

The use, and usefulness, of spatial conservation prioritizations: supporting information

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Literature Search Protocol

We identified prioritizations in the peer reviewed literature through the use of a multicriteria search in ISI Thompsons Web of Science. We entered the following list of terms into the “topic” criteria with each term linked by an “OR” command: conservation assessments, conservation planning, conservation plan, conservation evaluation, conservation value, reserve selection, area selection, area identification, priority area, bioregional conservation, bioregional planning, ecoregional assessment, ecoregional conservation, integrated conservation and natural areas identification. These terms were intended to identify prioritizations even where the authors had not identified their work as such. Because of frequent usage of the terms “prioritization” and “conservation prioritization” in other areas of conservation, these terms were not used. The search was not limited to any start date but the end date was limited to December 31st 2015. The search returned 17,588 papers. These were reviewed initially by title alone to identify papers which potentially included prioritizations. The abstracts of papers in the shortlist were then reviewed and excluded or included in the study according to the criteria in Table 16. Papers which were published before December 31st 2010 were reviewed by George Galloway and papers published after this date were reviewed by Sam Lloyd. Sam Lloyd familiarised himself with the application of the criteria as conducted by George Galloway before conducting the review. This process identified 645 papers which detailed prioritizations.

Supporting Information Table A. The criteria for identification of prioritizations in the literature.

Criteria for including papers
Those which present a spatial conservation prioritization which may include algorithms, specialist software or other specific process.
Prioritizations which identify focal, keystone, umbrella or threatened species and select priority areas.
Gap analyses of protected area networks where specific areas are identified for conservation action or intervention.
Criteria for excluding papers
Papers which present theoretical methods for prioritization or which use theoretical data.
Biogeographic analyses which could theoretically be used to identify priority areas.
Gap analyses of protected areas which do not identify priority areas for expansion or action.

Supporting Information Table B. The 6 comparison variables used to contrast and compare between clusters

Comparison variable	Response options
Has a conservation intervention been attempted on the ground at the priority areas identified by this prioritisation as a direct result of the prioritisation?	1) Yes 2) No 3) No intervention has yet been attempted, but a specific action, or actions, is currently being set-up with the intention of being implemented 4) Unsure
What data did you use in the prioritisation?	1) Genetic data 2) Species data 3) ecological or evolutionary processes 4) Habitat or ecosystem 5) Irreplaceability 6) Threat 7) Land use 8) Land value 9) Cost of implementation 10) Political costs and benefits 11) Landowner characteristics (e.g. willingness to conserve) 12) Hydrological data
What software was used?	1) No software was used 2) BIORAP 3) C-Plan 4) CODA 5) ConsNet 6) CLUZ 7) INFFER 8) GIS 9) Marxan 10) MCA 11) MCAS-S 12) R 13) ResNet 14) SCArPA 15) Spexan 16) Target 17) Zonation 18) Custom developed software 19) Other (please describe here)

Why was the area selected?	<ol style="list-style-type: none"> 1) Because it contains important ecosystems 2) It was an area of importance for a target species 3) Because of threats to the area 4) Because it is the area in which your organisation works 5) Because it has cultural significance 6) It was a region for which data already existed 7) Because national legislation required it 8) Opportunistically
Would you say that overall the prioritisation was effective in achieving its goals?	<ol style="list-style-type: none"> 1) Too early to say 2) Yes, very effective 3) Yes, somewhat effective 4) Too early to say 5) No, not effective 6) Unsure 7) Prefer not to say
What products did you produce?	<ol style="list-style-type: none"> 1) Electronic map 2) Hard copy map 3) Computer-based decision support system 4) Guidelines on how to use the map or decision support system products 5) Policy briefing for high-level decision-maker 6) Media articles 7) Peer-reviewed journal article 8) Funding application 9) Report

Supporting Information Table C. The eleven variables used in the cluster analysis

Cluster input variable	Response options
To what extent was an end user identified and involved?	1) No end user identified 2) End user identified but not included in development 3) End user identified and included in development
To what extent were NGOs involved	1) Strongly involved 2) Consulted 3) Not involved
To what extent was government involved	1) Strongly involved 2) Consulted 3) Not involved
To what extent were academics involved	1) Strongly involved 2) Consulted 3) Not involved
Was the prioritisation designed to comply with any laws	1) Yes 2) No
Was the prioritisation undertaken to achieve any specific outcomes?	1) Yes 2) No
Was the prioritisation was intended to translate to specific implementation?	1) Yes 2) No
What was the single most important intended outcome?	3) Biodiversity incorporated into a government process 4) Improved prioritisation techniques 5) More effective fund raising 6) A more effective protected area network 7) Increased effectiveness of a specific organisation 8) More effective negotiations 9) None of the above 10) A specific change in legislation
Collaboration metric	Based on involvement of stakeholder groups (score ranged from 0 to 15)

Which of the following best describes your process?	<div>1) Computer-based analysis was the sole means for conducting the prioritisation</div> <div>2) Computer-based analysis was the primary means for conducting the prioritisation, with some supporting expert knowledge</div> <div>3) An equal combination of computer based analysis and expert knowledge was used to conduct the prioritisation</div> <div>4) Expert knowledge was the primary means for conducting the prioritisation, with</div> <div>5) Expert knowledge was the sole means for conducting the prioritisation</div> <div>6) Other, please specify</div>
Did you produce a peer reviewed article?	<div>1) Yes</div> <div>2) No</div>

Supporting Information Table 1. The intent of prioritisation developers

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
created to comply with laws	No	60	87.0%	45	47.4%
	Unsure	0	0.0%	2	2.1%
	Yes	9	13.0%	48	50.5%
intention to achieve specific outcomes?	No	27	39.1%	11	12.1%
	Unsure	4	5.8%	3	3.3%
	Yes	38	55.1%	77	84.6%
intention to translate to specific implementation	No	49	72.1%	4	4.4%
	Unsure	3	4.4%	8	8.8%
	Yes	16	23.5%	79	86.8%

Supporting Information Table 2. The extent and identification of end users in prioritisation development

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Extent of identification and inclusion of end user	0	43	62.3%	18	18.8%
	1	20	29.0%	7	7.3%
	2	6	8.7%	71	74.0%

Supporting Information Table 3. The extent of stakeholder involvement in prioritisation development

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Conservation NGO collaboration in creation	Consulted	14	21.9%	28	29.5%
	Not involved	42	65.6%	11	11.6%
	Strongly involved	7	10.9%	56	58.9%
	Unsure	1	1.6%	0	0.0%
Government collaboration in creation	Consulted	20	31.3%	20	20.8%
	Not involved	33	51.6%	7	7.3%
	Strongly involved	11	17.2%	68	70.8%
	Unsure	0	0.0%	1	1.0%
Academics collaboration in creation	Consulted	11	16.7%	25	26.0%
	Not involved	5	7.6%	4	4.2%
	Strongly involved	50	75.8%	66	68.8%
	Unsure	0	0.0%	1	1.0%

Supporting Information Table 4. The extent of collaboration in prioritisation development

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Collaboration coefficient	0	2	2.9%	0	0.0%
	1	6	8.7%	0	0.0%
	2	23	33.3%	3	3.1%
	3	18	26.1%	1	1.0%
	4	12	17.4%	9	9.4%
	5	1	1.4%	13	13.5%
	6	3	4.3%	11	11.5%
	7	3	4.3%	17	17.7%
	8	0	0.0%	11	11.5%
	9	0	0.0%	10	10.4%
	10	1	1.4%	4	4.2%
	11	0	0.0%	2	2.1%
	12	0	0.0%	6	6.3%
	13	0	0.0%	5	5.2%
	14	0	0.0%	1	1.0%
	15	0	0.0%	3	3.1%

Supporting Information Table 5. The primary aim of prioritisations

		Clusters			
		Advancement focused		Implementation focused	
Primary aim		Count	Proportion	Count	Proportion
	A more effective protected area network	24	34.8%	35	36.5%
	A specific change in legislation	0	0.0%	1	1.0%
	Biodiversity incorporated into a government process	5	7.2%	25	26.0%
	Improved prioritisation techniques	31	44.9%	11	11.5%
	Increased effectiveness of a specific organisation	2	2.9%	6	6.3%
	More effective fund raising	0	0.0%	3	3.1%
	More effective negotiations	2	2.9%	3	3.1%
	None of the above	5	7.2%	12	12.5%

Supporting Information Table 6. The development process of prioritisations

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
prioritisation process	1) Expert knowledge was the sole means for conducting the prioritisation	1	1.4%	6	6.4%
	2) Computer-based analysis was the sole means for conducting the prioritisation	23	33.3%	5	5.3%
	3) Expert knowledge was the primary means for conducting the prioritisation, with some supporting computer-based analysis	7	10.1%	19	20.2%
	4) Computer-based analysis was the primary means for conducting the prioritisation, with some supporting expert knowledge	25	36.2%	29	30.9%
	5) An equal combination of computer based analysis and expert knowledge was used to conduct the prioritisation	12	17.4%	27	28.7%
	6) Other, please specify	1	1.4%	8	8.5%

Supporting Information Table 7. The extent of peer reviewed article production

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
production of peer reviewed article	No	0	0.0%	31	35.2%
	Unsure	0	0.0%	2	2.3%
	Yes	67	100.0%	55	62.5%

Supporting Information Table 8. The extent of translation to implementation of prioritisations

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Conservation intervention attempted on ground	No intervention has been attempted	43	63.2%	11	12.1%
	No intervention has yet been attempted, but a specific action, or actions, is currently being set-up with the intention	6	8.8%	21	23.1%
	Unsure	11	16.2%	13	14.3%
	Yes	8	11.8%	46	50.5%

Supporting Information Table 9. The data used in prioritisations

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Genetic data	No	55	94.8%	74	85.1%
	Unsure	0	0.0%	2	2.3%
	Yes	3	5.2%	11	12.6%
Species data	No	6	9.4%	4	4.3%
	Unsure	1	1.6%	0	0.0%
	Yes	57	89.1%	89	95.7%
ecological or evolutionary processes	No	42	72.4%	39	43.3%
	Unsure	1	1.7%	2	2.2%
	Yes	15	25.9%	49	54.4%
Habitat or ecosystem	No	16	25.0%	7	7.6%
	Yes	48	75.0%	85	92.4%
Irreplaceability	No	34	55.7%	27	30.3%
	Unsure	3	4.9%	7	7.9%
	Yes	24	39.3%	55	61.8%
Threat	No	25	41.0%	16	17.4%
	Unsure	0	0.0%	4	4.3%
	Yes	36	59.0%	72	78.3%
Land use	No	20	32.8%	14	15.6%
	Unsure	0	0.0%	2	2.2%
	Yes	41	67.2%	74	82.2%
Land value	No	50	86.2%	64	73.6%
	Unsure	0	0.0%	2	2.3%
	Yes	8	13.8%	21	24.1%
Cost of implementation	No	43	74.1%	56	63.6%
	Unsure	1	1.7%	3	3.4%
	Yes	14	24.1%	29	33.0%
Political costs and benefits	No	50	89.3%	61	70.1%
	Unsure	0	0.0%	2	2.3%
	Yes	6	10.7%	24	27.6%
Landowner characteristics (e.g. willingness to conserve)	No	51	89.5%	57	64.8%
	Unsure	0	0.0%	3	3.4%
	Yes	6	10.5%	28	31.8%
Hydrological data	No	50	86.2%	44	48.9%
	Unsure	0	0.0%	1	1.1%
	Yes	8	13.8%	45	50.0%

Supporting Information Table 10. The associated products developed alongside the prioritisation

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Electronic map	No	13	21.7%	4	4.4%
	Yes	47	78.3%	87	95.6%
Hard copy map	No	30	55.6%	18	20.5%
	Unsure	2	3.7%	0	0.0%
	Yes	22	40.7%	70	79.5%
Computer-based decision support system	No	37	66.1%	46	54.1%
	Unsure	1	1.8%	1	1.2%
	Yes	18	32.1%	38	44.7%
Guidelines on how to use the map or decision support system products	No	37	67.3%	25	29.1%
	Unsure	1	1.8%	1	1.2%
	Yes	17	30.9%	60	69.8%
Policy briefing for high-level decision-maker	No	48	90.6%	31	36.0%
	Unsure	0	0.0%	6	7.0%
	Yes	5	9.4%	49	57.0%
Media articles	No	44	81.5%	33	38.8%
	Unsure	0	0.0%	5	5.9%
	Yes	10	18.5%	47	55.3%
Peer-reviewed journal article	No	0	0.0%	31	35.2%
	Unsure	0	0.0%	2	2.3%
	Yes	67	100.0%	55	62.5%
Funding application	No	45	84.9%	52	68.4%
	Unsure	1	1.9%	2	2.6%
	Yes	7	13.2%	22	28.9%
Report	No	32	58.2%	14	15.9%
	Unsure	0	0.0%	1	1.1%
	Yes	23	41.8%	73	83.0%

Supporting Information Table 11. The reported effectiveness of prioritisations

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Was the prioritisation effective in achieving its goals?	No, not effective	3	4.4%	4	4.4%
	Prefer not to say	2	2.9%	0	0.0%
	Too early to say	13	19.1%	15	16.5%
	Unsure	11	16.2%	4	4.4%
	Yes, somewhat effective	20	29.4%	41	45.1%
	Yes, very effective	19	27.9%	27	29.7%

Supporting Information Table 12. The software used in prioritisation development

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
No software was used	not used	66	95.7%	88	91.7%
	used	3	4.3%	8	8.3%
BIORAP	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
C-Plan	not used	68	98.6%	94	97.9%
	used	1	1.4%	2	2.1%
CODA	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
ConsNet	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
CLUZ	not used	69	100.0%	92	95.8%
	used	0	0.0%	4	4.2%
INFFER	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
GIS	not used	35	50.7%	38	39.6%
	used	34	49.3%	58	60.4%
Marxan	not used	52	75.4%	63	65.6%
	used	17	24.6%	33	34.4%
MCA	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
MCAS-S	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
R	not used	49	71.0%	82	85.4%
	used	20	29.0%	14	14.6%
ResNet	not used	67	97.1%	96	100.0%
	used	2	2.9%	0	0.0%
SCaRPA	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
Spexan	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
Target	not used	69	100.0%	96	100.0%
	used	0	0.0%	0	0.0%
Zonation	not used	61	88.4%	86	89.6%
	used	8	11.6%	10	10.4%

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Custom developed software	not used	62	89.9%	92	95.8%
	used	7	10.1%	4	4.2%
Other	not used	53	76.8%	73	76.0%
	used	16	23.2%	23	24.0%

Supporting Information Table 13. The reason for selection of the study area of prioritisations

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Because it contains important ecosystems	A primary reason for choosing the study area	30	49.2%	54	68.4%
	Not a primary reason but considered	22	36.1%	20	25.3%
	Not considered	9	14.8%	5	6.3%
It was an area of importance for a target species	A primary reason for choosing the study area	29	50.0%	43	56.6%
	Not a primary reason but considered	15	25.9%	23	30.3%
	Not considered	14	24.1%	9	11.8%
	Unsure	0	0.0%	1	1.3%
Because of threats to the area	A primary reason for choosing the study area	31	51.7%	45	57.7%
	Not a primary reason but considered	19	31.7%	27	34.6%
	Not considered	10	16.7%	6	7.7%
Because it is the area in which your organisation works	A primary reason for choosing the study area	22	39.3%	53	60.9%
	Not a primary reason but considered	18	32.1%	14	16.1%
	Not considered	16	28.6%	19	21.8%
	Unsure	0	0.0%	1	1.1%
Because it has cultural significance	A primary reason for choosing the study area	5	9.3%	12	16.4%
	Not a primary reason but considered	14	25.9%	23	31.5%
	Not considered	35	64.8%	37	50.7%
	Unsure	0	0.0%	1	1.4%
It was a region for which data already existed	A primary reason for choosing the study area	30	50.8%	21	29.6%
	Not a primary reason but considered	17	28.8%	25	35.2%
	Not considered	12	20.3%	25	35.2%

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Because national legislation required it	A primary reason for choosing the study area	4	7.5%	29	36.7%
	Not a primary reason but considered	7	13.2%	18	22.8%
	Not considered	40	75.5%	32	40.5%
	Unsure	2	3.8%	0	0.0%
Opportunistically	A primary reason for choosing the study area	9	16.7%	10	15.2%
	Not a primary reason but considered	10	18.5%	11	16.7%
	Not considered	29	53.7%	43	65.2%
	Unsure	6	11.1%	2	3.0%

Supporting Information Table 14. The extent to which prioritisations led to a specific positive conservation impact

		Clusters			
		Advancement focused		Implementation focused	
		Count	Proportion	Count	Proportion
Was a specific positive conservation impact achieved as a direct result of the prioritisation?	No	33	48.5%	8	9.0%
	Unsure	27	39.7%	40	44.9%
	Yes	8	11.8%	41	46.1%

Supporting Information Table 15. The extent of prioritization effectiveness in relation to aim

	Yes, very effective	Yes, somewhat effective	Too early to say	No, not effective	Unsure	Prefer not to say
A more effective protected area network	15	23	12	2	5	2
A specific change in legislation	0	0	1	0	0	0
Biodiversity incorporated into a government process	9	11	6	3	0	0
Improved prioritisation techniques	13	15	4	1	7	0
Increased effectiveness of a specific organisation	2	5	0	0	1	0
More effective fund raising	3	0	0	0	0	0
More effective negotiations	1	2	1	0	0	0
None of the above	3	5	4	1	2	0

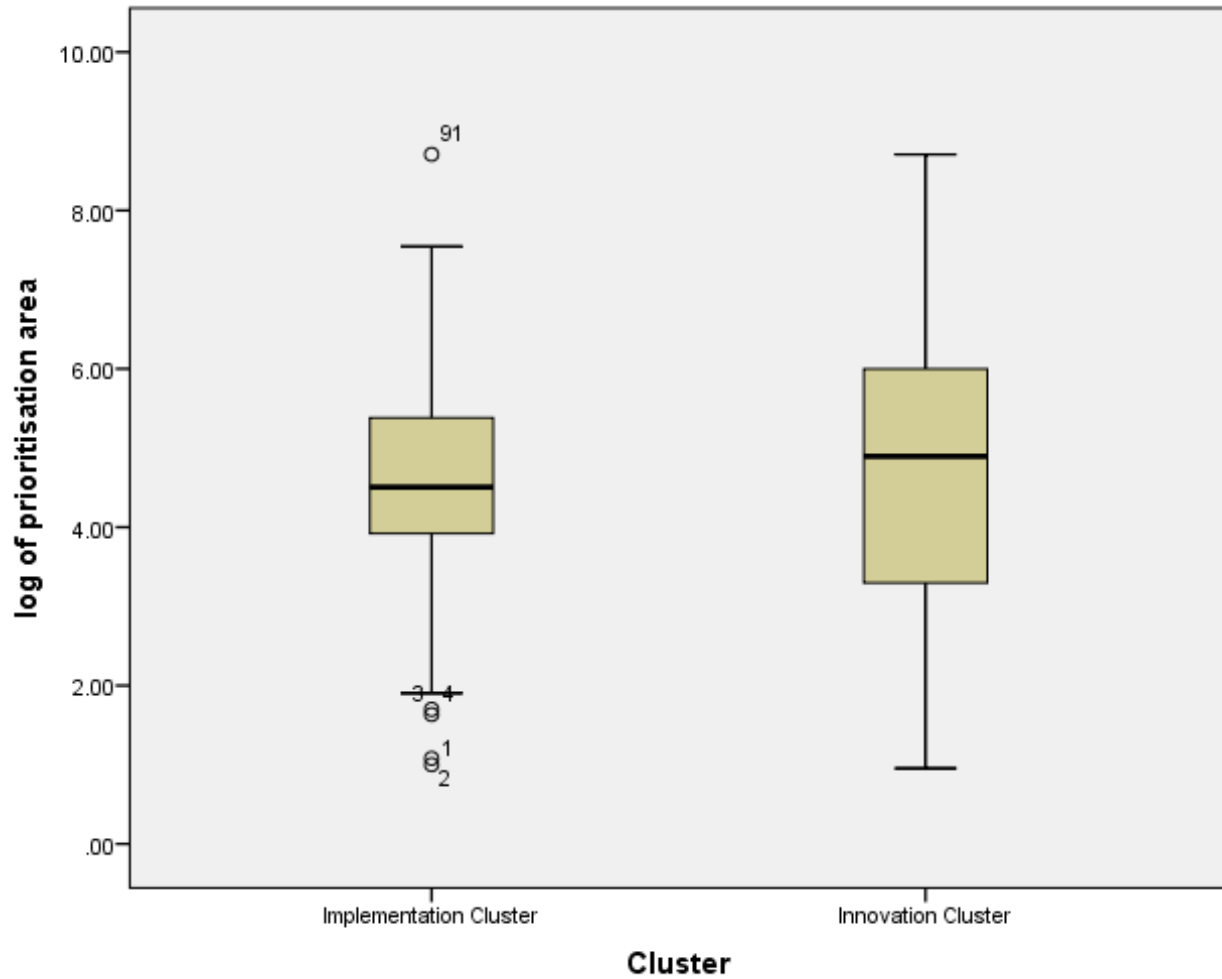
Table 16: The Schwarz's Bayesian Criterion calculations used to determine cluster number

Auto-Clustering				
Number of Clusters	Schwarz's Bayesian Criterion (BIC)	BIC Change ^a	Ratio of BIC Changes ^b	Ratio of Distance Measures ^c
1	3204.812			
2	2975.470	-229.342	1.000	2.075
3	2952.198	-23.272	.101	1.600
4	3000.833	48.635	-.212	1.120
5	3062.357	61.524	-.268	1.055
6	3129.487	67.130	-.293	1.112
7	3206.804	77.317	-.337	1.104
8	3292.738	85.934	-.375	1.079
9	3384.684	91.946	-.401	1.163
10	3487.340	102.656	-.448	1.001
11	3590.055	102.715	-.448	1.049
12	3695.846	105.791	-.461	1.053
13	3804.807	108.961	-.475	1.050
14	3916.620	111.814	-.488	1.118
15	4034.419	117.799	-.514	1.014

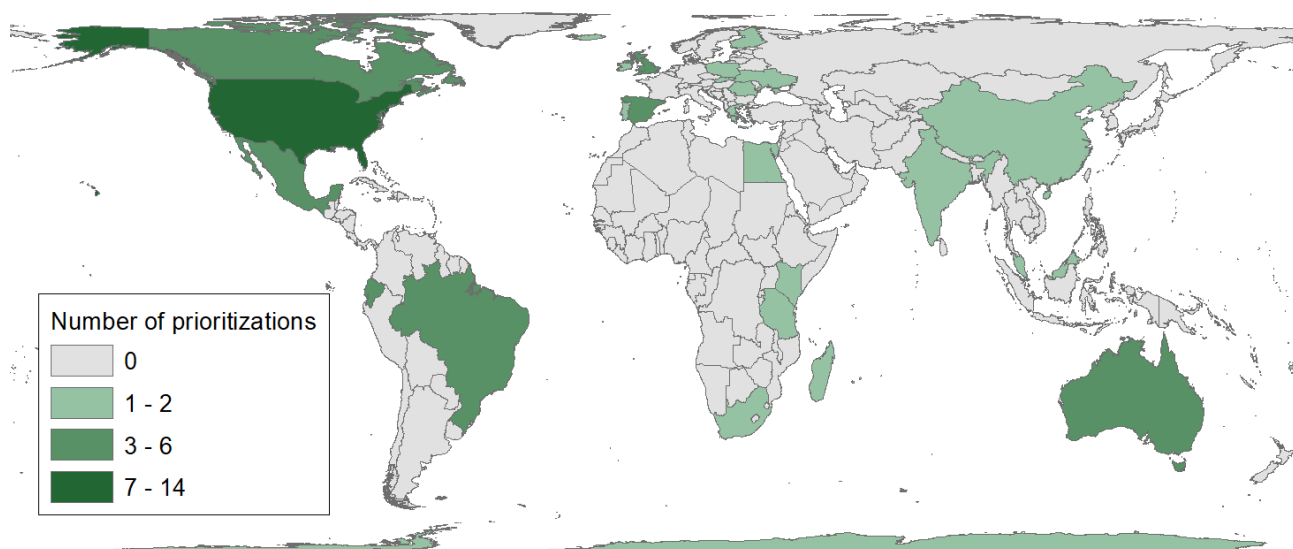
a. The changes are from the previous number of clusters in the table.

b. The ratios of changes are relative to the change for the two cluster solution.

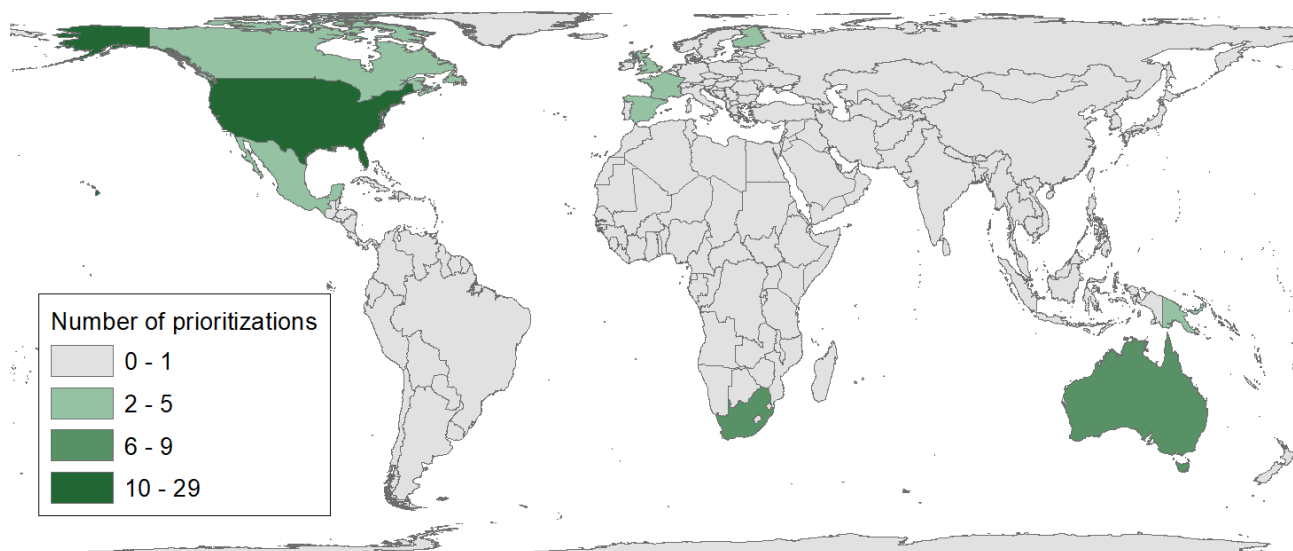
c. The ratios of distance measures are based on the current number of clusters against the previous number of clusters.



Supporting Information Figure 1. The area covered by the prioritizations expressed logarithmically. The innovation cluster ranged from 10km^2 to $5.1 \times 10^8 \text{ km}^2$ (global study) with a mean of 33151km^2 and a standard deviation of 53523164 . The implementation cluster ranged from 9km^2 to $5.1 \times 10^8 \text{ km}^2$ (global study) with a mean of 49516 and a standard deviation of 67521343 .



Supporting Information Figure 2. The number of innovation focused prioritizations by country



Supporting Information Figure 3. The number of implementation focused prioritizations by country

Cluster Analysis Terminology

Schwarz Bayesian Criterion

Cluster analyses describe complex data by identifying discrete groups or clusters. One of the key steps in this process is determining the appropriate number of clusters. Schwarz Bayesian Criterion is used in cluster analyses to produce a relative measure of “goodness-of-fit”, the measure is used in turn to determine the distance between clusters, known as the “ratio of distance measures” (Schwarz 1978; Barabba 1990). The “ratio of distance measures” is then used to identify the most appropriate number of clusters. The highest ratio of distance measure indicates the most suitable number of clusters however as it is a relative measure, the value itself does not convey further meaning.

Silhouette Coefficient

In a good cluster solution, the identified clusters are cohesive between members of the cluster yet clearly separate to other clusters. The silhouette coefficient is a measure firstly of the degree to which members of a cluster are grouped together, and secondly of the degree of separation between clusters (Barabba 1990). Thus, the silhouette coefficient indicates the suitability of the model to explain the data.

References:

Barabba, V.P. (1990). *The market research encyclopedia*. Harv. Bus. Rev.

Schwarz, G. (1978). Estimating the Dimension of a Model. *Ann. Stat.*, 6, 461–464.