Potential for academic institutions to support international biodiversity commitments

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Abstract

The implementation of the Kunming-Montreal Global Biodiversity Framework (KMGBF) of the Convention on Biological Diversity (CBD) emphasises a “whole-of-government and whole-of-society” approach to achieving ambitious biodiversity conservation Goals and Targets. The Conference of the Parties (COP) to the CBD invites academic and research institutions to support the implementation of the KMGBF and recently established regional/sub-regional Technical and Scientific Cooperation Centres (TSCCs) to assist Parties to the CBD. Yet, it remains to be determined to what extent and in what ways academics and research institutions can support the KMGBF, and how such support can be coordinated with the actions of TSCCs. Through a network analysis of the actors involved in the National Biodiversity Strategies and Action Plans (NBSAPs) of 51 African countries, we assessed the expected contributions of academic institutions as knowledge providers and facilitators. Academics are expected to play a key role in the implementation of global biodiversity policies. Network analyses show that TSCCs improve information and knowledge exchange by structuring the network and increasing interactions between Parties in the same region. Moreover, the integration of a coherent network of universities, exemplified by the UK's “CASCADE” consortium, further strengthens these exchanges by establishing relationships that promote diversity of interactions between actors at and between local, regional and global scales. This is complementary to the structuring capacity

of the TSCCs, indicating that combining the organisational strengths of TSCCs with the collaborative potential of universities can improve knowledge flow within the network, essential to advancing the implementation of the KMGBF. As such, the engagement of academic institutions is not merely supportive but foundational, creating structured mechanisms for long-term knowledge production, capacity-building, and policy guidance. Promoting structured engagement and collaboration between TSCCs and academic institutions can significantly advance biodiversity conservation efforts by filling knowledge gaps and facilitating targeted capacity-building initiatives at various scales.

Introduction

The Convention on Biological on Diversity (CBD) has the Vision that people will live in harmony with nature by 2050 (CBD/COP/DEC/15/4). The CBD was negotiated at the Rio Earth Summit in 1992, came into force in 1993, and now has 196 Parties (195 countries and the European Union). After two plans (8 and 10 years respectively) that were widely considered to have had minimal gains (Carroll et al., 2022; Global Biodiversity Outlook 5, 2020; Rounsevell et al., 2020), the Parties to the Convention adopted the Kunming-Montréal Global Biodiversity Framework (KMGBF: CBD/COP/DEC/15/4) at COP15 held in Montréal, Canada in December 2022. There are two important differences between this Framework and its predecessors. First, the Framework itself is part of a package of Decisions. These include: a monitoring framework (CBD/COP/DEC/15/5); and mechanisms for planning, monitoring, reporting and review (CBD/COP/DEC/15/6); mechanisms to provide means for implementation, notably for mobilising resources (CBD/COP/DEC/15/7); and a mechanism for capacity building and development and technical and scientific cooperation (CBD/COP/DEC/15/8). The intent was to provide greater coherence to the implementation of the Framework, recognising the urgency of delivering its ambitions and the structural mechanisms needed to support it, particularly through regional and subregional TSC Centres.

The second important development was the inclusion into the Framework of a Section outlining 'Considerations' for the implementation of the KMGBF "*to be understood, acted upon, implemented, reported and evaluated, consistent with*" (Section C: CBD/COP/DEC/15/4). One of the key Considerations is the need for all of governments and

all of society to be fully engaged in implementation and not just the Environment Ministries of Party governments. These Considerations are already being woven into implementation and will have to be included in Parties' reporting. This collective emphasis approach necessitates systematic collaboration between policy implementers and knowledge providers, especially academic institutions whose contributions are instrumental in shaping, informing, and scaling biodiversity actions.

Taken together, the Considerations and Decisions acknowledge that there is a pressing need for much broader and deeper commitment across society to implement the KMGBF and that, in particular, there is a need for academia, and its core activities, to be much more attentive to what is needed to deliver this Framework. Whilst the KMGBF was negotiated globally, it will be delivered nationally and locally so all Parties are expected to make significant progress towards each of the four Goals and twenty-three Targets. In this regard, each Party outlines its commitments in its National Biodiversity Strategy and Action Plan (NBSAP) and then reports progress periodically through the CBD's institutionalised National Reports. Thirty-five Parties had submitted their completed NBSAPs by September 2025 (Online Reporting Tool - Clearing House Mechanism, CBD, 2025). These NBSAPs not only outline national ambition, but which entities are expected to play a role in implementation. This is where governments state what they will do to implement the KMGBF at the national level and contribute to its goals and targets and the key actors that will play a role, including particular institutions, agencies, and organisations, as well as sectors of society such as business, academia, indigenous peoples and local communities (IPLCs), women and youth. Substantial 'tools and guidance' are available to Parties on issues related to the Goals and Targets of the KMGBF. It was reported at the 26th meeting of the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), held in May 2024, that more than 1200 separate tools and guidance documents had been submitted by Parties and other stakeholders (CBD/SBSTTA/26/INF/16/Rev.1). At the same meeting, a detailed consideration of overarching scientific and technical needs (CBD/SBSTTA/26/3) and a fuller gap and needs analysis (CBD/SBSTTA/26/INF/15) were presented. These highlight that scientific and capacity gaps remain, related to issues central to delivering the KMGBF.

Recognising that supporting Parties with appropriate knowledge, capacity building expertise and to effectively utilise science, technology and innovation to support the implementation of the KMGBF involves substantial challenges, the Parties adopted a mechanism of regional and subregional Technical and Scientific Cooperation Centres (TSCCs), plus a global co-ordination entity (CBD/COP/DEC/15/8). Eighteen TSCCs have been established (see https://www.cbd.int/tsc/tscm/subregionalcentres) to promote and facilitate on a 'demand-driven basis', providing a "*one-stop shop for scientific, technical, and technological support*" (CBD/SBI/REC/4/5; CBD, 2024). Each TSCC will support a specified group of Parties, and there will be both subregional and regional co-ordination (e.g. across the five centres in Africa, five centres in Asia and Oceania, three centres in the Americas and five centres in Europe) and global co-ordination provided via an entity hosted by the CBD Secretariat (COP/DEC/16/12). There is, therefore, an emerging CBD 'landscape' of implementation support structures under the CBD to engage and enable Parties to access relevant and actionable science and innovation in a form that is needs-driven and easy to understand. However, the effectiveness of these structures depends upon how well they interact as a coherent global network to meet the knowledge needs of Parties. This includes evaluating the potential of academic institutions to contribute not only as knowledge providers but also as institutional partners embedded within TSC governance and operational frameworks.

In principle, academic institutions could play a particularly important and influential role in supporting Parties' knowledge and capacity building needs. Often, they are publicly funded institutions with a mission to carry out research and education, and with many having outreach programmes they are generally well set up to contribute. They also operate at a useful range of scales, encompassing their host communities or cities, with national and international-level collaboration. Many universities are already actively providing their governments and international bodies and processes with policy-relevant information and advice guiding evidence-based decision-making on biodiversity in the context of the CBD. However, universities are complex and have other competing activities and constraints (e.g. funding or metrics of academic progress), and it should not be assumed that they are able to provide support to the CBD.

The CBD (Decisions 15/8 and 13/8) and academics (e.g. Leadley et al., 2022) highlight the importance of international academic collaboration for the implementation of the KMGBF. However, there is also debate about the added value that international collaborations can bring to conservation, with the term "parachute science" being used to describe collaborations where Global North researchers descend on a Global South country to carry out potentially exploitative science with inequitable power dynamics, whilst failing to build local capacity (de Vos & Schwartz, 2022). If universities in the Global North are to contribute in an equitable and useful way to the fulfilment of the KMGBF outside of their own country, then they need to add value to what is already in place. One way in which they could do this is by leveraging the partnerships that individual academic researchers have built up with colleagues in Global South countries, in a way that coordinate with, aligns with, supports and enhances the networks already put in place by the CBD and Parties.

Here, we consider whether the structures are in place to enable the effective mobilisation of academic and research institutions to support to the implementation of the KMGBF. We examine :

a) which actors are identified by Parties in their NBSAPs as important for delivering biodiversity conservation, and what is the relative importance of academic institutions;
b) the extent to which these actors could be networked, and how these networks could increase their coherence - for example, by working together at a continental scale;
c) how the emerging TSCCs can increase the potential for knowledge exchange; and
d) whether proactive and systematic engagement by external networks of universities, with their pre-existing collaborative networks, could further enhance the timely provision of relevant scientific information and capacity to Parties.

An institutional model of engagement, beyond project-based collaboration, can ensure sustained academic support for TSCCs in strategy development, reporting, and policy innovation.

Material and methods

a) Actors identified in NBSAPs

Considering that post-COP15 NBSAPs have not yet been made available by all Parties (55/196 as of September 2025, including 10 in Africa), we reviewed pre-COP15 NBSAPs referencing Aichi Targets. NBSAPs present how each Party will implement the work of the Convention. For each Target or Objective, we identified the actors that the Party expects to contribute to implementation. Different types of actors can be proposed by Parties to support the implementation of a specific Target. We consider that an actor identified by Parties to support a Target constitutes a desired relationship, implying that there is actual, or potential, collaboration and knowledge exchange between Parties and the identified actor. In line with the way actors are generally categorised in NBSAPs, we categorise them into sectoral categories, including academic and research institutions, private sector, non-governmental organisations (NGO), IPLC, civil society or biodiversity institutions (full categorisation in Supplementary Information 1).

To evaluate the demand by Parties for particular sectors to contribute towards NBSAP implementation we reviewed the NBSAPs of all 54 African Parties that were available on the CBD's Clearing House Mechanism (CHM) website (Supplementary Information 2). Most of these NBSAPs were published in 2015 (the earliest in 2000). We excluded three NBSAPs (Djibouti, Libya and Uganda) where the actors responsible for the implementation were not explicitly identified, resulting in the analysis of 51 NBSAPs. Although these NBSAPs vary in their structure, most of them include a description of the country's biodiversity (data, graphical and cartographic representations providing an overview of the issues in protecting biodiversity) and a section summarising the different Targets and listing the actors expected to contribute to their achievement. We chose to analyse African NBSAPs because these represented a geographically coherent set (i.e. countries in the same continent), which was near-complete, and which encompassed a range of circumstances faced by Parties. Additionally, most African countries are Targets for the CBD's capacity-building support, and

so it is particularly relevant to identify these countries' needs and desires regarding partnerships to implement their Targets.

We consider linkages between actors to be potential or actual knowledge exchange channels. Therefore, for each country's NBSAP, we extracted, by Target, the actors listed as involved in their implementation and used this information to create an undirected network of actors for each Target (Target-network) using *igraph* (Version 2.1.1) in *R* software. Target-networks were then pooled by Party to obtain a Party-NBSAP network (Table 1) of the actors expected to contribute to the implementation of all Targets (i.e. the whole NBSAP), resulting in a multigraph based on binary relationships (Actor-Party). We analysed each of these 51 Party-NBSAP networks at the node-level (actor level) using metrics to quantify whether there are distinct clusters of interacting actors, how well connected the overall network is and how core different actors are connecting different clusters (Table 1). This enables us to determine the expectations of input expressed African Parties for each actor-type. We ranked each actor for each metric and Party to evaluate their expected importance for the implementation of the Aïchi Targets. The actors' ranks were then pooled among the 51 Parties, and we computed the median rank for each actor to evaluate the overall expected importance of each actor. We considered these metrics using two categories: radial and medial metrics which together scribe the (potential or actual) flow of knowledge. Actors (nodes) with high radial metrics are those that have many links to other actors which might be good in this context for rapidly sharing information (Borgatti & Everett, 2006). Actors with high medial metrics are those that play key roles in bridging otherwise separate groups of actors which might be good for brokering knowledge exchange (Borgatti & Everett, 2006). Based on this classification, we assumed that a network can be described by a combination of the organisation of the network (the contribution of an actor to the *structure* of the network) and the flow of knowledge (the contribution of an actor to the *relations* within a network; Peng et al., 2020). At the network level, we computed global clustering coefficient metrics that describe the overall structure and organisation of the network. At the actor level, we identified actors that are important in their contribution to the *structure* of the network (*structural effect*) and to the relationships within the network (*relational effect*). These

effects are not mutually exclusive. Based on these analyses, we explored the role of academic and research institutions, relative to the other actors in the Party-NBSAP networks.

Table 1. Summary of the networks analysed and definition and interpretation of the parameters used in the analysis

Network name	**Network description**	**Node description (Actor)**	**Edge description (Relationship)**
Party-NBSAP network	Network of expected actors' contribution for each Party	Actors (e.g. Government, NGO…)	Expected collaboration (Knowledge exchange pathway)
NBSAPs network	Merged Party-NBSAP networks linked by each Government-related actor to the CBD Secretariat	Actors and CBD Secretariat	
NBSAP-TSCC	NBSAPs network with added TSCCs	Actors, CBD Secretariat, TSC	
NBSAP-TSCC-CASCADE	Subset of Party-NBSAP networks with only Parties mentioned in the CASCADE survey. We added the related TSCCs	CBD Secretariat, Parties mentioned in the CASCADE survey, related actors and TSCCs, CASCADE	
Category (Borgatti & Everett, 2006)	**Metric**	**Definition**	**Contextualised Interpretation**
Node level: Radial	Degree centrality	Number of direct neighbours in a network (Score)	Prominence of an institution/actor or set of institutions/actors in the network structure in terms of direct collaboration
Node level: Radial	Closeness centrality	Inverse average shortest distance between each node (0-1). Highest values indicating a more central role.	Degree to which an institution/actor is close to other institutions/actors in terms of collaborative links
Node level: Radial	Eigenvector centrality	Measure of node's influence on the whole network. It	Global influence of the institution/actor on the whole network.

		considers how well connected a node is through the entire network.	
Node level: Medial	Betweenness centrality	Relative number of times a node is located on the shortest pathway between a pair of nodes (0-1)	Degree to which information is more likely to pass through a given institution/actor, reflecting the role of the institution/actor as an "information distribution platform"
Node level: Medial	Average Local Clustering coefficient	The proportion of a node's neighbours that are neighbours of each other (0-1)	Tendency of institutions/actors to form a group
Node level: Medial	Global Clustering coefficient	The proportion of links that could exist that do exist (0-1)	Connectedness of the network, i.e. nodes interacting with each other

b) The potential increased benefit to knowledge sharing of the establishment of Technical and Scientific Cooperation Centres (TSCCs)

During COP-16, five TSCCs were approved for the Africa region to increase cooperation: the Sahel and Sahara Observatory for Northern Africa, Ecological Monitoring Centre for Western Africa, Central African Forest Commission for Central Africa, South African National Biodiversity Institute for Southern Africa, and Regional Centre for Mapping of Resources for Development for Eastern Africa. The appointment of these TSCCs follows a CBD request to increase cooperation between Parties. Each is an existing research agency, taking on additional responsibilities based on their designation as TSCCs. They were selected because of their capacity to design and implement projects cutting across countries and their alignment with the CBD and its KMGBF.

At a COP16 side-event of the African TSCCs, participants emphasised the need for these centres to take a coordinated, continent-wide, approach to supporting implementation of the KMGBF with the active involvement of the African Union Commission (https://www.oss-

online.org/en/node/879). This provides African Parties with the mechanism to exchange knowledge between actors at national level (i.e. NBSAP), regionally (i.e. TSCC), and continentally (i.e. inter-TSCC collaborations coordinated by the African Union Commission), as well as between these three levels and globally.

In order to evaluate the effect of the TSCCs on the overall network of African NBSAPs, we connected individual Party-NBSAP networks into a single network by connecting each government node to the coordination entity, the CBD Secretariat. We obtained a "NBSAP network" representing the total network of African NBSAPs. We then connected TSCCs as nodes to the Government actor of each related Party and to the CBD Secretariat. We thus obtained an NBSAP-TSCC network. We then bootstrapped the NBSAP and the NBSAP-TSCC networks in rewiring their edges. The aim was to identify whether adding TSCCs primarily impacts the NBSAP network through their specific interactions with other actors or only because of their addition as an extra actor (full methodology in Supplementary information 3).

We used our bootstrapped networks to compare the NBSAP and NBSAP-TSCC networks to measure the effect of adding a new actor (TSCC). We aimed to distinguish between two types of potential effects (Figure 1):

- Relational effects: These arise specifically from the unique relationships formed by TSCCs.
- Structural effects: These result solely from adding extra actors to the network.

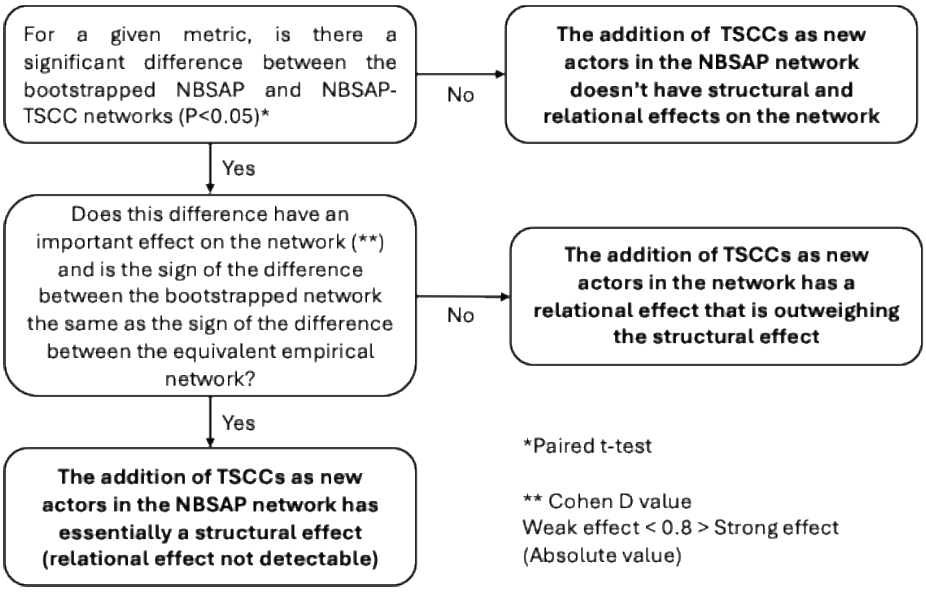


Figure 1. Decision tree for the network of African NBSAPs.

To compare NBSAP and NBSAP-TSCC networks, we mobilised the detailed reasoning presented in Figure 1, which involves: (1) comparing the random networks (bootstrapped) to determine whether the addition of an extra actor has a structural effect on the original network; (2) using Cohen's D to assess whether any potential significant differences have a tangible impact on the network's structure, or whether the statistical significance is merely due to minor differences with limited relevance to the network; and finally (3), establishing whether adding an extra actor has a relational effect on the network by comparing the direction of the differences between empirical networks and those between bootstrapped networks. This has been done for each metric.

c) **The potential increased benefit to knowledge sharing of the inclusion of a dedicated university network**

To examine how a coherent network of academic and research institutions could increase information flow across the NBSAP network, we used, as a case-study, the network to which many of us we belong, the Conservation and Sustainability Consortium of Academic Institutions (CASCADE: https://www.cascade.ac.uk). CASCADE is a recently established network of 35 UK universities and research institutions aiming to enhance knowledge

exchange in support of implementing the KMGBF. The analysis therefore sheds light on how a country such as the UK could contribute to the capacity building and scientific exchange envisaged in the KMGBF Decisions and Considerations. We disseminated an online survey within the CASCADE consortium to map external partnerships with countries benefiting from Official Development Assistance (ODA), which included all of the African countries in our study. The survey received ethical clearance from Newcastle University ethics committee (Ref: 44129/2023: see Supplementary Materials). Individuals from CASCADE institutions were asked to submit up to five partnerships with organisations in ODA countries (including governments, NGOs or other actors) and to identify the KMGBF Targets to which each partnership could contribute. The online survey resulted in 49 responses, listing 98 partnerships across 16 CASCADE institutions, including 57 partnerships with African actors. The results from this survey underestimate the number and extent of CASCADE partnerships with external collaborators, as it is based on declared partnerships of a non-exhaustive list of CASCADE institutions and individuals. However, the dataset provides a snapshot of the type of partnerships that a particular university network, based in a Global North country, could contribute to KMGBF implementation.

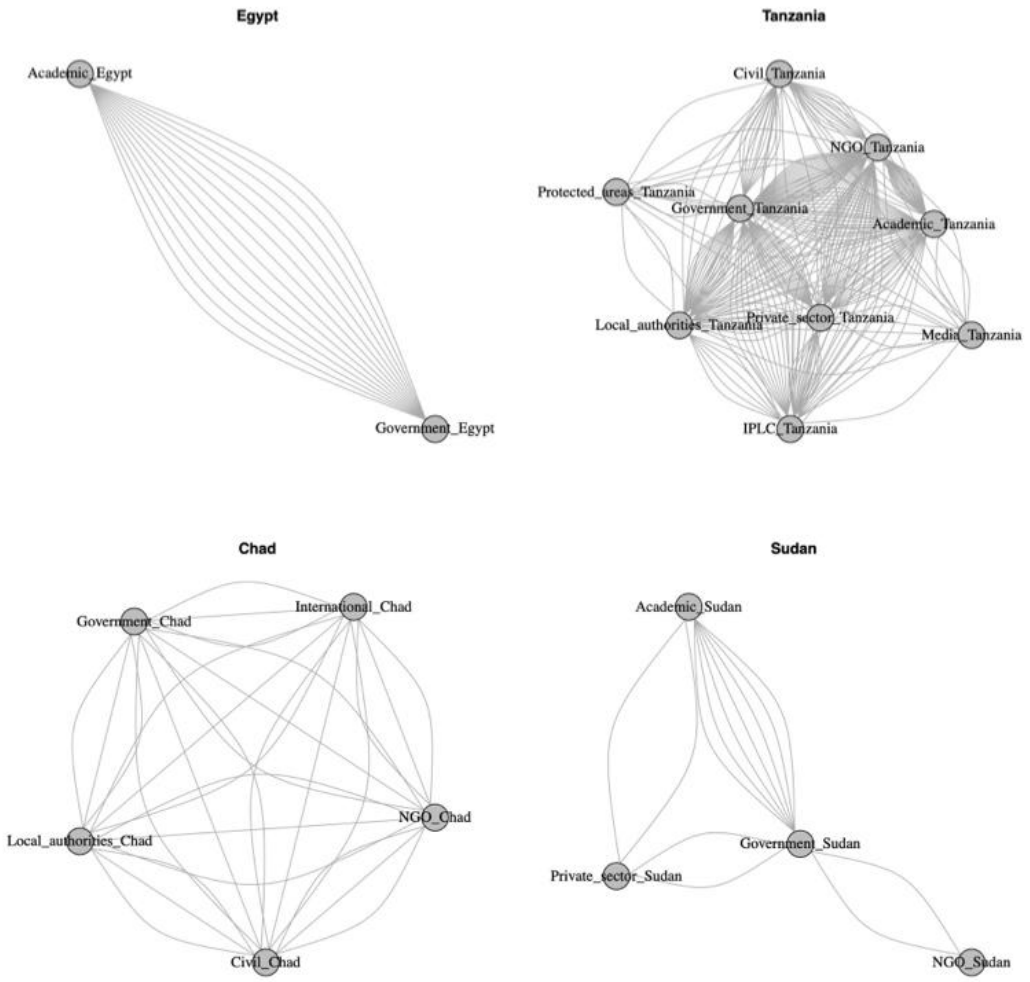
We integrated CASCADE into a subset of the NBSAP-TSCC network (restricted NBSAP-TSCC network) representing the countries in which CASCADE has partnerships, to create a NBSAP-TSCC-CASCADE network. We aimed to identify how the inclusion of CASCADE could be complementary to the TSCCs in enhancing knowledge exchange. As in our TSCC analysis, we bootstrapped the restricted NBSAP-TSCC and NBSAP-TSCC-CASCADE networks and used a decision tree to interpret the results (Figure 1).

Results

a) The actors identified by Parties in their NBSAPs

Party-NBSAP networks present a diversity of structures with multiple different interacting actors (Figure 2 and Table 2). Government institutions (ministries and other affiliated institutions) are the most central to the NBSAPs' networks both in individual countries and for the international NBSAP network. This is not surprising given that NBSAPs are the

responsibility of governments (full results in Supplementary Information 5). However, a range of other actors are recognised by these governments as central to the implementation of the KMGBF Targets at a national scale (Table 3). The network analysis suggests that academic institutions have a high ability to capture information in Party-NBSAP networks (second highest Degree centrality value together with NGOs), a high ability to act as information bridges across the whole network (second highest Betweenness centrality value together with NGOs), proximity to all other actors (second highest Closeness centrality value), and a high influence on the global structure of the network (second highest Eigenvector centrality value together with NGOs).



Country	Degree	Betweenness	Eigenvector	Closeness	Clustering
Egypt	14	0.00	1.00	1.00	NA
Tanzania	68	0.33	0.82	0.12	0.93
Chad	NA	NA	NA	NA	NA
Sudan	9	0.00	0.97	0.25	1.00

Figure 2. Example Party-NBSAP networks: Egypt has only two actors with a high density of expected contributions across a range of Targets; Tanzania has 9 different actors and a diversity of expected contributions; Chad has a centralised organisation of interactions between actors, in a hub-style approach; while Sudan has specific actors (academic institutions and government) which act as important bridges for connecting other actors. The table represents the metrics associated to the academic actor. These four examples highlight the diversity of Party-NBSAP networks (see the full list of Party-NBSAP networks in Supplementary material 4).

Table 2. Network metrics in practice: illustrations from the Party-NBSAP network analysis

Metric	Meaning in practice	Example
Number of actors	Diversity of actors in each NBSAP	The average is 7.66 actors per NBSAP. Egypt and Niger have only two actors while Algeria and South Africa have 11 actors.
Closeness centrality	Proximity between actors (short distance)	The average is 0.86 per NBSAP. Egypt and Niger have actors that are very close (1.00) and Nigeria's NBSAP has more distant actors (0.70).
Average number of relationships of actors in each NBSAP (Mean Degree centrality)	Intensity of the collaboration between actors in each NBSAP	The average number of relationships that actors have in each NBSAP is 22.14, varying from 1.33 for Congo to 52.89 for Tanzania.
Density of relationships (proportion of similar relationships shared by identical actors among all potential connections). Because we have multigraphs, we can have density >1.	Actors that interact more together than with others	Egypt has a density of 14 (Government and Academics are expected to work exclusively together for all of the 14 Egyptian Targets) while Zambia is more diversified with 0.87.
Mean Betweenness centrality	Actors acting as "bridge" for knowledge sharing	Sudan relies on a few specific actors, with a value of 0.16, while Burkina Faso is not relying on specific actors to link with others.
Mean Eigenvector centrality	Centralised organisation around few important actors or decentralised organisation. At the actor level, this metric represents the overall importance of a given actor for the whole network.	The Chadian network is very concentrated around specific important actors (Eigenvector centrality value: 1.00) while the Rwandan network is decentralised with less dominant actors (Eigenvector centrality value: 0.43)

Table 3. Most important actors in African National Biodiversity Strategy and Action Plans (median of the rank based on metrics for each national network). Please see Table 1 for meanings of the various metrics.

	Degree centrality	**Betweenness centrality**	**Closeness centrality**	**Eigenvector centrality**
Rank 1	Government	Government	Government	Government
Rank 2	Academic, NGO	Academic, NGO	Academic	Academic, NGO
Rank 3	Biodiversity institution	Biodiversity institution	NGO	Biodiversity institution
Rank 4	Indigenous People and Local Communities (IPLC), Civil society, Private sector	Civil society, Local authorities, Private sector	Biodiversity institution, Civil society, Private sector	Private sector

Influence can be measured in terms of the importance of the actor as a direct expertise provider (e.g. academic expertise that will enable the KMGBF to be achieved: knowledge provider, as proxied by Degree Centrality), but also in its ability to contribute to the dynamics of the network by enabling bridges to be built between actors who can respond to different objectives or Targets (knowledge broker, as proxied by Betweenness centrality). Academic institutions are particularly closely connected to other actors (Closeness centrality) and therefore play a particularly important role in NBSAP networks (Eigenvector centrality). Interestingly, private consultants (both national and international) were listed as being involved in the production of 19 out of the 51 NBSAPs but were not seen as important implementation partners; they were only mentioned once in this role, in the South African NBSAP.

b) Linkages between pre-COP NBSAPs and the TSCCs and the potential to increase knowledge exchange

For all the metrics assessed, there is a significant difference between the random NBSAP network and the same network with TSCCs added. When TSCCs are added, therefore, there is a structural effect on the global network for each metric. For the global Clustering coefficient we observe a large Cohen D's value, indicating an important structural effect of

adding TSCCs. This is, however, outweighed by an important relational effect, because if there was only a structural effect, the same difference will be observed in comparing the random networks. But the sign of the difference between networks, either empirical or bootstrapped, is different in this case. It suggests that a relational effect is outweighing the observed structural effect (Figure 1) and that integrating TSCCs into the NBSAP network leads to more cohesive subgroups (Table 4).

We also observe a high value of Cohen's D for the Betweenness centrality metric, suggesting an important structural effect of the TSCCs on the network in making new bridges between actors. For the empirical network, when adding the TSCCs, the mean betweenness centrality increases while for the random network, adding the TSCC decreases the mean betweenness centrality. This difference of sign between bootstrapped and empirical suggests an important relational effect because it outweighs the observed structural effect in the random networks. This is as a result of the relationships that the TSCCs have with actors in the NBSAP network and highlights the important role of each TSC as a knowledge exchange facilitator. For the average local Clustering coefficient, representing the tendency of actors to belong to strongly connected communities, we observe that the addition of TSCCs as new actors in the network has essentially a structural effect. However, this is not what we observe in the Table 4 because both empirical and theoretical networks comparison have the same sign. This implies that the addition of TSCCs to the network is not likely to promote new relationships between actors within existing subgroups. The very low Cohen D's value for the Eigenvector centrality metric suggests that the inclusion of TSCCs into the NBSAP network has a negligible structural effect on the overall network. The comparison between empirical networks also shows that if there is any relational effect, it is negligible. Finally, for the Closeness centrality, we observe a low Cohen's D value suggesting that the structural effect caused by the integration of TSCCs into the NBSAP network does not have a major effect on the proximity between actors. Instead, the effect of the inclusion of TSCCs is mainly structural, related to the addition of an extra actor into the network (Table 4).

To summarise, the inclusion of TSCCs in the NBSAP network promotes more cohesive subgroups and supports specific actors to act as bridges between these actor groups.

TSCCs appear not to have the potential to enhance the proximity between actors (Closeness) nor to catalyse novel interactions between actors of the same subgroup (local Clustering) or lead to more decentralisation of the network (Eigenvector). These results indicate that TSCCs mainly have an organisational role in the network, benefiting the supervision of implementation rather than the generation of new knowledge exchange opportunities.

Table 4. Evaluation of the difference between empirical and bootstrapped NBSAP and NBSAP-TSCC networks, for various metrics (see Table 1 for an explanation of the interpretation of the metrics). A Paired T-Test is used to evaluate whether the differences between the two network types are significant (see Figure 1), with (*) indicating a significant difference. Cohen's D represents the actual effect of the addition of the extra actor on the network. It is based on the comparison between two networks, depending on the comparison the value can be positive or negative. Absolute values below the 0.8 threshold represent a negligible effect.

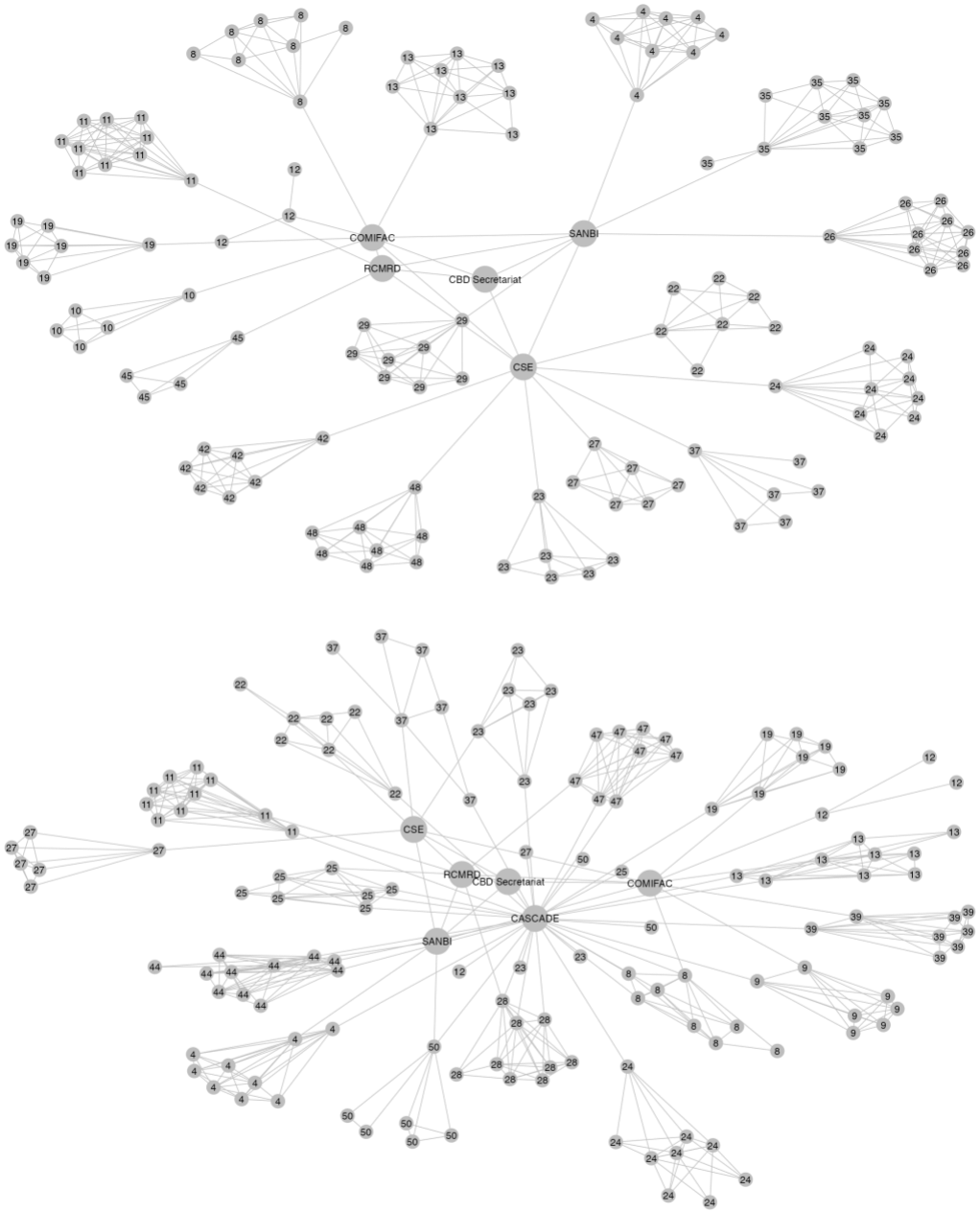
Metric	Network	Empirical value	Random $\bar{x}$	Random SD	Paired t-test	Cohen's D
Average local Clustering	NBSAP	0.864	0.185	5.34e-3	P<0.05*	**0.84**
	+TSCC	0.857	0.180	5.18e-3		
Global Clustering	NBSAP	0.692	0.170	2.02e-3	P<0.05*	**1.86**
	+TSCC	0.768	0.166	2.01e-3		
Closeness centrality	NBSAP	0.275	0.443	8.82e-4	P<0.05*	0.52
	+TSCC	0.228	0.442	8.90e-4		
Eigenvector centrality	NBSAP	0.014	0.281	7.86e-3	P<0.05*	0.05
	+TSCC	0.014	0.281	7.91e-3		
Betweenness centrality	NBSAP	0.007	3.31e-3	1.35e-5	P<0.05*	**2.70**
	+TSCC	0.009	3.28e-3	1.35e-5		

c) Potential for a network of external universities to support knowledge exchange

The networks compared here are, on the one hand, the restricted NBSAP-TSCC network (a subset of NBSAP-TSCC including only the Parties with which CASCADE maintains a partnership), and on the other hand, the same restricted NBSAP-TSCC network with CASCADE included (Figure 3).

The inclusion of CASCADE partnerships into the restricted NBSAP-TSCC network has a structural effect for all metrics tested (Table 5). The decrease in Betweenness and the

increase in Closeness centrality values when CASCADE is added is only related to a structural effect of the addition of an extra actor (Table 5). However, the decrease in both global and mean local Clustering coefficient values and the increase in Eigenvector centrality value are relational effects (Table 5). CASCADE connects actors that are not connected by TSCCs (i.e. Clustering coefficients), while also connecting with already-influential actors (i.e. Eigenvector centrality). CASCADE is, thus, strategically positioned in the network, connecting different groups of actors without forming its own group.



Botswana	4	Comoros	11	Gabon	19	Côte d'Ivoire	24	Madagascar	28	South Africa	44
Cameroon	8	Congo	12	Guinea	22	Kenya	25	Nigeria	37	Tanzania	47
Central African Republic	9	Democratic Republic of the Congo	13	Guinea Bissau	23	Liberia	27	Sao Tome	39	Zambia	50

Figure 3. Graphical representation of the restricted NBSAP-TSCC (above) and NBSAP-TSCC-CASCADE (below) networks. Each node represents an actor belonging to a Party. Each Party has a corresponding number for identification. Sahel and Sahara Observatory (OSS), Ecological Monitoring Centre (CSE), Central African Forest Commission (COMIFAC), South African National Biodiversity Institute (SANBI), and Regional Centre for Mapping of Resources for Development (RCMRD) as well as CASCADE in the NBSAP-TSCC-CASCADE network are included.

Table 5. Evaluation of the difference between empirical and bootstrapped restricted NBSAP-TSCC and restricted NBSAP-TSCC+CASCADE networks, for various metrics (see Table 1 for an explanation of the interpretation of the metrics). A Paired T-Test is used to evaluate whether the differences between the two network types are significant (see Figure 1), with (*) indicating a significant difference. Cohen's D represents the actual effect of the addition of the extra actor on the network. It is based on the comparison between two networks, depending on the comparison the value can thus be positive or negative. Absolute values below the 0.8 threshold represent a negligible effect.

	Network	Empirical value	Random $\bar{x}$	Random sd	Paired T-Test	Cohen D
Clustering local	Restricted NBSAP-TSCC	0.840	0.504	1.17e-2	P<0.05*	**-8.31**
	+CASCADE	0.798	0.604	1.22e-2		
Clustering global	Restricted NBSAP-TSCC	0.775	0.386	4.94e-3	P<0.05*	**-16.58**
	+CASCADE	0.614	0.460	3.96e-3		
Betweenness centrality	Restricted NBSAP-TSCC	0.024	0.007	6.23e-5	P<0.05*	**9.78**
	+CASCADE	0.017	0.007	6.14e-5		
Closeness centrality	Restricted NBSAP-TSCC	0.242	0.513	1.77e-3	P<0.05*	-0.71
	+CASCADE	0.295	0.514	1.93e-3		
Eigenvector centrality	Restricted NBSAP-TSCC	0.033	0.341	9.58e-3	P<0.05*	**1.54**
	+CASCADE	0.043	0.326	1.07e-2		

Discussion

Academic and research institutions, alongside NGOs, are expected by Parties to be key partners in the implementation of their NBSAPs. Parties have different needs and strategies for implementation partnerships. Egypt for instance seems to rely solely on academic and research institutions which risks facing difficulties for NBSAP implementation in sectors dominated by other actors (e.g. private sector). Tanzania relies on a diversity of actors with the risk of none owning the implementation of the NBSAP targets making it potentially harder to work in an integrated way. These discrepancies between Parties are probably related to differences in terms of capacity mobilisation and structures of conservation governance.

The mobilisation of academic and research institutions can be limited for some Parties which can be reflected in their NBSAP. The implementation structure of the NBSAPs, especially the difference between centralised and decentralised structures, can influence the relationship between governmental-related entities and other actors including academic and research institutions which could shape the structure of the NBSAP network.

While the inclusion of TSCCs into the international NBSAP network improves the organisation of the knowledge exchange network, establishing coherent pathways for information flow, the inclusion of a collaborative network of external universities such as CASCADE could enhance knowledge flow between actors at different scales (Party, TSCCs, and inter-TSCCs) without compromising the structure and organisation promoted by the TSCCs. It is thus critically important to understand how TSCCs and academics and research institutions can work together to support the implementation of NBSAPs, and especially how academics could practically contribute to this effort. We discuss our findings in the context of two key observations: the complementarity between TSCCs and academic and research institutions and the need for a coherent network of universities to support international biodiversity commitments.

1) **Technical and Scientific Cooperation Centres and Academic and Research institutions are complementary in promoting knowledge exchange**

TSCCs and academic and research institutions have central roles in the emerging CBD 'landscape" of implementation support structures and calls for engagement. They can promote a network of knowledge exchange (both as providers and as brokers) that can help meet, perhaps substantially, the knowledge exchange needs of Parties. The comparison of networks revealed a tension between the need for a clear structure of knowledge exchange and the richness of exchanges with a diversity of actors and knowledge systems at different scales. It is by combining these two critical aspects of knowledge exchange - structure and flow - that the complementarity of TSCCs and academic and research institutions could support the implementation of the KMGBF. Beyond the numbers and network metrics, it's important to rethink how we work together. A country's academic and research institutions

should have a seat at the table, co-designing TSCC strategies, contributing to decision-making bodies, and helping build lasting research partnerships. Their role goes beyond sharing knowledge; they should be true partners in shaping and owning the solutions for biodiversity in their country.

From a descriptive perspective, TSCCs may support, and strengthen, cooperation between Parties at three levels: intra-regional, inter-regional and continental through the 'global co-ordination entity' (CBD/COP/DEC/15/8). Considering what knowledge is needed and which actors should be involved is important when establishing the TSCCs' terms of working. By providing an additional organisational level at the regional scale, TSCCs should enable a more efficient flow of technical and scientific support between the 196 Parties than at present. TSCCs are intended to constitute a "*one-stop shop for scientific, technical, and technological support*" (CBD/SBI/REC/4/5; CBD, 2024) enabling the integration of national scale NBSAPs to the regional/subregional scales and, in the African context, to the continental scale via the African Union. This should allow, in due course, more effective implementation of NBSAPs that are adapted to the national context (in terms of social-ecological issues and implementation capacities), while informing, and being informed by, higher-scale considerations. Our network analysis shows that the definition of TSCCs as "one-stop shops" does indeed reflect their organisational and structural importance. Their bridging role between different subgroups of actors increases the proximity between these actors. This role of intermediary is critical for the efficiency of the CBD's complex global processes such as monitoring and evaluation of NBSAP progress. It should also facilitate communication with the CBD Secretariat and with TSCCs from other regions.

Academic and research institutions can support and enhance the TSCCs' role. Our network analyses (Party-NBSAP in particular) revealed that academic and research institutions are not only expected to be knowledge providers but to work collaboratively with a wide range of non-academic actors. The high Degree centrality of academic and research institutions highlights their important role in establishing and maintaining connections with a diversity of actors, their high Closeness centrality shows their ability to bring different actors close to each other, and their high Betweenness centrality shows they are able to fulfil the role of

bridge between different actors (Borgatti & Everett, 2006). It is worth noting that these roles are also played by actors such as NGOs.

The knowledge exchange role of academic and research institutions is visible in their linking of different actors. For instance, in the Democratic Republic of Congo, academics are expected to establish links between IPLCs and the media. By linking these different actors, academics can create potential new routes for exchanging information and knowledge that would benefit the entire network.

Academic and research institutions can also promote synergies across Targets. For instance, in Zimbabwe, academics are the only actor expected to participate in both National Target 6 (reducing and preventing ecosystem pollution) and National Target 10 (conserving and protecting endangered species). Recognising potential synergies between Targets has been identified as key to combatting biodiversity loss (Rist et al., 2024; Sylvester et al., 2023). Therefore, if academics talk to each other, and make connections between Targets, then they could add huge value. This is exactly the role that academic consortia should play, in ensuring that dialogue between academics is taking place and is orientated towards coordinated action to support Parties in the implementation of the KMGBF. Tengö et al. (2017) identified five "tasks" required for collaboration between different knowledge systems (e.g. scientific knowledge systems and local or policy knowledge systems): knowledge mobilisation, synthesis, translation, negotiation, and application. The key role of academic and research institutions in knowledge exchange, revealed by our analysis, suggests that academics should not only be involved to mobilising and synthesising knowledge (through the production of research papers, for instance) but also in facilitating and enhancing the flow of knowledge between a diversity of actors with different knowledge systems (Marzocchi et al., 2023; Tengö et al., 2017), for example through workshops, briefings, and transdisciplinary projects.

The complementarity between TSCCs and academic and research institutions both in-country, and externally, offers a pathway for collaboration that could substantially enhance knowledge and understanding available to Parties. TSCCs, through their unique position of facilitating cooperative activities amongst relevant government entities representing the

Parties, could also help guide academic and research institutions to collaborate at various scales, to meet specific needs of Parties, or a group of Parties. This could benefit all the actors in the NBSAP network through capacity-sharing and capacity-building and contribute to global knowledge exchange within the CBD framework. It seems appropriate, therefore, for TSCCs and academia (at both the national level within Parties, and internationally) to work proactively together to realise these potential benefits.

2) From individual academics to a coherent network of universities

Decision 15/8 of the COP15 on *capacity building and development and technical and scientific cooperation* invites universities and other academic institutions around the world to support the Kunming-Montréal Global Biodiversity Framework. This call for academia and research institutions has been reaffirmed during SBI-04 by a range of Parties, including:

> "*It is essential to see the scientific and academic community reflected as relevant actors, as actors that systematically produce, curate and publish data, information and knowledge as part of their mission"* (Colombia, Statement on item 5, SBI4)
>
> "*...despite the Secretariat's active and multilateral partnership with various organizations, financial institutions and environmental initiatives in the field of capacity-building and development, technical and scientific cooperation, we are forced to note the lack of interaction with national scientific institutions*..." (Tajikistan, Statement on Item 5.1, SBI4 plenary)
>
> "*Addressing inequalities between countries in the capacities to collect, generate and process biodiversity-relevant data, including by enhancing capacity building, scientific and technical cooperation and access to and transfer of technology, is critical to enable the implementation of the knowledge management strategy"* (Brazil, Amendment on CBD/SBI/4/7 document)

These calls underline the need for academic and research institutions to be more unified in the way that they engage with Parties in their effort to support implementation of the KMGBF both as knowledge providers (through evidence) and as facilitators. When academic

institutions join forces as a consortium, they can better support regional strategies, shared learning, and joint monitoring—exactly the kind of collaboration TSC Centres need to succeed.

In this study, we assumed that academic and research institutions could act as a single actor. We thus considered that knowledge exchange flows smoothly between individual academic and research institutions. However, this is challenging to achieve in practice (Kosmützky & Krücken, 2023). Improving the coherence of the knowledge exchange provided by academic institutions could enhance their contributions to the KMGBF substantially. The CASCADE initiative is one example of such efforts undertaken by academics in UK universities to structure themselves with the aim of engaging with Parties and the CBD as a united academic entity. For instance, CASCADE maintains close partnerships with government, academics, NGO and other actors across TSCCs and continents. This interconnectedness of CASCADE's network depends on the effective and equitable collaboration of CASCADE academics within the network. This "consortium" structure requires both internal mechanisms of knowledge exchange and the ability to maintain relationships with other actors, encouraging "capacity-sharing". Other examples of academic consortia include the African Academy of Science (https://aasciences.africa), Eklipse (https://eklipse.eu/), aiming to bridge the gap between research and academic institutions and European policy on biodiversity, "Universities Policy Engagement Network" (https://upen.ac.uk) or the "Climate Adapted Pathways for Education" alliance (https://www.capealliance.org.uk/).

Academic and research institutions working as a cohesive entity will be much more straightforward for Parties to engage with, and so could play a much enhanced role of knowledge exchange facilitator between biodiversity science and policy knowledge systems with a diversity of actors (Jessani et al., 2016; Kangas & Aarrevaara, 2020; Knight & Lyall, 2013). Considering the role of researchers in this context of interrelations between different knowledge systems implies promoting not only interdisciplinarity but also transdisciplinary research that actively involves non-scientists in the scientific process. It implies for researchers to be able to understand how to do knowledge brokerage. This will make

biodiversity-related research more “credible, legitimate and salient” (Cash & Belloy, 2020; Cash et al., 2003).

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