doi: 10.17221/207/2015-AGRICECON

A study on research hot-spots and frontiers of agricultural science and technology innovation – visualization analysis based on the Citespace III

Qi-Qi CHEN[1, 2], Jun-Biao ZHANG[1, 2], Yu HUO[1, 3]

[1]*College of Economics & Management, Huazhong Agricultural University, Wuhan, China*
[2]*Hubei Rural Development Research Center, Wuhan, China*
[3]*Tarim University, Xinjiang, China.*

Abstract: At present, the fundamental development way of agricultural production lies in science and technology to achieve the agricultural sustainable and stable development and ensure the effective supply of agricultural products for a long time. Many Chinese scholars had done many researches about the agricultural science and technology innovation. Numerous scholars got much valuable research conclusions for improving the construction of agricultural science and technology innovation system. However, there were still some problems existing in the current agricultural science research system, such as that the agricultural science and technology studies were divorced from the agricultural production, the mechanism of the market was still imperfect, there was an unreasonable layout in the agricultural science and technology. Therefore, we wanted to know the dynamic and the evolution path of the international agricultural science and technology innovation. What is more, we wanted to know whether there was a significant difference between the domestic and overseas agricultural science and technology innovation and if the international experience was good for the development of the Chinese agricultural science and technology innovation. So, there was analysed the research theme, the hot-spots and frontiers of international agricultural science and technology innovation based on the Citespace III to get the situation and character of the relevant international research.

Keywords: agricultural science and technology innovation, Citespace III, research hot-spots, research frontier, visualization analysis

As the saying goes, agriculture is the fundament of the world. It is clear that China is no exception. Sannong issue (i.e. agriculture, rural areas and farmers) has always been the focus of the Chinese government and the foundation of the national stable development. Therefore, the Chinese government supported agriculture development with the majority of preferential and protection policies. Such as, the Central File No. 1 kept focus on the agriculture development and the rural areas reform in five consecutive years since the first Central File in 1982. Since the 21st century, there were 12 Central Files No. 1 which kept focus on the San-nong issue until 2015. With all the implementation of the favourable agricultural policies, the Chinese agriculture production and the current situation in rural areas have been continuing to improve with the steady development rate. The crop production has seen a continuous growth in 11 years, reached an historical level. The income gap between the urban and rural residents has been continuing to shrink and the rural people's livelihood has been improving along with the rural areas reforms. Currently, the agricultural production development has entered into the critical period of the traditional agriculture changing into the modern agriculture.

As we knew, science and technology is the first sine qua non of productivity. The current agricultural scientific research system played an important role in the balance of the agricultural products supply and demand. It changed the long-term shortage situation. In addition, considering the features of agriculture, such as fundamentality, publicity, particularity and a weak quality, many Chinese scholars realized the significant role of the agricultural science and tech-

Supported by the National Nature Science Foundation of China (NSFC71333006 and NSFC71463011) and the cultivation project of innovation team in the Huazhong agricultural university in Hubei provinces (2013PY042).

doi: 10.17221/207/2015-AGRICECON

nology in the development of modern agriculture. The majority of scholars devoted themselves to the relevant research in the field of agricultural science and technology since the early 1980s (Ji Chuanru 2012). And then, many scholars (Ling Yuanyun 1995; Li Furong 1996; Zhang Huijie 1996; Xu Yanping 1997; Zhu Xigang 1997; Hu Ruifa et al. 1999; Huang Jikun and Hu Ruifa 2000; Huang Jikun et al. 2009) carried out a research on this issue. At present, the whole research in the issue focused on four aspects, such as the connotation definition of agricultural science and technology innovation (David et al. 1992; David et al. 2001; Jiang Heping 2014), its current state and trend analysis (Yin Yan et al 2010; Huang Wenhuai 2011), the evaluation of the innovation level (Zhong Funing and Sun Jiangming 2007; Lin Bode 2010; Li Hongwen and Li Dongsheng 2010), the problems and counter-measures (Ji Shaoqin 2005; Zeng Weizhong and Chen Xiulan 2010; Ma Hongxia and Liu Qi 2010; Guo Wenbao and Ma Qing 2011; Xu Jinhai et al. 2011; Wan Baorui 2012).

To sum up, numerous Chinese scholars applied many analysis methods to study the relevant issues of the agricultural science and technology innovation from different perspectives. To some extent, they got valuable research results which were convenient for supplying solutions for the problems of the present situation, operational performance, and development trends. However, everything has two sides. The present agricultural scientific system also has some issue needed to be solved, such as the agricultural scientific research being disconnected from the actual production. There was still an unreasonable lagging in the agricultural science and technology resources. The input of agricultural science and technology was still insufficient. What is more, with the development of industrialization and urbanization, agriculture production still faced double restraints of resources and market, the dual pressure of economic growth and ecological conservation and double challenges of the farmers' income growth and food safety (Chen Qiqi et al. 2015). Therefore, we need a further research to perfect the system construction, to improve the system efficiency and to promote the sustainable development of agricultural economy.

As it is well known, the innovation theory originated from the economic development theory written by Joseph Schumpeter (Zhang Shuhui 2014). The researches of Chinese scholars were carried out by the means of the advanced foreign theory to a great extent. So it is easy to think that the current development degree of the studies area of agricultural science and technology is on the level with abroad. And what are the future development trends of the international agricultural science and technology innovation? Is there any significant difference between the Chinese and abroad agricultural science and technology innovation? If there is a gap, the international experience should promote the construction of agricultural science and technology innovation in China. However, we must know the present situation, the research hot-spots and frontiers, development trends of the international agricultural science and technology innovation when we want to solve the above questions. Therefore, based on the visualization analysis software (Citespace III), we made a literature measurement analysis on the international agricultural science and technology innovation research to discuss the theory basis in this field. And then we excavated the key document nodes by analysing the evolution of the knowledge network map. Finally, we studied the classical literature and the research focus and frontiers of international agricultural science and technology innovation to fully display the research status, the research focus and the development trend of the international agricultural science and technology innovation.

THEORETICAL BASIS

The evolution of the innovation theory

When it comes to innovation, People always easily thought of the innovation theory of Schumpeter. He wrote the book named Theory of Economic Development as the first monograph to elaborate the emergence and development of the capitalism with the innovation theory. To sum up, he thought that "innovation" could be divided into five aspects, such as the introduction of new products, reference to new technology (i.e. new production methods), opening up a new market, controlling the new sources of material supply and achieving the new organization of the enterprise (Schumpeter 1934). The innovation theory of Schumpeter established the important foundation for the theory of technology innovation and induced more scholars to attend the relevant research of technology innovation.

With the development and evolution of Schumpeter's innovation theory, many economists put technological progress into the frame of the neoclassical economics.

doi: 10.17221/207/2015-AGRICECON

And then, the innovation theory gradually derived two famous economic theories. One was the neoclassical economic growth theory which took Solow as its representative. The other was the endogenous economic growth theory which took Romer as the representative. Both the neoclassical and endogenous economic growth theory realized the effect of the technology progress on the economic growth, which led subsequent economists to explore the national innovation system to some extent. In addition, as for the agricultural science and technology innovation, which was taken as the important research embranchment of innovation theory, can we take the Schumpeter's technology innovation theory as its theory basis?

The relevant concept definition

Regarding the above analysis, we knew that agriculture was always a significant foundation for the development of the national stability. Numerous scholars put themselves into the study of agricultural science and technology innovation and gave a detailed presentation of its concept. Such as, both David et al. (1999) and David (2001) thought that we should understand the concept of agricultural science and technology innovation from two aspects. In the narrow sense, the agricultural science and technology innovation referred to the new inventions, new technology, new method and new technical research and development which met the demand of agricultural production. However, in the broad sense, agricultural science and technology innovation was not just the invention and success of agricultural technology, but the whole transformation process of innovation achievements which included the agricultural scientific basic research, applied research, demonstration and extension research.

On the whole, the connotation of the agricultural science and technology innovation could be summarized as follows, with the full use of the research and development system, connecting the system and the application system of agricultural science and technology and the study of the process of technology innovation and diffusion. The main subjects of agricultural science and technology innovation realized the goal of the agricultural economic development (Ji Chuanru 2012). However, the scholars always specified and refined the concept of innovation in the articles researching on the agricultural science and technology innovation. There were many forms of the specific innovation in the study field of the agricultural science and technology innovation, such as the new technology researches (Carletto 2001; Koundouri et al. 2006), the new variety studies (Basu and Leeuwis 2012), the research of system and institutional reforms (Lundvall 1992; Hounkonnou et al. 2012), the study of agro-ecological innovation (Blazy et al. 2011). In addition, the need of a special note was that the diversification of the agricultural science and technology innovation detailed form was one of the important reasons that we used many of the conversion forms of the agricultural science and technology innovation to search data in the following analysis.

METHODOLOGY AND MATERIALS

Research method

Information visualization is an analysis method which can realize the interactive visualization analysis on abstract data by using computer and enhance the people's perception of the abstract information (Bederson and Ben 2003). Information visualization analysis showed the development trends, the hot-spots and frontiers of scientific research in the way of the dynamic graph visualization based on the analysis on the existing literature data. To some extent, information visualization offers a quick independent scientific judgment of the objective evidences (Chen Chaomei 2006). As a result, as an important and useful analysis tool, information visualization can contribute for scientists to know and predict the frontiers and dynamics of scientific research in the shortest time and to create a new research field in the complex scientific research information. Therefore, we have utilised the

Citespace software[1] developed by the team of Chen Chaomei in the Drexel University, USA. It is a Java application program used to identify the scientific literature and information visualization. As a result, it has a great influence in the field of the information analysis (Xiao Ming et al. 2011). Recently, many scholars have used the Citespace in many research fields, such as the psychometric, nanotechnology, the aviation engineering, the economic geography, the

[1]We can get the newest Citespace software in free by http://cluster.ischool.drexel.edu/~cchen/citespace/download.htm

doi: 10.17221/207/2015-AGRICECON

strategic management, the ecological security and the science and technology policy analysis. Nevertheless, there are some less relevant reports in the studies area of the agricultural science and technology innovation analysed by the Citespace. Based on the above analysis, we tried to make the visualization analysis on the field of the agricultural science and technology innovation research by the Citespace in order to deeply investigate the international agricultural science and the technology innovation study.

Data sources and processing

We took the web of science (WOS) database as the basic retrieval tool and chose the WOS^{TM} core database as the source of the search-able database. At the same time, the citation database contained the science citation index expanded (SCIE) and the science citation index (SSCI) databases. In this research, we took the "topic = agricultural science and technology innovation[2]" as the main retrieval type. We got 585 literature records with setting the retrieve years from 2002 to 2015. We set the record content as the "full record and cite references", saved those retrieved results as the plain text and named them as the "download the file name.txt". What is more, we downloaded these literatures information on January 13, 2015.

We can use the Citespace software to analyse the different nodes of 585 literature records. According to the records information, the time zones were from 2002 to 2015 in this study and the time span was set by one year. The node type set as five kinds (i.e. "Author", "Institution", "Country", "Keyword" and "Cited reference") as the requirement of the study. Some nodes set as "threshold selection = Top 50% per slice" and "pruning choice = Pruning Sliced Networks and Minimum Spanning Tree". Others are set as the default value.

Brief description of agricultural science and technology innovation literature

Number and type of documents analysis

Based on 585 literature records, we made a brief measurement analysis on the literature published status (Figure 1), the type of literature (Table 1) and the source publications of literature (Figure 2) with the analysis function of the WOS. Therefore, as for the international agricultural science and technology innovation research, we had a simple perception and understanding.

Specifically, as shown in Figure 1, the histogram denoted the literature quantity of the international agricultural science and technology innovation research and the line chart showed the literature proportion that the literature number accounted to the total literature in every research year. However, we should note that the literature quantity was quite lower in 2015 due to the deadline retrieval time (January 13, 2015). As a whole, the quantity of the published literature showed an increasing trend with the average annual growth rate of 22.51% in the international agricultural science and technology innovation research from 2002 to 2014. In detail, we watched four peaks which showed, respectively, in 2003, 2008, 2012 and 2014 in the whole research

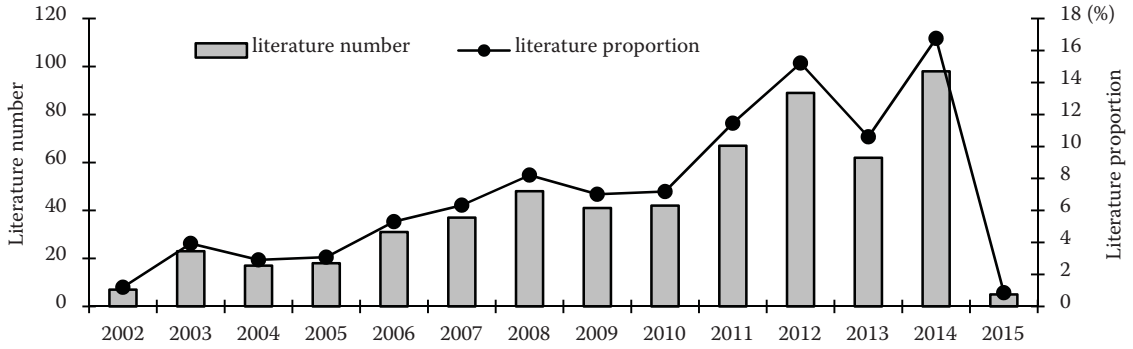

Figure 1. The trend change of the published literature in the studied area of the international agricultural science and technology innovation research (2002–2015)

[2]Although we took topic as the main retrieval way, the actual retrieval set as many kinds of "topic = agricultural science and technology innovation" such as, topic = agricultural science* and technology* innovation* or topic = agricultural technology innovation* or topic = agricultural sci-tech innovation* or topic = agriculture technological innovation*.

doi: 10.17221/207/2015-AGRICECON

Table 1. The situation of the literature classification

Category	Literature type	Quantity	The proportion in the total literature (%)
1	Article	519	88.72
2	Proceedings paper	40	6.84
3	Book chapter	7	1.20
4	Book review	1	0.17
5	Review	55	9.40
6	Editorial material	10	1.71

time. Considering the quantity and the proportion trend of the literature, we divided the whole research time into four parts which are listed as 2002 to 2003, 2004 to 2008, 2009 to 2012, 2013 to 2014, and the corresponding annual growth rate is listed as 81.27%, 23.07%, 21.38% and 25.72%.

We elaborated the reasons of the above trend characteristics from three aspects. Firstly, they associated with the global economic and political background. As such, we had the SARS spread in 2003 and the sub-prime mortgage crisis in 2008. What is more, the global economic situation was quite complicated along with the turbulent international situation and the deteriorating global climate in the recent years. As a result, the agricultural science and technology innovation research had been influenced to some extent. Therefore, the published literature quantity in this field had a fluctuation trend. Secondly, the proportion of the published literature quantity had an increasing trend as a whole. This trend feature was concerned with the fundamental position of agriculture. As we knew, agriculture was the pillar industry to the development of the second and third industry[3]and it was the intertwined product of social and natural economy. Therefore, the agricultural science and technology innovation was always the focus of attention. Thirdly, the development of the agricultural science and technology innovation has been benefited from the government attaching importance to agricultural science and technology. As analysed above, the development of agriculture depended on science and technology under the increasing natural and resource restraints. As a result, many governments gave different preferential policies for agricultural production and these policies promoted the development of agricultural science and technology innovation to a certain extent.

Analysing the Figure 1, we also knew that all the agricultural science and technology innovation literature could be roughly classified into 6 kinds, such as "Article", "Proceedings paper", "Book chapter", "Book review", "Review" and "Editorial material". According to the quantity of the literature, "Article", "Review" and "Proceedings paper" were located on the top three of all the literature types. Therefore, we came to an important conclusion that the international agricultural science and technology innovation research always took "article" as the main channel to show the research results, same as in the Chinese research situation. More specifically, the actual type, the quantity and proportion of the relevant literature were given in the second, third and fourth column in Table 1. So we did not give any detailed explanation here. However, it should be specially explained that the total published quantity of 6 kinds of literature was more than 585 because every kind of literature existed crosswise. Therefore, as for the proportion

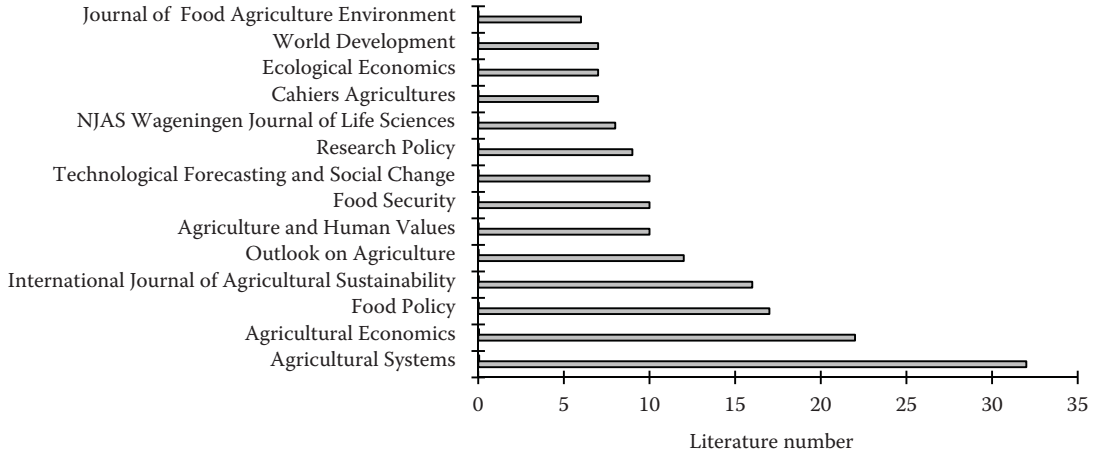

Figure 2. The literature quantity of source publications

[3]The second industry refers to industry and the third industry means service industry in China.

doi: 10.17221/207/2015-AGRICECON

of the total literature, the total proportion was more than 1.

According to the published quantity, we listed the top ten journals in the studied area of agricultural science and technology innovation (Figure 2). As a result, we found easily that journals in which we published the research achievements of the agricultural science and technology innovation were quite scattered. However, the above conclusion reflected that we had many choices when we wanted to publish our agricultural science and technology innovation research achievements. As a whole, the number of magazines in which we can publish our research results was more than 100 in the studied area of the agricultural science and technology innovation. In the top 100 journals with the order by the published quantity, some magazines which published 2 or 3 relevant articles had the percentage of 67%, some journals which merely published 2 relevant papers had the proportion of 43%, and the others had a quite lower proportion of all the journals. As for Figure 2, we needed to note that there were 14 journals which were in the top 10 place, because some journals had the same published quantity. The journals "Agriculture and Human Values", "Food Security" and "Technological Forecasting and Social Change" all published 10 articles from 2002 to 2015. "Cahiers Agricultures", "Ecological Economics" and "World Development" all published 6 papers. In all the journals which published the related achievements in the studied area of agricultural science and technology innovation, "Agricultural Systems" published 32 articles and reached to the top one position. The second journal was "Agricultural Economics". The published quantities of other journals were less than 20.

Countries or districts analysis

We set the "Node Types" to "Country" and other options to the defaults. And then we could use the ring size and colour to show the published quantity and the specific time of every country or district. As given in Figure 3, there were 81 nodes and 100 attachment lines. The circular nodes were on behalf of the states. Specifically, we found that the size of some nodes were quite bigger than the others. In fact, it was the particular function of the Citespace. It meant that the country or district was more important than the bigger size of nodes. The colour of the ring corresponded to the colour of the year in the above of Figure 3. The rings colour showed the time of cited. The thickness of the rings represented the number of references. Purple rings were on behalf of the key nodes and their thickness represented the centrality of nodes. The greater the thickness, the higher the centrality. As a result, we came to the conclusion that the United States, Netherlands, the UK, Australia, Canada, Spain and China belonged to important nodes. These countries published a lot of literature in the field of agricultural science and technology innovation study.

Based on the analysis on the Figure 3, we tried to show concretely the published number of key nodes and the influence degree of relevant researches. As shown in Table 2, the United State published quantity was the most in the top 10 countries researching on agricultural science and technology innovation. In details, America published 151 papers, accounted for about a quarter of all literature from 2000 to 2015. At the same research time, China was located in the tenth. Its published number was 22, accounted

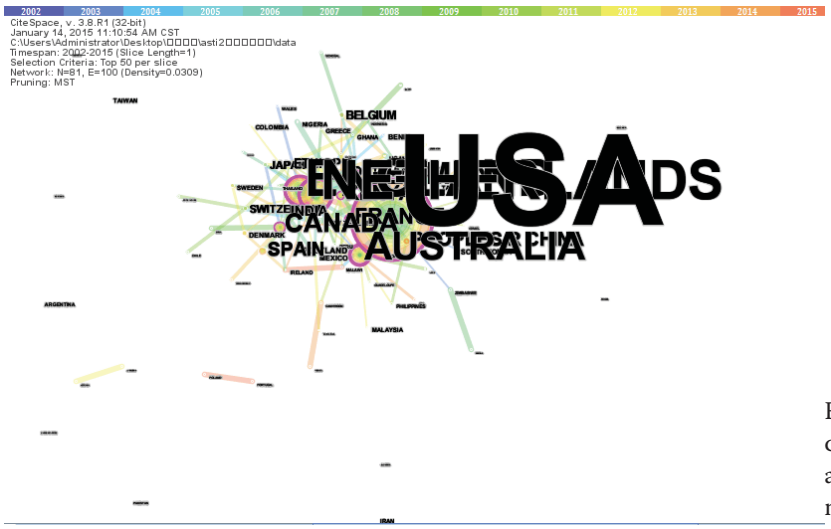

Figure 3. The visualization map of countries or districts analysis on the agricultural science and technology innovation research

doi: 10.17221/207/2015-AGRICECON

Table 2. The top ten countries or districts of the publishing frequency

No.	Country	Published quantity	Proportion (%)	Centrality	The year of centrality
1	USA	151	25.81	0.30	2003
2	NETHERLANDS	66	11.28	0.29	2003
3	GREAT BRITAIN	63	10.68	0.33	2002
4	AUSTRALIA	46	7.86	0.21	2002
5	GERMANY	38	6.50	0.20	2003
6	CANADA	33	5.64	0.12	2003
7	FRANCE	26	4.44	0.18	2003
8	KENYA	26	4.44	0.12	2002
9	SPAIN	23	3.93	0.00	2008
10	PEOPLES R CHINA	22	3.76	0.01	2007

for only 3.76%, quite below the levels of the United States. In the perspective of centrality appeared year, UK, Australia and Kenya were this kind of countries which was happened the centrality early. However, China and Spain happened the centrality later. As for the centrality value, we found that UK, America and Netherlands were located in the top third and their relevant researches had a significant influence in the field of agricultural science and technology innovation. But combing with the published number, we discovered that the influence of UK agricultural science and technology innovation research were in the top one and its influence was much greater then America's. Relatively speaking, the influence of China and Spain were quite weak in the field of agricultural science and technology innovation study.

Then, we wanted to check which country or district was belonging to the active area in the studied area of agricultural science and technology innovation from 2000 to 2015. Making use of the function "Burst", we can easily show the relative active areas. The details showed in the Figure 4. Analysis on the result of burst detection, agricultural science and technology innovation research began to active from 2014 in China. As a result, we found that Chinese agricultural science and technology innovation issue had become the focus of academic circles recently, and it had a more important influence. Unluckily, the Chinese influence was still lower than the influence of other countries. For example, Kenya was the most active country in the studied area of agricultural science and technology innovation in 2001 and its influence reached to 3.35, located in the top one position. The UK and Japan were in the second and third place and their active time were early in the 21st century, respectively from 2002 to 2004 and from 2003 to 2005.

Institutions and authors analysis

Similarly, with the set of nodes, we could visualize the institutions and authors status of the published literature. However, the co-lines colour of nodes was quite light in the visualization map because there were not very good cooperation relationships between the institutions or authors. So we showed the relative research results in the Table 3 to clearly describe the publishing situation of institutions or authors.

Analysing the Table 3, we discovered that there were more than 100 institutions working on the agricultural science and technology innovation research. However, there was still bigger development space in the studied area of agricultural science and technology innovation if we integrated resources more moderate and optimized the resources allocation ability of relevant institution. In details, from the perspective of published frequency, the published records of the Wageningen University in the Netherlands reached 37 with a proportion of 6.33% of the total literature the top position of 14 institutions. The published records in other institutions were all less than 20. The Indian International Crop Research Institute for the Semi-Arid Tropics, the American Michigan State

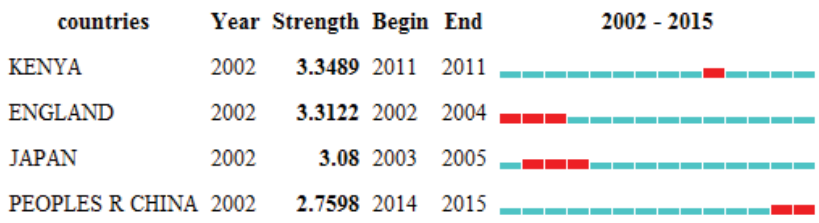

Figure 4. The surge published situation of countries or districts

doi: 10.17221/207/2015-AGRICECON

Table 3. The top 14 institutions and authors' situation of publishing frequency

NO.	Institutions	Number	Proportion (%)	Authors	Number	Proportion (%)
1	Wageningen Univ.	37	6.33	Klerkx L.	9	1.54
2	INRA	14	2.39	Leeuwis C.	8	1.37
3	Cornell Univ.	12	2.05	Qaim M.	7	1.20
4	Univ. Wageningen & Res. Ctr.	12	2.05	Van Huis A.	6	1.03
5	Univ. Western Australia	12	2.05	Spielman D.J.	6	1.03
6	Univ. Calif. Berkeley	10	1.71	Van Ittersum M.K.	5	0.86
7	Arizona State Univ.	9	1.54	Hounkonnou D.	5	0.86
8	Int. Food Policy Res. Inst.	9	1.54	Zilberman D.	4	0.68
9	Univ. Manchester	9	1.54	Van Keulen H.	4	0.68
10	Univ. Calif. Davis	8	1.37	Sumberg J.	4	0.68
11	Univ. Sussex	8	1.37	Sulaiman V.R.	4	0.68
12	Int. Crops Res. Inst Semi Arid Trop	7	1.20	Shiferaw B.	4	0.68
13	Michigan State Univ.	7	1.20	Roling N.G.	4	0.68
14	Washington State Univ.	7	1.20	Hall J.	4	0.68

University and Washington State University had a quite lower published frequency, located in the last place. In addition, the institutions which published 2 or 3 pieces of literature had the proportion of 51% and the institutions which published 3 literatures had a proportion of 39%.

As for the publishing frequency of authors, their publishing situation was same as regarding the institutions'. So we should try to strengthen the cooperation between authors to serve the agricultural science and technology innovation and to produce a more relevant output. As shown in the Table 3, although the authors were located in the top 14 by the publishing frequency, their published quantity was not very high. Klerkx (2010) was located in the first place of the authors publishing frequency, but his record was just 9 with the proportion of 1.54%. In short, there were more than 100 authors working on the agricultural science and technology innovation study. Regarding the top 100 authors of the publishing frequency in the studied area of the agricultural science and technology innovation from 2002 to 2015, those authors who published 2 papers had the proportion of 67% and were located in the first place. Authors publishing 3 articles were located in the second place with the proportion of 19%.

Research focus and frontiers analysis on the agricultural science and technology innovation

Research focus analysis

Research hot-spots are science issues or special subjects studied by a cluster of theses with the interconnection in a short period of the recent time (Li Wan and Sun Bingdong 2014). Keywords are the core and kernel of academic papers. They are a high generalization and refining of research topics and the important index of research (Yi Chunbo and Xu Xin 2014). Therefore, we could get the research hot-spots and the main subjects of one studied area by analysing the change trend and characteristic of the keywords frequency. Similar to the above method, we can get the visualization map of keywords in the studied area of the international agricultural science and technology innovation, as shown in the Figure 5.

Analysing the literature records, we found that there were 372 keywords in the 585 international agricultural science and technology innovation relevant research. What is more, we discovered that

Figure 5. The visualization map of keywords in the field of the agricultural science and technology innovation research

doi: 10.17221/207/2015-AGRICECON

Table 4. The top 10 keywords situation of the agricultural science and technology innovation research

No.	Frequency	Keyword	Year	No.	Frequency	Keyword	Year
1	124	innovation	2003	6	51	agricultural innovations	2003
2	84	technology	2003	7	43	systems	2003
3	83	adoption	2003	8	39	technology adoption	2006
4	75	agriculture	2003	9	37	farmers	2003
5	64	management	2004	10	34	impact	2005

the research subjects were quite concentrated in the studied area of the international agricultural science and technology innovation according to the cluster of keywords. In addition, due to the special function of the Citespace, namely, the bigger the size of nodes, the more important the node in the visualization maps. It was easy to find that some keywords ("innovation", "adoption", "management" and "agricultural innovation") had a quite bigger size compared with other keywords. As a result, the agricultural science and technology innovation, the agricultural technology innovation and the agricultural technology adaptability had become the research hot-spots and the main subjects in the studies of the majority of scholars.

From the frequency of keywords, we can broadly summarize that the international agricultural science and technology innovation research focused on "agricultural science and technology innovation", "technology adoption", "farmers' technology adoption behaviour and its influence factors", "technology management" and "agricultural science and technology innovation system construction". In detail, the appearance frequencies of 140 keywords were all 1 and these keywords had the proportion of 37.63% in the 372 keywords. However, the keyword "innovation" appeared 124, located in the first place. The frequency of others was in all cases lower than 100. The keyword "impact" was located in the tenth place with the frequency 34. As for the top 10 keywords, "innovation", "technology", "adoption", "agriculture", "management", "agricultural innovation", "system", "technology adoption", "farmer" and "impact" belonged to the keywords with the higher appearance frequency. At the same time, there were 7 top keywords appearing in 2003, among which the keywords, and "management", "technology adoption", and "impact" appeared relatively often also in 2004, 2006 and 2005. So we verified that the agricultural science and technology innovation issue became the international research hot-spots in the early 21st century and it got more attention from 2003 (Table 4).

To check deeply the influence degree of research subjects and the new focus issues, we analysed the keywords with the "Burst Detection" function, as shown in the Figure 6. We discovered that "agricultural innovation", "knowledge innovation" and "technology extension" became the research focus in the early 21st century, particularly, before 2008. However, "climate change" and "ecological vulnerability" began to become the research hot-spots of many scholars after 2011. At the same time, the majority of scholars tried to set up a science system of the agricultural science and technology innovation to improve the allocation ability of the agricultural science and technology resources and promote the harmonious development of nature, society and economy. The reason of the above conclusion were as follows.

As analysed, "agricultural innovation", "knowledge", "extension", "vulnerability", "climate change" and "networks", both "agricultural innovation" and "extension" had a high appearance frequency from 2006 to 2008. The influence degree of "agricultural innovation" reached to 3.59 and was located in the top one apposition, much higher than "extension" with the impact degree of 3.22. "Knowledge" reached

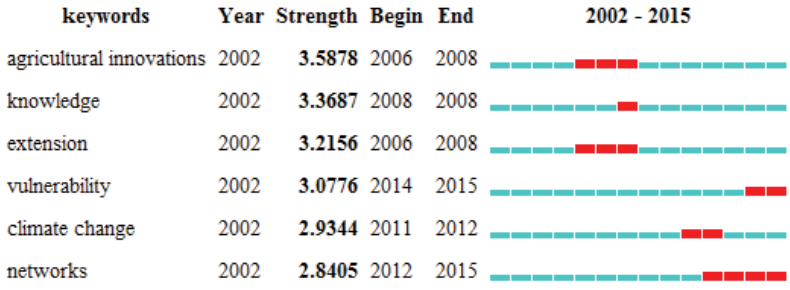

Figure 6. The influence of research hot-spots in the studied agricultural science and technology innovation area

doi: 10.17221/207/2015-AGRICECON

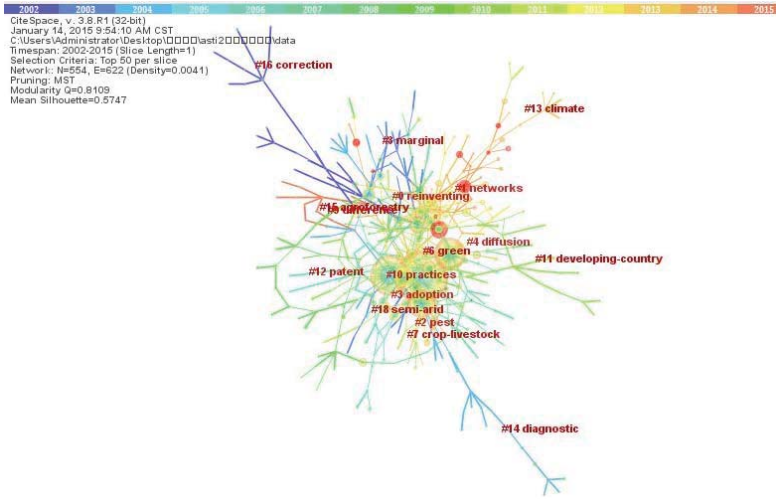

Figure 7. Cluster analysis of the co-cited literature

the second top frequency with the influence degree of 3.37. "Climate change" appeared continually with the impact factor of 2.93. In the recent years, "vulnerability" and "networks" became the high appearance frequency keywords. However, the scholars began to pay more attention to "networks" from 2012, and its influence degree was 2.84. However, in 2014, many researchers began to change their attention to "vulnerability" and the impact degree of this keyword reached to 3.08. As a whole, the influence of "vulnerability" was much bigger than that of "networks".

Research frontiers analysis

Research frontiers are the research issues and fields with the feature of the newest, advanced and potential development (Chen Shiji 2009). It could reflect the research frontiers by analysing on the co-cited literature with the Citespace (Chen Chaomei 2010). With the analysis of the Citespace III software, we clustered the visualization map and analysed the citation burst, as shown in the Figure 7. There were 554 nodes and 622 main connected lines. We found that the coupling of clusters was quite loose due to the high modular value of 0.81 and the homogeneity of every cluster was not high, merely on the general level according to the mean silhouette equal to 0.58 in the Figure 7. Similarly, the definition of rings was same as in the above explanations. However, it should be noted that the red ring meant the literature which was cited more in that time and this node would be the next research hot-spots in the future.

Analysing on the cluster results, there were 58 clusters in all the co-cited references, as shown in the Figures 7–8. We showed the starting time and the influence degree of clusters and listed out merely the road maps of the former 35 clusters because the rest clusters had a short active time and a small influence degree in Figure 8. Among the clusters, "No. 20 historical" was the earliest research frontiers since 1920. It kept a long time, but it did not form the influence reference node. However, there were nodes with a different influence degree from "No. 0 reinventing" to "No. 18 semi-arid". We found that the references nodes with a high influence degree were mostly located between NO.0 to No. 4 cluster. Particularly, "No. 3 adoption" and "No. 4 diffusion" had more main reference nodes with a quite higher

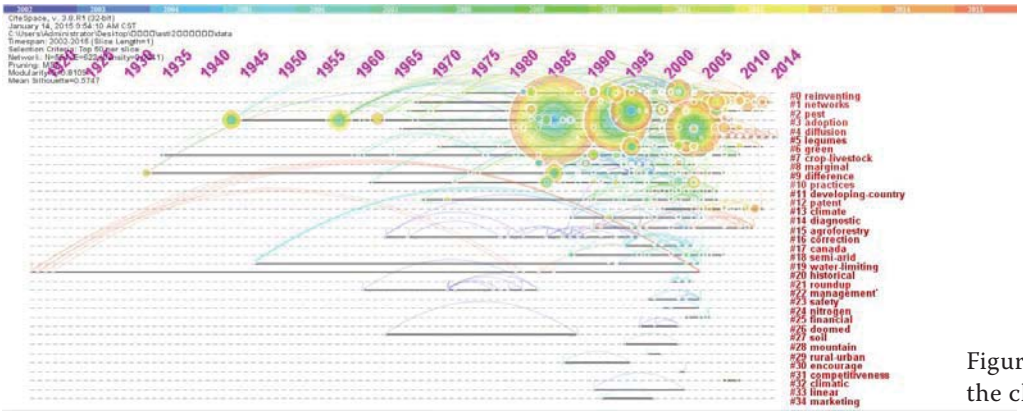

Figure 8. The time zone of the cluster analysis

doi: 10.17221/207/2015-AGRICECON

Table 5. The top 10 literatures with highly cited frequency

No.	Cited frequency	Year	Article title (literature information)	Cluster
1	66	1985	Adoption of agricultural innovations in developing countries	3
2	51	1993	The adoption of agricultural innovations – A review	3
3	41	2003	Diffusion of Innovations 5th ed.	4
4	36	1995	Diffusion of Innovation 4th ed.	2
5	23	2004	Knowledge and Perception, in Communication for Rural Innovation: Rethinking Agricultural Extension, 3rd ed.	1
6	23	2001	Hall A.: World Development, V29, P783	0
7	22	1957	Griliches Z.: Econometrica, V25, P501	3
8	20	1995	Learning by doing and learning from others: human capital and technical change in agriculture	6
9	18	1995	Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting.	0
10	18	1992	National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning	0

influence degree. From the perspective of the nodes' time dimension, "No. 1 networks" was the recent research hot-spots. And there was a close relationship between the cluster "No. 5 legumes" and other clusters. Combined with the above analysis, we discovered there was consistency between the analysis on the keywords nodes and the co-cited references. For example, the agricultural science and technology innovation and the agricultural science and technology promotion were the research hot-spots. What is more, the researchers began to consider the background of the climate environment degradation and the restraints of natural resources when they studied the agricultural science and technology innovation.

Combined with the cluster analysis theory of Chen Chaomei(2014), we named the clusters by topic, abstracts and keywords with different arithmetic. However, there was no denying that we could not express the integrated connotation of the research focus when analysing the clusters named by a single word or word group. Therefore, we tried to do a deep analysis on the co-cited reference clusters. Firstly, we checked the top 10 high cited literature in the Table 5 to study the relevant research basic. Secondly, combined with the silhouette value of every cluster, we analysed the clusters whose size was bigger than 15 to summarize the research frontiers. Finally, we analysed the highly cited references shown in the Figure 9 to discuss the new research hot-spots and the next possible research frontier in the future.

(1) Analysis on high cited references

Analysing the Table 5, there were 3 references belonging to the cluster No. 0, 3 literatures belonging to the cluster No. 3 and other references belonging to the clusters No. 1, No. 2, No. 4 and No. 6. From the perspective of literature publishing year, the majority of highly cited references was published between the medium-term of 1980s and 1990s. The earliest highly cited reference happened in 1957. Then, there were only 3 references which were located, respectively, in the third, fifth and sixth citation in the early period

Figure 9. The highlighting status of the references citations

doi: 10.17221/207/2015-AGRICECON

of 21st century. As for the citation frequency, the whole highly cited frequency was not very high. For example, the first top highly cited reference (Feder et al. 1985) just had 66 citations. And others had a quite lower citation frequency, particularly, as for the tenth place of the highly cited references (Lundvall 1992), its number of citation was just 18. In addition, we found that the study always chose a theoretical research (Lundvall 1992; Alston 1995; Rogers 1995 and 2003; Leeuwis and Van den Ban 2004) as the main study issue, some researches referred to the technology adoption (Feder et al. 1985; Feder and Umali 1993) and the influence factor of extension (Foster and Rosenzweig 1995) and other studies had a quite lower proportion.

In detail, as for the theory studies, Lundvall (1992) studied the relevant issues of the national innovation system based on the innovation and interaction theory. Rogers (1995 and 2003) elaborated the origin and development of the innovation extension theory, verified the development and the effect of the science and technology innovation by many case study and discussed the basic paradigm of the innovation extension and the special reasons of the technology extension termination. As for the adoption and promotion of agricultural science and technology innovation, Feder et al. (1985), Feder and Umali (1993) made a deep analysis of the technology adoption in the developing countries and gave detail overviews of the current researches. At the same time, they analysed the extension reasons of green technology from the perspective of agricultural production environment and government policies. Foster and Rosenzwieg (1995) studied the human caption from the aspect of farmers, especially the farmers who can get experience from their own practices or from the others help, and the influence of farmers using agricultural technology.

(2) Analysis on the co-cited references

We found that there were 16 clusters whose size was bigger than 15 by the analysis of the co-cited references. In addition, the researcher frontiers focused on the path selection and mechanism establishment of the agricultural science and technology promotion, the adoption, assimilation and innovation of agricultural technology and other aspect. As for the extension of the agricultural science and technology innovation, Sulaiman and Hall (2002) studied the reason why it was difficult to promote the new technology, viewpoint, and theory by the case of the agricultural technology promotion in India. And the results showed that the responsibility and relationship of main body and subject, the professional knowledge of the technology users were the more important reason which had a significant impact on the agricultural technology promotion. Therefore, we should regroup the promotion mechanism of the agricultural science and technology and improve the construction of the agricultural science and technology innovation system.

As for the adoption, assimilation and innovation of agricultural technology, many scholars took this aspect as their research focus. At present, we can divide this kind of research into 4 aspects. Firstly, in the studied area of the technology promotion reasons, Basu and Leeuwis (2012) discussed that the technology promotion should be based on the perfect network system combined with the effective media publicity with the case of the rapid spread of the rice intensification (SRI) system in Andhra Pradesh. Secondly, as for the research of the technology extension process, Calatrava and Agustin (2011) took olive gardens in the Southern Spain as the main research area and elaborated the use and diffusion process of the plastic mulching technology, especially the diffusion of the technology with the crop straw as mulch. Thirdly, in the aspect of the influence factor of the technology diffusion, Conley and Udry (2010), Ito (2010) and Koundouri et al. (2006) studied some key factors of the technology extension based on the perspective of the farmer's social learning ability, communications skills and human capital. Meijer et al. (2015) researched the impact factors of agricultural technology absorbed from both the farmer's intrinsic and extrinsic factors. Fourthly, as for the agricultural science and technology innovation research, some scholars (Roling et al. 2004; Amede et al. 2009; Ito 2010) studied its impact on agricultural productivity and the agricultural innovation ability. Naseem et al. (2010) discussed the impact of the private investment in the scientific research system. As for other research aspects, some scholars (Carletto et al. 2010, Harvey and Pilgrim 2011, Vaz et al. 2015) discussed the impact of climate, energy change and globalization on the agricultural science and technology innovation based on the background of agricultural production.

(3) Analysis on the surge cited references

To deeply analyse the present co-cited references and show the new research frontiers, we analysed the

doi: 10.17221/207/2015-AGRICECON

surge cited situation of the co-cited references. As shown in the Figure 9, we got the top ten references with the surge cited frequency. Among them, the earliest phenomenon with the surge cited showed in 200, and the main cited reference belonged to Alston et al. (1995). We found that the impact of Alston et al. (1995) was much bigger than of the other cited reference combined with the surge cited time and the size of the impact strength. What is more, the references of Alston also belonged to the theory based research as discussed above. So the scholars paid more attention to the theory research in the study area of the agricultural science and technology innovation in this period. From 2012 Klerkx et al. (2010) showed a surge cited frequency and this trend continued to 2015. The reason might be that Klerkx et al. (2010) investigated the effective reformism with a very concrete case, verified the impact of the innovation network and its environment on the agricultural science and technology innovation. Their research implied other researchers as the agricultural innovation policies should, instead of aiming to only plan and control innovation, to foster the emergence of such flexible support instruments that enable the adaptive innovation management. So the impact of Klerkx et al. (2010) research reached to 6.01 higher than others references, up to the top one.

From the whole analysis, we discovered that the recent research frontier focused on the applicability management of agricultural science and technology innovation system (Klerkx et al. 2010), the innovation system method (Hounkonnou et al. 2012), the role of innovation agent (Klerkx and Leeuwis 2009), the background of innovation (Tilman et al. 2002; Foley 2011), because there were 7 references showing surge cited after 2011 in the top ten references listed by the surge cited time and quantity. Combined with the research basis and frontiers, the research focus had a shift from the specific agricultural technology diffusion, extension, absorption and innovation to the more systematic and comprehensive research area. The present researches paid more attention to the economic, social and natural benefits and the natural constraints and climate change of the agricultural science and technology innovation. Researchers tried to discuss the applicability of agricultural science and technology innovation method and system on a different innovation level. And the recent researches paid more attention to the role of the innovation agent in the whole construction of the agricultural science and technology innovation system.

DISCUSSION

Compared with the international agricultural science and technology innovation researches, notwithstanding the published quantity of references, the influence of the published articles or the dynamic evolution of the whole research of agricultural science and technology innovation in China, we all fell behind some developed countries, such as the USA, Great Britain, the Netherlands and so on. Regarding the above analysis, there were still some problems in the process of the agricultural science and technology innovation mechanism. Such as, that agricultural science and technology was disjointed from agricultural production. And the mechanism of market was still imperfect and the allocation of agricultural science and technology resources was not reasonable.

Therefore, Chinese scholars could follow the evolution trace of the international agricultural science and technology innovation research hot-spots and focuses in the future studied areas of the agricultural science and technology innovation so that we can put our science and technology research into connection with the factual production to some extent. In details, first, we should summarize the theory basis of the agricultural science and technology innovation researches combined with the present research achievements. And then, we can deduce the process of the technology extension, promotion and innovation with the background of the current specific agricultural technology in China. Finally, according to the background of agricultural production, we could complete the construction of the market mechanism, to improve the allocation ability of agricultural science and technology resources, so that we can promote the construction of the agricultural science and technology innovation system, improve the comprehensive strength of agricultural science and technology and consolidate and uplift the overall agricultural production capacity.

In addition, compared with the previous relevant review of researches (Ji Chuanru 2012), this paper made an analysis on the research hot-spots and frontiers of the international agricultural science and technology innovation by the bibliometrics and the visualization analysis of the Citespace III in the first time. The above descriptions also prove the innovation of the method application in our study. What is more, different from the previous researches (Jiang Heping and Liu Xueyu 2014), we analysed the gap between China and other countries in the studied

doi: 10.17221/207/2015-AGRICECON

area of the agricultural science and technology innovation based on the present situation and development trend of Chinese agricultural science and technology innovation research. And not same as the relevant researches (Meijer et al. 2015), we discussed the integrated research of agricultural science and technology innovation and were not limited to a new technology, attitude or production mode. Therefore, we found some roads, as shown above, to reduce the gap between China and some advanced countries and to improve the whole innovation ability of agricultural science and technology in China by using the international experience for reference.

However, this study also showed some disadvantages. For example, although we found that there were obvious differences and gaps between China and some developed countries in the studied area of the agricultural science and technology innovation, we just gave the simple reviews analysis without an empirical method. Therefore, we would plan to keep working on the construction of the agricultural science and technology innovation system and its management mechanism to dissect the reason of the above specific gap in the future study, so that we can narrow the gap between China and the international developed countries in the field of the agricultural science and technology innovation research, to comprehensively improve the capacity of agricultural science and technology. In turn, we can keep the agricultural production stable and ensure the food security.

CONCLUSIONS

According to the analysis on the relevant references in the studied area of the agricultural science and technology innovation, we discovered that the Chinese agricultural science and technology innovation researchers focused on four aspects (the connotation, the present situation and the development trend, the evaluation of the innovation level, the problems and countermeasures). In addition, we analysed the international studies from the aspect of the references' quantity, type and source publication, country or districts, institution and author, keywords, and co-cited references. On the whole, the results showed that:

Firstly, the agricultural science and technology innovation has been one of the continued research focus in the studied of many academics and the majority of scholars tended to publish papers to show their research achievements. Among these source journals, "Agricultural Systems", "Agricultural Economics" and "Food Policy" were the top three journals which published more articles than other journals in the field of the agricultural science and technology innovation research.

Secondly, there was a gap between China and some developed countries in the researches of the agricultural science and technology innovation. For example, the USA, the Netherlands and the Great Britain were the top three countries which published a high number of relevant articles in the studied area of the agricultural science and technology innovation. However, the impact of the Great Britain was much more profound than that of the USA according to the centrality index. From the perspective of the influence strength, the Great Britain was in the first place. The published quantity of references in China was not up to 1/5 of that in the USA, it merely reached 1/3 of the published quantity in the Great Britain. Nevertheless, China started to have slightly higher influence strength in 2007. And this issue in China became the focus of the whole academic sphere and began to occupy the important place in the whole field of the agricultural science and technology innovation.

Thirdly, there were many institutions and authors working on the research of the agricultural science and technology innovation, respectively more than 100. Among them, on the one hand, the institution which published 3 articles was in the first place with the proportion of 39%. On the other hand, the authors who published 2 papers were in the top one position with the proportion of 67%. In addition, there was much space to improve the cooperation of institutions or authors because the present cooperation relationships were not very closely analysed by the visualization map. Therefore, it is important to improve the allocation ability of resources (institutions or authors), so that we can promote the development of the agricultural science and technology innovation.

Fourthly, the issue of the agricultural science and technology innovation had been the focus of many countries in the world early in the 21st century. Especially after 2003, this issue got more attention and became one of the research focuses of the academics. In details, the agricultural innovation, knowledge innovation and technology innovation became the research focus in 2008. However, the climate change, ecological vulnerability began to form the new studies hot-spots, especially the impact of ecological vulnerability on the agricultural science

doi: 10.17221/207/2015-AGRICECON

and technology innovation after 2011. Therefore, the majority of scholars tended to set up a scientific agricultural science and technology innovation system so that we can improve the utilization rate of resources and promote the harmonious development between nature, society and economy.

Fifthly, the researches mainly focused on the theory analysis in the studied area of the international agricultural science and technology innovation and the partial studies gave more attention to the agricultural technology adaptation and their influence factor. In details, researchers focused on the three aspects, such as the choice of agricultural science and the technology innovation promotion path and its construction promotion mechanism, the extension, absorption and innovation of specific agricultural technology and other researches. In addition, the research began to shift from the extension, absorption and innovation of a specific agricultural technology to more systematic and comprehensive research fields from 2011. For example, the academics started to put natural constraints and climate change into the whole study and to pay more attention to the integrated benefits of nature, society and economy. What is more, the scholars tried to discuss the adaptation of the agricultural science and technology innovation method and system with a different innovation level and paid more attention to the role of the innovation agent in the whole construction of the agricultural science and technology innovation system.

REFERENCES

Alston J.M., Norton G.W., Pardey P.G. (1995): Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press, Ithaca, New York.

Amede T., Descheemaeker K., Peden D., Van Rooyen A. (2009): Harnessing benefits from improved livestock water productivity in crop-livestock systems of Sub-Saharan Africa: Synthesis. Rangeland Journal, 31: 169–178.

Basu S., Leeuwis C. (2012): Understanding the rapid spread of System of Rice Intensification (SRI). In: Andhra Pradesh: Exploring the building of support networks and media representation. Agricultural Systems, 111: 34–44.

Bederson B.B., Ben S. (2003): The Craft of Information Visualization: Reading and Reflections. Morgan Kaufman, San Francisco.

Blazy J.M., Carpentier A., Thomas A. (2011): The willingness to adopt agro-ecological innovation: application of choice modeling to Caribbean banana planters. Ecological Economics, 72: 140–150.

Calatrava J., Agustin F.J. (2011): Using pruning residues as mulch: analysis of its adoption and process of diffusion in southern Spain olive orchards. Journal of Environment Management, 92: 620–629.

Carletto C., Kirk A., Winters P.C. B. (2001): Globalization and smallholders: the adoption, diffusion, and welfare impact of non-traditional export crops in Guatemala. World Development, 38: 814–827.

Chen Chaomei (2006): Citespace II detecting and visualizing emerging trends and transient patterns in scientific literature. Journal of the American Society for Information Science and Technology, 57: 359–377.

Chen Chaomei (2010): The structure and dynamics of co-citation clusters: a multiple-perspective co-citation analysis. Journal of the American Society for Information Science and Technology, 61: 1386–1409.

Chen Chaomei (2014): The Citespace Manual. Available at http://cluster.ischool.drexel.edu/–cchen/citespace/CitespaceManual.pdf 1 (accessed December, 2014).

Chen Qiqi, Zhang Junbiao, Zhang Lu (2015): Risk assessment, partition and economic loss estimation of rice production in China. Sustainability, 7: 563–583.

Chen Shiji (2009): Survey of approaches to research front detection. New Technology of Library and Information Service, 9: 28–33.

Conley T.G., Udry C.R. (2010): Learning about a new technology: pineapple in Ghana. American Economic Review, 100: 35–69.

David F.T. (2001): Employment-based analysis: an alternative methodology for project evaluation in developing regions, with an application to agriculture in Yucatan. Ecological Economics, 36: 249–262.

David M., Scott R. Templeton M.K. (1999): Agriculture and the environment: an economic perspective with implications for nutrition. Food Policy, 24: 221–229.

Feder G., Just R.E., Zilberman D. (1985): Adoption of agricultural innovations in developing countries. Economic Development and Cultural Change, 33: 255–298.

Feder G., Umali D.L. (1993): The adoption of agricultural innovations – a review. Technological Forecasting and Social Change, 43: 215–239.

Foley J.A., Ramankutty N., Brauman K.A., Cassidy E.S., Gerber J.S., Johnston M., Mueller N.D., O'Connell C. et al. (2011): Solutions for a cultivated planet. Nature, 478: 337–342.

Foster A.D., Rosenzweig M.R. (1995): Learning by doing and learning from others: human capital and technical change in agriculture. Journal of Political Economy, 103: 1176–1209.

doi: 10.17221/207/2015-AGRICECON

Guo Wenbao, Ma Qing (2011): Existing problems and countermeasures of agricultural technology innovation system. Journal of Anhui Agricultural Science, 39: 20190– 20192.

Hall A. (2002): Beyond technology dissemination: reinventing agricultural extension. Outlook on Agriculture, 31: 225–233.

Harvey M., Pilgrim S. (2011): The new competition for land: food, energy, and climate change. Food Policy, 36: S40–S51.

Hounkonnou D., Kossou D., Kuyper T.W., Leeuwis C., Nederlof E.S., Röling N., Sakyi-Dawson O., Traoré M., van Huis A. (2012): An innovation systems approach to institutional change: smallholder development in West Africa. Agricultural Systems, 108: 74–83.

Hu Ruifa, Huang Jikun (1999): The reconsideration of scientific research system reform: scientific research behavior analysis on agricultural scientific research personnel under the condition of market economy. China Rural Survey, 6: 1–10.

Huang Jikun, Hu Ruifa (2000): Investment system and mode of agricultural science and technology: present situation and the international comparison. Management World, 3: 170–179.

Huang Jikun, Hu Ruifa, Zhi Huayong (2009): Development and reform of agricultural technology popularization system in 30 years. Journal of Agrotechnical Economics, 1: 4–10.

Huang Wenhuai (2011): An empirical study on the influence of agricultural science and technology innovation on the rural economy. Science and Technology Management Research, 12: 1–4.

Ito J. (2010): Inter-regional difference of agricultural productivity in China: Distinction between biochemical and machinery technology. China Economic Review, 21: 394–410.

Ji Chuanru (2012): Advances in innovation of agricultural science and technology. Guizhou Agricultural Sciences, 40: 216–220.

Ji Shaoqin (2005): Study on National Innovation System of Science and Technology in Agriculture. [Ph. D. thesis.] Chinese Academy of Agricultural Science, Beijing.

Jiang Heping, Liu Xueyu (2014): Review of studies on innovation system of agricultural science and technology in China. Journal of Agricultural Science and Technology, 16: 1–9.

Jing Fei (2007): Scientific research behavioral analysis to paddy rice breeding scientific researches – Empirical studies Besed on Jiangsu Province. Technology Economics, 26: 88–93.

Klerkx L., Aarts N., Leeuwis C. (2010): Adaptive management in agricultural innovation systems: the interactions between innovation networks and their environment. Agricultural System, 103: 390–400.

Klerkx L., Leeuwis C. (2009): Establishment and embedding of innovation brokers at different innovation system levels: insights from the Dutch agricultural sector. Technological Forecasting and Social Change, 76: 849–860.

Koundouri P., Nauges C., Tzouvelekas V. (2006): Technology adoption under production uncertainty: theory and application to irrigation technology. American Journal of Agricultural Economics, 88: 657–670.

Leeuwis C., Van den Ban A. (eds) (2004): Knowledge and Perception, in Communication for Rural Innovation: Rethinking Agricultural Extension. 3rd ed. Blackwell Science Ltd, Oxford.

Li Furong (1996): Research on the Supply of Agricultural Science and Technology Innovation and the Reform of Agricultural Scientific Research Mechanism in the Development of Chinese Agriculture. [Master Degree Thesis.] Southwest Agricultural University, Chongqing.

Li Hongwei, Li Dongsheng (2013): Research on the innovation ability of agricultural science and technology: illustrated by Hubei province. Journal of Agrotechnical Economics, 10: 114–119.

Li Wan, Sun Bingdong (2014): The knowledge and research hot-spots of west economic geography: visualized quantitative research based on citespace. Economic Geography, 34: 7–12, 45.

Lin Bbode (2010): Assessment of the theoretical model on the evaluation of agricultural science and technology innovation ability. Journal of Fujian Agricultural and Forestry University (Philosophy and Social Science), 13: 54–59.

Ling Yuanyun (1995): Research on Transformation Mechanism of Agricultural Science and Technology Achievements. [Master Degree Thesis.] Huazhong Agricultural University.

Lundvall B. (1992): National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter, London.

Ma Hongxia, Liu Qi. (2010): The main problems and resolutions of agricultural science and technology innovation in China. Journal of Jilin Normal University (Humanities & social science edition), 5: 68–71.

Meijer S.S., Catacutan D., Ajayi O.C., Gudeta W. Sileshi G.W., Nieuwenhuis M. (2015): The role of knowledge, attitudes and perceptions in the uptake of agricultural and agro-forestry innovations among smallholder farmers in sub-Saharan Africa. International Journal of Agricultural Sustainability, 13: 40–54.

doi: 10.17221/207/2015-AGRICECON

Naseem A., Spielman D.J., Omamo S.W. (2010): Private-sector investment in R&D: a review of policy options to promote its growth in developing-country agriculture. Agribusiness, 26: 143–173.

Rogers E.M. (1995, 2003): Diffusion of Innovation. 4th ed., 5th ed. The Free Press, New York.

Roling N.G., Hounkonnou D., Offei S.K., Tossou R., Van Huis A. (2004): Linking science and farmers' innovative capacity: diagnostic studies from Ghana and Benin. NJAS-Wageingen Journal of Life Sciences, 52: 211–235.

Schumpeter J.A. (1934): The Theory of Economic Development: an Inquiry into Profits, Capital, Credit, Interest and the Business Cycle. Harvard University Press (English Version), The United States.

Sulaiman V.R., Hall A. (2002): Beyond technology dissemination: reinventing agricultural extension. Outlook on Agriculture, 31: 225–233.

Tilman D., Cassman K.G., Matson P.A., Naylor R., Polasky S. (2002): Agricultural sustainability and intensive production practices. Nature, 418: 671–677.

Vaz P., Maria C., Amarowicz R., Aryee A. N. A., Boye J.I. Chung Hyun-Jung, Martín-Cabrejas M.A., Domoney C. (2015): Achievements and challenges in improving the nutritional quality of food legumes. Critical Reviews in Plant Sciences, 34(SI): 105–143.

Wan Baorui (2012): Five big changes to realize agricultural science and technology innovation. Issues in Agricultural Economy, 10: 4–7.

Xiao Ming, Chen Jiayong, Li Guojun (2011): Visualization analysis on the research of mapping knowledge domains based on citespace. Library and Information Service, 55: 91–95.

Xu Jinhai, Jiang Naihua, Qin Weiwei (2011): An empirical research on the demand intention and performance of farmer in agricultural science and technology training service. Issues in Agricultural Economy, 12: 66–72.

Xu Yanping (1997): Research on the Operation Mechanism of Agricultural Science and Technology System: Illustrated by Shangdong Province. [Ph.D. Degree Thesis.] Shandong Agricultural University.

Yi Chunbo, Xu Xin (2014): A study on research hot-spots and frontiers of free trade area – bibliometric analysis based on citespace III. Shanghai Journal of Economics, 3: 67–78.

Yin Yan, Kang Yizhi, Zhang Luxiang, Fang Wei, Mei Yingjie (2010): The strategic vision of the construction in Guangdong agricultural science and technology innovation system. Guangdong Agricultural Sciences, 1: 260–262.

Zeng Weizhong, Chen Xiulan (2010): Analysis on the influence factors of scientific research personnel participation of agricultural popularization: illustrated by Sichuan Province. Journal of Agrotechnical Economics, 4: 36–41.

Zhang Huijie (1996): The theory and practice research on agricultural science and technology policies in China. [Ph.D. Thesis.] Nanjing Agricultural University, Nanjing.

Zhang Shuhui (2014): Research on the drive mechanism of agricultural science and technology innovation in Shanxi province. [Ph.D. Thesis.] Beijing Forestry University, Beijing.

Zhong Funing, Sun Jiangming (2007): The establishment of evaluation index system of agricultural science and technology demonstration garden. Agricultural Development & Equipment, 1: 21–27.

Zhu Xigang (1997): Measurement Method of Contribution Rate in Agricultural Technology Progress. China Agriculture Press, Beijing.

Received: 30th June 2015
Accepted: 19th November 2015

Contact address:

Jun-Biao Zhang, College of Economics & Management, Huazhong Agricultural University, Wuhan 430070, China
e-mail: zhangjb513@126.com