Changing Patterns And Trends In Author Co-Authorship Networks Of HIV/AIDS Research In Eastern And Southern Africa

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Abstract

Social networks play an important role in the analysis and tracking of relationships between the participating entities (i.e. words, individuals, institutions, and countries, etc). Social networks are likely to play an even greater role now and in the future than before due to the complex nature of un-resolved issues such as HIV/AIDS. The proliferation of local and international conferences has opened up new avenues for 'networking', a term that is increasingly becoming common, amongst researchers. This study examines collaboration networks amongst HIV/AIDS researchers in Eastern and Southern Africa, aiming to provide a better understanding of the nature and composition HIV/AIDS research networks; the changing patterns of the networks; and the geographic regions of study for each network. The paper ends by providing recommendations on some of the ways through which research collaboration and 'networking' in Africa can be promoted.

Keywords

Social networks, Social network analysis, HIV, Acquired Immunodeficiency Syndrome, Collaboration, Africa

1 Introduction

In simple terms, social networks can be defined as structures consisting of nodes that are linked to each other by one or more specific types of relations (Wikipedia 2007). The nodes in a social network can represent individuals, words, organizations or even countries, while the relationships between the actors would usually take the form of any of the following: values, visions, ideas, financial exchange, friendships, kinship, conflict, trade, web links, sexual relations, disease transmission, or airline routes, etc.

Phillips and Phillips (1998:330) add that the "relationships under scrutiny [in social networks] could include friendship, influence or in the case of a scientific discipline, patterns of communication or strength of association between members in a scientific community". Network analysis, which Scott in Phillips and Phillips (1998:330) defines as "a body of quantitative and qualitative measures which are used to better understand the relationships between and among members in a given social network" is increasingly becoming one of the most commonly used techniques/approaches in the study of patterns that show up in scholarly communication. The technique has attracted scholars from many disciplines including sociology, anthropology, sociolinguistics, geography, social psychology, communication studies, information science, organizational studies, economics, and biology. Social network analysis can help in determining the way problems are solved; organisations are run; and the degree to which individuals succeed in achieving goals. In epidemiology, social networks may help in understanding how patterns of human contact aid or inhibit the spread of diseases such as HIV/AIDS (Wikipedia 2007). The spread of new ideas and practices in different disciplines can also be monitored using social network analysis.

A quick examination of two of the most recently published International Society for Scientometrics and Informetrics' (ISSI) conference proceedings (i.e. Ingwersen & Larsen 2005; Torres-Salinas & Moed 2007) shows a growing interest in mapping and/or visualizing research and scholarly communication using social network analysis within the subject domain of informetrics. For instance, the ISSI 2005 proceedings record a total of 17 articles that employed social networks to map research in various disciplines while the 2006 proceedings published a total of 28 such papers, a percentage increase of 40% over a period of two years. An analysis of these papers reveals that the technique has been largely applied to mapping and/or visualising citation patterns (e.g. bibliographic coupling, co-citation analysis, etc), web-linking patterns (e.g. co-linking, government-university web-linking, link structures of web documents, etc.) and content analysis (e.g. word co-occurrence, relationships between and/or among keyword descriptors and/or documents, etc). Examples of the papers which fall into the aforementioned categories include Small (2001); Morris and Boyack (2001); and Janssens, Glenisson, Glanze and De Moor (2005); etc.

A research area that is increasingly using social network analysis is the study of research collaboration. Although the phrase 'research collaboration' has a "very fuzzy or ill-defined border" (Katz & Martin 1997:8), it has been variously defined as "partnership, alliance or network, aimed at a mutually beneficial clearly defined outcome" (Commonwealth of Australia 2004:1); a "concept of two or more researchers (or researchers from two or more organizations or countries) working together" (Diodato 1994:47); and a "system of research activities by several actors related in a functional way to

attain a research goal corresponding with these actors' research goals or interests" (Laudel 2001:370). Thus, research collaboration, which is commonly measured by the co-authorship of the published literature in a given subject domain, can be conducted between and/or among individuals, institutions, and countries. The emergence of HIV/AIDS in the early 1980s provided a common area of research interest for many researchers, resulting in a flurry of research activities that involved both local and international researchers (Cohen 2000a; 2000b). Both Cohen (2000a; 2000b) and Macias-Chapula and Mijangos-Nolasco (2002) observe that there is a high pattern of collaboration between individuals, institutions and countries in HIV/AIDS research in Africa. In their study entitled *Bibliometric analysis of AIDS literature in Central Africa*, Macias-Chapula and Mijangos-Nolasco (2002) noted a very high pattern of collaboration through multiple-authorship of HIV/AIDS publications, accounting for 92.54% of the total number of publications.

2 Purpose Of The Study

This study examines the HIV/AIDS literature published by and on Eastern and Southern Africa as indexed in the Thomson Scientific's Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) in order to map networks of HIV/AIDS researchers in the two regions between 1980 and 2005. Specifically, the study uses the network analysis technique to:

1. Identify collaborating authors
2. Examine the growth and composition of author collaborative networks
3. Track changes in both the number and composition of author networks
4. Establish the main geographic areas of research focus in each author network
5. Identify potential collaborators for future research activities

3 Methodology

The Thomson Scientific citation indexes (i.e. SCI and SSCI) were purposefully selected for data collection due to their provision of authors' addresses which was the main determining factor for the choice of databases. In addition to the provision of authors' names, the 'address field' provides information about the author's institutional affiliation and country. The following is an example of the information provided in the 'address field':

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C1 Univ British Columbia, Ctr Dis Control, Vancouver, BC V5Z
   1M9, Canada.
   Univ Washington, Dept Obstet & Gynecol, Seattle, WA 98195 USA.
   Univ Nairobi, Dept Med Microbiol, Nairobi, Kenya
   Kenya Med Res Inst, Ctr Microbiol Res, Nairobi, Kenya.
   Univ Manitoba, Dept Med Microbiol, Winnipeg, MB, Canada.
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In order to extract HIV/AIDS records from the two citation indexes (i.e. SCI and SSCI) an advanced search strategy that combined the names of countries/geographic regions and HIV/AIDS descriptors was adopted. The searches were conducted within the Title, Abstract, Address and Keyword fields using TI, TS and AD field tags. The citation indexes permit a combination of searches using the Boolean operators, AND, OR and/or NOT. The 'search history' feature was used to conduct multiple searches, e.g. number 1 AND number 2, which instructed the database to search for documents that satisfy the requirements of both search number 1 AND number 2, where, for example:

- Search number 1 took the form of *TI Angola OR TI Botswana OR TI Djibouti OR TI Eritrea OR TI Ethiopia OR TI Kenya OR TI Lesotho OR TI Malawi OR TI Mozambique OR TI Namibia OR TI Somalia OR TI South Africa OR TI Sudan OR TI Swaziland OR TI Tanzania OR TI Uganda OR TI Zambia OR TI Zimbabwe*
- Search number 2 took the form of *TI HIV* OR TI Acquired Immunodeficiency syndrome TI Human Immunodeficiency syndrome,* etc.

And, where *TI* represents the Title field tag.

The relevant records were selected and saved in a format that was compatible with CITESPACE[1] computer-aided software. The file names were in the format 'download-Angola2005.txt', where the term 'download' is the name given to the file so that the software can recognise it for purposes of data analysis; and 'Angola2005' is a unique name given by us to the file containing records published by and on Angola in the year 2005. Each file's data was then fed into CITESPACE for the production of author co-authorship (ACA) networks by selecting the option 'citing authors' and appropriately setting other configurations that impacted on ACA analysis, e.g. citation, co-citation and co-citation co-efficient (i.e. c, cc, and ccv, respectively) thresholds and the type of network visualisation, which in this case was the cluster view. The program's user interface is illustrated in Figure 1.

1. CITESPACE is a java program for co-citation analysis, specifically for visualising co-citation networks. Currently, it takes citation data in Thomson Scientific Export format and generates node-and-link drawings of co-citation networks. The program uses the following information of a bibliographic record to generate maps: (a) authors; (b) title, descriptors, identifiers, and abstract; (c) cited references; (d) times cited; and (e) year of publication. The co-citation networks that the program generates include author co-authorship networks created by analysing the citing authors, among others.

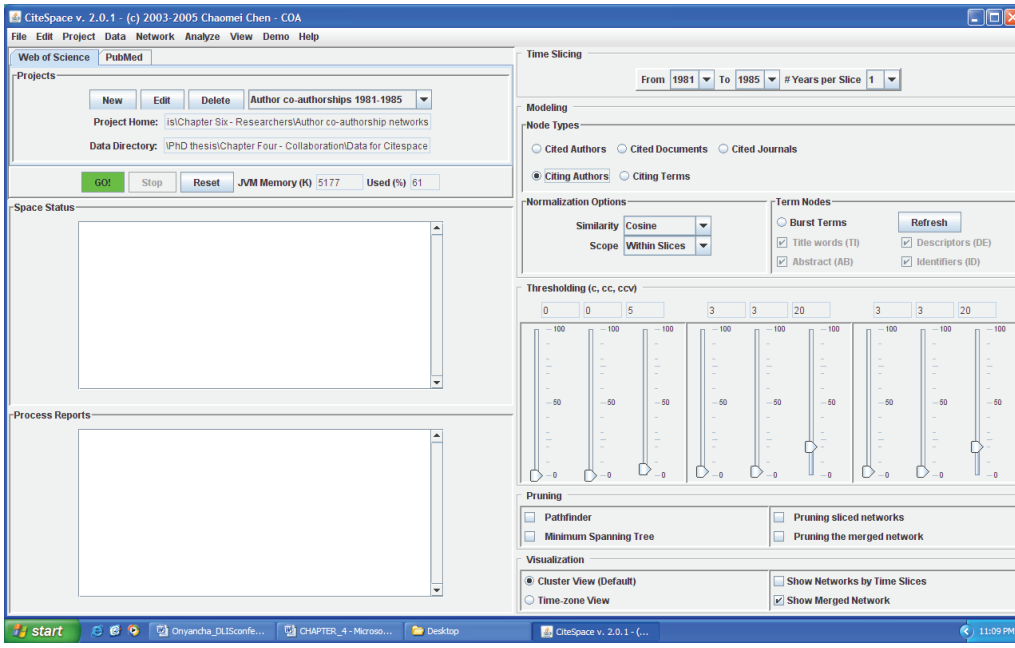

Figure 1: Citespace v. 7.0.1 (© 2003-2005) user interface (developed by Chaomei Chen)

Figures 2 to 6 provide a time analysis of author collaboration from 1981 to 2005, split into six five-year periods. The 5-year time slice was chosen in order for the analysis to produce a reasonable number of networks which could be used to draw generalised conclusions as well as check for shifts in partnerships within a reasonably short time period. A summary of the network threshold settings is given under each figure. Different citation thresholds were set for each time analysis in order to produce manageable networks. Slicing a time interval into smaller segments is meant to assist one to clearly understand how co-citation networks over individual time slices are patched together. We did not consider slicing the time further into smaller segments as necessary because the five-year period, with 1 year per slice, was manageable. Time slices were set as follows: 1981-1985; 1986-1990; 1991-1995; 1996-2000; and 2001-2005. The year 1980 was left out (i.e. pruned) as it did not yield any nodes nor links.

The networks that were generated in CITESPACE were not illegible nor were we able to clean them of certain errors, such as the presence of names of authors who satisfied the threshold requirements but did not belong to any network. Secondly, it was difficult to copy the generated networks to Microsoft Word for interpretation and

presentation. Consequently, we exported the network data to UCINET[2] using the *Export to UCINET Network Format (DL)* option, where DL was used to identify the file as a data language file. We used *PAJEK,* one of the visualisation programs integrated into *UCINET* analytic technologies, to produce the co-authorship networks presented in section 4. A 2-dimensional Fruchterman Reingold analysis was adopted to prepare the networks for legibility purposes. Finally, all stand-alone names of authors were deleted from the networks using Microsoft Corporation's Paint program (version 5.1, ©2001) in order to obtain clear and visible co-author social networks in Figures 2 to 7. Normalisation options were set as 'Cosine' and 'Within slices' meaning that the program was commanded to draw similar (i.e. closely related participants) together using their cosines within the scope of the slices. The authors whose link strengths were presumed to be strong produced thicker lines as shown in Figures 2-7, i.e. the thicker the line (link) joining a pair of authors, the stronger their co-authorship. The strength values, generated by CITESPACE, are also provided to support the findings illustrated in the Figures.

4 Results And Discussion

This section presents and discusses the findings using a time-series analysis approach, which was necessitated by the yearly classification of HIV/AIDS records as discussed in the methodology section, i.e. 1981-1985; 1986-1990; 1991-1995; 1996-2000; and 2001-2005. The presentation and discussion of the countries of research focus for the entire period of study (i.e. 1980-2005) is provided in sub-section 4.7.

4.1 Growth Of Author Collaboration Networks, 1981-2005

As aforementioned, the nodes in a social network represent participating entities who, in this case are authors, while the links (i.e. lines joining a pair of nodes) represent co-authorship relationships. In order to measure the growth of the author co-authorship networks, uniform citation thresholds were set for each time slice of two years each. It was noted that both the number of nodes and links have continued to increase as shown in Table 1, thereby implying a continued growth of author collaborations. The number of nodes increased from 5 in 1984-1985 to 830 in 2004-2005, accounting for a percentage increase of 16500%. There were 4 links in 1984-1985 while 2004-2005

2. UCINET version 6 for Windows is a comprehensive package for the analysis of social network data as well as other 1-mode and 2-mode data. It can read and write a multitude of differently formatted text files, as well as Excel files. At this stage, we employed it to conduct a purely plain visualisation of the co-author networks. For more information about UCINET, visit: http://www.analytictech.com/ucinet/ucinet.htm (Accessed 25 September 2007).

produced the highest number of links, i.e. 2067 links. One aspect of social networks that is worth mentioning here is the fact that the more the links per node in a network, the more the relationships amongst the network's participants. It therefore follows that 1994-1995 produced the highest number of links per node (i.e. 4.9), implying more relationships amongst the authors in the networks. As a matter of fact, the largest network comprising of 48 authors was recorded in 1994.

Table 1: Growth in the number of network nodes and links, 1982-2005

2-year slices	*Citation threshold*			*articles*	*nodes*		*links*	
	c	*cc*	*ccv*	*no.*	*no.*	*increase*	*no.*	*increase*
1982-1983	2	2	0.15	3	0	0	0	0
1984-1985	2	2	0.15	8	5	5	4	4
1986-1987	2	2	0.15	31	17	12	18	14
1988-1989	2	2	0.15	102	42	25	62	44
1990-1991	2	2	0.15	251	146	104	253	191
1992-1993	2	2	0.15	358	216	70	441	188
1994-1995	2	2	0.15	538	374	158	1837	1396
1996-1997	2	2	0.15	594	366	-8	949	-888
1998-1999	2	2	0.15	790	534	168	1321	372
2000-2001	2	2	0.15	1116	697	163	1911	590
2002-2003	2	2	0.15	1254	757	60	1754	-157
2004-2005	2	2	0.15	1322	830	73	2067	313

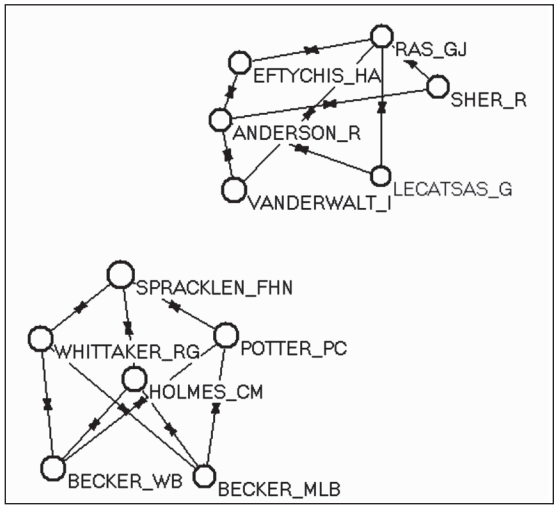

Figure 2: Author co-authorship networks: 1981-1985

1-year slices	*c | cc | ccv*	*space*	*nodes*	*links*
1981-1981	*0 | 0 | 0.15*	*0*	*0*	*0*
1982-1982	*0 | 0 | 0.15*	*0*	*0*	*0*
1983-1983	*0 | 0 | 0.15*	*10*	*10*	*10*
1984-1984	*0 | 0 | 0.15*	*28*	*28*	*53*
1985-1985	*0 | 0 | 0.15*	*11*	*11*	*16*

4.2 Author Collaboration Networks Of HIV/AIDS Literature In Eastern and Southern Africa: 1981-1985

Figure 2 shows that there were two author networks that met the citation threshold requirements. It also illustrates that (not displayed in the illustration but shown on the accompanying Table immediately below the illustration) several individual authors met the set requirements but produced no networks. Each of the ties produced a strength value of 0.29, implying equal strength of collaborative links among all authors in a given network. Each network consisted of 6 authors.

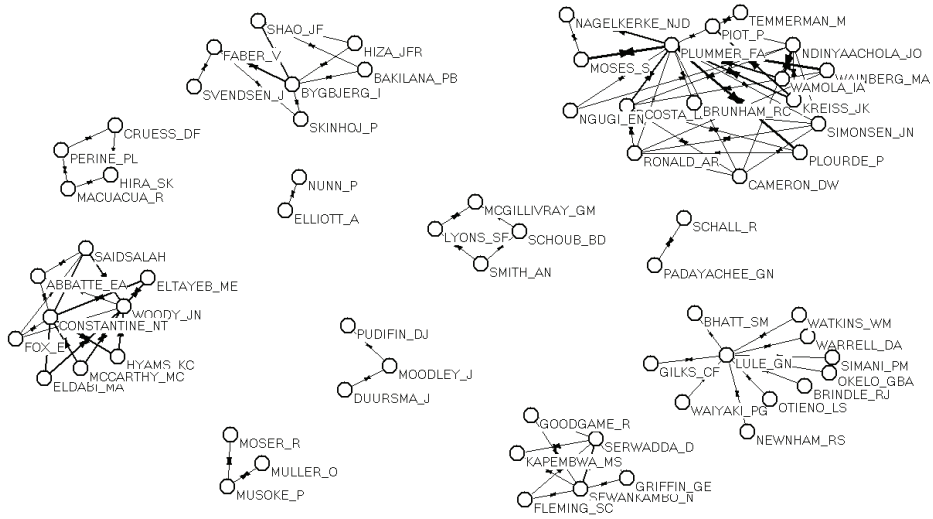

Figure 3: Author co-authorship networks: 1986-1990

1-year slices	*c | cc | ccv*	*space*	*nodes*	*links*
1986-1986	*2 | 2 | 0.15*	*40*	*4*	*1*
1987-1987	*2 | 2 | 0.15*	*139*	*14*	*17*
1988-1988	*2 | 2 | 0.15*	*223*	*16*	*19*
1989-1989	*2 | 2 | 0.15*	*303*	*33*	*42*
1990-1990	*2 | 2 | 0.15*	*486*	*82*	*152*

4.3 Author Collaboration Networks Of HIV/AIDS Literature In E&S Africa: 1986-1990

Figure 3 provides the authors' collaborative networks between 1986 and 1990. The illustration indicates that there were five major networks (i.e. networks that consisted of over 6 authors) that emerged during this period. The largest network comprised 15 authors, including Plummer FA, Ndinya-Achola JO, Cameron DW, Plourde P, Wainberg MA and others. The geographic research focus area of these authors was Kenya. Also worth noting is the absence of the two author networks of 1981-1985, which therefore suggests that all eleven of the 1986-1990 author networks were new. It was observed that, unlike the previous year period, the 1991-1995 year period produced links of varied strengths. The highest tie strengths were recorded between Plummer FA and Wainberg MA (0.55); Plummer FA and Plourde P (0.55); Plummer FA and Moses S (0.55); Wamola IA and Ndinya-Achola J (0.53).

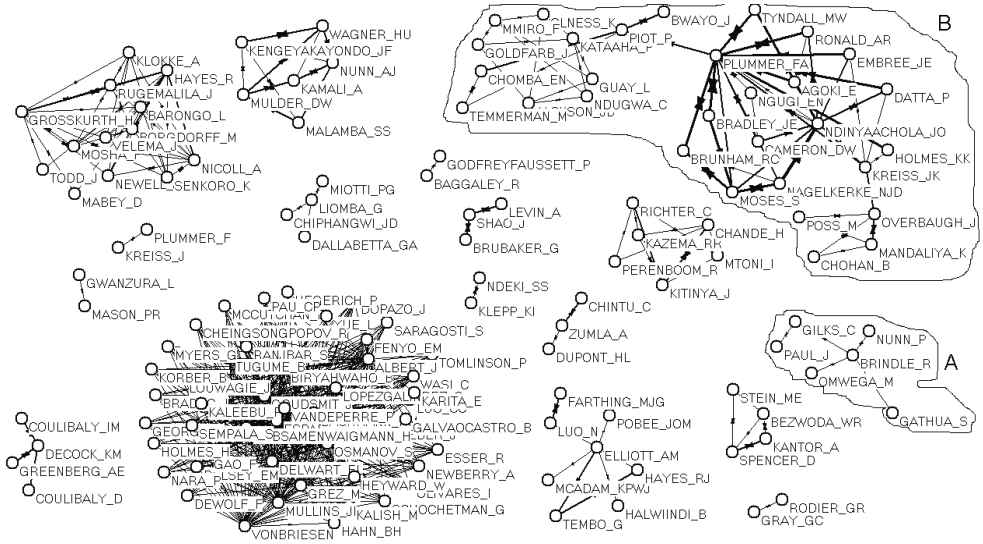

Figure 4: Author co-authorship networks: 1991-1995

1-year slices	*c | cc | ccv*	*space*	*nodes*	*links*
1991-1991	*3 | 3 | 0.15*	*679*	*27*	*32*
1992-1992	*3 | 3 | 0.15*	*791*	*30*	*36*
1993-1993	*3 | 3 | 0.15*	*922*	*45*	*81*
1994-1994	*3 | 3 | 0.15*	*1229*	*106*	*1190*
1995-1995	*3 | 3 | 0.15*	*1571*	*80*	*55*

4.4 Author Collaboration Networks Of HIV/AIDS Literature In Eastern And Southern Africa: 1991-1995

The 1991-1995 year-period yielded a total of 17 author networks as shown in Figure 4. The largest collaborative network stemmed from three authors, namely Biryahwaho B, Delwart EL and Esparza J, who produced over twenty links each. With the exception of two networks (marked A and B and circled) that had the names of some of the authors who had featured in the previous year-period's collaborative network, the networks that met the set threshold requirements for the 1991-1995 year-period were largely new. Networks A and B reveal that the key authors were Brindle R in network A, and Plummer FA, Nagelkerke NJD, Brunham RC, Ndinya-Achola JO, and Piot P in network B. These authors produced majority links with other authors in the same networks. The strengths of the co-authorship ties were as follows: Ndinya-Acholla JO and Nagelkerke NJD (0.67); Plummer FA and Agoki E (0.57); and Ndinya-Acholla and Tyndall MW (0.5), just to mention a few.

4.5 Author Collaboration Networks Of HIV/AIDS Literature In Eastern And Southern Africa: 1996-2000

The author collaborative network in Figure 5 consists of a total of 18 networks, with several names of authors that appeared in the previous year-period (see Figure 4) featuring prominently. The networks that contain previously active collaborators are marked C-H. An observation derived from these networks is the participation of new authors that previously had either not featured anywhere (so to speak), or partnered with other authors in different collaborative activities. For instance, some names in network C (e.g. Plummer FA, Nagelkerke NJD, Ndinya-Achola JO, Mandaliya K, etc) formed a part of network B in the previous year-period. The new names in network C include Kimani J, MacDonald KS, and Moses S. Generally, each of these networks witnessed the entry of new names. A further observation that can be made is the split of network B into two networks in 1996-2000 (i.e. C and F). It can also be seen that several new networks emerged in 1996-2000 as illustrated by those that are unmarked. Most of these networks remained in place in the first-half of this decade (2001-2010). Another notable aspect was the lower strength values of the links among the authors when compared with the previous year period's values. The highest strength value was recorded between Bwayo JJ and Mandaliya K (i.e. 0.54) while the rest of the links produced strength values of less than 0.5. This pattern was also witnessed in the 2001-2005 year period, a situation that may imply less collaboration activities among the same authors.

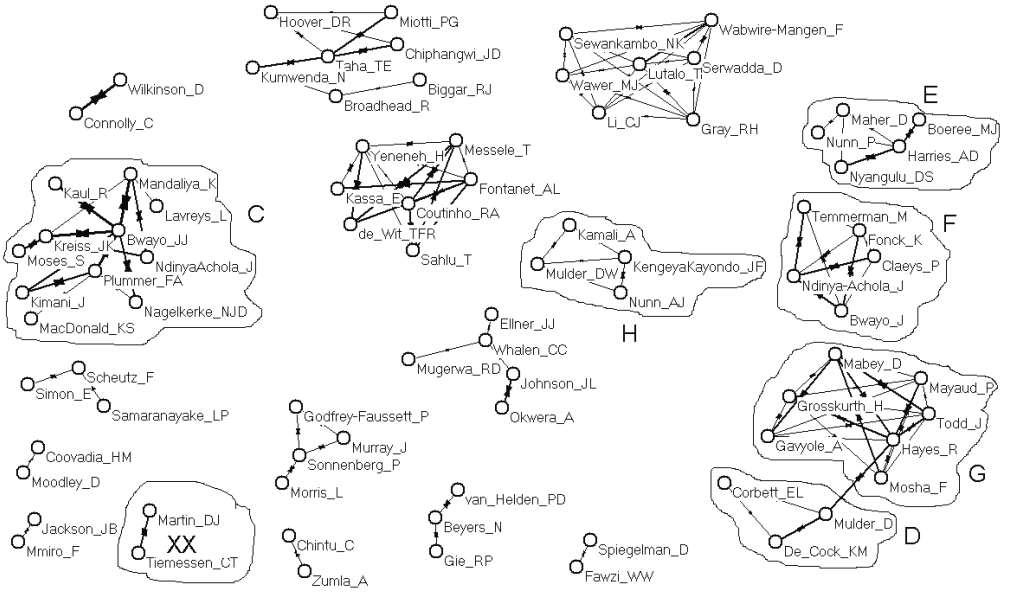

Figure 5: Author co-authorship networks: 1996-2000

1-year slices	*c | cc | ccv*	*space*	*nodes*	*links*
1996-1996	*4 | 4 | 0.15*	*1362*	*19*	*6*
1997-1997	*4 | 4 | 0.15*	*1654*	*43*	*41*
1998-1998	*4 | 4 | 0.15*	*1728*	*44*	*12*
1999-1999	*4 | 4 | 0.15*	*2084*	*72*	*56*
2000-2000	*4 | 4 | 0.15*	*2474*	*84*	*37*

4.6 Author Collaboration Networks Of HIV/AIDS Literature In Eastern And Southern Africa: 2001-2005

Figure 6 provides 18 co-authorship networks for the period 2001-2005. Several of these networks (7 out of 18) existed in, or comprised authors who had formed some of the networks between 1996 and 2000. These are marked I-O. It should, however, be noted that most of these networks contained a number of names that did not feature in the previous year-period(s). Take for instance network N. The network was thought to have originated from the network marked XX in Figure 5. At the time (i.e. 1996-2000), the network contained two names (i.e. Martin DJ and Tiemessen CT) in 1996-2000. By 2001-2005, the number of the participating authors had grown to 5. Four of the names were new. Similarly, network K comprised two names (i.e. Fawzi WW and Spiegelman D) in 1996-2000. This pattern of previously active authors sometimes appearing to disappear from the collaboration scene with new ones entering into partnerships with a few of the remaining authors is true in most networks throughout the period of study. Just as in 1996-2000, 2001-2005 produced only one strength value that was above 0.5. A tie strength value of 0.56 was recorded by Kuhn L and Coutsoudis A. The rest of the ties produced strength values less than 0.5.

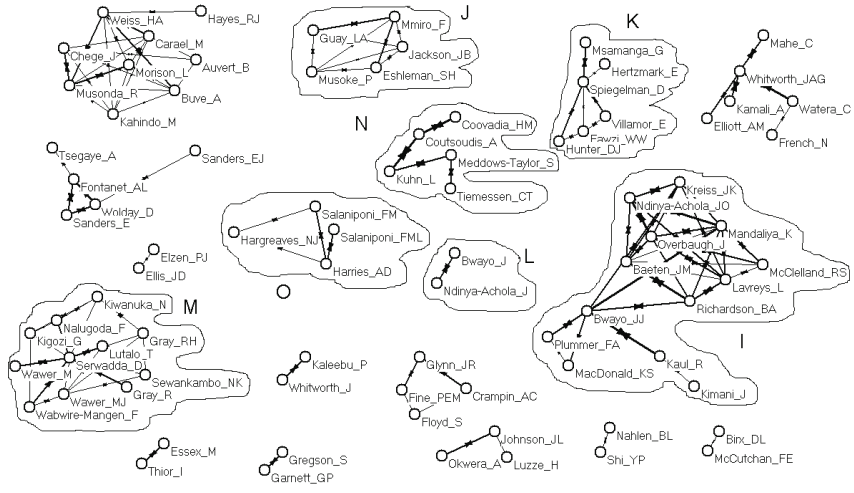

Figure 6: Author co-authorship networks: 2001-2005

1-year slices	*c | cc | ccv*	*space*	*nodes*	*links*
2001-2001	*5 | 5 | 0.15*	*2671*	*69*	*54*
2002-2002	*5 | 5 | 0.15*	*2848*	*55*	*19*
2003-2003	*5 | 5 | 0.15*	*3092*	*41*	*15*
2004-2004	*5 | 5 | 0.15*	*3692*	*70*	*50*
2005-2005	*5 | 5 | 0.15*	*3128*	*29*	*14*

4.7 Geographic Regions Of Research Focus Of Author Co-Authorship Networks, 1981-2005

Figure 7 provides an illustration of several author collaborative networks in Eastern and Southern Africa for the entire period of study (i.e. 1980-2005). Threshold requirements were set at 7 citations, 7 co-citations and a co-citation coefficient of 0.2. There were a total of 16 networks labeled A to O, in descending order (i.e. according to the number of authors in each network). The figure shows that the sizes of the networks ranged from 2 to 48 authors. It identifies the largest network, i.e. A, as consisting of 48 authors, while the smallest network has 2 authors.

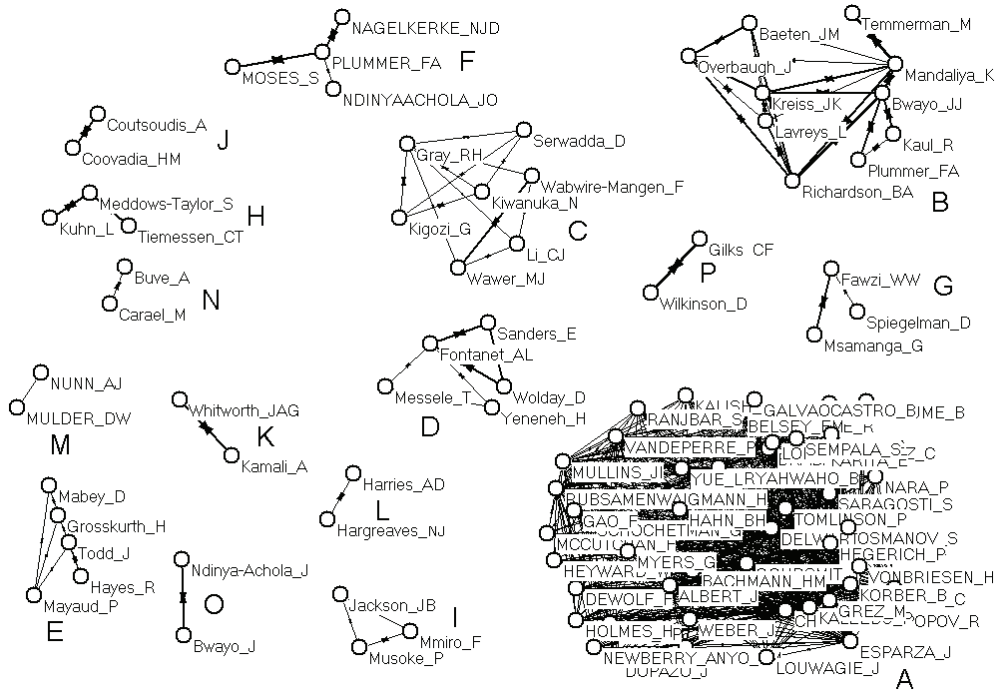

Figure 7: Author co-authorship Networks, 1981-2005

Thresholds: c = 7, cc=7, ccv = 20 (or .20), nodes = 103, E = 1194

In considering the composition of the networks in Figure 7, it was found that network A consisted of authors from a number of different institutions and countries. It has the largest number of authors as well as the broadest geographical coverage. The authors' country and institutional affiliation include, but are not limited to: South Africa (e.g. Bachmann HM, University of the Orange Free State, Dept of Community Health; and Holmes H, University of the Western Cape, Faculty of Dentistry), Sweden (e.g. Albert J, Karolinska Inst, Swedish Inst Infect Dis Control & Microbiol, Dept Virol; Fenyo EM, Karolinska Inst, Microbiol & Tumorbiol Ctr) and the USA (e.g. Gao F, Duke Univ, Med Ctr, Dept Med; Hahn BH, Univ Alabama, Dept Med; Korber B, Los Alamos Natl Lab; Delwart EL, Blood Syst Res Inst; Mullins JI, Univ Washington, Sch Med, Dept Microbiol). Others include Holmes H (Imperial Coll Sch Med, Chelsea & Westminster Hosp, Dept Immunol, London, England), Kaleebu P (Uganda Virus Res Inst, MRC, Programme AIDS Uganda, Entebbe, Uganda), Lopez-Galindez C (Inst Salud Carlos III, Ctr Nacl Microbiol, Madrid, Spain), Luo CC (Zhejiang Univ, Key Lab Mol Design & Nutr Engn, Ningbo Inst Technol, Ningbo, China), Osmanov S (WHO, UNAIDS HIV Vaccine Initiat, Geneva, Switzerland), Saragosti S (INSERM, IMEA, Paris, France), and Esparza J (WHO, UNAIDS HIV Vaccine Initiat, Geneva, Switzerland). The authors' research focus was Uganda.

Network B, which is the second largest author network, consisted of ten authors who met the threshold requirements. They include Baeten JM (Univ Washington, Dept Epidemiol, Seattle, USA), Bwayo J (Univ Nairobi, Dept Med Microbiol, Mombasa, Kenya), Kreiss JK (IARTP, Seattle, USA), Lavreys L (Univ Washington, Dept Epidemiol, Seattle, USA), Mandaliya K (Coast Prov Gen Hosp, Mombasa, Kenya), Overbaugh J (Fred Hutchinson Canc Res Ctr, Div Human Biol, Seattle, USA), and Plummer FA (University of Manitoba, Dept of Medical Microbiology, Canada). Others in this collaborative network are Richardson BA (Richardson BA (Univ Washington, Dept Biostat, Seattle, USA) and Temmerman M (State Univ Ghent, Dept Obstet & Gynaecol, ICRH, Ghent, Belgium). This group of authors mainly focused on HIV/AIDS in Kenya.

Network C – whose focus was Uganda – brought together authors from the USA and Uganda. These authors include Kiwanuka N (Uganda Virus Res Inst, Rakai Project, Entebbe, Uganda), Wawer MJ (Columbia Univ, Mailman Sch Publ Hlth, New York, USA), Wabwire-Mangen F (Makerere Univ, Inst Publ Hlth, Kampala, Uganda), Gray RH (Johns Hopkins Univ, Bloomberg Sch Publ Hlth, Dept Populat & Family Hlth Sci, Baltimore, USA) and Serwadda D (Johns Hopkins University, USA). Uganda was also the country of focus in network I, where the main players were Jackson JB (Johns Hopkins University, Baltimore, USA), Mmiro F (Makerere University, Dept Obstet & Gynaecol., Kampala, Uganda) and Musoke P (Makerere Med Sch, Dept Paediat & Child Hlth, Kampala, Uganda).

Network D focused on Ethiopia, while research activities of networks E and G centered on Tanzania and network F concentrated on HIV/AIDS research in Kenya. The main participating collaborators in Ethiopia were Fontanet AL (Inst Pasteur, Emerging Dis Epidemiol Unit, Paris, France) and Wolday D (Ethiopian Hlth & Nutr Res Inst, Ethio-Netherlands AIDS Res Project, Addis Ababa, Ethiopia), among others. Tanzania's key collaborators in network E were Mayaud P (Univ London London Sch Hyg & Trop Med, Dept Infect & Trop Dis, London, England), Todd J (Univ London London Sch Hyg & Trop Med, London, England), Hayes RJ (Univ London London Sch Hyg & Trop Med, Dept Infect & Trop Dis, London, England), Mabey D (Univ London London Sch Hyg & Trop Med, Dept Infect & Trop Dis, Clin Res Unit, London, England), and Grosskurth H (Univ London London Sch Hyg & Trop Med, Dept Infect & Trop Dis, London, England). Network G has Msamanga G (Muhimbili Univ, Coll Hlth Sci, Dept Community Hlth, Dar es Salaam, Tanzania) and Fawzi W (Harvard Univ, Sch Publ Hlth, Dept Nutr, Boston, USA). Moses S (University of Manitoba, Dept Med Microbiol Winnipeg, Canada), Plummer FA (University of Manitoba, Dept of Med Microbiol, Canada), Ndinya-Achola JO (University of Nairobi, Kenya) and Nagelkerke NJD (University of Manitoba, Dept of Med Microbiol, Canada) are the key authors in network F whose focus was Kenya.

Other networks (J-P) largely consisted of two collaborators, and their main countries of research focus were as follows: J – South Africa, K – Uganda, L – Malawi, M – Uganda, N – Zambia, and O – Kenya. Although their centers of research activity were not clearly identified in this study, each group of authors can be said to be involved in research in the countries being researched. The results also show that Uganda produced the highest number of author networks (i.e. 5), followed by Kenya (3); while South Africa and Tanzania produced two networks each. Ethiopia, Malawi and Zambia were each represented in one collaborative network.

4.8 Most Productive Pairs Of Authors

The highest contribution between two authors came from Ndinya-Achola JO and Plummer FA, who contributed 46 papers, followed by Wawer MJ and Serwadda D (44), Gray RH and Serwadda D (43), and Gray RH and Wawer MJ (42). The rest of the top 10 two-author collaborators were as follows: Richardson BA and Kreiss JK (39); Overbaugh J and Kreiss JK (38); Mandaliya K and Kreiss JK (38); Mmiro F and Jackson JB (37); Plummer FA and Bwayo JJ (36); Plummer FA and Negelkerke NJD (32); and Lavreys L and Mandaliya K (32).

Table 2: Most productive collaborations (N = 6367)

No.	Rank	Author-A	Author-B	No of records	Percentage
1	1	Plummer FA	Ndinya-Achola JO	46	0.72
2	2	Wawer MJ	Serwadda D	44	0.69
3	3	Serwadda D	Gray RH	43	0.68
4	4	Wawer MJ	Gray RH	42	0.66
5	5	Richardson BA	Kreiss JK	39	0.61
6	6	Overbaugh J	Kreiss JK	38	0.60
7	6	Kreiss JK	Mandaliya K	38	0.60
8	7	Mmiro F	Jackson JB	37	0.58
9	8	Plummer FA	Bwayo JJ	36	0.57
10	8	Serwadda D	Sewankambo NK	36	0.57
11	8	Harries AD	Salaniponi FM	36	0.57
12	9	Wawer MJ	Sewankambo NK	35	0.55
13	10	Sewankambo NK	Gray RH	35	0.55
14	11	Biberfeld G	Mhalu F	33	0.52
15	12	Plummer FA	Nagelkerke NJD	32	0.50
16	12	Nagelkerke NJD	Plummer FA	32	0.50
17	13	Overbaugh J	Mandaliya K	31	0.49
18	14	Mmiro F	Ndugwa C	30	0.47
19	15	Coovadia HM	Coutsoudis A	29	0.46
20	15	Grosskurth H	Hayes R	29	0.46

5 Conclusions And Recommendations

Generally, it is noted that there has been a continued growth in the number of collaborative networks. The networks grew from just two in 1981-1985, to a total of 18 in 2001-2005, accounting for a growth rate of about 800%. Obviously there were more networks than these since the networks that are presented in Figures 2 to 7 are only

those that met specific threshold requirements. This growth pattern of collaborative networks could be attributed to several reasons, chief among them, the complexity as well as cost of HIV/AIDS research. This, compounded by the lack of a cure for the disease, may have led researchers to seek alliances. The pattern may have also been caused by more students (particularly post-graduates) jointly authoring papers with their academic promoters. Other factors that generally influence collaboration amongst researchers include personal reasons (e.g. trust, expertise, social networks, personal compatibility, common professional traits); resource-related factors (e.g. support from funding agencies, support from scientists' institutions, literature, scientific publishing, students, time); motivational factors (e.g. learning and teaching, new discoveries, fun, external rewards); and "common ground" factors (e.g. physical proximity, research organizations, disciplinary bias, discipline-specific languages, bridges), etc (Maglaughlin & Sonnenwald 2005:507).

Figures 2 to 6 also indicate that a number of collaborative networks have recently emerged, while several others that previously existed have disappeared, or are on the verge of disappearing, from the most active author networks. It would be interesting to investigate the factors that cause or might have caused such patterns. We speculate that this phenomenon could be caused by the completion of a project, which would mean that researchers do not have any reason for continued cooperation, unless they register for further projects. This includes post-graduate students' projects which are largely conducted jointly with promoters. Once the students complete their studies, they are likely to discontinue their research collaboration with their promoters. Although very rare, the non-completion of a project due to factors such as the misappropriation of research funds, mistrust, dissatisfaction on the part of some researchers, etc., may also cause the break up of a collaborative network. Sometimes, author networks can be dissolved when their participants form new alliances, become incapacitated or die. Finally, donor funding may dictate the type of researchers who are incorporated into a network. These factors, and many others, also may have influenced the movement of some researchers from one network to another. None of these factors could, however, be confirmed from the analyses in Figure 2 to 6. Great caution is necessary when making generalized observations and conclusions given that the networks in Figure 2 to 6 were only those that met the threshold requirements. Some of the authors may have continued to participate in their respective author networks, but perhaps did not meet the set thresholds and therefore did not feature in the illustrations. It could not, therefore, be concluded that certain researchers had totally disappeared. They may have become less active.

The composition of the social networks reflects a high pattern of collaboration between local and foreign researchers. The study has shown that collaboration is gaining

recognition, perhaps as a result of the benefits associated with it. HIV/AIDS research in the region is currently being conducted largely through collaboration. Countries in the region are therefore encouraged to continue supporting collaborative ventures in HIV/AIDS research given that research collaboration increases research impact, among other benefits. They should encourage both internal and international collaboration – the latter being for purposes of international visibility and impact – by (for example) organizing international conferences within Eastern and Southern Africa during which researchers can exchange ideas, and in so doing, identify researchers from other countries with whom they can collaborate. Conferences can also be held to find out ways of strengthening collaboration in HIV/AIDS research. A few conferences have previously been organized and held in order to discover ways and means of strengthening HIV/AIDS research collaboration between the developed countries and Africa. One such conference was organized by the Africa Program of the Center for Strategic and International Studies (CSIS) and the Brookings Institution's Center on the United States and France (CUSF); to find ways of strengthening U.S-French collaboration on HIV/AIDS in Africa. The aim was to identify new opportunities for active collaboration between France and the United States in combating HIV/AIDS in Africa. The focus areas included the importance of HIV/AIDS to U.S. and French foreign policy and security assessments, the disease's likely destabilizing impact on African states, the role of the Global Fund to fight AIDS, TB, and Malaria, and the need for closer collaboration between U.S, French, and African researchers, policy makers, and program implementers. It was noted that local participation was highly necessary in order for any successful research collaboration effort to take place (Morrison & Gordon 2001).

Concerning future HIV/AIDS research collaborations, this study may assist researchers in identifying potential collaborators as opined by Boyack (2007). Boyack (2007) argues that potential collaborators can be identified by way of visualizing patterns of co-authorships using social networks in one or more disciplines. He does, however, hasten to add that:

> "Just because a potential collaboration is identified based on a common topic focus, this does not necessarily mean that collaboration should occur. Many factors are typically considered when choosing collaborations, including funding, detailed skill sets, and personal relationships" (Boyack 2007:134)

The following should form an agenda for further research:

1. To what extent do conferences and other similar gatherings of researchers affect HIV/AIDS research collaboration?
2. How much of the 'networking' at conferences results in active collaborations?
3. What are the main sub-fields of HIV/AIDS research represented in each social network?

4. What are the relationships represented by the links in each social network? Are the authors' colleagues in the same department, student and lecturers, colleagues in the same institution, etc?

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