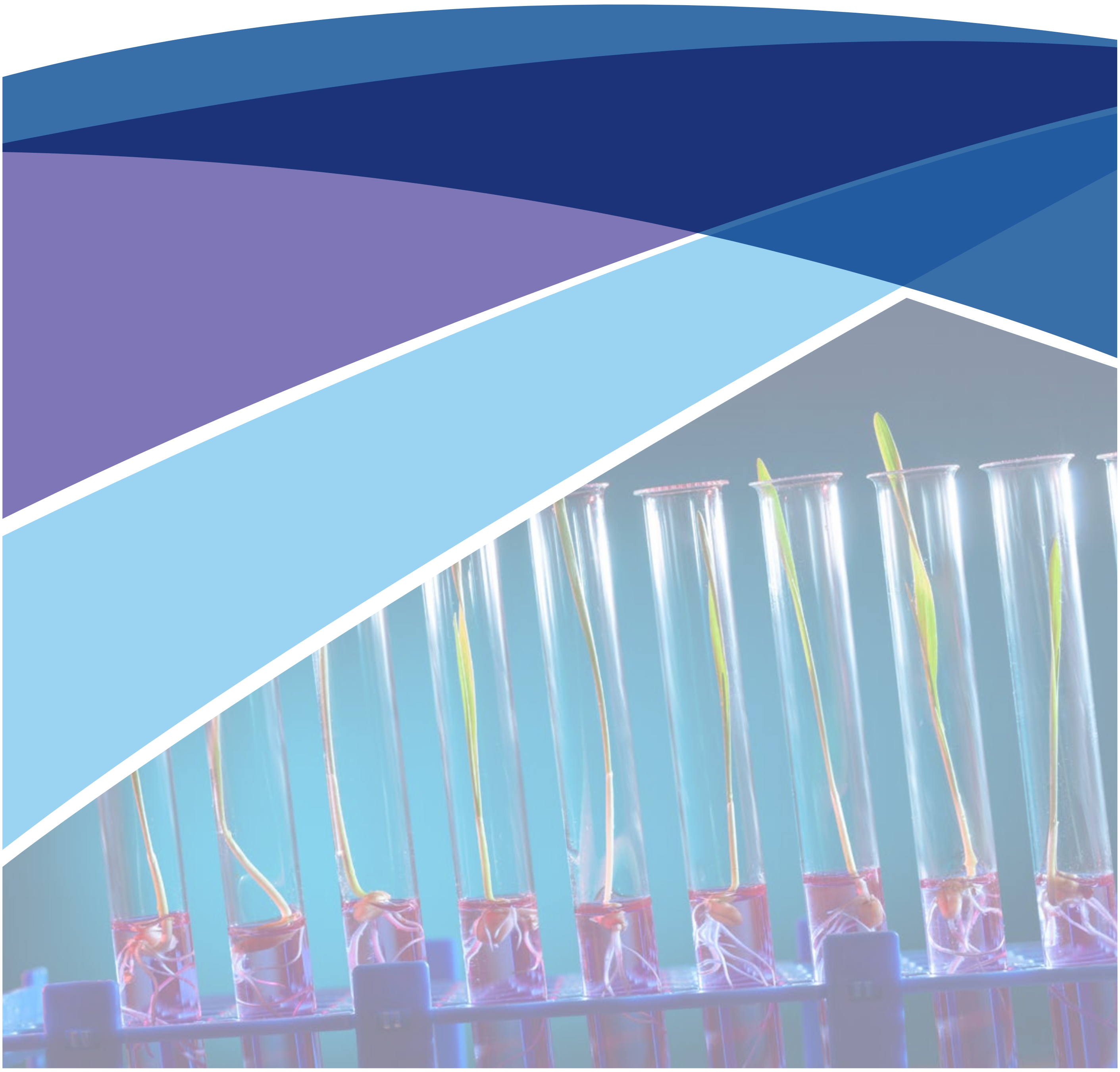
Intellectual Property Office

Eight Great Technologies

Agri-Science

A patent overview



#8Great

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Contents

1 Introduction

The UK Government has identified ‘eight great technologies’ plus a further two which will propel the UK to future growth. These are:

- the big data revolution and energy-efficient computing;
- satellites and commercial applications of space;
- robotics and autonomous systems;
- life sciences, genomics and synthetic biology;
- regenerative medicine;
- agri-science;
- advanced materials and nanotechnology;
- energy and its storage;
- quantum technologies;
- the internet of things.

Patent data can give a valuable insight into innovative activity, to the extent that it has been codified in patent applications, and the IPO Informatics team is producing a series of patent landscape reports looking at each of these technology spaces and the current level of UK patenting on the world stage. As an aid to help people understand the eight great technologies and to consider the direction of future funding, the IPO is offering a comprehensive overview of patenting activity in each of these technologies.

This report analyses the worldwide patent landscape for technology directed towards agri-science. Agri-science is the study of the science and management of biological systems for the sustainable production of food. It encompasses a broad range of different technologies including pest control, crop production techniques, irrigation management, maximising agricultural productivity and addressing the global food demand. There are millions of published patents worldwide relating to agriculture and food production[1], but the dataset used for this report was limited to core agri-science patents that relate to the application of scientific principles to agriculture. However, this does not mean that the dataset was limited to patents originating from the research laboratory (pesticides, fertilisers etc) because core agri-science patents also include the mechanical hardware required to improve agricultural production and implement modern agricultural management systems, such as smart combine harvesters and automated agricultural robots.

The dataset used for analysis was extracted from worldwide patent databases following detailed discussion and consultation with patent examiners from the Intellectual Property Office who are experts in the field and who, on a day-to-day basis, search, examine and grant patent applications relating to the technologies involved. Published patent application data was analysed rather than granted patent data. Published patent application data gives more information about technological activity than granted patent data because a number of factors determine whether an application ever proceeds to grant; these include the inherent lag in patent processing at national IP offices worldwide and the patenting strategies of applicants who may file more applications than they ever intend to pursue.

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[1] More information can be found in our 2012 report giving a brief overview of the worldwide agri-foods patent landscape - http://www.ipo.gov.uk/informatic-agrifood.pdf.

2 Worldwide patent analysis

2.1 Overview

Table 1 gives a summary of the extracted and cleaned dataset used for this analysis of the agri-science patent landscape. All of the analysis undertaken in this report was performed on this dataset or a subset of this dataset. The worldwide dataset for agri-science patents published between 2004 and 2013 contains more than 118,000 published patents equating to over 400,000 patent families. Published patents may be at the application or grant stage, so are not necessarily granted patents. A patent family is one or more published patent originating from a single original (priority) application. Analysis by patent family more accurately reflects the number of inventions present because generally there is one invention per patent family, whereas analysis by raw number of patent publications inevitably involves multiple counting because one patent family may contain dozens of patent publications if the applicant files for the same invention in more than one country. Hence analysis by patent family gives more accurate results regarding the inventive effort that patenting activity represents.

Table 1: Summary of worldwide patent dataset for agri-science

Number of patent families	118,425
Number of patent publications	413,175
Publication year range	2004-2013
Peak publication year	2012
Top applicant	Iseki (Japan)
Number of patent assignees	121,340
Number of inventors	68,664
Priority countries	85
IPC sub-groups	23,935

Figure 1 shows the total number of published patents by publication year (top) and the total number of patent families by priority year (bottom – considered to be the best indication of when the original invention took place). Figure 1 suggests a general increase in agri-science patenting between 2004 and 2008 but since 2008 this has stabilised with a similar number of agri-science patents published in each of the last six years. The patent family chart in red does not show any patents filed after 2011 because a patent application is normally published 18 months after the priority date or the filing (application) date, whichever is earlier. Hence, the 2012 and 2013 data is incomplete and has been ignored.

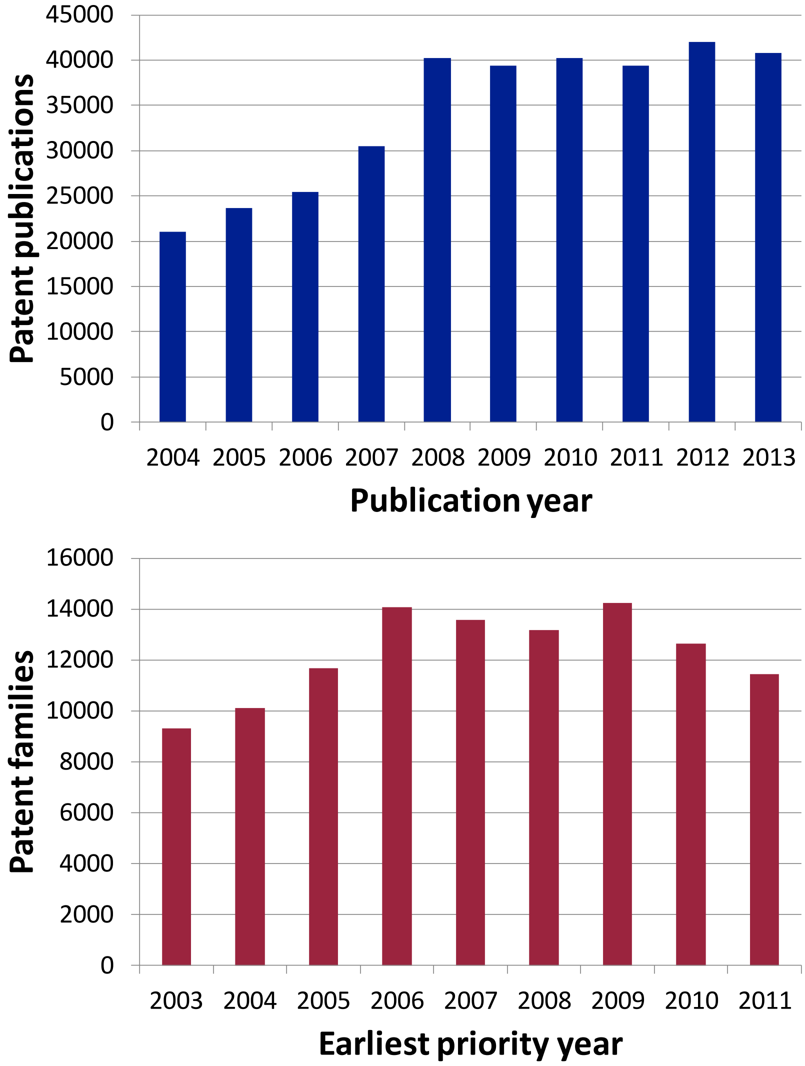

Figure 1: Patent publications by publication year (top) and patent families by priority year (bottom)

In real-world terms only limited information can be gleaned from the generally upward trends shown in Figure 1 because overall patenting levels globally continue to grow at an ever-increasing rate. Figure 2 addresses this issue by normalising the data shown in Figure 1 and presenting the annual increase in the size of worldwide patent databases across all technologies against the year-on-year increase in the size of the agri-science dataset. For example, between 2011 and 2012 worldwide patenting across all areas of technology increased by 12.7% and this can be compared to a 6.7% increase in agri-science patenting over the same time period.

Figure 2 shows that the increase in agri-science patenting in the first half of the last decade (shown in Figure 1) is well above the general increase in the size of the worldwide patent databases across all technologies with a 32% increase in agri-science patenting between 2007 and 2008 compared to a 4.2% increase in worldwide patenting across all areas of technology. The ‘plateau effect’ in overall agri-science patenting between 2008 and 2013 is clearly shown in Figure 2 with the last five data points hovering around a 0% year-on-year change. This is noticeably lower than the year-on-year increase in global patenting activity over the same time period which has varied between a 5% and 13%.

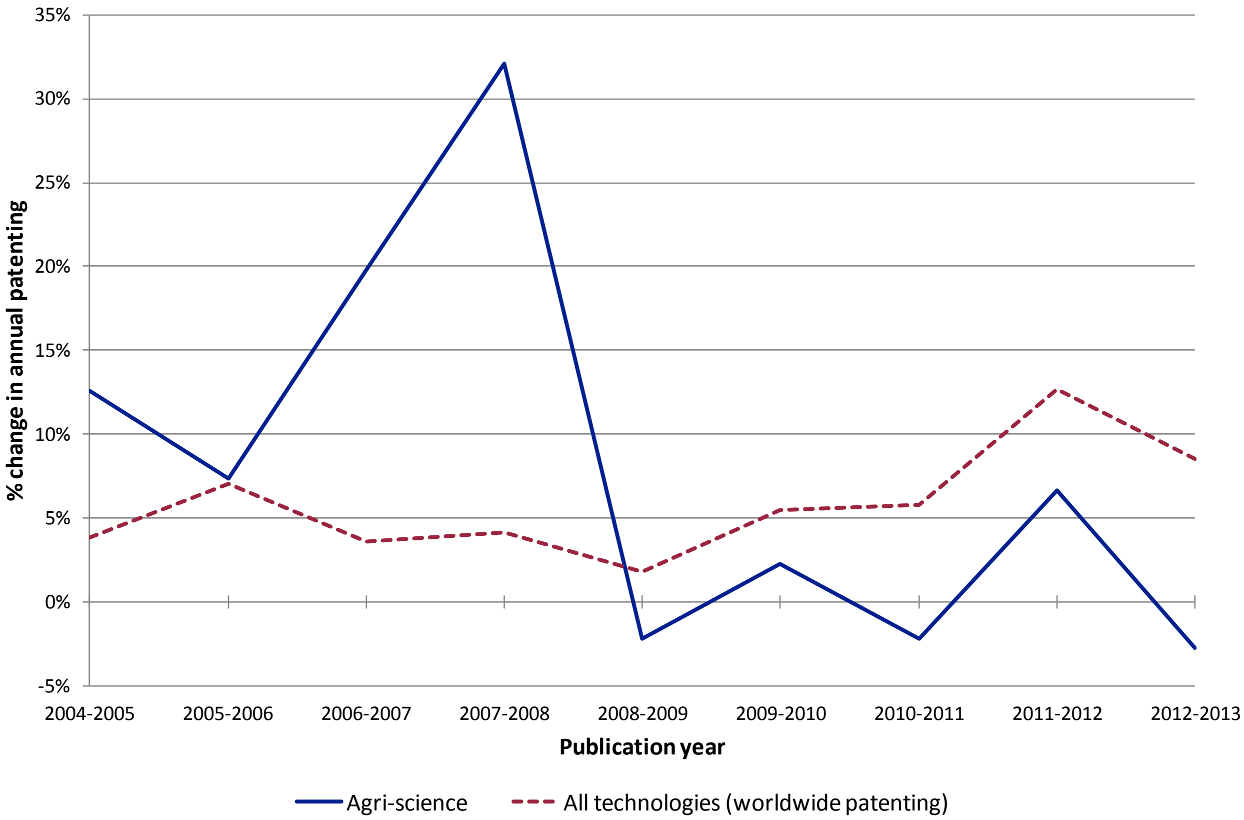

Figure 2: Year-on-year change in agri-science patenting compared to worldwide patenting across all technologies

Figure 3 shows the priority country distribution across the dataset with almost three-quarters of agri-science patent families having their first filing in China, the USA or Japan. 2% of agri-science patent families are first filed in the UK. Traditionally priority country analysis has been a good indicator of where the invention is actually taking place because many applicants will file patent applications first in the country in which they reside[2], but in recent years drawing firm conclusions from this data is harder because there may be other strategic reasons for an applicant choosing the country of first filing (*e.g.* tax treatment).

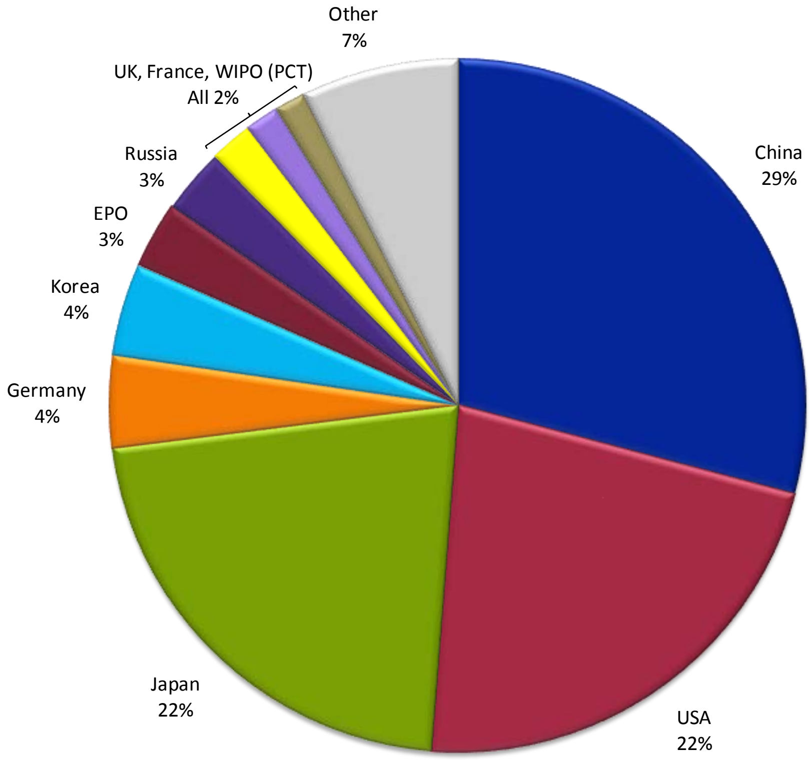

Figure 3: Priority country distribution

[2] In some countries this is/was a requirement (*e.g.* in the UK this was a requirement until 2005).

It is very difficult to draw accurate conclusions from simply presenting data based on the country of residence of patent applicants because there is a greater propensity to patent in certain countries than others. However the Relative Specialisation Index (RSI)[3] for each applicant country (Figure 4) has been calculated to give an indication of the level of invention in agri-science patenting for each country compared to the overall level of invention in that country.

The RSI shown in Figure 4 appears to suggest a different picture to the priority country distribution shown in Figure 3 which is dominated by China, the USA and Japan and suggests that these three countries are relatively specialised in agri-science since they account for almost three-quarters for the first filings of all agri-science patent families. When the RSI is applied, China is ranked 3rd, the USA 10th and Japan 8th, well below countries such as Israel and Australia. These high-ranking countries show much greater levels of patenting in agri-science than expected despite their absolute levels of patenting; many of Israel's agri-science patents stem from Yissum Research Development Company, a technology transfer office of the Hebrew University of Jerusalem, and Yeda Research and Development, a technology transfer company of the Weizmann Institute of Science. It is not surprising to see Australia ranked 2nd by RSI given the importance of agriculture to the Australian economy despite their modest absolute levels of patenting. Similarly, Taiwan's large negative RSI is not surprising since this relatively small nation (by physical size) is well known for its high-tech electronics research rather than its agriculture industry. The UK is ranked 7th with a slightly positive RSI value of 0.07, suggesting that there are slightly more agri-science patents filed by UK applicants compared to the overall level of patenting from UK applicants across all technology areas.

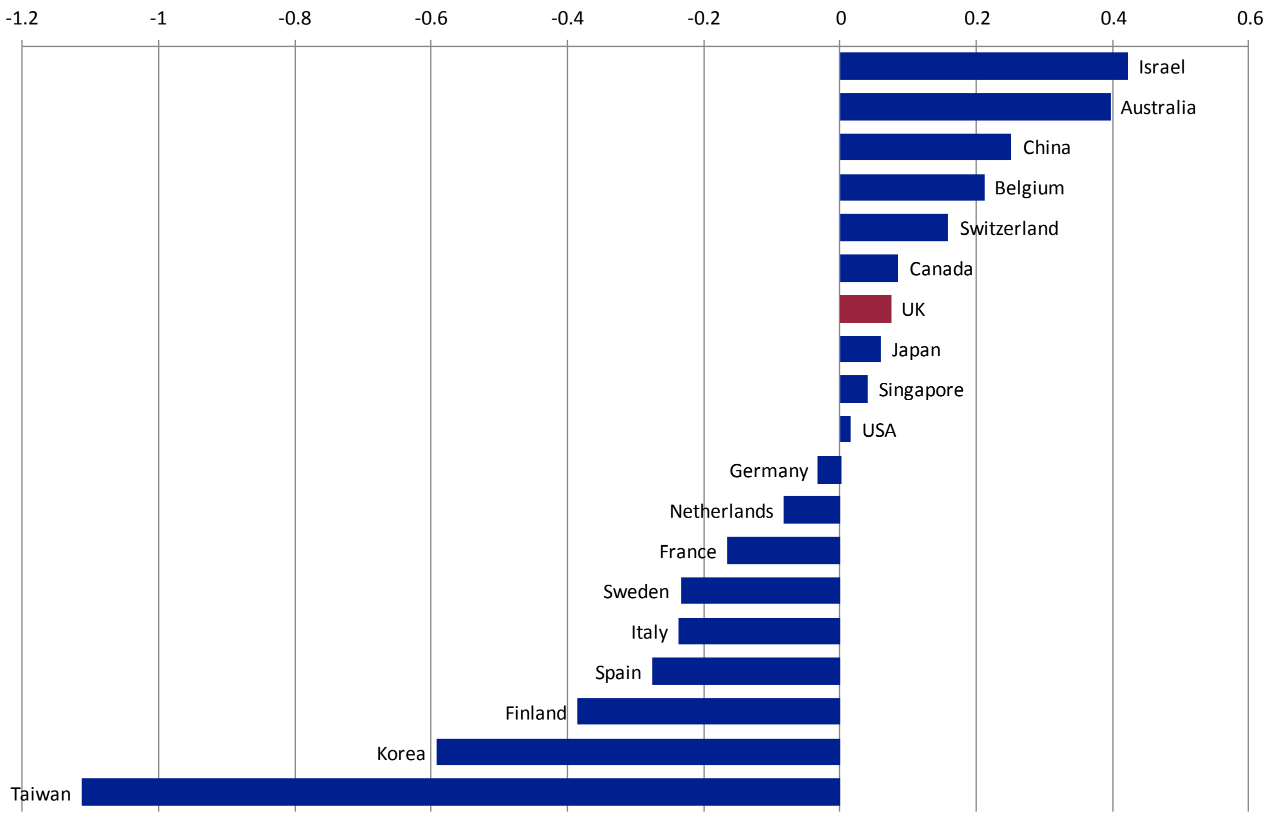

Figure 4: Relative Specialisation Index (RSI) by applicant country

[3] See Appendix B for full details of how the Relative Specialisation Index is calculated.

Figure 5 shows the countries in which applicants in the field of agri-science are interested in seeking patent protection, with the strength of colour reflecting the quantity of published patents in each jurisdiction. The strong coverage of China and the USA is expected given the propensity to patent in these countries. Neither Australia nor Brazil appear in the top priority countries shown in Figure 3 but their strong showing in Figure 5 potentially illustrates that, although few patents originate from these countries, they are important markets for agri-science patent protection because of the strength of the agriculture industry in these countries. Published patents filed via the EPO [] and WIPO (PCT) [ ] routes are also presented, with Figure 5 showing a relatively strong level of patenting via the EP patent and PCT routes evidenced by the dark orange colour given to the blobs that represent the EPO and WIPO.

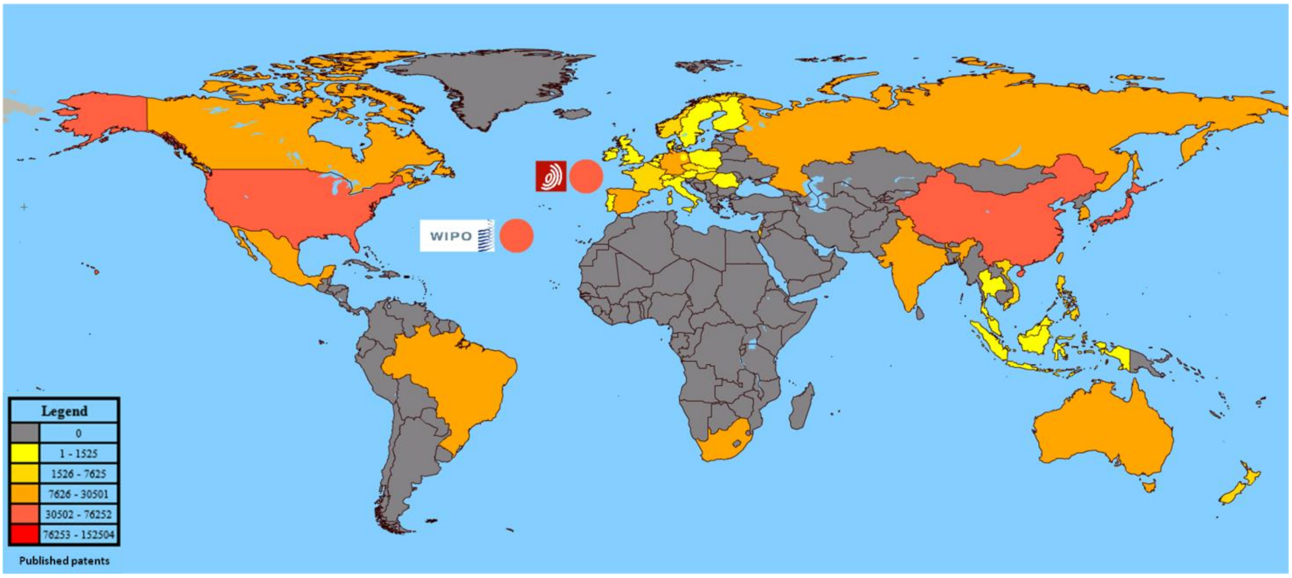

Figure 5: Patent coverage (publication country coverage)

2.2 Top applicants

Patent applicant names within the dataset were cleaned to remove duplicate entries arising from spelling errors, initialisation, international variation and equivalence[4]. Figure 6 shows the top 20 agri-science applicants in the dataset with a mixture of major multinational chemical companies such as Bayer and BASF alongside multinational agricultural machinery companies such as Iseki, Kubota and John Deere.

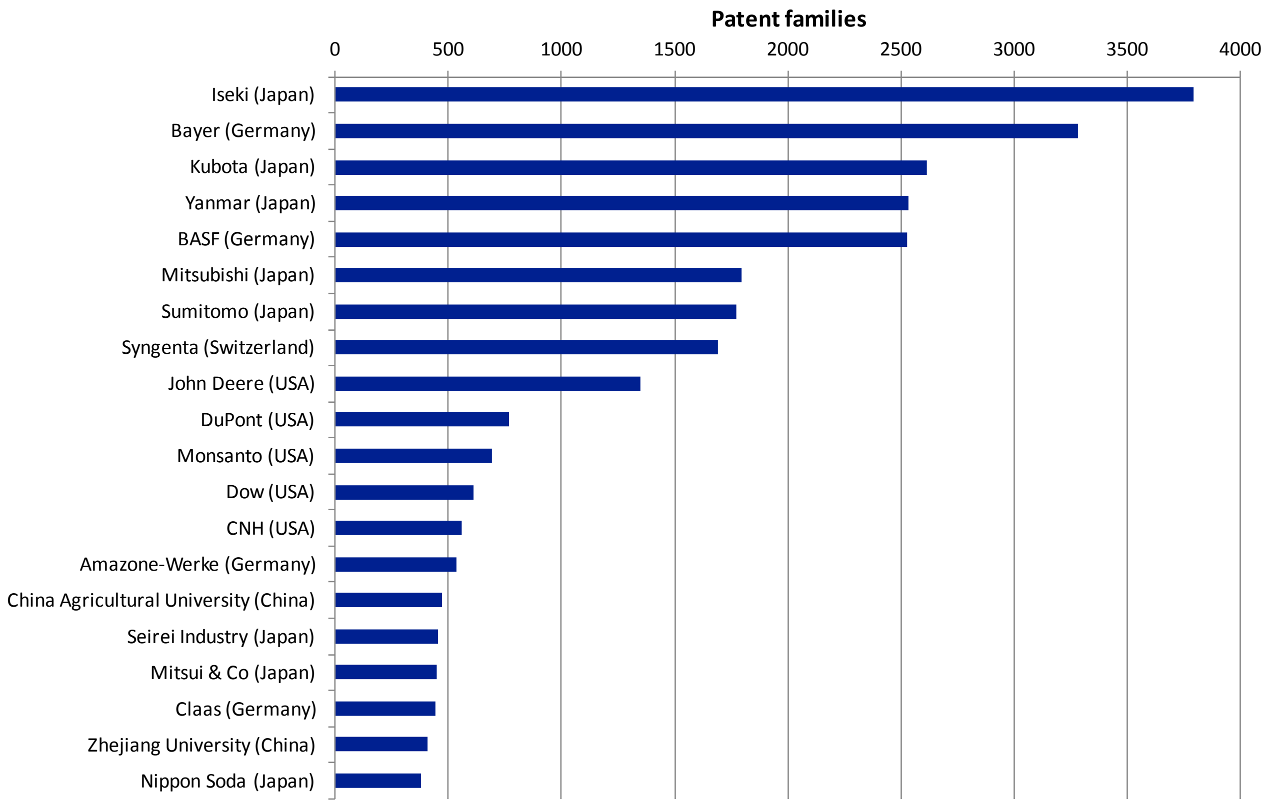

Figure 6: Top applicants

[4] See Appendix A.4 for further details.

Figure 7 is a bubble map showing a timeline for the top 20 applicants and shows the filing activity of these applicants in the last 10 years. It shows that most of the top applicants have been involved in agri-science patenting throughout the last decade in quite a uniform manner albeit at varying absolute levels. Figure 7 shows absolute number of patent publications whereas Figure 6 shows patent families (inventions); from the differences it is clear that although Iseki have the most patent families they are relatively small families compared to those held by BASF and Bayer.

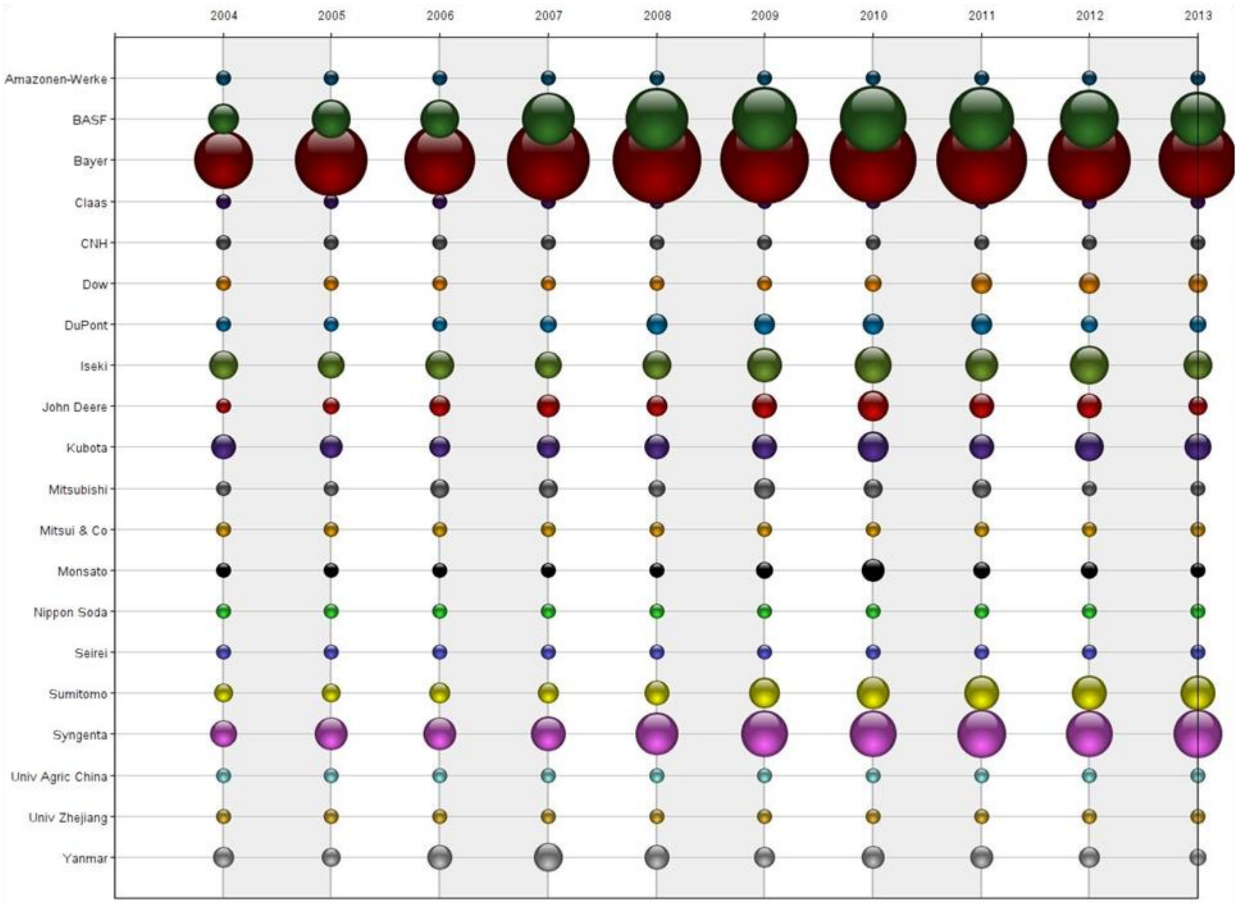

Figure 7: Applicant timeline of published patents by publication year

2.3 Technology breakdown

Figure 8 shows the top International Patent Classification (IPC) sub-groups and Table 2 lists the description of each of these sub-groups. The IPC provides for a hierarchical system of language-independent symbols for the classification of patent applications according to the different areas of technology to which they relate.

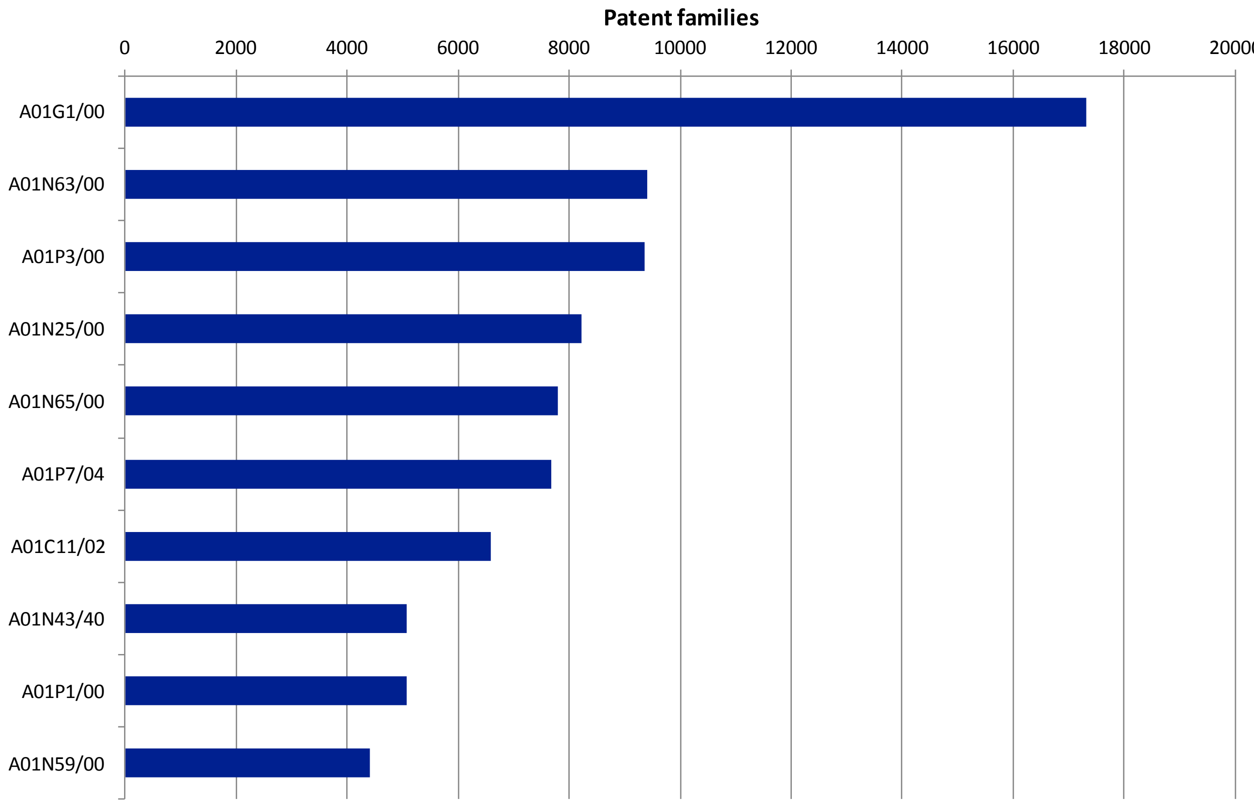

Figure 8: Top IPC sub-groups

Table 2: Key to IPC sub-groups referred to in Figure 8

A01G1/00	Horticulture; Cultivation of vegetables
A01N63/00	Biocides, pest repellants or attractants, or plant growth regulators containing micro-organisms, viruses, microbial fungi, enzymes, fermentates or substances produced by, or extracted from, micro-organisms or animal material *e.g.* enzymes or fermentates > containing compounds of determined constitution
A01P3/00	Fungicides
A01N25/00	Substances for reducing the noxious effect of the active ingredients to organisms other than pests
A01N65/00	Biocides, pest repellants or attractants, or plant growth regulators containing material from algae, lichens, bryophyta, multi-cellular fungi or plants, or extracts thereof
A01P7/04	Arthropodicides > Insecticides
A01C11/02	Transplanting machines > for seedlings
A01N43/40	Biocides, pest repellants or attractants, or plant growth regulators containing heterocyclic compounds > six-membered rings
A01P1/00	Disinfectants; Antimicrobial compounds or mixtures thereof
A01N59/00	Biocides, pest repellants or attractants, or plant growth regulators, containing organic compounds containing elements other than carbon, hydrogen, halogen, oxygen, nitrogen and sulphur > containing organo-phosphorus compounds

3 The UK landscape

3.1 Top UK applicants

Figure 9 shows the top UK-based applicants within the agri-science dataset. The number of patent families shown in the name of Syngenta is lower than the value shown in Figure 6 because the data presented in Figure 9 relates to the UK-based part of Syngenta. Examples of some of the most recent UK agri-science patenting from these top UK applicants include: a herbicidal composition comprising mesotrione and triazine for controlling triazine-tolerant weeds (Syngenta), pest control microcapsules with a polyurea shell wall of oligomeric acetal groups (AstraZeneca), a monocot plant structure coating composition to increase seedling vigour and plant growth and protect the plant structure (Exosect), and a non-leguminous or leguminous plants (*e.g.* soybean, clover, rice, maize) containing nitrogen-fixing bacteria located intracellularly in living plants to provide fixed nitrogen to the plant (University of Nottingham).

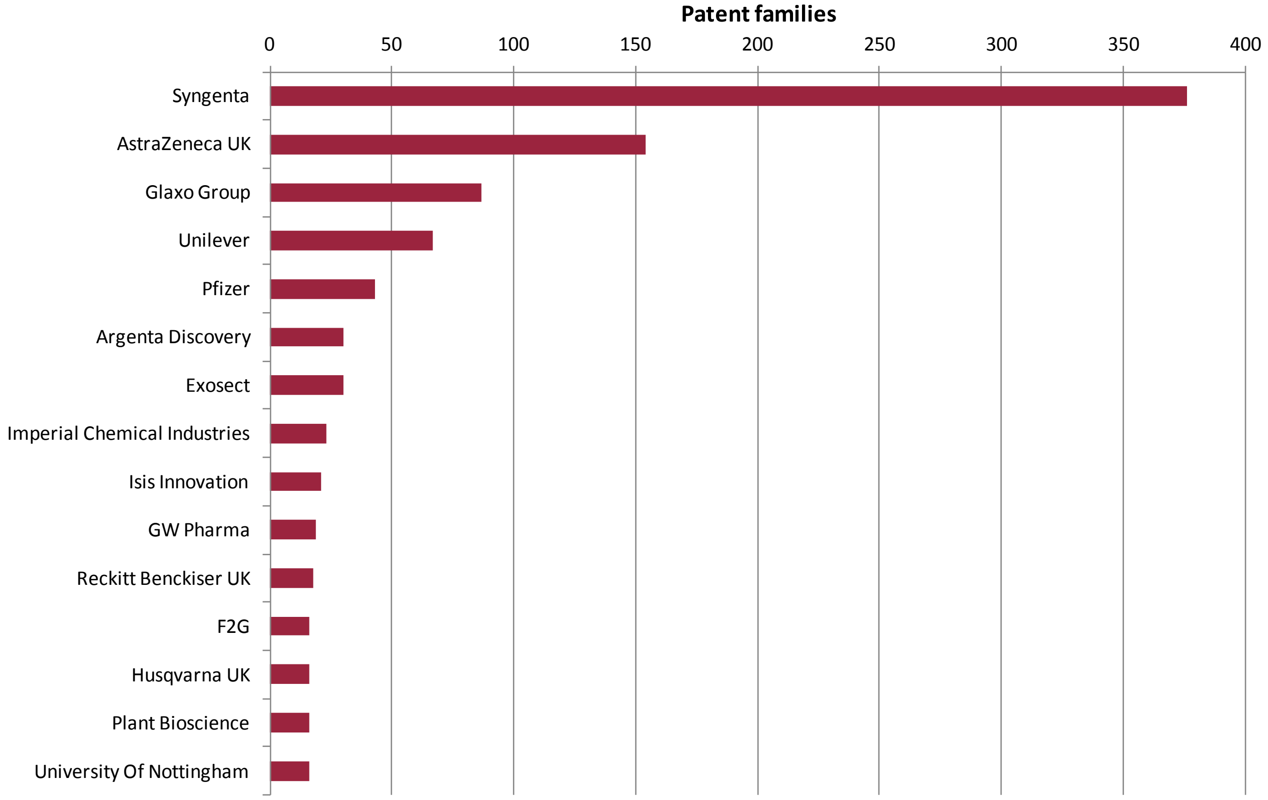

Figure 9: Top UK applicants

3.2 Collaboration

Figure 10 is a collaboration map showing all collaborations between the top ten UK applicants in the dataset and their collaborators. Each dot on the collaboration map represents a patent family and two applicants are linked together if they are named as joint applicants on a patent application. A collaboration map indicates instances where joint work in solving a problem has resulted in a shared application for a patent.

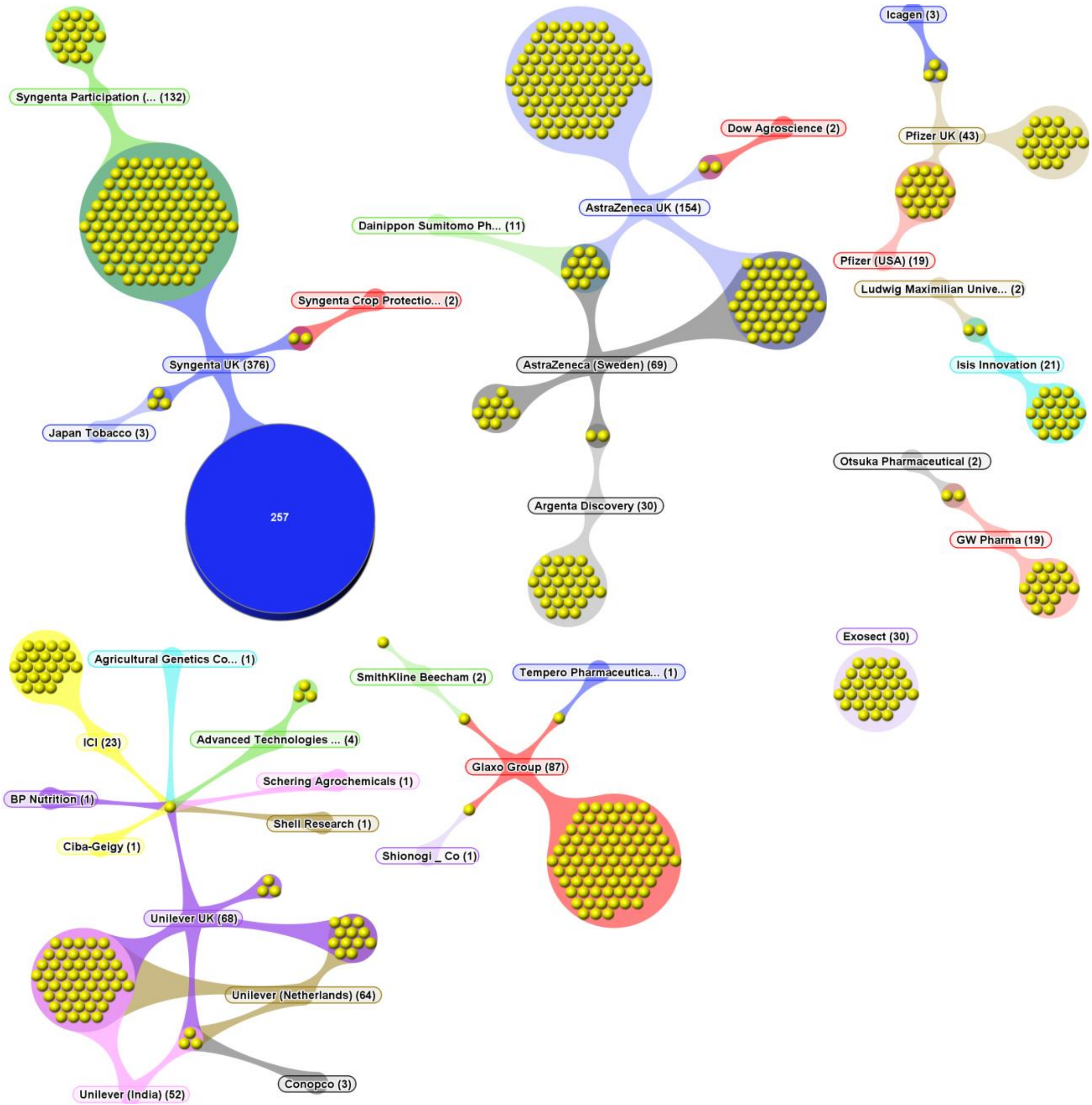

Figure 10: Collaboration map showing all collaborations between the top 10 UK applicants and their collaborators

Figure 10 shows that none of the top five applicants (Syngenta, AstraZeneca, Glaxo Group, Unilever or Pfizer) have worked together on any joint patent applications. Some collaboration is clearly evident, including a fair degree of international collaboration, though very little involves academia.

3.3 UK inventor mobility

Figure 11 shows the top worldwide applicants with named UK inventors on their published patents. Comparison with the number of patent families from the top UK applicants, Figure 9, suggests that many UK inventors work for UK applicants, including multinational applicants like Syngenta and AstraZeneca that have operations in the UK and therefore appear in the top UK applicants chart (Figure 9).

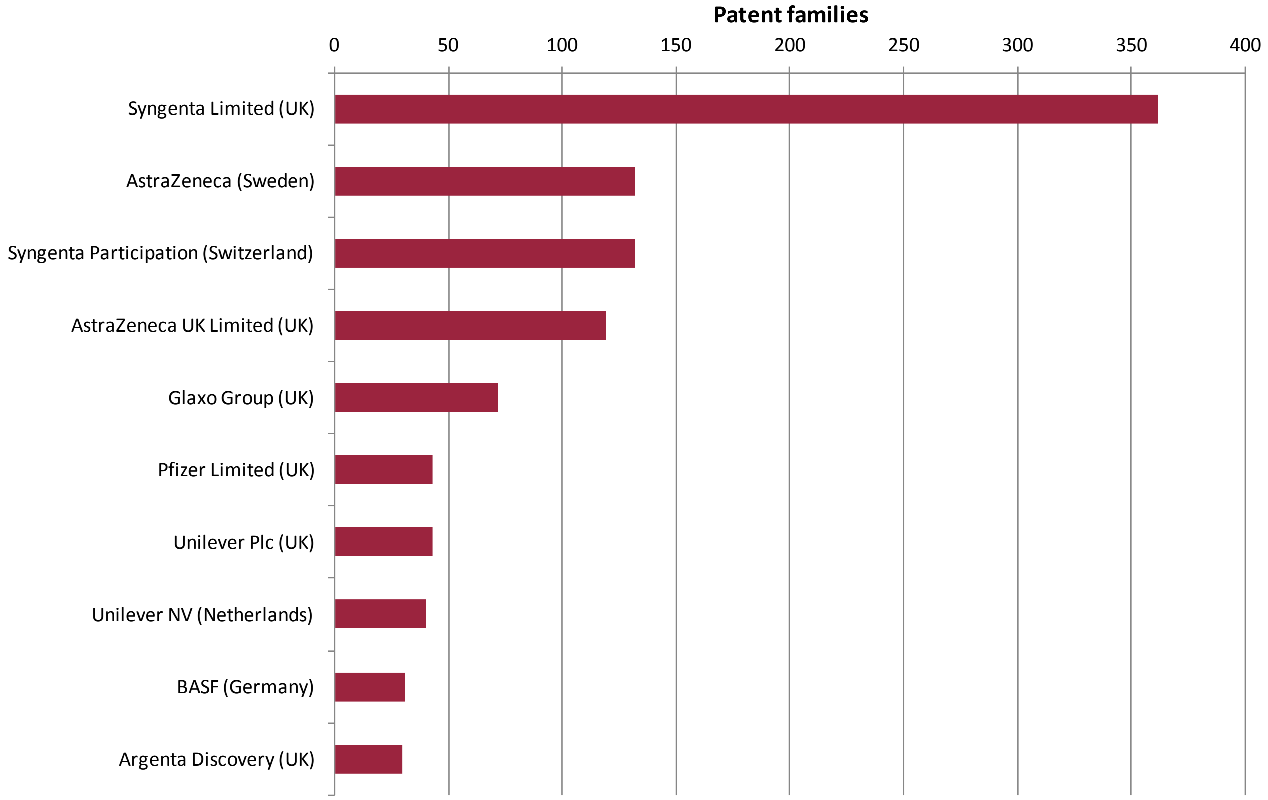

Figure 11: Top worldwide applicants with named UK-based inventors

3.4 How active is the UK?

A subset of the main worldwide patent dataset designed to reflect UK patenting activity was selected. Figure 12 shows the annual change in agri-science patenting arising from UK patenting activity against the worldwide year-on-year change in this field shown in Figure 2; this shows that UK patenting activity in agri-science has been lower than the worldwide change in agri-science patenting activity for seven of the nine data points plotted in Figure 12. The last three years measured have shown a bigger difference between UK agri-science patenting activity compared to worldwide patenting activity.

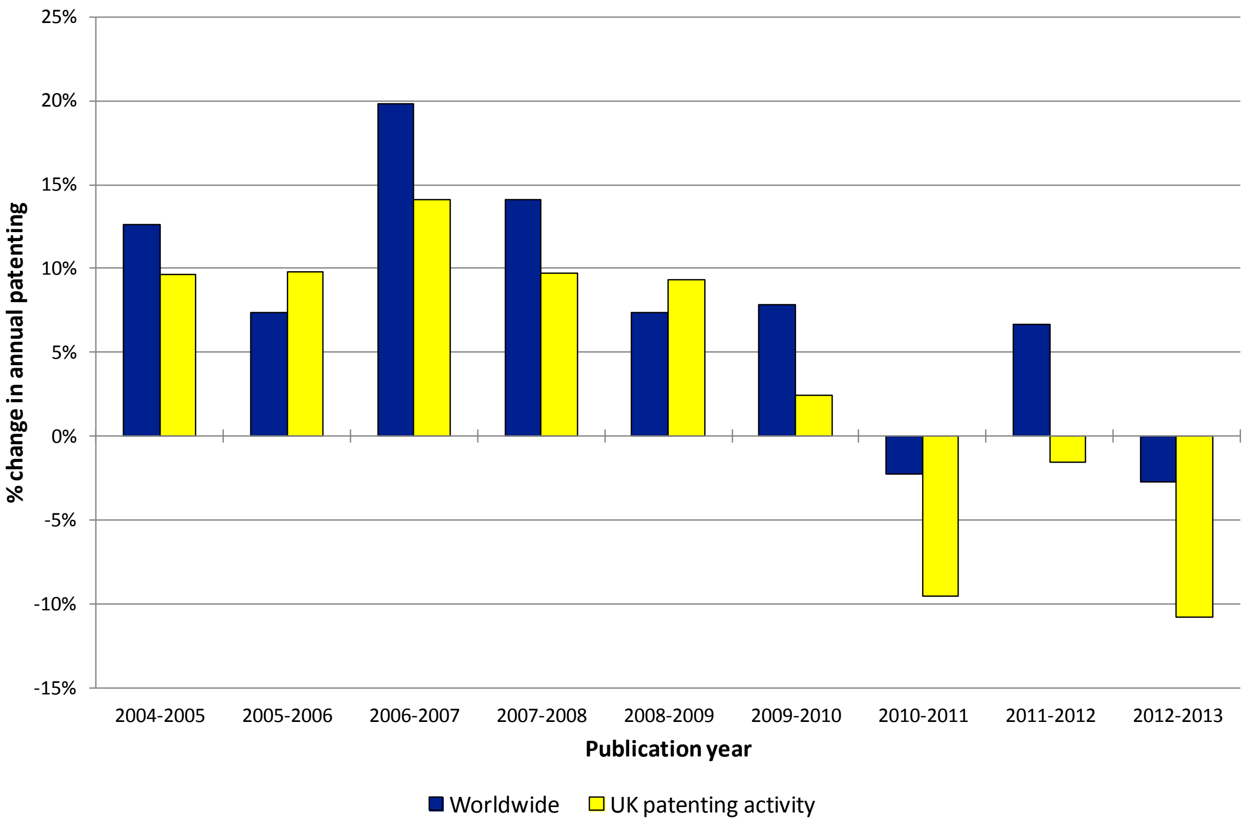

Figure 12: Year-on-year change in UK and worldwide agri-science patenting

Similar patent subsets were created to reflect patenting activity taking place in several comparator countries (France, Germany, USA, Japan and China) to produce the comparison chart shown in Figure 13.

Chinese patenting activity overshadows many of the other data points across most of the time period analysed, especially the 240% increase in Chinese patenting activity between 2006 and 2007. The majority of Chinese patenting activity in the step-shift since 2006 are applications from Chinese universities. This sharp increase is explained by a change in Chinese government policy to give Chinese universities grants to pay for filing patent applications and a change to rank Chinese universities against each other according to how many patents they have filed[5]. In 2004 Chinese patenting activity resulted in 3000 patent families compared to over 38,000 in 2013 and the average annual growth of Chinese patenting activity in agri-science over the time period measured is almost 50%. This significant and rapid growth resulting from Chinese patenting activity is not specific to agri-science and is often seen in a wide range of different technology areas.

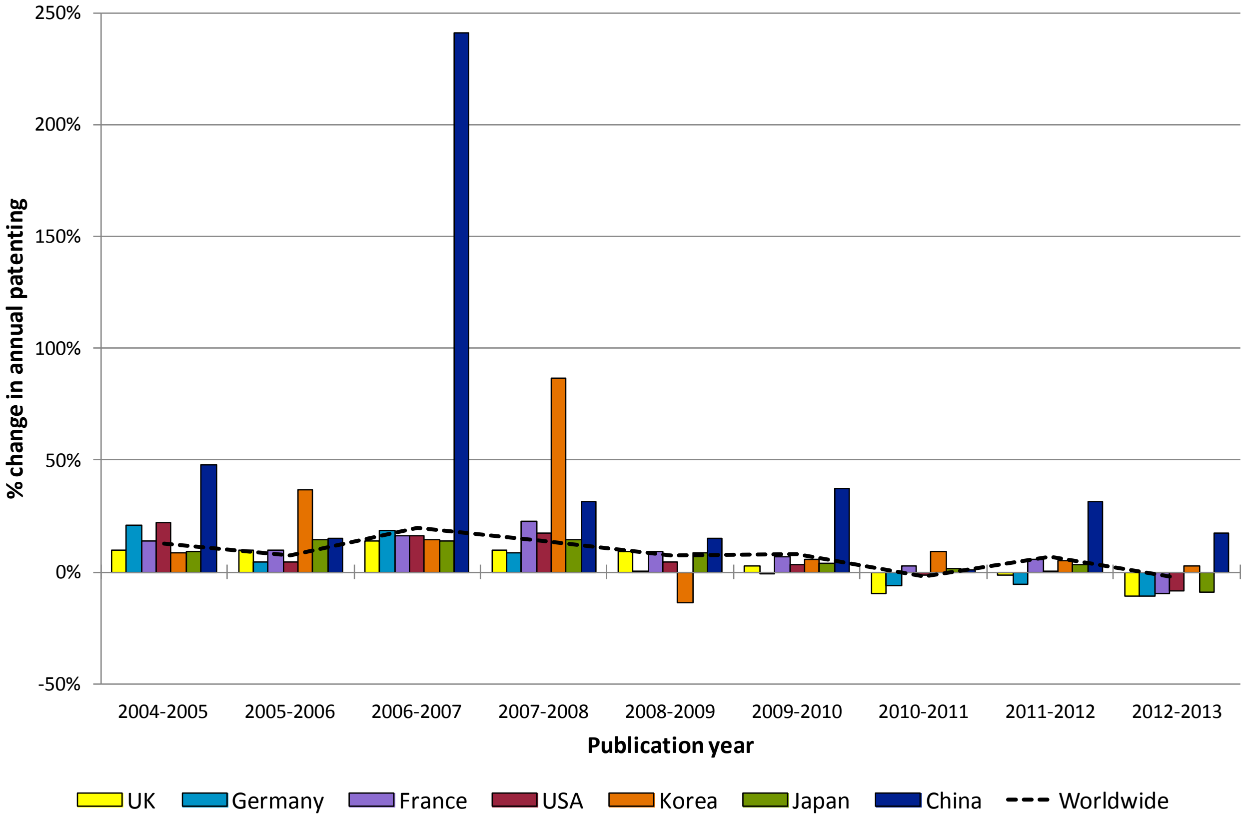

Figure 13: Year-on-year change in UK agri-science patenting against comparison countries

[5] Fisch et al - http://www.uni-patente.de/wordpress/wp-content/uploads/Download.pdf.

The influence of the significant increase in Chinese patenting activity makes it difficult to draw comparisons between the other countries presented in Figure 13, so the same content has been reproduced in Figure 14 but with Chinese patenting activity removed. Figure 14 makes it a lot easier to compare UK patenting activity against the other comparator countries and the worldwide trend.

Although the quantity of US and Japanese patenting in agri-science is high (as shown in Figure 3), Figure 14 highlights that US and Japanese patenting activity has shown a smaller change with an average year-on-year growth over the time period analysed of only 6.6%. This is in direct comparison to the growth arising from Korean patenting activity which has averaged over 17% year-on-year growth over the ten-year time period studied, with an 87% increase between 2007 and 2008.

Figure 3 shows that UK patenting activity in agri-science is relatively small and Figure 14 shows that, on a side-by-side comparison, UK patenting activity is still behind most comparator countries. Germany has a lower average year-on-year growth (3.2%) than the UK (3.7%) with all the other comparison countries showing considerably higher average year-on-year growth over the time period analysed (France 8.5%, Korea 17.3%, Japan 6.6%, USA 6.6%), with a worldwide average year-on-year growth of 7.9% between 2004 and 2013.

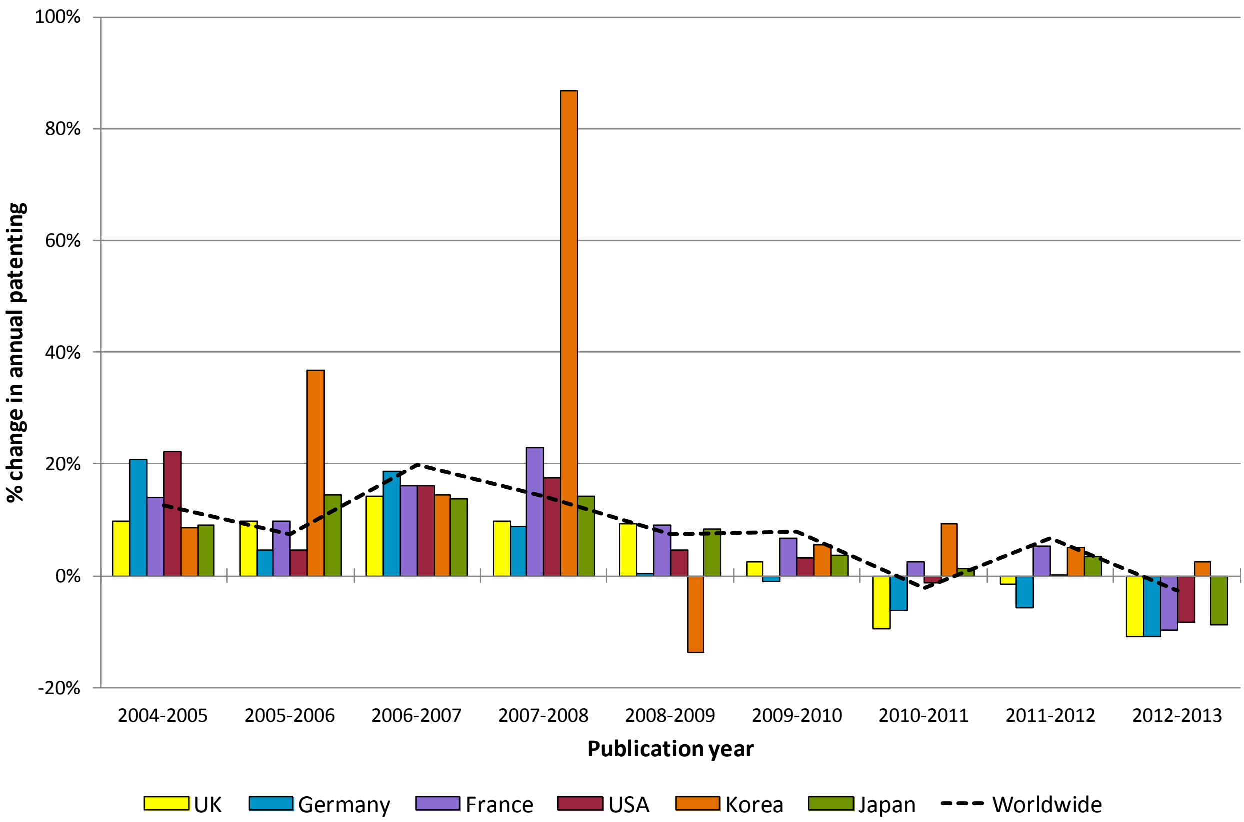

Figure 14: Year-on-year change in UK agri-science patenting against comparison countries (excluding China)

4 Patent landscape map analysis

In order to give a snapshot as to what the agri-science patent landscape looks like, a patent map provides a visual representation of the dataset. Patent families are represented on a patent map by dots and the more intense the concentration of patents (*i.e.* the more closely related they are) the higher the topography as shown by contour lines. The patents are grouped according to the occurrence of keywords in the title and abstract and examples of the reoccurring keywords appear on the patent map[6].

Figure 15 shows a patent landscape map of the most recent agri-science patent families (2011-2013). The map shows a clear divide between mechanical-based agri-science patents and biochemistry agri-science patents. The keywords surrounding the largest ‘snow-capped peak’ in the top-right of the landscape map shows that the highest concentration of inventions (patent families) in this dataset appear to be directed towards chemicals, such as herbicides, fungicides and pesticides to prevent crop and plant damage and improve production.

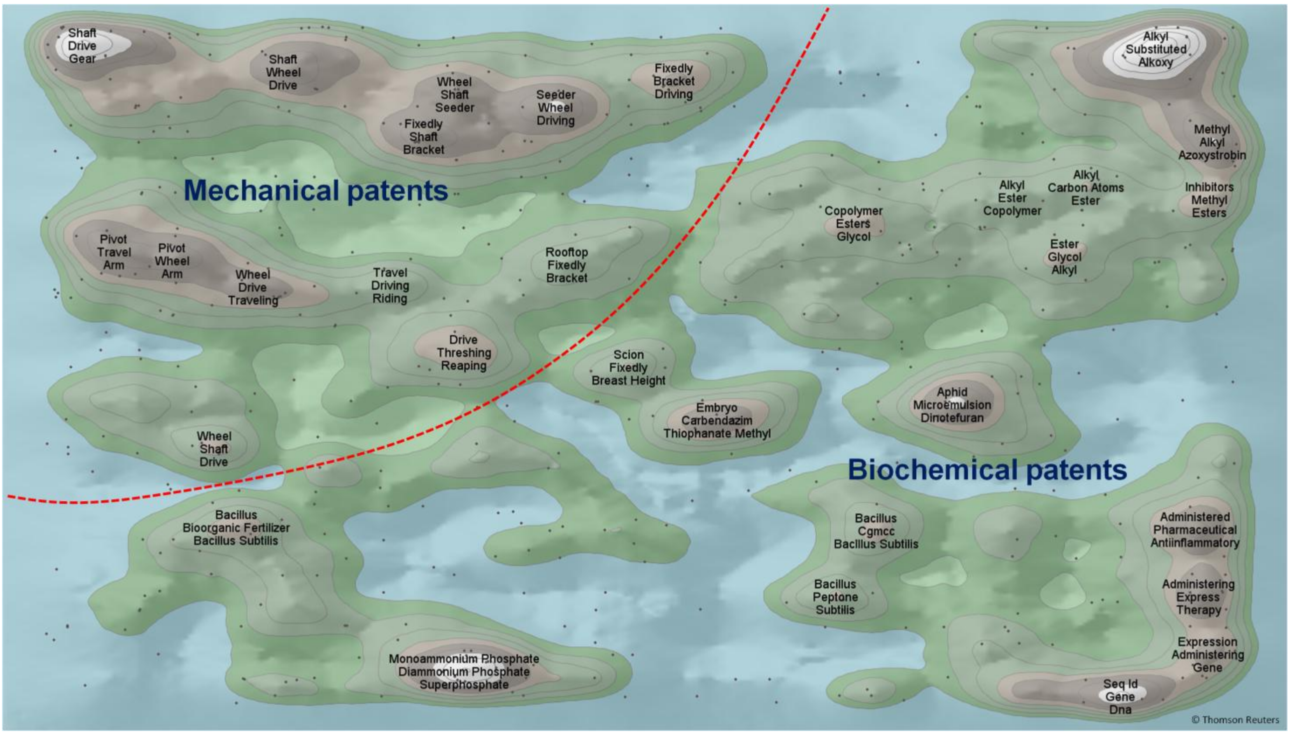

Figure 15: Patent landscape map of all patent families relating to agri-science (2011-2013)

The patent landscape map shown in Figure 16 is the same patent map shown in Figure 15, but with specific patent families (dots) highlighted. The map in Figure 16 highlights the patent families filed by the top five worldwide ‘mechanical’ applicants within the agri-science sector, namely Iseki, Kubota, Yanmar, Mitsubishi and John Deere. Examples of these inventions include automated seedling transplanters, combine harvester header float systems, smart fertiliser distributors, and biomechanical seed assessment systems. There is a relatively tight grouping of patents from these applicants suggesting multiple inventions with potentially overlapping scopes within the same technology space.

[6] Further details regarding how patent landscape maps are produced is given in Appendix C.

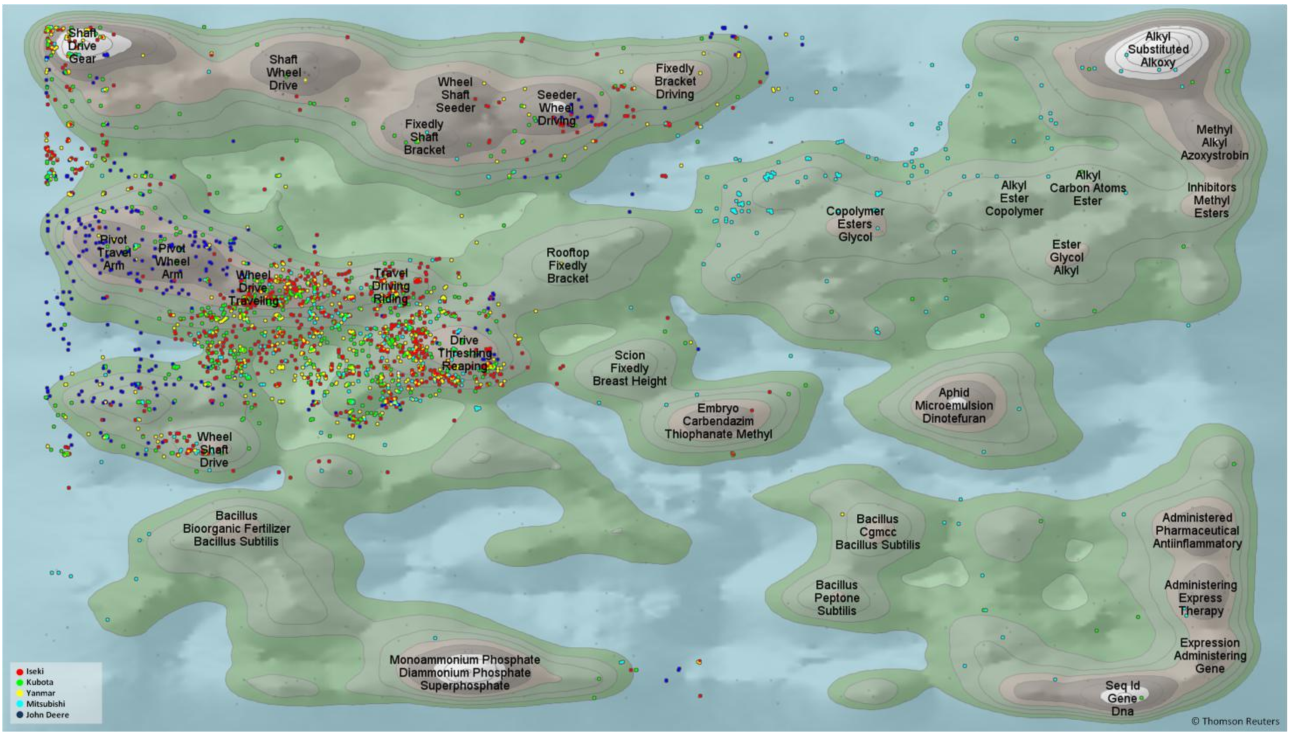

Figure 16: Agri-science patent landscape map with top 'mechanical' applicants highlighted

Figure 17 shows the same landscape map but with the top worldwide 'biochemical' applicants within the agri-science sector highlighted, namely Bayer, Sumitomo, BASF and Syngenta. As in Figure 16 there is a noticeable clustering of patents from these companies in recent years (2011-2013). Examples of these inventions include plant protection agents, improving paddy field damage using neonicotinoides or arylpyrazoles, and producing water-absorbing resin particles.

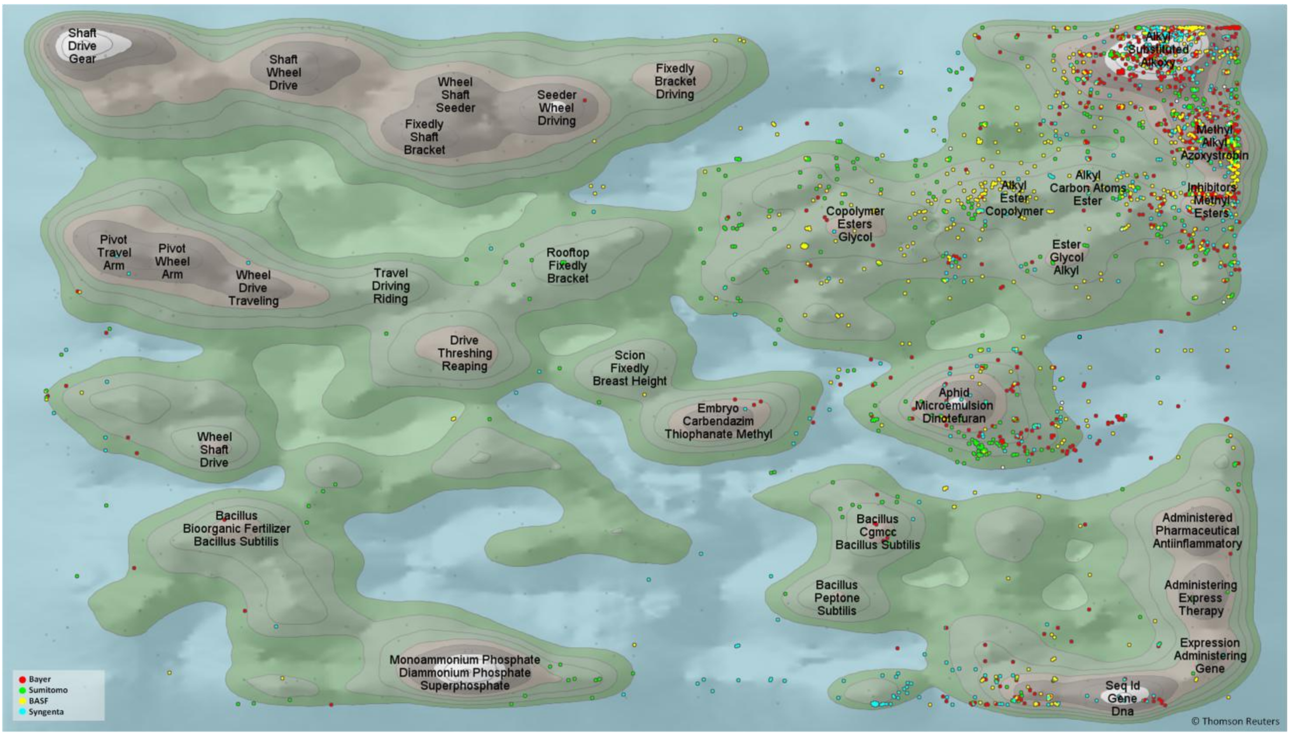

Figure 17: Agri-science patent landscape map with top 'biochemical' applicants highlighted

5 Conclusions

There are more than 400,000 published patent applications between 2004 and 2013 relating to agri-science, resulting in almost 120,000 patent families (inventions). Patenting activity in this field grew steadily over the first half of the last decade at a level well above the general worldwide increase in patenting but agri-science patenting has levelled out in recent years and since 2010 it is around 10% lower than the general worldwide increase in patenting.

The Japanese agricultural machinery company Iseki has the most patent families with several other manufacturing companies appearing in the list of top applicants, including Kubota, Yanmar, Mitsubishi and John Deere. Unsurprisingly there is also a large proportion of agri-science patents belonging to major chemical companies, including Bayer, BASF and Syngenta, who are developing new chemicals to improve, for example, pest control and crop productivity rates.

Approximately three-quarters of all agri-science inventions are filed by Chinese, US and Japanese applicants, with UK applicants accounting for just 2.3% of the dataset. UK patenting activity in agri-science increased steadily between 2004 and 2010 but has dropped in the last three years with the amount of UK agri-science patenting activity in 2013 back at the level last seen in 2007. This has had the knock-on effect that UK patenting activity in agri-science is relatively low compared to the other major patenting nations and the average year-on-year growth in UK agri-science patenting activity between 2004 and 2013 is less than half of the worldwide average.

However, the UK has filed slightly more agri-science patents than expected given the overall level of patenting activity from UK applicants across all areas of technology and the Relative Specialisation Index suggests that UK applicants are more specialised in agri-science than their counterparts in Japan, USA, Germany, Netherlands, France, Sweden, Italy and Spain.

Appendix A Interpretation notes

A.1 Patent databases used

The *Thomson Reuters* World Patent Index (WPI) was interrogated using *Thomson Innovation*[7], a web-based patent analytics tool produced by *Thomson Reuters*. This database holds bibliographic and abstract data of published patents and patent applications derived from the majority of leading industrialised countries and patent organisations, *e.g.* the World Intellectual Property Organisation (WIPO), European Patent Office (EPO) and the African Regional Industry Property Organisation (ARIPO). It should be noted that patents are generally classified and published 18 months after the priority date. This should be borne in mind when considering recent patent trends (within the last 18 months).

The WPI database contains one record for each patent family. A patent family is defined as all documents directly or indirectly linked via a priority document. This provides an indication of the number of inventions an applicant may hold, as opposed to how many individual patent applications they might have filed in different countries for the same invention.

A.2 Priority date and publication date

Priority date: The earliest date of an associated patent application containing information about the invention.

Publication date: The date when the patent application is published (normally 18 months after the priority date or the application date, whichever is earlier).

Analysis by priority year gives the earliest indication of invention.

A.3 WO and EP patent applications

International patent applications (WO) and European patent applications (EP) may be made through the World Intellectual Property Organization (WIPO) and the European Patent Office (EPO) respectively.

International patent applications may designate any signatory states or regions to the Patent Cooperation Treaty (PCT) and will have the same effect as national or regional patent applications in each designated state or region, leading to a granted patent in each state or region.

European patent applications are regional patent applications which may designate any signatory state to the European Patent Convention (EPC), and lead to granted patents having the same effect as a bundle of national patents for the designated states.

Figures for patent families with WO and EP as priority country have been included for completeness although no single attributable country is immediately apparent.

[7] http://info.thomsoninnovation.com

A.4 Patent documents analysed

The agri-science patent dataset for analysis was identified in conjunction with patent examiner technology-specific expertise. A search strategy was developed and the resulting dataset was extracted in July 2014 using International Patent Classification (IPC) codes, Co-operative Patent Classification (CPC) codes and keyword searching of titles and abstracts in the *Thomson Reuters* World Patent Index (WPI) and limited to patent families with publications between 2004 and 2013.

The applicant and inventor data was cleaned to remove duplicate entries arising from spelling errors, initialisation, international variation (Ltd, Pty, GmbH *etc*.), or equivalence (Ltd., Limited, *etc*.).

A.5 Analytics software used

The main computer software used for this report was a text mining and analytics package called *VantagePoint*[8] produced by *Search Technology* in the USA. The patent records exported from *Thomson Innovation* were imported into *VantagePoint* where the data was cleaned and analysed. The patent landscape maps used in this report were produced using *Thomson Innovation*.

[8] http://www.thevantagepoint.com

Appendix B Relative Specialisation Index

Relative Specialisation Index (RSI) was calculated as a correction to absolute numbers of patent families in order to account for the fact that some countries file more patent applications than others in all fields of technology. In particular, US and Japanese inventors are prolific patentees. RSI compares the fraction of agri-science patents found in each country to the fraction of patents found in that country overall. A logarithm was applied to scale the fractions more suitably. The formula is given below:

$$\log_{10}\left(\frac{n_i / n_{total}}{N_i / N_{total}}\right)$$

where
n_i = number of agri-science patent publications in country i
n_{total} = total number of agri-science patent publications in dataset
N_i = total number of patent publications in country i
N_{total} = total number of patent publications in dataset

The effect of this is to highlight countries which have a greater level of patenting in agri-science than expected from their overall level of patenting, and which would otherwise languish much further down in the lists, unnoticed. Please not that India is **not** included in the RSI measure because the worldwide patent databases have poor coverage of Indian applicant address (applicant country) data.

Appendix C Patent landscape maps

A patent landscape map is a visual representation of a dataset and is generated by applying a complex algorithm with four stages:

i) **Harvesting documents** – When the software harvests the documents it reads the text from each document (ranging from titles through to the full text). Non-relevant words, known as stopwords, (*e.g.* “a”, “an”, “able”, “about” *etc*) are then discounted and words with common stems are then associated together (*e.g.* “measure”, “measures”, “measuring”, “measurement” *etc*).

ii) **Analysing documents** – Words are then analysed to see how many times they appear in each document in comparison with the words’ frequency in the overall dataset. During analysis, very frequently and very infrequently used words (*i.e.* words above and below a threshold) are eliminated from consideration. A topic list of statistically significant words is then created.

iii) **Clustering documents** – A Naive Bayes classifier is used to assign document vectors and Vector Space Modelling is applied to plot documents in n-dimensional space (*i.e.* documents with similar topics are clustered around a central coordinate). The application of different vectors (*i.e.* topics) enables the relative positions of documents in n-dimensional space to be varied.

iv) **Creating the patent map** – The final n-dimensional model is then rendered into a two-dimensional map using a self-organising mapping algorithm. Contours are created to simulate a depth dimension. The final map can sometimes be misleading because it is important to interpret the map as if it were formed on a three-dimensional sphere.

Thus, in summary, published patents are represented on the patent map by dots and the more intense the concentration of patents (*i.e.* the more closely related they are) the higher the topography as shown by contour lines. The patents are grouped according to the occurrence of keywords in the title and abstract and examples of the reoccurring keywords appear on the patent map. Please remember there is no relationship between the patent landscape maps and any geographical map.

Please note that the patent maps shown in this report are snapshots of the patent landscape, and that patent maps are best used as an interactive tool where analysis of specific areas, patents, applicants, inventors *etc* can be undertaken ‘on-the-fly’.

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