



Executive Summary

Patent Mapping – Bioeconomy Phase II

Prepared for Office of National Higher Education Science Research and
Innovation Policy Council

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Project objectives and summary

Project objectives

- This section focuses on an analysis of published granted patents, patent applications from global sources and those with inventors located in Thailand and non-patent technical literature originating from global sources and those located in Thailand within the last 10 years and determine Thai strengths in the following research areas. An additional objective of this study is to identify underlying technologies that are common amongst these research areas. Research areas were provided and defined as follows:
 - Modern agriculture and food for the future
 - Precision agricultural
 - Gene utilization
 - Functional food
 - Tourism
 - Water and waste management
 - Energy and biomaterials
 - Biorefinery
 - Biomaterial
 - Health and medical
 - Precision medicine
 - Biopharmaceuticals
- Query strings were developed for each topic and were searched against the Derwent World Patents Database (DWPI) from priority filing year 2008 forward, and against the Web of Science from publication year 2008 forward.

Overview and summary

- In both patents and literature publications, all categories show growth over the past decade. In patents, water and waste management and precision agriculture show the greatest recent growth, suggesting strong investment in these spaces.
- When comparing Clarivate IP index and recency (remaining potential enforceability) several spaces show a high IP index (biopharmaceuticals, gene utilization and precision medicine) and several show high recency (precision agriculture, water and waste management, and functional food). None show high values in both measurements.
- Water and waste management, biorefinery and biomaterials show higher than average correlation between categories, suggesting an intersection of these technical spaces. Additionally, precision medicine and biopharmaceuticals also show overlap in the space.
- Comparing patent volumes and literature, nearly all spaces show higher volume in literature, with the exceptions of biorefinery, in which patent volumes are ahead of literature for the entire timeline, suggesting a stronger commercial focus of research in this space. Higher literature publication counts may be suggestive of increased primary research, but also may be a function of a lower barrier to publishing, compared to the financial expenditure required to file patents. Functional food, which begins with more literature than patents, but a strong increase beginning in 2015 shows patent volumes surpassing literature in 2016. Water and waste management patent filing also surpasses literature in 2015.
- Chinese entities feature prominently in nearly all technical categories. In water and waste management, 9 of the top 10 assignees originate in China. This corresponds with current overall trends in Chinese patenting.
- In Thai literature analysis, health and medical technology had the highest output. Most top 10 Thai entities in each space were academic institutions.
- This presentation provides a high-level overview of the patents and literature publication trends in the study. More information, including listings of Thai papers and patents, highly cited papers and high Clarivate IP index patents may be found in the accompanying Excel files.

Overall technology time trends and technical correlation

Overall technology time trends and technical correlation

- The following section contains charts and metrics for each of the 8 subcategories from the 4 main research areas.
- Correlation charts provide insight to the 8 technical spaces, showing regional filing information, remaining enforceability, and Clarivate IP index score.
- An explanation of the Clarivate IP score can be found at the end of this presentation.
- Additionally, a cross correlation table is provided, showing any overlap of documents between the 8 technical categories.

Technology timeline of patents

Technology Category		08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	AAGR (2013 - 2016)	Growth rate - 2008 - 2016 (inventions/yr.)
Topic 1	Precision agriculture	343	437	510	592	731	1038	1142	1792	2664	2520	337	12106	84%	22%	250.98
	Gene utilization	2936	3278	3627	3888	4214	4639	3969	4216	5352	3814	556	40489	66%	0%	231.88
	Functional food	832	885	860	1089	1231	1293	1413	2139	2686	1916	227	14571	75%	13%	208.13
Topic 2	Water and waste management	14302	16688	19610	12776	17236	30319	34947	46510	56980	56532	7113	313013	80%	25%	5139.92
Topic 3	Biorefinery	2274	2419	2606	2799	3140	3084	3166	3449	3560	2436	320	29253	65%	2%	160.65
	Biomaterial	1141	1249	1432	1446	1469	1384	1552	1664	1807	1399	225	14768	64%	3%	68.12
Topic 4	Precision Medicine	1708	1708	1991	2226	2070	2448	2515	2704	3130	1976	344	22820	67%	6%	165.77
	Biopharmaceuticals	14986	14414	15347	16075	16248	17313	17439	20132	22386	11207	1366	166913	64%	5%	869.60

- All of the technical categories show growth increases over the 10 years of the study.
- The highest growth rates from 2012 – 2016 (the last year for which patent data is likely complete) (average annual growth rate or AAGR) are found in water and waste management (25%) and precision agriculture (22%).
- Other technologies show lower AAGR: precision medicine (6%), biopharmaceuticals (5%), biomaterials (3%) and biorefinery (2%). This suggests a recent slowing in innovation in these technologies. Gene utilization has an AAGR of 0%, indicating that recent activity in this space is essentially flat.

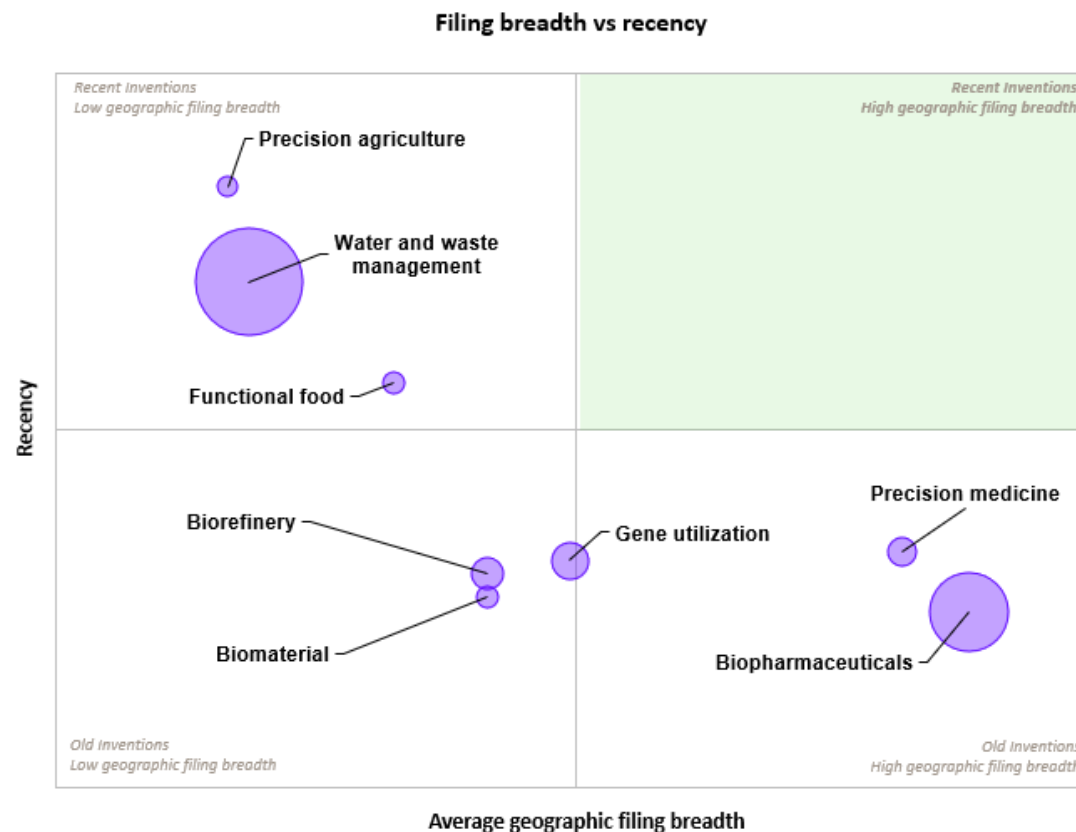
Technology timeline of publications

<i>Technology Category</i>		<i>08</i>	<i>09</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>Total publications</i>	<i>% recency (publications since 2012)</i>
Topic 1	Precision agriculture	2109	2327	2315	2456	2914	3334	3479	3680	4223	4359	2245	33441	66%
	Gene utilization	4699	5035	5129	5479	5362	5584	5750	6030	6021	5993	5123	60205	58%
	Functional food	1100	1304	1380	1609	1731	1898	1958	2441	2443	2815	2170	20849	64%
Topic 2	Water and waste management	22962	25980	29578	29833	34336	36258	36715	41884	46617	46701	32722	383586	63%
Topic 3	Biorefinery	453	693	1031	1370	1456	1734	1878	1781	2039	2002	1395	15832	69%
	Biomaterial	861	1192	1510	1711	1873	1943	2085	2068	2236	2366	1474	19319	65%
Topic 4	Precision medicine	4717	5666	6603	7676	8423	9021	9976	10647	11533	12708	8905	95875	65%
	Biopharmaceuticals	49162	51903	55264	58758	62148	64569	67287	70254	72327	73706	52369	677747	61%

- In literature, all of the technical categories show growth increases over the 10 years of the study.
- Growth is generally lower than that seen in the patent trends. This again may reflect relative maturity in primary research having transitioned to commercial applications in patents.
- Biorefinery papers have the highest degree of recency, with 69% of papers in this space published since 2012.
- Biopharmaceuticals and water and waste management represent the largest literature collections in the study.

Technical correlation: filing breadth vs recency

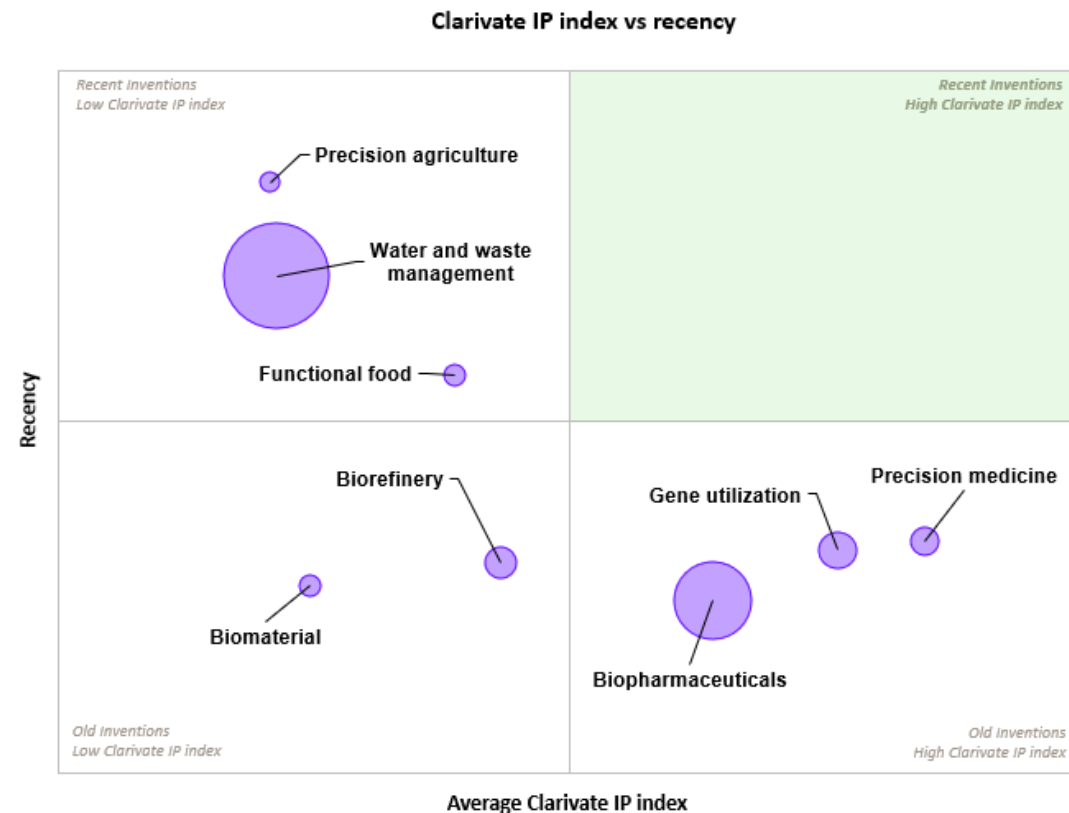
	Technology Category	Geographic filing breadth	% Recency (inventions filed since 2012)	Total inventions
Topic 1	Precision agriculture	1.13	84%	12106
	Gene utilization	1.79	66%	40489
	Functional food	1.45	75%	14571
Topic 2	Water and waste management	1.17	80%	313013
Topic 3	Biorefinery	1.63	65%	29253
	Biomaterial	1.63	64%	14768
Topic 4	Precision medicine	2.43	67%	22820
	Biopharmaceuticals	2.56	64%	166913



- These graphics show the comparison of geographic filing breadth with recency. Filing breadth is a view of how widely the inventions in the technical space have been filed internationally. As foreign filing represents significant financial investment, this is generally an indication of the commercial potential value an invention has. Precision medicine and biopharmaceuticals show high filing breadth, suggesting more potential international commercial value of these technologies.
- Recency describes the remaining potential enforceable time remaining. High recency suggests that a technical space is experiencing growth, as new inventions are being filed. Precision agriculture, water and waste management and functional food have above average recency.
- There are no technical spaces in this study which have both high recency and high filing breadth.

Technical correlation: Clarivate IP index vs recency

	<i>Technology Category</i>	<i>Average Clarivate IP index</i>	<i>% Recency (inventions filed since 2012)</i>	<i>Total inventions</i>
Topic 1	Precision agriculture	27.13	84%	12106
	Gene utilization	38.27	66%	40489
	Functional food	30.76	75%	14571
Topic 2	Water and waste management	27.26	80%	313013
Topic 3	Biorefinery	31.67	65%	29253
	Biomaterial	27.93	64%	14768
Topic 4	Precision medicine	39.97	67%	22820
	Biopharmaceuticals	35.82	64%	166913



- These graphics show the intersection of Clarivate IP index and recency. A description of the IP index can be found at the end of this document.
- Precision medicine, gene utilization and biopharmaceuticals have the highest IP index values, but low comparative recency. Precision agriculture, water and waste management and functional food have high recency but low IP index values. As the items that comprise the IP index are frequently reliant on time (citations, filing breadth) these topics may increase in IP index over time.

Technology correlation across categories

	Precision agriculture	Gene utilization	Functional food	Water and waste management	Biorefinery	Biomaterials	Precision medicine	Biopharmaceuticals
Precision agriculture	12106	135	4	112	6	6	10	16
Gene utilization	135	40489	782	144	150	82	339	3145
Functional food	4	782	14571	86	9	8	41	396
Water and waste management	112	144	86	332243	5108	1198	83	603
Biorefinery	6	150	9	5108	29253	6121	2	65
Biomaterials	6	82	8	1198	6121	14768	1	22
Precision medicine	10	339	41	83	2	1	22820	10799
Biopharmaceuticals	16	3145	396	603	65	22	10799	134061

- This table shows the correlation of the 8 technology categories.
- There appears to be above-average correlation between water and waste management and both biorefinery and biomaterials.
- There is some correlation in the Topic 1 categories (precision agriculture, gene utilization and functional food) suggesting some technical overlap in this topic.
- Additionally, precision medicine and biopharmaceuticals show strong correlation between the categories.

Patents of Thai origin

<i>Category</i>	<i>08</i>	<i>09</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>Total inventions</i>	<i>% Recency (inventions filed since 2012)</i>	<i>Average Clarivate IP index</i>
Modern agriculture and food for the future	2	3		4	2	2	6	2	4			25	64%	90.72
Water and waste management	4	6	2	1	1	2	2	3	2			23	43%	75.13
Energy and biomaterials	1	3	1	4	3	3	1	2	1	1		20	55%	72.65
Health and medical	5	2	5	13	5	5	3	1	4			43	42%	76.83

- This table represents patents of Thai origin across the 4 main technical categories. These patents are defined as having Thai priority (first filed with the Thai patent office) or having an inventor with an address listed in Thailand. Thus, these patents do not necessarily reflect entities solely located in Thailand.
- Health and medical shows the highest overall volume, with 43 total inventions. Most of these inventions were filed in 2011, so the recency value for this category is comparatively low at 42%.
- Patents in modern agriculture and food for the future have the highest average Clarivate IP index, at 90.72.
- The metrics for these categories should be used with caution, as even a few outlier publications can significantly change the values. A listing of all patents with corresponding metadata can be found in the accompanying documentation.

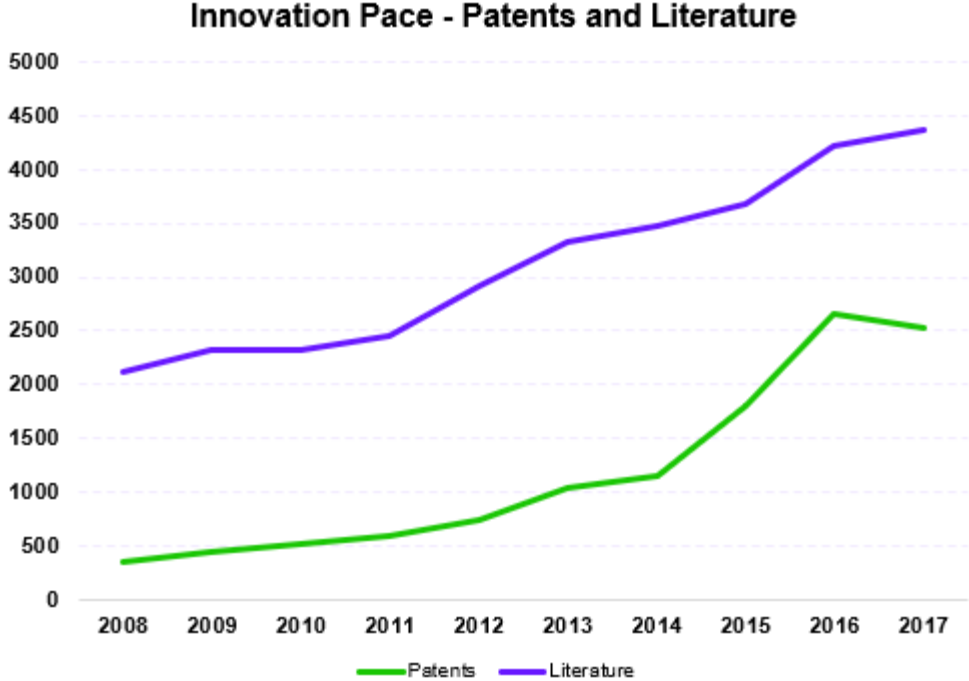
Patent and literature time trends

Patent and literature time trends

- The following section contains charts and metrics for each of the 8 subcategories from the 4 main research areas.
- Patents are shown by priority (year of first invention filing) year, and literature articles are shown by year of article publication.
- For patents, the latest 2 years may present an incomplete view of invention activity. There is typically a statutory delay from priority filing until inventions are published (generally 18 months) so a decrease in recent years is likely not indicative of a decline in inventive activity in the technical area.
- Similarly, as 2018 is not complete, literature articles do not show a complete picture of publishing activity in the current year and thus 2018 is not captured in the accompanying graphs.
- The accompanying Excel analytics file contains a listing of the top 10 inventors for each for the 8 subcategories.

Precision agriculture technology

Topic 1		
Precision agriculture		
Year	Patents	Literature
2008	343	2109
2009	437	2327
2010	510	2315
2011	592	2456
2012	731	2914
2013	1038	3334
2014	1142	3479
2015	1792	3680
2016	2664	4223
2017	2520	4359
2018	337	2245



- Precision agriculture shows a steady increase over time of both patents and literature publications over the past 10 years.
- Literature trends show a relatively steady growth in this space over time.
- Patents show a higher than previously seen increase in patent filing, beginning in 2015.

Precision agriculture – top organizations

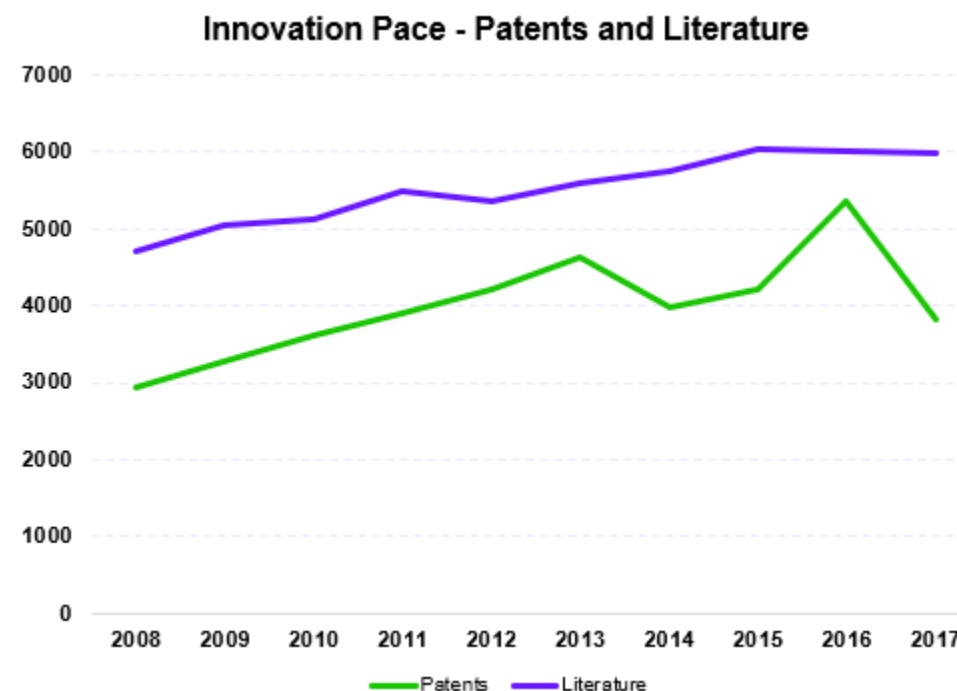
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	Average Clarivate IP index
ISEKI	13	9	17	17	19	24	11	12	18	5	1	146	62%	21.33
China Agricultural University	5	2	12	7	9	14	21	10	23	13	10	126	79%	23.41
Northwest A&F University	3	2	1	7	5	17	10	16	20	17	3	101	87%	23.68
Shandong Agricultural University			1	5	5	1	7	19	24	23	7	92	93%	23.50
John Deere	7	4	5	6	10	13	8	8	11	3		75	71%	116.88
Jiangsu University	2	2	5	7	9	12	8	10	8	11		74	78%	31.05
Huazhong Agricultural University	12	9	6	6	3	5	7	7	10	6	1	72	54%	17.11
Zhejiang University	2	1	4	4	11	4	7	13	6	11	6	69	84%	23.43
South China Agricultural University	5	4	1	8	5	3	8	10	7	13	2	66	73%	25.75
Shihezi University	5	3		3	2	3	6	11	11	8		52	79%	16.21

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Chinese Academy of Sciences	Research Institute	38	47	63	45	64	70	77	97	105	110	37	753	74%	8.01
Centre National de la Recherche Scientifique (CNRS)	Research Institute	23	41	40	47	44	42	41	47	61	58	19	463	67%	10.25
University of California System	Academic	39	46	28	27	44	41	44	33	50	56	21	429	67%	20.45
United States Department of Agriculture (USDA)	Government	38	28	48	28	35	34	29	33	41	34	21	369	62%	12.53
State University System of Florida	Academic	16	35	32	24	18	35	39	33	46	40	12	330	68%	10.00
Helmholtz Association	Research Institute	9	23	22	18	19	29	22	27	48	33	10	260	72%	11.53
Indian Institute of Technology System (IIT System)	Academic	20	15	9	21	14	13	25	24	38	42	15	236	72%	8.50
Consejo Superior de Investigaciones Cientificas (CSIC)	Research Council	13	16	14	20	18	24	27	24	34	29	13	232	73%	18.05
Consiglio Nazionale delle Ricerche (CNR)	Research Institute	12	16	10	16	14	24	27	32	33	32	12	228	76%	9.67
University System of Georgia	Academic	16	16	21	22	20	23	24	21	23	25	14	225	67%	12.00

- In patents, most of the top 10 assignees are from China (8 of the top 10). ISEKI (JP) and John Deere (US) are the exceptions in this space. Shandong Agricultural University has the highest % recency, with 93% of patents filed since 2012.
- Literature publications show a more international distribution, with US-based entities (4) leading. Chinese Academy of Science is the top organization, but is the only Chinese entity in the top 10. CAS also shows high recency, but a comparatively low citation impact score.

Gene utilization technology

Topic 1		
Gene utilization		
Year	Patents	Literature
2008	2936	4699
2009	3278	5035
2010	3627	5129
2011	3888	5479
2012	4214	5362
2013	4639	5584
2014	3969	5750
2015	4216	6030
2016	5352	6021
2017	3814	5993
2018	556	4123



- Gene utilization technology shows a moderate increase in literature publications, following a small decrease in publishing in 2012.
- Patent activity shows an increase in filing over the timeframe of the investigation, but there is a moderate decline in 2014. Filing increases in 2015, followed by a sharp increase in 2016.
- Taken as a whole, the overall filing trends in gene utilization are relatively constant, when the decline and sharp increase in the middle part of the decade are taken into account.

Gene utilization – top organizations

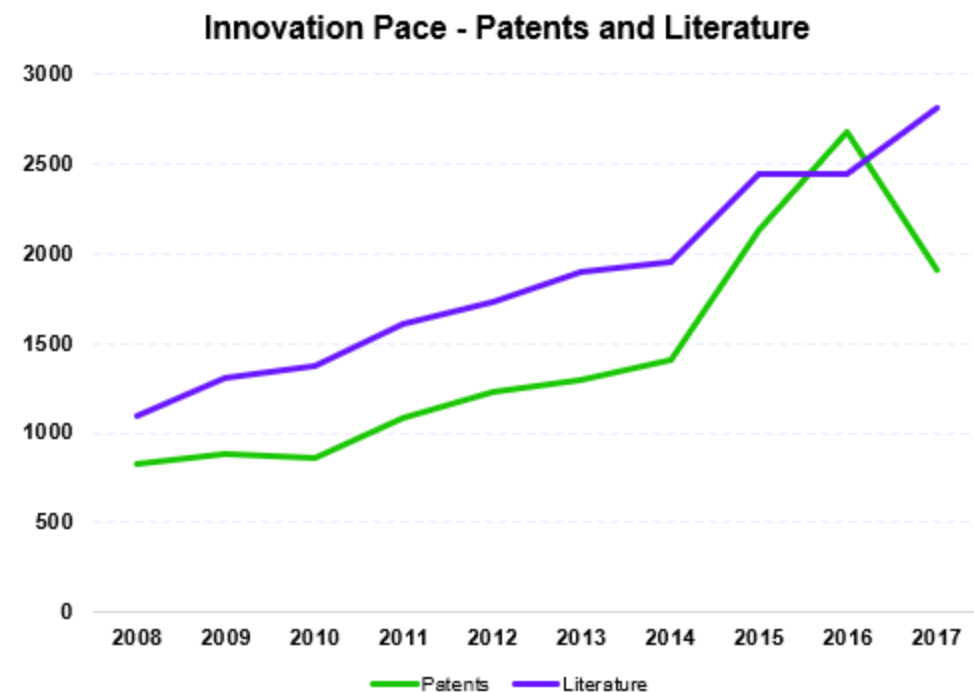
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	Average Clarivate IP index
Monsanto	372	359	407	468	388	425	440	406	344	116		3725	57%	48.26
DowDuPont	297	398	502	436	476	514	277	157	273	202		3532	54%	48.70
Bayer	62	114	89	89	127	99	90	67	73	16	1	827	57%	59.83
Syngenta	50	63	62	97	71	102	58	75	75	58		711	62%	52.03
Chinese Academy of Agricultural Sciences	27	34	52	53	77	143	76	83	45	58	17	665	75%	29.01
China Agricultural University	18	15	47	35	57	55	45	47	43	45	6	413	72%	29.54
Stine Seed Farm	41	48	64	35	59	32	41	19	16	20		375	50%	37.57
Nanjing Agricultural University	11	25	38	35	34	38	26	33	61	46	13	360	70%	31.06
Rural Development Administration	21	30	37	31	38	51	39	34	39	1		321	63%	23.14
Huazhong Agricultural University	18	16	23	37	29	35	25	32	33	33	8	289	67%	29.69

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
United States Department of Agriculture (USDA)	Government	221	195	183	180	177	201	188	223	223	213	95	2099	63%	16.63
Chinese Academy of Sciences	Research Institute	147	159	140	184	184	200	197	219	228	232	98	1988	68%	19.15
Chinese Academy of Agricultural Sciences	Research Institute	89	86	91	138	146	138	174	243	261	248	140	1754	77%	14.62
Indian Council of Agricultural Research (ICAR)	Research Council	57	69	108	93	116	134	135	174	169	190	93	1338	76%	6.43
University of California System	Academic	118	102	109	132	115	118	116	120	104	114	44	1192	61%	25.67
Institut National de la Recherche Agronomique (INRA)	Research Institute	101	93	89	102	84	116	108	80	100	105	46	1024	62%	19.84
Consejo Superior de Investigaciones Cientificas (CSIC)	Research Council	93	72	99	93	93	71	86	76	75	96	24	878	59%	19.54
Empresa Brasileira de Pesquisa Agropecuaria (Embrapa)	Government	80	77	80	65	91	86	104	90	80	92	32	877	66%	7.51
Centre National de la Recherche Scientifique (CNRS)	Research Institute	93	83	78	66	66	81	78	63	84	78	29	799	60%	23.54
China Agricultural University	Academic	60	52	43	60	83	70	73	89	73	81	60	744	71%	15.74

- In gene utilization patents, US/International conglomerates are the top entities, with Monsanto and DowDuPont leading the top organizations. These two entities show filing rates an order of magnitude higher than others, demonstrating a dominant market position. Chinese universities make up half of the top entities in patents.
- In literature, the global spread is more diverse, with the US, China, and South American entities appearing. China shows high % recency from Chinese Academy of Science and Chinese Academy of Agricultural Sciences. Gene utilization shows heavy investment by agricultural entities

Functional food technology

Topic 1		
Functional food		
Year	Patents	Literature
2008	832	1100
2009	885	1304
2010	860	1380
2011	1089	1609
2012	1231	1731
2013	1293	1898
2014	1413	1958
2015	2139	2441
2016	2686	2443
2017	1916	2815
2018	227	2170



- Functional food show close correlation in trends from 2008 through 2014. Both patents and literature show an increase in documents beginning in 2015, but the increase is significantly higher in patents, with an increase from 1,413 filings in 2014 to in 2,139 filings in 2015.
- There appears to be increasing commercial interest in this space, reflective of the higher rate in filing in the later years of the study. It will be interesting to see if this increase continues. This may be reflective of trends towards increasing nutritional yield with less investment of resources as countries cope with growing populations.

Functional food – top organizations

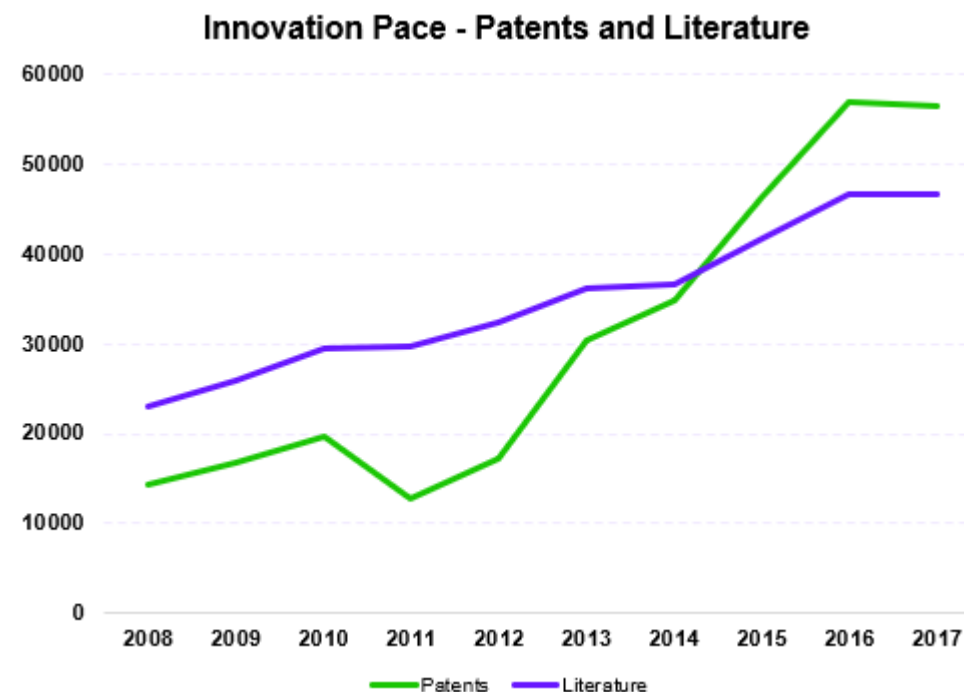
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	Average Clarivate IP index
Jinshanmei Biotechnology					2	3		167	4			176	100%	30.29
Changsha Xiehaoji Biological Eng										141		141	100%	38.41
Rural Development Administration	1	2	6	4	11	7	9	46	43	5		134	90%	27.12
Korea Food Research Institute	5	4	4	12	13	8	18	20	32	8		124	80%	28.06
Nestle	7	20	21	14	19	6	12	6	8			113	45%	68.61
Kyung Hee University	3	1	2	4	9	11	7	24	27	12		100	90%	32.44
Korea Institute of Oriental Medicine		6	2	2	5	1	15	26	25	6		88	89%	34.19
Korea Research Institute Bioscience & Biotechnology	3	5	2	5	10	2	14	14	18	1		74	80%	43.35
Jiangnan University	6	2	6	9	5	3	7	8	9	4	7	66	65%	25.92
Korea Bio Medical Science Institute			6	47	4		1	1	2			61	13%	9.86

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Consejo Superior de Investigaciones Cientificas (CSIC)	Research Council	33	39	43	36	55	54	54	58	63	73	41	549	72%	20.54
United States Department of Agriculture (USDA)	Government	22	28	20	23	29	18	29	35	28	25	12	269	65%	17.66
Indian Council of Agricultural Research (ICAR)	Research Council	9	11	11	13	26	16	22	37	29	41	17	232	81%	11.68
Universidade de Sao Paulo	Academic	15	16	19	22	14	19	28	31	27	24	14	229	69%	14.35
University of California System	Academic	19	21	19	22	25	19	23	20	18	25	8	219	63%	21.86
Institut National de la Recherche Agronomique (INRA)	Research Institute	16	13	20	14	23	15	23	22	25	27	14	212	70%	17.77
University of Massachusetts System	Academic	10	11	10	16	19	15	13	34	32	27	10	197	76%	38.95
University of Massachusetts Amherst	Academic	10	10	8	15	17	15	12	33	30	26	10	186	77%	41.24
Council of Scientific & Industrial Research (CSIR) - India	Academic	6	9	18	17	19	15	20	28	24	17	9	182	73%	16.33
Consejo Nacional de Investigaciones Cientificas y Tecnicas (CONICET)	Academic	4	6	13	13	14	14	28	18	31	23	16	180	80%	12.47

- In patents, Jinshanmi Biotechnology is the top patent assignee in functional food, followed closely by Changsha Xiehaoji Biological Eng. Interestingly, they both show a 100% recency, with nearly all of their filings occurring since 2015. Highest average Clarivate IP index is seen at Switzerland-based Nestle.
- CSIC has the most publications in this space with 529. The Indian Council of Agricultural Research (ICAR) has the highest percent recency, at 81%. University of Massachusetts Amherst has the highest citation impact, at 41.24.

Water and waste management technology

Topic 2		
Water and waste management		
Year	Patents	Literature
2008	14302	22962
2009	16688	25980
2010	19610	29578
2011	12776	29833
2012	17236	32336
2013	30319	36258
2014	34947	36714
2015	46510	41884
2016	56980	46671
2017	56532	46701
2018	7113	32722



- Water and waste management initially show similar rate increases in document from 2008 – 2010. After 2010, publishing continues this general increase. Patents show a decline in 2011, but then show a strong increase in filing, overtaking literature in 2015.
- This is suggestive of a rapid increase in commercial activity in the space. As water is an important resource, it is not unsurprising that entities are interested in commercial protection of innovation in this technology. Continuing environmental pressures may drive new innovation in this space.

Water and waste management – top organizations

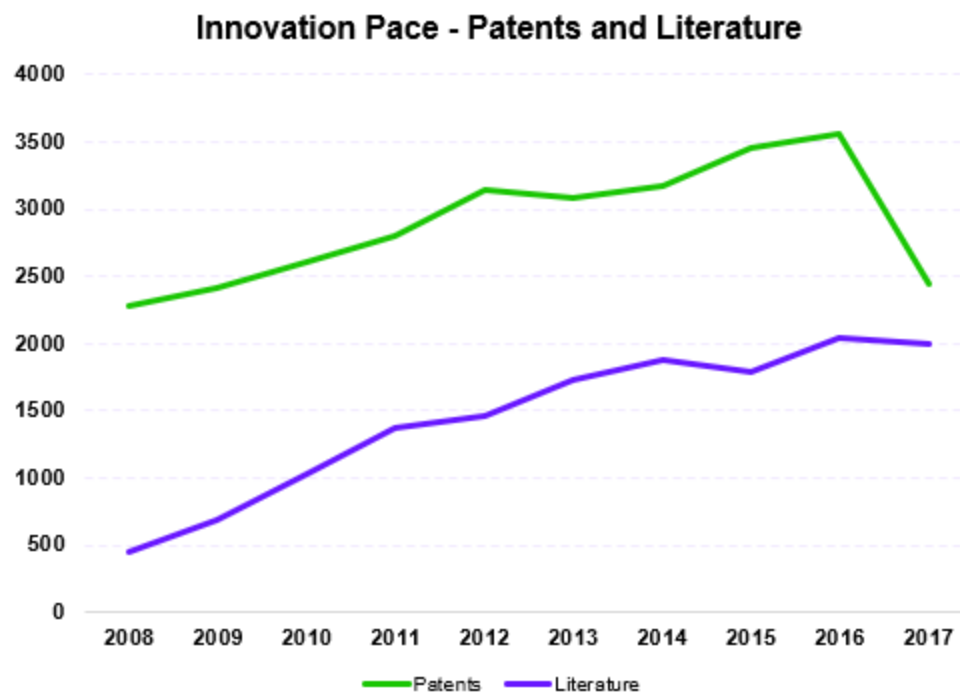
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)
Changzhou University			23	15	284	52	137	188	151	167	36	1053	96%
Harbin Institute of Technology	61	72	105	29	79	117	107	172	92	114	32	980	73%
Tongji University	55	75	83	63	108	109	111	94	111	126	29	964	71%
Zhejiang University	77	73	90	34	52	95	101	153	132	107	14	928	70%
Kurita Water Industries	110	75	89	149	98	108	95	62	97	40	1	924	54%
Beijing University of Technology	41	36	36	27	61	164	167	98	122	96	15	863	84%
Sichuan Normal University	3	2	1	1	64	2	1	4	321	397		796	99%
South China University of Technology	27	52	37	17	41	72	105	117	123	139	23	753	82%
Hohai University					8	45	100	117	195	248	27	740	100%
Nanjing University	50	70	59	34	80	67	85	85	81	100	15	726	71%

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Chinese Academy of Sciences	Research Institute	423	558	710	829	1083	1207	1200	1558	1669	1716	925	11878	79%	15.41
Centre National de la Recherche Scientifique (CNRS)	Research Institute	394	415	487	515	497	547	580	607	660	642	294	5638	68%	15.86
University of California System	Academic	432	452	401	459	473	570	537	597	672	634	320	5547	69%	19.44
United States Department of Agriculture (USDA)	Government	402	353	320	342	382	330	353	384	421	440	182	3909	64%	14.20
Helmholtz Association	Research Institute	209	264	299	335	344	375	353	401	459	460	189	3688	70%	15.26
Indian Institute of Technology System (IIT System)	Academic	249	229	272	256	297	302	333	423	529	495	236	3621	72%	13.12
United States Department of the Interior	Government	262	273	299	293	324	362	350	353	391	342	147	3396	67%	14.86
University of Chinese Academy of Sciences, CAS	Research Institute	90	106	154	192	224	278	269	418	500	605	416	3252	83%	15.13
State University System of Florida	Academic	212	202	252	298	288	308	350	336	406	369	204	3225	70%	12.28
United States Geological Survey	Government	236	253	280	269	294	333	328	318	360	313	131	3115	67%	15.61

- In patents, 9 of the top 10 assignees are Chinese institutions. Most have a very high proportion of recent filings. Sichuan Normal University has a significant number of publications in 2016 and 2017. The sole Japanese entity, Kurita Water has the lowest proportion of recent filings, with 54% filed since 2012.
- Literature entities are more varied, with organizations from China, the US, India, and Europe. Chinese Academy of Sciences shows the highest recency, with 79% of publications submitted since 2012. Citation impact is comparatively low, which may be reflective of higher proportions of recent publications.

Biorefinery technology

Topic 3		
Biorefinery		
Year	Patents	Literature
2008	2274	453
2009	2419	693
2010	2606	1031
2011	2799	1370
2012	3140	1456
2013	3084	1734
2014	3166	1878
2015	3449	1781
2016	3560	2039
2017	2436	2002
2018	320	1395



- Biorefinery technology is the one space where patenting activity is consistently above literature publication. Both spaces show steady increases in activity, but patents are above literature publication in all years considered.
- This may suggest a more mature technical space, as developing technology often begins with academic research published in journals prior to commercial activity. Regardless, it appears that this space is one in which commercial activity is leading innovation.
- Biofuel innovation makes up a significant proportion of these patents. As countries look to move away from petroleum consumption, innovation in bio-based fuels may offer an alternative to fossil fuels.

Biorefinery – top organizations

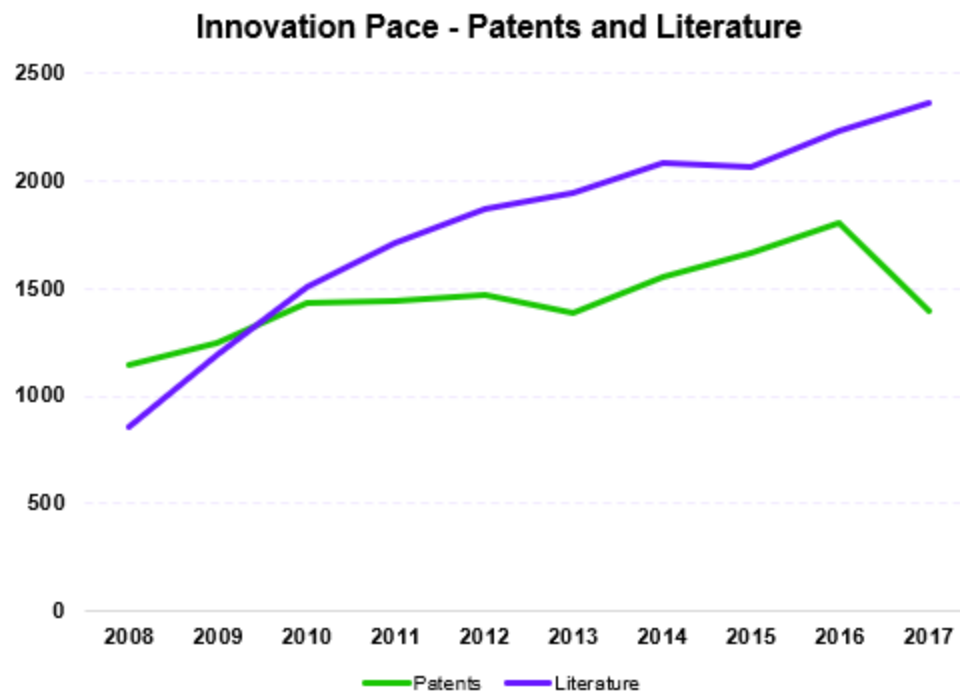
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	Average Clarivate IP index
China Petroleum & Chemical Corp (SINOPEC)	14	21	39	44	92	73	79	90	82	56	2	592	80%	23.01
China National Petroleum Corp (CNPC)	10	13	30	29	110	86	73	50	57	43	4	505	84%	19.37
Shell Oil	32	31	28	48	46	27	21	22	9	1		265	48%	56.69
Southwest Petroleum University	3	3	11	26	12	17	26	25	44	30	7	204	79%	27.10
China National Offshore Oil Corp (CNOOC)	3	1	8	17	20	22	23	41	14	21	6	176	84%	25.47
China University of Petroleum	5	2	8	11	6	16	16	27	23	45	6	165	84%	33.68
Honeywell International	19	12	27	16	27	18	16	10	4			149	50%	49.23
Schlumberger Technology	13	15	10	18	20	25	22	16	10			149	62%	52.36
Halliburton	5	9	3	14	25	39	19	10	14			138	78%	66.26
Chevron	26	13	14	14	19	15	8	10	7	1		127	47%	54.10

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Indian Institute of Technology System (IIT System)	Academic	11	18	19	32	22	25	39	41	69	68	31	375	79%	43.42
Chinese Academy of Sciences	Research Institute	11	5	15	33	40	46	52	58	39	47	19	365	82%	42.83
Council of Scientific & Industrial Research (CSIR) - India	Academic	4	7	15	25	28	24	27	34	41	28	15	248	79%	42.64
Universiti Malaya	Academic	1	3	8	20	19	31	44	28	40	33	14	241	87%	51.75
United States Department of Energy (DOE)	Government	4	7	15	22	20	29	24	20	27	20	11	199	76%	40.50
Universiti Sains Malaysia	Academic	4	17	21	26	18	25	34	16	12	14	6	193	65%	45.90
Tianjin University	Academic	7	6	8	14	12	22	20	26	24	22	12	173	80%	29.27
Universidade Estadual de Campinas	Academic	6	7	7	18	17	16	19	11	28	17	9	155	75%	21.77
University of Chinese Academy of Sciences, CAS	Research Institute	5	2	6	10	11	19	21	30	19	17	8	148	84%	36.00
United States Department of Agriculture (USDA)	Government	13	21	23	11	18	11	16	9	12	6	7	147	54%	34.60

- China appears to be leading innovation in patents in the space, with half of the top 10 assignees based in China. Traditional petrochemical companies dominate the western entities. Halliburton and Shell have the highest average Clarivate IP index scores, at 66.26 and 56.69 respectively
- The Indian Institute of Technology System is the top publisher in the space, and also shows a relatively high percent recency at 79%.

Biomaterials technology

Topic 3		
Biomaterials		
Year	Patents	Literature
2008	1141	861
2009	1249	1192
2010	1432	1510
2011	1446	1711
2012	1469	1873
2013	1384	1943
2014	1552	2085
2015	1664	2068
2016	1807	2236
2017	1399	2366
2018	225	1474



- Biomaterials patents are above literature papers in the first 2 years of the investigation, but literature papers has a higher growth rate, overtaking patent publications in 2010. This may be suggestive of increased academic interest in primary research.
- Patents do appear to show an increase in rate of filing beginning in 2014.

Biomaterials – top organizations

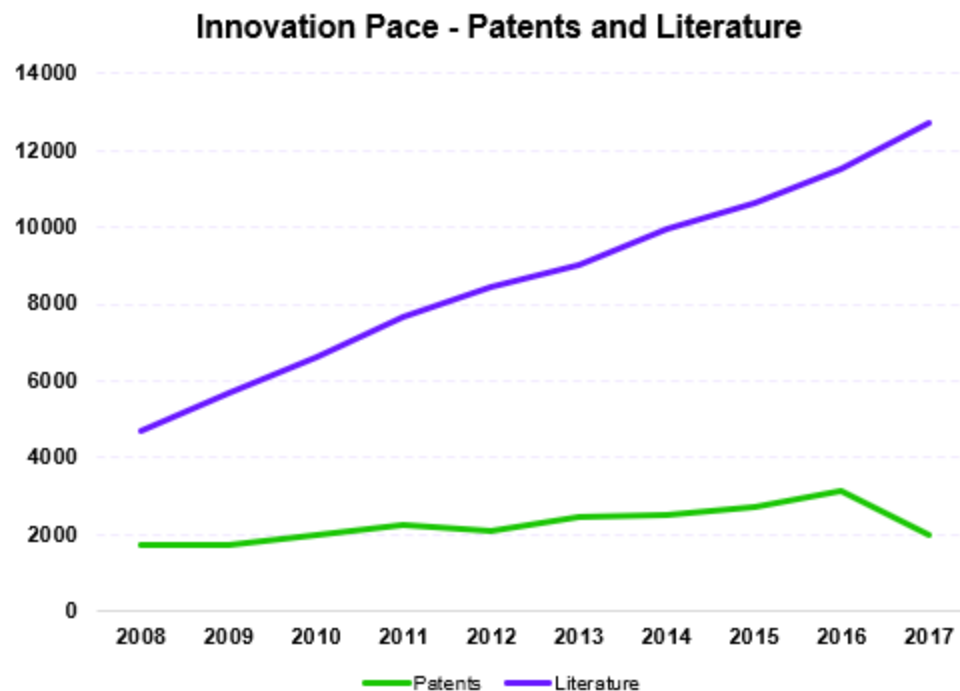
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)	Average Clarivate IP index
Shell Oil	7	8	15	33	36	29	18	19	6			171	63%	62.31
IFP Energies nouvelles	12	6	15	18	11	9	17	8	4			100	49%	52.34
KiOR	19	13	25	13	13	4	4					91	23%	47.06
Shenwu Environmental Technology					4	6	2	17	56	1		86	100%	26.76
Guangzhou Devotion Thermal Technology	2	3	42	12	1	6	6	11	1			84	30%	9.06
Honeywell International	9	8	17	12	15	4	8	7	1			81	43%	42.86
Beijing SJ Environmental Protection & New Material							6	24	12	27		69	100%	24.90
Wuhan Kaidi Engineering Technology Research Institute	4	2	2	20	3	7	10	5	2	10	1	66	58%	38.75
Kunming University of Science and Technology	1		6	2	9	6	6	10	15	10		65	86%	20.13
Korea Institute of Energy Research (KIER)	3		8	4	10	11	11	6	8	1		62	76%	23.20

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Indian Institute of Technology System (IIT System)	Academic	19	18	26	33	39	29	41	43	72	62	23	405	76%	26.78
Universiti Malaya	Academic	3	9	15	20	19	39	60	47	52	44	10	318	85%	33.00
Chinese Academy of Sciences	Research Institute	16	8	19	30	30	27	28	35	28	31	15	267	73%	28.58
Council of Scientific & Industrial Research (CSIR) - India	Academic	5	10	21	29	21	23	19	35	32	24	19	238	73%	30.86
Universidade Estadual de Campinas	Academic	11	22	18	25	26	26	23	29	24	19	11	234	68%	12.06
Universidade de Sao Paulo	Academic	8	15	12	23	24	23	19	19	17	33	10	203	71%	15.99
Universiti Sains Malaysia	Academic	4	14	24	18	14	26	24	16	12	11	4	167	64%	38.64
Universidade Federal do Rio de Janeiro	Academic	7	9	18	12	8	17	13	17	25	22	7	155	70%	15.23
Universiti Putra Malaysia	Academic		1	2	16	11	10	23	32	15	29	10	149	87%	20.58
United States Department of Agriculture (USDA)	Government	17	26	15	19	14	14	5	8	7	10	8	143	46%	27.52

- Shell is the top assignee in biomaterials, with 171 inventions. Shenwu Environmental Technology and Beijing SJ Environmental Protection & New Material have all of their inventions filed since 2013.
- Indian Institute of Technology System is the top publishing organization with 405 publications, and also has high recency at 76%. Universiti Malaya, Universiti Sains Malaysia and Universiti Putra Malaysia have the highest recency, suggesting new investigations of this technology in Malaysia.

Precision medicine technology

Topic 4		
Precision medicine		
Year	Patents	Literature
2008	1708	4717
2009	1708	5666
2010	1991	6603
2011	2226	7676
2012	2070	8423
2013	2448	9021
2014	2515	9976
2015	2704	10647
2016	3130	11533
2017	1976	12705
2018	344	8905



- Precision medicine shows a strong difference between patent and literature. Patent filing is increasing at a low rate, increasing from just over 1700 patents in 2008 to 3130 in 2017.
- Conversely, literature publications have shown a larger increase, from 4717 publications in 2008 to 12705 published papers in 2017.

Precision medicine – top organizations

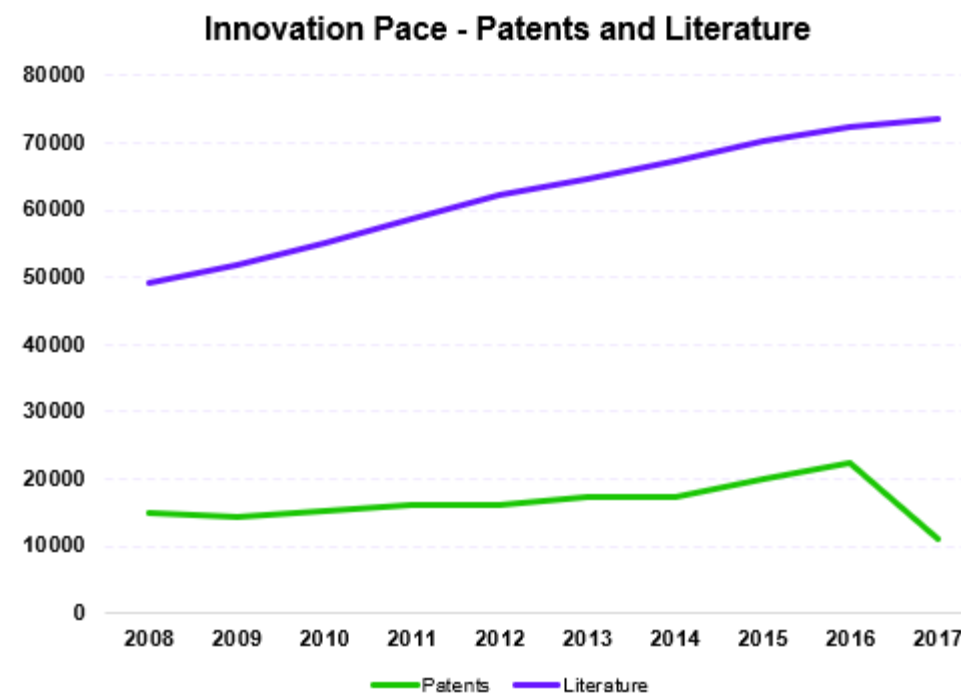
<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)
Institut National de la Sante et de la Recherche Medicale (Inserm)	26	34	31	48	57	50	54	54	50	9		413	66%
Hoffmann-La Roche	29	31	48	45	33	30	47	25	28	3		319	52%
Y.Shen Bioinfo Co							2	71	115	100	22	310	100%
University of California	42	35	27	39	31	30	30	24	30	3		291	51%
Johns Hopkins University	22	13	25	26	26	29	22	24	3	1		191	55%
Centre National de la Recherche Scientifique (CNRS)	8	12	15	27	26	21	25	28	24	4		190	67%
YONSEI University Industrial-Academic Coop Foundation	9	7	14	13	13	29	22	27	32	5		171	75%
Assistance Publique Hopitaux Paris (APHP)	12	8	6	19	21	21	24	25	13	5		154	71%
Dana-Farber Cancer Institute	10	5	16	13	20	29	19	17	11	2		142	69%
Leland Stanford Junior University	11	14	20	13	10	24	18	11	11			132	56%

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
Harvard University	Academic	168	209	219	246	292	291	304	384	423	461	200	3197	74%	35.55
University of California System	Academic	167	213	213	277	274	275	333	350	393	413	184	3092	72%	26.63
University of London	Academic	88	126	134	163	203	215	246	253	288	336	146	2198	77%	26.21
University of Texas System	Academic	107	122	153	190	196	184	232	231	248	278	138	2079	72%	23.75
Institut National de la Sante et de la Recherche Medicale (Inserm)	Research Institute	106	115	135	180	194	149	189	228	258	306	134	1994	73%	21.93
VA Boston Healthcare System	Health	106	132	126	154	181	187	211	243	259	281	114	1994	74%	35.97
National Institutes of Health (NIH) - USA	Government	90	110	159	150	162	159	174	161	188	202	94	1649	69%	28.60
University of Toronto	Academic	64	81	107	107	150	144	169	181	182	200	106	1491	76%	24.10
Stanford University	Academic	86	88	119	138	146	148	150	159	169	180	105	1488	71%	28.81
Assistance Publique Hopitaux Paris (APHP)	Health	87	106	109	118	124	91	136	191	170	188	94	1414	70%	22.93

- Inserm is the top assignee in precision medicine, with 413 inventions. Y.Shen Bioinfo had no inventions prior to 2013, but a high recency in the past 3 years shows a strong investment in this space.
- Harvard, University of California System and University of London are the top publishers in this space, and also show strong recency, at 74%, 72%, and 77% respectively.

Biopharmaceuticals technology

Topic 4		
Biopharmaceuticals		
Year	Patents	Literature
2008	14986	49162
2009	14414	51903
2010	15347	55264
2011	16075	58758
2012	16248	62148
2013	17313	64569
2014	17439	67287
2015	20132	70154
2016	22386	72327
2017	11207	73706
2018	1366	52369



- In biopharmaceuticals, literature publication shows a greater rate of growth over the study. Additionally, literature volume is higher than patents, in many cases 2-3 times patent volumes.
- Patents do show a slight increase in filing frequency beginning in 2015. Generally filing trends are fairly flat, which may reflect a maturing commercial market, as well as impact of regulatory pressures on this technology.

Biopharmaceuticals – top organizations

<i>Top assignees - patents</i>	08	09	10	11	12	13	14	15	16	17	18	Total inventions	% Recency (inventions filed since 2012)
Hoffmann-La Roche	262	285	254	216	247	253	250	227	172	25		2191	54%
University of California	126	125	125	170	159	169	141	157	170	37		1379	60%
Institut National de la Sante et de la Recherche Medicale (Inserm)	77	113	86	166	115	146	146	189	181	33		1252	65%
Novartis	122	119	113	105	103	125	119	74	66	21		967	53%
US Department of Health & Human Services	136	103	88	111	88	105	98	96	80	16		921	52%
Centre National de la Recherche Scientifique (CNRS)	76	89	78	115	77	125	96	116	110	16		898	60%
Zhejiang University	80	41	65	66	62	67	79	59	100	84	8	711	65%
University of Texas System	59	62	64	60	59	81	88	86	87	18		664	63%
Leland Stanford Junior University	48	50	73	50	66	94	60	73	88	12		614	64%
Harvard College	51	36	56	52	60	96	79	85	77	7		599	67%

<i>Top organizations - literature</i>	<i>Organization type</i>	08	09	10	11	12	13	14	15	16	17	18	Total publications	% Recency (publications since 2012)	Citation impact
University of California System	Academic	1550	1572	1734	1742	1795	1805	1923	894	1908	1942	1956	18821	65%	30.55
Harvard University	Academic	1249	1270	1399	1455	1510	1636	1735	857	1730	1733	1766	16340	67%	36.82
University of London	Academic	1393	618	1226	1255	1270	873	921	972	1007	1116	1134	11785	62%	27.67
Institut National de la Sante et de la Recherche Medicale (Inserm)	Research Institute	1109	1081	1160	1255	548	1226	1216	1228	862	872	948	11505	60%	24.67
National Institutes of Health (NIH) - USA	Government	1049	1015	1109	1152	1135	1118	1095	476	1114	1104	1120	11487	62%	31.20
University of Texas System	Academic	1015	941	982	1167	538	1064	1168	1152	1064	1069	1038	11198	63%	28.96
VA Boston Healthcare System	Health	1051	471	972	938	998	791	808	841	620	617	704	8811	61%	40.59
Assistance Publique Hopitaux Paris (APHP)	Health	718	691	780	855	816	870	908	406	928	903	843	8718	65%	26.49
Pennsylvania Commonwealth System of Higher Education (PCSHE)	Academic	623	661	699	731	775	753	797	332	776	706	780	7633	64%	25.91
Centre National de la Recherche Scientifique (CNRS)	Research Institute	833	356	752	776	826	505	599	598	620	639	749	7253	63%	22.07

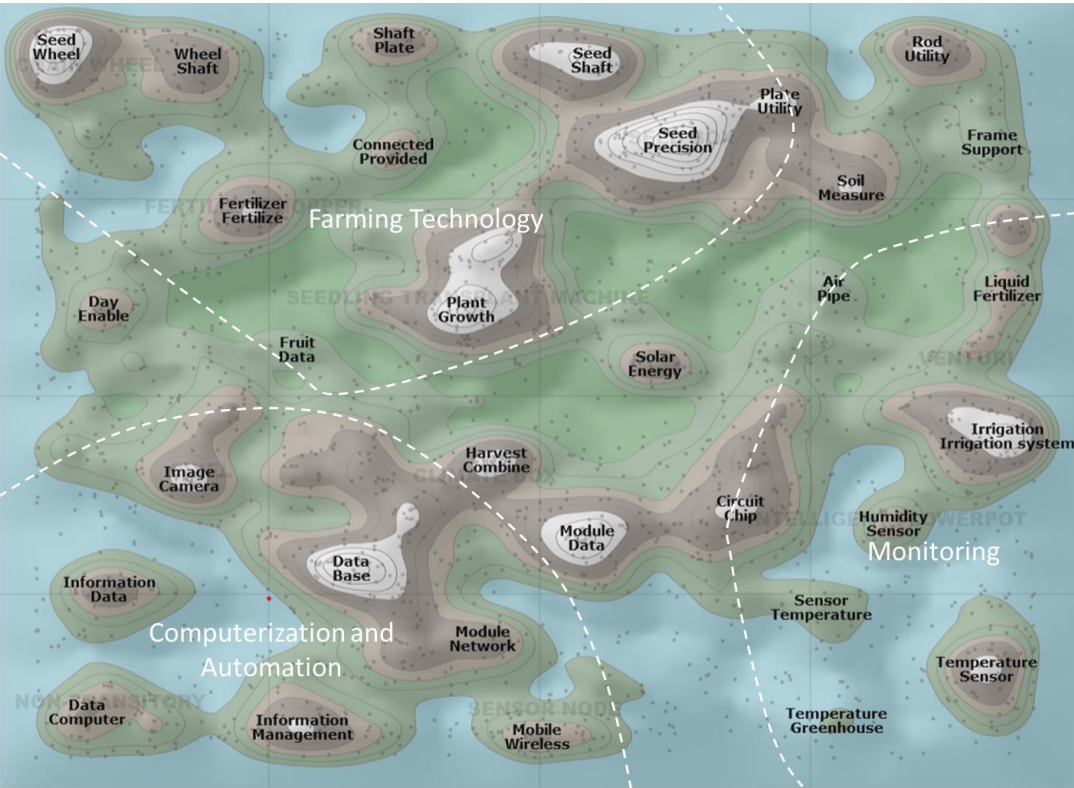
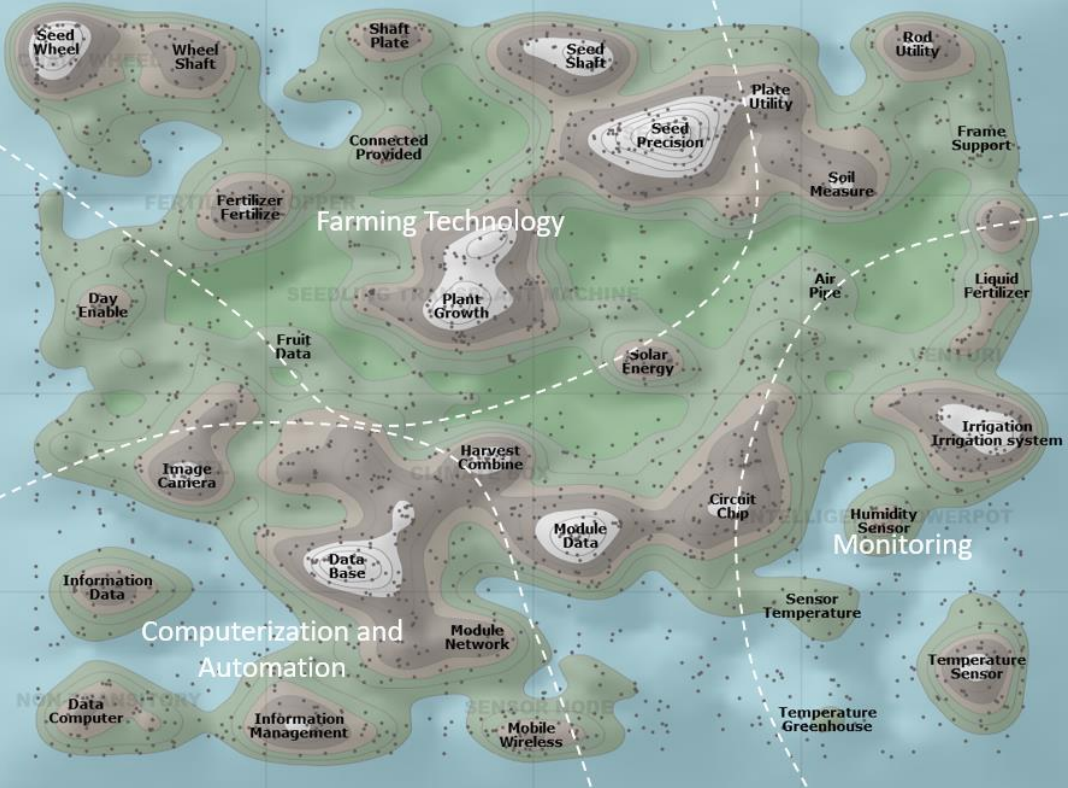
- Biopharmaceutical top assignees are unusual compared to other technical spaces, in that there is a low number of Chinese entities. Only Zhejiang University appears in the top 10. The majority of top assignees are established pharmaceutical entities, universities and research foundations. % recency is relatively low (ranging from 52% to 67%), suggestive of a well-established technical category.
- Literature is again more internationally diverse, with the US, UK, and France highly represented in the top 10 institutions. Recency is also comparatively low.

Patent and literature ThemeScape maps

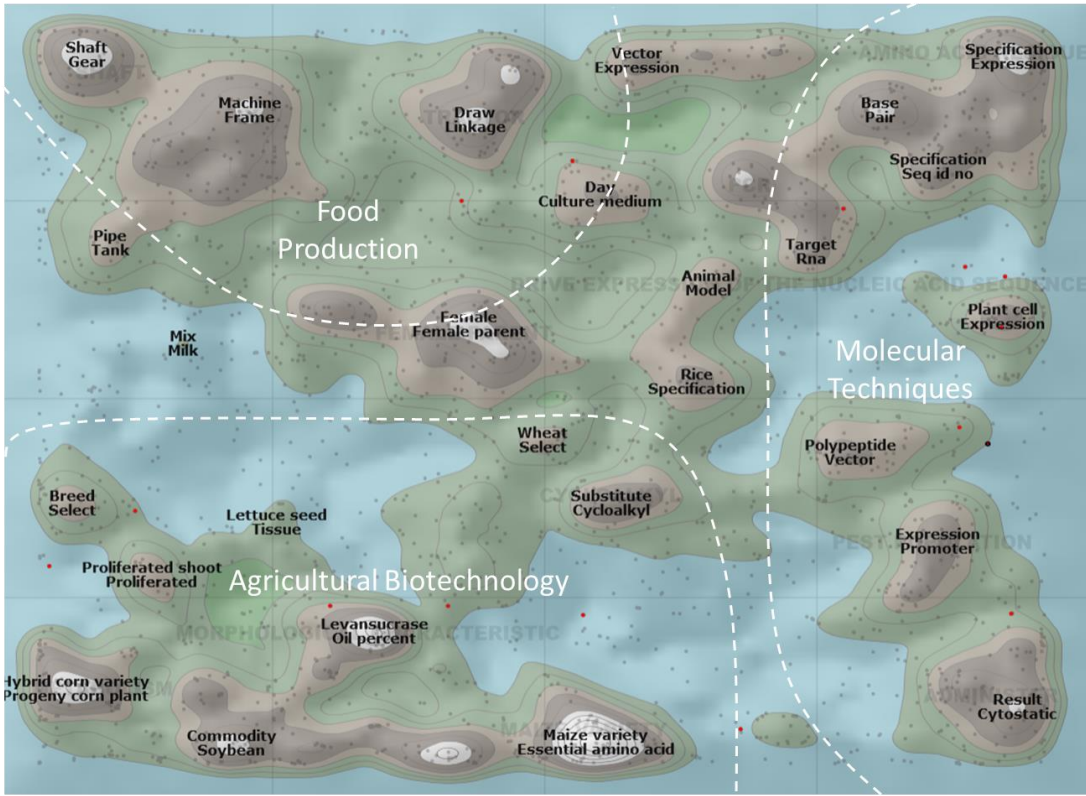
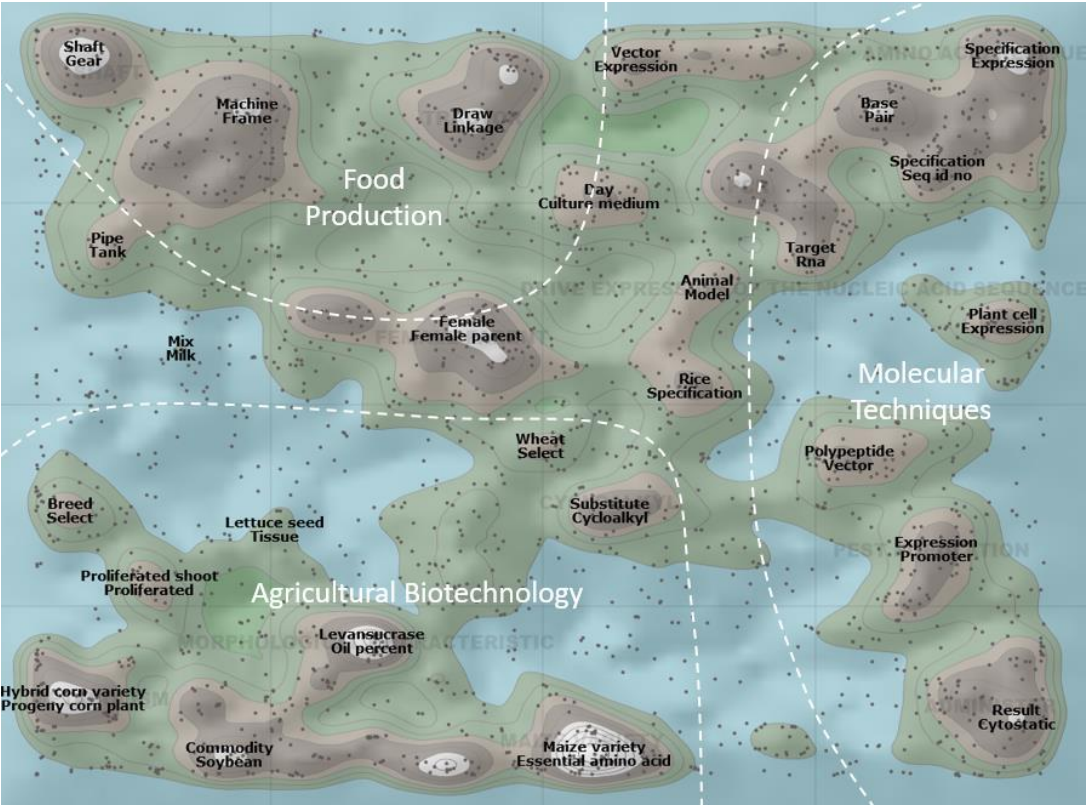
ThemeScape maps of technical categories

- ThemeScape is a powerful tool that offers a qualitative and visual overview of the main subject matter presented in the data collection.
- ThemeScape employs algorithms that analyze the content (such as the titles and abstracts of the records) and place patent records into different locations based on their technical similarity to each other.
- Within the map, each dot represents an invention. Inventions with similar contents are enclosed in a contour circle. The distances between inventions are determined by similarity or dissimilarity in their technological content: the closer in location, the more similar. The map coloration corresponds to record density: white for highly populated, green for moderately populated, and blue for low population.
- The portion of the invention record that was mapped was the DWPI Use field, generating a map that focuses on the technical intent for which the inventions were made. Literature papers were mapped using title and original abstract of the publication.
- ThemeScape maps of literature are significantly limited in Derwent Innovation, with a map limit of 15,000 documents. A statistical sampling model was created, choosing documents at random from each publication year to create a representative collection of records for mapping purposes.
- Additional labels have been added to the map to approximate locations of similar technology.
- All Thai-origin articles have been included in the maps, and the maps in your Derwent Innovation account reflect the collection.

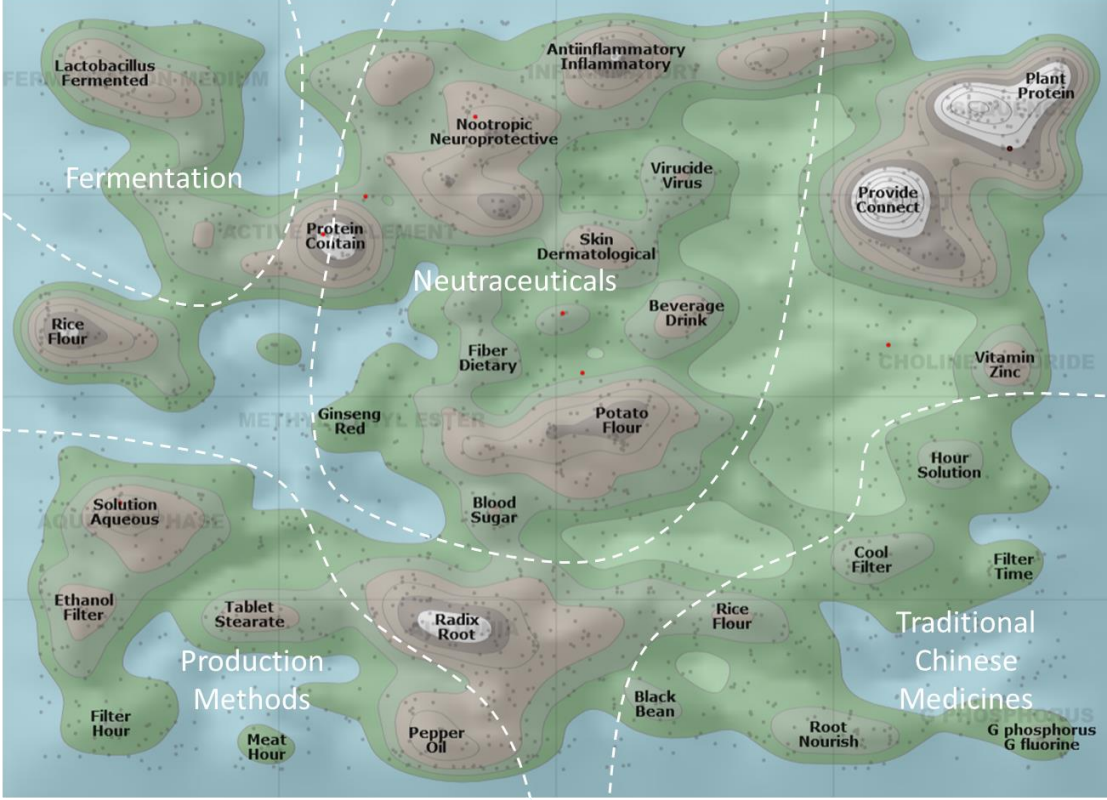
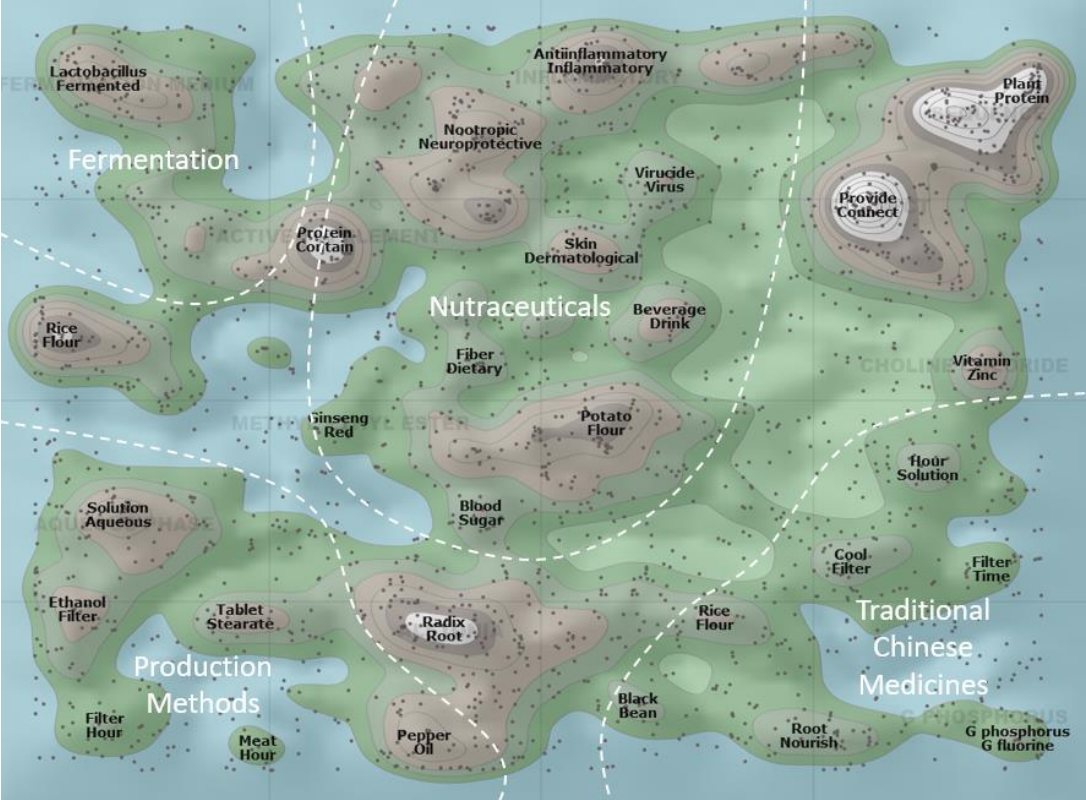
Precision agriculture patent



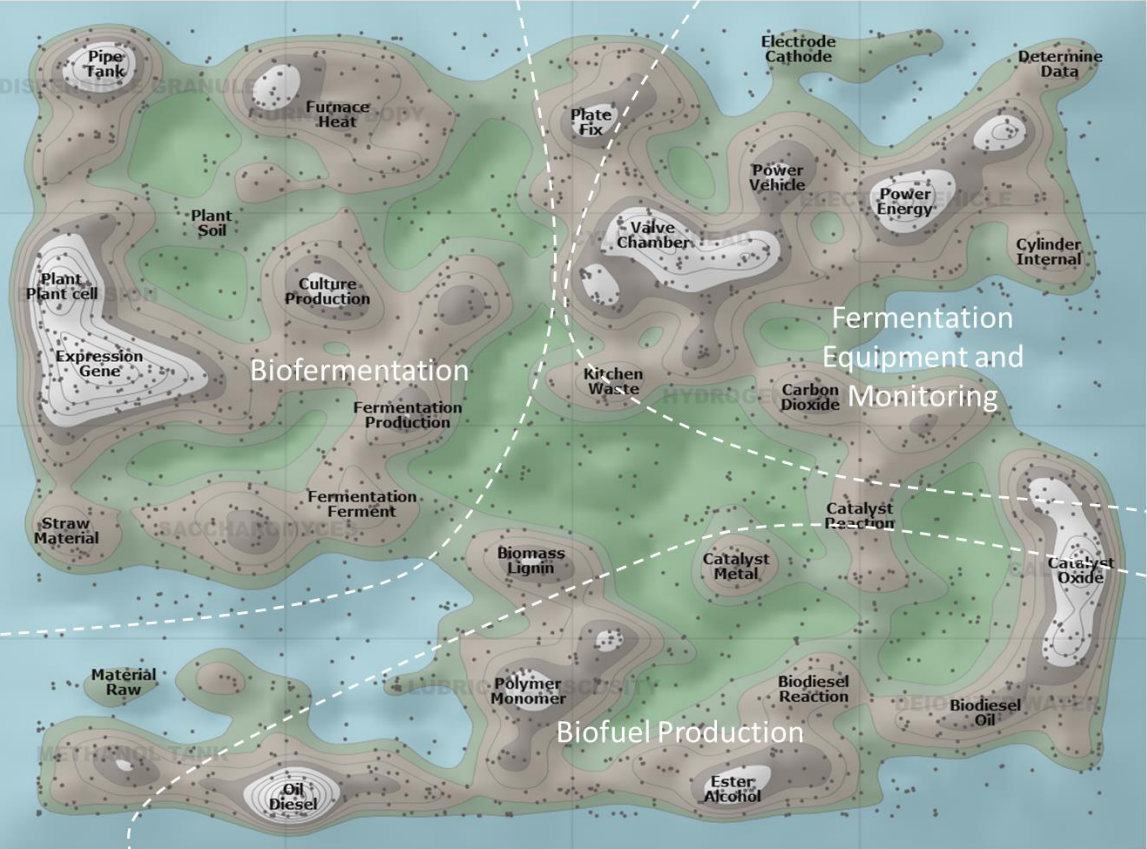
Gene utilization patent



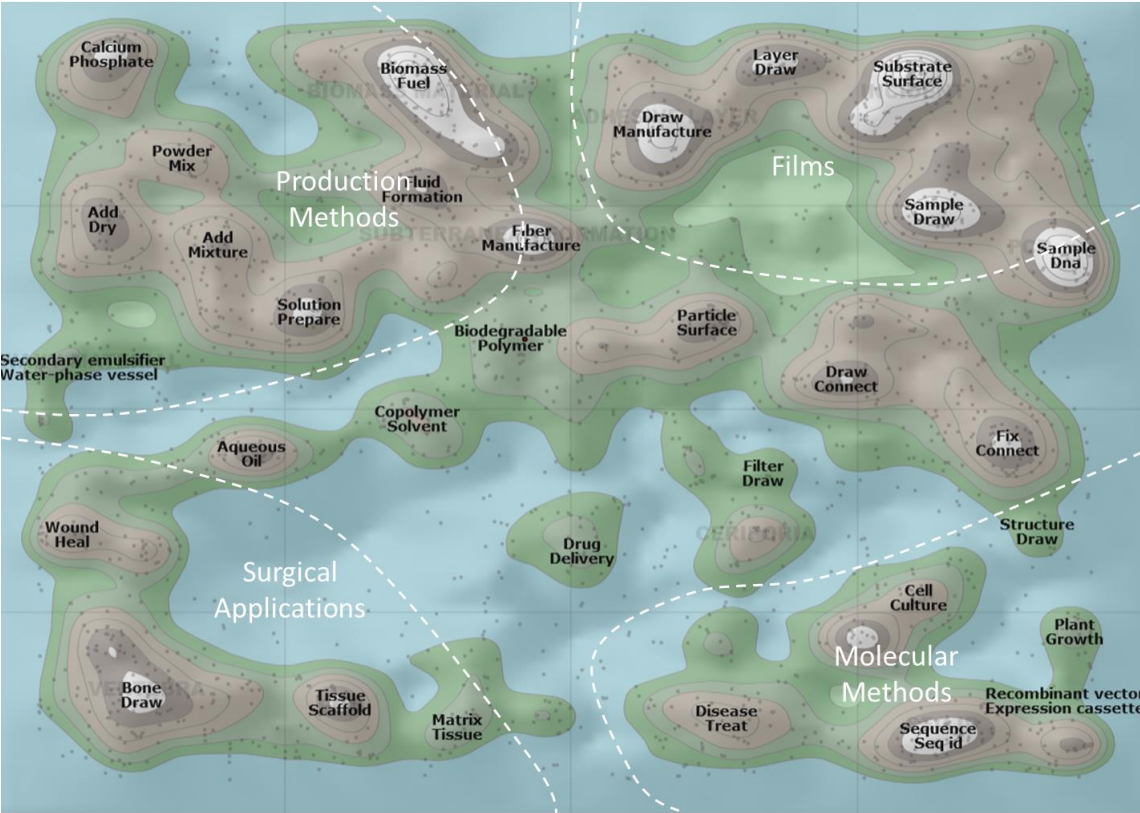
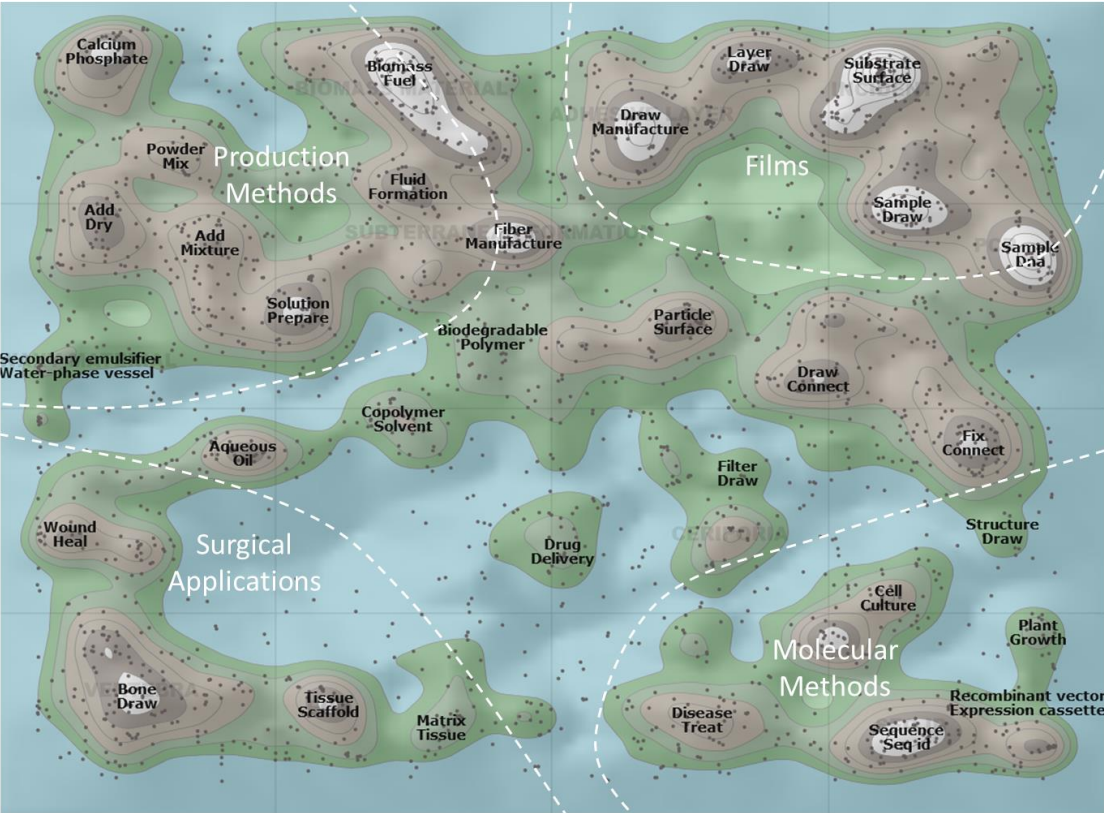
Functional food patent



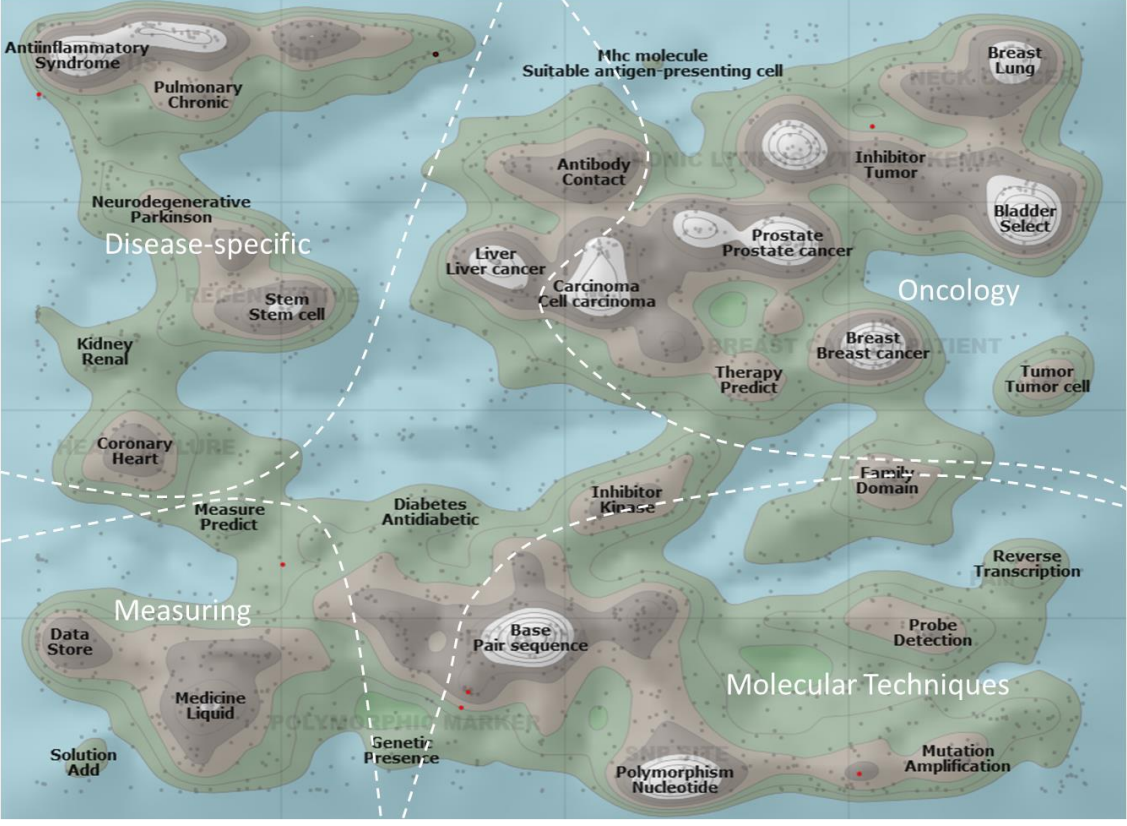
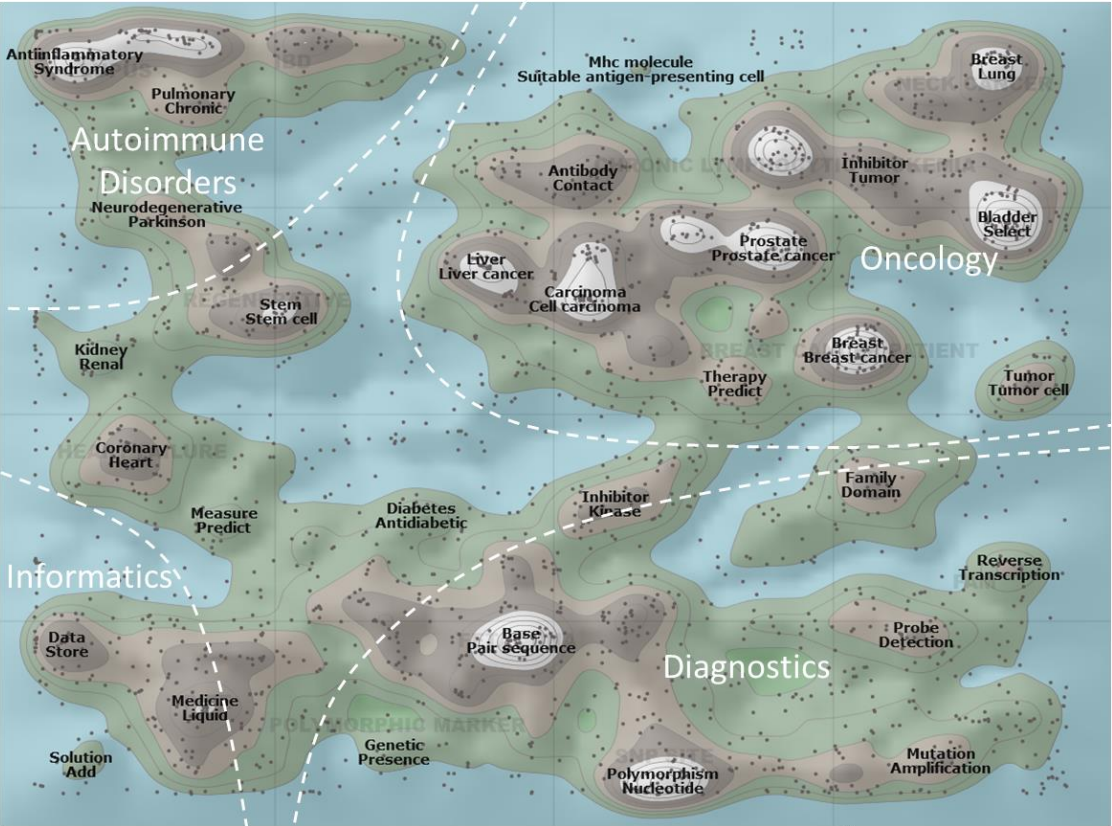
Biorefinery patent



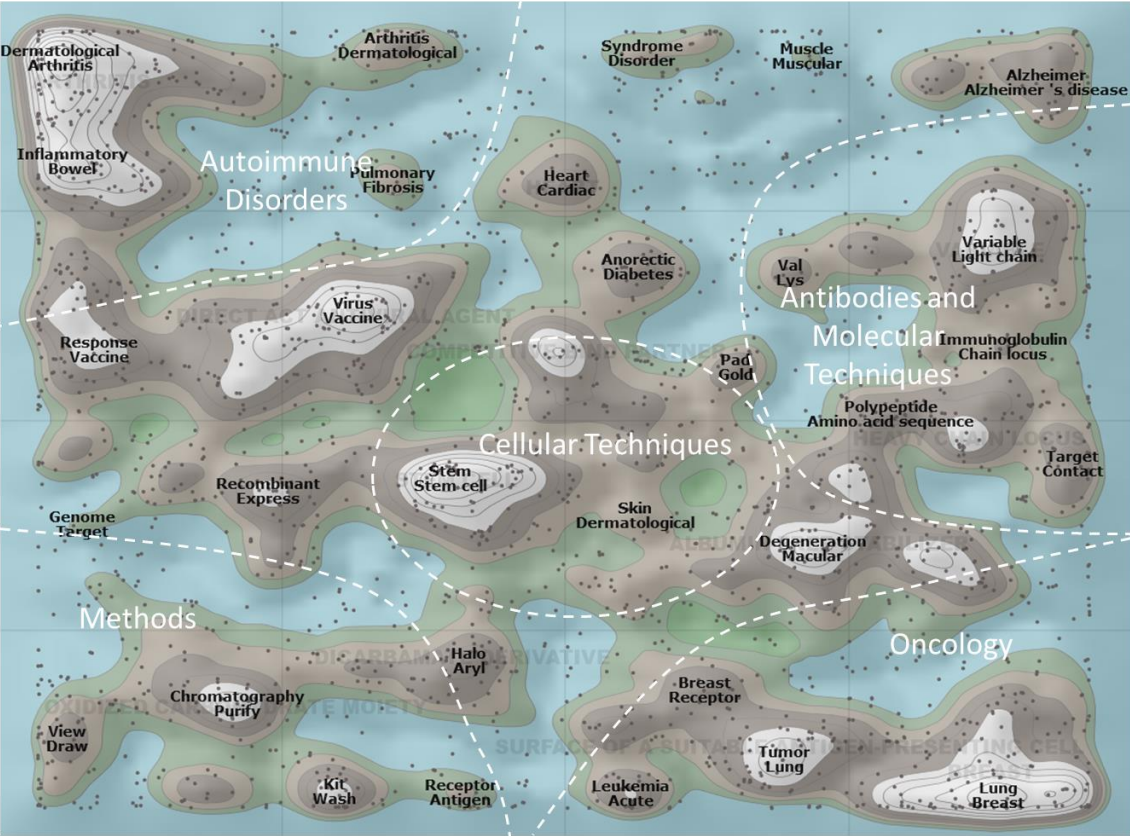
Biomaterials patent



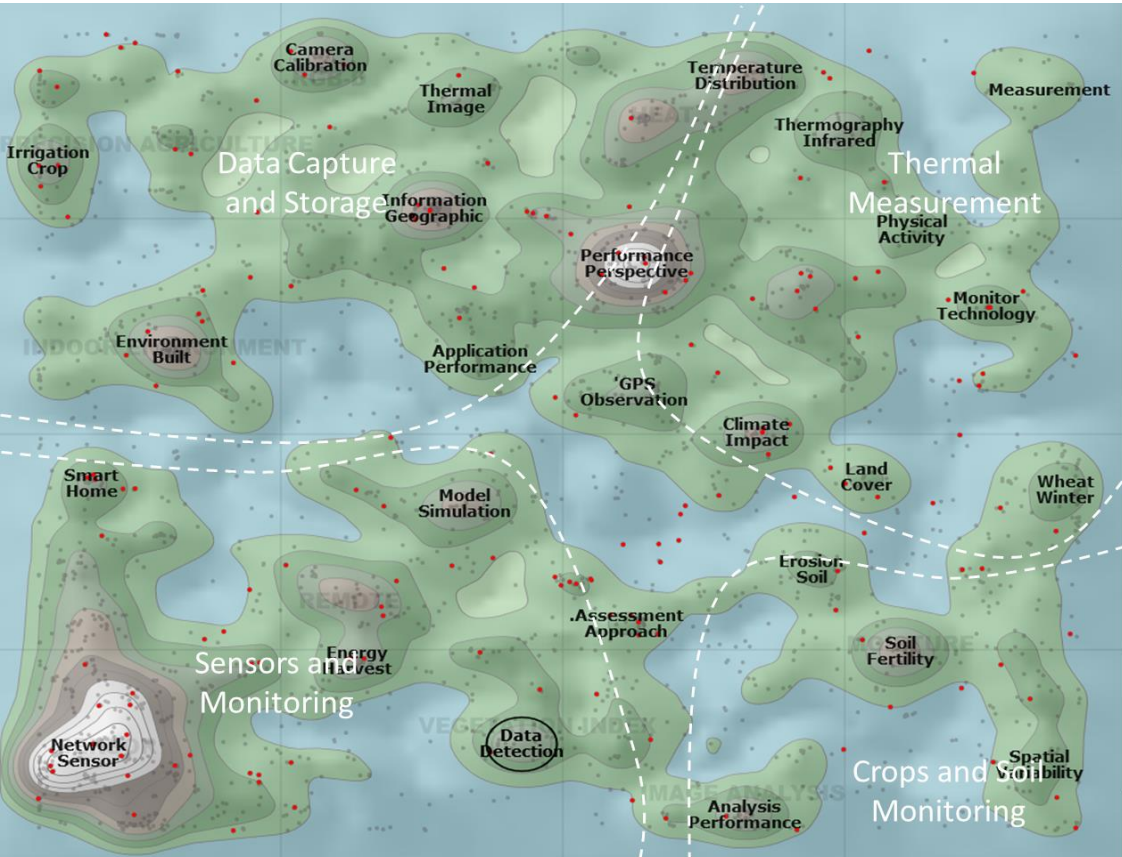
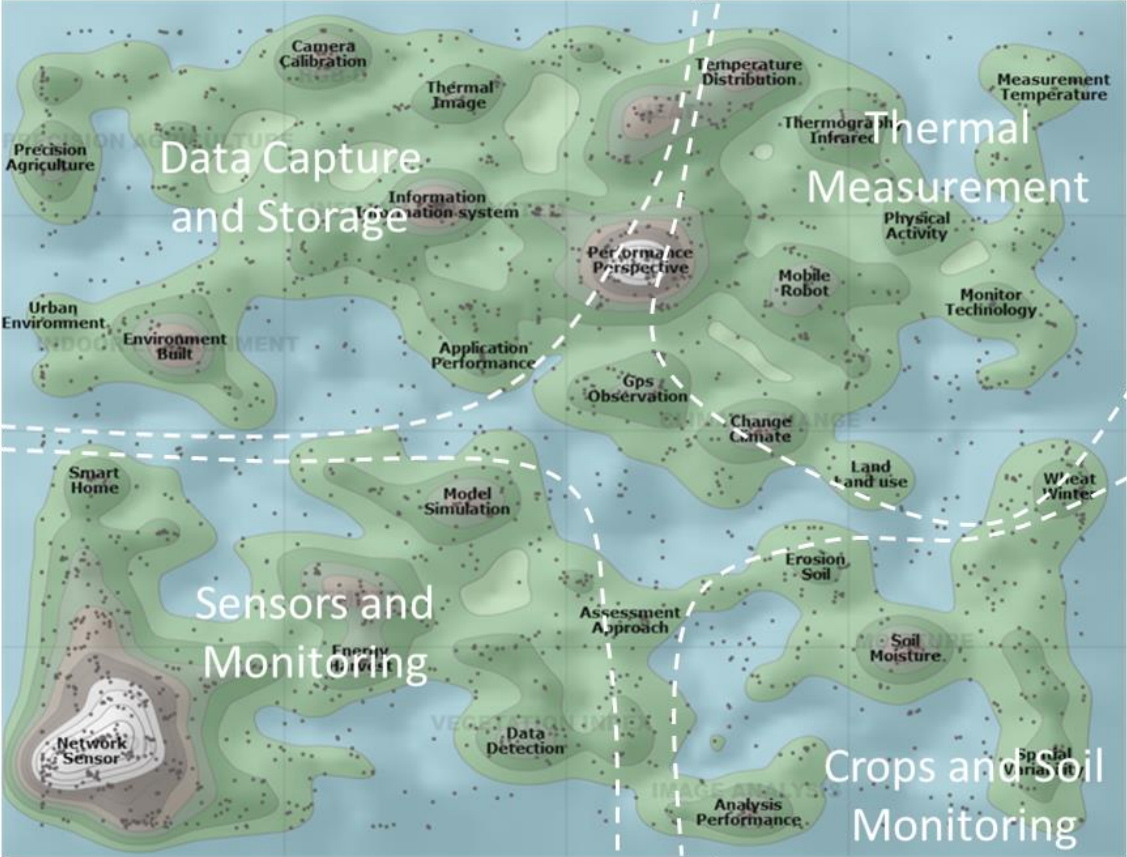
Precision medicine patent



Biopharmaceuticals patent



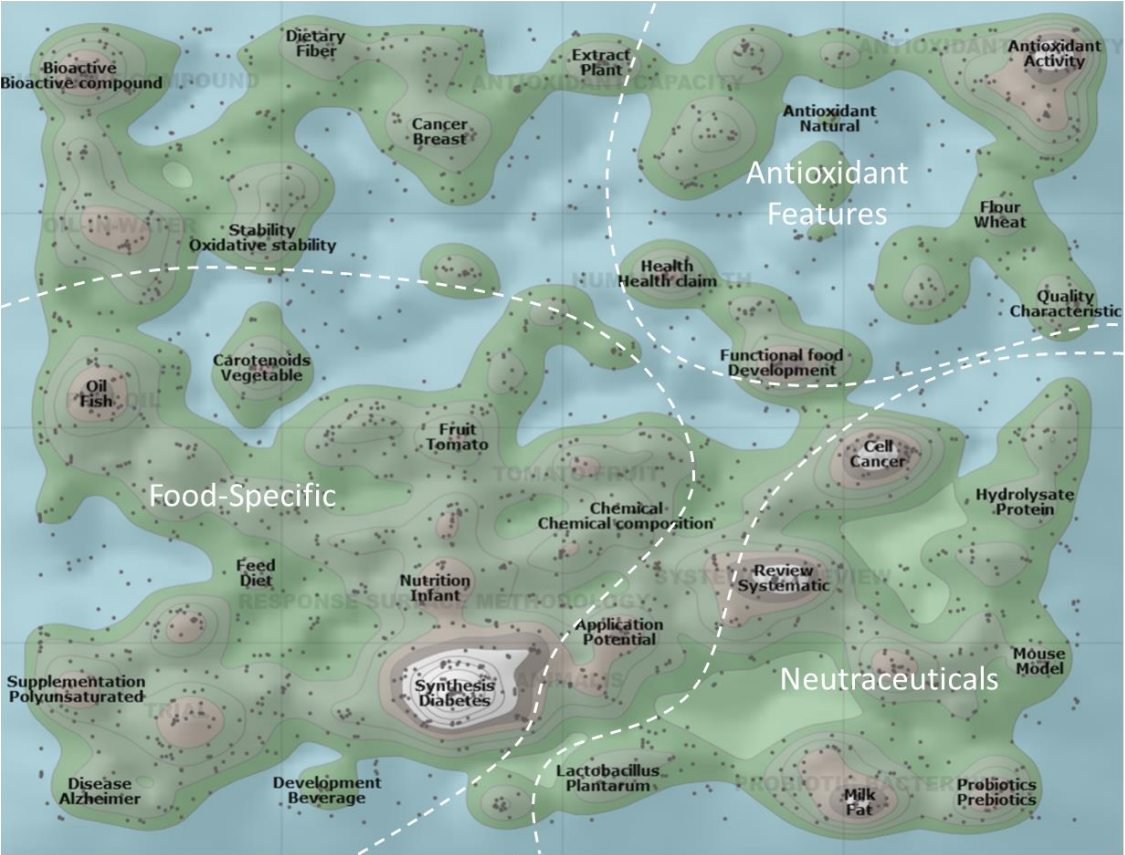
Precision agriculture publications



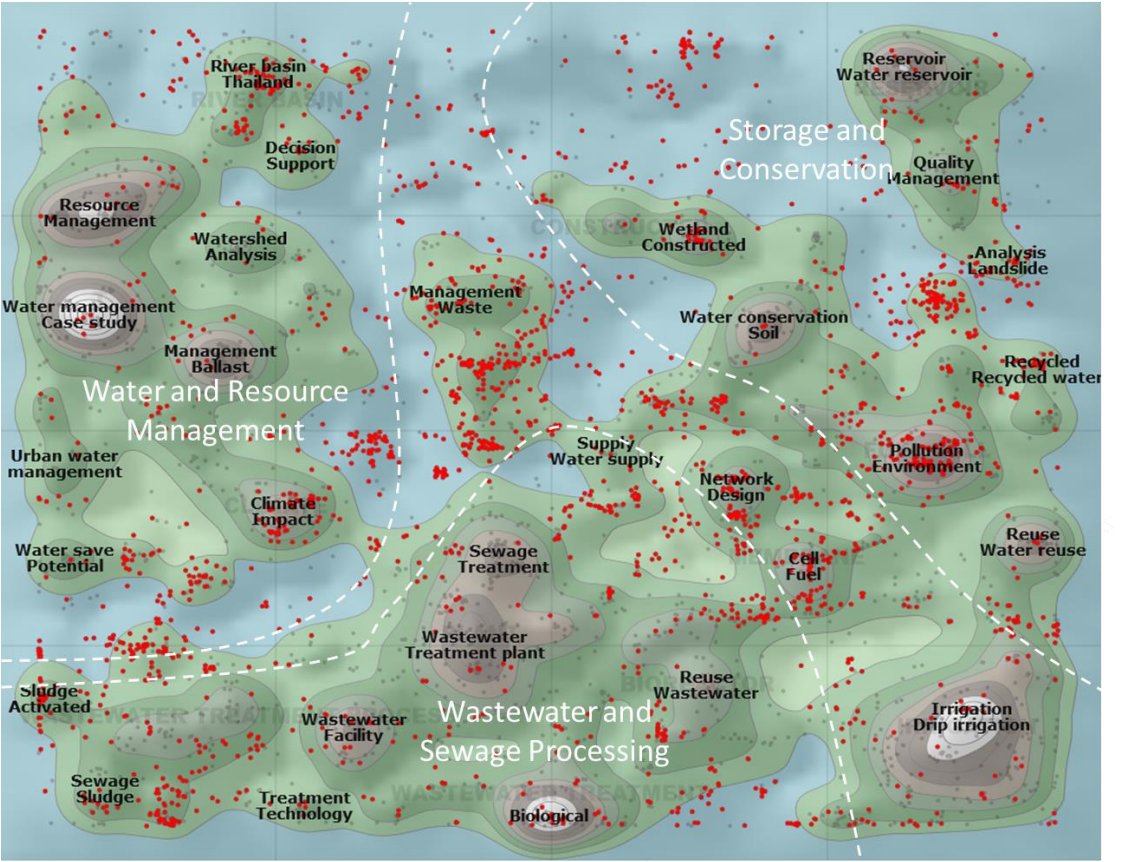
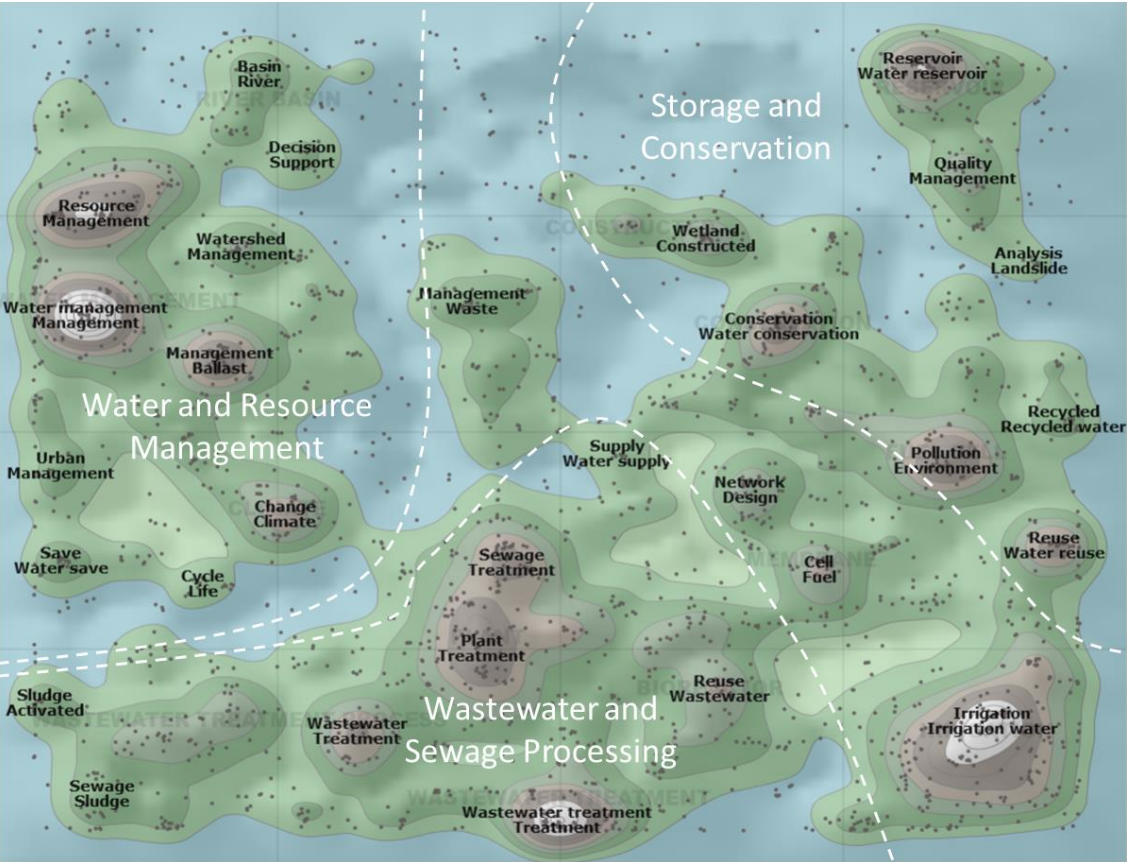
Gene utilization publications



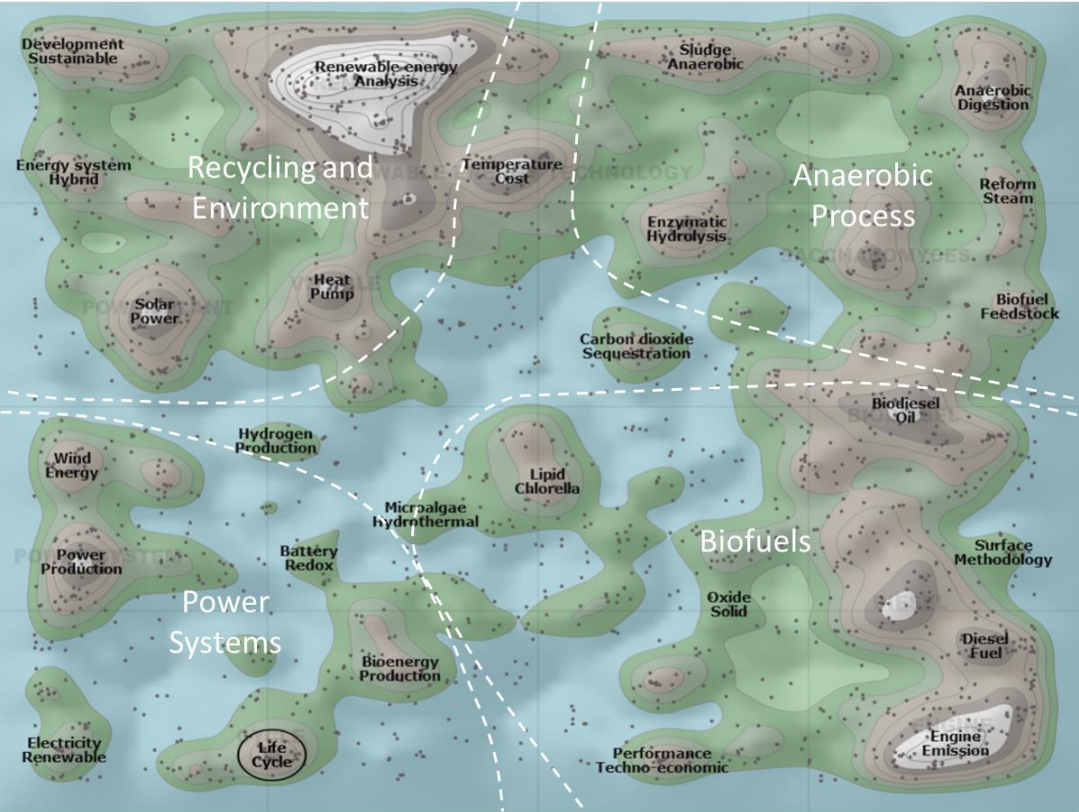
Functional food publications



Wastewater publications



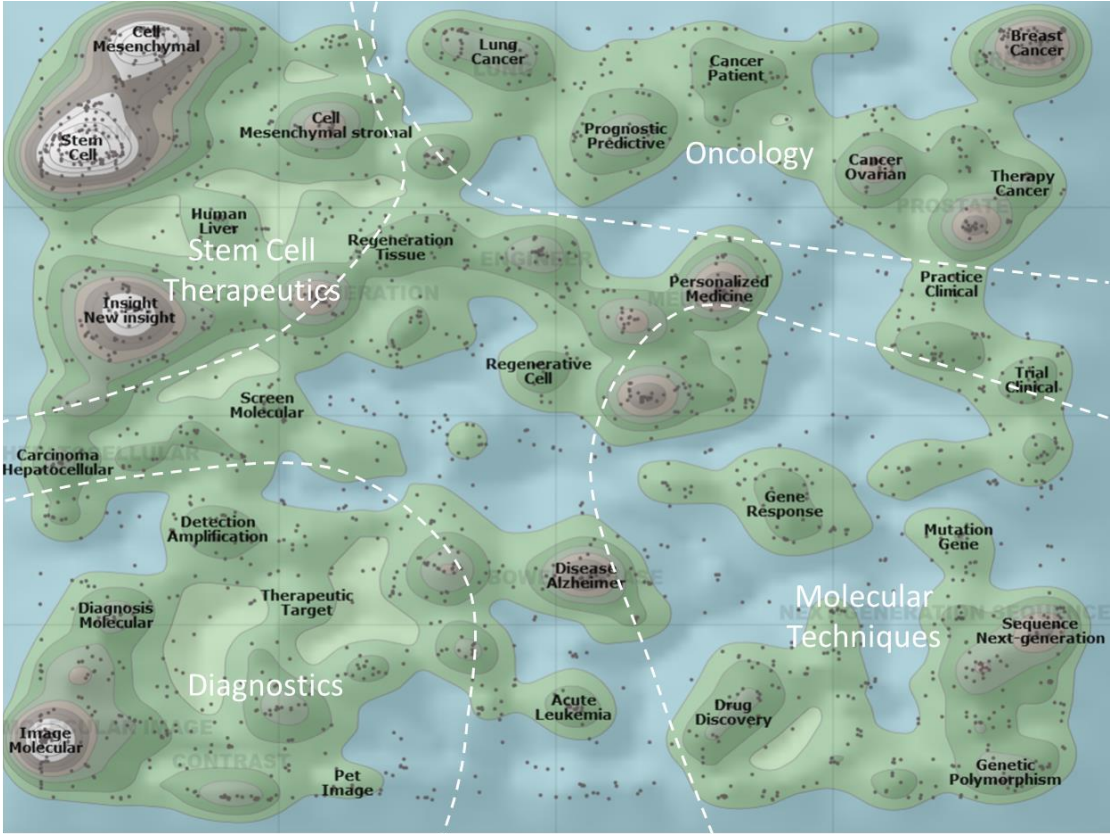
Biorefinery publications



Biomaterials publications



Precision medicine publications



Biopharmaceuticals publications



Top 10 Thai entity literature analysis

Definitions of metrics

- Web of Science Documents
 - Number of Web of Science Documents
- Category Normalized Citation Impact (CNCI)
 - Citation impact (citations per paper) normalized for subject, year and document type
- Citation Impact
 - Average (mean) number of citations per paper
- Times Cited
 - Number of times the set of publications has been cited
- % Documents Cited
 - Percentage of publications that have been cited one or more times
- % Documents in Q1 Journals
 - % Documents in Q1 Journals = $(\text{Count of Documents in Q1 Journals}) / (\text{Count of Documents in JIF Journals})$
- % Documents in Top 1%
 - Percentage of publications in the top 1% based on citations by category, year, and document type
- % Documents in Top 10%
 - Percentage of publications in the top 10% based on citations by category, year, and document type
- % Highly Cited Papers
 - Percentage of publications that are assigned as Highly Cited in Essential Science Indicators (ESI) (top 1% by citations for field and year)
- % Hot Papers
 - Percentage of publications that are assigned as Hot Papers in ESI (top 0.1% by citations for field and age)
- Organization Type
 - Type of organization (academic, government, research institution)

Literature analysis

- Within the top ten, by number of Web of Science documents, organizations, health and medical had the highest output.
- All top ten organizations within the topic Health and Medical published top 1% documents.
- Most organizations presented in the analysis are in the academic field.
- It should be noted that some organizations included in the top ten lists have low output (under 50 publications). The metrics for such institutions should be used with caution, as even a few outlier publications can significantly change the values

Modern agriculture and food for the future - all types

Name	Rank	Category		Citation Impact	Times Cited	% Docs Cited	%			% Highly Cited Papers	% Hot Papers	Organization Type
		Web of Science Documents	Normalized Citation Impact				Documents in Q1 Journals	Documents in Top 1%	Documents in Top 10%			
Kasetsart University	1	118	0.68	6.55	773	77.97	43.69	0	5.08	0	0	Academic
Mahidol University	2	117	0.88	10.67	1248	77.78	42.71	0.85	6.84	0	0	Academic
Chulalongkorn University	3	113	0.77	7.51	849	76.11	35.56	0	7.08	0	0	Academic
Khon Kaen University	4	107	0.91	6.5	695	72.9	40	0	8.41	0	0	Academic
National Science & Technology Development Agency - Thailand	5	84	0.69	9.37	787	80.95	42.25	0	7.14	0	0	Academic
Chiang Mai University	6	75	0.7	6.95	521	65.33	25.49	1.33	2.67	0	0	Academic
Prince of Songkla University	7	55	0.91	7.75	426	74.55	39.13	0	5.45	0	0	Academic
King Mongkuts Institute of Technology Ladkrabang	8	42	0.53	5.62	236	66.67	6.67	0	2.38	0	0	Academic
Asian Institute of Technology	9	41	0.9	6.17	253	68.29	19.05	0	9.76	0	0	Academic
Suranaree University of Technology	10	39	0.78	12.03	469	89.74	33.33	0	7.69	0	0	Academic

- Kasetsart University is the top institution by research in topic modern agriculture and food for the future, followed closely by Mahidol University and Chulalongkorn University.
- Suranaree University of Technology has the highest citation impact, at 12.03 with a total of 39 documents. Mahidol University is second, with an impact of 10.67 with a total of 117 documents.
- There are two academic institutions with documents in the top 1% of documents: Mahidol University and Chiang Mai University.
- Khon Kaen University and Prince of Songkla University have the highest category normalized citation impact (CNCI), at 0.91, very close to the world average CNCI impact of 1.0.

Tourism - all types

Name	Rank	Web of Science Documents	Category Normalized Citation Impact	Citation Impact	Times Cited	% Docs Cited	% Documents in Q1 Journals	% Documents in Top 1%	% Documents in Top 10%	% Highly Cited Papers	% Hot Papers	Organization Type
Chulalongkorn University	1	410	0.85	9.1	3731	69.27	36.99	0.98	7.32	0.24	0	Academic
Asian Institute of Technology	2	342	0.8	9.11	3114	80.7	29.86	0.29	7.6	0	0	Academic
Kasetsart University	3	277	0.94	7.24	2006	72.2	42.51	0.72	8.66	0.36	0	Academic
King Mongkuts University of Technology Thonburi	4	228	0.67	7.95	1812	70.61	37.36	0	5.26	0	0	Academic
Chiang Mai University	5	170	1.18	10.05	1708	71.76	34.13	1.76	13.53	2.35	0	Academic
Khon Kaen University	6	150	0.9	8	1200	76.67	38.58	0.67	8	0.67	0	Academic
Mahidol University	7	142	0.83	6.36	903	71.13	26.89	0.7	6.34	0	0	Academic
Prince of Songkla University	8	140	0.96	7.11	995	80.71	30.7	0	8.57	0	0	Academic
Thammasat University	9	131	0.84	5.23	685	66.41	32.99	0.76	6.11	0.76	0	Academic
National Science & Technology Development Agency - Thailand	10	86	0.85	7.83	673	72.09	42.19	0	8.14	0	0	Academic

- In Tourism, Chulalongkorn University is the top institution, with 410 papers. Asian Institute of Technology and Kasetsart University round out the top 3, with 342 and 277 papers, respectively.
- Chiang Mai University has the highest citation impact score at 10.05. Asian Institute of Technology and Chulalongkorn University follow closely at 9.11 and 9.10.
- Chiang Mai University also has the highest percentage of highly cited papers, with 2.35%.
- Chiang Mai University has a CNCI of 1.18, higher than the world average of 1.0.

Energy and biomaterials - all types

Name	Rank	Web of Science Documents	Category Normalized Citation Impact	Citation Impact	Times Cited	% Docs Cited	% Documents in Q1 Journals	% Documents in Top 1%	% Documents in Top 10%	% Highly Cited Papers	% Hot Papers	Organization Type
Chulalongkorn University	1	164	1.31	12.66	2077	76.22	56.56	1.22	17.68	0.61	0	Academic
King Mongkuts University of Technology Thonburi	2	81	1.16	17.25	1397	87.65	72.06	0	14.81	0	0	Academic
Prince of Songkla University	3	78	1.62	17.69	1380	75.64	65	5.13	16.67	1.28	0	Academic
National Science & Technology Development Agency - Thailand	4	69	1.3	14.9	1028	78.26	72.22	0	21.74	1.45	0	Academic
Kasetsart University	5	60	1.14	7.38	443	66.67	45	0	11.67	0	0	Academic
Mahidol University	6	39	0.64	8.59	335	71.79	66.67	0	2.56	0	0	Academic
Khon Kaen University	7	35	1.95	4.6	161	60	25	5.71	11.43	0	0	Academic
King Mongkuts University of Technology North Bangkok	8	25	0.93	3.72	93	72	61.11	0	8	0	0	Academic
Silpakorn University	9	21	0.9	10.86	228	76.19	44.44	0	9.52	0	0	Academic
King Mongkuts Institute of Technology Ladkrabang	10	19	1.17	8.84	168	63.16	70	0	21.05	0	0	Academic

- Chulalongkorn University is also highest in Energy and biomaterials, with 164 publications, more than twice the second-appearing entity, King Mongkuts University of Technology Thonburi. Prince of Songkla University is third, with 78 papers.
- Prince of Songkla University has the highest citation impact score at 17.69. King Mongkuts University of Technology Thonburi is close behind at 17.25, and Chulalongkorn University in third at 12.66.
- National Science & Technology Development Agency – Thailand has 1.45 % of highly cited papers in this category.
- Several institutions in this space have an above average CNCI, with 6 of the top 10 showing CNCI values over 1.0.

Health and medical - all types

Name	Rank	Category		Citation Impact	Times Cited	% Docs Cited	%			% Highly Cited Papers	% Hot Papers	Organization Type
		Web of Science Documents	Normalized Citation Impact				Documents in Q1 Journals	Documents in Top 1%	Documents in Top 10%			
Mahidol University	1	1533	1.22	16.12	24715	82.19	44.28	2.15	10.63	2.02	0.07	Academic
Chulalongkorn University	2	901	1.04	11.27	10156	76.69	40.91	1.44	8.88	1.44	0.11	Academic
Chiang Mai University	3	410	0.76	9.54	3910	78.78	35.87	0.73	5.61	0.73	0	Academic
Khon Kaen University	4	406	0.91	12.23	4964	77.59	33.6	1.23	7.39	0.99	0	Academic
Ministry of Public Health - Thailand	5	251	1.62	24.1	6048	84.86	51.28	2.39	13.15	1.59	0.4	Academic
United States Department of Defense	6	211	1.67	24.51	5171	85.78	62.12	4.27	16.11	2.37	0	Government
Armed Forces Research Institute of Medical Sciences - Thailand	7	210	1.85	26.9	5648	87.14	63.27	5.24	18.1	2.86	0	Research Institute
National Science & Technology Development Agency - Thailand	7	210	0.8	10.21	2145	84.76	48.15	0.48	4.76	0.95	0	Academic
United States Army	9	204	1.71	24.88	5075	86.76	62.3	4.41	16.67	2.45	0	Government
Prince of Songkla University	10	201	1.89	26.95	5417	80.1	41.49	3.98	12.94	3.98	0	Academic
University of Oxford	11	172	1.89	30.79	5296	90.7	73.05	4.65	22.67	6.4	0	Academic

- Mahidol University has the most papers in the health and medical technical space, with 1533 papers. Chulalongkorn University follows with 901 papers, and Chiang Mai University is 3rd with 410 papers.
- The University of Oxford has the highest citation impact, at 30.79, followed closely by Prince of Songkla University at 26.95.
- The Ministry of Public Health – Thailand has the highest proportion of hot papers, at 0.4% in this space.
- All of the entities in health and medical have papers appearing in the Highly Cited Papers.
- Health and medical stands out in the technical spaces in that the top 10 institutions are not all academic. There are 2 governmental organizations (US Department of Defense and US Army) and one research institute (Ministry of Public Health – Thailand).
- Prince of Songkla University and the University of Oxford have CNCI Values of 1.89, above the international average of 1.0.

Modern agriculture and food for the future – articles and proceedings all types

Name	Rank	Web of Science Documents	Category	Citation Impact	Citation Impact	Times Cited	% Docs Cited	%	%	%	% Highly Cited Papers	% Hot Papers	Organization Type
			Normalized Citation Impact					Documents in Q1 Journals	Documents in Top 1%	Documents in Top 10%			
Kasetsart University	1	117	0.68	6.61	773	78.63	43.14	0	5.13	0	0	Academic	
Mahidol University	2	112	0.91	10.87	1217	80.36	43.01	0.89	7.14	0	0	Academic	
Chulalongkorn University	3	108	0.77	7.72	834	77.78	35.63	0	7.41	0	0	Academic	
Khon Kaen University	4	104	0.9	6.49	675	73.08	40.96	0	8.65	0	0	Academic	
National Science & Technology Development Agency - Thailand	5	84	0.69	9.37	787	80.95	42.25	0	7.14	0	0	Academic	
Chiang Mai University	6	72	0.71	6.15	443	66.67	24.49	1.39	2.78	0	0	Academic	
Prince of Songkla University	7	54	0.92	7.87	425	74.07	37.78	0	5.56	0	0	Academic	
King Mongkuts Institute of Technology Ladkrabang	8	42	0.53	5.62	236	66.67	6.67	0	2.38	0	0	Academic	
Asian Institute of Technology	9	40	0.92	6.33	253	70	19.05	0	10	0	0	Academic	
Suranaree University of Technology	10	38	0.76	8.92	339	89.47	31.43	0	7.89	0	0	Academic	

- In technical topic modern agriculture and food for the future, Kasetsart University, Mahidol University, Chulalongkorn University and Khon Kaen University have very similar publications in articles and proceedings, ranging from a high of 117 to 104.
- Mahidol University has the highest citation impact at 10.87.
- Chiang Mai University and Mahidol University have documents in the top 1% of papers, at 1.39 and 0.89 percent respectively.

Tourism - proceedings all types

Name	Rank	Web of Science Documents	Category Normalized Citation Impact	Citation Impact	Times Cited	% Docs Cited	% Documents in Q1 Journals	% Documents in Top 1%	% Documents in Top 10%	% Highly Cited Papers	% Hot Papers	Organization Type
Chulalongkorn University	1	398	0.84	8.97	3571	69.6	36.04	1.01	7.04	0.25	0	Academic
Asian Institute of Technology	2	324	0.82	8.94	2898	82.1	30.4	0.31	7.72	0	0	Academic
Kasetsart University	3	270	0.96	7.34	1981	72.59	42.5	0.74	8.89	0.37	0	Academic
King Mongkuts University of Technology Thonburi	4	222	0.67	8.05	1788	70.72	35.88	0	4.95	0	0	Academic
Chiang Mai University	5	165	1.21	9.95	1642	72.73	33.88	1.82	13.94	2.42	0	Academic
Khon Kaen University	6	147	0.92	8.16	1200	78.23	39.2	0.68	8.16	0.68	0	Academic
Prince of Songkla University	7	139	0.97	7.16	995	81.29	30.97	0	8.63	0	0	Academic
Mahidol University	8	138	0.85	6.54	902	72.46	27.12	0.72	6.52	0	0	Academic
Thammasat University	9	127	0.85	5.11	649	65.35	31.18	0.79	6.3	0.79	0	Academic
National Science & Technology Development Agency - Thailand	10	86	0.85	7.83	673	72.09	42.19	0	8.14	0	0	Academic

- Water and waste management is led in documents output by Chulalongkorn University with 398 papers. Asian Institute of Technology is second at 324, and Kasetsart University is at third with 270 publications.
- Citation impact scores are relatively similar across all of the top 10 institutions, ranging from a high of 9.95 (Chiang Mai University) to a low of 5.11 (Thammasat University).
- There are 5 academic institutions in this space with papers considered highly cited. Chiang Mai University has the highest percentage at 2.42.
- Chiang Mai University has a CNCI above global averages, at 1.21.

Energy and biomaterials – proceedings all types

Name	Rank	Category		Citation Impact	Times Cited	% Docs Cited	%			% Hot Papers	Organization Type	
		Web of Science Documents	Normalized Citation Impact				Documents in Q1 Journals	Documents in Top 1%	Documents in Top 10%			
Chulalongkorn University	1	157	1.2	12.47	1958	77.07	56.41	0.64	17.83	0.64	0	Academic
King Mongkuts University of Technology Thonburi	2	78	1.18	17.14	1337	88.46	72.31	0	15.38	0	0	Academic
Prince of Songkla University	3	77	1.64	17.92	1380	76.62	66.1	5.19	16.88	1.3	0	Academic
National Science & Technology Development Agency - Thailand	4	67	1.34	15.18	1017	79.1	73.08	0	22.39	1.49	0	Academic
Kasetsart University	5	59	0.98	7.47	441	66.1	46.15	0	10.17	0	0	Academic
Mahidol University	6	36	0.67	8.53	307	75	70	0	2.78	0	0	Academic
Khon Kaen University	7	29	0.56	5.1	148	65.52	30.77	0	6.9	0	0	Academic
King Mongkuts University of Technology North Bangkok	8	25	0.93	3.72	93	72	61.11	0	8	0	0	Academic
Silpakorn University	9	21	0.9	10.86	228	76.19	44.44	0	9.52	0	0	Academic
King Mongkuts Institute of Technology Ladkrabang	10	19	1.17	8.84	168	63.16	70	0	21.05	0	0	Academic

- Chulalongkorn University is highest in energy and biomaterials (157), with approximately twice as many publications as the second institution, King Mongkuts University of Technology Thonburi.
- Prince of Songkla University has the highest citation impact (17.92), followed closely by King Mongkuts University of Technology Thonburi at 17.14.
- National Science & Technology Development Agency – Thailand has the highest proportion of highly cited papers with 1.49%.

Health and medical – proceedings all types

Name	Rank	Web of Science Documents	Category Normalized Citation Impact	Citation Impact	Times Cited	% Docs Cited	% Documents in Q1 Journals	% Documents in Top 1%	% Documents in Top 10%	% Highly Cited Papers	% Hot Papers	Organization Type
Mahidol University	1	1370	1.19	15.73	21554	83.43	43.79	1.97	10.29	1.82	0.07	Academic
Chulalongkorn University	2	798	1.03	11.53	9198	78.32	39.2	1.38	9.15	1.5	0.13	Academic
Chiang Mai University	3	377	0.79	9.8	3693	80.11	34.63	0.8	6.1	0.8	0	Academic
Khon Kaen University	4	368	0.85	11.06	4070	79.35	31.18	1.09	7.34	0.82	0	Academic
Ministry of Public Health - Thailand	5	239	1.67	24.71	5906	85.36	51.12	2.51	13.81	1.67	0.42	Academic
National Science & Technology Development Agency - Thailand	6	202	0.81	9.78	1975	84.65	47.51	0.5	4.95	0.99	0	Academic
Armed Forces Research Institute of Medical Sciences - Thailand	7	190	2	28.7	5453	87.89	63.84	5.79	19.47	3.16	0	Research Institute
United States Department of Defense	8	189	1.81	26.28	4966	86.77	63.28	4.76	17.46	2.65	0	Government
United States Army	9	184	1.85	26.56	4887	87.5	63.37	4.89	17.93	2.72	0	Government
Prince of Songkla University	10	174	1.61	23.72	4128	82.76	39.51	2.87	12.07	2.87	0	Academic
University of Oxford	11	158	1.83	26.63	4207	90.51	72.73	4.43	21.52	5.7	0	Academic

- Mahidol University leads in overall publications in health and medical proceedings, with 1,370 papers. Chulalongkorn University follows with 798, and Chiang Mai University at 377.
- University of Oxford has the highest citation impact at 26.63, followed by United States Army (26.56) and United States Department of Defense (26.28).
- There are three academic institutions with hot papers in this space: Ministry of Public Health – Thailand (0.42%), Chulalongkorn University (0.13%) and Mahidol University (0.07%).

Appendix

Source data and collection building

Search string creation and quality control

- The creation of the search strings for all technology searches were performed iteratively, with the results of each generation of search string reviewed and evaluated to inform and tailor the search to become more accurate.
- As each search string is created, the results are sampled and reviewed for relevancy, and keywords and classifications amended as appropriate. Further, the results of each string are data mined for further key terms of interest, synonyms and alphanumeric technology classification codes of relevance, which are then incorporated in revised search strings. This process is repeated for each search until revisions perform only minor variations in results. At this point, the search string is locked in its configuration.

Assumptions and definitions

- The patent study is constructed around the Derwent World Patents Index database structure. DWPI uses “patent families” as the definition for each record, rather than individual patent publication documents. Each invention-related patent application and granted patent is added to the DWPI family record as it is published. This being the case, all counts of records in the study refer to patent families or inventions, and not to individual patent documents. For example, the European application, European granted patent and the US granted patent for a single invention family is counted as “1” in all the analyses in this report unless otherwise noted.
- This provides a more accurate measure of the level of inventive activity from an entity within the technical space, and a truer picture of the overall level of innovation across the field as a whole.
- As each DWPI record contains potentially many individual publication events, this report uses the earliest known priority filing date for each patent family. The tables and charts included in the report use this date unless otherwise noted, because it provides the most accurate indication of the time of the inventive activity.
- A single patent only provides a statutory monopoly for the patented technology within the legal jurisdiction of the authority that granted the patent. This means that inventors must file applications for a patent in each jurisdiction where they foresee a need for protection.
- Priority refers to the first application for a particular invention which when filed at any patent office becomes the “priority application”, with the date of this event defining the priority date. The patent office location of the first filing is defined as the priority country. The priority filing provides the patent applicant with a grace period to file on the same invention in other patent jurisdictions without loss of the “novelty” requirement for patentability.

Patent applicant naming variations

- Assignee names appearing on patent documents are also inconsistently formatted. To the extent possible, such formatting anomalies are regularized during the assignee clean-up process, which benefits from the name standardization provided by the Derwent World Patents Index (DWPI) as well as employing additional automated and manual review. Assignee name reformatting reduces the heterogeneity in assignee names to a more manageable and more instructive level.
- Assignee names attached to patent documents reflect the ownership at time of document publication. Changes in ownership (reassignments) that occur after publication may or may not be reflected in the US reassignment field or in the INPADOC legal status field. To the extent the information is available in these two fields; the assignee name will be updated to reflect the reassignments. It is also expected that in US applications, many assignees will be “unknown” because assignees may not have been registered with the US PTO before publication. Usually the absent assignee can be inferred by checking ownership of other patent family members, or by observing assignments in other records by the same inventor. All of these methods are used to improve the quality of the assignee data to be used for analysis.
- Lastly, company name changes, acquisitions and mergers, and hidden relationships are expected to affect true ownership of patent documents that may not be reflected in the collection data per se. For selected higher volume or critical assignees, we may rely on information from the Derwent Patent Assignee Code (PACO) system, and also may obtain information on acquisitions and other company transactions from outside sources, such as Hoovers Online Business Information and selected company web sites.

Clarivate IP index

- At a high level, the metrics that make up the Clarivate IP Index cover the level of investment by the applicant, downstream 3rd party impact, commitment and success/patentability of the patent applications, the breadth of the technology covered by the invention and how the patent has been prosecuted and/or asserted. Specifically, the Strength Index measures:
 - Geographic Filing Breadth
 - Grant Success/Grant Commitment and Granted Patent Locations
 - Frequency of Citation by Downstream Patent Applications
 - Technical Breadth
 - Opposition Proceeding Survival
 - Patent Age
- These measurements are combined together statistically, typically self-referential to the dataset at hand, to provide an overall strength score per patent family. The family definition used is that specific to the Derwent World Patents Index™, which provides for a synonymous relationship between each family and an individual “invention” – e.g. one specific set of claims language in each legal jurisdiction in which protection has been sought.
- This strength score is then aggregated across portfolios and technologies for benchmarking purposes.
- Very recent patents will frequently have a lower index score due to their age. Patents accrue citations and foreign filings over time, so a recent invention has not had sufficient time to build this history. This may also be reflective of regional patent practice. For example, China patents currently have very low rates of citation and international filing, and thus have lower IP index scores compared to other nations.

Literature analytics

- The citation impact of a set of documents is calculated by dividing the total number of citations by the total number of publications. Citation impact shows the average number of citations that a document has received.

$$\text{Citation Impact} = \frac{\sum \text{Citations}}{\sum \text{Papers}}$$

- Citation Impact has been extensively used as a bibliometric indicator in research performance evaluation and can be applied at all organizational levels (author, institution, country/region, research field or journal). However, there are limitations to the indicator. For example, it ignores the total volume of research outputs.
- At the field level, the Citation Impact of certain disciplines is often higher than in other scientific fields due to several factors, such as the degree to which references from other fields are cited.
- The Category Normalized Citation Impact (CNCI) of a document is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. When a document is assigned to more than one subject area an average of the ratios of the actual to expected citations is used. The CNCI of a set of documents, for example the collected works of an individual, institution or country/region, is the average of the CNCI values for all the documents in the set.
- CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus of document type. An CNCI value of 1 represents performance at par with world average, values above 1 are considered above average and values below 1 are considered below average.

Literature analytics

- The Journal Impact Factor quartile is the quotient of a journal's rank in category (X) and the total number of journals in the category (Y), so that $(X / Y) = \text{Percentile Rank } Z$.
 - Q1: $0.0 < Z \leq 0.25$, Q2: $0.25 < Z \leq 0.5$, Q3: $0.5 < Z \leq 0.75$, Q4: $0.75 < Z$
- Documents published in Q1 – Q4 journals
 - Number of documents that appear in a journal in a particular Journal Impact Factor Quartile in a given year. For instance, if a value of 100 is displayed, it indicates that 100 documents in the set were published in journals of the specified Journal Impact Factor Quartile in that year.
- InCites uses the best quartile for journals that appear in multiple Web of Science Research Areas. When a research area is specified, the quartile for that particular journal and research area is used.
- % Documents in Q1 – Q4
 - % of documents that appear in a journal in a particular Journal Impact Factor Quartile in a given year. For instance, if a value of 10% is displayed, it indicates that 10% of the documents in the set were published in journals of the specified Journal Impact Factor Quartile in that year.
- The Highly Cited Papers indicator shows the volume of papers that are classified as highly cited in Essential Science IndicatorsSM (ESI). ESI is a separate service also hosted on the InCites platform and should not be confused with the subject scheme of the same name.
- Highly cited papers are the top one percent in each of the 22 ESI subject areas per year. They are based on the most recent 10 years of publications. Highly Cited Papers are considered to be indicators of scientific excellence and top performance and can be used to benchmark research performance against field baselines worldwide. Although Highly Cited Papers are synonymous with % Documents in the Top 1% in InCites, they are not the identical because of differences in subject scheme, time period and document type.
- The % Highly Cited Papers indicator shows the number of ESI Highly Cited Papers for an entity (paper, author, institution, country, journal and field) divided by the total number of documents produced by the given entity, represented as a percentage.
- It is a measure of excellence and can show what percentage of an institutions output is among the most impactful papers in the world.



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