 2006); and sectoral innovation systems, which analyze institutional conditions specific to innovation in a sector of activity (Malerba, 2002). At the same time, the components of IS were being identified, incorporating the contributions of adjacent scientific communities (Carlsson *et al.*, 2002): taking mechanisms for disseminating innovation into account; more precise characterization of institutions and different "knowledge bases"; analysis of enterprise or actors networks… Relationships between specific entities have also been emphasized, such as in the "triple helix" model which links industry, universities and the State (Leydesdorff, Etzkowitz, 1998).

Other lines of research have sought to integrate or adapt the concept of IS. For example, regulationist research has done so to analyse the transformations of capitalism and its various national forms (Amable *et al.*, 1997), including at territorial and sectoral scales (Lung, Bouneau, 2009). Institutions dedicated to research and innovation then find their place in a broader economic analysis, where they complement the canonical institutional forms regulating the wage relations, money and competition. The concept of "social system of innovation and production" has been proposed to account for innovation-related institutional complementarities and to incorporate technological dynamics (Amable, 2003). Sociologists undertaking "*Science and Technology Studies*" have also used the notion of IS, but without adopting it as a distinct analytical category. It was thus used to describe the national context of the development of a technology or a

socio-technical network (Naubahar, 2006; Hacket *et al.*, 2008) or to consider interactions of key actors as "*innovation intermediaries*" (Meyer, Kearnes, 2013). Reference to IS is also present in research into innovation management (Smits, Kuhlman, 2004; Shane, 2008) and in work on the transition of socio-technical systems that claim critical affiliation with the evolutionary approaches of Sectoral Innovation Systems (Geels, 2004).

Influenced by this body of academic work, national and international development agencies have appropriated the concept of IS. Since the 1990s, OECD has broadened the definition of IS by including "framework conditions" necessary for innovation, such as tax regimes, regulations, culture and behaviour (OECD, 2001). The World Bank has also shared its definition of the concept of IS as a "*network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the system's behaviour and performance*" (World Bank, 2006). It has deepened its commitment through the publication of a "Sourcebook" for decision makers and investors of the Bank and its partners, offering an overview of the concept and its application (World Bank, 2012). The European Union has also introduced the concept as part of its overall strategy to move towards a "*knowledge-based economy*" (Borras, 2004). National and regional innovation policies have followed suit, for example, in France with the generalizing of the concept of the regional innovation system by giving it a normative content (Prager, 2010).

Starting from its initial definition, the concept of IS has therefore been enriched and diversified under the influence of several disciplines and theoretical currents (dominated by evolutionary reference) as well as of confrontations in different application settings (country, region, sector, companies network, etc.) with different uses (descriptive, analytical, normative, etc.). The approaches are divided between a restricted vision of an IS, limited to institutions and networks dedicated to innovation (the institutional and formal context of innovation processes), and a broader vision that encompasses informal structures and innovation and learning processes themselves (Malerba, 2002). The diversity of existing definitions of IS nonetheless has a common conceptual basis, which goes beyond the principles propounded by the evolutionary core: an *interactionist* view of innovation, extending the analysis to a multiplicity of actors and the environment in which they operate; a key role accorded not only to *knowledge and institutions* but also (in a more or less explicit manner) to social relationships and *networks*; a *systemic framework* seeking to understand patterns in the complex network of actors and institutions participating in the innovation process.

A framework for analysing research on Innovation Systems

This brief look at how research on IS has evolved leads us to propose a generic analytical framework to determine how the concept is mobilized in scientific articles and policy-related work and documents, particularly in a domain such as agriculture and agrifood systems. This analytical framework is organized around three axes, already suggested by Amable (2003) and Martin (2012), and, more broadly, by research on the history of the concepts in the social sciences (Christin, 2010).

The *first axis* questions the *system of thought, the paradigm or theoretical framework* with which the author(s) associate the concept of IS. This reference may be explicit or implicit. The IS concept can be restricted to a scientific discipline or one of its streams (for example, evolutionary or institutionalist economics) or can even be promoted as an interdisciplinary category. But in addition to the disciplines, it is necessary to specify which elements and relationships are taken into account to define the IS: individual actors or categories of actors, organizations, companies, the State, institutions, public policies, networks, knowledge, information systems, technical objects, learnings, processes, etc. This first axis helps clarify the innovation approach or paradigm associated with the concept of IS by exploring its institutional, cognitive, relational and systemic dimensions. It also allows us to determine the vision of IS the text forms part of: i) limited, formal and often functionalist (institutions dedicated to research, education and innovation), ii) extended to informal aspects of the social context of innovation (networks, cultural norms, etc.), or iii) even wider by including innovation processes used in enterprises, i.e., an "*innovation and production system*" (Malerba, 2002).

The *second axis* corresponds to the *concept's domain and space of application*, i.e., to both the specific nature of the activities and objects that concern the innovation or to which the IS is dedicated, as well as to the extension of the system itself. Does it refer to i) a politico-administrative space in which the IS institutions are at work (national, regional or sectoral space) or ii) a topological space consisting of a set of enterprises (a multinational group or consortium) or one constructed on the basis of the observation of the innovation process itself (technological system, socio-technical system)? The concept can also span several scales and spaces. Indeed, their combination is a major challenge that current thinking on innovation has to deal with in the context of economic globalization (Carlsson, 2006). The temporal dimension is also a key element in defining the analytical domain: Is it a long-term study (historical or longitudinal approach) or does it pertain to a shorter period (a state of the IS)?

The *third axis* accounts for the *social use of the concept*, the *purposes* for which it is meant, or even categories of actors or the social classes it can benefit. Is the IS concept simply used to describe (or recall) the institutional context of an innovation being studied? Or is it being used instead to produce new knowledge about the institutions and networks of innovation or even about more wide-ranging transformations of an economic and social system or changes in the relationship between science and society? The IS can then be regarded as an object of knowledge in itself. But the concept can also be directly exploited to formulate policies for innovation or research and to recast the relationships between research institutions and economic actors. Often associated with these normative approaches, the IS can also be used to assess the impacts of research institutions on development by analyzing their bearing on the emergence and diffusion of innovations.

METHODOLOGY AND RESULTS OF THE BIBLIOMETRIC STUDY

Selection of articles

The analytical framework described above allows us to explore the scientific output that uses the IS concept in research on agriculture and agrifood systems. We have therefore undertaken a bibliometric study[2] using three search engines: CAB[3], Web of Science[4], and Scopus[5]. These databases were chosen because between them they account for most of the international literature on agriculture and agrifood systems across a variety of scientific disciplines, although some French journals and social science journals are not present in these databases. The queries were made on the terms "Innovation System" (IS), "IS + agrifood", "IS + agriculture", "IS + biotechnology" and "IS + rural" in English, French and Spanish. The search was conducted on the title, abstract and keywords of the articles, for a period spanning from 1995 to 2011.

We then read the summaries of all the articles that the searches threw up. After weeding out those we judged not relevant, we were left with a final set

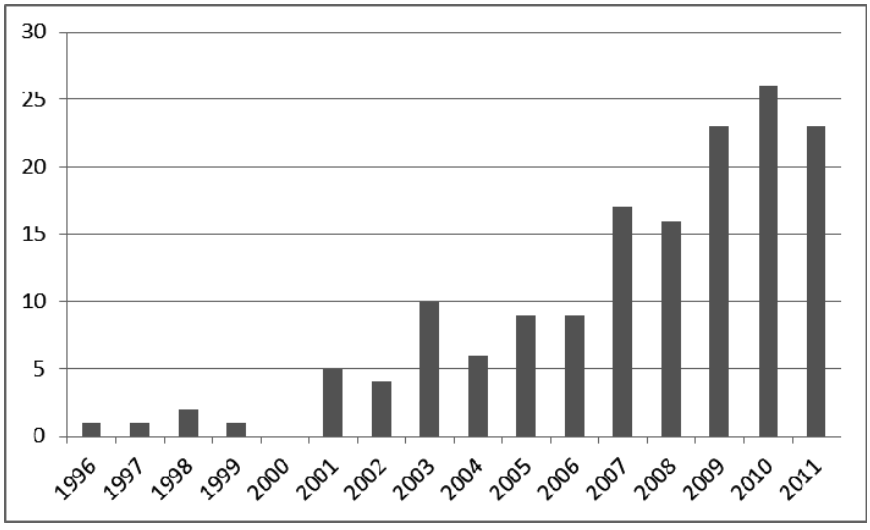
2. With the assistance of Marie-Christine Duchamp of Cirad.
3. CAB is the database of the Centre for Agriculture and Biosciences International. It lists publications on agriculture and the life sciences since 1972: 7400 international journals, 7 million references.
4. Web of Science (WoS) is a module of the platform of the Institute for Scientific Information. It is multidisciplinary and lists more than 10,000 journals.
5. Scopus is a database of abstracts and citations spanning 19,000 scientific journals.

of 155 articles. Most of them pertained directly to agriculture and agrifood systems. We included some that dealt with biotechnology and rural development if they appeared related to agriculture or agrifood systems (e.g., GMO seeds, biopesticides or biofuels). Of this corpus, 59% of the articles referred primarily to agriculture (as sector or activity), 19% to biotechnology, 17% to industry or agrifood products and 5% to resource management (water, forest, biodiversity) or rural development (Table 1).

Table 1 – Distribution of articles on Innovation Systems according to domains

	Number of articles	Frequency
Agriculture (production, support, research, sector, etc.)	92	59%
Biotechnology (research, patent, use in production, etc.)	29	19%
Agrifood systems (processing, products, etc.)	26	17%
Rural development, resource management (water, forests, etc.)	7	5%
Total Agriculture or Agrifood systems + related rural and biotechnology	*155*	*100%*

Figure 1 – Yearly number of publications which referred to the IS concept in connection with agriculture or agrifood systems between 1996 and 2011 (N = 155)



Four journals have more than four references each and together account for nearly 20% of the articles: *Research Policy*, *Agricultural Systems*, *Food*

Policy and *Outlook on Agriculture*. A chronological analysis of the 155 articles (Figure 1) highlights a significant increase in annual production starting in 1996, divided into three periods: low production from 1996 to 2000 (one or two articles per year); moderate growth between 2001 and 2006 (from 4 to 10 articles per year); strong growth from 2007 to 2011 (over 20 articles per year since 2009).

Construction of the variables and of their modalities

We selected two or three variables per axis of our analytical framework, and specified their modalities (Table 2):

– Two variables indicate the theoretical and analytical framework that the articles refer to (first axis): a classification according to theoretical disciplines and currents, when the reference is explained in the summary or clearly stated by the authors; and an inventory of the occurrence of analytical categories in the summary (institution, knowledge, network, etc.);

– Three variables are used to characterize the domain of application and extension of the IS being studied (second axis): the primary activity (which structured the database used for this article), the location of innovations or IS (by country categories), and the scale of the analysis (from local to international);

– Two variables were used to decode the uses and purposes of the IS concept in each article (third axis): the references to a purpose in the abstract, for example, policy recommendations or impact assessment; and the manner in which the IS concept is used in the study, such as the subject of research or, conversely, a single contextual element.

Table 2 – Variables and modalities chosen according to the three axes of IS analysis

Axis of analysis	Variables and their modalities used for the bibliometric study
Axis 1. Theoretical foundation and construction of the analytical framework	**1.1.** Theoretical **reference** (author expertise and references): • evolutionary, institutionalist, actor-network/STS, • agricultural economics/rural sociology/farming system, without reference **1.2.** Analytical **category** used (citations within the abstract): • institutions, networks, actors, knowledge, policy, research, food systems, etc.

Axis 2. Area of application, nature and extent of the phenomena studied	**2.1. Activities** targeted by the IS (citations and expertise): • Agriculture, biotechnology, agrifood systems, rural development **2.2.** Geographical **location** of the study (citation and evaluation of abstract): • Least developed countries, emerging countries, countries in transition (Far and Middle East), • Western OECD, Mediterranean OECD, comparative studies **2.3.** IS **scale** (citation in abstract): • national (NIS), regional (RIS), local, international, sectoral (SIS), etc. • topological space defined by enterprises or a technology
Axis 3. Use and purposes of the concept	**3.1. Purposes**: • Orienting public policies, evaluating impact of research • Supporting enterprises, analysing an innovation or science/society links **3.2.** Methodological **use** of the IS concept**:** • Treating the IS as a global object, studying one component of an IS • Using the IS as an explanatory aid, contextualization of a study

Two main theoretical frames of reference used by the authors

In general, the theoretical frame of reference is rarely specified in abstracts, titles and keywords. A third of the articles do not refer to a particular frame of reference (Table 3); they usually correspond to descriptive analyses, sometimes written by authors from the engineering sciences or technical disciplines (agronomy, agrifood technology). In the rest of the articles, two theoretical frames of references dominate. The first, used in work that refers to sociology, rural economics, or, more broadly, to "farming system" approaches, is the most common (31%). It pertains mainly to the analysis of agricultural innovations or assessments of the role of agricultural research. The second is the evolutionary framework for innovation (22% of references), which can be identified by the use of specific terms (adoption, technological trajectory, absorption capacity, spillover, etc.), and is mainly found in articles from journals such as Research Policy or those devoted to biotechnology. In addition, historical or institutionalist approaches can be identified but are less common (10%) and some articles (5%) have a more methodological character (e.g., method of network analysis).

Table 3 – Disciplinary references of articles on IS in agriculture and agrifood systems

	Number	Frequency
Without any explicit theoretical reference	51	33%
Sociology, rural economics, Farming System	48	31%
Evolutionary theory, industrial economics	34	2 %
Institutionalist or historical approaches	15	10%
Technical or methodological contribution	7	5%
TOTAL	155	100%

The identification of IS-associated analytical categories highlights general concepts such as "research" (present in 61% of abstracts), "institution" (45%) or holistic concepts encompassing relationships between activities (48%): a product industry (banana, cassava, wine, etc.), a sector or subsector (fruits, bioenergy, etc.), a supply chain, a cluster, etc. The inclusion of terms such as "policy" (34%), "knowledge" (32%) or "actors" (27%) suggests a common analytical foundation to many articles. In contrast, only 14% of the articles mention "network" in their abstracts, indicating that this dimension is so far only fully considered by a fraction of the articles mobilizing the IS concept.

Table 4 – Frequency of occurrence of the categories in article abstracts

	Number of articles	Frequency
Research	96	62%
(Agri)Food sector, chain or system	74	48%
Institution/institutional	69	45%
Policy	53	34%
Knowledge	49	32%
Actor	42	27%
Networks	22	14%

Note: a given article can refer to more than one category

Prevalence of three geographical blocks and national scales of analysis

The articles focus mainly on three geographical areas (Table 5). The *Least Developed Countries* (Sub-Saharan Africa for the most part) are the ones concerned most often, with 34% of publications pertaining to them and usually focusing on the analysis of agricultural innovations. One reason for this prominence is the use of the IS approach by researchers associated with the CGIAR[6] and the World Bank to propose a restructuring of agricultural research and to accelerate "North-South" technology transfers. African researchers (mainly from Nigeria, Ghana and East Africa) also mobilize the IS concept to analyse innovations related to local societies. *Western OECD countries* (mainly Canada, USA, UK, Australia, the Nordic countries) form the second most prominent geographical region (22%), with themes that focus on the relationships between the public and private sectors, or on biotechnology (agricultural supplies, varietal breeding, biofuels). *Emerging*

6. Consultative Group on International Agronomic Research

Countries (Argentina, Brazil, Indonesia, China, India, etc.) constitute the third geographical area, with an increasing number of articles (21%) concerning them and pertaining to agriculture, agrifood systems or the use of biotechnology and bioenergy. *Countries in transition* and *Mediterranean countries* find occasional mention (6%, with articles mainly on Spain), as are comparative articles exploring the international dimension of IS (less than 15% of articles).

Table 5 – Geographical distribution of issues covered by articles on IS

	Number	Frequency
Least developed countries	52	34%
Western OECD countries	34	22%
Emerging countries	33	21%
European Mediterranean OECD	9	6%
Countries in transition	7	5%
International (comparisons)	20	13%
Total	155	100%

The articles can also be differentiated on the basis of scales of analysis (Table 6). National and sectoral scales dominate in more than 60% of the articles. This is due to the fact these articles mainly study either the relationships between agriculture and the National Innovation System or Agricultural Innovation Systems. Some of them also analyse innovation in national supply chains. The Regional Innovation Systems (12%) primarily concern OECD countries. Research articles on innovation at the international level and on internationalization of IS are equally few (12%), although these issues are often addressed through the role of multinational corporations and international institutions. Finally, articles approaching the IS concept from a network of actors or of companies are even fewer in number (10%) and quite heterogeneous, confirming the preponderance of analyses closely linked to politico-administrative frameworks for agriculture.

Table 6 – Scale of Innovation Systems discussed in the articles

	Number	Frequency
National Innovation System	56	36%
Sectoral Innovation System, AKIS or AIS	47	30%
Regional Innovation System	18	12%
Internationalization of IS	18	12%
IS considered from a network of companies	16	10%
Total	155	100%

An orientation towards policies on research, innovation and development

The main purpose of the use of IS in agriculture (46% of publications – Table 7) pertains to the formulation or orientation of public policies on innovation, research and development. This is often referred to explicitly in the abstract, with the domain varying, depending on the nature of the public entity and its area of intervention (knowledge transfer, funding, promotion of biotechnology, etc.). Assessing the impact of research is a separate objective, attributable to 17% of the articles. Methodological issues are very present in these articles, as also the construction of arguments to justify research investments. References to direct support to companies, on the other hand, are few in number (8%) and concern, for example, the role of technology platforms or of "facilitators" who provide a link between public and private entities. Finally, nearly a third of the articles do not refer to a political or economic purpose, but instead aim for production of knowledge on innovation or on research institutions. A few articles concern discussions on sustainable development or cast a critical look at the models of innovation.

In 22% of the articles, the IS is an object of study as a whole, as a system. Most often however (42%), articles focus on one IS component (research, advisory organizations, relationships between companies and institutions, etc.). Less than a quarter of the articles mention the IS only as an external factor, influencing the innovation process or an organization's strategy. Finally, in 15% of the articles the IS is mentioned simply as a context of the study.

Table 7 – Uses and purposes of IS in agriculture and agrifood systems

	Number	Frequency
Orienting public policy	72	46%
Assessing the impact of research	27	17%
Supporting enterprises and sectoral actors	12	8%
Analyzing an innovation, research/society links	46	30%
Considering the IS as a complete system to be studied	34	22%
Studying one component of an IS	65	42%
Using the IS as an explanatory factor	34	22%
Addressing the IS as a context of the study	21	15%

Identification of article profiles by multiple correspondence analysis

To summarize these findings and identify combinations of theoretical foundations, areas of application and uses of IS, we conducted a factor analysis[7] (Multiple Correspondence Analysis) using the Burt table which brought together all the variables described above. The first three principal axes have a significant weightage (50% of the inertia) and allow us to describe the main orientations of the articles (Figure 2).

The first factorial axis (23% of the inertia) distinguishes (i) articles that pertain to agriculture, to LDCs, to rural economics or sociology, to a component of IS and to policy recommendations from (ii) the articles on biotechnology and agrifood systems, on OECD countries or which use evolutionary reference or the concept of the Regional Innovation System. We find here a convergence between the oppositions of "North *vs*. South", "upstream/downstream technologies *vs*. agricultural production systems" and "evolutionary approaches *vs*. more ruralist work".

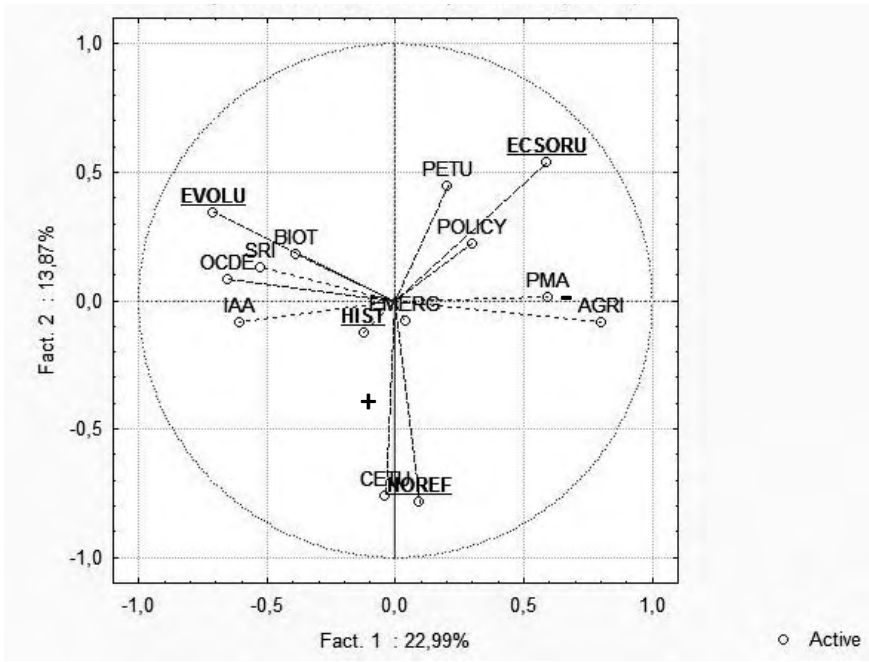
The second factorial axis (14%) is marked by the presence of the "no theoretical reference" and "use of IS as a context" modalities. It thus distinguishes articles with a limited reference to the concept of IS for operational or descriptive studies with those that analyze the IS as a whole or one of its components, with reference to an established theoretical framework.

The third factorial axis (13%) isolates the specific contribution of a historical or institutionalist reference in conjunction with the lack of any policy recommendation. So it distinguishes (i) a critical stance and one that is detached from the action from (ii) approaches more focused on development or policy actions (with or without reference to other theoretical frameworks).

This factor analysis shows the weightage of the "theoretical framework" variable, each modality of which (except for strictly methodological work) contributes significantly to the different factorial axes, and is linked to certain modalities of other variables. A contingency analysis between the modalities of the theoretical reference and those of the other variables clarifies this observation (Table 8).

7. With the assistance of Salif Derra, doctoral student, Montpellier Supagro, Innovation JRU.

Figure 2 – Results of the Factor Analysis
(projection of the variable on the axes 1 2, axis 3: + and -)



ECSORU: rural economy/sociology; PETU: part of the IS; POLICY: policy usage; PMA (LDC): least developed countries; AGRI: agriculture; EMERG: emerging countries HIST: history; EVOLU: evolutionary; BIOT: biotechnology; SRI: regional innovation system; OCDE: OECD countries; IAA: agrifood systems; CETU: context of the study; NOREF: no theoretical reference

Table 8 – Contingency table between theoretical references and 3 other variables

Theoretical foundation	Domain of activity**				Countries**			Use of the concept**				
	AGRI	BIOT	IAF	RUR	LDC	EMER	OECD	POLIC	GLOB	PSTU	FACT	CSTU
RUECSO 48	**42****	**3***	**1****	2	**27****	7	**7***	**30***	10	**28***	8	**1***
EVOLU 34	**4****	**15****	**14****	1	**3****	8	**16****	12	**15****	10	7	**1***
HIST 15	9	2	3	1	**2***	4	5	**1****	2	4	**7***	2
NOREF 51	31	10	7	3	20	11	14	26	**5****	17	12	**17****

148 articles (methodological articles excluded); tests Chi2 **: p<0.01; *: 0.01<p<0.05

Columns: AGRI: agriculture BIOT: biotechnology IAF: agrifood systems RUR: rural economy/sociology LDC: least developed countries EMER: emerging countries OECD: OECD countries POLIC: policy usage GLOB: IS focus of the study PSTU: part of the IS; FACT Explanatory factor CSTU: context of the study

Lines: RUECSO: Rural economy / sociology; EVOLU Evolutionary, HIST History NOREF: no theoretical reference

KNOWLEDGE COMMUNITIES AND AGRICULTURAL SPECIFICITIES OF IS

Several knowledge communities use the concept of IS in agriculture

The bibliometric analysis suggests that there exist four groups of articles with different theoretical references. These groups can be the expression of knowledge communities (Wenger, 1998) involved in the construction of different meanings and uses of IS for agriculture and agrifood systems. These communities are more or less structured groupings of scientists using the concept of IS, in association with political or economic actors. They can be characterized according to cognitive processes or attributes that constitute them, by using the classification developed by research in sociology and economics of knowledge (Cohendet *et al.*, 2010): "practicing" communities, sharing knowledge around common activities; "epistemic" communities which are structured for a common cognitive project; communities "of interest", sharing information because of common positions, ideas or characteristics. The results of our bibliometric analysis can then be interpreted in terms of this classification and by relying on our broader knowledge of agricultural research and stakeholders. We suggest four knowledge communities, each associated with a different form of "theoretical framework" of the factor analysis (Figure 3).

The *first community* brings together university researchers (in economics or management) who refer broadly to evolutionary approaches to innovation and actors who formulate innovation policies (e.g., Directorate Generals of Research in the EU), development agencies and firms related to biotechnology or agrifood systems, mainly in OECD or emerging countries. In their articles, the concept of IS is generally not specified in relation to agriculture. Instead, the established categories of NIS, SIS, RIS or clusters are used or indeed the "triple helix" model. In this community, we find both academic work as well as studies directly pertaining to national innovation strategies (Menrad, 2004) or regional ones (Asheim, Coenen, 2005), or even to the explicit promotion of biofuels and GMOs by companies (Qaim, 2009). The authors refer to the innovation processes and the role of knowledge, but their visions are often quite close to diffusionist theses, according a key role to research and the evaluation of the conditions under which innovations are acceptable, with increasing attention to environmental issues (Cunha *et al.*, 2011). The technological object (food processing, biofuels, GMOs, ICTs in agriculture, etc.) lends itself well to this type of analysis. We can suggest that this group constitutes a "*community of interest*", sharing a positive vision

of progress through biotechnology and consisting of researchers who have found an opportunity to apply a theoretical framework, proponents of policies of innovation, and firms that want to exploit the concept to create an environment conducive to the diffusion of the technologies they produce. This vision's attachment to technological and economic development and the reliance on a generic theoretical framework can be associated *with the analysis of a loss of specificity of the agricultural sector in globalization*: commodification and financialization, re-industrialization of agriculture through biotechnology, etc.

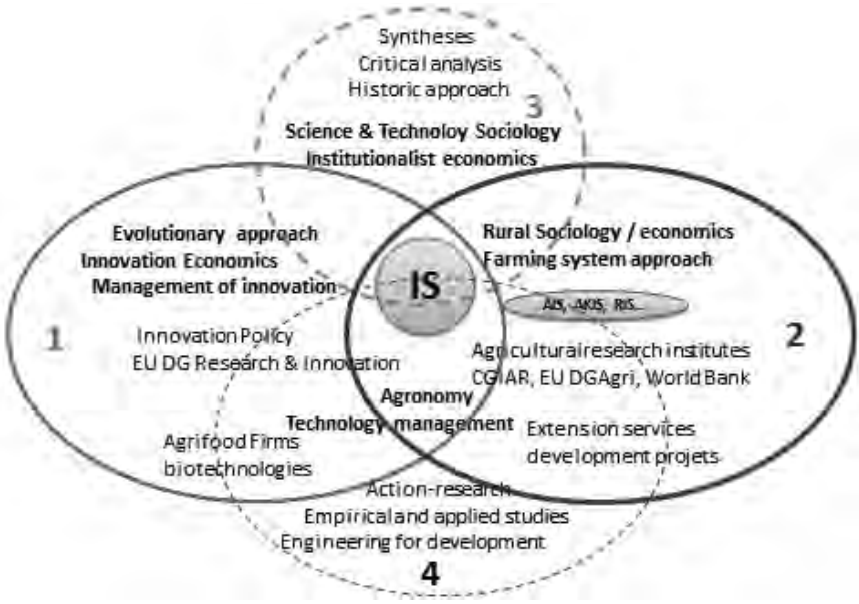
The *second community* brings together sociologists and economists of agricultural and rural development (countries of the South as well as of the North), leaders of organizations in agricultural research and development at the national or international levels (CGIAR, Directorate Generals of Agriculture in the EU, etc.), and agronomists involved in development programmes, especially in the LDCs. In this community, specific concepts now associated with IS are mobilized: Agricultural Knowledge and Innovation System (AKIS), Agricultural Innovation System (AIS) (Klerkx *et al.*, 2010.), Rural Innovation System (Spielman *et al.*, 2011.), etc. Scientists in this community originate mainly from a research tradition built around agriculture (work on agricultural development, analysis of systems of agronomic research, Farming System approaches, etc.) and are associated with agricultural research and development institutions. A "reformist" thought, concerned with sustainable development, is prominent in this community (Coudel *et al.*, 2012) and examines the confrontation between *top-down* processes (whose proponents are the institutions) and *bottom-up* processes (initiated by farmers and rural entrepreneurs) (Faure, Compagnone, 2011). It also explores how both "traditional" as well as "entrepreneurial" sectors are taken into account (Adeoti, Olubamiwa, 2009), the articulation between different forms of knowledge (Ekboir *et al.*, 2008) and how agricultural institutions can contribute to the challenges of poverty reduction, food security, natural resource management (World Bank, 2006; Roling, 2009), etc. More original forms of organizing relationships between research and companies are discussed or suggested, for example, through the use of regional consultation platforms or of "participatory approaches" (Abate *et al.*, 2011). Furthermore, this community has the characteristics of an "epistemic community", at least one under construction. Indeed, scientific articles are supplemented by reports, educational materials, calls for projects, and a desire to help promote new knowledge about an approach based on IS in agriculture (EU SCAR, 2012). In this community, it is *the taking into account of sectoral specificities which justifies the creation of categories, approaches and concepts themselves specific for innovation and IS*.

The *third community* is made up of scientists who refer to the evolutionary framework or rural sociology but mainly reflects other influences (history and sociology of science, institutional economics, regulation theory, etc.). This work is less directly linked to political or economic actors. These tend to be studies on histories, summaries, comparative analyses, theoretical questions on the transformation of agricultural and agrifood activities (Allaire, Wolf, 2004; Lindkvist, Sanchez, 2008; Cypher, 2011). There exists a more critical viewpoint, detached from the interests of economic and political stakeholders. This group is smaller than the previous two and cannot reasonably be associated to an epistemic community specific to the agricultural sector, even if references to the agro-ecological transition or diversity of agrifood trajectories could create a body of new knowledge (Touzard, 2009; Sanchez *et al.*, 2010). Obviously, it is not around the concept of IS that a critical approach to innovation in agriculture is developing. Other scientific communities (Sociology of Science and Technology in particular) have claimed that role, for example, around the journal *Science, Technology and Human Values*. For this third community, the issue of *agricultural specificity tends to be addressed in the form of a research question, in order to undertake comparisons between sectors*, but this does not necessarily lead to the production of specific concepts and approaches.

The *fourth community* consists, in contrast, of scientists, engineers and agricultural actors directly involved in the implementation of innovation processes or the formulation of agricultural policy. The concept of IS is used to contextualize, analyse, or support these processes and to highlight its institutional conditions without necessarily questioning the evolution or the effects of the concerned institutions. Francophone work on Localised Agrifood System (LAS) is thus starting to refer to it to take into account the constraints and opportunities of the sectoral or national context of local innovations (Muchnik *et al.*, 2007). The use of IS tends to be more descriptive or rhetorical, and is normally not key (unlike for the second community). Scientists may deal with the engineering of development or training which is focused on innovations in rural environments and action research (Sanginga *et al.*, 2009; Faure *et al.*, 2010). *Different communities of practice* can be identified behind this group. They address concrete problems within a framework of different networks (a company and its stakeholders, a mechanism for evaluating public policy, development projects in a region or sector). In these communities, *the specificity of the use of the concept of IS is contrasting, to meet the challenges of solving problems that are encountered*. Some research merely makes a formal reference to the proposals of communities 1 and 2, others are content to "tinker" with the components of an IS or adapt its use.

These four communities agree broadly on the main characteristics of IS (innovation as a process, key role of institutions and knowledge, systemic approach). They differ however in the types of actors that belong to them (with different positions and practices within IS), in the theoretical references and uses of the concept of IS, and in the terminology and questioning on agricultural and agrifood specificities. While these communities are linked to each other by key authors (e.g., A Hall), they are also marked by a significant dualism between communities 1 and 2: a conceptual and methodological distinction arising from the opposition between an agro-industrial model linked to the development of biotechnology and an "alternative" model centred on peasant agriculture and agroecology (Vanloqueren, Barret, 2009).

Figure 3 – The four knowledge communities on IS in agriculture and agrifood systems (Diagram derived from factor analysis)



Re-examining the agricultural specificity of innovation, IS and IS research

Identifying these knowledge communities brings us back to the issue of the construction of definitions and uses of the concept of IS specific to agriculture and agrifood systems. Indeed, the four identified communities differ

from each other in this respect. Are agriculture and agrifood systems only a domain of application of a generic concept or is this sector a "scientific niche" in which agricultural realities lead to the emergence of new questions and proposals? This question can be approached on the basis of the arguments developed by the epistemic community since it seeks to produce agriculture-specific IS (AIS, AKIS, etc.). Its arguments start from an identification of the agricultural sector's characteristics that are liable to induce original features in this sector's innovation processes and its IS:

– *Configurations of particular actors and organizations* orient innovation in the agriculture and agrifood sector. Centres of research, training and development dedicated to agriculture are confronted by a multitude of independent farms, a concentration of upstream and downstream firms, and the existence of specific actors playing the role of "brokers" (Klerkx, Leeuwis, 2009), such as NGOs, consulting firms, trade unions, etc. These configurations can explain, for example, the importance of collective action in agricultural innovation, the role that public or professional organizations have in providing economies of scale for R&D activities, forms of innovation networks articulating local and distant links (Chiffoleau, Touzard, 2014; Spielman *et al.*, 2011) or even particular modes of supporting and monitoring the innovation, which engenders tension between private oligopolies, governments, professional organizations and consumers (control of seeds, biotechnologies, food products, etc.).

– More broadly these actors are part of sectoral *institutional mechanisms* which have existed for a long time, with clearly identified agricultural policies, as well as specific forms of organization of production (family labour, pluriactivity, etc.), trade (long *vs.* short supply chains, certifications, geographical indications, etc.) and consumption (Temple *et al.*, 2011). This institutional framework combines objective rules and compromises between social representations that support a diversity of innovation regimes (Allaire, Wolf, 2004). The example of geographical indications, mainly applied to agrifood products, illustrates a form of labelling of the product that is based on a codification of practices and innovations, and which requires collective action and important political negotiations to modify the scope of possible innovations.

– Beyond these institutions, the sector is characterized by a diversity of *agrifood models or systems and their hybrid forms* (Colonna *et al.*, 2010.). One can even wonder whether a specificity of the agricultural/agrifood sector does not lie in the coexistence of a variety of

agrifood models, sometimes reduced to a dualism between an "agro-industrial" model, nowadays linked to the development of biotechnologies, and "alternative" – even traditional – models (in the South in particular). Innovation and the IS would then both form part of each of these agrifood systems (path dependence) as well as in their economic interactions and political confrontations (Touzard, 2009).

– More fundamentally perhaps, the *relationships with nature* of agricultural and agrifood activities and products (biological systems, links to the land and ecosystems, food intake, etc.) have an influence on innovation and the institutions that support them. These relationships raise heritage-related issues, a high inertia of investments as well as a high instability due to seasonality, constraints and environmental considerations (degradation and natural resource management), climatic risks, the perishability of many products and health issues (Colonna *et al.*, 2012). This uncertain environment not only affects the definition of specific areas of application of research and innovation but also the conditions of implementing technical change. Innovation appears to be both more risky than in other sectors and therefore often faces what could be interpreted as resistance or inertia from the producers. These relationships with nature can also be considered as one of the foundations of the symbolic dimension of food (Muchnik *et al.*, 2007), applied to possible or forbidden domains of innovation.

– Many authors insist more generally on functions and externalities of agriculture and consequently its contribution (positive or negative) to the *production of public goods*: satisfaction of food needs and impacts on health, implication of agricultural activities in the management of natural resources, production of landscapes and cultural and symbolic goods, land use, etc. The recognition and governance of these public goods justify the combination of collective action and government intervention (Ostrom, 2011) and helps substantially in publicizing the debates on innovations in agriculture (Coudel *et al.*, 2010).

– The involvement of the *knowledge base* in productive and innovative agriculture and agrifood processes is also highlighted as original by various authors (Labarthe, 2005; Klerkx, Leeuwis, 2009). Multiple areas of technical and organizational learning, the need for local adaptation of and experimentation with generic knowledge, the importance of "tacit knowledge" as well as the increasing involvement of citizen consumers in the conditions of production all orient training requirements and forms of mediation associated with the construction of this knowledge (Goulet, Vinck, 2012). Through its expertise,

research itself is participating in a new way in public debates on food innovation. Going beyond its usual contributions to the development of a technology, it is contributing to the legitimization of IS in agriculture and agrifood systems.

– Finally, perhaps more than other sectors, agriculture and agrifood systems are confronted by a *revival of issues* that call for the consideration of agricultural innovations in a long-term perspective: adaptations to climate change (agriculture is the economic sector most affected), the rise of food security worries, long-term commitments to processes of managing biodiversity and natural resources, structural review of the role of the State (regionalization) and redefinition of public/private relationships (Touzard, Temple, 2012). These more complex issues reinforce the need to include agricultural innovation in multidisciplinary and forward-looking approaches (Coudel *et al.*, 2012).

While it is true that, at the end, agriculture and agrifood systems have characteristics which are not always exclusive to this sector, the combination of these characteristics provides a specific set of conditions for innovation and ways of supporting it, and therefore for IS. These particular sectoral features can justify the use of specific approaches and concepts, such as "Agricultural Innovation Systems". But they also call for developing research on Sectoral Innovation Systems (Malerba, 2002) by comparing the agricultural and agrifood example to other sectors in order to strengthen the conceptual structure for studying innovation.

CONCLUSION

Using a bibliometric and bibliographical analysis, we have shown that the concept of IS is being increasingly used in research on innovation in agriculture and agrifood systems. The growing success of the concept in this sector appears to be related to the co-evolution of several knowledge communities, some of which are attempting to apply the theoretical and analytical framework of Innovation Studies (Martin, 2012) while others attempt to build a body of more original concepts and methods, relying on the work developed in rural sociology/economics, in Farming System Approach and in development studies. The question of the specific conditions for innovation in the agricultural sector is key and is being increasingly revisited due to issues that today place this activity in long-term perspectives and in current societal debates. The evolution of the use of the concept in research on agricultural innovation has, however, not yet stabilized. As far as research

which applies evolutionary concepts is concerned, the debate between the recognition of a sectoral specificity (via the concept of Sectoral Innovation System) and minimization of this issue (e.g., as is the case for the dissemination of biotechnologies) is far from being resolved. On the other hand, the epistemic community originating from the rural sociology/economics, and linked to the reorientation of agricultural research and development institutions, is at pains to choose between a clearer theoretical affiliation with studies promoting IS or similar concepts (such as socio-technical systems) and the desire to (re)build an autonomous and interdisciplinary scientific space. In any case, the continued existence of interactions between different communities around the usage of IS is a sign of scientific vitality.

Finally, these results call for applying our approach to other sectors than the agrifood one. Knowledge plays a central role in IS and is generally associated with specific sectoral conditions such as existing technology, industrial structure, demand, institutions (Malerba, Nelson, 2012). But as we show in the case of agriculture, the building of scientific knowledge on innovation could also be sectoral specific, expressing the confrontations between different knowledge communities where scientists are interacting with political and economic actors. The co-evolution of different technological models within a sector (such as "agro-industrial" vs "alternative" in agriculture) seems to be crucial, orienting the social and scientific representations on innovation. Research on health or energy sectors suggests similar dynamics (Consoli, Mina, 2009), while research on ICT, automobile or aeronautics tend to show a more consensual view on innovation (and IS) in the sector (Touzard, 2014). A broader comparative research is thus necessary, using our analytical framework on IS, in order to explore both the specificities of sectoral dynamics and the representation on innovation. This research will also contribute to better identify the source of innovation and their contribution to economic development.

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