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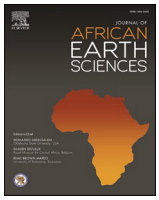

Quantitative datasets reveal marked gender disparities in Earth Sciences faculty rank in Africa

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ABSTRACT

As in most disciplines of science, technology, engineering, mathematics and medicine (STEMM), gender disparity is prevalent in the ranking of Earth Sciences faculties at senior and advanced levels. (i.e., Associate and Full Professors). In this study, a robust database was mined, created, and analyzed to assess the faculty compositions of 142 Earth Science departments in 39 countries across Africa. The data were collected from verifiable online resources focusing on ranks and gender ratios within each department. The studied earth science departments cut across universities in northern, southern, central, eastern, and western Africa. Our data revealed that female faculty members are predominantly underrepresented in most of the departments documented and are markedly uncommon in senior positions such as Professors, associate Professors, and senior researchers compared to their male counterparts. On the contrary, female faculty members are predominant in the lower cadres, such as lecturers, teaching, and graduate assistants. The observed male to female ratio is 4:1. At the base of this gender gap is the lower enrolment of female students in Earth Science courses from undergraudate to graduate studies. To achieve gender equality in Earth Science faculty composition in Africa, we recommend increasing female students' enrollment, mentoring, awareness, timely promotion of accomplished female researchers, and formulation of enabling government policies. More work-related policies that guarantee work-life balance for female earth science academic professionals should be formulated to attract and retain more women into Earth Sciences careers.

1. Introduction

In the last few decades, there has been a growing interest in academic rank, especially in gender disparity (Alper, 1993; Fox, 2020; Shaw and Stanton, 2012). Several works have shown a wide gap and disproportionate decline in academic rank between males and females (Alper, 1993; Card and Payne, 2021; Holman et al., 2018; Smart, 1991; Xu, 2008). Although women are progressively studying Science, Technology, Engineering, Mathematics, and Medicine (STEMM) courses at undergraduate levels (Holman et al., 2018), they still take a minority position in academic staffing and ranking (Aguirre Jr, 2000; Knights and Richards, 2003; Menges and Exum, 1983; Pyke, 2013; Walker et al., 2020). Women faculty members particularly remain significantly underrepresented at the senior professorship levels (Austen, 2004; Booth et al., 2000; Huang et al., 2020; Mixon and Treviño, 2005; Mumford, 2000; Ward, 2001). They are also less often trained in top research groups, are impeded during faculty promotion, and are often more than men likely to leave STEMM careers (Clark Blickenstaff, 2005; Holman et al., 2018; Moors et al., 2014; Xu, 2008).

In several fields of STEMM, women's underrepresentation in higher faculty ranks is ubiquitous and pervasive as compared to the humanities and social sciences. This is probably because men dominate the STEMM fields while women are clustered in the social sciences, humanities and health sciences (Charlesworth and Banaji, 2019; Fry et al., 2021; Wang and Degol, 2017). For example, in the US, between 2008 and 2020, there was a significant rise in the overrepresentation of males at higher academic ranks in academic psychiatry faculty appointments, with females increasing in proportion at lower academic ranks (Chaudhary et al., 2020). Similar trends are known in other disciplines of medicine such as anesthesiology (Pashkova et al., 2013), hematology and oncology (Riaz et al., 2020), and neurology (McDermott et al., 2018). This gender gap in faculty ranks is not restricted to medicine but also extended to other Science, Technology, Engineering, and Mathematics fields both in the US and the rest of the world (Casad et al., 2021; Huang et al., 2020; Kalender et al., 2019; McCullough, 2019; McDermott et al., 2018).

In the Earth sciences (e.g., geology, geophysics, oceanography, hydrology, meteorology, climatology etc.), gender disparity in faculty ranks is also known but scarcely reported and documented especially in Africa. Most previous works discussing gender disparity or the so-called leaky pipeline in the Earth sciences come from the US (Dutt et al., 2016; Holmes et al., 2008; Popp et al., 2019; Stokes et al., 2015). Other studies elsewhere are scanty and mostly focused on understanding the structure of Earth science academia, population or numbers of women Earth Science academic professionals, women's views and choices, academic metrics, productivity/publication puzzle, and women representation in professional organizations (Handley et al., 2020; Henriques and Garcia, 2022; Holmes et al., 2008; Nature Geoscience Editorial, 2016; Piccoli and Guidobaldi, 2021; Pico et al., 2020; Witze, 2016). Studies on gender disparity or imbalance in Africa STEMM disciplines and the Earth sciences are uncommon, and the few works known or published are restricted to fields such as mathematics (Ouedraogo et al., 2021), geography (Awumbila, 2007), and specific topics (Fru et al., 2021; Owili et al., 2018).

To fulfill this gap in research, this study, therefore, performed a gender versus cadre analysis (GVCA) of 3316 faculty members in 39 countries in Africa to understand the current ratios of male to female faculty members (Fig. 1, supplementary data). The investigated Earth sciences departments largely represent different cultures and regions of Africa as the data here were mined from 142 universities in northern (43), western (40), central (15), eastern (31), and southern Africa (13). Using insights from a secondary database on current student enrolment,

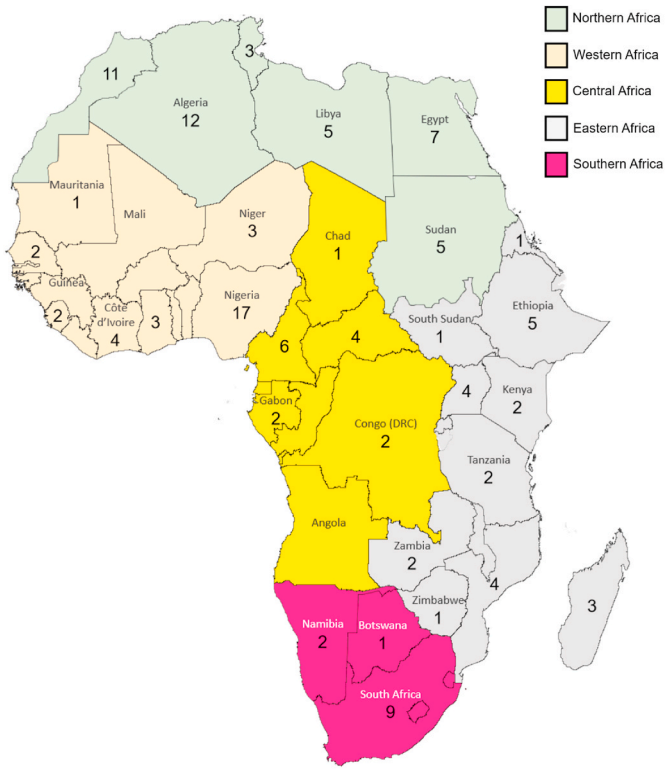

Fig. 1. Map of Africa showing the distribution of Earth science departments per country as collected from online sources and search engines such as

we further identified low female intake as a primary factor responsible for the lower engagement of females as faculty members in Earth sciences departments in some of these countries. Importantly, our results show two distinct disparities, (a) a lower number of female faculty members versus a higher number of male faculty members and (b) a lower number of females in top faculty positions (more in lower cadres) versus a higher number of males in top faculty positions (more minor in lower cadres). Hence, the new knowledge from this study showed marked gender disparity/imbalance in Earth sciences faculty ranks and enrolments in Africa and the need to take action to avert the trend immediately.

2. Data collection and methods

The approach used in this study was entirely based on evidence-based research. The data analyzed in this work were collected and mined online between July 1 to November 30, 2020, and sourced from academic databases, search engines, and available websites of individual universities offering Earth science courses in Africa. The main information collected for this study was the composition/ranks of faculty members (teaching, non-teaching, technical and administrative), their gender, and their ranks. In our data collection, we ensured that (a) several countries in different geographical regions of Africa, i.e., north, west, central, south, and east, were covered (b) institutions or universities offering Earth sciences in each country were assessed and, (c) that the number of male to female faculty members in each department was assessed (Supplementary data I and II). A secondary data from an electronic survey (Supplementary data III) was analyzed to further investigate the primary cause of gender disparity in Africa. The survey was administered online between November 1, 2019, to March 31, 2020, for current and graduate students of Earth science in Africa and students of African origin who had some Earth science education in Africa before moving to the diaspora. The electronic survey was done online using google forms and completed anonymously. Furthermore, all the collected data were analyzed using IBM SPSS Statistics 20 and Microsoft® Excel ® for Office 365 software, with emphasis on descriptive statistics such as mean, ratios, and percentages.

The main challenges during the data collection are (a) language barrier, (b) lack of data from 17 countries, and (c) lack of or incomplete data on gender in some of the assessed countries. Language was a major issue in accessing websites in some western and northern African countries, where the websites were written in Arabic, French, and Portuguese. In other countries, most websites have incomplete information or are not recently updated (Supplementary data). Hence, some ranks and gender were tagged 'U' i.e., unknown'. An important caveat to mention here is that gender for some faculty members was also determined based on the profile pictures presented on their departmental websites. In places like Egypt, Tunisia, and Morocco, the profile pictures of women faculty members mainly were not displayed, possibly for religious reasons. We understand that the final data presented here may not entirely represent current events in the whole of Africa. However, the significant gender-based insights shown in the data and the inclusion of data from major developing African countries, where Earth science courses are being taught, permit a valid statement and conclusions to be made on the data.

2.1. Variation in titles and homogenization of faculty ranks

An obvious inconsistency in faculty ranking systems exists across all the Earth sciences departments investigated and in different parts of Africa. For example, the Earth sciences departments in South Africa and Tunisia use ranking systems that are quite different from the other countries (Fig. 2). Titles such as Honorary Professor, Head of the department, and temporary Research Professor are used to describe Professorial positions in South Africa. At the same time, lecturers are named Junior lecturer, nGAP lecturer, extraordinary lecturer, honorary

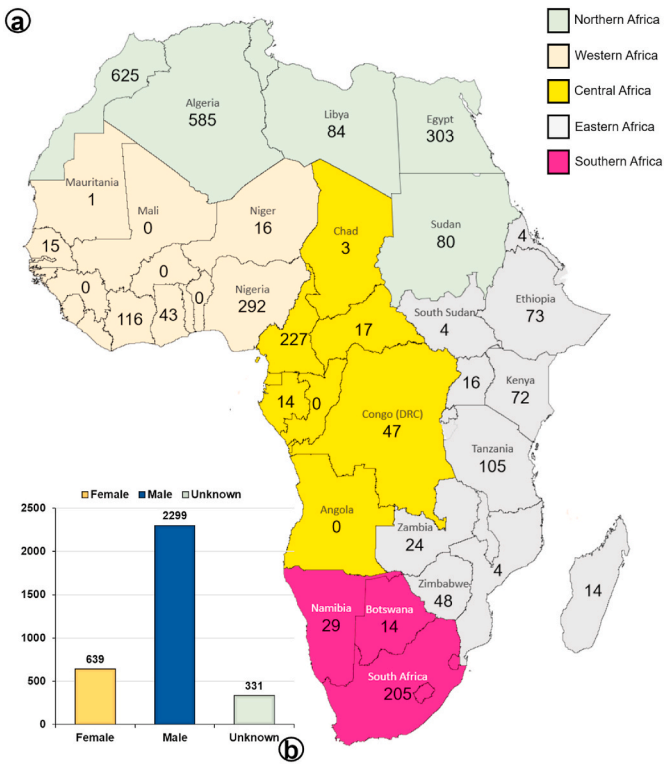

Fig. 2. (a) Map of Africa showing the distribution of Earth Science faculty members per country and (b) Histogram showing the gender of the documented faculty members in (a).

Lecturer, and researcher, and PT lecturer. In Tunisia, Baccalaureate +6 and Assistant Master describe graduate assistant positions. Hence, it was important to use a common ranking system for the analyses presented here. The ranks were first categorized according to their levels or equivalents and acronymized for ease of analyses, and discussion. Therefore, researchers are tagged 'R' and include ranks such as researcher, specialist, research geologist, and research assistants. The rank 'SR' includes principal researchers, senior research fellows, and research chairs, while GA are graduate assistants, graduate assistant III, graduate assistant III, graduate assistant I, demonstrators, tutors, master students, instructors, assistants, technical graduate assistants, tutorial fellows, teachers, teaching fellows, qualified graduate assistants, Masters graduate assistants, and Baccalaureate +1. The non-teaching academic staff (NA) include laboratory technicians, departmental administrators, staff development fellows, chief technicians, secretaries, museum curators, senior technicians, and staff associates. At the senior academic cadre, Profs or Professors include Deputy Dean, Head of School, Dean, Honorary Prof, and Research Director. Lecturers (L) are NGAP Lecturer, Extraordinary Lecturer and Honorary Lecturers (all three ranks commonly used in South Africa), junior lecturers, and adjunct lecturers, while PR are assistant postgraduate researcher I, Assistant postgraduate researcher II, Master assistants, postgraduate researchers, and assistant postgraduate researchers. In summary, the main acronyms include E Prof for Emeritus Professors, Prof for Professors, Ass Prof for Assistant Professors, Asso Prof for Associate Professors, R for Researchers, SL for Senior Lecturers, SR for Senior Researchers, L for Lecturers, AL for Assistant Lecturers, GA for Graduate Assistants, L1 for lecturer 1, L2 for lecturer 2, NA for non-academic staff, PhD for PhD candidates, PR for postgraduate researchers and U for Unknown.

3. Results

3.1. Compositions of earth science faculties in Africa

A total of 3269 Earth science faculty members from 39 countries and 142 universities were analyzed for their gender and ranks (Figs. 1 and 2). Among these countries, Nigeria has the highest number of universities (17) followed by Algeria (12), Morocco (11), and South Africa (9), respectively (Fig. 1 and Table 1). Countries with the least number of universities offering Earth sciences and related courses are Botswana, Cape Verde, Chad, Djibouti, Eritrea, Eswatini, Liberia, Mauritania, Seychelles, and South Africa, Sudan, and Zimbabwe. These are mostly countries in eastern, central, and western Africa (Fig. 1). No data were found on Angola, Sao Tome and Principe, Congo Brazzaville and Equatorial Guinea in Central Africa, Burundi, Comoros, Rwanda in Eastern Africa, Lesotho in Southern Africa, and Togo, Mali, Guinea, Burkina Faso, Benin, and Guinea Bissau in Western Africa. In the case of Angola, the available information was mostly in Portuguese. In terms of Earth science faculty members, the countries with the highest number of academic staff are Morocco (625), Algeria (585), Nigeria (292), Cameroon (227), and South Africa (205) in that order (Fig. 2, Table 1, Supplementary data I and II). Notably, the Université des sciences et de la technologie d'Alger and Houari Boumediène in Algeria accounts for the highest number (227) of faculty members documented in this work followed by University of Yaounde I in Cameroon (119), Sidi Mohamed Ben Abdellah University, Fes in and Cadi Ayyad University, Marrakech, both in Morocco (95 and 95 faculty members, respectively).

3.2. Gender of faculty members per country

Of the 3269 Earth Science faculty members documented, 2299 of them are males while 639 are females (male to female ratio of 4:1). Significantly, more male academic staff are markedly in Morocco, Algeria, South Africa, Uganda, Gabon, Kenya, Cape Verde, Eritrea, and Namibia (Fig. 3a and b). In fact, the countries with the highest faculty members do not necessarily fulfill the gender ratio of 4:1 that is expressed above. In Morocco, with 625 faculty members documented, 470 are males while 153 are females, with only two staff with unknown gender (Supplementary data I). Hence, the general ratio in Morocco is 3:1. Algeria, Nigeria, Cameroon, and South Africa have gender ratio of 2:1, 7:1, 3.5:1, and 2.7:1. Moreover, these countries also vary in terms of faculty members per capita, i.e., ratio of female academic staff members to the sum of all faculty members in each country, including the unknown. The faculty members per capita for Morocco, Algeria, Nigeria, Cameroon, and South Africa are 0.24, 0.37, 0.09, 0.19, and 0.27 (Figs. 4 and 5).

3.3. Faculty ranks per gender in Africa Earth Sciences departments

In Supplementary data II and Fig. 6, a summary of the ranks of the faculty staff members in the different countries is provided. The main ranks documented from all the universities are Emeritus Professor (39), Professors (368), Assistant Professors (10), Associate Professors (85), researchers (34), senior lecturers (166), senior researchers (16), assistant lecturers (120), graduate assistants (209), lecturers (366), lecturer 1s (89), lecturer 2s (87), non-academic staff (72), PhD candidates (504), postgraduate researchers (769), and several members with unknown ranks (U-335) that are not stated on the websites (Fig. 6). PhD candidates and postgraduate researchers who take both teaching and research duties constitute the highest documented group. Among the PhD candidates, 188 are females while 305 are males (gender ratio of 1.6:1). Eleven (11) PhD candidates with unknown ranks are documented (Fig. 6b). Among the postgraduate researchers, 590 are males, 177 are females (gender ratio of 3.3:1) and there are two (2) unknown ranks. In the other ranks, females are more present in lower cadres such as assistant lecturers, graduate assistants, lecturers, non-academic staff, PhD,

Table 1
Universities across African where the ranks of their Earth Sciences Faculty are presented in this work.

Country/University	No.
Algeria	**585**
Université de Khemis Miliana - Djilali Bounaama	15
Université de Batna 2 - Mustapha Ben Boulaid	30
Université de Tébessa - Larbi Tébessi	38
Université des sciences et de la technologie d'Alger, Houari Boumediène	227
Université de Annaba - Badji Mokhtar	55
Université de BouMerdès - M'haMed Bougara	46
Université de Constantine 1 - Frères Mentouri	9
Université de Jijel - MohaMMed Seddik Ben yahia	37
Université de Ouargla - Kasdi Merbah	47
Université de OuM El Bouaghi - Larbi Ben M'hidi	18
Université de Sétif 1 - Ferhat Abbas	41
Université d'Oran 2 - MohaMed Ben AhMed	22
Botswana	**14**
Univeristy of Botswana	14
Cameroon	**227**
University of Bamenda	12
University of Douala	20
University of Dschang	48
University of Maroua	11
University of Ngaoundere	20
University of Yaounde I	116
Cape Verde	**4**
University of Cape Verde	4
Central African Republic	**17**
Euclid University	4
Institut Superieur de Science	1
Institut Superieur de Technology	1
University of Bangui	11
Chad	**3**
University of N'DjaMena Chad	3
Cote d'Ivoire	**116**
Felix Houphouet Boigny University Cote D'Ivoire	53
National Polytechnique Institute Felix Houphouet Boigny	32
Universite Jean Lorougnon Guede Cote D'Ivoire	8
University of Nangui Abrogoua	23
Djibouti	**1**
University of Djibouti	1
DRC Congo	**47**
University of Kinshasa Congo	20
University of Lubumbashi Congo	27
Egypt	**303**
Al-Azhar University	7
Alexandria University	18
Assiut University	75
Benha University	11
Cairo University	79
Mansoura University	53
Tanta University	60
Eritrea	**4**
Eritrea Institute of Technology	4
Eswatini	**15**
University of Eswatini	15
Ethiopia	**73**
Addis Ababa University	15
Bahir Dar University	15
Mekelle University	13
Samara University	22
Wollo University	8
Gabon	**14**
École Normale Supérieure Libreville	7
Universite des Sciences et Techniques de Masuku	7
Gambia	**7**
Stafford University	1
University of Gambia	6
Ghana	**43**
University for Developmental Studies	10
University of Ghana	21
University of Mining and technology	12
Kenya	**72**
Kenyatta University	46
University of Nairobi	26
Liberia	**15**

(continued on next page)

Table 1 (*continued*)

Country/University	No.
Uni of Liberia	15
Libya	**84**
Misurata University	2
Sebha University	11
University of Benghazi	20
University of Tripoli	31
University of Zawya	20
Madagascar	**14**
Toliara University	1
University of Antananarivo	12
University of Tulear Madagascar	1
Malawi	**22**
Geological Survey Department	2
Malawi University of Science and Technology	7
University of Malawi	9
University of Malawi-The Polytechnic	4
Mauritania	**1**
University of Oregon	1
Mauritius	**4**
Middlesex University in Mauritius	1
Université des Mascareignes, Mauritius	1
University of Mauritius	1
University of Technology	1
Morocco	**625**
Abdelmalek Essaadi University, Tetouen	35
Cadi Ayyad University, Marrakech	90
Chouaib Doukali University, Eljadida	39
Hassan II University, Casablanca	72
Ibn Tofail University, Kenetra	38
Mohamed Ist University, Oujda	44
Mohamed V University, Rabat	82
Moulay Ismail University, Meknes,	60
Moulay Slimane University, Beni Mellal	23
Sidi Mohamed Ben Abdellah University, fes,	95
University of Ibno Zohr Agadir	47
Mozambique	**4**
Pedagogical University	1
The Technical University of Mozambique	1
Universidade Eduardo Mondlane	1
Zambezi University	1
Namibia	**29**
Namibia University of Science and Technology	18
University of Namibia	11
Niger	**16**
Abdou Moumouni University	1
Université Abdou Moumouni de Niamey	12
University of Difa	3
Nigeria	**292**
Adekunle Ajasin University (A.A.U.A)	21
Ahmadu Bello University (A.B·U)	23
Ajayi Crowther University (A.C·U)	6
Akwa- Ibom University (AKSU	8
Delta State University (DELSU)	10
Ebonyi State University (EBSU)	18
federal University of Akure (FUTA)	23
federal University of Akure (FUTA) (Applied Geology)	29
federal University of Oye- Ekiti (FUOYE)	12
federal University of Technology Owerri, (FUTO)	36
Ibrahim Badamosi Babangida University (IBBU)	5
Mountain Top University (M.T.U)	5
Niger Delta University (N.D.U)	12
Olabisi Onabanjo University (O·O·U)	5
University of Ibadan (U·I)	24
University of Nigeria (U·N·N)	22
University of Port Harcourt (UNIPORT)	33
Senegal	**15**
University Cheikh Anta Diop of Dakar	11
University Gaston Berger of Saint-Louis	4
Seychelles	**5**
University of Seychelles	5
Sierra Leone	**16**
Foural bay college University of Sierra Leone	14
Njala University	2
South Africa	**205**
Fort Hare University	7
University of cape town	12
University of Free state	40
University of Johannesburg	22
University of Limpopo	26
University of northwest	13
University of Pretoria	19
University of Venda	30
Wits	36
South Sudan	**4**
University of Juba	4
Sudan	**80**
The Future University	6
Alneelain University	49
International University of Africa	2
Sudan University of Science and Technology	1
University of Khartoum	22
Tanzania	**105**
University OF DAR ES SALAAM	42
University of Dodoma	63
Tunisia	**100**
University of Gabès faculty of Sciences of Gabès	17
University of Sfax	43
University of Tunis El Manar	40
Uganda	**16**
Makerere University	11
Islamic University of Uganda	1
Kampala International University	3
Mbarara University of Sciences and Technology	1
Zambia	**24**
The Copperbelt University	14
University of Zambia	10
Zimbabwe	**48**
University of Zimbabwe	48
Grand Total	**3269**

and postgraduate researchers. As for senior cadres, female Earth science faculty members are far less represented. For example, of the 39 Emeritus Professors, only one female is documented, while 15 females are recorded as compared to 293 male Professors of Earth sciences. This is a staggering 39:1 and 20:1 ratio. Same trend persists at the levels of Assistant and Associate Professors, Researchers, senior lecturers, and researchers (Fig. 6a). Remarkably countries with the highest numbers of academic staff also boast of the highest number of senior academic staff. Morocco has more Professors (370) than the other 38 countries, while Nigeria has the second-highest number of Professors (Supplementary data II).

3.4. Variation in gender and faculty ranks by country and region

In this section, further analysis of gender ratios from the countries with the highest numbers of Earth science faculty members is presented. Fig. 7 shows bivariate plots of ranks per country. The countries with the highest numbers of Earth science faculty members coincidentally also serve as representatives of the different regions, i.e., Morocco and Algeria (northern Africa), Cameroon (central Africa), Nigeria (western Africa), and South Africa (southern Africa). The data from Tanzania (105 academic staff) is analyzed for eastern Africa. The Earth Science academic staff in Morocco and Algeria are mostly male (Figs. 4 and 7). In Morocco, the documented ranks include PhD candidates (89 female, 142 males) and Postgraduate researchers, including 64 females and 328 males (Supplementary data I and II). The faculty members in Algeria are also predominantly male. They include graduate assistants (4 female, 1 male), lecturers (2 males), Lecturer 1 (19 females, 34 male), lecturer 2 (15 females, 25 males and 1 unknown), non-academic staff (1 female), PhD candidates (74 female, 94 males and 1 unknown), postgraduate researchers (105 females, 207 males), and 1 senior male researcher (Supplementary data I and II). Cameroon in Central Africa has 93 faculty members with unknown ranks, while a majority of the academic staff are PhD candidates (53) with some teaching or administrative duties in any

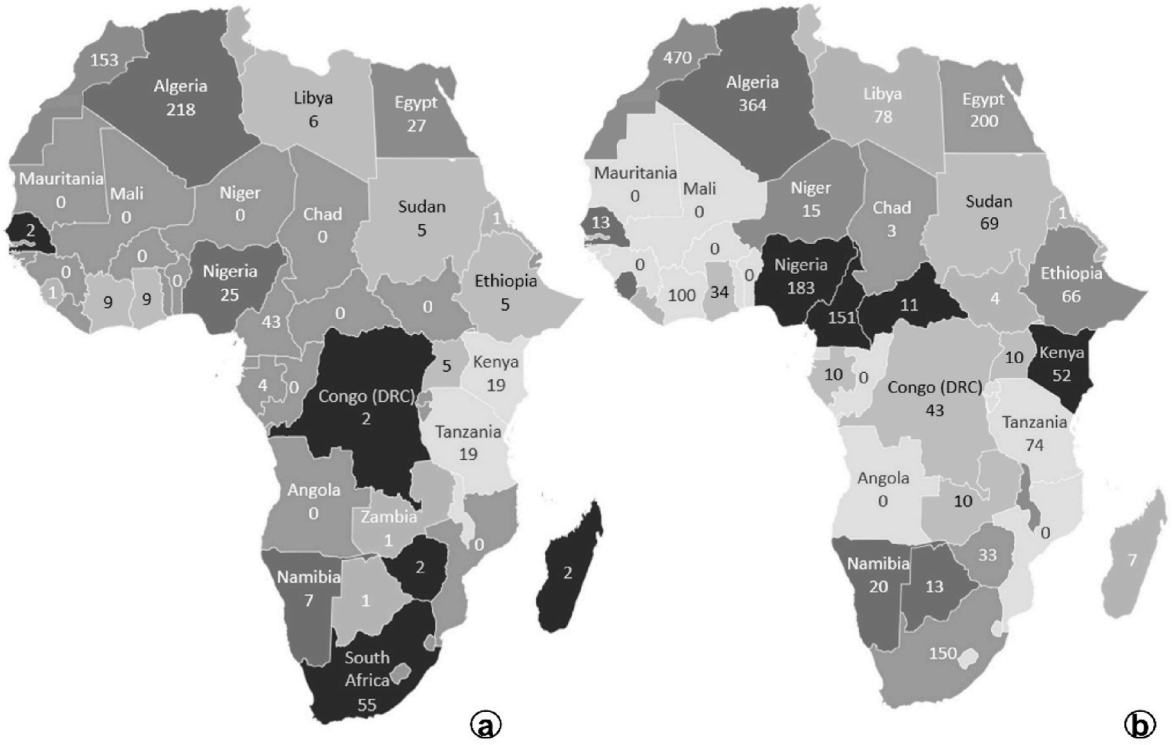

Fig. 3. (a) Number of female Earth Sciences faculty staff per country and (b) Number of Male Earth Sciences faculty staff per country examined in Africa.

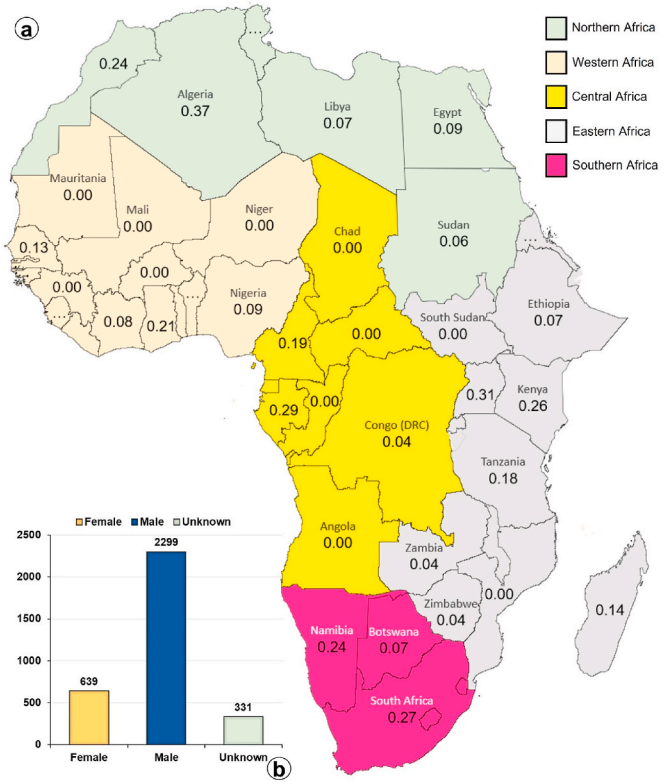

Fig. 4. (a) Faculty members per capita calculated as the ratio of female academic members of staff to the sum of the total number of faculty members in each country. (b) Histogram showing the gender of the documented faculty members in (a). *Note: Countries with 0.*00 had *no data available or useable online.*

of the universities (Supplementary data I and II). Other ranks include lecturers (32), Assistant lecturers (9), Professors (8), Associate Prof (10), Assistant Prof (2), Senior lecturers (13), and Graduate assistants (8). In terms of gender, there are more males than females across all ranks. At the professorship level, there is just 1 female professor compared to 7 male professors. In Nigeria, the academic staff are dominantly male, 64 Senior lecturers (male-43, female-2, unknown-19), 56 Professors (male-41, female-1, unknown-14), 19 Associate Professors (male-14, unknown-5), 44 lecturer II (male-22, female-4, unknown-18), 34 lecturer I (male-17, female-4, unknown-13). Others include 32 Assistant lecturers (male-16, female-7, unknown-9), and 16 Graduate Assistants (male-11, female-1, unknown-4). All the departments have 25 Technical staff (male-18, female-6, unknown-1), and 2 members with unknown ranks (male-1 and unknown-1). The gender balance in Tanzania and South Africa are not so different from the other countries. Male faculty members also dominate. The documented staff include 40 Assistant Lecturers (male-30, female-10), 28 Graduate Assistants (male-22, female-5, unknown-1), 12 lecturers (male-11 and unknown-1), 8 non-academic staff (male-2, female-1, unknown-5), 1 female PhD candidate, 4 male postgraduate researchers, 1 female and 1 male Professor, and 9 senior lecturers (male-5, unknown-4). In South Africa, the faculty composition of Earth science departments is more diverse than all the other countries (Supplementary data). The academic staff includes lecturers (85), Senior lecturers (40), Professors (51), non-academic staff (18), Associate Professors (5), and Senior Researchers (3). Of the 51 professors, 46 are males while 5 females (supplementary data).

4. Current and graduate students of Earth Sciences

795 graduate and current students across 36 countries participated in the online survey (Fig. 8). The highest number of respondents came from Nigeria (584, 73.46%), followed by South Africa (57, 7.17%) and Morocco (25, 3.14%). Out of the 795 respondents, 62% were males and 38% females (Fig. 9a). The respondents fell within four (4) age groups (Fig. 9b), with 371 (46.66%) in the <25 years age group, 322 (40.50%) within the 25–35 years group, 90 (11.32%) in the 35–45 age bracket,

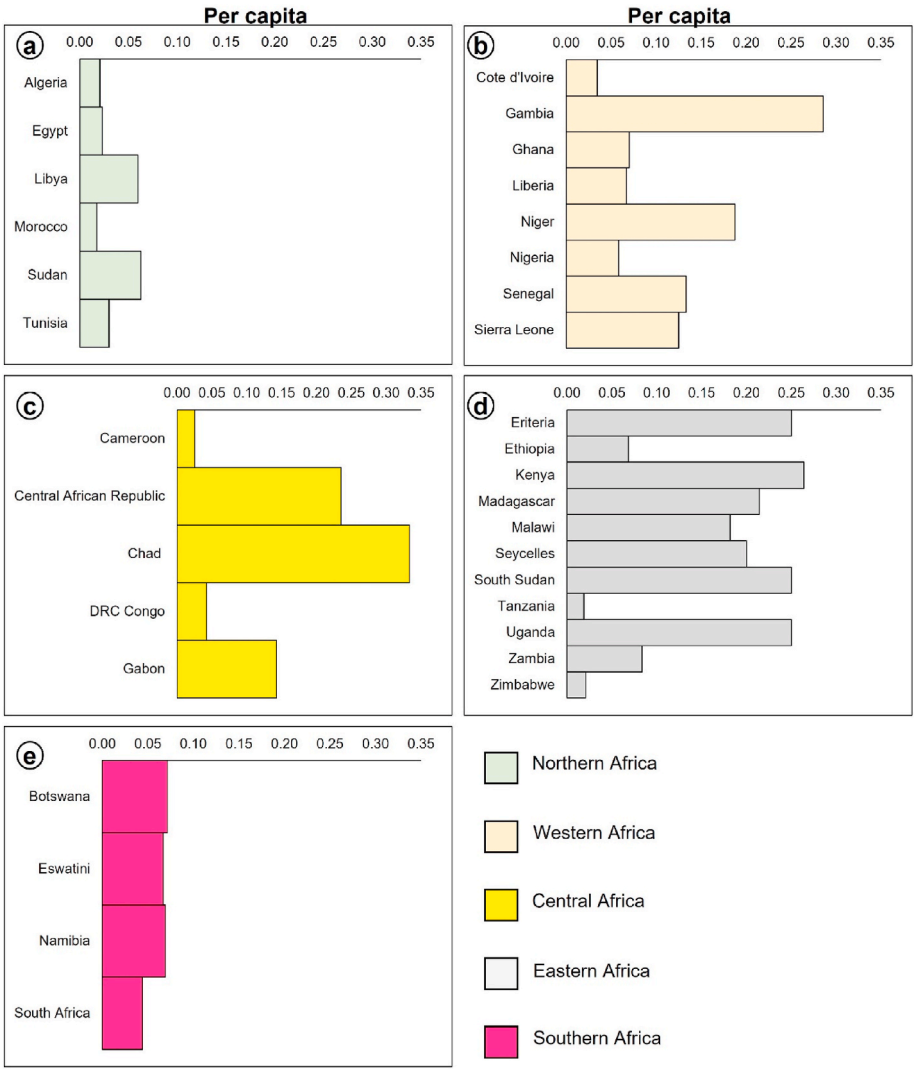

Fig. 5. Histogram showing the detailed 'faculty members per capita' in (a) Northern (b) Western (c) Central (d) Eastern and Southern Africa.

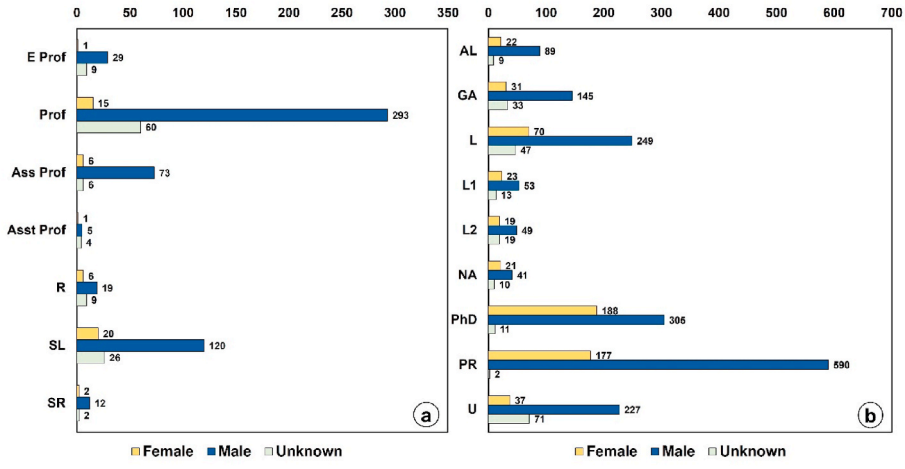

Fig. 6. Gender versus cadre analysis (GVCA) for (a) Senior faculty members and (b) Junior faculty members in Earth Science departments in Africa. Note: E Prof- Emeritus Professor, Prof- Professor, Ass-Assistant Professor, Asso Prof- Associate Professor, R- Researcher, SL-Senior Lecturer, SR-Senior Researcher, L-Lecturer, AL- Assistant Lecturer, GA-Graduate Assistant, L-Lecturer, L1-Lecturer 1, L2-Lecturer 2, NA- Non-academic staff, PhD-PhD candidate, PR- Postgraduate Researcher and U-Unknown.

and 12 (1.52%) within the >45 years age group (Fig. 9b). In terms of level of education (Figs. 9c), 500 (62.89%) have BSc or are currently undergraduate students, 208 have MSc (26.16%), 77 (9.68%) are PhD candidates, 7 (0.88%) Diploma students, 2 (0.26%) were classified as college students and 1 (0.13%) were at Higher National Diploma (HND) level. In addition, the students areas of specialization (Fig. 9d) were grouped into 11 categories, with a total of 439 (55.22%) respondents (180 females and 259 males) specializing in geology, 178 (22.39%, 50 females and 128 males) in geophysics, 43 (5.41%, 21 females and 22 males) in geochemistry, 34 (4.28%) in economic geology including

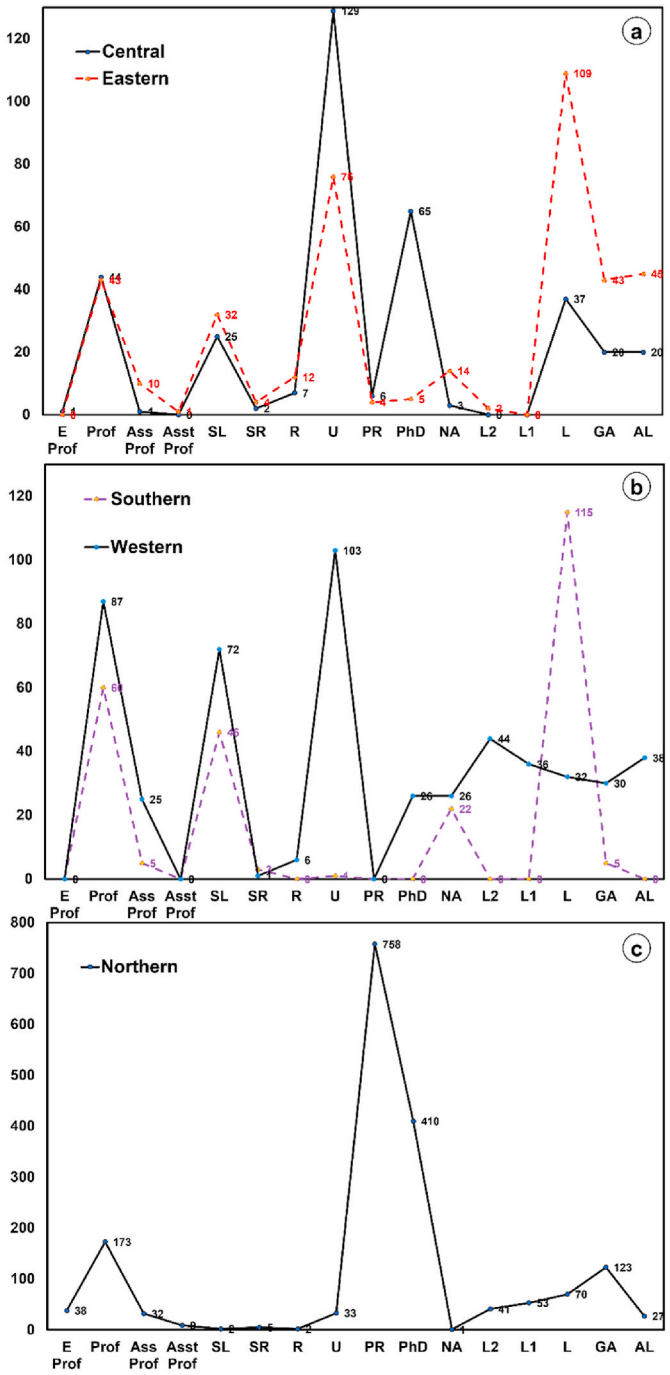

Fig. 7. Faculty members rank per region (a) Central and Eastern Africa (b) Southern and Western Africa and (c) Northern Africa. Strikingly, northern Africa accounts for the highest number of Emeritus Professors and Postgraduate researchers.

mining and renewable energy, 29 (3.65%, 9 females and 20 males) in hydrology, Engineering and Geotechnics had 33 (4.15%) respondents (9 females and 24 males), and paleontology with 2 male students (0.25%), 37 (4.65%) students (18 females and 19 males). Other areas of Earth science such as oceanography, and soil science have no respondents (Fig. 9d).

5. Discussion

Our results show that male faculty members dominate the majority of the Earth science departments examined and that there is a marked disparity in the ranks of the academic staff across these countries (Figs. 1–7). There are more males than females in top academic positions across all the Universities investigated (Figs. 5 and 6, Supplementary data I and II). This implies that female geoscientists are seldom employed in academia or have not advanced to the top cadres in Africa Earth sciences departments. To truly improve women's involvement in STEMM and Earth sciences, it is important to understand the factors impacting females' appointment, promotion, and growth in Earth sciences faculties. Generally, several factors have been proposed for 'leaky pipeline' or gender disparity in STEMM elsewhere. These include discrimination (Mixon and Treviño, 2005), lack of role models (Booth et al., 2000), career breaks (Asmar, 1999; Reed et al., 2003; Todd and Bird, 2000), reluctance among women to apply for promotion (Carvalho and Santiago, 2010; Ross-Smith et al., 2005), low representation of women on decision-making panels (Carrington and Pratt, 2003), and the concentration of women in areas that are less likely to attract funding (White, 2003). Although, it is impossible to attribute the gender disparity observed here in different parts of the continent to the same factors. Nonetheless, we identified certain issues that can likely influence disparity or lack of equity in male-female representation in the Earth sciences faculties in Africa. Apart from the general factors highlighted above, some of these factors peculiar to Africa may include underwhelming enrolment of female students into Earth sciences courses, cultural and religious practices towards girl child education, poverty, staff employment policies, opportunity for work-life balance, remuneration, and poor promotion practices against women.

5.1. Religion, culture, poverty, and low enrolment of females as root causes of leaky pipeline in African earth-sciences departments

Religious and cultural practices may contribute to the under-representation of females in the Earth Sciences in Africa. For example, during data collection, we observed that many female researchers in North African Universities do not have their pictures displayed on the websites of their respective departments. This practice may be guided by religious and cultural reasons in many Islamic societies (Abokhodair and Vieweg, 2016) since religious perspectives may hinder learning in science in general (Mansour, 2010; Reiss, 2010, 2014). Such practices may determine how easily females participate in the Earth sciences, which often involve exposure to fieldwork and gender intermixing. Moreover, practices that discourage girls' education are deeply rooted in some African cultures, especially in communities where girls are given out in child marriage (e.g., Petroni et al., 2017). This culture has perhaps limited the level of support or encouragement, e.g., lack of educational resources at home, shown to female children by their parents, teachers, or guardians in such communities, and may ultimately affect female participation in higher education and STEMM courses (Morley et al., 2007; Pantazis and Ruspini, 2006; Richardson, 2008).

Superstitious or irrational attitudes towards women and girls are an integral part of many cultures. For example, an old myth about women in mines, bringing bad luck is pervasive and widely practised in Africa and in many other cultures. As far back as the 1800s, female miners in Northern Africa and in Europe have been subjected to different discriminatory regulations (e.g., The, 1842 Mines Act) and segregation. Then, women are often perceived as bad luck for mining (Tallichet, 1995). This notion is unfounded and may be grounded because, historically, women have only been in mines in times of tragedy (e.g., Davies, 2006; Kraybill et al., 2010). In addition, women are often seen as fragile and unable to withstand the rigours and hazards associated with mines (Allman, 1975). These cultures could also explain the marked under-representation of women in Earth science research in Africa, particularly in fields like economic geology, mining and geotechnical engineering.

In addition, poverty is also a factor limiting girls' access to education, denying up to 130 million girls (aged 6 to 17) access to education in Africa (World Bank, 2022). This alarming estimate most likely stems

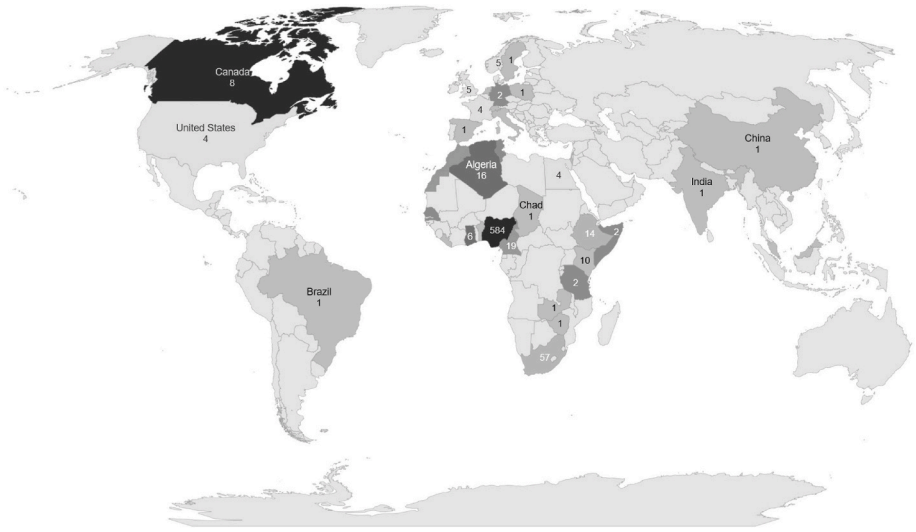

Fig. 8. Spread of respondents for current and graduate students plotted from the secondary survey (Supplementary data III). The color code is cosmetic and only used to differentiate countries with respondent from those where no respondents were recorded.

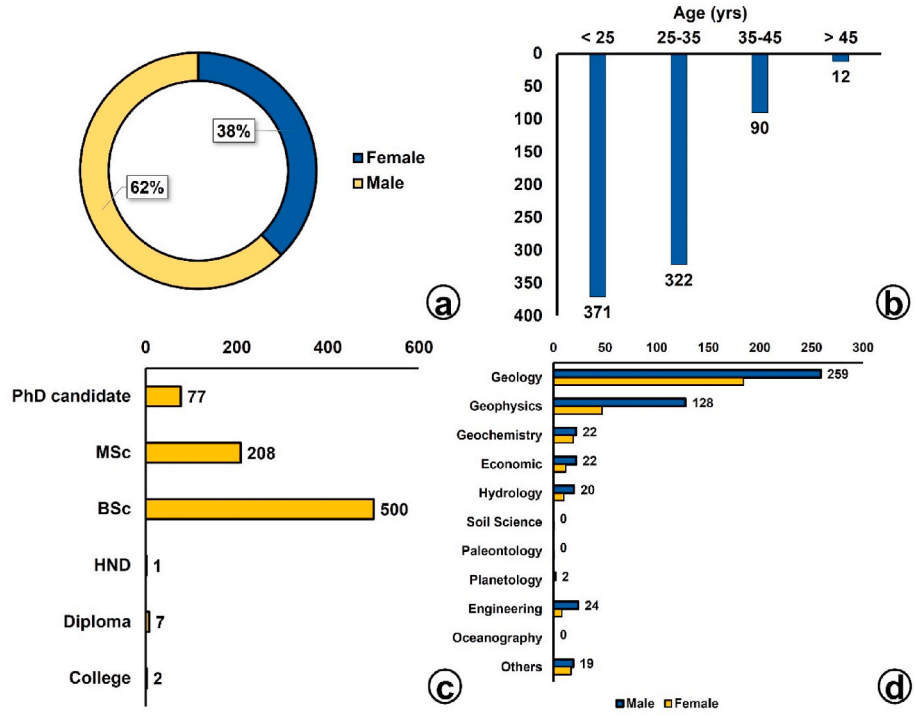

Fig. 9. Gender, age, level of education, and areas of specialization of respondents for (a)–(d) the students and graduate students survey (Supplementary data III).

from disability (commonly linked to war/violence), high level of poverty, living in remote or underserved communities with little access to schools, low family income, poor access to information, and more (World Bank, 2022). All of these factors will undoubtedly have a negative impact on access to education, particularly STEMM and invariably Earth science research. Since most STEMM courses are also generally underfunded in Africa (Adeyemi, 2011), students will usually have to pay heavily at every step in their education. Although poverty affects both girls and boys (White et al., 2001), in terms of education, poverty affects girls more than boys (see Otoo-Oyortey and Pobi, 2003), and may strongly deter girls from disadvantaged backgrounds who may otherwise be interested in the Earth Sciences.

Based on the observed disparity in gender ratios and gender per capita, we conclude that there is low recruitment of females in the Earth Science academic community in Africa. This skewness may reflect a lack of interest or sense of insecurity by women who find it difficult to work optimally in a predominantly male-dominated ambience. This may be common in environments where certain incentives that are expected to encourage and improve work-life balance and facilitate career progression are inadequate. Some of these barriers may also force women to consider careers outside the academia even after being tenured (Holmes et al., 2008). Additionally, the current low number of female professors and academics presently available in the African Earth science research community (Fig. 3) may make Earth sciences unattractive to prospective female students. This low number of female professors would translate to low number of female Earth Science academics/mentors for young

African girls who may want to study Earth sciences. Hence, limiting the attainment of gender balance in the Earth sciences.

5.2. Mitigating gender disparity in Earth Sciences faculty composition and enrolment

To encourage increased female participation in the Earth sciences and reduce the leaky pipeline in Earth science departments across Africa, we propose four types of mitigation strategies: (a) mentoring and early-stage Earth Science education, (b) government and university policies, (c) transparency and accountability in academic recruitment and selection, and (c) active involvement of men in gender-equality advocacy.

Mentoring has been identified as a strategy that improves women's participation in STEMM (Blake-Beard et al., 2011; Dennehy and Dasgupta, 2017). Establishing focused and perhaps same-gender mentoring programs will provide linkage between young girls (mentees) and their mentors who are professional geoscientists. It would also create guidance and support for the young girls (Dennehy and Dasgupta, 2017) and encourage them to take up careers in the academia. This can be a strategy for introducing Earth sciences to young girls early in their lives, regardless of their location. We propose that running focused mentoring programs in parts of Africa will help drive more women into Earth sciences. Although, many young girls live in remote and rural areas of Africa (Mukeredzi, 2017), a factor that often limits their access to potential mentors. Nevertheless, growing internet access in Africa promises to help foster communication (e-mentoring) between mentors and mentees. In addition, introducing early-stage components of education to elementary school pupils can be a positive step. Doing this will require focused and perhaps government-backed modifications to existing education/teaching curriculum in schools. This may as well be achieved through community Earth science outreach programs organized for young pupils and students by university Earth science departments. This strategy will assist in introducing the very basic aspects of Earth sciences to young girls across Africa. In fact, many of these girls will learn about the several Earth science career opportunities early in their lives. Hence, the common trend where universities are the first places where many girls get to learn about Earth Sciences could be reversed.

Governments and universities in Africa can also help to create policies needed to increase female participation and retention in the Earth sciences. Policies which encourage recruitment of more female Earth science researchers (e.g., into government/privately-owned universities), work-life balance for female geoscientists and academics, timely promotion of deserving female researchers (Vila-Concejo et al., 2018), regular leaves, and reversal of any pay disparity between male and female Earth science researchers of the same cadre should be developed. Additionally, African governments, Non-Governmental Organizations, private individuals/companies and funding agencies can further help reduce the gender disparity by providing scholarships and research grants targeted at prospective indigent and deserving female students to study Earth sciences in Africa. To overcome the problems of low recruitment, the advert, interview and selection process should be transparent and accountable (van den Brink et al., 2010). Although it seems like a herculean task as most recruiting processes are often besieged by micro-politics, double standards, and false fairness. The recruitment process can be made more transparent in terms of protocols and decisions by ensuring full compliance to regulations, creating incentives and sanctions to guarantee full implementation of the recruitment process, and by training of recruitment committee members to identify double standards and routine gender inequalities in the appointment process (van den Brink et al., 2010).

Finally, the role of men in the achievement of gender balance in the departments of Earth Sciences cannot be overstated. In the last few decades, the role of men regarding gender equality has become increasingly relevant (Scambor et al., 2014). Men are at the center of all gender acts (physical, psychological, and sexual). Their full engagement is crucial to achieve a gender-balance (e.g., Carlson et al., 2015; Casey, 2010)not only in Earth sciences faculty composition but also in all STEMM disciplines and the society at large. We recommend that the primary role of men begin with the recognition and acceptance of women as their equals in terms of intellectual, emotional, and psychological capacities. Women earth scientists should be equitably recognized, applauded and rewarded for their contributions, ideas, and works. Men should also champion gender-balance in faculty recruitment and speak up against sexism in Earth sciences. Moreover, female leaders should enjoy unparalleled support of their male colleagues for higher faculty positions.

6. Conclusions

The main conclusions from this study are that.

1. Earth science courses are offered in every region of Africa and in at least 39 countries and 142 faculties.
2. Most of the Earth sciences departments have accessible information on their faculty ranks and position online, albeit there are few departments with inconsistent information in terms of gender and ranks.
3. The ranking system used for Earth science faculties is inconsistent. However, there is a common underlying definition of each title or rank.
4. Generally, there are more male faculty members in all the countries investigated, with an average male to female ratio of 4:1. However, this ratio can vary significantly in countries with higher number of Earth sciences departments and faculty members. In fact, the male: female ratio can reach 2:1 and 3:1 in some countries.
5. Countries with the highest number of Earth science departments do not necessarily have the highest number of female faculty members.
6. There is marked disparity at the top cadre, i.e., senior lecturers, senior researchers, Associate Professors and Professors. Men dominate these top ranks.
7. The current disparity in male: female African Earth science faculties is worrisome and requires urgent positive actions to reverse.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used has been attached

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jafrearsci.2022.104768.

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