

# Digital Sequence Information: A Looming Disaster or Hidden Opportunity for Positive Change?



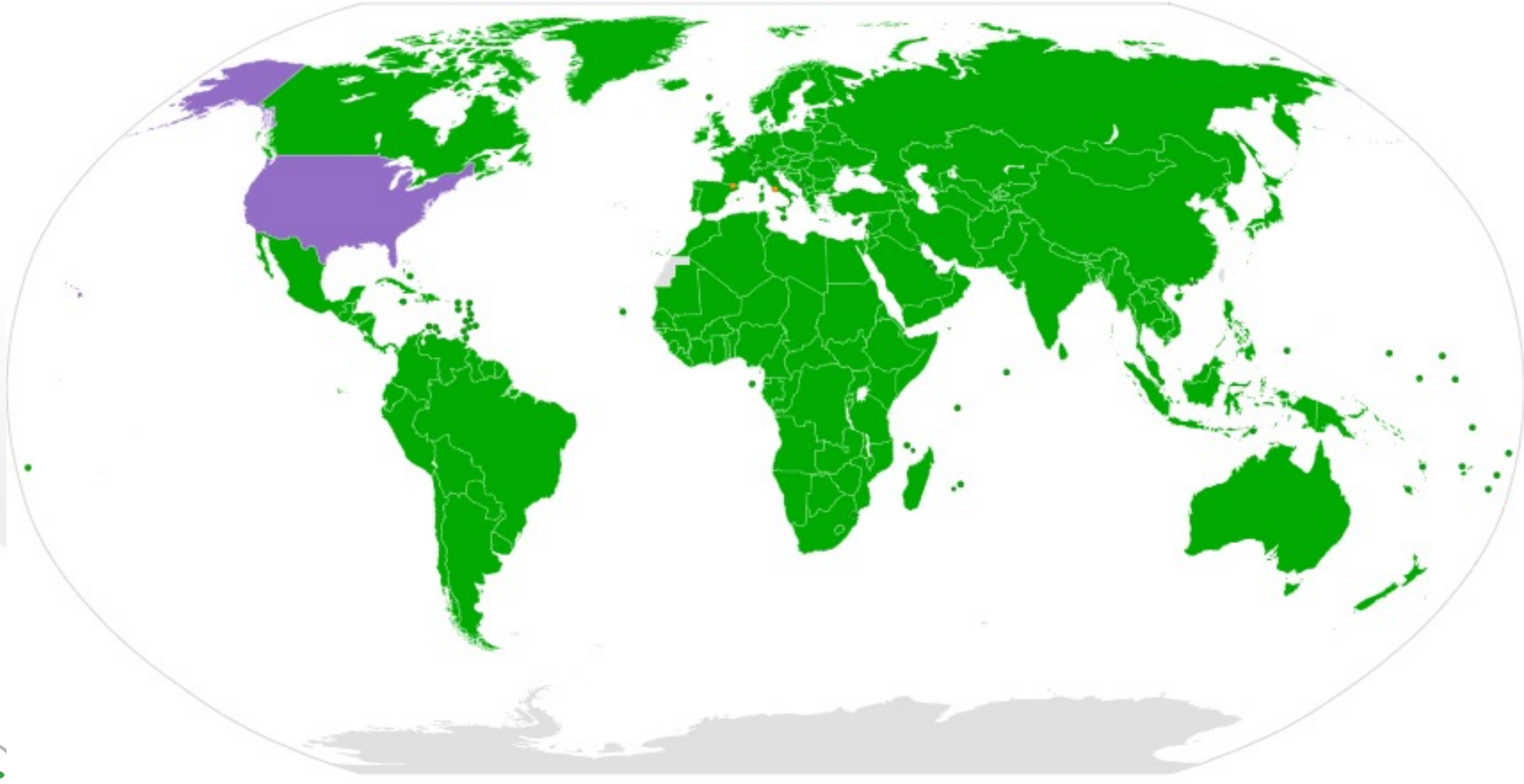
GROW Webinar  
August 26, 2021



**Dr. Amber Hartman Scholz, Deputy to the Director**



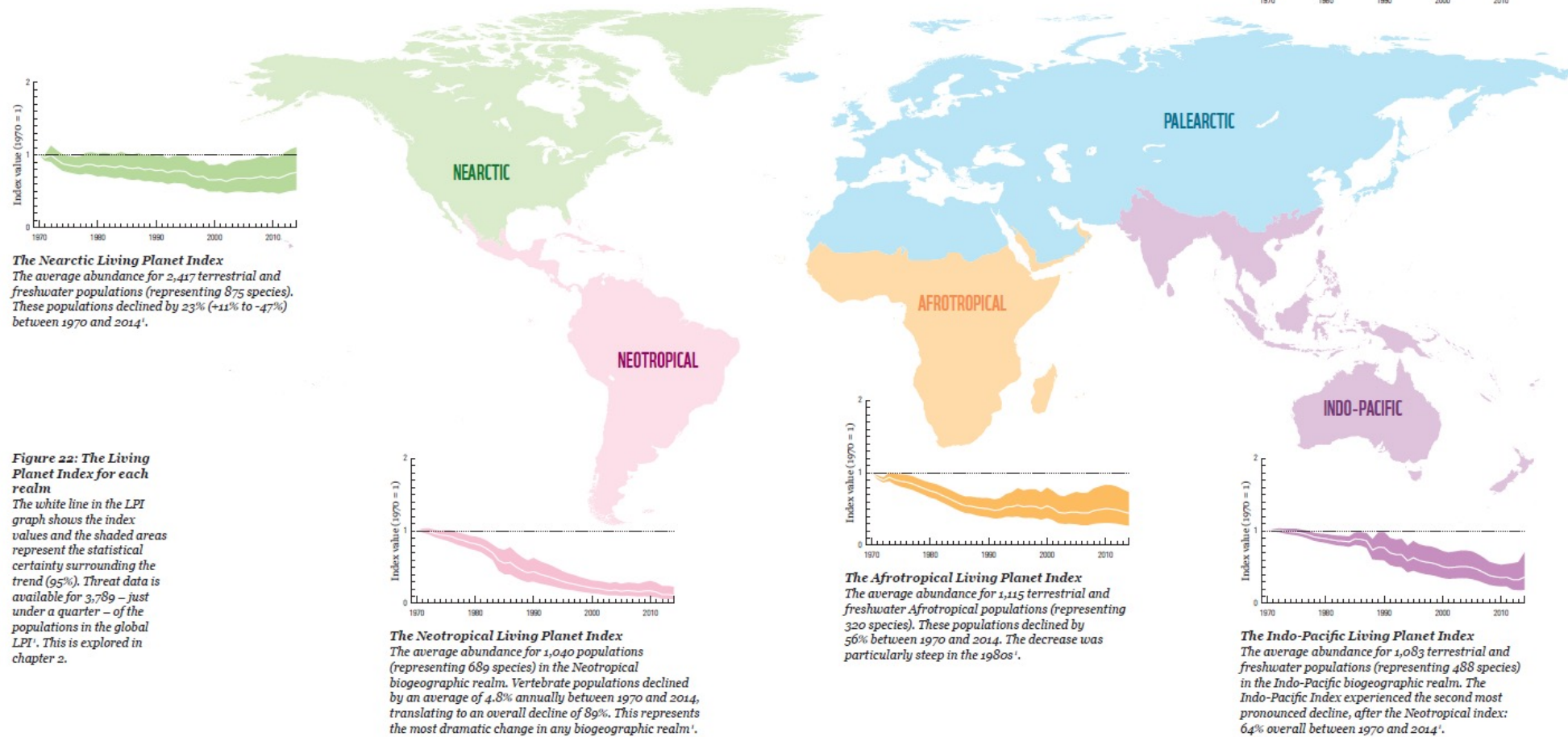
# The Convention on Biological Diversity has 3 objectives



# The CBD was not enough....

## Realm Living Planet Indices

As seen in the map below (figure 22), populations are in decline in all realms, but declines are especially pronounced in the three tropical realms. Here, average vertebrate abundance in 2014 was less than half of what it was in 1970. The LPI indicates that the Neotropical realm, covering South and Central America, and the Caribbean, has suffered the most dramatic decline at 89% loss compared to 1970. Nearctic and Palearctic populations are faring slightly better with declines of 23% and 31%.



**Figure 22: The Living Planet Index for each realm**  
The white line in the LPI graph shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95%). Threat data is available for 3,789 – just under a quarter – of the populations in the global LPI<sup>1</sup>. This is explored in chapter 2.

**COP 10**  
**October 2010, Nagoya, Japan**

**A horse trade / Kuhhandel:  
The Nagoya Protocol & The Aichi Targets**



# Aichi Targets



Understand values



Mainstream biodiversity



Address incentives



Sustainable production



Halve rate of loss



Sustainable fisheries



Manage within limits



Reduce pollution



Reduce invasive spp.



Minimize reef loss



Protected areas



Prevent extinctions



Conserve gene pool



Restore ecosystems



Enhance resilience



Implement Nagoya Prot.



Revise NBSAPs



Respect and conserve TK



Improve knowledge



Mobilize resources

# The Nagoya Protocol

*Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (NP)*  
to the Convention on Biological Diversity (CBD)

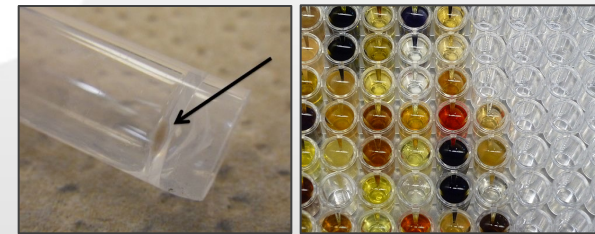
## Aims

- to provide **legal certainty** for the actors involved in the use and international exchange of genetic resources & traditional knowledge
- to specify **means for sharing benefits** gained from the use of genetic materials & traditional knowledge

## Need to know

Genetic resources - plants, animal, fungi, microbes  
- biochemical compounds  
- DNA/RNA

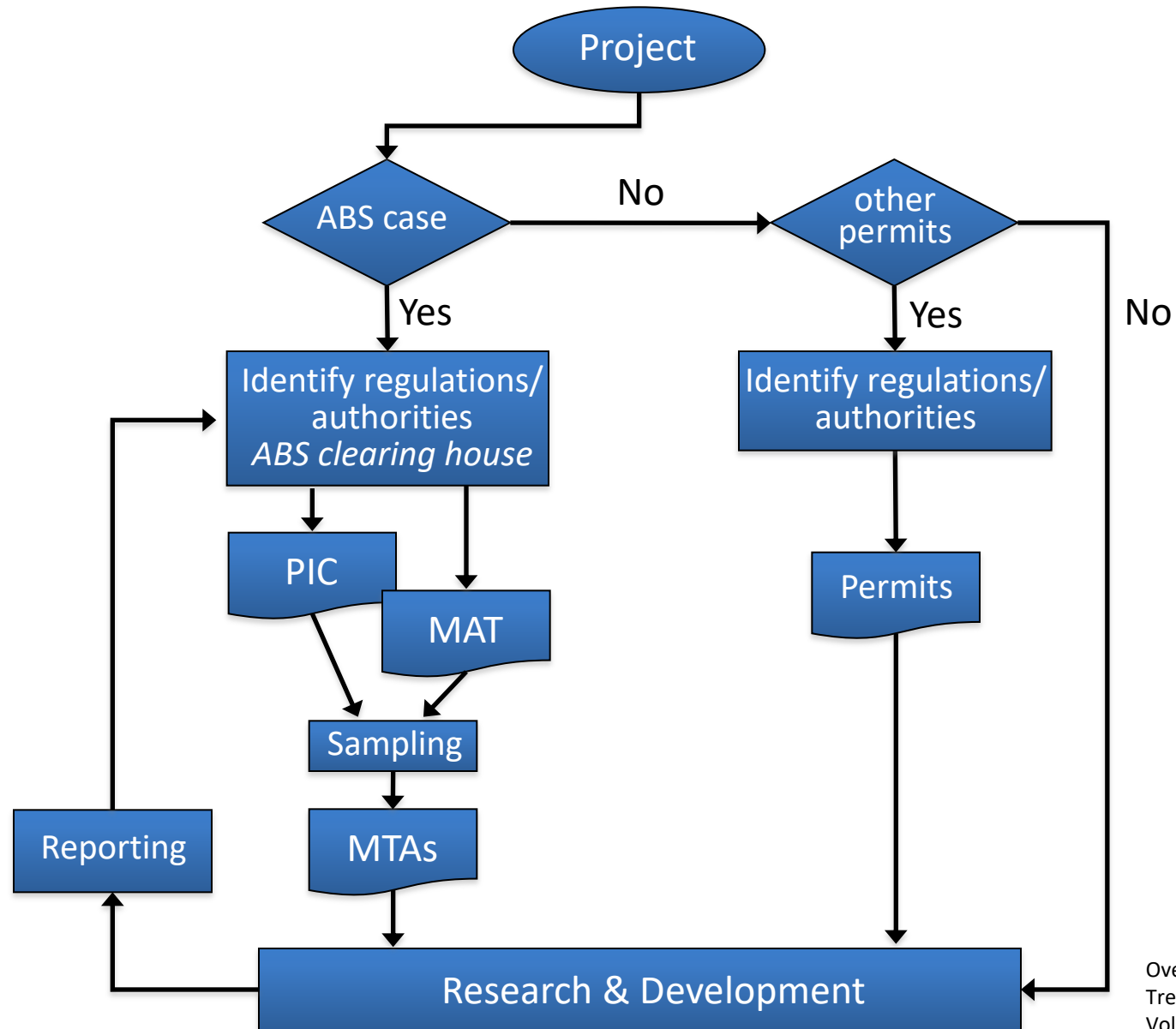
Use = **non-commercial** and commercial



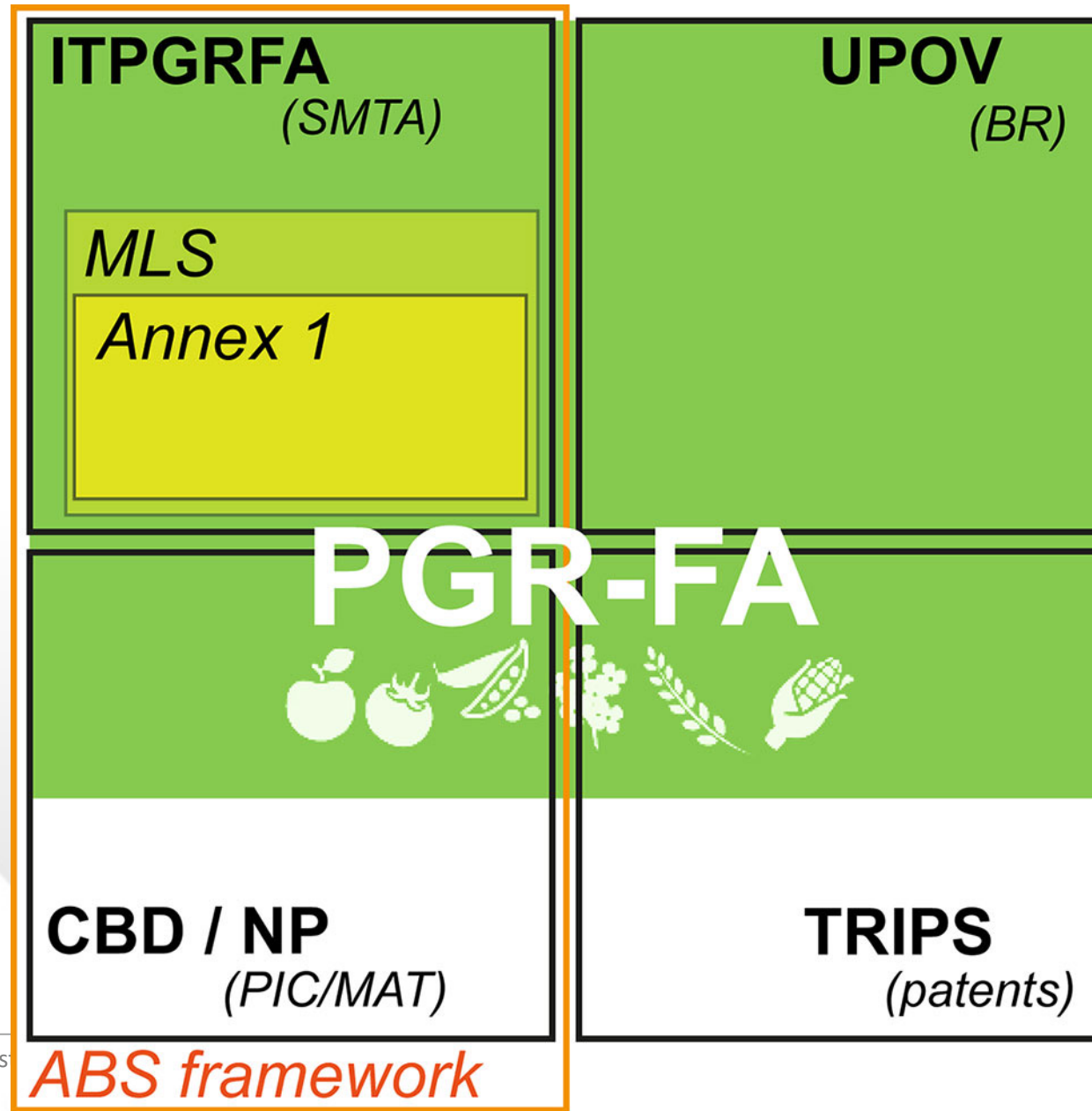
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ATG AAA ACT CTG CTG CTG ACC TTG CTG GTG GTG ACA ATC GTG TGC CTA GAC TTA 54
      L K C Y Q H G K V V T C H R D 36
GGA TAC TCC CTG AAA TGT TAC CAA CAT GGT AAA GTT GTG ACT TGT CAT CGA GAT 108
M K F C Y H N T G M P F R N L K L I 54
ATG AAG TTT TGC TAT CAT AAC ACT GGC ATG CCT TTT CGA AAT CTC AAG CTC ATC 162
L Q G C S S S C S E T E N N K C C S 72
CTA CAG GGA TGT TCT TCT TCG TGC AGT GAA ACA GAA AAC AAT AAG TGT TGC TCA 216
```



# Procedure to comply with CBD and NP



# Plant scientists have a complicated ABS situation



Aubry, S- Front. Plant Sci., 30 August 2019  
<https://doi.org/10.3389/fpls.2019.01046>



**COP 15**  
**October 2021 / May 2022, Kunming, China**

**Another horse trade?**  
**Global Biodiversity Framework &**  
**Digital Sequence Information**



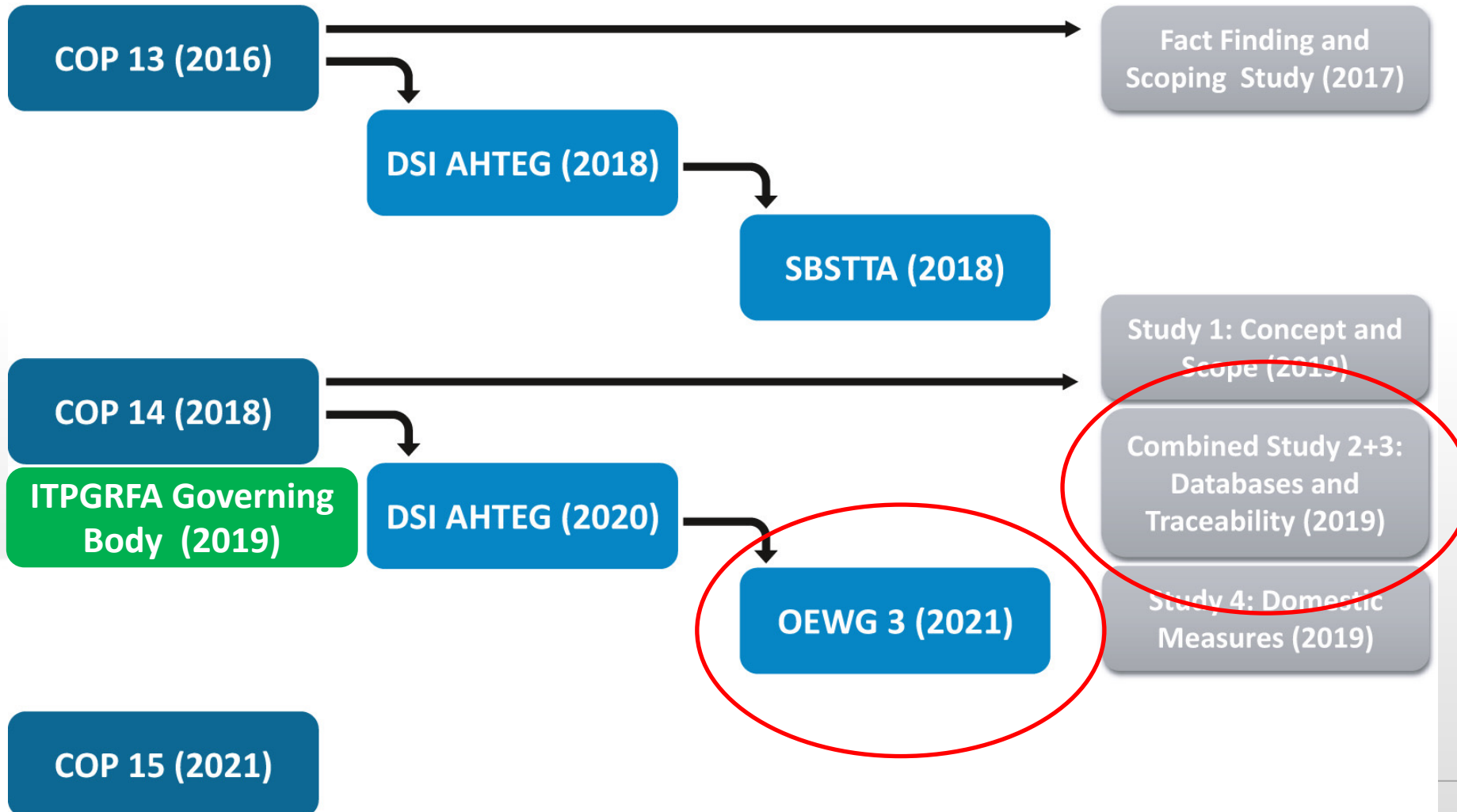
# The Aichi Targets expired in 2020

Up next:  
**2020 Global Biodiversity Framework**  
 → set regional goals, be more specific!



TABLE 2 Trends shown by agreed indicators of progress towards the 2010 biodiversity target		
<b>Status and trends of the components of biological diversity</b>		
	Trends in extent of selected biomes, ecosystems, and habitats	Most habitats in most parts of the world are declining in extent, although forest area expands in some regions, and the loss of mangroves has slowed significantly, except in Asia.
	Trends in abundance and distribution of selected species	Most species with limited population size and distribution are being further reduced, while some common and invasive species become more common.
	Change in status of threatened species	The risk of extinction increases for many threatened species, although some species recovery programmes have been very successful.
	Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance	It is likely that the genetic variety of cultivated species is declining, but the extent of such decline and its overall impacts are not well understood.
	Coverage of protected areas	There has been a significant increase in coverage of protected areas, both terrestrial and marine, over the past decade. However, many ecological regions, particularly in marine ecosystems, remain underprotected, and the management effectiveness of protected areas remains variable.
<b>Ecosystem integrity and ecosystem goods and services</b>		
	Marine Trophic Index	Despite intense pressure the Marine Trophic Index has shown a modest increase globally since 1970. However there is substantial regional variation with declines being recorded in half of the marine areas with data.
	Connectivity – fragmentation of ecosystems	Most terrestrial and aquatic ecosystems are becoming increasingly fragmented, despite an increased recognition of the value of corridors and connections, especially in climate change adaptation.
	Water quality of aquatic ecosystems	Most parts of the world are likely to be suffering from declines in water quality, although quality in some areas has improved through control of point-source pollution.
<b>Threats to biodiversity</b>		
	Nitrogen deposition	Human activity has doubled the rate of creation of reactive nitrogen on the planet's surface. Pressure on biodiversity from nutrient pollution continues to increase, although some measures to use nutrients more efficiently, to reduce their release into water and the atmosphere, are beginning to show positive effects.
	Trends in invasive alien species	The number and rate of spread of alien species is increasing in all continents and all ecosystem types.
<b>Sustainable use</b>		
	Area of forest, agricultural and aquaculture ecosystems under sustainable management	There are considerable efforts under way to increase the extent of areas of land under sustainable management. Regional efforts on sustainable forest management are expected to contribute to this. Traditional agricultural practices are being maintained and revitalized as the demand for ethical and healthy products increases. However, these are still relatively small niches and major efforts are required to substantially increase the areas under sustainable management.
	Ecological footprint and related concepts	The ecological footprint of humanity is increasing. Efforts at increasing resource efficiency are more than compensated by increased consumption by a growing and more prosperous human population.
<b>Status of traditional knowledge, innovations and practices</b>		
	Status and trends of linguistic diversity and numbers of speakers of indigenous languages	A large number of minority languages are believed in danger of disappearing, and linguistic diversity is very likely declining.
<b>Status of access and benefit sharing</b>		
	Indicator of access and benefit-sharing to be developed	The need and possible options for additional indicators are being examined by the Ad Hoc Open-ended Working Group on Access and Benefit-sharing.
<b>Status of resources transfers</b>		
	Official development assistance (ODA) provided in support of the Convention	The volume of ODA for biodiversity has increased over the past few years.
	Negative changes	No clear global trend. Positive and negative changes are occurring depending on the region or biome considered.
	Positive changes	
	Insufficient information to reach a definitive conclusion.	
Degree of certainty:  Low  Medium  High		

# DSI under the CBD: what is happening during the 2018–2020 intersessional period?



# Nature crisis: Talks resume on global plan to protect biodiversity

By Matt McGrath  
Environment correspondent

🕒 2 days ago



COP26



## Preparations for the Post-2020 Biodiversity Framework

Third meeting of the Open-ended Working Group on the Post-2020 Global Biodiversity Framework

Join the WG2020 3 meeting

UN negotiators have resumed nature and species for the next decade.

The draft **Global Biodiversity Framework** aims to conserve at least 30% of the world's land and oceans.

### Tweets by @UNBiodiversity

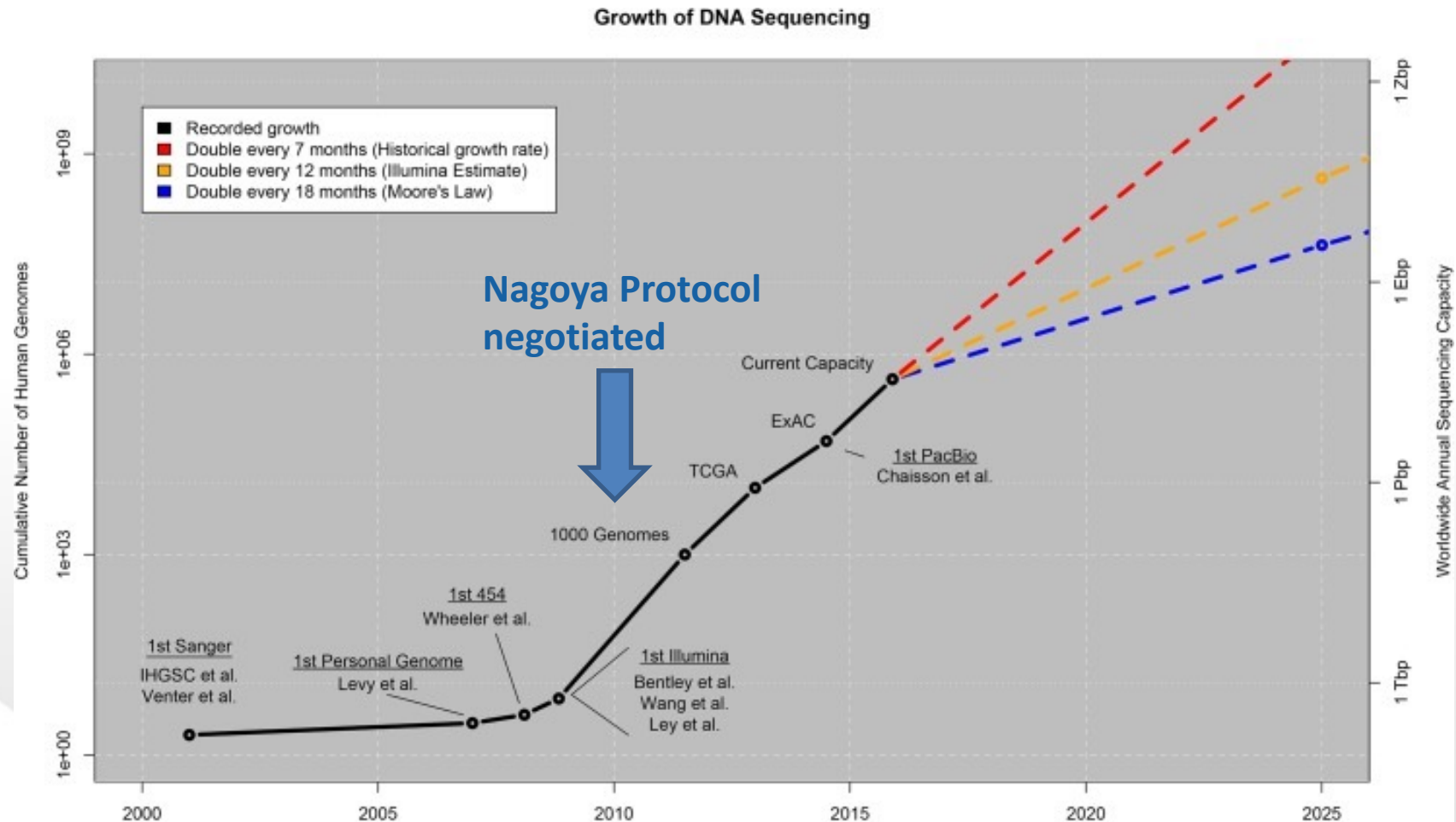
UN Biodiversity Retweeted

**UN Biodiversity** ✓  
@UNBiodiversity

The Open-ended Working Group on the #Post2020 Framework meets from 23 August to 3 September. @UNEP Executive Director @Anderson\_Inger underscores the importance of

# Why is there a call for benefit sharing from DSI?





There has been an explosion in sequencing since the Nagoya Protocol



<https://www.ncbi.nlm.nih.gov/genbank/statistics/>

# The biotechnological tools have also changed significantly since 2010!

## Synthetic biology & Gene editing

	 Bacteria	 Yeast	 Plant (nucleus)	 Plant (plastid)
<b>Biological features</b>				
Genomic simplicity	**	*	*	***
Physiological simplicity	***	**	*	**
Homologous recombination	**	***	*	***
Polycistronic gene expression	***	*	*	***
Gene expression strength	**	**	*	***
Absence of transgene silencing	***	**	*	***
Biological transgene containment	*	*	*	**
Photoautotrophic growth	**	*	***	***
<b>Available tools and techniques</b>				
Ease of genetic manipulation	***	***	**	*
Speed of genetic manipulation	***	***	**	*
Genetic parts	***	**	*	*
Genetic part characterization	***	**	*	*
Genetic part assembly	***	***	**	**
Genetic part insulation	***	**	**	*
Gene expression control	***	**	**	*
Genetic & metabolic network models	***	**	*	*
<b>Demonstrated applications</b>				
Synthetic metabolic pathways	***	***	**	***
Synthetic genetic circuits	***	**	*	*
Synthetic subcompartments	**	**	*	*
Synthetic genomes	**	*	*	**



CRISPR-Cas9 „genetic scissors“  
2020 Nobel Prize in Medicine

<https://hub.jhu.edu/2021/01/29/crispr-cas9-gene-dimmer/>

Christian R. Boehm and Ralph Bock Plant Physiol. 2018;179:794-802

# But the data ecosystem is NOT like the Nagoya Protocol

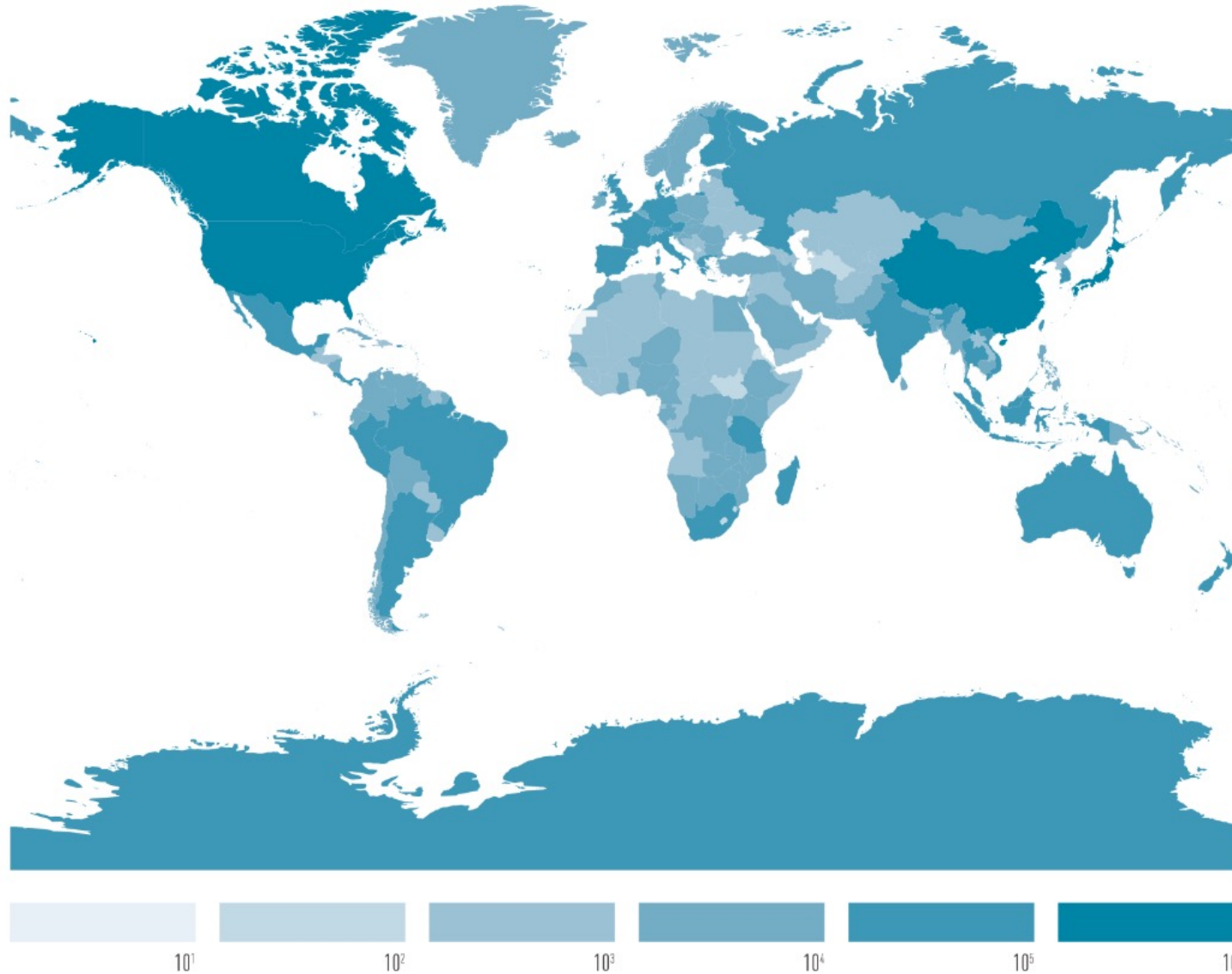
- **212 billion sequences (from every country in the world)**
- **Entire DSI dataset downloaded 34 million times a year**
- **10-15 million users (in every country in the world)**
- **Promulgated via 2,000 downstream databases**
- **Half a million publications and patent applications**

# Most DSI does NOT come from low-/middle-income countries

What is the country of origin for non-human NSD?

1. China	18.23 %
2. United States	17.39 %
3. Canada	9.10 %
4. Japan	7.24 %
5. India	3.46 %
6. Australia	2.66 %
7. Mexico	2.54 %
8. Brazil	2.30 %
9. Germany	1.83 %
10. Spain	1.58 %

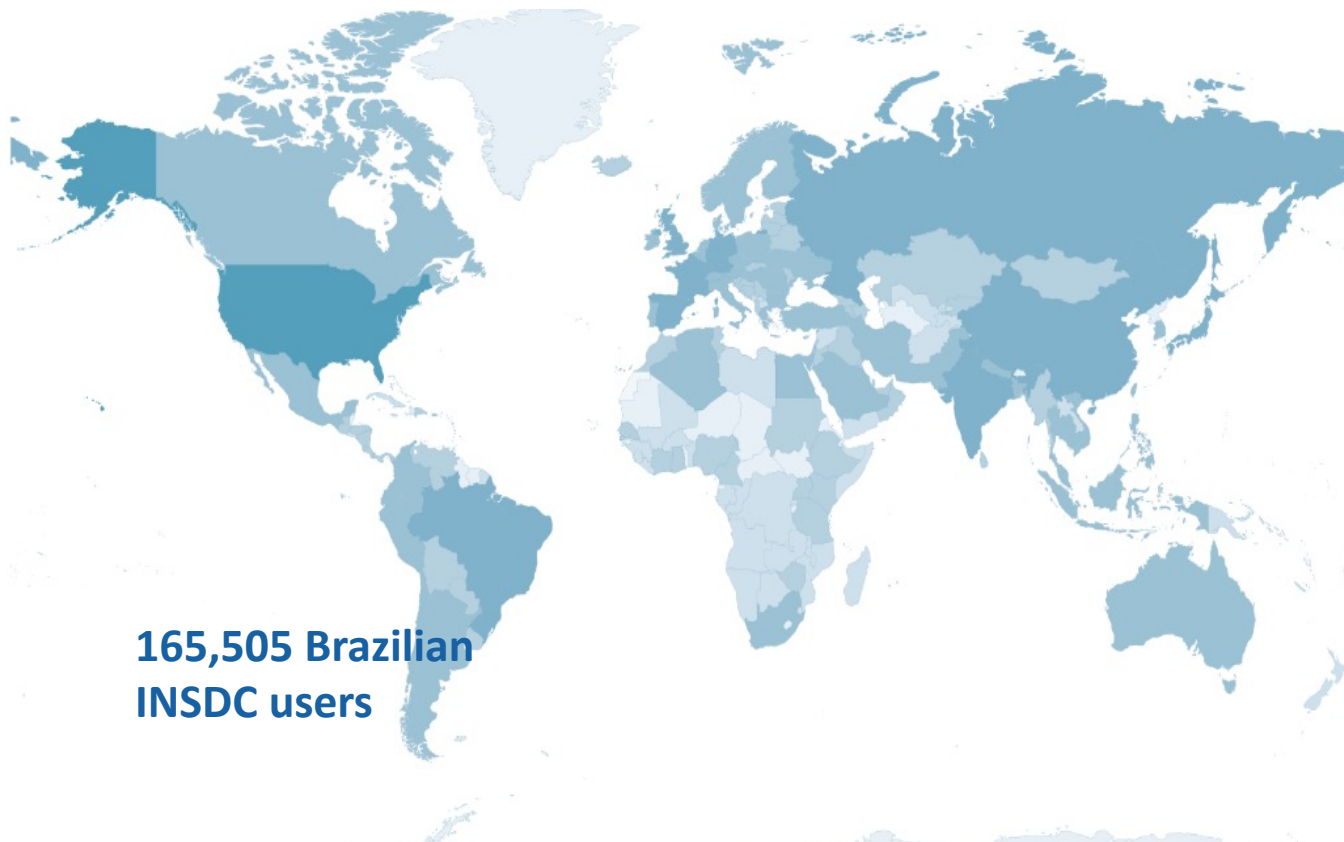
**52% of DSI comes from 4 countries**





# There are 10-15 million users of the core DSI databases (INSDC). They live in every country in the world.

1. United States	22.69 %
2. China	15.42 %
3. India	6.16 %
4. Japan	3.97 %
5. Germany	3.67 %
6. United Kingdom	3.45 %
7. France	2.84 %
8. Brazil	2.83 %
9. Spain	2.31 %
10. Russian Federation	2.25 %



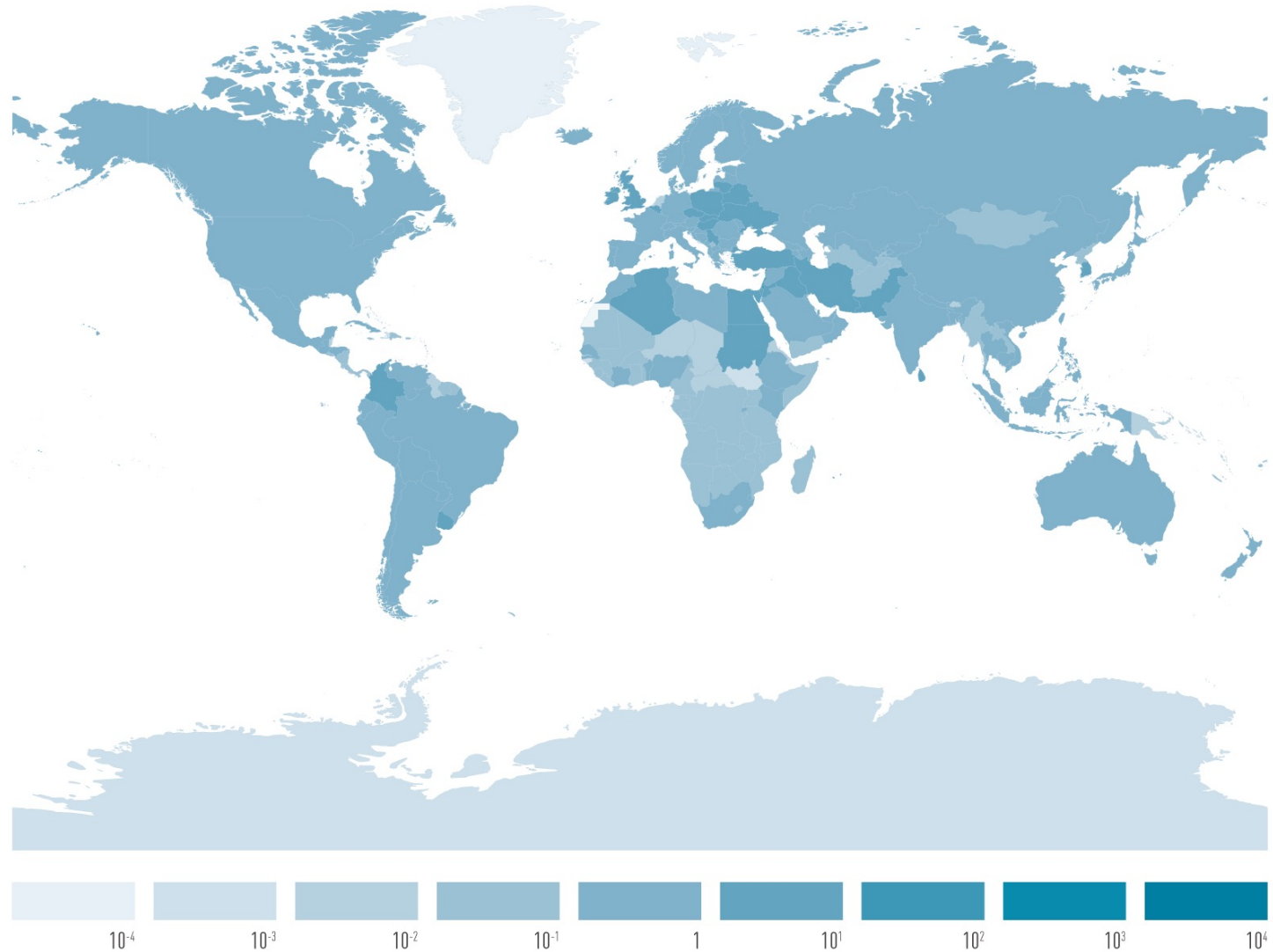
**INSDC infrastructure costs: \$50 million per year → \$3-5 per user**  
**~50% of users live in countries that do not contribute to infrastructure costs.**  
**Their use is currently “subsidized”.**



# Which countries use more than they provide?

How does database usage compare to provided sequences?

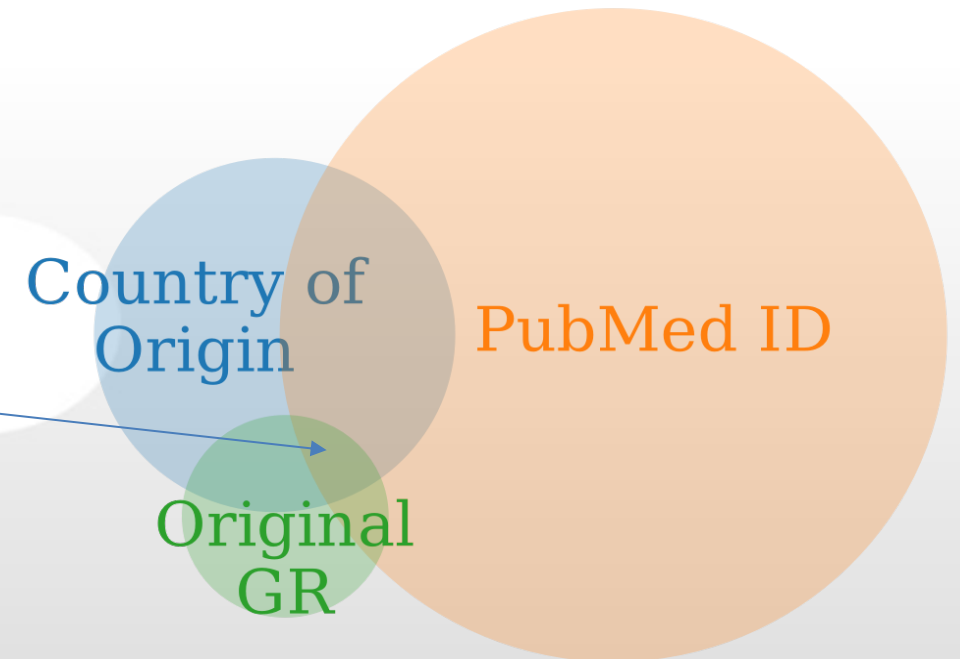
1. Lebanon	27.68
2. Ukraine	23.84
3. Belarus	22.88
4. Iraq	21.41
5. Colombia	19.79
6. Algeria	19.54
7. Pakistan	19.37
8. Republic of Korea	18.81
9. Belgium	17.83
10. Poland	17.47



# Technical observations

- 16% of DSI entries reported country information
- 44% of DSI entries did not report a country but should have
- 4% of NSD entries linked to GR

Genebanks are well-positioned to improve DSI metadata!!!



# What about the commercial use of DSI?

1. **20% of DSI in INSDC comes from patent-associated NSD directly deposited by a patent office**
2. **NSD itself is more frequently listed as reference material than the basis for the invention**
3. **No country information associated with DSI in databases even if listed in patent application**
4. **Patent NSD often receives a new AN even if it originated in INSDC**

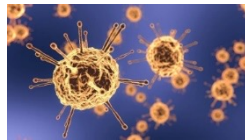
**Fall 2019:**

**There is a DSI deal that will be made someday soon.**

**How can the scientific community contribute?**



# WiLDSI project: asking scientists how to maintain open access and engage with benefit-sharing



Epidemiology

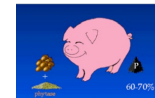


Wildlife conservation



Thicklip grey mullet

Pollutant effects in fish

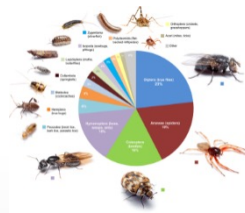


60-70%

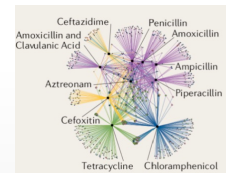
Reducing waste in pig feed



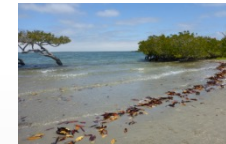
PANGAEA: Data Publisher for Earth & Environmental Science



Insect taxonomy & Loss of pollinators



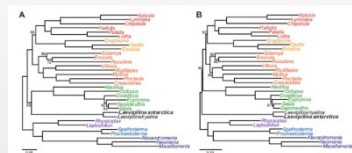
Antimicrobial resistance



Tropical ecosystem research & climate change adaptation



Poaching & Wildlife trade



Mollusk barcoding



Fungal diversity & nutrient cycling



Viral metagenomics & bioprospecting



Freshwater Biodiversity and Evolution

# 5 requirements for successful science

1. **Open Access**
2. **Simplicity: Learn from the Nagoya Protocol**
3. **„Future-Proof“**
4. **Legal Certainty**
5. **Opt-in Genetic Resources**

# Not all DSI is under the CBD... „Universal solution“?



UNIVERSAL SOLUTION?

**DSI is tangled up together in one core infrastructure! Users use EVERYTHING!**





W i L D S I



W i L D S I

**FINDING COMPROMISE ON  
ABS & DSI IN THE CBD:  
REQUIREMENTS & POLICY IDEAS  
FROM A SCIENTIFIC  
PERSPECTIVE**



[https://www.youtube.com/watch?v=rO\\_pAQDDHII](https://www.youtube.com/watch?v=rO_pAQDDHII)

Scholz, A.H., Hillebrand, U., Freitag, J., Cancio, I., dos S. Ribeiro, C., Haringhuizen, G., Oldham, P., Saxena, D., Seitz, C., Thiele, T., van Zimmeren, E. (2020) Finding Compromise on ABS & DSI in the CBD: Requirements & Policy Ideas from a Scientific Perspective. doi: 10.13140/RG.2.2.35180.80001.

# 5 Open-Access Policy Options for DSI

**Option 1 : Micro-Levy (multilateral)**

**Option 2: Membership Fee (multilateral)**

**Option 3: Cloud-based fees (multilateral)**

**Option 4: Commons Licenses for DSI (bilateral with multilateral licenses)**

**Option 5: Blockchain Metadata, open DSI (bilateral with multilateral elements)**

# March 2021: DSI policy options synthesized by the CBD Secretariat

Access regulated	PIC	MAT	0	<b>Status quo</b> – Parties have not agreed on how to address ABS for DSI of GR	BS linked to DSI data	Requires tracing of country of origin	Bilateral mechanism
			1	<b>DSI Fully integrated</b> into approach of CBD & NP PIC and MAT (DSI= GR)			
Access not regulated	NO PIC	NO MAT	2.1	No PIC. <b>Each country has Standard MAT</b> (benefit-sharing is triggered by use of DSI)	BS NOT linked to DSI data	Does NOT require tracing of country of origin	Multilateral mechanism
			2.2	No PIC. <b>Standard MAT at international level</b> (benefit-sharing is triggered by use of DSI)			
			3.1	<b>Payment for access to DSI.</b> No PIC. No MAT			
			3.2	<b>Other payments and contributions</b> (micro-levy, voluntary). No PIC. No MAT			
			4	<b>Technical and scientific cooperation</b> – could be complementary to other options			
			5	No PIC, No MAT. <b>No Benefit Sharing from DSI.</b> (DSI is not considered equal to GR)			

## So which DSI option is the best?

Let's learn more from data on DSI provision and use

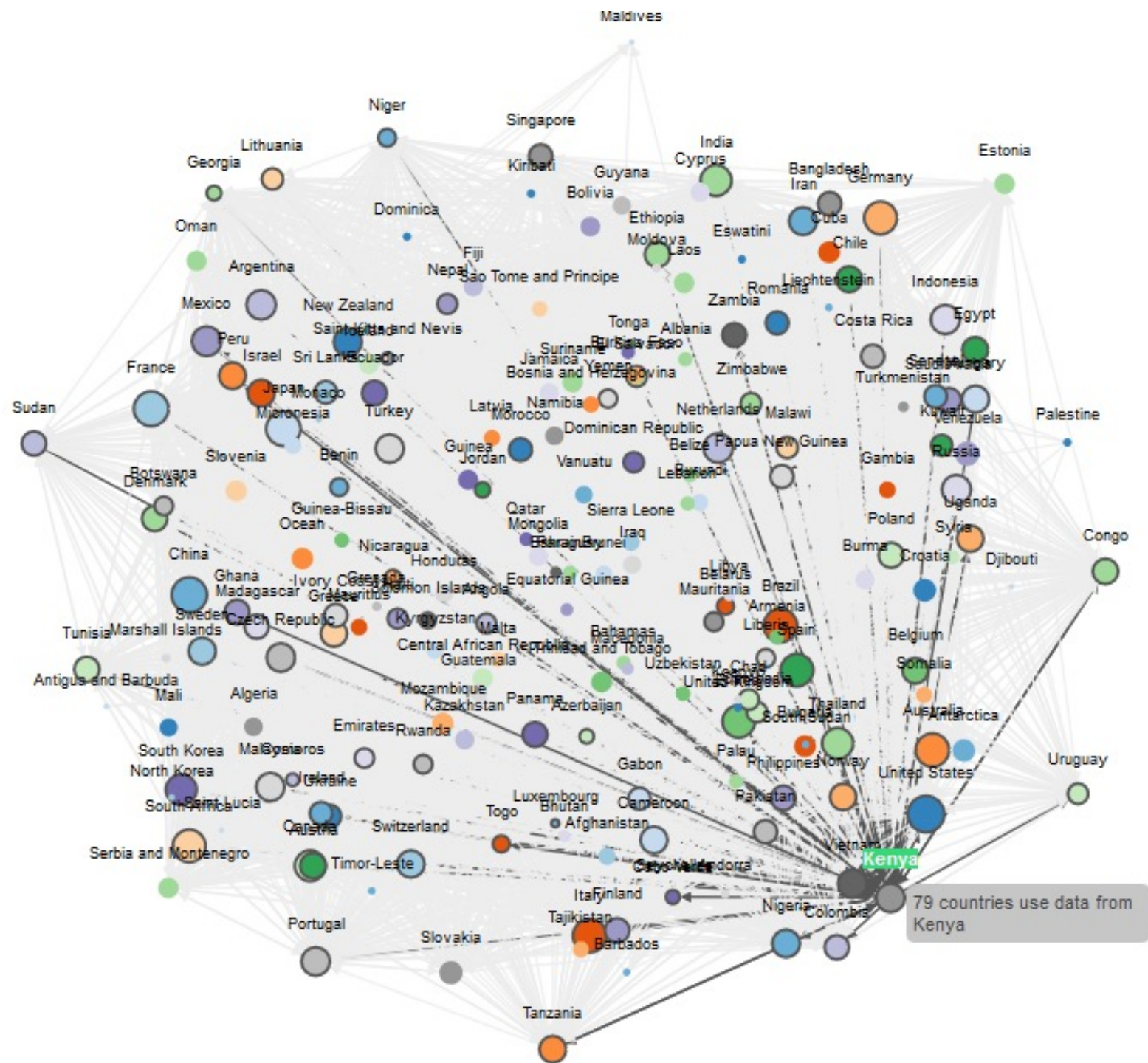
<http://wildsi.ipk-gatersleben.de/>

Scholz et al. Myth-busting the provider-user relationship for digital sequence information. BioRxiv pre-print. DOI: 10.1101/2021.08.02.454535.

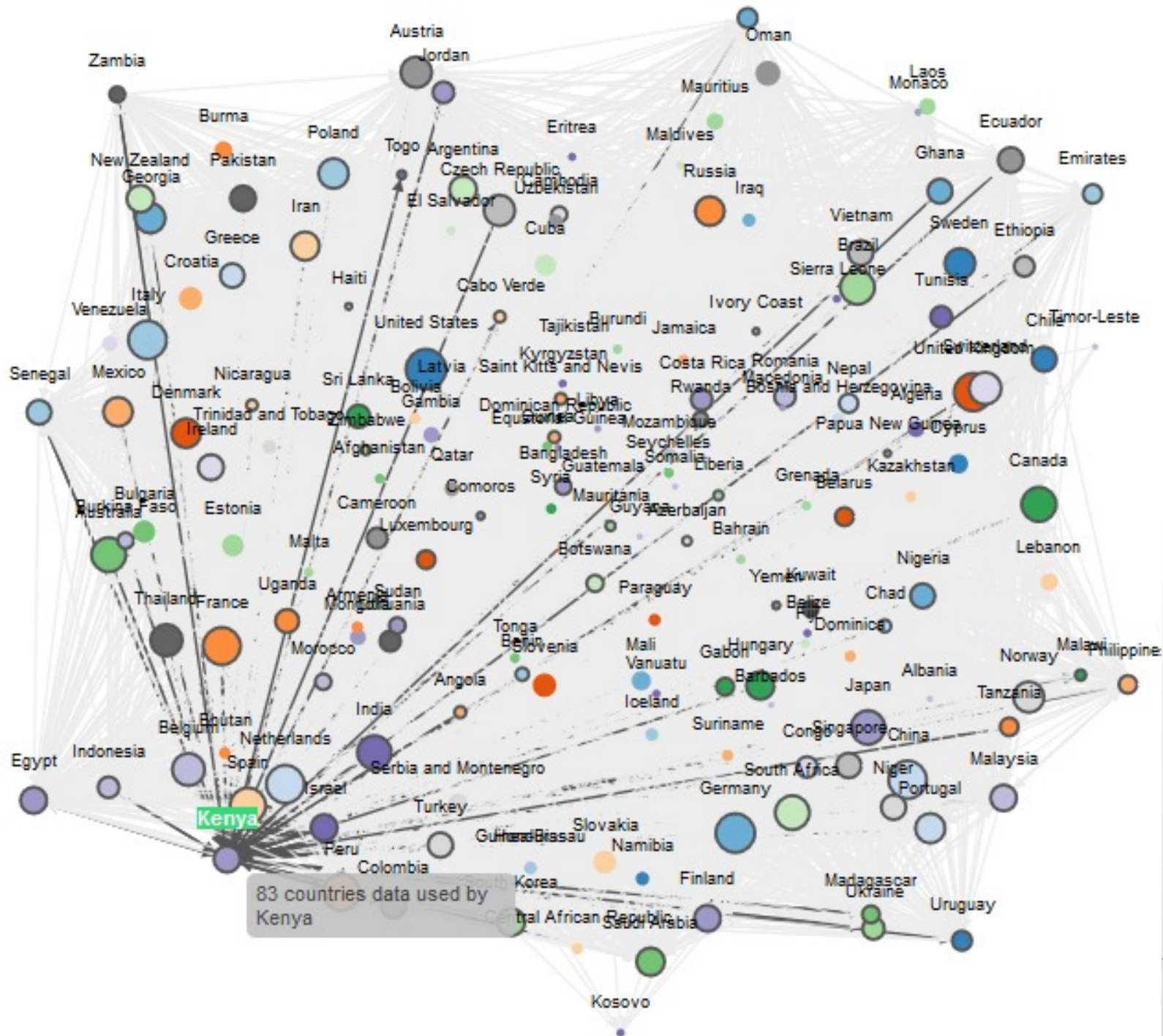




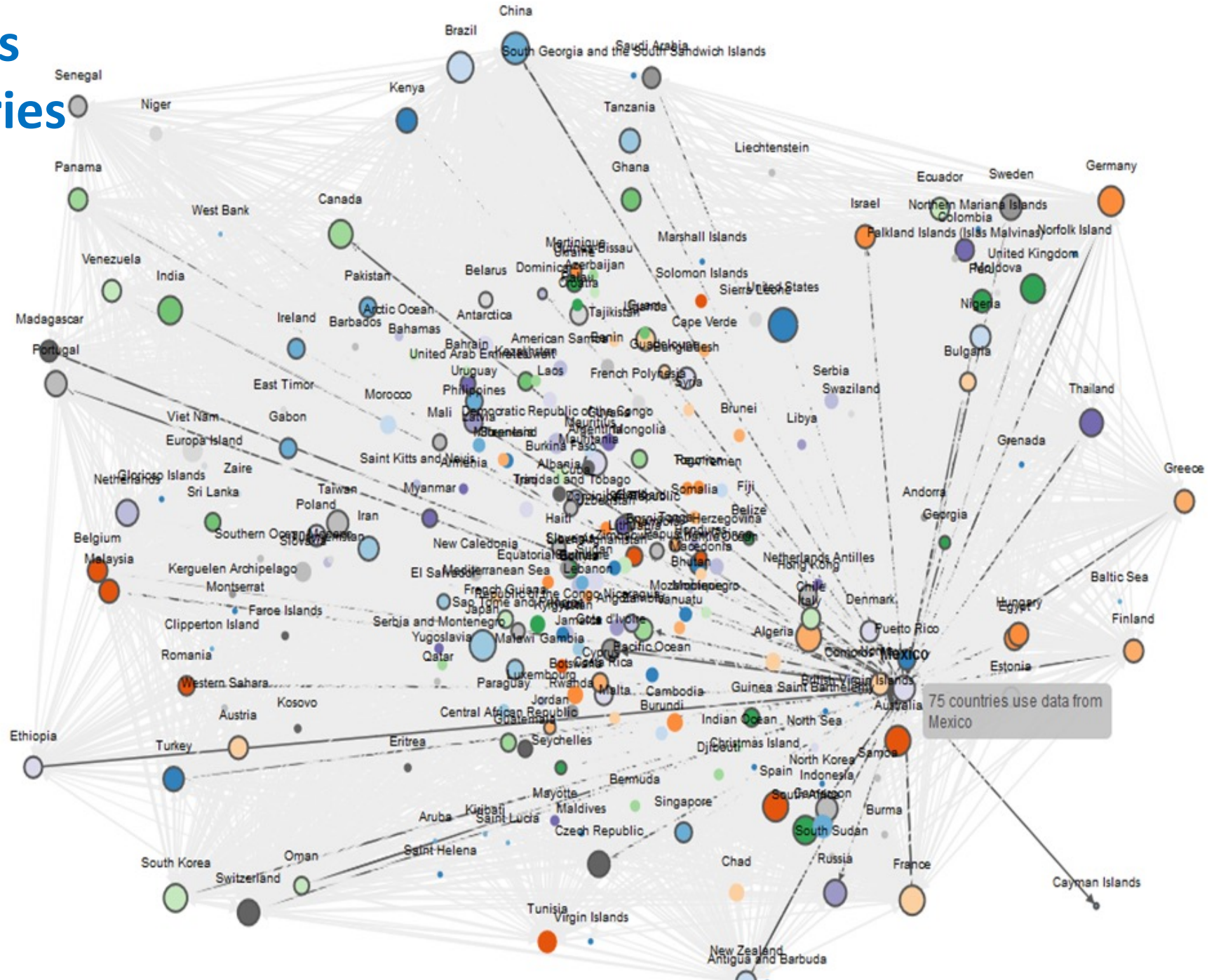
# 79 countries are using Kenyan DSI



# Kenyan scientists are using DSI from 83 countries

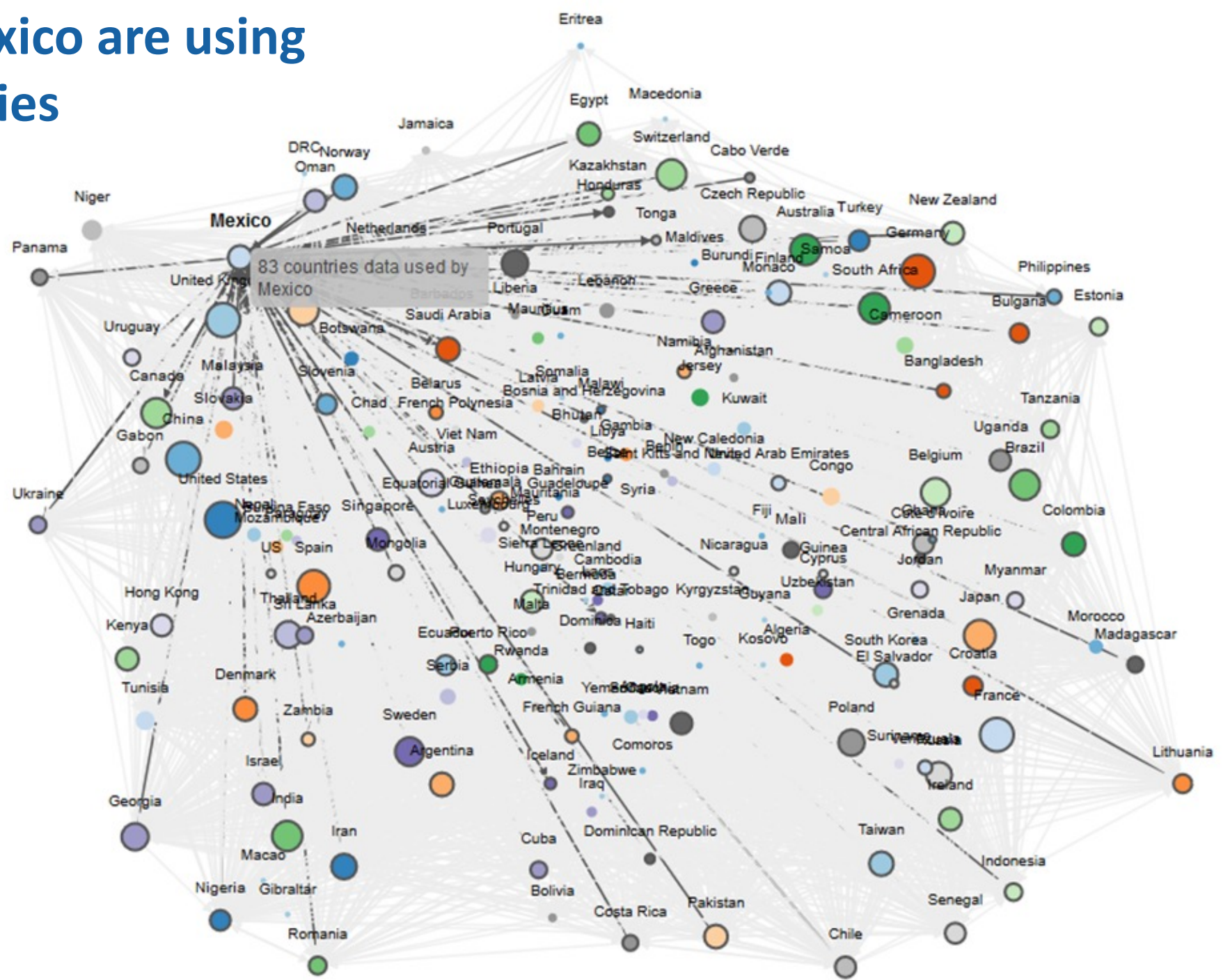


# DSI from Mexico is used by 75 countries

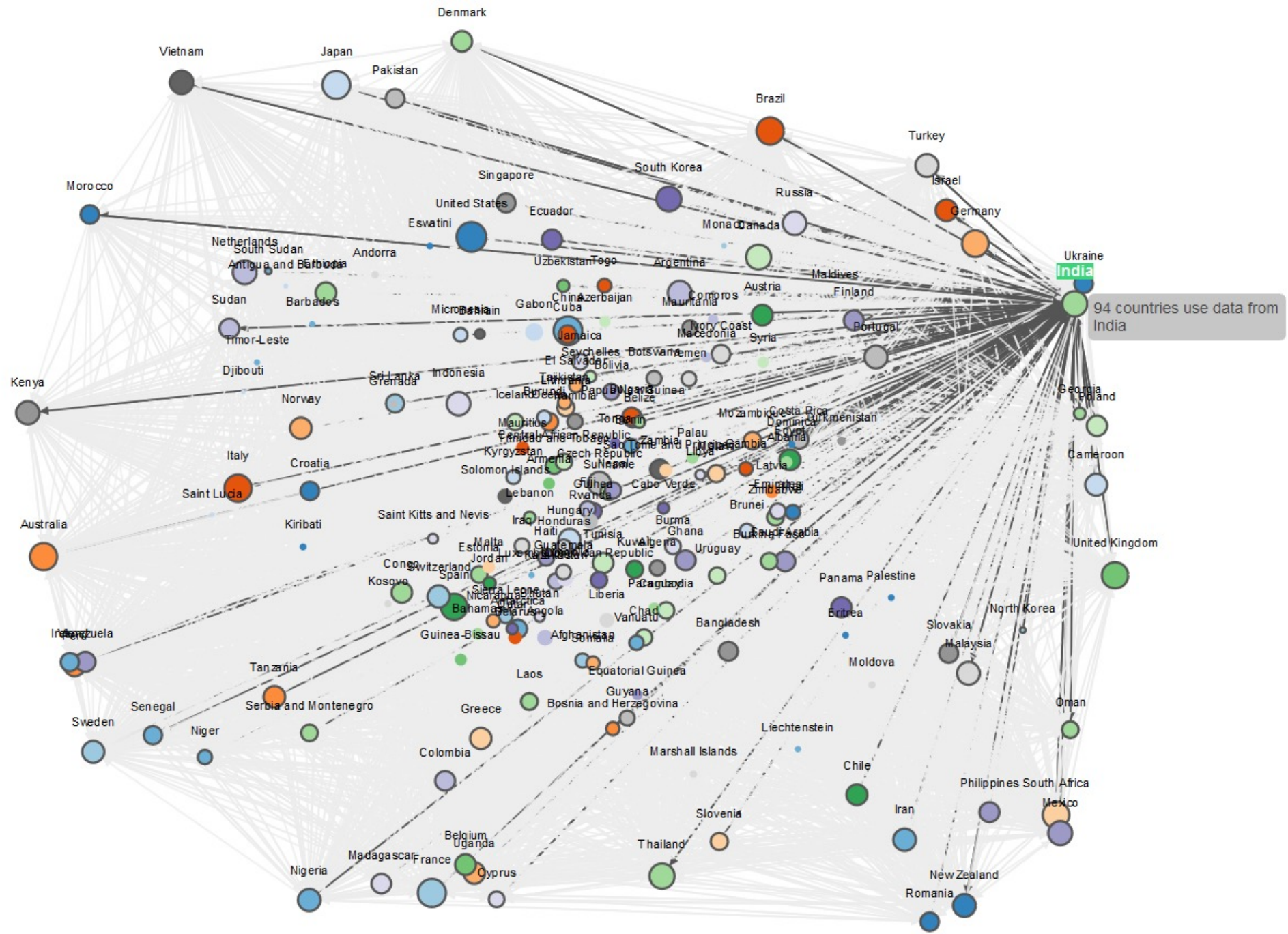




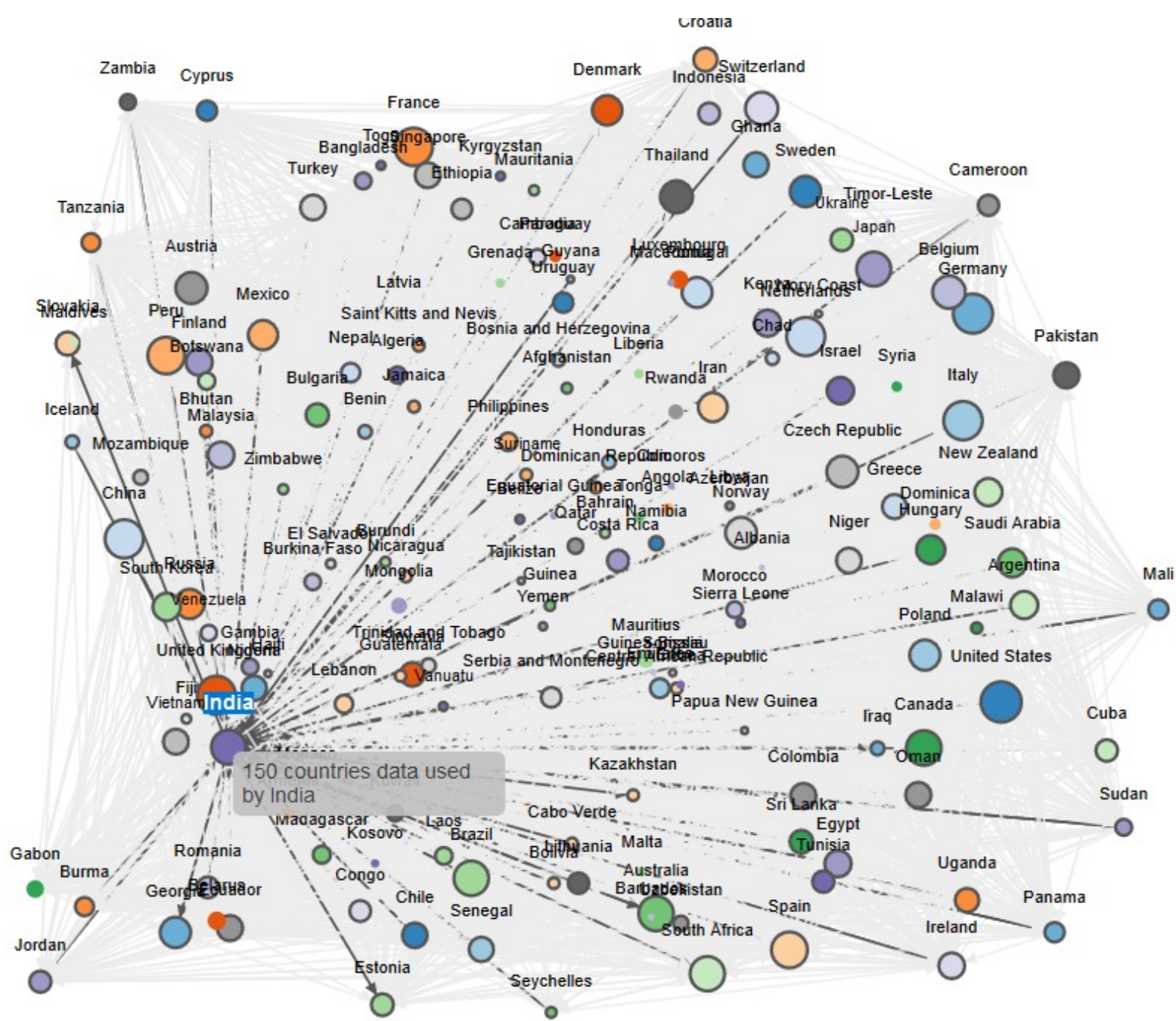
# Scientists from Mexico are using DSI from 83 countries



# 94 countries are using Indian DSI

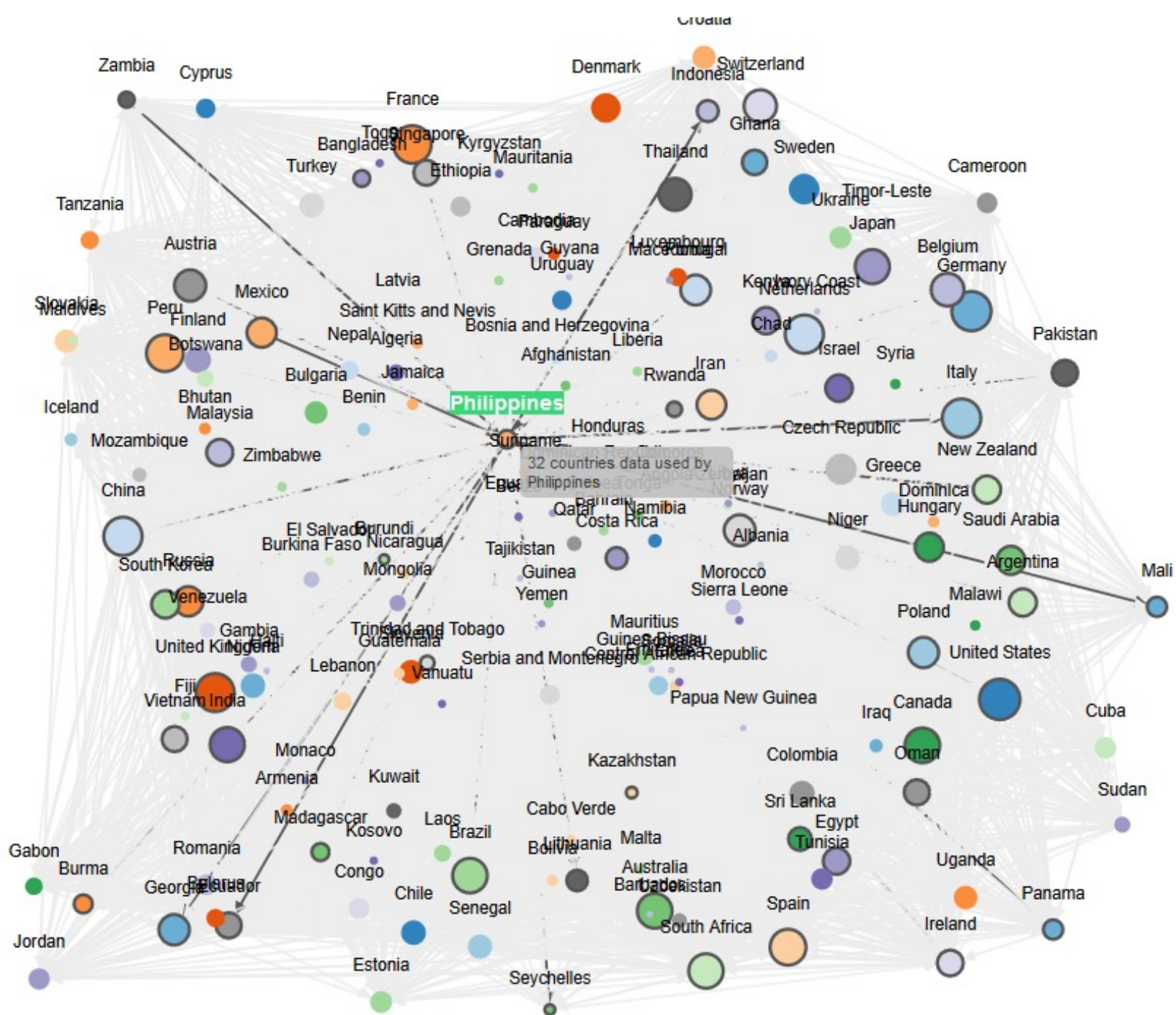


# Indian scientists are using DSI from 150 countries

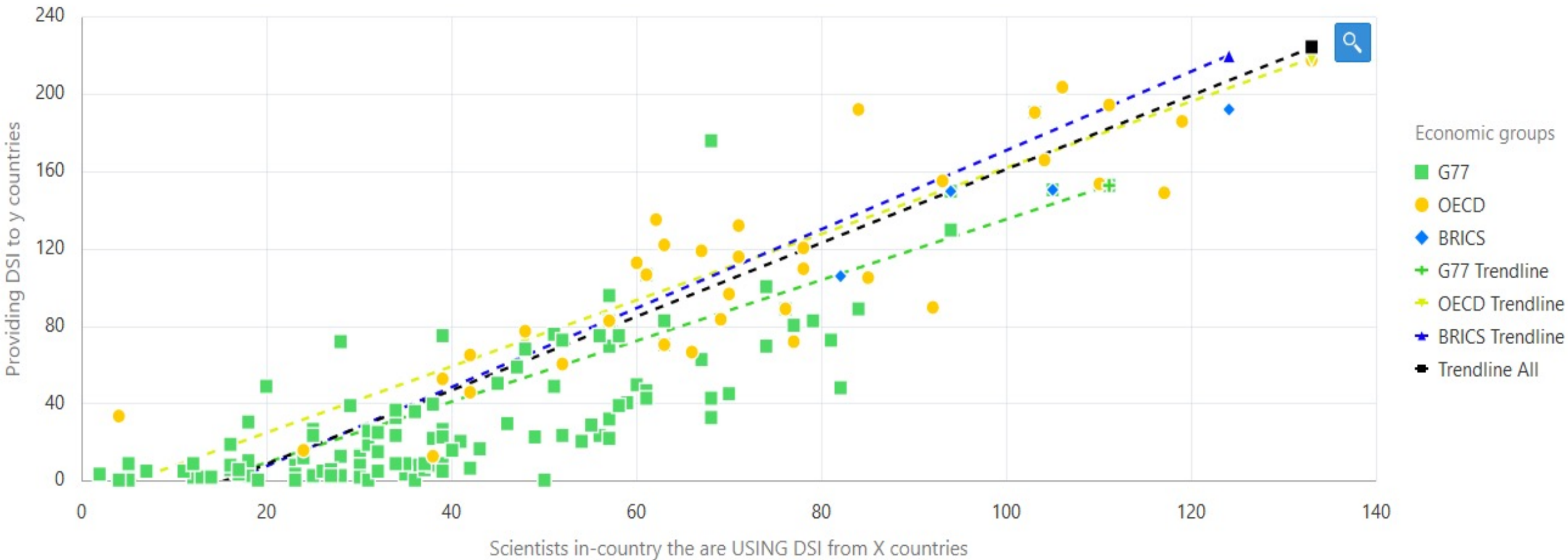




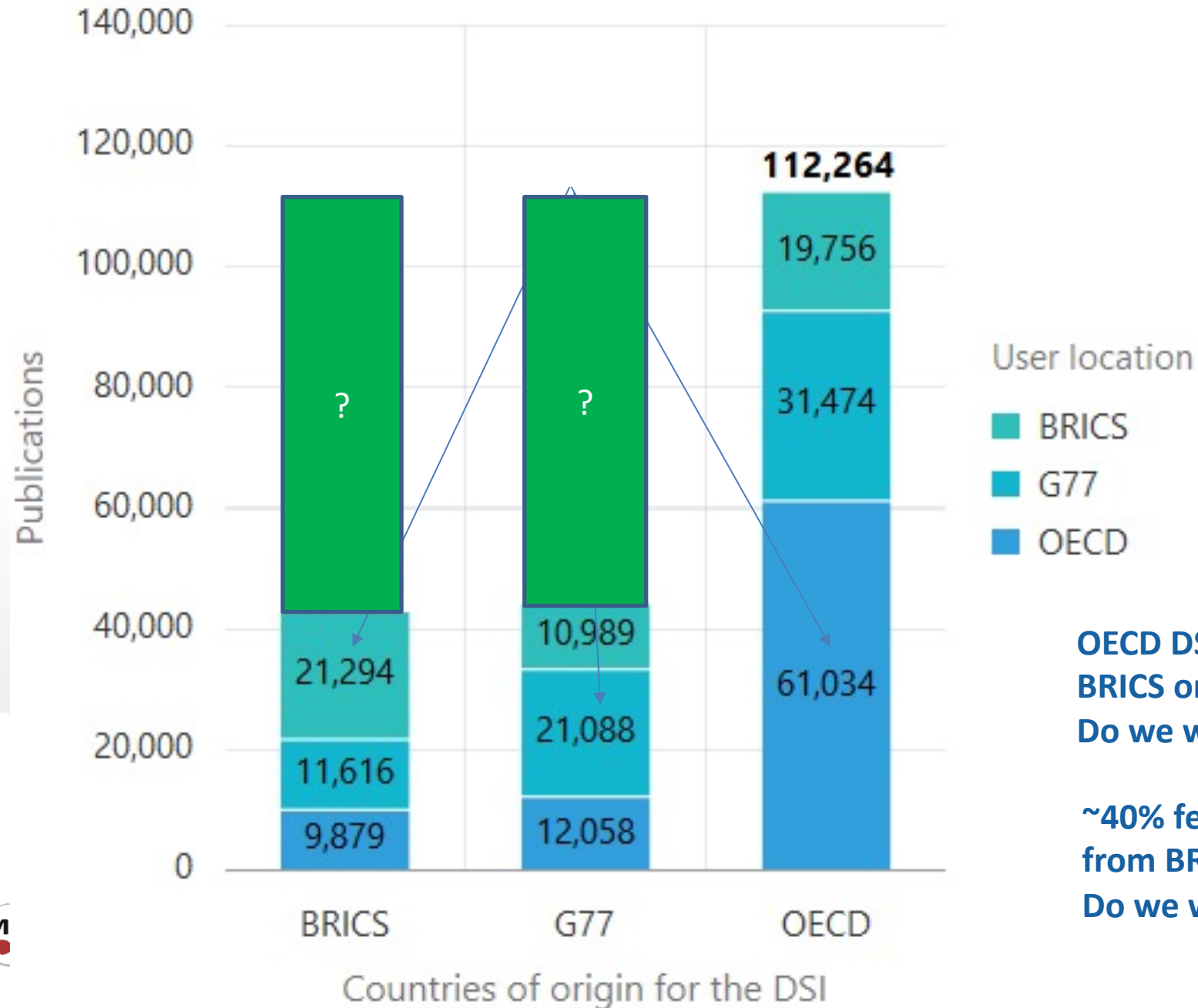
# Philippine scientists are using DSI from 32 countries



# Countries are both providers AND users of DSI – often roughly equally



# DSI is used more by „locals“ than by „foreigners“



OECD DSI is used 3x more than BRICS or G77 DSI.

Do we want this to change?

~40% fewer DSI-based publications from BRICS/G77 authors

Do we want this to change?

# DSI Scientific Network

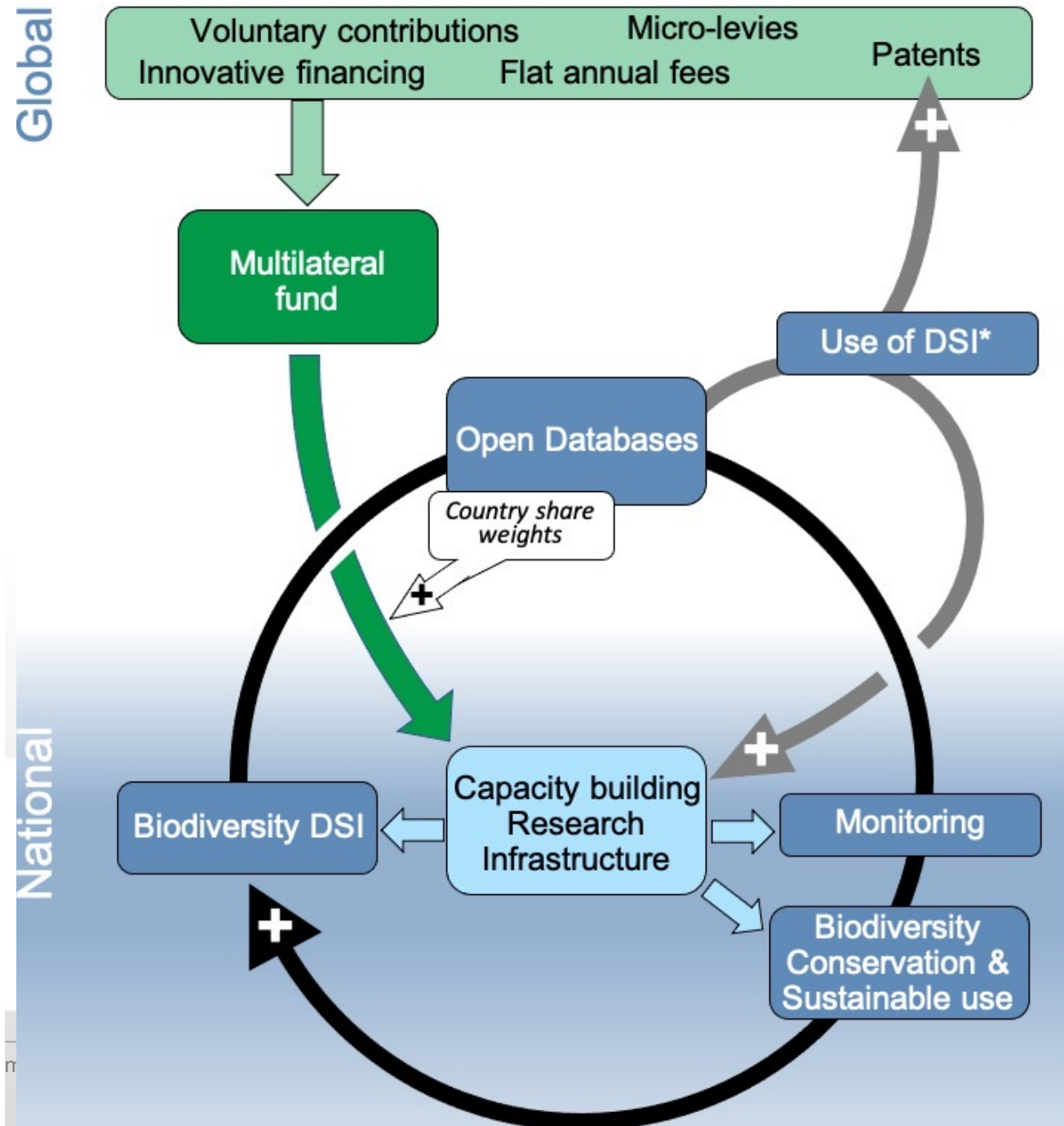
- **Founded in November 2020, 36 members, 16 Countries**
- **Members are DSI providers, users, researchers**
- **Mission:** to contribute to policymakers and other stakeholders' **understanding of DSI**, its applications and contributions to research supporting biodiversity conservation and public health, as well as the global benefits of open access to DSI databases.
- **Goal:** Members recognise that finding a solution, which balances the value of **open access** for researchers with the importance of **benefit sharing**, including monetary benefits, is essential to deliver a global biodiversity framework that meets the priorities of different stakeholders and contributes to the Sustainable Development Goals.





# A *de-coupled* multilateral framework for DSI-BS

1. A bilateral or „tagged“ mechanism will disincentivize use of LMIC-sourced DSI
2. Access should be de-coupled from benefit-sharing (facilitate rather than compete)
3. Virtuous cycle: Recognize and incentivize national contributions (esp. from LMICs)
4. Core focus: Conservation, sustainable use and bioeconomic innovation (complement the GBF goals)
5. Capacity building for science to improve DSI exploitation (rather than regulatory mechanisms)



# Acknowledgments

Data and graphs: <http://wildsi.ipk-gatersleben.de/>



Mehmood Ghaffar  
IPK former



Dr. Matthias Lange  
IPK



Pia Katherina-Habekost  
IPK



Jens Freitag, IPK



Dr. Guy Cochrane  
EMBL-EBI



Dr. Blaise Alako  
EMBL-EBI



Upneet Hillebrand, DSMZ former



Fabian Rohden, DSMZ former



Bundesministerium  
für Bildung  
und Forschung



CBD



Convention on  
Biological Diversity

Distr.  
GENERAL

CBD/DSI/AHTEG/2020/1/4  
31 January 2020

ENGLISH ONLY

AD HOC TECHNICAL EXPERT GROUP  
ON DIGITAL SEQUENCE  
INFORMATION ON GENETIC  
RESOURCES  
Montreal, Canada, 17-20 March 2020

COMBINED STUDY ON DIGITAL SEQUENCE INFORMATION IN PUBLIC AND PRIVATE  
DATABASES AND TRACEABILITY

<https://www.cbd.int/doc/c/1f8f/d793/57cb114ca40cb6468f479584/dsi-ahteg-2020-01-04-en.pdf>



# Thank you!

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New DSI workshop series: <http://io.aibs.org/nagoya>.

<https://www.dsmz.de/collection/nagoya-protocol/digital-sequence-information>

<http://wildsi.ipk-gatersleben.de/>

