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Geographic biases in cane rat (Thryonomyds) research may impede broader wildlife utilization and conservation in Africa: A systematic review

Shadia I. Kilwanila[a,*], George M. Msalya[b], Charles M. Lyimo[c], Alfan A. Rija[a]

[a] Department of Wildlife Management, Sokoine University of Agriculture (SUA), PO Box 3073, Chuo Kikuu, Morogoro, Tanzania
[b] Department of Animal, Aquaculture, and Range Sciences (DAARS), SUA, PO Box 3004, Chuo Kikuu, Morogoro, Tanzania
[c] Department of Biosciences, Sokoine University of Agriculture, P.O. Box 3038, Chuo Kikuu, Morogoro Tanzania

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ABSTRACT

There is a growing body of literature about cane rat species but most of the published work is patchy and current spatial distribution is unknown which limits its wide application in the utilization of the species for the broader commercial game industry and for improving wildlife conservation across Africa. We conducted a systematic review of 56 years (1964 - 2020) of cane rat research to understand existing research gaps, to analyze the spatiotemporal and thematic patterns, and investigated factors that influence the publication of the cane rat research in widely recognized journal outlets. We found 308 publications on the cane rat species from 14 countries authored by 39 nationalities globally. The publications increased significantly over the study period, with 97.7% of these biased geographically and thematically towards the west and central African region. Further, the published research mostly covered one species, the greater cane rat, and none had covered the biogeography, food biology, and conservation of any of the two cane rat species in situ. Also, the author's nationality had the strongest influence on publishing the research in journals with or without impact factor. These results suggest that the financial limitation and quality of the research influenced most cane rat research published in local national or regional journals which mostly had limited accessibility for widespread research use to improve applied conservation programs. Expanding coverage of the cane rat research in other species-range countries in the east and southern African regions will be necessary to tap the species as a priority commercial game to reducing exploitation pressure on the wild mammal populations particularly in the African savannas where illegal hunting for bushmeat consumption is a growing problem.

* Corresponding author.
E-mail address: shadiaibrahim42@gmail.com (S.I. Kilwanila).

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Introduction

Cane rats are wild rodent species that belong to the Thryonomydae family, historically endemic to Africa and widely distributed in eastern Cameroon, Central African Republic, Sudan, Kenya, Tanzania, Uganda, The Democratic Republic of Congo, Zambia, Malawi, Mozambique, and Zimbabwe [43]. Two recognized species, the smaller (*Thryonomys gregoriunus*) and greater cane rat (*Thryonomys swinderiunus*) occupy different habitats including swampy lowland along riverbanks and streams and higher altitudes in drier and rocky areas [13]. These small mammals are important both to man and the environment through maintaining food webs and chains [23]. They consume plant material and enhance the mineralization of organic matter making them an essential component of the ecosystem [26]. They are also agricultural pests, feeding on different plants ranging from leguminous fodder, tubers (e.g. cassava (*Manihot esculenta*) and sweet potatoes (*Ipomoea batatas*)), fruits (e.g. pawpaw (*Carica papaya*), pineapple (*Ananas comosus*), and mango (*Mangifera indica*)) to food crops such as rice (*Oryza sativa*) and maize (*Zea mays*) [1]. Also, they harbor parasites that transmit diseases to human beings and other animals, for example, salmonellosis, trypanosomosis, gastrointestinal parasites, and ticks [17,30].

Further, in some African countries, cane rats body parts such as pancrease and hairs are used in traditional medicine for healing wounds, restoring fertility in women, and diabetes treatment [14]. The species are increasingly regarded as important game animals of high-quality meat and delicacy across many countries in Africa and for this reason, they are hunted aggressively in their range areas [6]. Furthermore, meat from the cane rats is considered to be in high demand partly because its consumption has no religious, gender, age, and ethnic prohibitions at least in some countries [3,33], making cane rats a potentially suitable game species for commercial wild meat industries in Africa. As a result, there have been efforts and attempts to domesticate them to curb the potential over exploitation of wild populations especially in the west and central African countries [8]. Domestication provides an alternative source of income for farmers and increases farmers' access to and utilization of animal protein for dietary needs [31]. According to Ajayi et al. [5], cane rats have a great turn-over rate for meat production within a short period, thus making it a prospective good source of generating income. Coupled with this, their potential as a source of ecotourism to entertain interested viewers in zoological gardens has substantially increased efforts to domesticate cane rats in recent decades in these countries [32]. Accordingly, cane rat farming could be promoted in other African countries where the growing demand for wild meat (henceforth named as bushmeat) is fueling wildlife poaching crisis for bushmeat across the African savannas [48], causing wild mammal population decline in many targeted protected areas [38]. Domestication of cane rats in form of wildlife farms, zoos, or ranches would promote conservation of wild mammals in protected areas and livelihood of local communities, especially where cane rats are considered as commercial game animals for farming or ranching programs.

Although advocating for cane rat farming looks intuitive, however, its wider acceptance and implementation among many societies in east and southern African regions may be particularly challenging. This is because most cane rat information is based in the west and central African countries, and available knowledge is scattered and patchy, rendering wide use difficult. To date, only one study, by Mustapha et al. [27] has attempted to collate the available literature on cane rats. However, that study covered only one species, the greater cane rat, searched very few databases, ignored theses, and did not analyze important information such as the methods used in the published research, types of data collected, and where the research was published to facilitate the wider application of the research work in other regions.

Further, the approach used by Mustapha et al., [27] underreported the studies currently available and may limit the use of the research for advancing science and for guiding conservation and livelihood programs such as cane rats farming or ranching. A study that pulls together all the information available from all sources would be useful in informing future direction on the cane rat research and application. This study aimed to conduct a systematic assessment of the literature about cane rat species to understand the state of knowledge and to explore the future research options and the potential use of the cane rat species for wider conservation and livelihood programs in sub-Saharan Africa. Specifically, this study addressed four questions; what are the existing knowledge gaps both spatiotemporal and thematically, what are the research methodologies used, what outlets have been used by the current research to publish results, and what factors influence publication in the chosen journal outlets? This paper provides recommendations on the future research options and application of the cane rat knowledge in tackling conservation and development challenges in the African savanna regions.

Methodology

Performing search

A quantitative systematic review of available cane rat research was conducted following four steps that included planning (i.e. the formulation of the topic, review protocol and keywords), searching (i.e. selection of relevant data and assessment of publications), data extraction and database creation, and data synthesis [34,36]. All searches were conducted in the ISI Web of Science, Scopus, Google, and Google Scholar to access a comprehensive database of published information about cane rats from 19th March to 8th June 2020 and additional searches conducted from 20th October to 25th November 2020 (Table SM1). The search terms used were "cane rats" and "grasscutter". These search terms were used together with the established themes covering broader fields as ecology, conservation, genetics, production, reproduction, anatomy, nutrition, and diseases. The first search used a single search term together with any of the themes above. The second search was conducted using both search terms separated by either the OR operator or AND operator followed by the theme (see all

search terms in Table SM1). The same procedures were repeated until all themes were covered. All searches were done from Sokoine University of Agriculture (SUA) library, Tanzania to access journals which SUA library has subscribed to. Most journals where the retrieved papers were published were free access. For the journals that required paying, the papers were requested from individuals in other institutions that had access. We included all original articles, reviews, book chapters, published conference or symposium proceedings, and theses and excluded grey literature. No time frame limit was used in the search to allow for the retrieval of as much publication as possible [38]. If an article was available in non-English languages, the article was translated by a proficient speaker of that language based in the Language department at SUA. Search results were reported following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) protocol [25].

Paper screening

Retrieved papers from online databases were screened using a two-stage process [38,48]. First, titles and abstracts of the papers were read to look for relevance, and secondly, for any relevant paper identified based on the selection criteria below, the whole paper was read in-depth to extract the needed information (see extracted data in the following section-literature database). Only papers based on empirical studies and reviews of cane rats were included. To check for the validity of the screening process, two data sets of an equal number of papers were worked on by two independent reviewers working against the set exclusion criteria i.e. search terms not in the title, abstract, or mentioned few times in the whole paper and not an empirical study [48]. Both reviewers found 96.6% of all papers were relevant for inclusion in the review.

Building published literature database

The database of the cane rat literature required to answer the research questions addressed above included author name, title of the paper, publication year, research theme and subtheme, author nationality, study country, research collaborating nationalities, geographic location of the study (only country names were recorded as most studies did not indicate exact coordinate points where data collection were conducted), study methodology used, research type, outlet journal and impact factor (based on the journal online page and Clarivate Web of Science), journal coverage (i.e. whether local, regional or international based on description given on online journal page), species studied (greater or smaller cane rats or both) and number of studies (see Supplementary raw data I). Because most publications did not report the exact coordinate location of their study sites, we used Q-GIS version 3.10.3 to spatially locate the number of studies conducted in each country mentioned in the publication. The four stages followed when conducting systematic review are presented in Fig SM1.

Data analysis

Prior to conducting formal analysis, data cleaning and manipulation were conducted with the 'dplyr' package in the statistical software R version 3.6.3. We checked for distribution shapes of continuous variables using the histogram and created a visual display of most variables as most of the research objectives required simple analyses. To understand the predominant research topics and sub-topics, the research themes and subthemes were grouped and plotted as barplots and word cloud using 'ggplot2' and 'wordcloud' packages respectively. The trend of publications was examined using the Cox and Stuart trend test [9] and, the geographic distribution of research, and the research methods used in the cane rat research were assessed using descriptive statistics as most data were count. Most of the cane rat research works were published in online journals with or without impact factor. To assess what factors influence publishing in a journal with or without impact factors, we used generalized linear mixed models (GLMMs) with a binomial error term and logit link function implemented in the R-package'lme4' [7]. Before running the model cells with NAs (i.e. Not Applicable which represented non-journal article publications e.g. conference paper and book chapters) from a response variable- Journal impact factor (JIF) i.e. whether a paper was published in a journal with (scored as 1) or without impact factor (scored as 0) were excluded. We also, excluded countries with very few data points ($n<8$) in the model analysis, i.e. Cameroon, Zimbabwe, USA, Japan, Germany, Gabon, Senegal, France, Benin, and Kenya to remove noise. To analyze these data, we fitted the mixed model with the 'glmer' function implemented in the 'lme4' package where four fixed factors: author nationality, number of co-authoring countries, geographical location, and number of authors were used. As different publications were covering similar research topics and research areas, we included a research theme and country of study as random effects in the model. We examined the relative contribution of each fixed effect by using step-wise deletion of non-significant variables using 'drop1′ function and tested the model significance with the Chi-square test [7]. We obtained model confidence intervals around variables showing statistical significance in the minimum adequate model using the Wald-method [7]. To select the most parsimonious model, we compared two competing models using the Akaike information criterion (AIC), where the model with the smallest AIC value was selected. Furthermore, we built a prediction model of the significant fixed effect using a prediction package to understand how best the independent variable predicted the response variable in the model. The prediction was plotted using the 'ggplot2′ function. Finally, we calculated the squared correlation between the response variable and the predicted values to understand the model variance explained by the fixed effect [16].

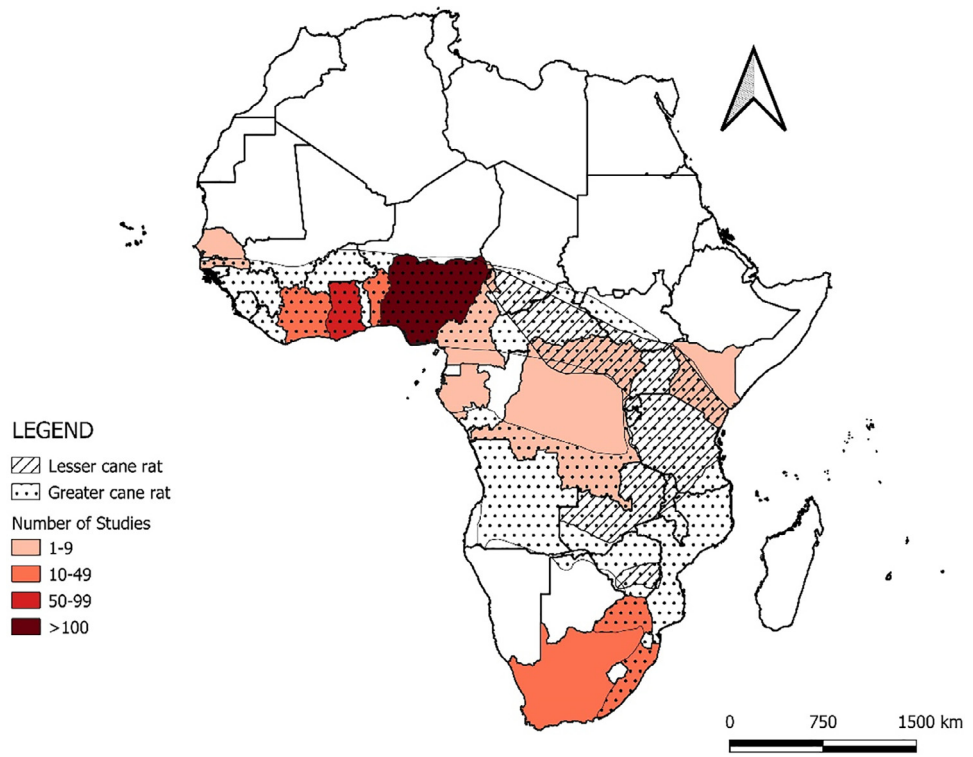

Fig. 1. Distribution of the published articles on cane rat in countries where samples were sourced and where first author of the publication was based. The cane rat species ranges presented here were constructed based on Skinner and Chimimba [43] and map used was sourced from Natural Earth, which is an open access map source.

Results

Spatial coverage, thematic pattern and research methods used

We analysed 308 papers over a period of 56 years mostly distributed in West and Central Africa (Fig 1). The cane rat studies were reported from 14 countries in four continents namely Africa, Europe, America, and Asia. Most published research studies were biased on study species, methods, and themes. Most papers (99.35%, n = 293) focused on a single species- the greater cane rat, mostly used captive individuals (87.99%, n = 271), and fewer were based on field surveys (17.21%, n = 53). Only twenty studies researched field-derived and captive animals (6.49%, n = 20) together (Fig SM2). The publications covered 29 themes and 36 subthemes with the popular theme and subtheme being ecology and reproduction respectively (Fig 2). Most studies (96.76%) had their main goal to improve the domestication of the cane rats in these regions with only five studies (3.24%) targeting to improve cane rat conservation in the wild.

Research trend, collaborations among countries and journal outlet

The publications on cane rats research have increased significantly over the study period ($z = 3.6056$, $n = 39$, $p = 0.0003$, Fig 3). The first topic to be published was on biodiversity followed by physiology in the same decade. About one-third of all the published papers were conducted in the first four decades (1964–2008) followed by a sharp publication spurt in the last decade (2009–2020) with almost two-thirds of the publications documented within this period. About 85.37% (n = 263) of the cane rat studies were conducted by researchers from the same country particularly from the west and central Africa and 14.61% (n = 45) was conducted by several collaborating countries from Africa and Europe, Asia and America (Fig. 4). About 2.59% (n = 8) of the papers was conducted by authors from non-African countries. The reviewed papers were published in 217 different outlets including 181 journals, 11 theses, 6 proceedings, 1 symposium, and 2 books. Most of the journals claimed to be international in coverage (68.06%) and few were regional or national (31.94%).

Factors influencing choice of a journal outlet for the cane rat research

Author nationality was found to have the strongest influence on the choice of the journal (Table SM2). Authors from South Africa had significantly higher probability of publishing in the journal with high impact factor (2.4079 ± 1.1441,

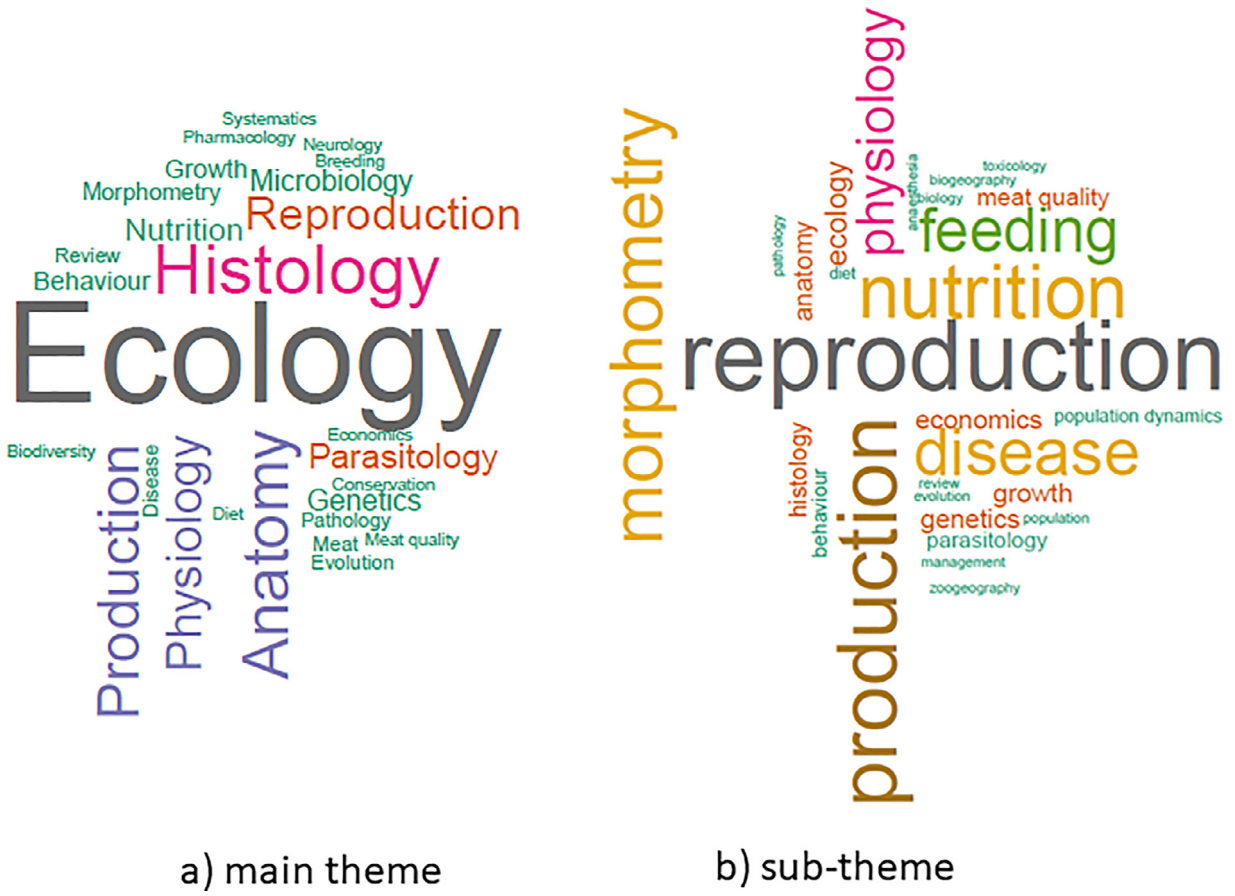

Fig. 2. Word clouds of the main theme (a) and sub theme (b) investigated in the cane rat literature. The size of each word increases with the increase in its frequency in the data.

z = 2.105, p = 0.0353) and while authors from Nigeria had lower probability (mean = -1.0016 ± 0.4943, z= -2.026, p = 0.0428, Fig. 5). There was no apparent effect of other factors included in the model such as the geographic location of research, research collaborator (co-country) and, number of authors in publishing in a journal with or without impact factor.

Discussion

This research aimed to understand the current breadth of cane rat research and to explore research gaps and examine factors that influence the publication of the cane rat research in the chosen journal. We found that publications on cane rats have increased significantly in the last 56 years, particularly in journals without impact factor. Most research focused on domesticating cane rats and were mostly in West and Central Africa. More studies focused on ecological themes particularly reproduction to improve cane rat domestication and no empirical studies conducted on the biogeography of the cane rats across its geographical range in Africa or on the species feeding ecology in the wild. Further, the available literature was also biased in favor of ex-situ rather than in situ conservation of the cane rat species. Furthermore, we found author nationality significantly influenced publication of the cane rat research in journals with an impact factor. Authors from South Africa were most likely to publish in high impact factor journals than authors from countries in west and central Africa where most of the cane rat research was conducted.

The geographical bias in cane rat research observed in this study is surprising given that both cane rat species have a much wider distribution in Africa [43]. The concentration of studies in west and central Africa could be attributed to increasing efforts to domesticate cane rats for bushmeat consumption cultures embedded among the residents and its impact on the wild population in these regions. Several studies on bushmeat harvesting across west and central Africa have reported severe declines in harvested wild species [8,12]. For example, 40% of primate species in West and Central Africa are now threatened with extinction due to hunting for bushmeat and habitat destruction through deforestation [11,19], several other non-primate wild mammals continue to experience severe range contraction and population declines in these regions due to hunting for commercial bushmeat trade and subsistence consumption [10,38]. Persistent harvesting of wild species

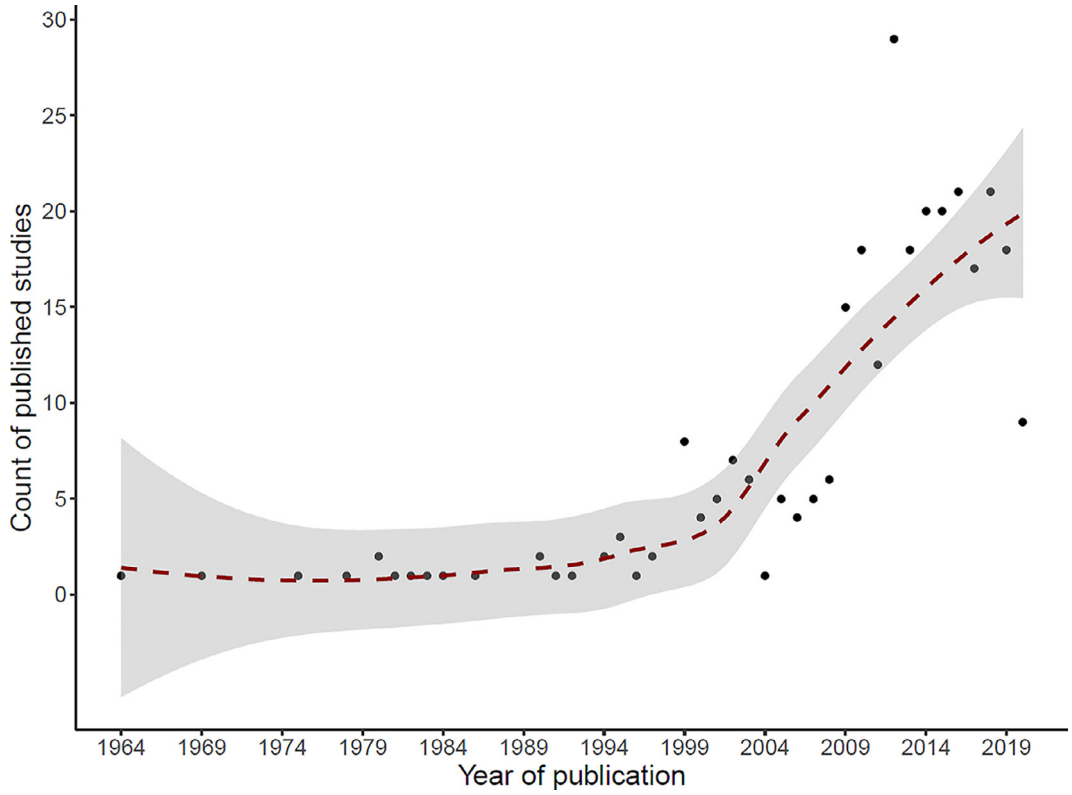

Fig. 3. Trend of publication on cane rat studies from 1964–2020. Shaded area indicates 95% confidence limit of the estimates.

is likely to disadvantage smaller and highly reproducing mammals such as cane rats in these regions [40]. This may have prompted more studies to improve alternative avenues for sourcing wild meat protein through domestication of wild cane rats [2,4,15].

Further, the quest to provide wild meat protein may have increased studies on reproduction, nutrition, production, and disease associated with animal husbandry observed in this study. Cane rat meat is considered a delicacy among several West African communities [2]. The species high reproductive potential together with the small area and relatively low financial capital needed to establish indoor husbandry [4] may have attracted wider domestication in the west and central Africa [15]. This is supported by the observed large number of publications on cane rat from Nigeria and Ghana which have many commercial cane rat farms [14,50]. The increased rate of publications on the cane rats, particularly in the last ten years (2009–2020) provides more evidence to the increasing interest in generating information to improving the cane rat farming programs in these west African countries.

The scant research on cane rat in east and southern Africa, on another hand, could probably be because the species has not fetched priority among the wildlife species normally consumed for bushmeat despite the species being a potential game animal for commercial wildlife zoos and ranches. Most illegal hunters in East Africa prefer larger mammals than smaller ones which provide them with bulky meat and high economic gains and there is a tendency for disregarding small mammals in poaching trips especially in communities where poaching for commercial gain is common [28,39]. Despite this, however, poaching of cane rats for subsistence is still common in several communities across the African savannah [29,38], suggesting the species importance on the dietary protein menu of the local communities in the continent. An alternative explanation could be that there is still low awareness among the local human population on the protein and economic potential of the cane rats which may have been due to limited knowledge about the species in East and southern Africa. We argue that the cane rat species could be utilized through game ranches and zoo farming in sub-Saharan savanna regions alike to alleviate the increasing wild meat demands especially in the rural communities where poaching for bushmeat is a growing conservation problem [37,48]. Notwithstanding this, however, there is a growing urge in countries in east and southern Africa such as Tanzania, Zimbabwe, and South Africa to improving the economic development of the local people through investing in wildlife businesses such as game farming and ranching. In Tanzania for example, this urge has been emphasized by his Excellence President Magufuli at several public addresses in 2019 and recently at the inauguration of the 12th Parliament held on 13th November 2020 (pg 47–49) in Dodoma that local Tanzania citizens should proactively engage in commercial wildlife ranching and farming to ensure the economic benefit from the wildlife resources [35]. Consequently, this has been mainstreamed within the government sector particularly through the Tanzania Wildlife Authority (TAWA) by

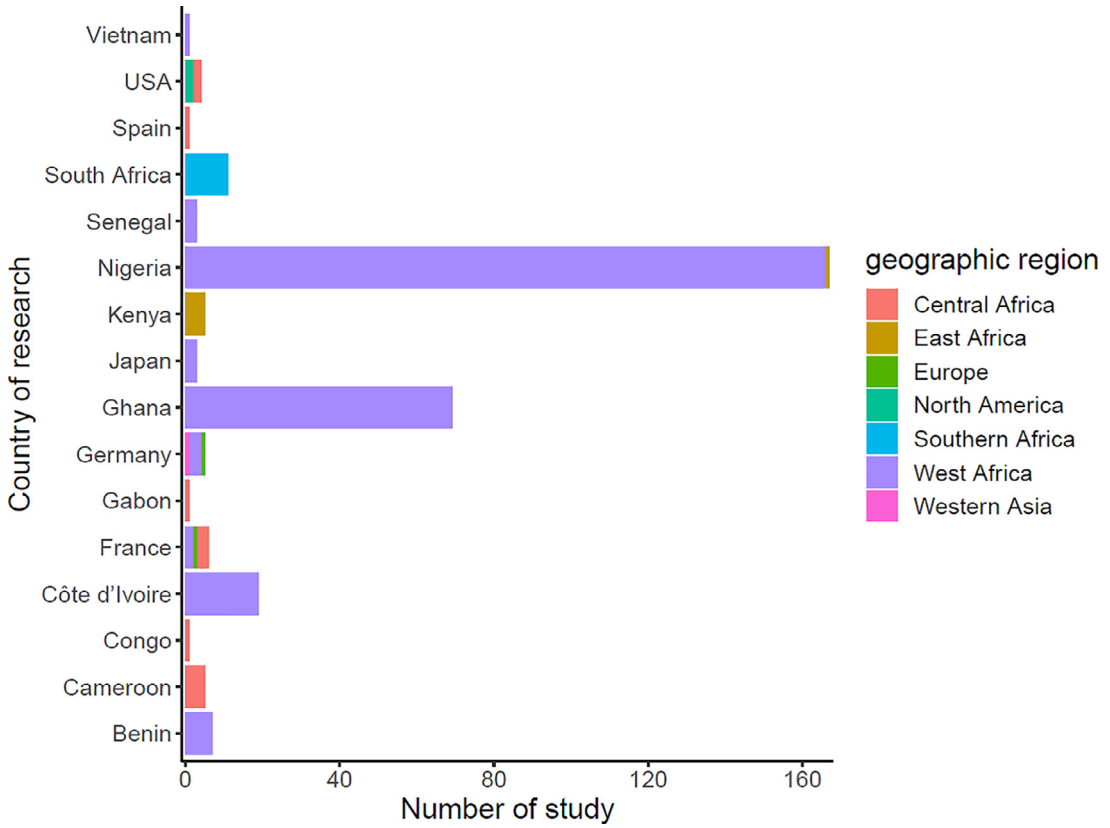

Fig. 4. Collaborating countries in conducting research on cane rat in four continents: Africa, Asia, Europe and America.

formulating game ranching/farming policy and enacting laws and regulations that will guide the implementation of wildlife farming and ranching in Tanzania [47]. It remains unclear, however, how the cane rat species will out-compete other wild species in such programs to remain sound and priority animal species among the local wildlife farmers and ranchers. This is particularly concerning given none of the two cane rat species has been studied in Tanzania or any dry savanna country to help guide the potential farming and ranching business.

There was a high number of cane rat research publications from countries in west and central Africa in local national, regional, and internationally-claimed journals. This may be attributed to three reasons. Firstly, the publication in local national journals could have been contributed by the financial limitations by the authors of the papers to publish in high-quality international journals that charge publication fees, a common impediment among many developing country researchers [18,21]. For instance, many papers from these regions were authored by the nationals of Nigeria and other West African countries both as single or multiple local authors and without collaboration with authors from outside these countries or regions. This has the potential of limiting wide readership and citations as most of such papers may only be accessed and utilized locally [42]. Secondly, the publishing in the local national journals could be because the results being communicated were less competitive in terms of their quality to be published in supposedly good international journals where publication space is often limited and that only good quality papers get through the usually stringent screening and review process of such journals [21,42]. Due to the lack of rigorous review, such local journals do not choose what they publish. For example, previous review research by [27] reported some duplicates in publications by authors from different countries repeatedly publishing similar research, a problem potentially caused by limited online accessibility by these local journals. Thirdly, although publishing in local journals does not necessarily imply low-quality research as some publish important and practical information that would be declined in the international journals [21], the perceived bias in some reviewers and editors in an international journal published in developed countries in judging articles from developing countries [22,45] could have increased the authors' propensity in publishing the cane rat research in the local national journals.

The strong influence of the author's nationality in publishing the cane rat research in high impact factor journals echoes the importance of collaboration with international authors from outside in furthering science. Although our mixed model analysis removed papers published from the developed countries such as the USA, Spain, and Japan due to low numbers of data points, however, the papers collaboratively authored by West African nationals and these developed countries were published in international journals with impact factors - a proxy of good quality [46]. Also, papers published by authors from South Africa had the highest probability of being published in high impact factor journals than papers authored by

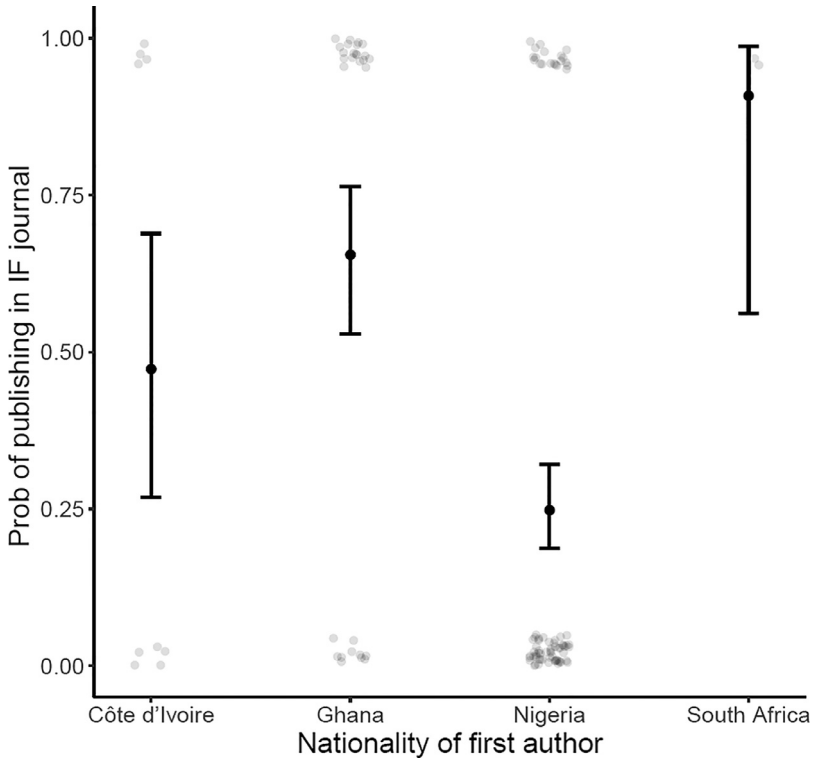

Fig. 5. Probability of publishing cane rat papers in impact factor journal. South Africa showed high probability of publishing in the journal with impact factor while Nigeria showed the lowest probability of publishing the paper in the journal with impact factor.

Nigeria and Cameroon nationals alone. The quality of research and journal attributes (i.e. strong editorial board and review process, impact factors, etc.) are currently acknowledged to influence the choice of a journal when publishing research [46], this study has added author nationality on the list of factors that influence the publication of the cane rat research in a journal with or without impact factors. The author nationality has nothing to do with race [41], but underscores the quality of the research and its output [44] that are strongly related to the wealth of the nations of the authors [18,49]. Furthermore, an alternative explanation to the authors from South Africa publishing in journal with impact factor could be caused by local institutional requirements and or regulations that compel them to do so. Such requirements could probably be non-existing in some institutions in West and Central Africa.

Most of the published articles were based on the greater cane rat in captivity but also focused on observational study or surveys. Further, many of the survey studies also relied on the direct questioning of the cane farmers to document the economic gain associated with animal husbandry. The biases on only one species and captive breeding programs may limit the wider potential utilization of both cane rat species in other regions of Africa. The observational studies on the captive cane rat provide limited information, particularly when considering in situ conservation and the implementation of the game ranching or farming in the savanna regions in east and southern Africa. This is because findings from such studies can hardly be generalized for all the cane rat species across their geographical range due to local variability in habitats and weather conditions that may have substantial impact on the reproduction and local population dynamics [20,24].

Conclusion and future directions

This study has revealed important insights into the available and accessible literature on the cane rat that is presently available. The study research indicates strong geographic, thematic, and species biases which most research outputs have been published in local national, or regional outlets where wider readership and thus utilization of the research findings are suggestively limited or low. There was generally an increasing trend in the publication of the cane rat research over the last 56 years and this trend looks set to increase as the species get widely accepted as a source of meat protein in many societies in the west and central Africa. However, to gain wide use as a commercial game species in other countries particularly of the dry savanna regions, there still a few issues to be addressed for this species to compete with the wild ungulates in the game/ranching programs across the southern African region. First, new research should focus to understanding the biological and ecological aspects of both cane rat species in the wild to inform any potential ranching/farming program in East and Southern Africa regions. Currently, there is a lack of understanding of the local species biogeography across its range states, the food spectrum of the lesser cane rat species [43], and the genetic information of isolated populations within a country

are yet unknown. Secondly, there appears to be a potential cultural barrier in meat consumption among tribes in the region (e.g. [28]). A study focusing to understand how the cultural norms among the local societies in the east and southern Africa shape the consumption patterns of the cane rat bushmeat will be a useful contribution to the development of the cane rat farming/ranching industry in these regions. Such research will also provide information on where the markets and demands for the cane rat bushmeat are. Strong scientific information generated in the region will improve the conservation of the cane rat species insitu and expedite the wide use for improving the food security and cash income among many societies in Africa. Also, a well-grounded cane rat ranching/farming industry will directly reduce the bushmeat poaching pressures on the protected areas in the savanna regions.

Declaration of Competing Interest

There is no competing interest.

CRediT authorship contribution statement

Shadia I. Kilwanila: Conceptualization, Data curtion, Formal analysis, Validation, Writing – original draft, Writing – review & editing. **George M. Msalya:** Writing – review & editing. **Charles M. Lyimo:** Writing – review & editing. **Alfan A. Rija:** Conceptualization, Formal analysis, Validation, Writing – review & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2021.e00785.

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