Identification and analysis of the main drivers for Ebola virus spillover

Donato Ricci, Eleonora Grotto

EXTERNAL SCIENTIFIC REPORT

Identification and analysis of the main drivers for Ebola virus spillover[1]

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SciencesPo MediaLab

ABSTRACT

In relation to the events of the current Ebola outbreak in West Africa, the European Commission requested EFSA to identify the drivers for occasional spillover event of Ebola virus, i.e. the transmission from animals to humans. As part of this work SciencesPo was contracted by EFSA to perform an analysis to visualise and communicate the drivers for spillover of Ebola virus. Based on information available in the peer-reviewed scientific literature, a set of drivers for spillover of infectious diseases was identified and a set of scientific studies was used to structure a corpus of relevant arguments. This corpus was used to analyse the driver network and visualise the driver behaviour. The analysis led to the identification of 40 drivers, connected through 142 linkages. The visualisation of the driver network showed that central drivers involved in spillover are 'Hunting', 'Deforestation/forest fragmentation', and 'Demographic changes of wildlife'. The most frequent driver links identified were 'Deforestation/forest fragmentation' leading to 'Ecosystem changes' and 'Livelihoods resilience' leading to 'Hunting'. Different publication biases may affect this methodology, therefore the findings reported should be interpreted as a representation of the current view of the scientific community on Ebola virus spillover, rather than a comprehensive analysis of drivers of spillover. The methodology used in this report demonstrates a more structured and transparent approach to analysing drivers for infectious diseases. Such visualisations help in apprehending and analysing the whole system, which is complex in nature since it involves bio-ecological, technical, political and socio-economic aspects. Furthermore the understanding of environmental, epidemiological and social factors that lead to such an outbreak may help to prevent future ones.

KEY WORDS

Ebola virus, spillover, reservoir, susceptible species, drivers

[1] Contract number: NP/EFSA/ALPHA/2014/15

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TABLE OF CONTENTS

BACKGROUND AS PROVIDED BY EFSA

Infections with some Ebola viruses (EBOV) cause a severe disease in humans called Ebola virus disease (EVD). The present outbreak of EVD in Upper West Africa is the worst ever recorded.

The principal mode of human-to-human transmission is through direct contact with a symptomatic or dead EVD person or with surfaces and materials contaminated with body fluids from an infected person.

Transmission of EBOV to humans is thought to occur by contact with dead or living infected animals. Hunting and butchering of infected animals, i.e. contact with infected blood, body secretions, tissues, organs and other bodily fluids, is a potential source of infection in humans. Spillover is defined as the passage from animals to humans; spillover event typically leads to an index case in humans.

The current outbreak is believed to have happened after a single spill-over event. All the human cases so far have been traced back to a confirmed or probable human to human transmission. The current index case would be a 2 year old boy living in Gueckedou (Guinea).

Understanding of environmental, epidemiological and social factors that lead to such an outbreak - their spatial and temporal heterogeneity - as well as their interconnections across the affected region and beyond - may help to prevent future outbreaks.

Drivers have been defined as issues shaping the development of a society, organisation, industry, research area, technology, etc. Drivers can be classified in categories such as STEEP (i.e. Social, Technological, Economic, Environmental, and Political). One important characteristic of drivers is that they may act as modifiers of effect on the onset of emerging risks, namely they can either amplify or attenuate the magnitude or frequency of risks arising from various sources. A large body of literature is available on drivers in different fields, including economy, social sciences, technology, health and environmental sciences. Many drivers can contribute to emergence of infectious diseases; drivers of emergence rarely act singly.

Spidergrams are representations of networks of drivers and have been used as a methodological tool to represent the networks of possible drivers and their interactions.

EFSA has been requested by the European Commission to provide advice on the drivers for occasional spillover event of EBOV. To this effect, a four step approach is proposed: 1) list possible drivers, grouped by family, 2) build a network of interaction (spidergrams), 3) aggregate data and information to the network and 4) propose visualization options of the interactions at different scales

TERMS OF REFERENCE AS PROVIDED BY EFSA

Against this background, activities carried out under this procurement will focus on step four of the process described above, visualisation options for the interactions between drivers.

The overall objective of the contract resulting from the present procurement procedure is to propose visualisation options for the interactions between drivers of Ebola virus spillover events. The objectives of the contract resulting from the present procurement procedure are to provide visualisation options allowing for:

- the identification of the different drivers' categories (for example Social, Technological, Economic, Environmental, Political as proposed in the STEEP approach)
- the identification of the drivers within each categories as well as their relations to other drivers and their respective weight
- the representation of the strength of evidence and data sources and areas of uncertainty

Acknowledgements

This contract was awarded by EFSA to:

Contractor: SciencesPo MediaLab, 27 rue Saint Guillaume, 75337 Paris Cedex 07

Contract title: Visualisation of drivers for spillover events of Ebola virus

Contract number: NP/EFSA/ALPHA/2014/15

INTRODUCTION

Ebola virus has recently had a certain public resonance and interest due to the Ebola epidemic in West Africa (2014), which is the one that counts the highest number of victims by now. Introduction of Ebola virus into the human population is thought to occur by contact with dead or living infected animals. Hunting and butchering of infected animals, i.e. contact with infected blood, body secretions, tissues, organs and other bodily fluids, is a potential source of infection in humans. The principal mode of transmission in human outbreaks is human-to-human transmission through direct contact with a symptomatic or dead from infected person or with surfaces and materials contaminated with body fluids from an infected person.

The present project is originated from a request by EFSA, which was asked by the European Commission to provide the technical assistance about the drivers for occasional spillover event of Ebola virus, i.e. the passage from animals to humans, which typically leads to an index case in humans. The present report is produced to inform the EFSA output addressing the above mentioned EC request (EFSA-Q-2014-00706). Under this mandate SciencesPo was requested by EFSA to perform an analysis to understand and communicate the drivers for spillover of Ebola virus from animals to humans. A set of visualisations (e.g. spidergrams, networks) based on information extracted from scientific literature is presented in this report in order to investigate links between drivers in the scenario. Such visualisations help in apprehending and analysing the whole system, which is complex in nature since it involves bio-ecological, technical, political and socio-economic aspects.

Understanding of environmental, epidemiological and social factors that lead to such an outbreak may help to prevent future outbreaks. Drivers have been defined as issues shaping the development of a society, organisation, industry, research area, technology, etc. They may act as modifiers of effect on the onset of emerging risks, namely they can either amplify or attenuate the magnitude or frequency of risks arising from various sources. The concept of drivers is used in different fields including economy, social sciences, technology, health and environmental sciences.

METHODOLOGY

The methodology used for the identification and visualisation of driver links and connections followed different steps. Firstly a set of possible drivers for spillover of infectious diseases were identified based on the literature and assigned to STEEP categories: Social, Technological, Environmental, Economic, and Political. The drivers were identified by screening a selected batch of scientific papers on factors leading to Ebola spillover events.

The selection of papers, drivers and endpoints/spillover events has been done by an EFSA team, according to the method agreed with the Sciences Po team.

The selection led to a final subset of 20 papers, out of those the main arguments were extracted and inserted in a data extraction table, where the driver linkages, the mutual implication of the links, the strength of the arguments, the related geographical entity and the citations connected to each argument were inserted. The data extraction table served for the analysis of the drivers' network. The outputs consisted in visualisations that showed the network of the drivers with their links, the strength of their links, their interaction with the two possible endpoints named alpha and beta spillover (spillover from reservoir species and from non-human susceptible species, respectively) and the relationship with geographical entities and the supporting citations to each driver link. Furthermore, based on the main arguments of the data extraction, a description of the drivers according to their assignment to each of the STEEP categories was presented.

Starting from the main data table, the data have been manipulated, re-organized and re-shaped using Excel functions, according to the type of visualisation to produce. These new

data tables have been used to produce each visualisation using Gephi, Adobe Illustrator and Raw and again Adobe Illustrator, for their finalisation.

Different types of analysis have been performed: quantitative data analysis, driver analysis (those two run crosswise almost all the visualizations), endpoint analysis, geographical analysis, citations analysis and corpus analysis.

In a total of 20 papers, 11 were original research papers and 9 review papers. In order to perform a sort of sensitivity analysis, comparative visualisations have been performed both with data from all papers and with data from the original research papers only.

The visualisations show the count of drivers, considering as well their roles as source of target, and the links between them, pointing out the connections and their strength and investigating the possible clusters highlighted by the network final configuration. An accurate analysis has been dedicated to the endpoints, to display the links that connect each driver to the endpoint. More complex networks show how geographic entities are connected with drivers and point out the relations between drivers, papers and citations. One last analysis performed concerns the content of each paper, considering the endpoint presence, the driver STEEP family and the drivers cluster."

RESULTS

The results are the visualisations of driver links, ranking and networks. These are displayed in the following pages together with an explanatory text. The format of the pages is wider than standard DIN A4 in order to better visualise the diagrams.

PAPERS AND DRIVERS

The selection of papers, drivers and endpoints (i.e. spillover events) was done by a team of scientists from EFSA. Data were extracted from the selected papers according to the methodology developed by SciencesPo.

LIST OF PAPERS

Original research papers

PAPER 2	**Nasi & others 2011**	Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins
PAPER 3	**Atherstone & others, 2014**	Ebola risk assessment in the pig value chain in Uganda
PAPER 7	**Kamins & others, 2011**	Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa.
PAPER 9	**Tejler 2012**	Outbreaks of African Swine fever in domestic pigs in Gulu district, Uganda
PAPER 10	**Chua & others, 2002**	Anthropogenic deforestation, El Nino and the emergence of Nipah virus in Malaysia
PAPER 13	**Cowlishaw & others, 2004**	The Bushmeat Commodity Chain: patterns of trade and sustainability in a mature urban market in West Africa
PAPER 15	**Willicox and Nambu, 2007**	Wildlife hunting practices and bushmeat dynamics of the Banyangi and Mbo people of Southwestern Cameroon
PAPER 16	**Saéz & others, 2015**	Investigating the zoonotic origin of the West African Ebola epidemic
PAPER 17	**Mayaux & others, 2013**	State and evolution of the African rainforests between 1990 and 2010
PAPER 19	**Amman & others, 2014**	Marburgvirus resurgence in Kitaka mine bat population after extermination attempts, Uganda
PAPER 20	**Price, 2015**	Does Productivity in the Formal Food Sector Drive Human Ebola Virus Infections in Sub-Saharan Africa?

Review research papers

PAPER 1	**Fa and Brown, 2009**	Impacts of hunting on mammals in African tropical moist forests: a review and synthesis
PAPER 4	**Milner-Gulland & others 2003**	Wild meat: the bigger picture
PAPER 5	**Wolfe & others 2009**	Bushmeat Hunting, Deforestation, and Prediction of Zoonotic Disease Emergence
PAPER 6	**Bausch & others, 2014**	Outbreak of ebola virus disease in Guinea: where ecology meets economy
PAPER 8	**Wallace & others, 2014**	Did Ebola emerge in West Africa by a policy-driven phase change in agroecology?
PAPER 11	**Luby & others, 2009**	Transmission of human infection with Nipah virus
PAPER 12	**Alexander & others, 2014**	What factors might have led to the emergence of Ebola in West Africa?
PAPER 14	**Carrere, 2010**	Oil palm in Africa: Past, present and future scenarios
PAPER 18	**Benatar, 2015**	Explaining and responding to the Ebola epidemic

LIST OF DRIVERS & RELATED FAMILIES

1. **Access to forest** Social, Technological, Environmental
2. **Agro-economic changes** Economic
3. **Butchering and preparing wildlife** Social, Economic
4. **Changes in animal husbandry methods** Economic, Technological
5. **Changes in demand for bushmeat** Economic, Social
6. **Changes in host-pathogen interaction** Environmental
7. **Changes in rate of spread of diseases** Environmental
8. **Climate change** Environmental
9. **Cultural practices** Social
10. **Deforestation/ forest fragmentation** Environmental
11. **Demographic changes of wildlife** Environmental
12. **Dietary and occupation changes** Social
13. **Disease control strategies** Technological
14. **EBOV spread in wildlife** Environmental
15. **Ecosystem changes** Environmental
16. **Food prices** Economic
17. **Food security** Social, Economic
18. **Forced migration** Political, Social
19. **Gender issues** Social
20. **Global market pressures** Economic
21. **Hunting** Social, Economic
22. **Hunting technology** Technological
23. **Immigration and urbanisation** Social
24. **Increasing population** Social
25. **Industrial plantations** Economic, Technological
26. **International/national/regional interactions** Political
27. **Lack of reliability of agriculture systems** Economic, Technological
28. **Livelihoods resilience** Social, Economic
29. **More intensive farming systems** Economic, Technological
30. **Poverty** Economic
31. **Public policy** Political
32. **Quality of health care** Social, Economic
33. **Quality of veterinary care** Social, Economic
34. **Roads and transport infrastructure** Technological
35. **Scale of trade** Economic
36. **Seasonal workers/ movement** Social, Economic
37. **Seasonality** Environmental
38. **Social cohesion** Social
39. **Socioeconomic impact of conflict** Social, Economic, Political
40. **Uncontrolled/unregulated trade** Economic, Social

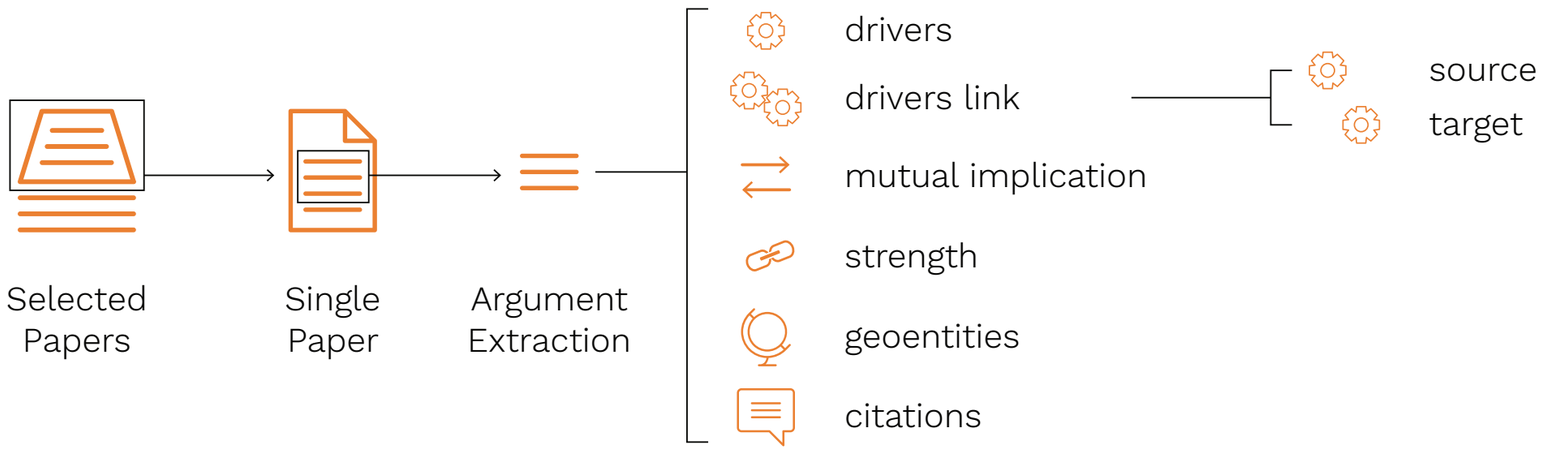
TYPE OF SPILLOVER

- α **Alpha** Spillover from reservoir species to humans
- β **Beta** Spillover from non-human susceptible host species to humans

SELECTION OF PAPERS AND DRIVERS

The project is based on a bibliographic corpus containing review and opinion papers as well as original research papers.
An initial list of drivers was grouped according to five STEEP families: Social, Technological, Environmental, Economic, and Political. A refinement of the drivers list was performed as the relevant literature was screened.
The data extraction table contains the original text lifted from the papers, a related translation into argument(s), the drivers involved, the mutual implication of the links between drivers, the strength of the argument, the related geographical entity, and the citations connected to the argument.
The strength of the argument was rated on a scale from 1 to 3: 1 (plausible argumentation), 2 (internal support in the text) or 3 (external support by references).

DATA EXTRACTION



DATA EXTRACTON TABLE

ID SHEET	Original (O) or Review (R)	ID link	LINK. For multiple link then use this syntax A> B>C (A implies B which implies C) or A> B,C (A implies B and C)	source	target	MUTUAL IMPLICATION (y/n)	STRENGTH (1-3) (1=plausible; 2=internal support; 3= external support)	GEO ENTITY	CITATION
1	R	1	Lack of reliability of agriculture systems > hunting	Lack of reliability of agriculture systems	Hunting	n	2	Tropical forest	non
1	R	2	Lack of reliability of agriculture systems > hunting	Lack of reliability of agriculture systems	Hunting	n	2	Tropical forest	non
1	R	3	Increasing population > changes in demand for bushmeat > Hunting	Increasing population	Changes in demand for bushmeat	n	3	West Africa	Fa & Peres 2001
1	R	3	Increasing population > changes in demand for bushmeat > Hunting	Changes in demand for bushmeat	Hunting	n	3		
1	R	4	Increasing population, Roads and transport infrastructure, Hunting technology > Hunting, Access to forest	Increasing population	Hunting	n	2	Africa	non

DATA VISUALISATION AND ANALYSIS (index)

Data was reorganised in Excel to allow for further analysis and data visualisation. Visualisations were produced using Gephi, Adobe Illustrator and Raw. Adobe Illustrator was also used to finalise the proposed visualisations.
The preliminary analysis of the drivers and the corresponding visualisations were submitted to subject matter experts and discussed. A refinement of the analysis was subsequently performed by the EFSA/SciencesPo team.
The visualizations are ordered according to the steps of analysis performed. The bibliographic corpus contains 11 original research papers and 9 review papers. In the report the visalizations based on all papers are presented first, followed by the analysis done usign only original research papers.

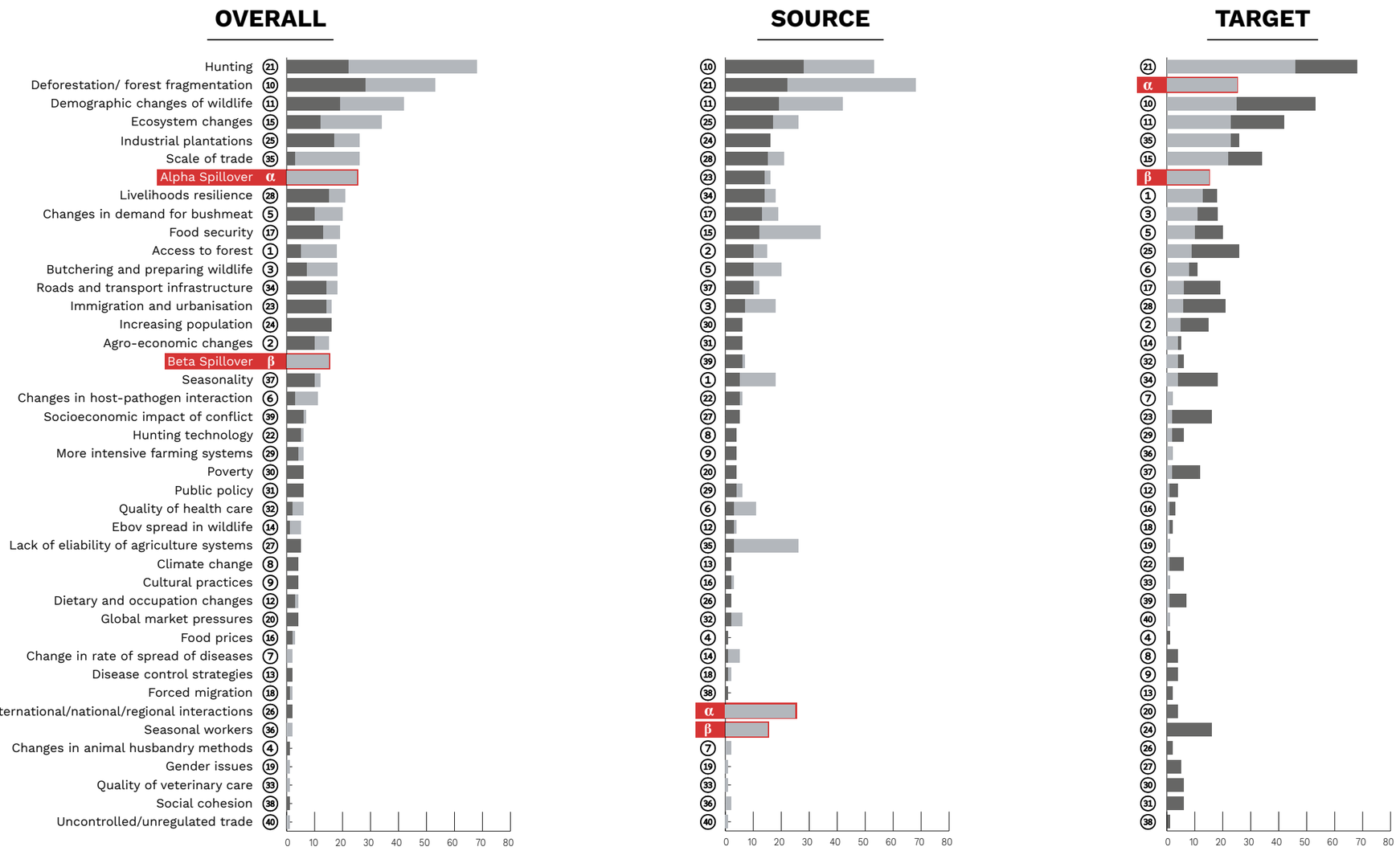
VISUALISATIONS INDEX

01. FREQUENCY OF DRIVERS all papers

The figures show how often an individual driver has been identified within the bibliographic corpus. Spillover events (alpha -from reservoir species to humans, and beta -from non-human susceptible species to humans) are also included.
Drivers may act as a source (i.e. linking to another driver or to an endpoint) or as a target. Dark gray bars represent the role of a driver as a source; light gray bars represent the role of a driver as a target.
Review and opinion papers as well as original research papers of the bibliographic corpus have been considered.

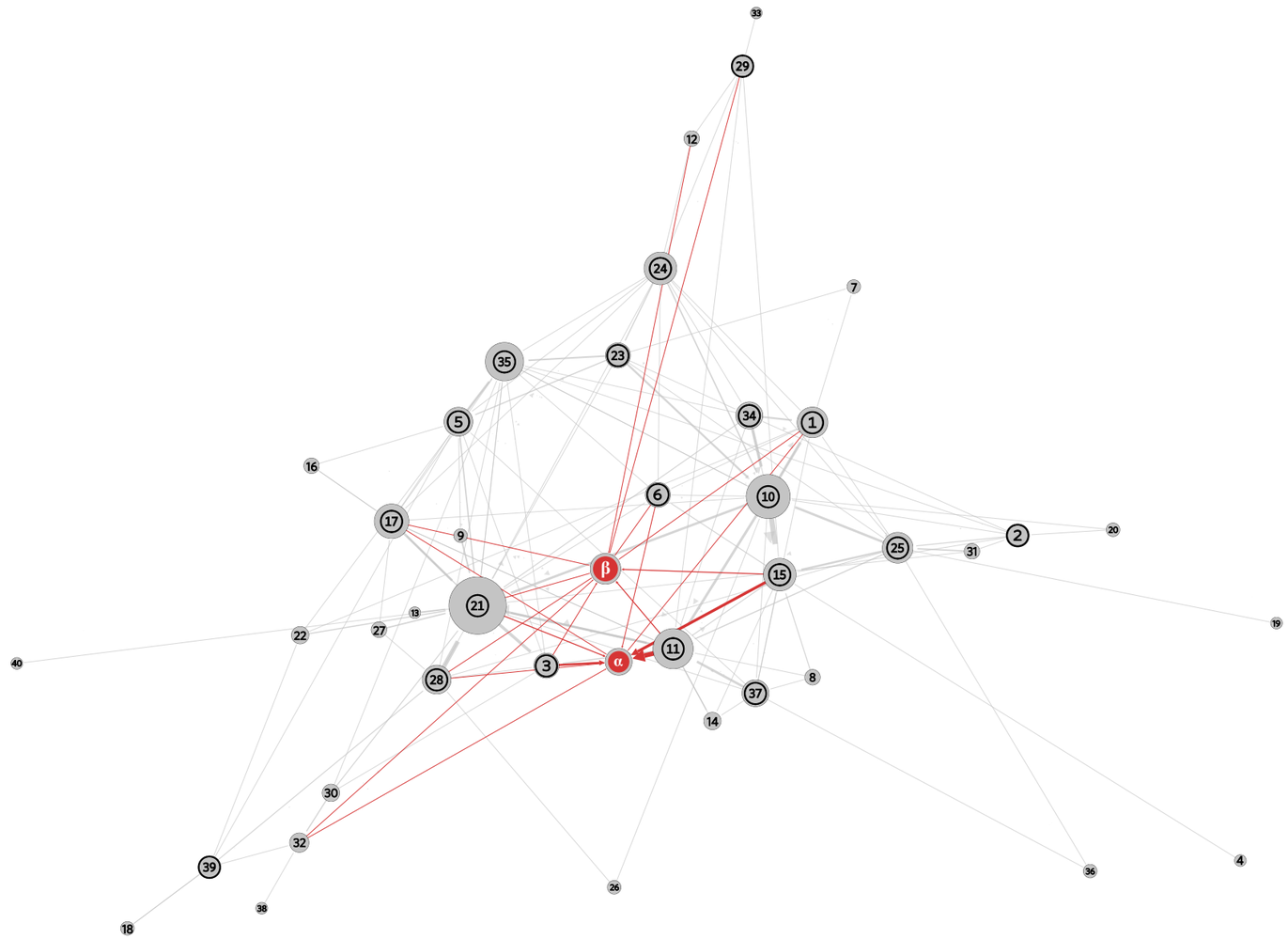
LEGEND

- Source role
- Target role
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Drivers count



02. DRIVER NETWORK all papers

The figure shows how each driver is linked to other drivers and/or spillover endpoints (shown in red). The network was produced using the Force Atlas 2 algorithm. Each driver is represented in the diagram as a node. The size of the nodes indicates the node degree, which is determined by how often a driver acts as a source or a target. Both review and original research papers in the bibliographic corpus have been considered here.



LEGEND

- Driver
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Node Size according to Degree
- link between drivers
- link to endpoint
- Link Size according to the strength assigned to a link between drivers

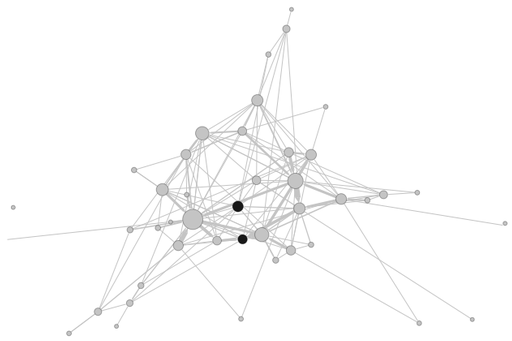
DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
18. Forced migration
19. Gender issues
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

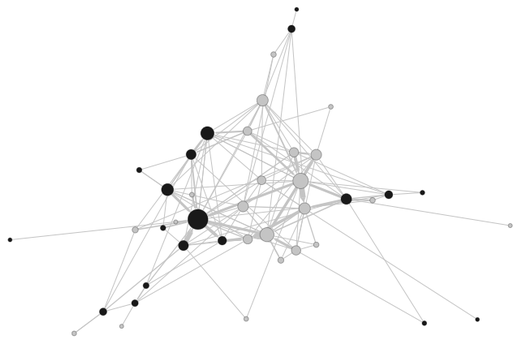
03. DRIVER DISTRIBUTION BY STEEP FAMILY

Each driver has been allocated to a STEEP family. Some drivers belong to more than one family. The visualisations show the pattern of driver distribution within the network as well as the positions of the alpha and beta endpoints.

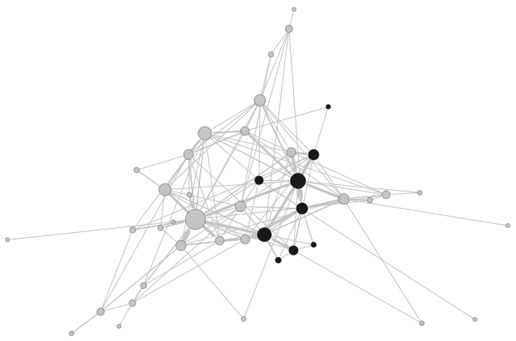
ENDPOINT



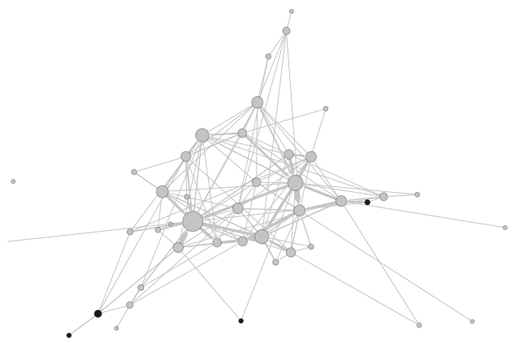
ECONOMIC



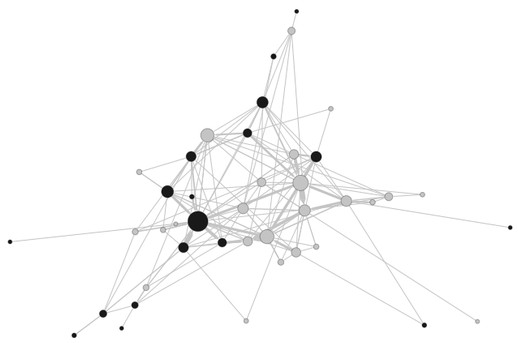
ENVIRONMENTAL



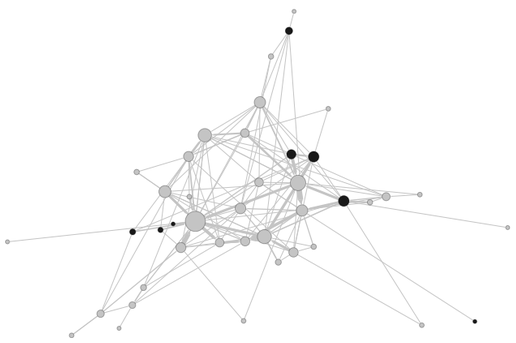
POLITICAL



SOCIAL



TECHNOLOGICAL



LEGEND

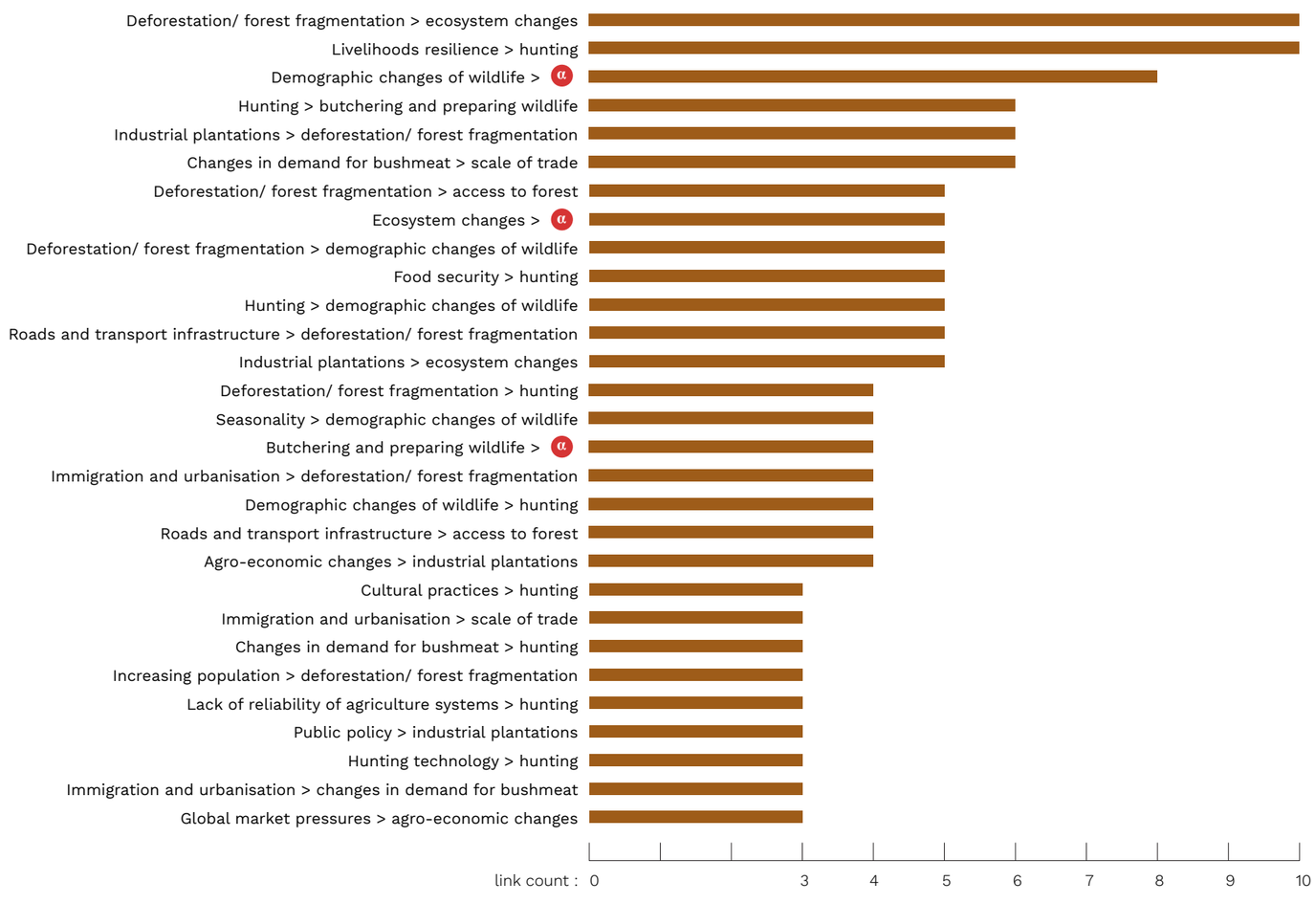
- Driver - Not belonging to steep family
- Driver - Belonging to steep family
- Node size according to degree
- Link between drivers
- Link size according to the strength assigned to each link

04. FREQUENCY OF LINKS

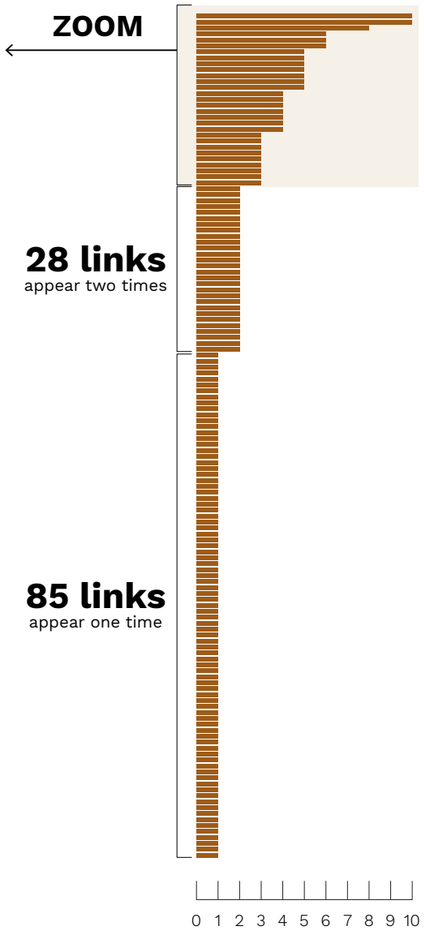
***strength has not been considered**

The figures show how often a specific link between two drivers, or between a link and an endpoint, appears. The main figure shows the 29 links that appear at least three times. In total, 142 unique links were identified during the project.

LINKS THAT APPEAR AT LEAST THREE TIME



OVERALL LINK COUNT



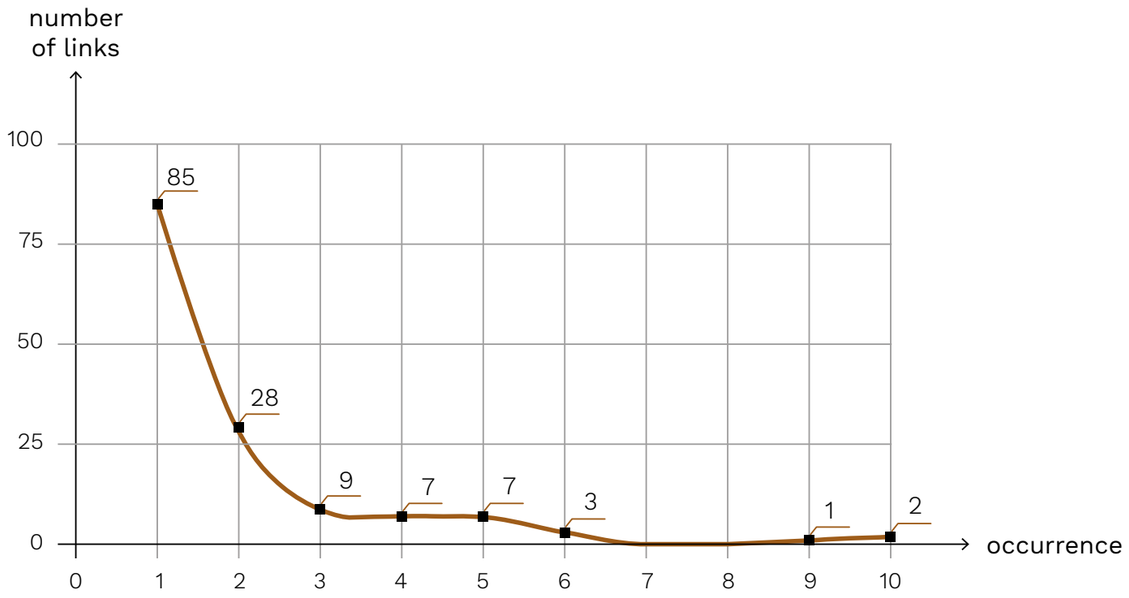
LEGEND

- Link
- α Spillover (reservoir species to humans)
- Endpoint
- > Link direction
- Links count

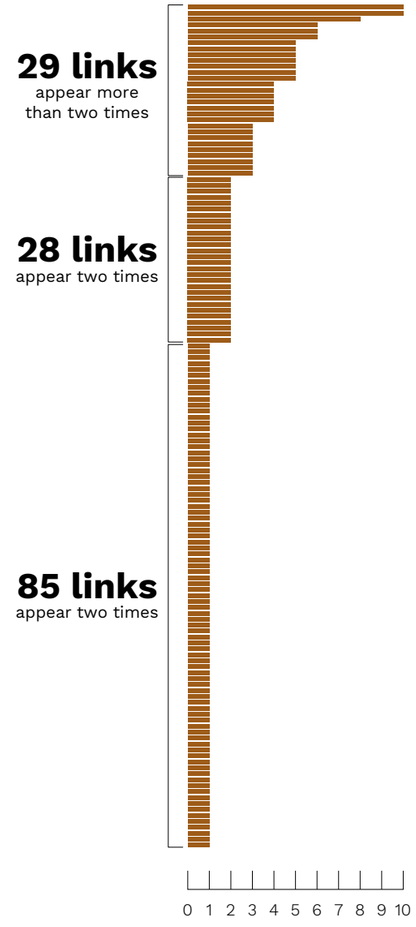
05. FREQUENCY OF LINKS
all papers

The figure shows the distribution of links as a function of their occurrence in the bibliographic corpus. The occurrence of a link is the number of times a link was identified between two drivers.
For example, there are 85 links that appear only once and only 2 links that appear 10 times.

NUMBER OF LINKS AND THEIR OCCURRENCE



OVERALL LINKS COUNT

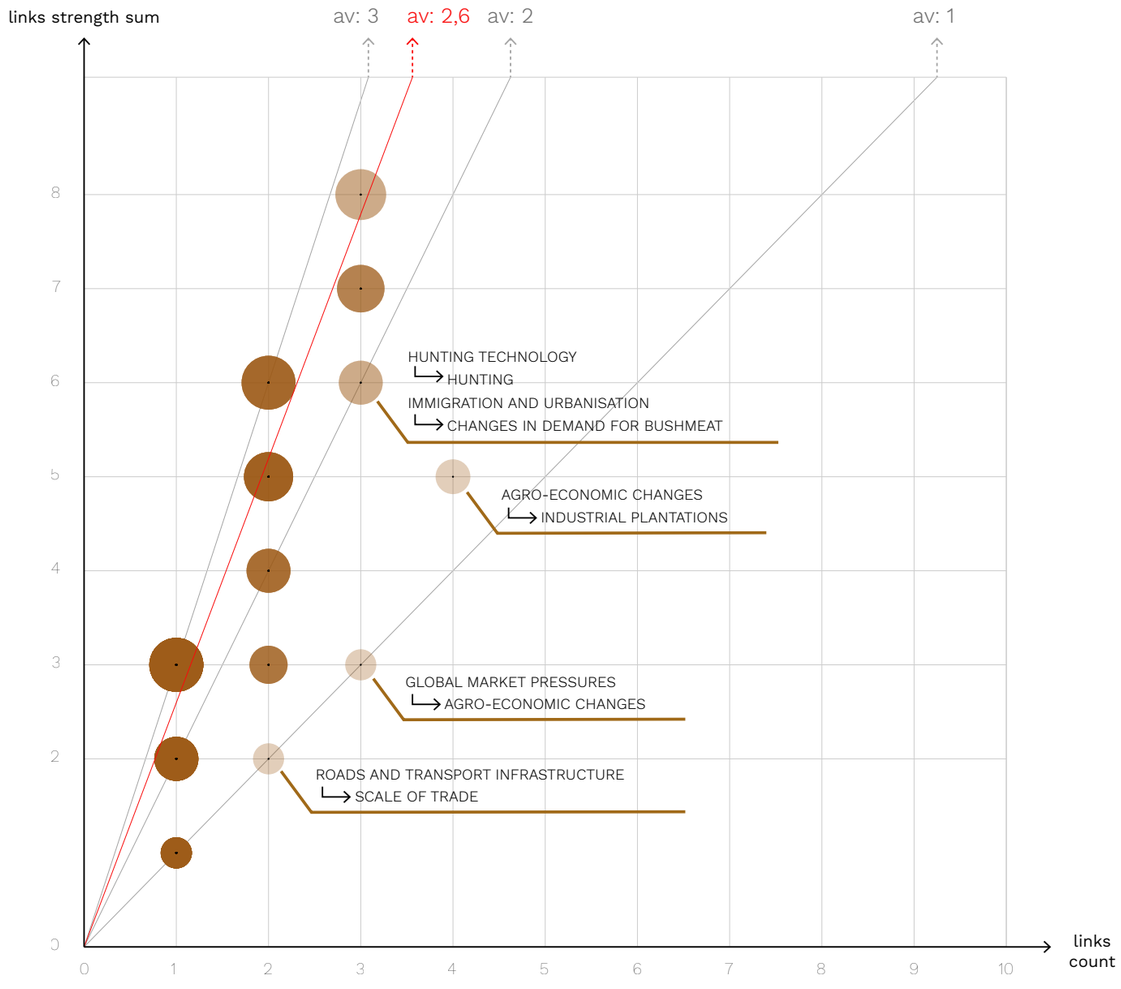


LEGEND

- Link
- Link count exact frequency
- Link direction
- Links count

06. LINKS COUNT VS LINKS STRENGTH zoom one of three

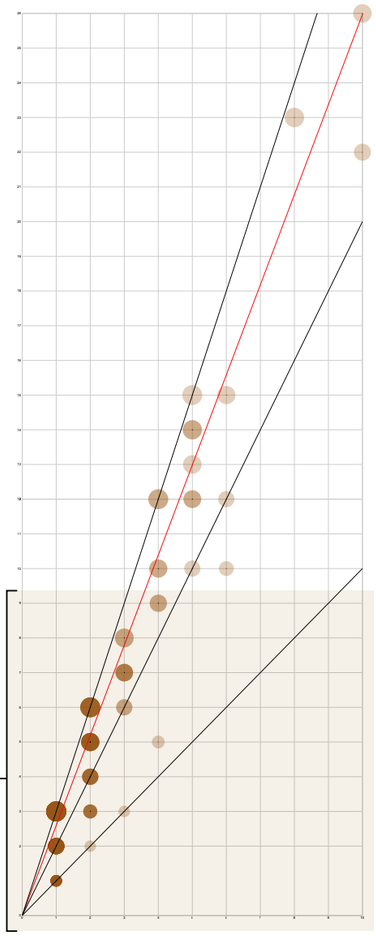
The scatterplot shows the sum of strength scores of the links against how often they occur.
A strength score has been assigned to each link. The strength of an argument was rated on a scale from 1 to 3: 1 (plausible argumentation), 2 (internal support in the text) or 3 (external support by references).
The slope of the red line is determined by the link having the highest scores for strength and counts. This line divides the graph in two areas: the area to the right of the red line is influenced by the counts; the area to the left of the red line is more influenced by the strength.
Figures 6-8 show zoom views of this scatter plot.



LEGEND

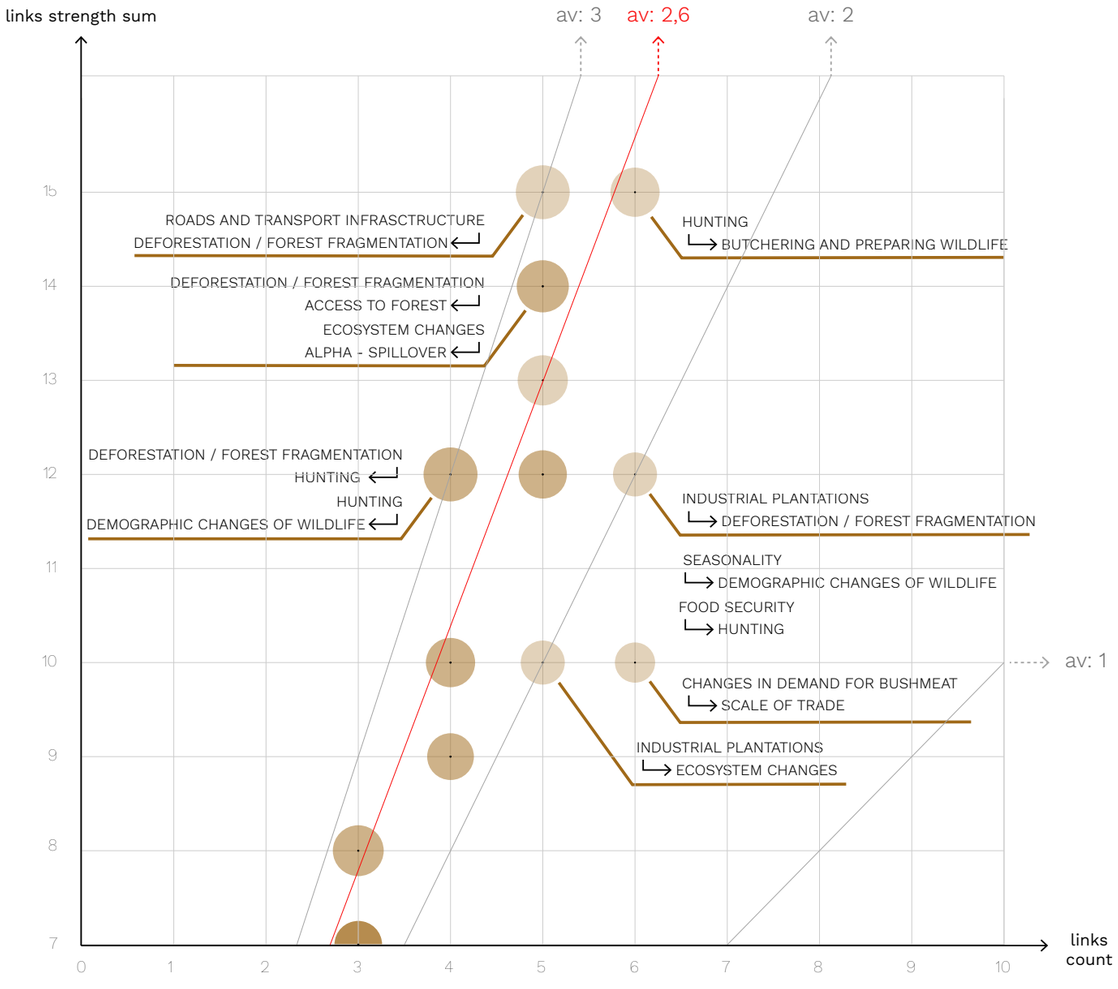
- Average between link count and link strength sum
- Number of links that have these specific values
- av: Average
- Link direction

OVERALL VIEW



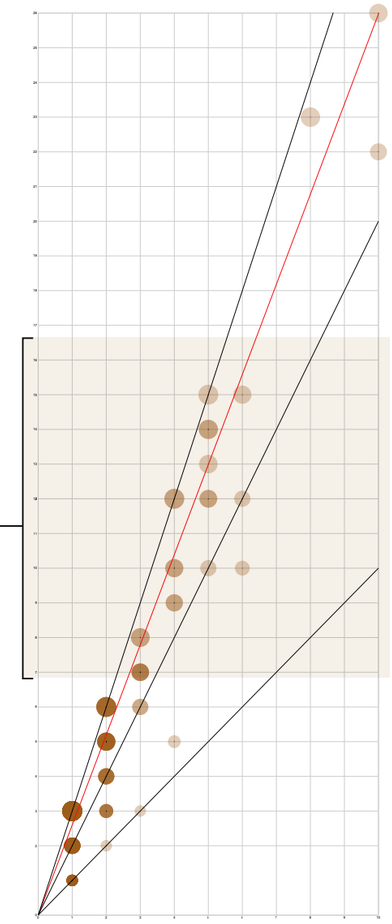
ZOOM

07. LINKS COUNT VS LINKS STRENGTH zoom two of three



OVERALL VIEW

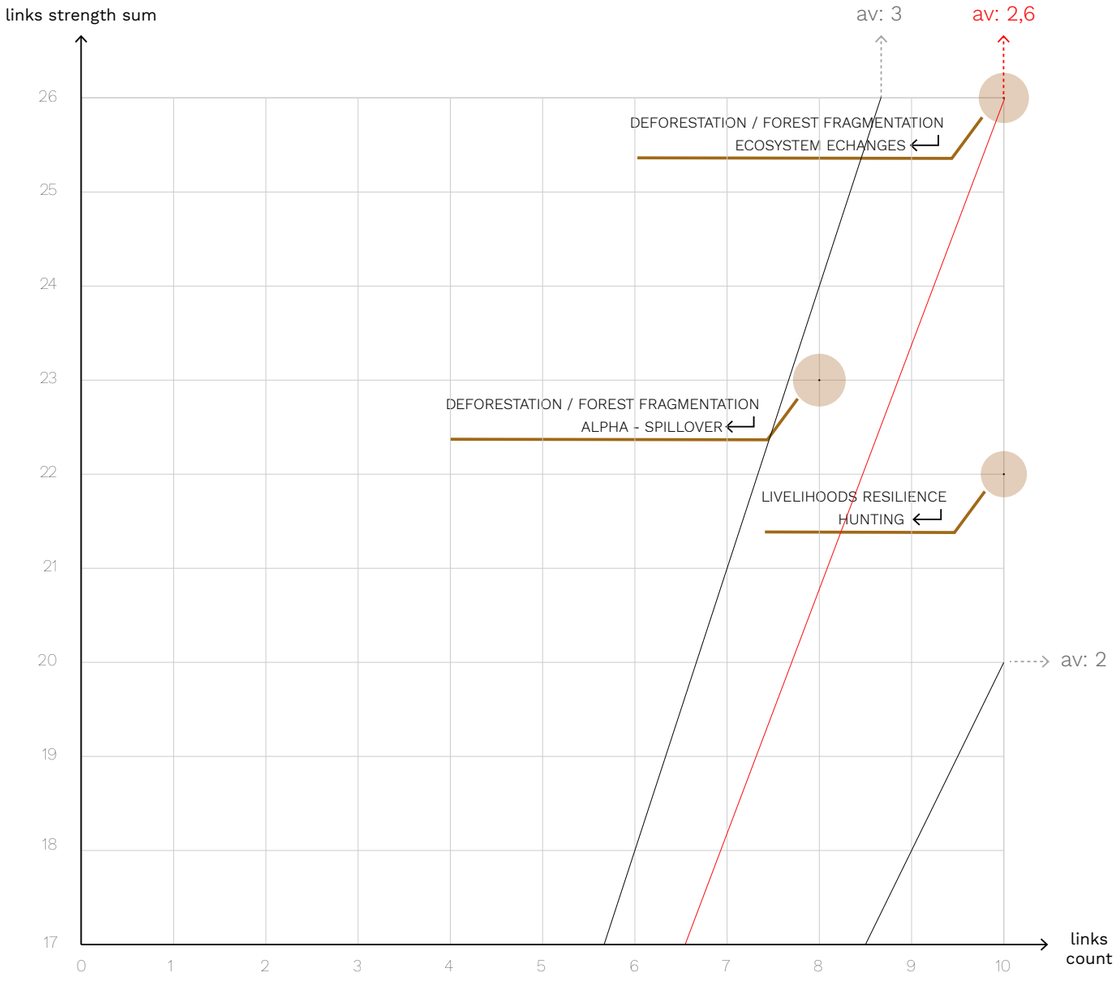
ZOOM

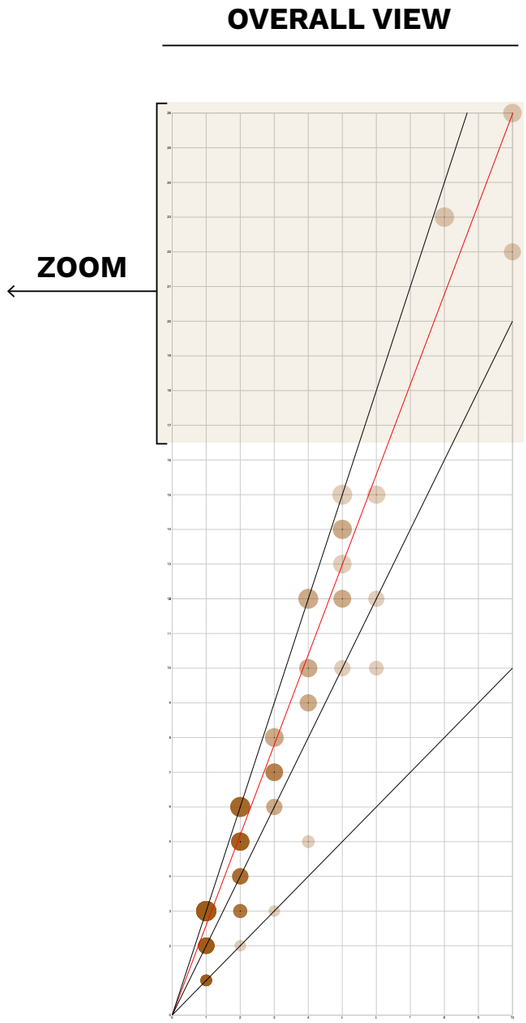


LEGEND

- Average between link count and link strength sum
- Number of links that have these specific values
- av: Average
- Link direction

08. LINKS COUNT VS LINKS STRENGTH
zoom three of three



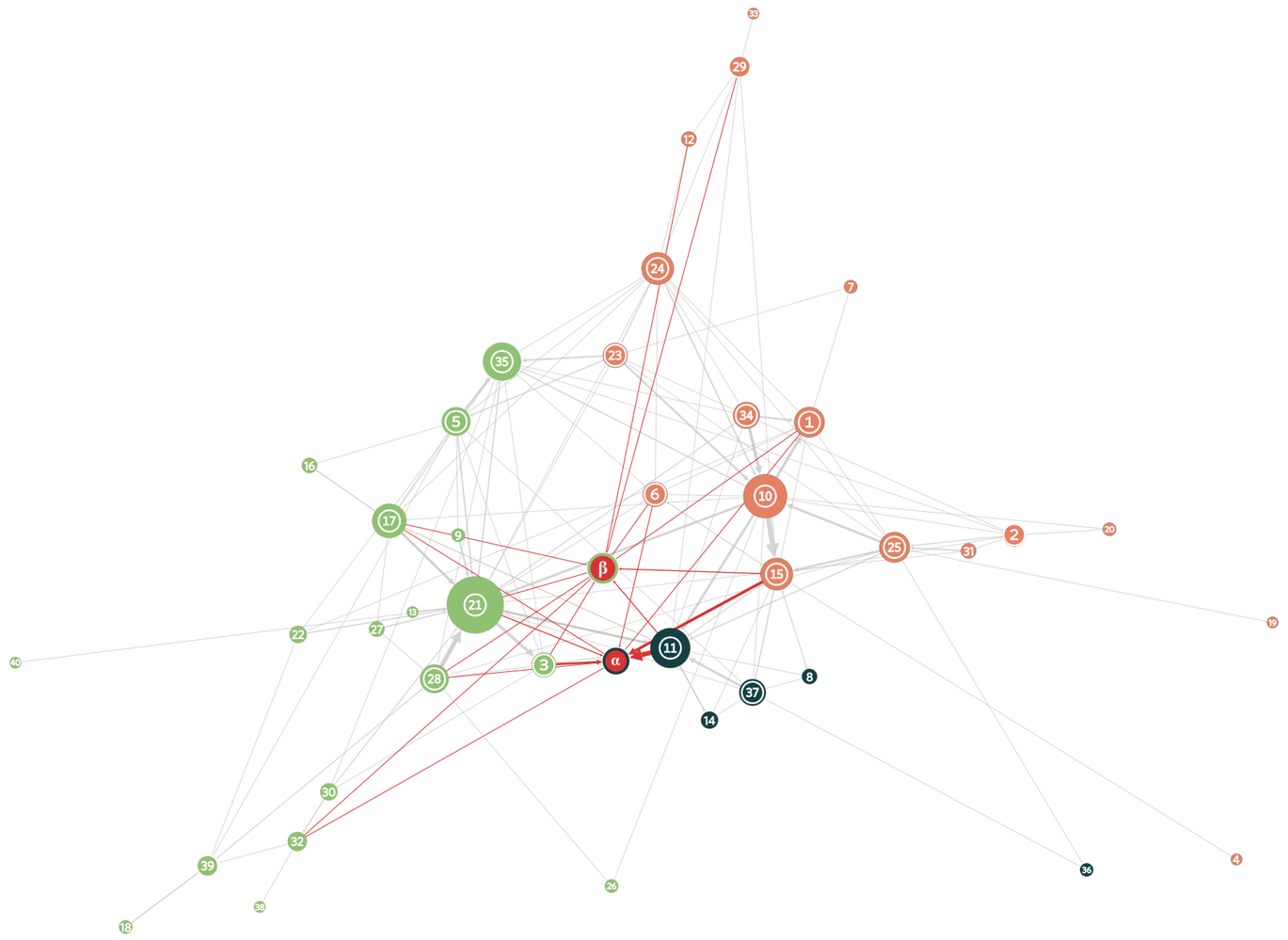


LEGEND

- Average between link count and link strength sum
- Number of links that have these specific values
- av: Average
- Link direction

09. DRIVER NETWORK all papers

Three clusters were identified using the Force Atlas 2 algorithm; Cluster 1 (green), Cluster 2 (black) and Cluster 3 (orange). Alpha and beta endpoints are show as red nodes. Red links are links which directly connect to an endpoint.
Both review/opinion papers and original research papers of the bibliographic corpus have been considered.



LEGEND

- Node size according to degree
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers
- Link to endpoint
- Link size according to the strength assigned to each link

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
18. Forced migration
19. Gender issues
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

10. FREQUENCY OF DRIVERS displaying clusters

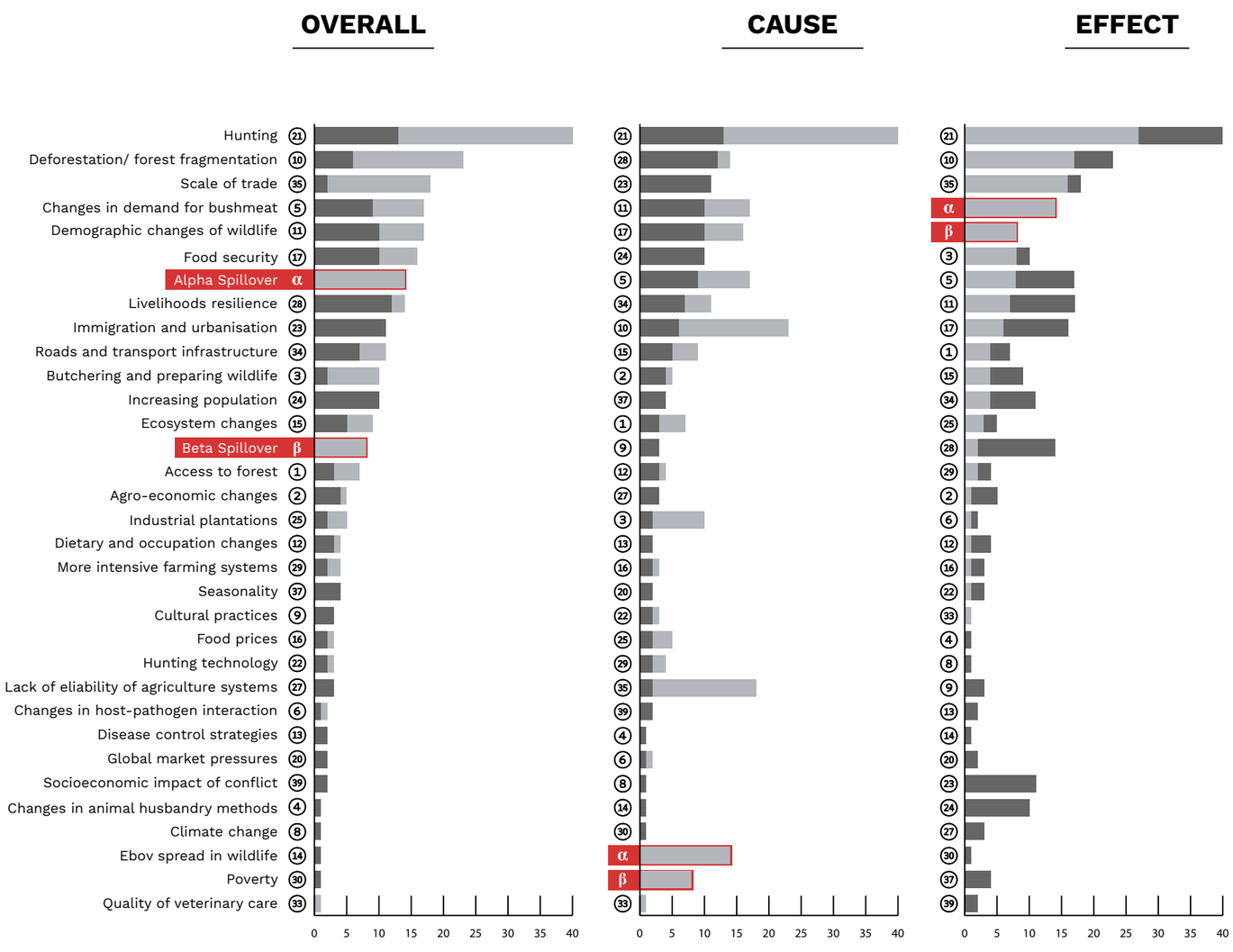
The diagram shows a bar plot representing the number of times a driver has been mentioned either as a source or as a target in a link between drivers. Only original research papers in the bibliographic corpus have been considered.

LEGEND

- Source role
- Target role
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Drivers count

11. FREQUENCY OF DRIVERS original papers

The figures show how often an individual driver has been identified within the bibliographic corpus, considering only original research papers. Spillover events (alpha -from reservoir species to humans, and beta -from non human susceptible species to humans) are also included. Drivers may act as a source (i.e. linking to another driver or to an endpoint) or as a target. Dark gray bars represent the role of a driver as a source; light gray bars represent the role of a driver as a target.



LIST OF DRIVERS THAT DOES NOT APPEAR IN THE ORIGINAL PAPERS

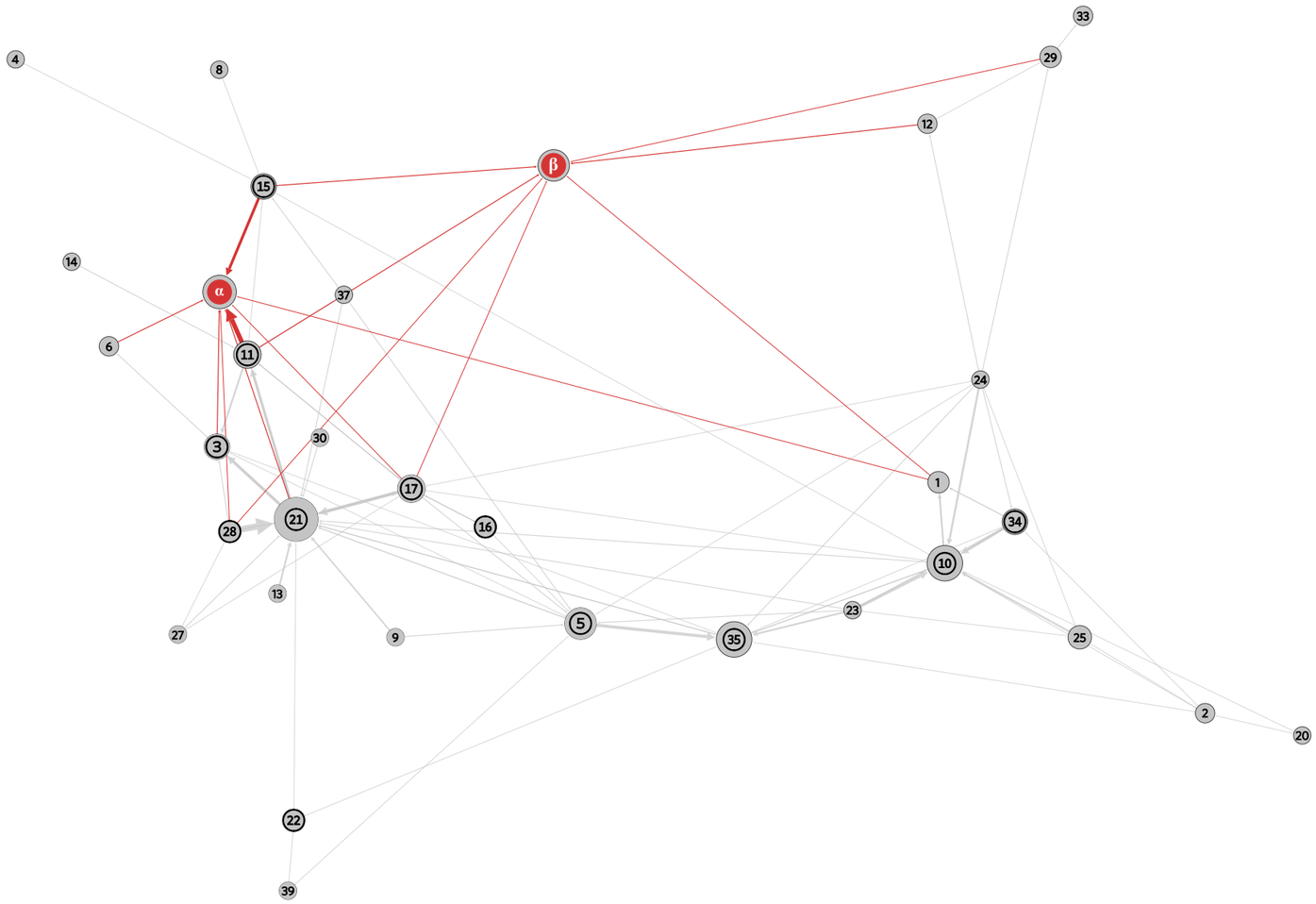
- 7 Changes in rate of spread of diseases
- 18 Forced migration
- 19 Gender issues
- 26 International/national/regional interactions
- 31 Public policy
- 32 Quality of health care
- 36 Seasonal workers/ movement
- 38 Social cohesion
- 40 Uncontrolled/unregulated trade

LEGEND

- Cause role
- Effect role
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Drivers count

12. DRIVER NETWORK original papers

The figure shows how each driver is linked to other drivers and/or spillover endpoints (shown in red). The network was produced using the Force Atlas 2 algorithm. Each driver is represented in the diagram as a node. The size of the node indicates the node degree, which is determined by how often a driver acts as a source or a target. Only original research papers in the bibliographic corpus have been considered.



LEGEND

- Driver
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Node size according to Degree
- Link between drivers
- Link to endpoint
- Link size according to the strength assigned to a link between drivers

DRIVERS (ORIGINAL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

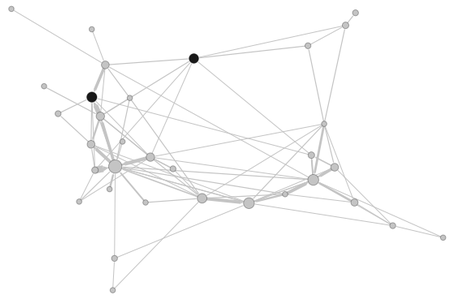
Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

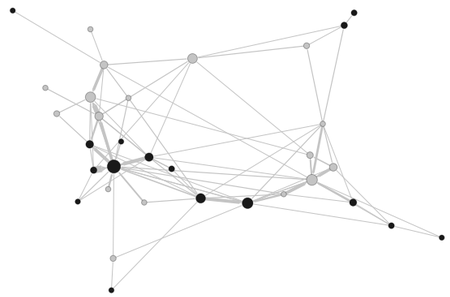
13. DRIVERS DISTRIBUTION BY STEEP FAMILY

The figure shows the driver network displaying the assignment of drivers to STEEP families, considering only original research papers in the bibliographic corpus.

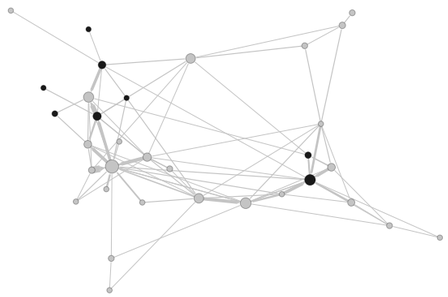
ENDPOINT



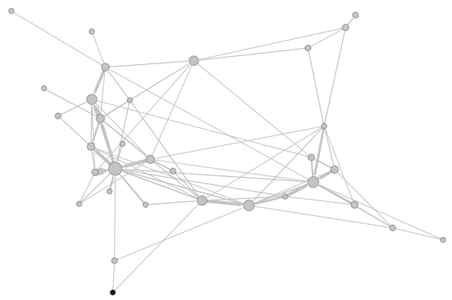
ECONOMIC



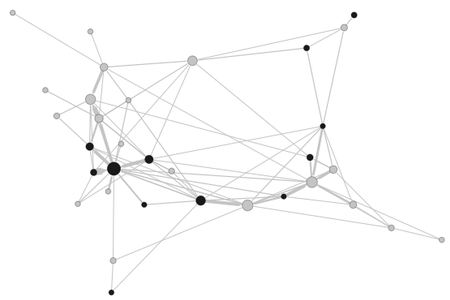
ENVIRONMENTAL



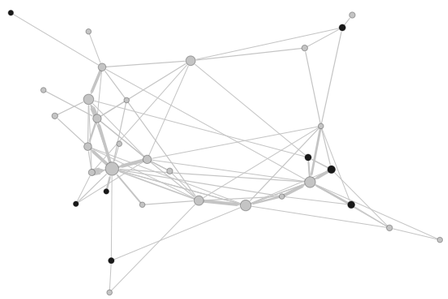
POLITICAL



SOCIAL



TECHNOLOGICAL

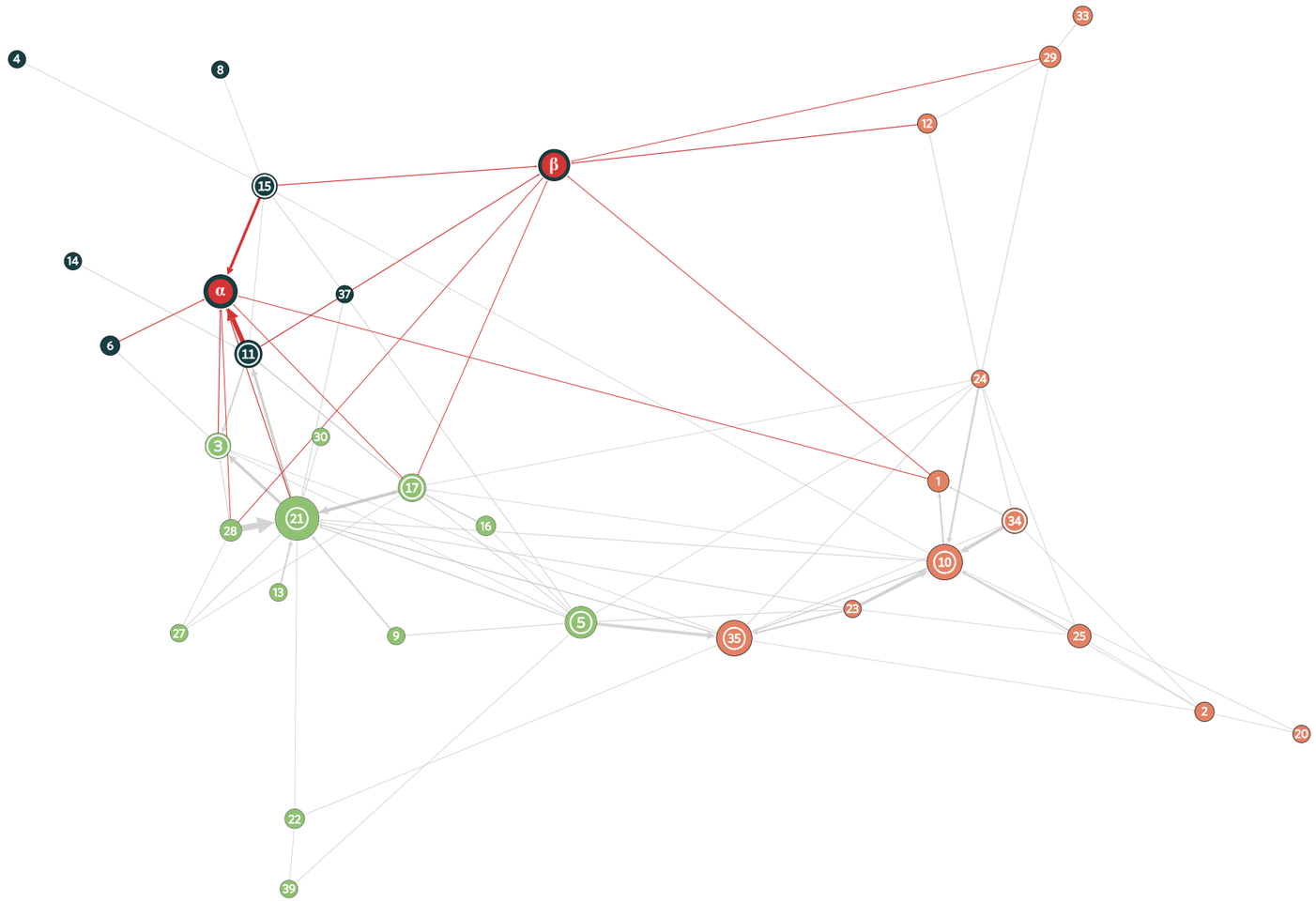


LEGEND

- Driver - Not belonging to steep family
- Driver - Belonging to steep family
- Link between drivers
- Node size according to Degree
- Link size according to the strength assigned to each link

14. DRIVER NETWORK original papers

Three clusters were identified using the Force Atlas 2 algorithm; Cluster 1 (green), Cluster 2 (black) and Cluster 3 (orange). Alpha and beta endpoints are show as red nodes. Red links are links which directly connect to an endpoint.Only original research papers in the bibliographic corpus have been considered.



LEGEND

- Node size according to degree
- Cluster 1
- Cluster 2
- Cluster 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers
- Link to endpoint
- Link size according to the strength assigned to each link

DRIVERS (ORIGINAL PAPERS)

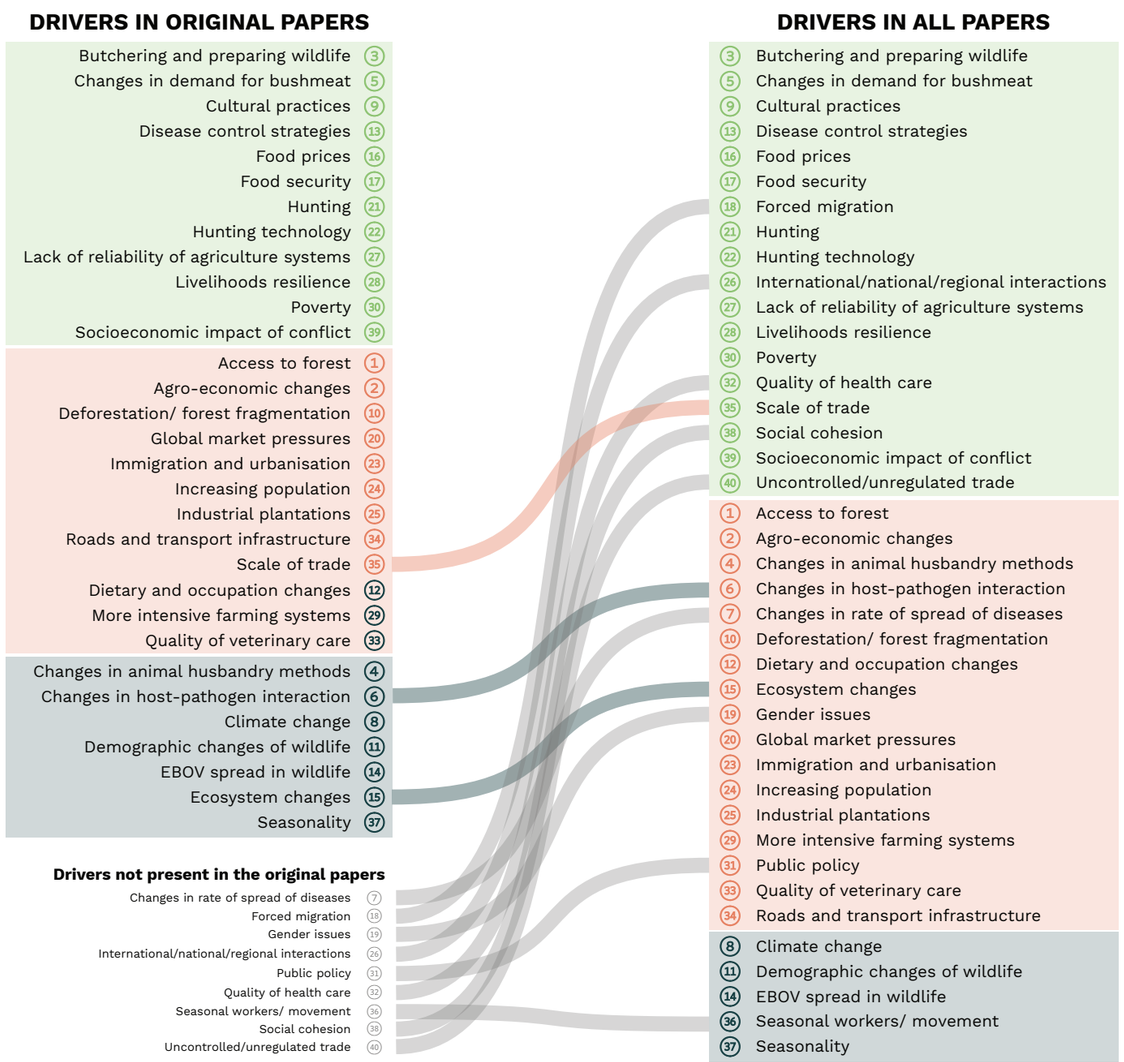
1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

15. DATA SOURCE INFLUENCE ON DRIVER CLUSTERING

For comparison purposes, the clustering was performed using Force Atlas 2 algorithm on drivers identified in the original research papers only, and on the complete bibliographic corpus. Main differences come from drivers that are used in opinion and review papers but that were not identified in the original research papers.



LEGEND

- Cluster 1
- Custer 2
- Custer 3

PAPERS

Original papers

PAPER 2	**Nasi & others 2011**	Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins
PAPER 3	**Atherstone & others, 2014**	Ebola risk assessment in the pig value chain in Uganda
PAPER 7	**Kamins & others, 2011**	Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa.
PAPER 9	**Tejler 2012**	Outbreaks of African Swine fever in domestic pigs in Gulu district, Uganda
PAPER 10	**Chua & others, 2002**	Anthropogenic deforestation, El Nino and the emergence of Nipah virus in Malaysia
PAPER 13	**Cowlishaw & others, 2004**	The Bushmeat Commodity Chain: patterns of trade and sustainability in a mature urban market in West Africa
PAPER 15	**Willicox and Nambu, 2007**	Wildlife hunting practices and bushmeat dynamics of the Banyangi and Mbo people of Southwestern Cameroon
PAPER 16	**Saéz & others, 2015**	Investigating the zoonotic origin of the West African Ebola epidemic
PAPER 17	**Mayaux & others, 2013**	State and evolution of the African rainforests between 1990 and 2010
PAPER 19	**Amman & others, 2014**	Marburgvirus resurgence in Kitaka mine bat population after extermination attempts, Uganda
PAPER 20	**Price, 2015**	Does Productivity in the Formal Food Sector Drive Human Ebola Virus Infections in Sub-Saharan Africa?

Reviewed papers

PAPER 1	**Fa and Brown, 2009**	Impacts of hunting on mammals in African tropical moist forests: a review and synthesis
PAPER 4	**Milner-Gulland & others 2003**	Wild meat: the bigger picture
PAPER 5	**Wolfe & others 2009**	Bushmeat Hunting, Deforestation, and Prediction of Zoonotic Disease Emergence
PAPER 6	**Bausch & others, 2014**	Outbreak of ebola virus disease in Guinea: where ecology meets economy
PAPER 8	**Wallace & others, 2014**	Did Ebola emerge in West Africa by a policy-driven phase change in agroecology?
PAPER 11	**Luby & others, 2009**	Transmission of human infection with Nipah virus
PAPER 12	**Alexander & others, 2014**	What factors might have led to the emergence of Ebola in West Africa?
PAPER 14	**Carrere, 2010**	Oil palm in Africa: Past, present and future scenarios
PAPER 18	**Benatar, 2015**	Explaining and responding to the Ebola epidemic

16. FREQUENCY OF DRIVERS displaying clusters

The diagram shows a bar plot representing the number of times a driver has been mentioned either as a source or as a target in a link between drivers. Only original research papers in the bibliographic corpus have been considered.

LEGEND

- Source role
- Target role
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Drivers count

DRIVERS (original papers)

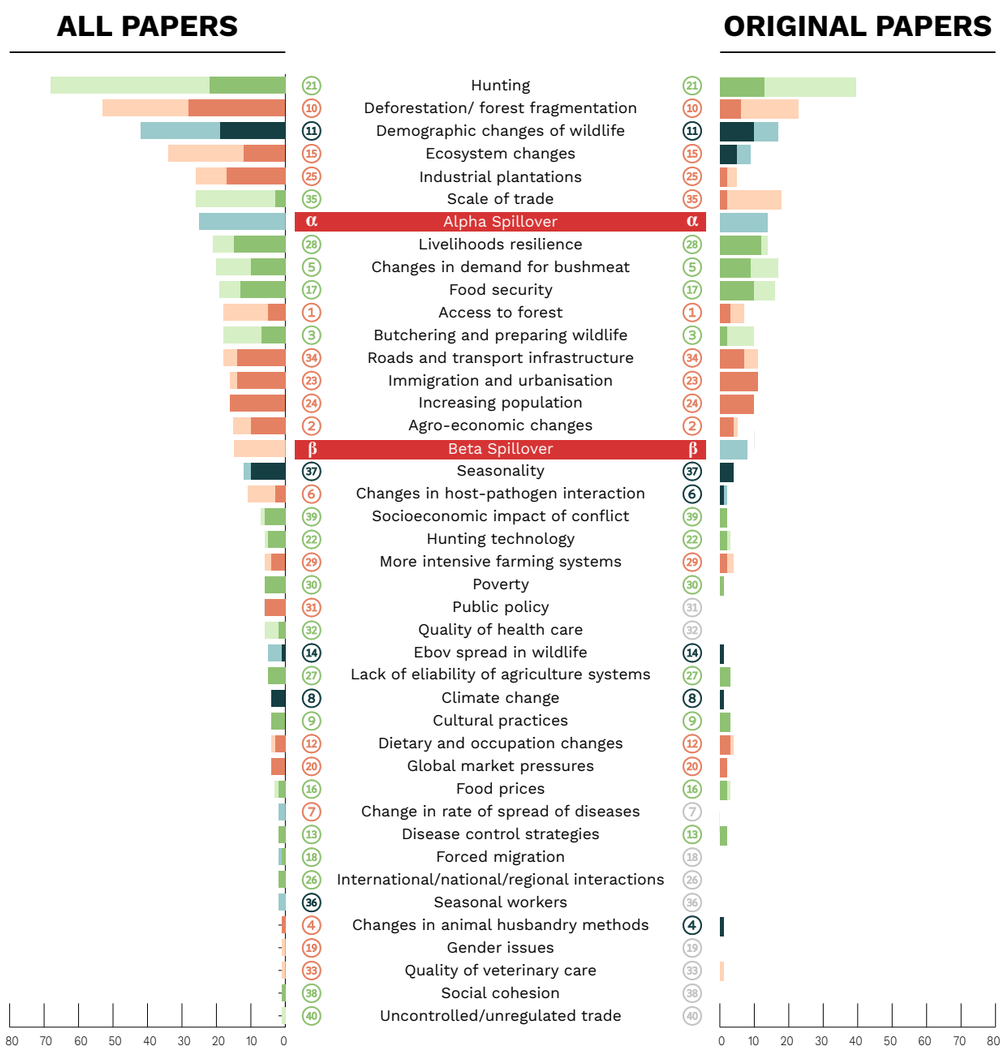
1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

17. DATA SOURCE INFLUENCE ON DRIVER COUNTS

For comparison purposes, the ranking of drivers based on counts in the complete bibliographic corpus is displayed against unranked driver counts in original research papers. Main differences come from drivers that are used in opinion and review papers but that were not identified in the original research papers.

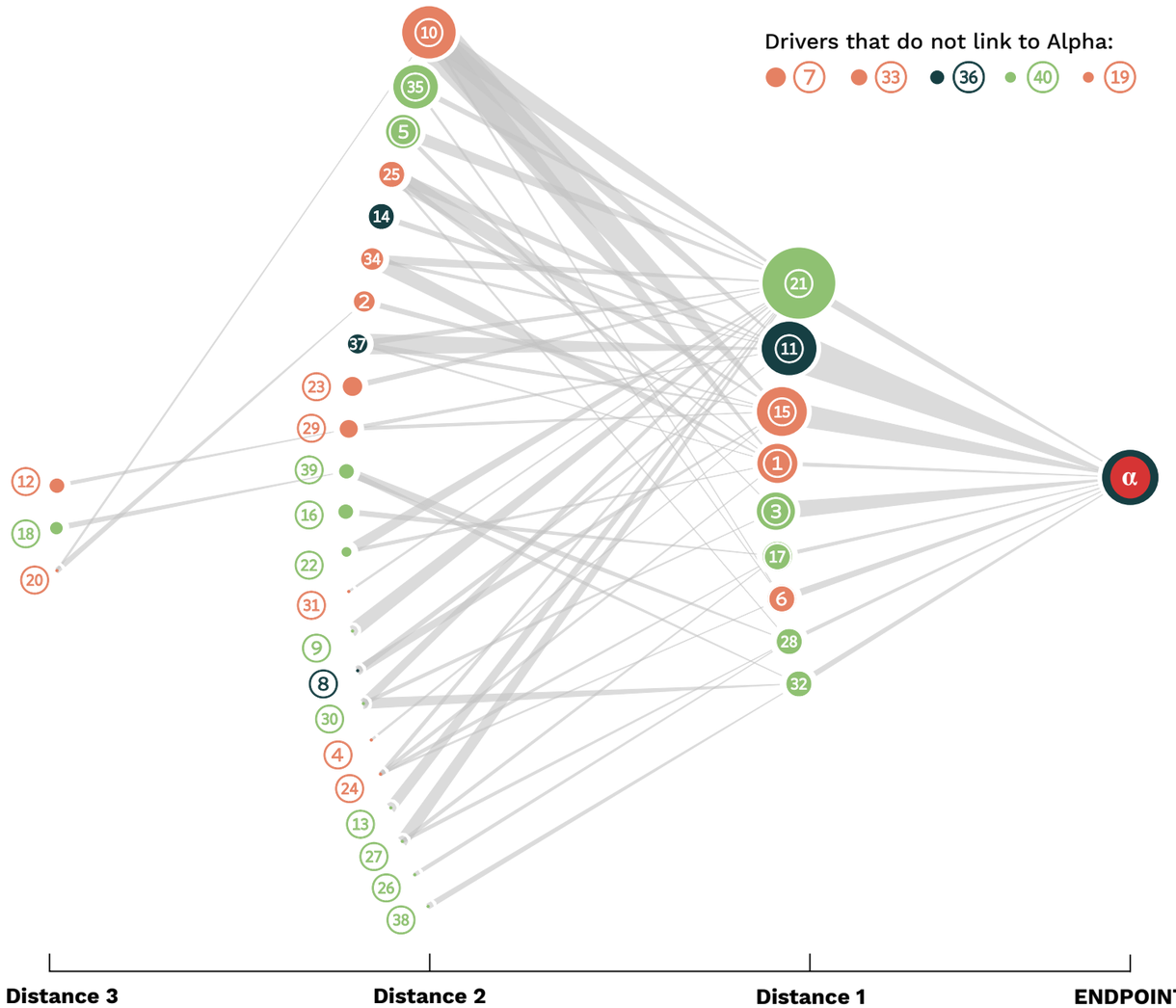


LEGEND

- Source role
- Target role
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Drivers counts

18. DRIVER PROXIMITY TO THE ALPHA ENDPOINT

The graph displays the drivers in relation to their proximity to the alpha endpoint (Distance 1, 2, and 3).
The colour of each node is related to the cluster it belongs to. The node size is related to the driver count. Links thickness is related to the number of links between drivers and between drivers and the alpha spillover. Both review and opinion papers as well as original research papers in the bibliographic corpus have been considered.



LEGEND

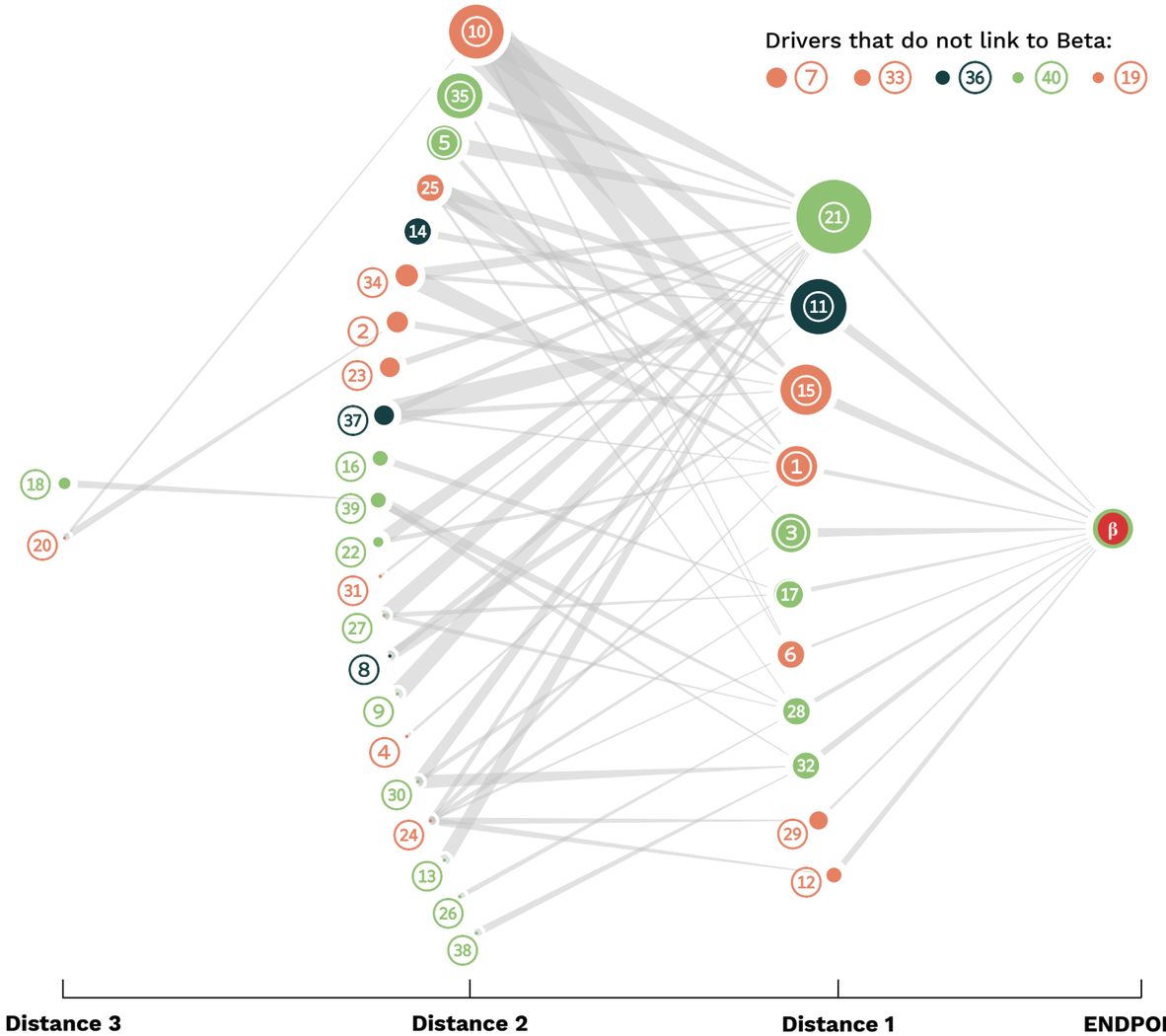
- Node Size according to driver counts
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers / to endpoint
- Link Size according to links strength from the driver to other drivers or to endpoint

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
18. Forced migration
19. Gender issues
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

19. DRIVER PROXIMITY TO THE BETA ENDPOINT

The graph displays the drivers in relation to their proximity to the beta endpoint (Distance 1, 2, and 3).
The colour of each node is related to the cluster it belongs to. The node size is related to the driver count. Links thickness is related to the number of links between drivers and between drivers and the beta spillover. Both review and opinion papers as well as original research papers in the bibliographic corpus have been considered.



LEGEND

- Node Size according to driver counts
- Cluster 1
- Cluster 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers / to endpoint
- Link Size according to links strength from the driver to other drivers or to endpoint

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
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18. Forced migration
19. Gender issues
20. Global market pressures
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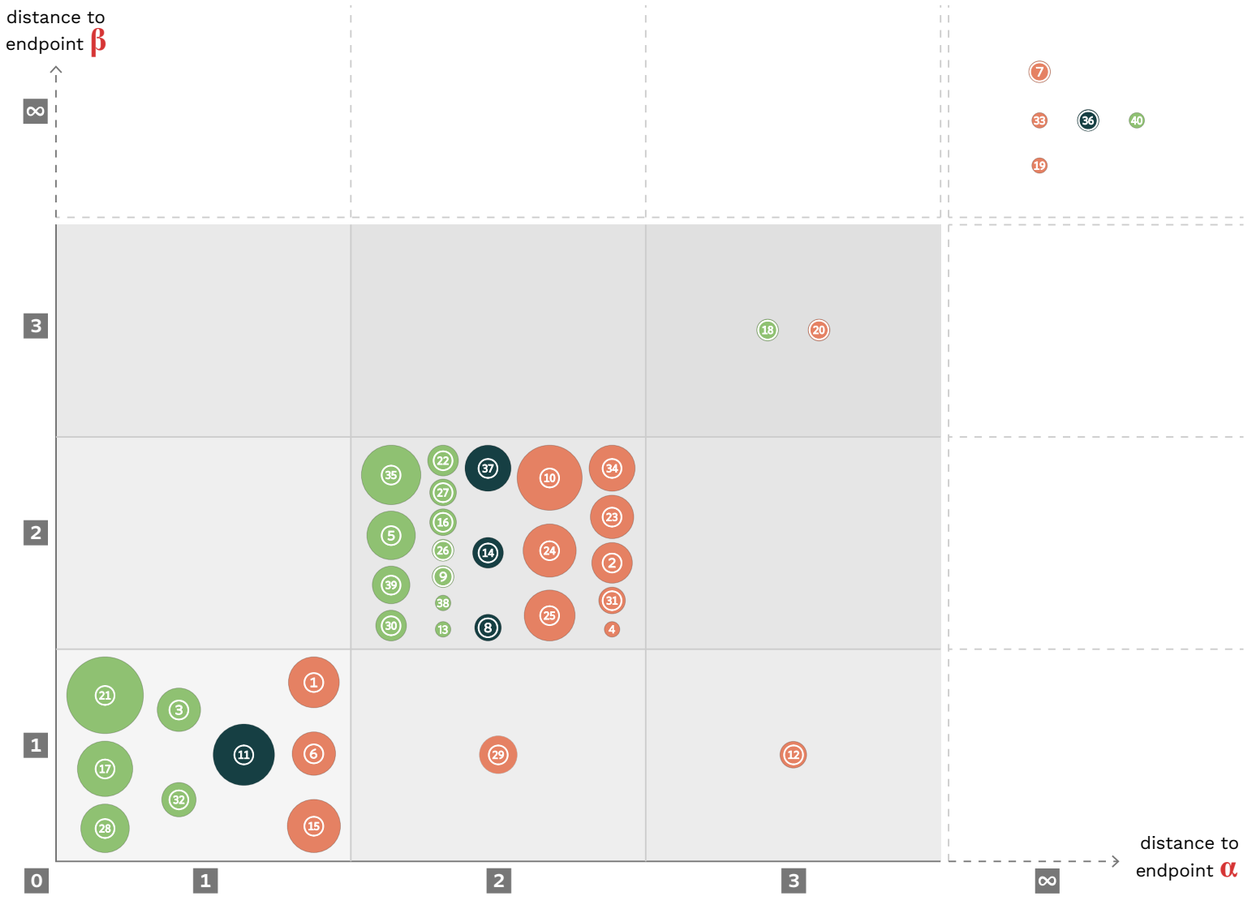
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

20. PROXIMITY OF DRIVERS TO ALPHA AND BETA

The graph displays the drivers in relation to their proximity to the alpha and beta endpoints (Distance 1, 2, and 3). Both review and opinion papers as well as original research papers in the bibliographic corpus have been considered.
Most drivers are equidistant from the two types of spillovers. Some drivers appear out of the graph because they only connect to one endpoint.
The drivers have been allocated to a cell within the grid, based on their respective distance to both endpoints. The colour of each node is related to the cluster it belongs to. The node size is related to the driver count.



LEGEND

- Cluster 1
- Cluster 2
- Cluster 3
- Node size according to degree
- 0 Distance to endpoint
- (40) Driver code
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
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19. Gender issues
20. Global market pressures
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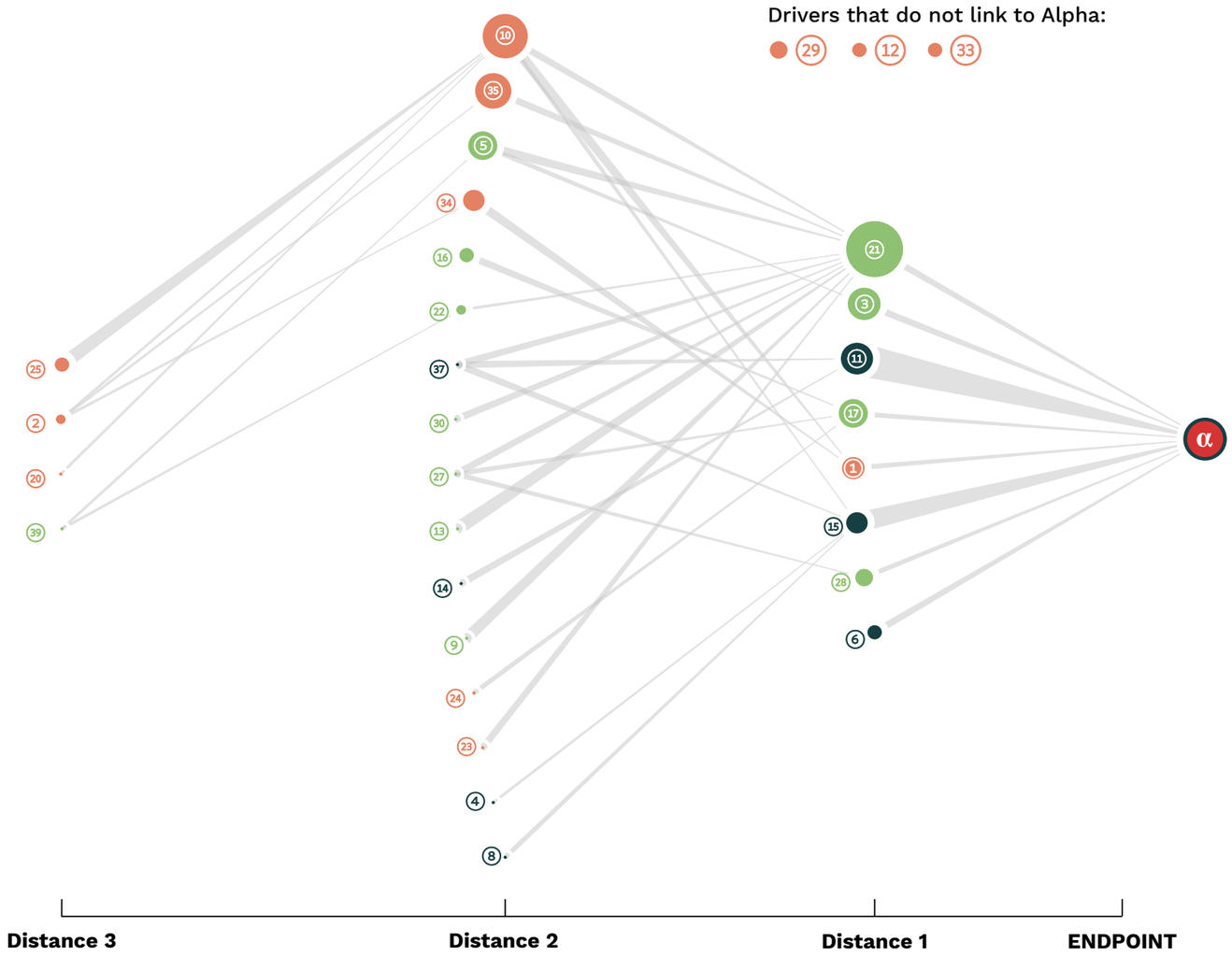
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

21. DRIVER PROXIMITY TO THE ALPHA ENDPOINT

The graph displays the drivers in relation to their proximity to the alpha endpoint (Distance, 1, 2, and 3).
The colour of each node is related to the cluster it belongs to. The node size is related to the driver count. Links thickness is related to the number of links between drivers and between drivers and the alpha spillover. Only original research papers in the bibliographic corpus have been considered.



LEGEND

- Node size according to drivers count
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers / to endpoint
- Link size according to links strength from the driver to other drivers or to endpoint

DRIVERS (original papers)

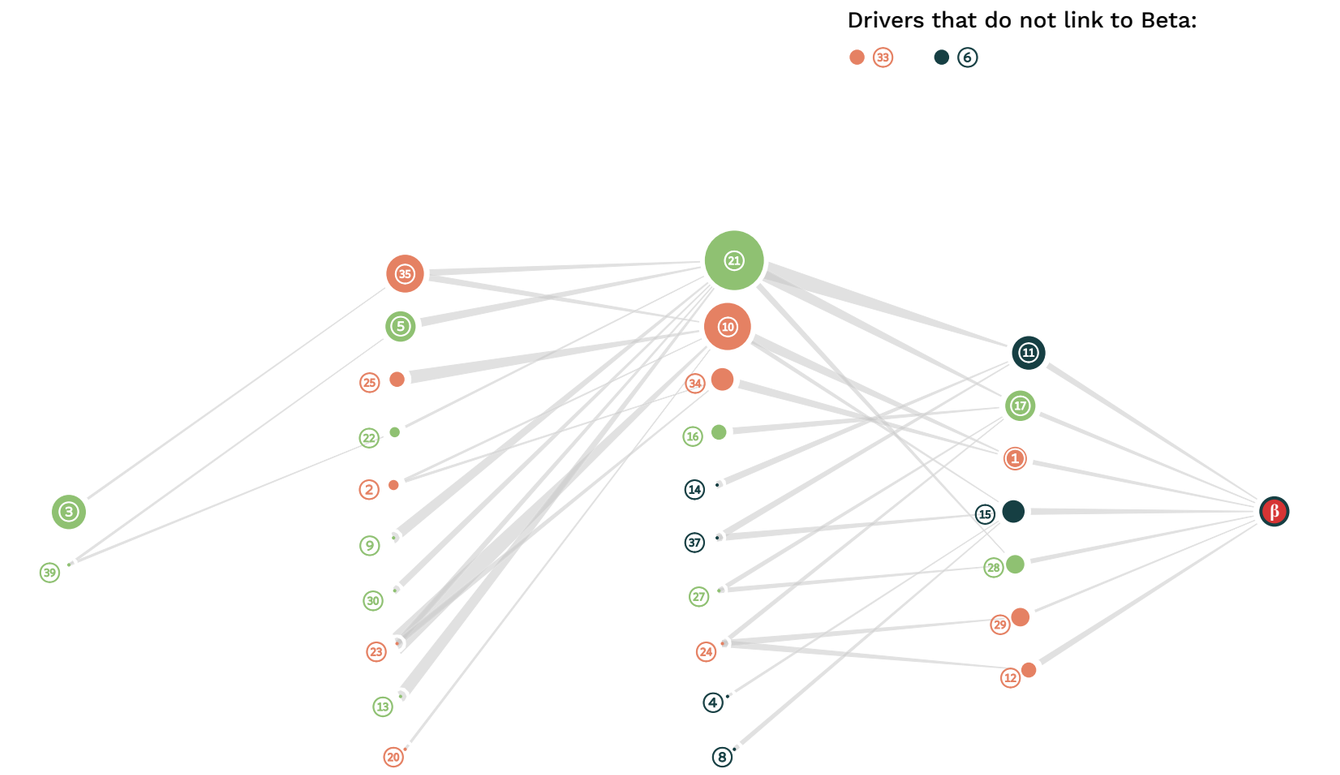
1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

22. DRIVER PROXIMITY TO THE BETA ENDPOINT

The graph displays the drivers in relation to their proximity to the beta endpoint (Distance, 1, 2, and 3).
The colour of each node is related to the cluster it belongs to. The node size is related to the driver count. Links thickness is related to the number of links between drivers and between drivers and the beta spillover. Only original research papers in the bibliographic corpus have been considered.



LEGEND

- Node size according to drivers count
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Link between drivers / to endpoint
- Link size according to links strength from the driver to other drivers or to endpoint

DRIVERS (original papers)

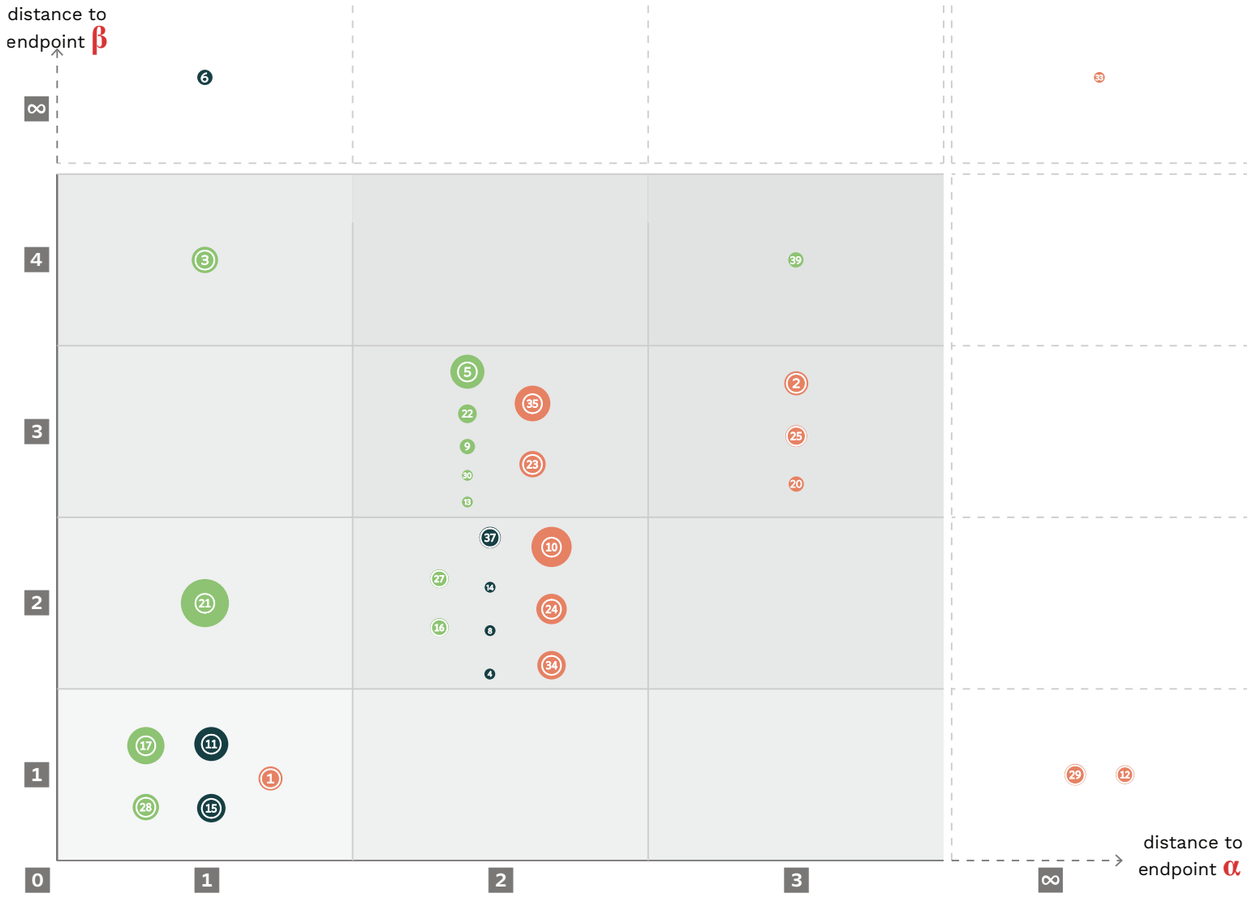
1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

23. PROXIMITY OF DRIVERS TO ALPHA AND BETA

The graph displays the drivers in relation to their proximity to the alpha and beta endpoints (Distance 1, 2, and 3). Only original research papers in the bibliographic corpus have been considered.
In comparison to Figure 20, the drivers are more scattered across the grid, showing affinity for an endpoint compared to the other. Some drivers appear out of the graph because they only connect to one endpoint.
The drivers have been allocated to a cell within the grid, based on their respective distance to both endpoints. The colour of each node is related to the cluster it belongs to. The node size is related to the driver count.



LEGEND

- Cluster 1
- Cluster 2
- Cluster 3
- Node size according to degree
- 0 Distance to endpoint
- (40) Driver code
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)

DRIVERS (ORIGINAL PAPERS)

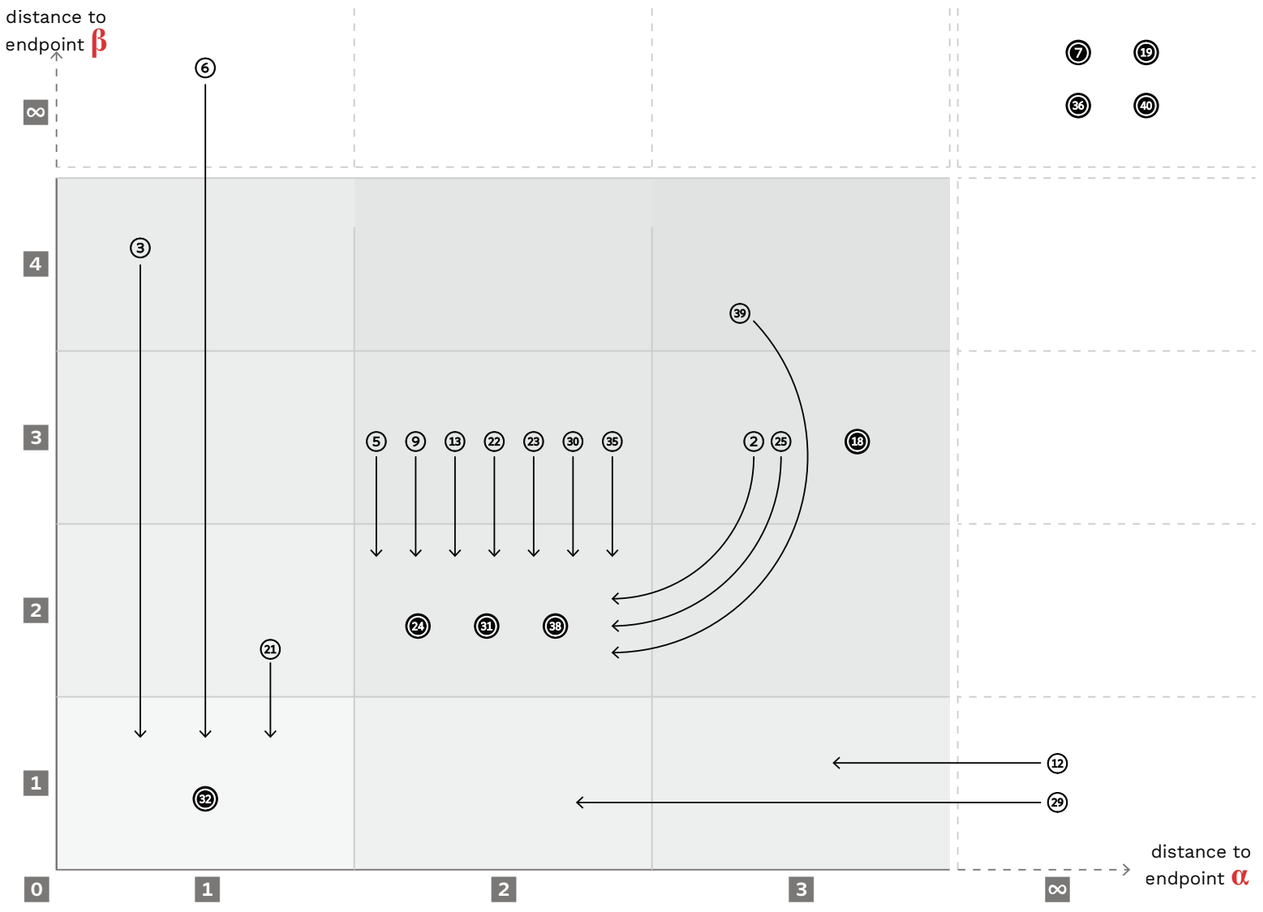
1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
37. Seasonality
39. Socioeconomic impact of conflict

Drivers not present in the original papers

7. Changes in rate of spread of diseases
18. Forced migration
19. Gender issues
26. International/national/regional interactions
31. Public policy
32. Quality of health care
36. Seasonal workers/ movement
38. Social cohesion
40. Uncontrolled/unregulated trade

24. PROXIMITY OF DRIVERS TO ALPHA AND BETA

The graph displays the change in position of the drivers when only original research papers are considered compared to when both original research papers and review/opinion papers of the bibliographic corpus are considered.
The drivers have been allocated to a cell within the grid, based on their respective distance to both endpoints.



LEGEND

- (5) Driver, as positioned considering original papers
- ● Driver, as positioned considering all papers
- (32) Drivers, present only in all papers analysis
- 0 Distance to endpoint
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)

DRIVERS

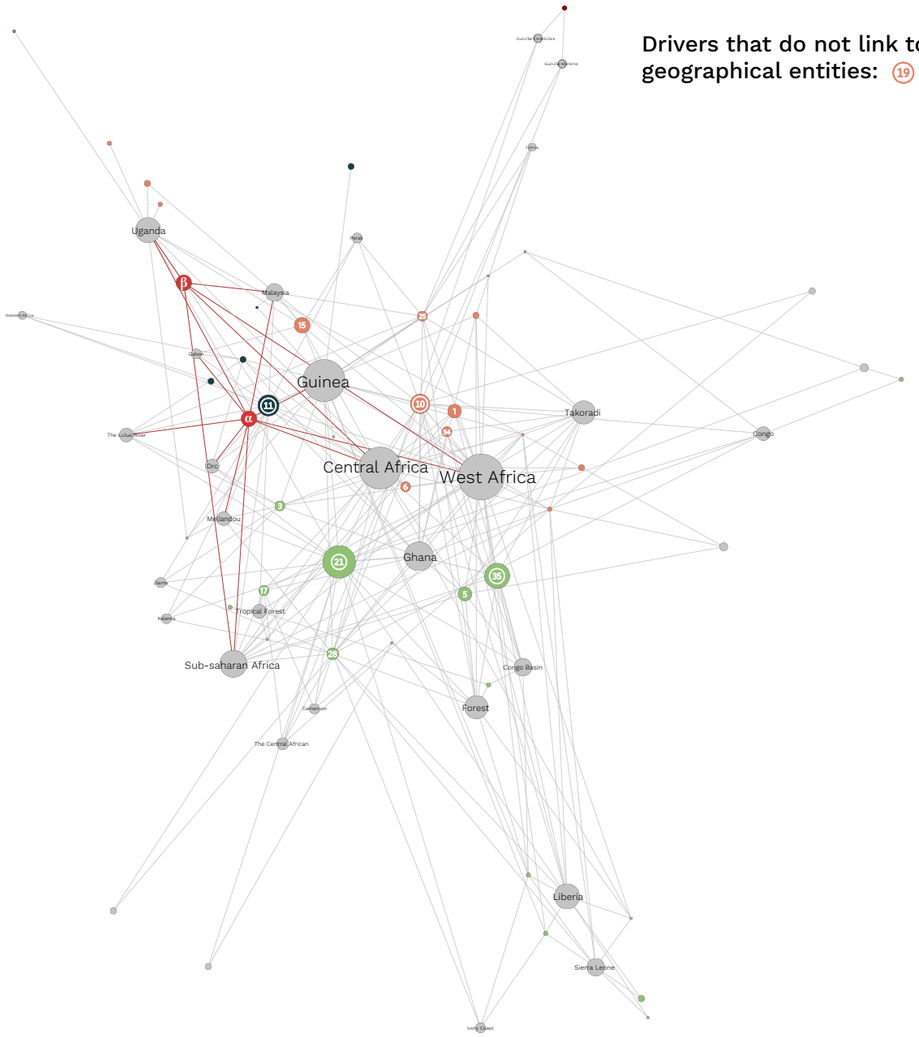
- (2) Agro-economic changes
- (3) Butchering and preparing wildlife
- (5) Changes in demand for bushmeat
- (6) Changes in host-pathogen interaction
- (7) Changes in rate of spread of diseases
- (9) Cultural practices
- (12) Dietary and occupation changes
- (13) Disease control strategies
- (19) Gender issues
- (21) Hunting
- (22) Hunting technology
- (23) Immigration and urbanisation
- (24) Increasing population
- (25) Industrial plantations
- (29) More intensive farming systems
- (30) Poverty
- (31) Public policy
- (32) Quality of health care
- (35) Scale of trade
- (36) Seasonal workers/ movement
- (38) Social cohesion
- (39) Socioeconomic impact of conflict
- (40) Uncontrolled/unregulated trade

Drivers that do not change distance

- (1) Access to forest
- (4) Changes in animal husbandry methods
- (8) Climate change
- (10) Deforestation/ forest fragmentation
- (11) Demographic changes of wildlife
- (14) EBOV spread in wildlife
- (15) Ecosystem changes
- (16) Food prices
- (17) Food security
- (18) Forced migration
- (20) Global market pressures
- (26) International/national/regional interactions
- (27) Lack of reliability of agriculture systems
- (28) Livelihoods resilience
- (33) Quality of veterinary care
- (34) Roads and transport infrastructure
- (37) Seasonality

25. GEOGRAPHICAL ENTITIES AND DRIVERS NETWORK

The figure displays the network of geographical entities mentioned in the bibliographic corpus and how these entities connect to drivers, either sources or targets.
The figure shows how specific papers deal with specific drivers in a specific context.
Drivers are colored according to their clustering.



Drivers that do not link to any geographical entities: 19

LEGEND

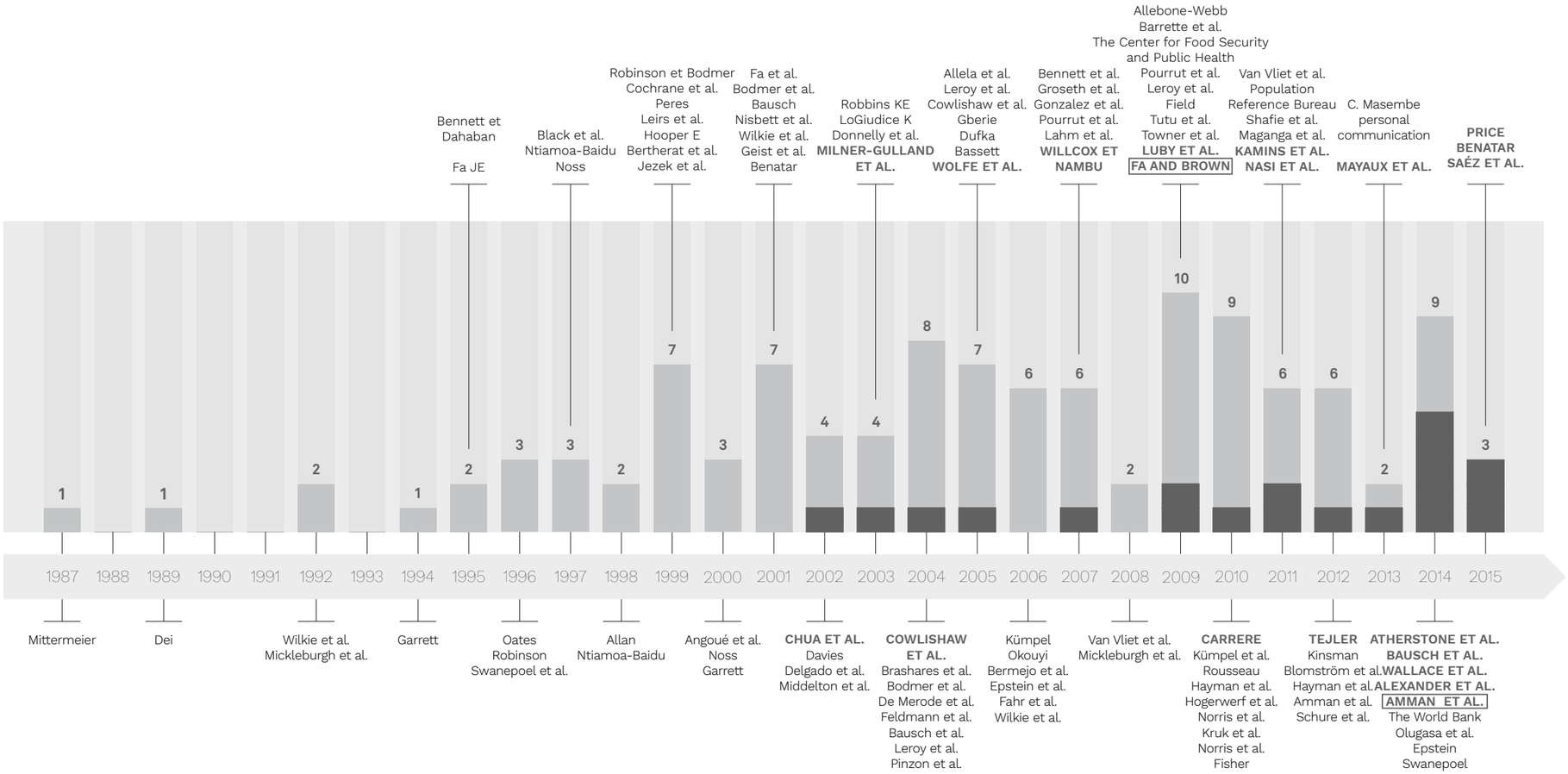
- Geographical Entity
- α Spillover from reservoir species to humans
- β Spillover from non human susceptible host species to humans
- Endpoint
- Link between drivers and geographical entities
- Link to endpoint
- Node size according to Indegree
- Cluster 1
- Custer 2
- Custer 3
- Link size according to the number of time a geographic entity is connected to a driver

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
15. Ecosystem changes
16. Food prices
17. Food security
18. Forced migration
19. Gender issues
20. Global market pressures
21. Hunting
22. Hunting technology
23. Immigration and urbanisation
24. Increasing population
25. Industrial plantations
26. International/national/regional interactions
27. Lack of reliability of agriculture systems
28. Livelihoods resilience
29. More intensive farming systems
30. Poverty
31. Public policy
32. Quality of health care
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

26. TIMELINE OF PAPERS BY PUBLICATION DATE

The figure shows the timeline of papers of the bibliographic corpus according to their date of publication. Dark grey bars represent papers from the bibliographic corpus, whereas the light grey bars represent papers identified as citations within the arguments extracted from the papers of the bibliograpic corpus itself.

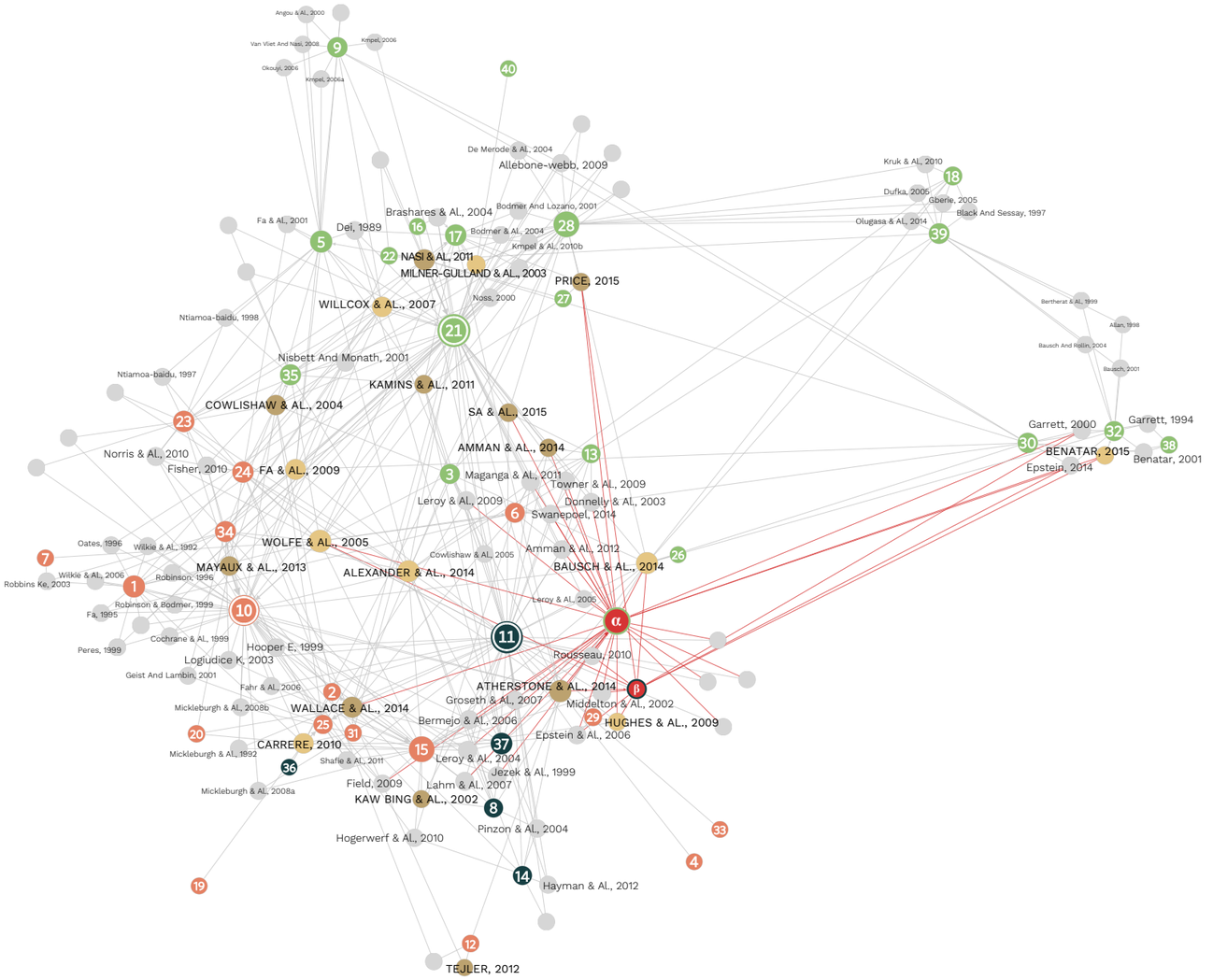


LEGEND

- Cited paper
- Garr Cited paper
- Corpus paper
- TEJ Corpus paper
- Corpus and cited paper
- 1 Number of papers per year

27. NETWORK OF CITATIONS AND DRIVERS

The figure displays the network of literature citations, both corpus and cited papers, connected to drivers, both sources and targets.
Each paper is connected to the drivers of the links identified in the argument extracted from the corpus papers.



LEGEND

- Node size according to Degree
- Cluster 1
- Custer 2
- Custer 3
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)
- Endpoint
- Author cited by papers
- Review papers' authors
- Original papers' authors
- Link from authors to drivers
- Link from authors to endpoint
- Link size according to the number of time an author cites a driver/endpoint

DRIVERS (ALL PAPERS)

1. Access to forest
2. Agro-economic changes
3. Butchering and preparing wildlife
4. Changes in animal husbandry methods
5. Changes in demand for bushmeat
6. Changes in host-pathogen interaction
7. Changes in rate of spread of diseases
8. Climate change
9. Cultural practices
10. Deforestation/ forest fragmentation
11. Demographic changes of wildlife
12. Dietary and occupation changes
13. Disease control strategies
14. EBOV spread in wildlife
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22. Hunting technology
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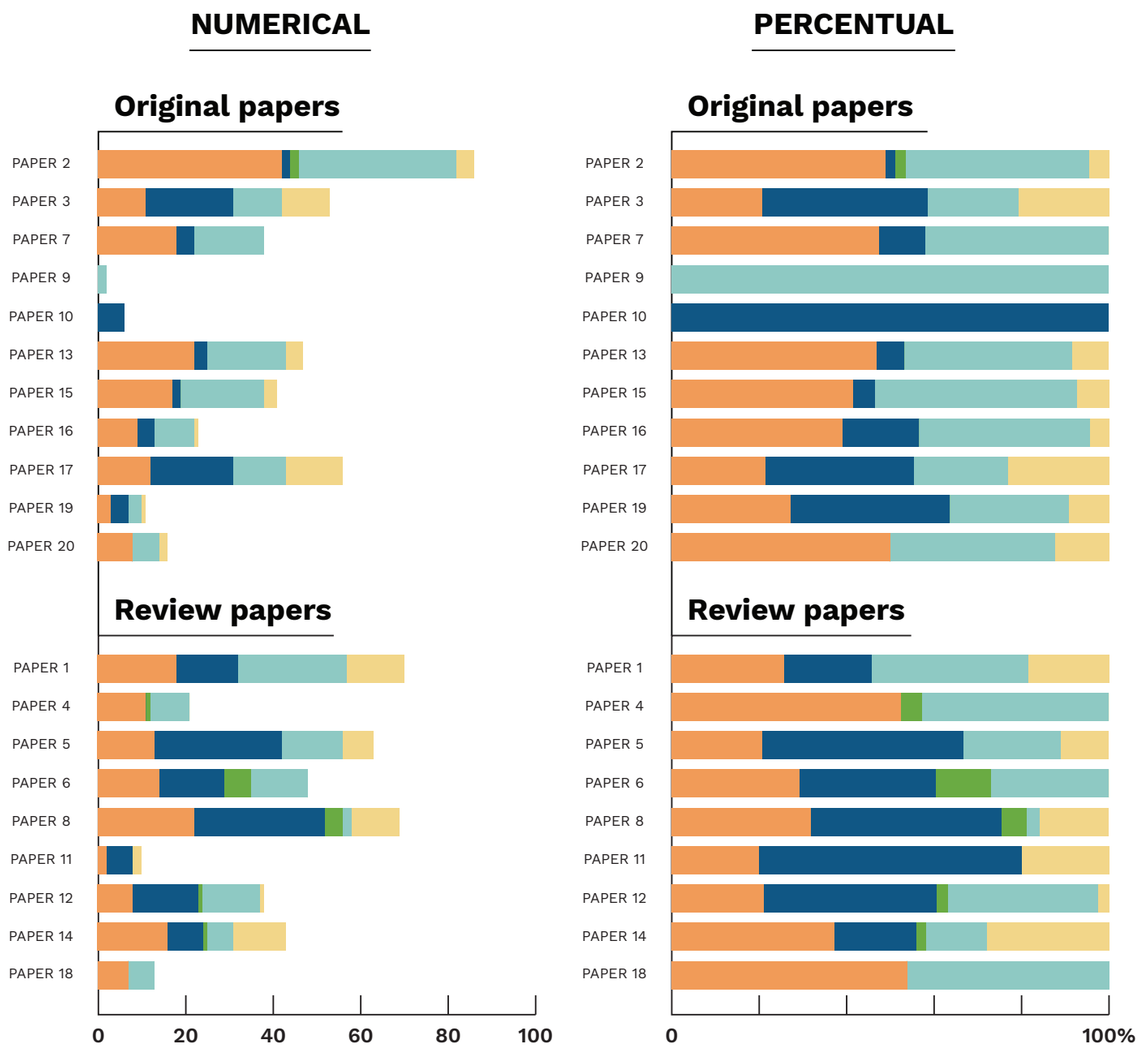
33. Quality of veterinary care
34. Roads and transport infrastructure
35. Scale of trade
36. Seasonal workers/ movement
37. Seasonality
38. Social cohesion
39. Socioeconomic impact of conflict
40. Uncontrolled/unregulated trade

28. STEEP FAMILIES DISTRIBUTION IN EACH PAPER

The figure shows the distribution of the five STEEP families in each paper (both review/opinion papers and original research papers), based on the STEEP family assignment of the drivers identified in each paper.
The numerical count is shown on the left, the frequency on the right.



LEGEND

- Economic steep family
- Enviromental steep family
- Political steep family
- Social steep family
- Technological steep family
- Count

PAPERS

Original papers

PAPER 2	**Nasi & others 2011**	Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins
PAPER 3	**Atherstone & others, 2014**	Ebola risk assessment in the pig value chain in Uganda
PAPER 7	**Kamins & others, 2011**	Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa.
PAPER 9	**Tejler 2012**	Outbreaks of African Swine fever in domestic pigs in Gulu district, Uganda
PAPER 10	**Chua & others, 2002**	Anthropogenic deforestation, El Nino and the emergence of Nipah virus in Malaysia
PAPER 13	**Cowlishaw & others, 2004**	The Bushmeat Commodity Chain: patterns of trade and sustainability in a mature urban market in West Africa
PAPER 15	**Willicox and Nambu, 2007**	Wildlife hunting practices and bushmeat dynamics of the Banyangi and Mbo people of Southwestern Cameroon
PAPER 16	**Saéz & others, 2015**	Investigating the zoonotic origin of the West African Ebola epidemic
PAPER 17	**Mayaux & others, 2013**	State and evolution of the African rainforests between 1990 and 2010
PAPER 19	**Amman & others, 2014**	Marburgvirus resurgence in Kitaka mine bat population after extermination attempts, Uganda
PAPER 20	**Price, 2015**	Does Productivity in the Formal Food Sector Drive Human Ebola Virus Infections in Sub-Saharan Africa?

Review papers

PAPER 1	**Fa and Brown, 2009**	Impacts of hunting on mammals in African tropical moist forests: a review and synthesis
PAPER 4	**Milner-Gulland & others 2003**	Wild meat: the bigger picture
PAPER 5	**Wolfe & others 2009**	Bushmeat Hunting, Deforestation, and Prediction of Zoonotic Disease Emergence
PAPER 6	**Bausch & others, 2014**	Outbreak of ebola virus disease in Guinea: where ecology meets economy
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PAPER 11	**Luby & others, 2009**	Transmission of human infection with Nipah virus
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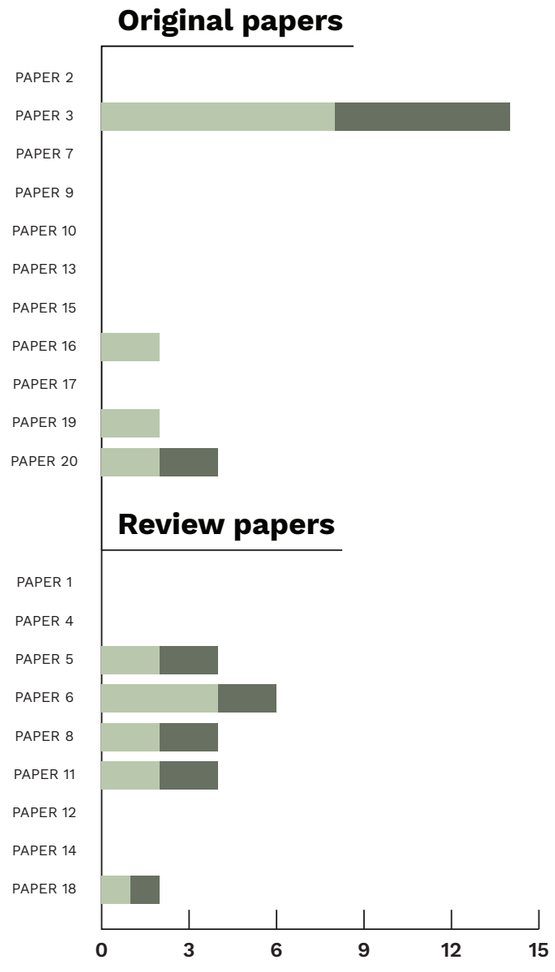
PAPER 14	**Carrere, 2010**	Oil palm in Africa: Past, present and future scenarios
PAPER 18	**Benatar, 2015**	Explaining and responding to the Ebola epidemic

29. ENDPOINTS IN EACH PAPER

The figure shows how many times the alpha and beta endpoints appear in the driver links identified in each paper.



LEGEND

- Endpoint Alpha
- Endpoint Beta
- Count
- α Spillover (reservoir species to humans)
- β Spillover (non human susceptible host species to humans)

PAPERS

Original papers

PAPER 2	**Nasi & others 2011**	Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins
PAPER 3	**Atherstone & others, 2014**	Ebola risk assessment in the pig value chain in Uganda
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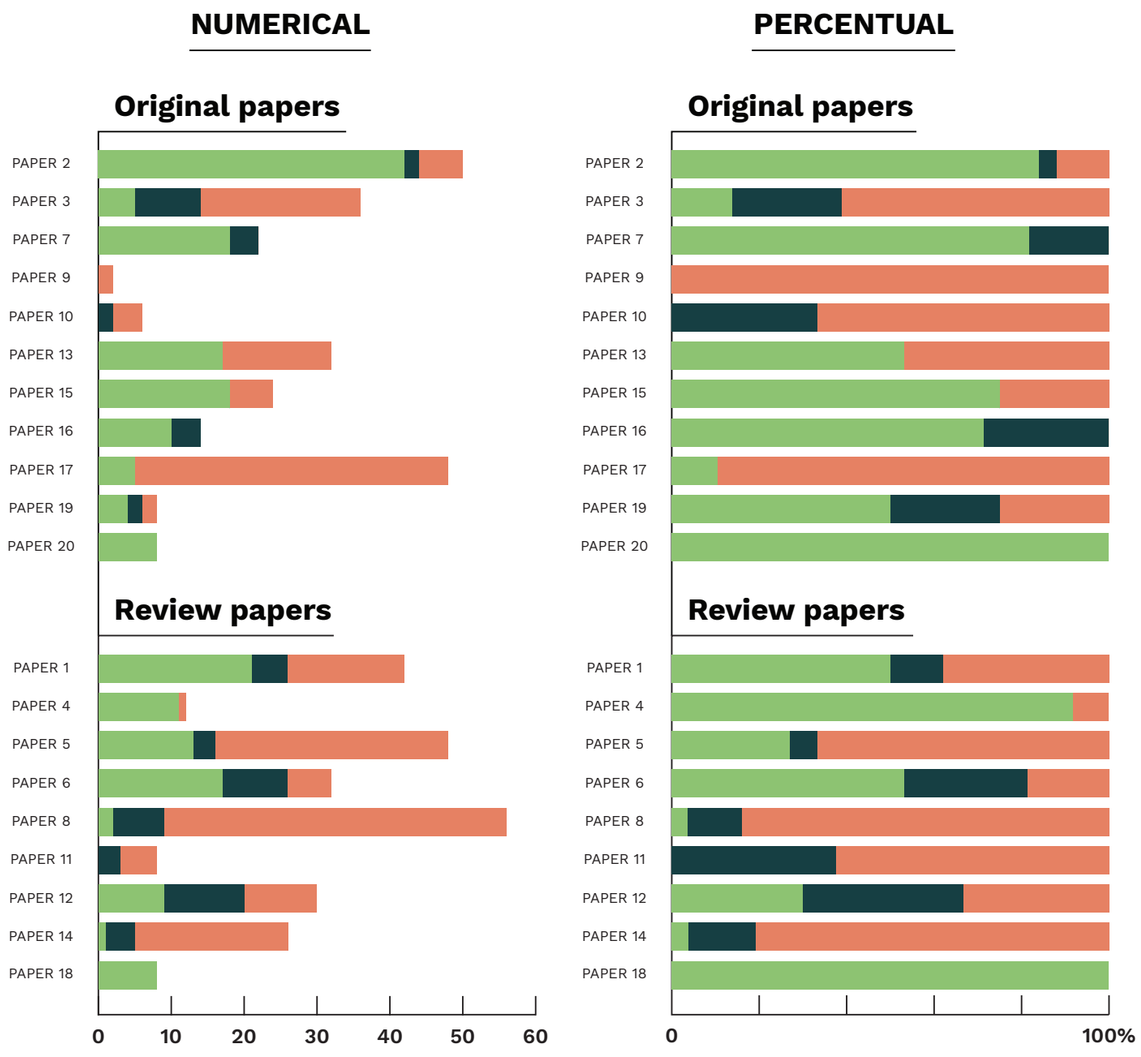
PAPER 18	**Benatar, 2015**	Explaining and responding to the Ebola epidemic

30. CLUSTERS IN EACH PAPER

The figure shows how many times each of the three driver clusters, as displayed in the driver network shown in figure 9, are identified in each paper. The graph has been constructed based on the number of times a driver belonging to a certain cluster is identified in each paper.
The numerical count is shown on the left, the frequency on the right.



PAPERS

Original papers

PAPER 2	**Nasi & others 2011**	Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins
PAPER 3	**Atherstone & others, 2014**	Ebola risk assessment in the pig value chain in Uganda
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PAPER 18	**Benatar, 2015**	Explaining and responding to the Ebola epidemic

CONCLUSIONS

The following could be concluded from the present report:

- The analysis of the drivers conducted on the basis of the selected studies has led to the identification of 40 drivers, connected through 142 linkages
- The network visualisations show that central drivers involved in spillover are 'Hunting', 'Deforestation/forest fragmentation', and 'Demographic changes of wildlife'.
- When analysing the role of drivers as source or target in the driver linkage, 'Hunting' is the driver which most often acts as a target in the corpus; while 'Deforestation/forest fragmentation' appears as the most frequent source.
- The alpha endpoint is mainly receiving direct links from 'Ecosystem changes', 'Demographic changes of wildlife' as well as 'Butchering and preparing wildlife'.
- The ranking of the most frequent driver links identified show that the most frequent ones are 'Deforestation/forest fragmentation' leading to 'Ecosystem changes' and 'Livelihoods resilience' leading to 'Hunting';
- According to the assignment of the drivers to each STEEP category, the three main represented categories are Social, Economic and Environmental.
- Most of the papers addressing the question of drivers for spillover of infectious disease from animals to humans focus on general aspects that equally apply to several diseases, not specifically related to EBOV spillover at the animal-human interface. Moreover most of these papers are reviews interpreting evidence from original research papers. The differential analysis of either all papers in the corpus (including review and opinion papers) or only original research papers highlight the influence of review and opinion papers on the network of drivers and the representation of EBOV spillover.
- The methodology used in this report demonstrates how a more structured and transparent approach can be used to identify and analyse drivers for infectious diseases. Each linkage is traceable to a specific argument from the literature and network diagrams were created using a set algorithm. This methodology could further be applied to other complex topics that would require visualisations of diverse yet connected factors.

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