SANBI Biodiversity for Life
South African National Biodiversity Institute

BOTHALIA – African Biodiversity & Conservation
ISSN: (Online) 2311-9284, (Print) 0006-8241

Trends in plant ecology research in Ethiopia (1969–2019): systematic analysis

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Dates
Submitted: 5 February 2021
Accepted: 22 October 2021
Published: 18 July 2022

How to cite this article:
Gebrehiwot, K. & Demissew, S., 2022, 'Trends in plant ecology research in Ethiopia (1969–2019): systematic analysis', *Bothalia* 52(1), a12. http://dx.doi.org/10.38201/btha.abc.v52.i1.12

Background: The current status of plant ecology research in Ethiopia is unknown with the result that it is challenging to judge the impact of existing research on policy development and conservation actions.

Objectives: The objective of this paper was to systematically analyse the trends in plant ecological research in Ethiopia over the past 50 years.

Methods: The inclusion and exclusion of articles for analysis was carried out using the Reporting Standards for Systematic Evidence Syntheses (ROSES) flow diagram developed for systematic review/meta-analysis.

Results: The number of articles published, authors and collaboration has increased dramatically since the 1960s. Most of the research (52.6%) focused on the Dry evergreen Afromontane Forest and grassland complex (DAF) and Moist evergreen Afromontane Forest (MAF) vegetation types. Of the remaining vegetation types, woodlands (14.3%) i.e. *Acacia–Commiphora* woodland and bushland proper (ACW), and *Combretum–Terminalia* woodland and wooded grassland (CTW), desert and semi-desert scrubland (DSS) (2.3%), and the Afroalpine (AA) and Ericaceous Belt (EB) (1.5%) received comparatively little attention. Classical plant ecology themes and descriptive plant community studies were dominant over the last five decades in contrast to the focus on contemporary themes globally. Reproductive and dispersal ecology of invasive plant species and pollination ecology seem to be largely neglected topics. Furthermore, the recommendations forwarded by most of the articles reviewed (38.1%, n = 51) were not result-based.

Conclusions: As a future direction, the Ethiopian government should develop a project database for both completed and ongoing projects.

Keywords: Afromontane Forest, research syntheses, ROSES, systematic review, vegetation ecology.

Introduction

Plant ecology as a standalone discipline of botany has a long history with links to the works of Alexander von Humbolt in the early nineteenth century (Hagen 2010). Subsequently, some branches of plant ecology emerged, such as synecology and autecology, which place emphasis on community ecology and individual species respectively. From the early nineteenth century onwards, plant ecologists have studied stands of vegetation, which they considered samples of a plant community (Mueller-Dombois & Ellenberg 1974). Currently, however, traditional ecological terms (e.g., synecology and autecology) are replaced by specialities such as population ecology, community ecology, ecosystem ecology, ecological modelling, global change biology and remote sensing (Hagen 2010; Asselin & Gagnon 2015; Grace 2019).

Even though plant communities were the focus of ecological research during the first half of the twentieth century (Hagen 2010), plant ecology as a discipline has changed as the scope of the research themes has grown over time. However, there are arguments about the evolution of plant ecological research. For example, Peters (1991) and O'Connor (2000) criticised the state of plant ecological research and argued that ecology as a science has not grown and had just progressed slowly. On their critical response to Peters' criticism and arguments, Grace (2019) and Nobis and Wohlgemuth (2004) countered that ecological research is growing both in scope and citation impact. It is believed that advances in population genetics and evolutionary theory shifted the theme of plant ecological research into a broader scope, which includes population ecology, which combines mathematical modelling and experimentation, to investigate population growth, dispersal and competition from an explicitly Darwinian perspective (Harper 1967, 1977; Hagen 2010; Asselin & Gagnon 2015; Grace 2019). McCallen et al. (2019) identified nearly 50 research topics in ecology over the past four decades.

Like the research topics, the methods employed in plant ecology research also vary depending on the objectives. These might vary in terms of spatial and temporal scale, and organisational levels such as species, population, community and ecosystem. Furthermore, the approaches could be either classical or advanced (Henderson 2012). Although some classical approaches have been retained, plant ecology research methods are evolving. Currently, research in plant ecology is supported by several software systems and is becoming more reputable, which could result in a substantial contribution to vegetation management and biodiversity conservation.

Ethiopia is a country with a very complex topography with elevation varying from about 125 m below sea level to about 4 533 m above sea level (m.a.s.l.) (Gebrehiwot et al. 2020). Two of the 36 biodiversity hotspots, the Eastern Afromontane and the Horn of Africa, are found in Ethiopia (Mittermeier et al. 2004; Hoffman et al. 2016; Gebrehiwot et al. 2020). Thus, Ethiopia is regarded as a major centre of diversity and endemism for several plant taxa though there are extensive anthropogenic disturbances. Taking the complex topography and diverse land use types into consideration, the country has the potential to offer a myriad of research opportunities in plant ecology across a range of themes. Some vegetation surveys were performed across north-eastern Africa (Ethiopia, Eritrea, Djibouti and Somalia) in the late 1950s (Pichi-Sermolli 1957). According to the information extracted from different sources, however, empirical plant ecology research in Ethiopia started only in the late 1960s (Supplementary Table S1).

The objective of, presumably, the first empirical plant ecology research in Ethiopia was to test community ecology hypotheses (Beals 1969). Since Beals' publication, significant numbers of plant ecological studies have been conducted. However, there is no empirical data on the trend in plant ecology research in Ethiopia. As a result, the progress of plant ecology research in the country is unknown. It is thus challenging to understand the progress made and the impact of the research on policy development and conservation actions. Therefore, a thorough bibliographic analysis of plant ecology research in Ethiopia is necessary to understand whether the discipline is growing as a science in the region. This is also important for documenting what research has been carried out in the past and for highlighting gaps that still exist.

The aim of this paper is to systematically analyse the trends in plant ecological research in Ethiopia in order to answer the following questions: (i) What are the most researched vegetation types (i.e. type of natural ecosystem, such as forests) and land use types (i.e. the purpose for which the land is used, for example farmland)?; (ii) What are the most researched domains of plant ecology?; (iii) Is plant ecology research influencing national plant biodiversity conservation policy?; and, (iv) Is there ecological research funding from the government and international sources?

Materials and Methods

Data sources and key search terms used

To minimise bias, improve reporting and ensure a better quality and comprehensive systematic review, we followed the Reporting Standards for Systematic Evidence Syntheses (ROSES) flow diagram developed for systematic review/meta-analysis (Haddaway et al. 2018) (Figure 1).

Research publications were filtered and extracted from different sources covering the years between 1969 and 2019. The sources included Scopus, PubMed, African Journals Online (AJOL), Addis Ababa University (AAU) Institutional Repository/Electronic Theses and Dissertations, and Google Scholar. The search covered terms in the articles and in the title, abstract and keywords. The terms included in searching were: ['Floristic' AND 'Ethiopia']; ['woody' AND 'diversity' OR 'structur' AND 'Ethiopia']; ['vegetation' AND 'ecology' AND 'Ethiopia'], ['plant' AND 'communit' AND 'Ethiopia']; ['ordination' AND 'classification' AND 'Ethiopia']; ['invasive AND Ethiopia']; ['species' AND 'distribution' OR 'Model' AND 'Ethiopia']; ['Restoration' AND 'Ecologi'] and ['Elevation' OR 'Altitud' AND 'gradient' OR 'Environment' AND 'Ethiopia']. The combination of terms in the square brackets were entered into the database search bars. The terms used were believed to cover broader plant ecology research themes such as population ecology, community/ecosystem ecology, restoration ecology, and invasive species ecology.

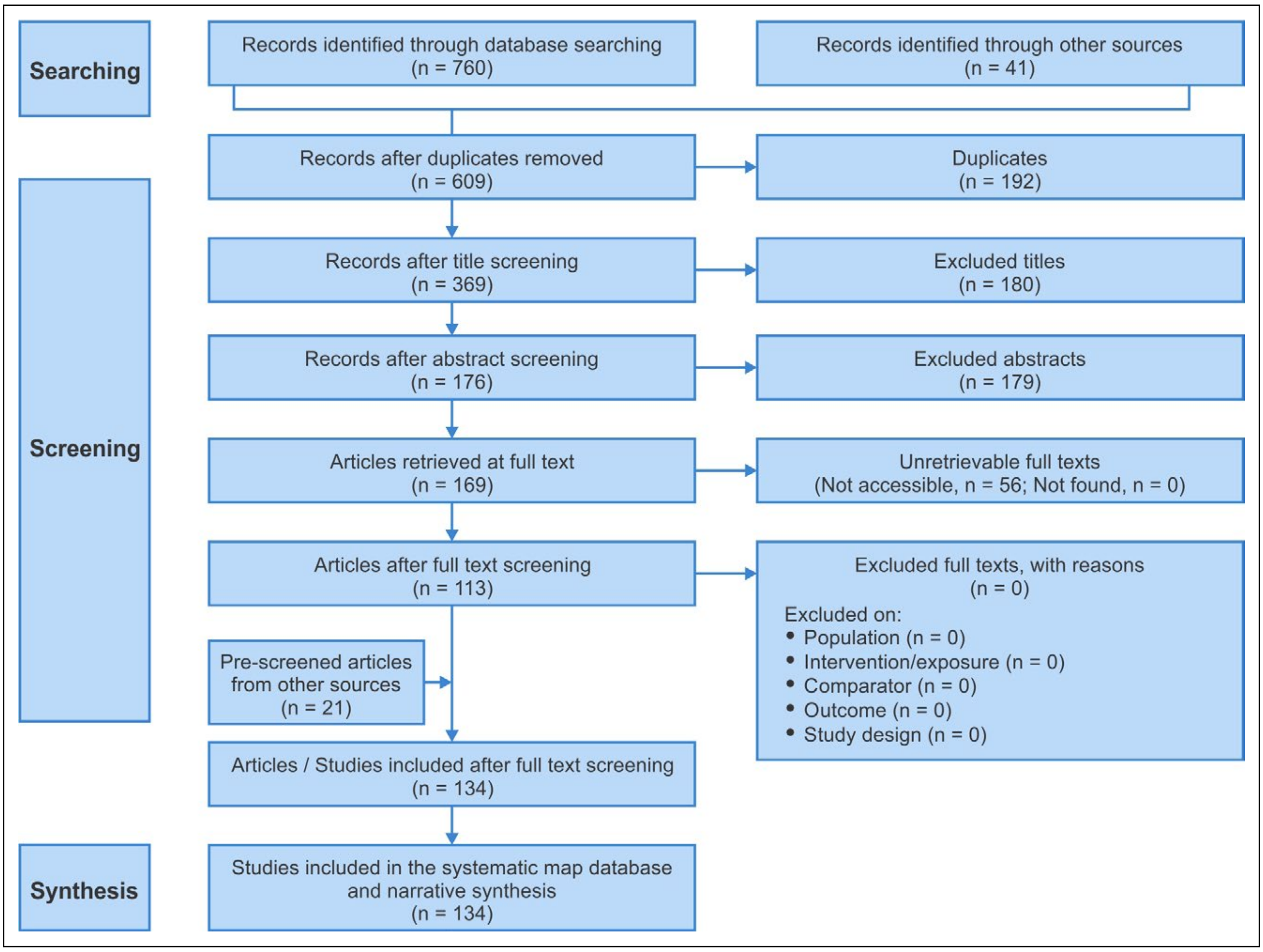

Figure 1. ROSES flow diagram for analysis and inclusion of research articles from several databases. Modified from Haddaway et al. (2018).

Six-hundred-and-nine (609) articles from 56 journals were filtered from Scopus, 21 PhD and MSc theses were identified from AAU Institutional Repository/Electronic Theses and Dissertations, and further 20 articles were extracted from AJOL. The articles from Scopus had to pass through a thorough selection procedure. In the first phase, materials that did not follow standard scientific reporting methods such as books and conference papers were excluded. In the second round, articles that focussed only on land use/land cover change although their title includes terms like forest/vegetation cover were excluded. Nevertheless, land use/land cover change that incorporated plant ecological research through GIS and Remote Sensing were included in the analysis. This filtering resulted in 134 articles being included in the study.

Data analysis

A pre-analysis coding system for the variables was applied (Table 1). The authorship and collaboration, plant ecological research components, descriptive/experimental, vegetation types, community types, methods employed (sampling and analysis), recommendations and funding were coded. Descriptive statistics were employed for the analysis.

Results

Authorship and collaboration

Vegetation ecology research in Ethiopia revealed a linear increase in publication (Figure 2A). However, there have been interruptions between the 1960s and 1990s. There has been a dramatic increase after the 1990s, which is illustrated by the figures for 1969 (two articles published) and 2018 (27 articles published). Similarly, the number of authors per publication also showed an increasing trend (Figure 2B). While one author per publication was recorded in several years, the highest number of authors per publication (24) was recorded in 2016. This indicates a trend of increasing collaborative research over the study period.

The author/s affiliation/collaboration involved showed that local authors are dominant and responsible for 83 (62%) of the articles published. International collaborators and foreign authors were responsible for only 48 (35.8%) and three (2.2%) articles respectively. International collaborations started in the late 1990s and grew steadily. Research conducted by foreign nationals only

Table 1. Pre-analysis coding system applied to the artcles (AAS = Afroalpine and sub-Afroalpine; DAF = Dry evergreen Afromontane Forest; MAF = Moist evergreen Afromontane Forest; CTW = *Combretum–Terminalia* woodland and wooded grassland; ACB = *Acacia–Commiphora* woodland and bushland proper; DSS = Desert and semi-desert scrubland; TRF = Transitional Rain Forest; WGG = Wooded grassland of the Western Gambela region, SSB = Soil seed bank)

No.	Criteria	Definition	Code
1	Year of publication	The year the publication was published.	
2	Author/s collaboration	The affiliation of the author/s involved in the study.	2.1 = Ethiopian, 2.2 = international collaboration, 2.3 = foreign nationals only
3	Journal quartile	Indicator to evaluate the importance or visibility of a journal.	3.0 = Indexed but journal quartile not indicated, 3.1 = Q1, 3.2 = Q2, 3.3 = Q3, 3.4 = Q4, UI = unindexed, WS = indexed in Web of Science but no quartile yet
4	Objectives	The objectives of the study (indication of the ecological domain).	4.1 = floristic (woody/herbaceous), 4.2 = floristic, structure, regeneration status (count), 4.3 = floristic, structure, soil seedbank, 4.4 = vegetation–environmental–disturbance relationships OR carbon estimation, 4.5 = theory–approach development OR life form/functional traits OR climate change/sustainability, 4.6 = vegetation–environmental disturbance relationships, GIS & remote sensing
5	Land use and vegetation types	The site where the study was conducted. Single species ecology is a study about a particular species that can be performed across land use, vegetation types.	5.1 = AAS, 5.2 = DAF, 5.3 = MAF, 5.4 = CTW, 5.5 = ACW, 5.6 = WGG, 5.7 = DSS, 5.8 = plantation forest, 5.9 = area exclosure/watershed, 5.10 = church forest, 5.11 = TRF, 5.12 = riverine vegetation/wetland, 5.13 = farming landscape, 5.14 = > 1 vegetation types, 5.15 = grasslands/rangelands, and 5.16 = Single species ecology
6	Variables	The biotic and abiotic parameters investigated	6.1 = woody/herbaceous species, 6.2 = floristic, soil seed bank, disturbances, 6.3 = floristic, geographic OR satellite image, 6.4 = floristic soil OR satellite images and aerial images, 6.5 = floristic, geographic, soil, disturbance OR social/sustainability, 6.6 = floristic, geographic, soil, disturbance, soil seedbank 6.7 = floristic, soil, geographic, soil seedbank, remote sensing/allometric equations
7	Sampling method	The data collection design used in the study.	7.0 = not mentioned, 7.1 = random, 7.2 = systematic, 7.3 = preferential, 7.4 = stratified, 7.5 = combination, 7.6 = Plot + GIS, 7.7 = experimental
8	Data analysis method	The data analysis method employed.	8.1 = descriptive, 8.2 = descriptive, community classification, 8.3 = descriptive, classification, ordination, 8.4 = descriptive, classification, ordination plus socio-economic, 8.5 = model, 8.6 = ordination and GIS/ Remote sensing
9	Recommendation	The suggestions made in the article.	9.0 = not available, 9.1 = not result based, 9.2 = shows gap, 9.3 = based on result
10	Funding	The source of funding to run the research.	10.0 = not mentioned, 10.1 = government, 10.2 = international, 10.3 = government & others

is negligible and the only articles published solely by foreign nationals were in 1969 and 2017.

Plant ecological research components

Results revealed that most of the articles' objectives were descriptive (Table 2). A few articles dealt with some advanced objectives. About 42 (31%) of the articles' objectives were related to floristic survey, community structure analysis and assessing the regeneration status of a forest based on a seedling, sapling and mature tree count. A theoretical approach development or life form/functional traits and climate change/sustainability themes were covered by only five (3.7%) of the articles. Few articles have been published on invasive plant species distribution and economic impact, and studies on reproductive and dispersal ecology of invasive species

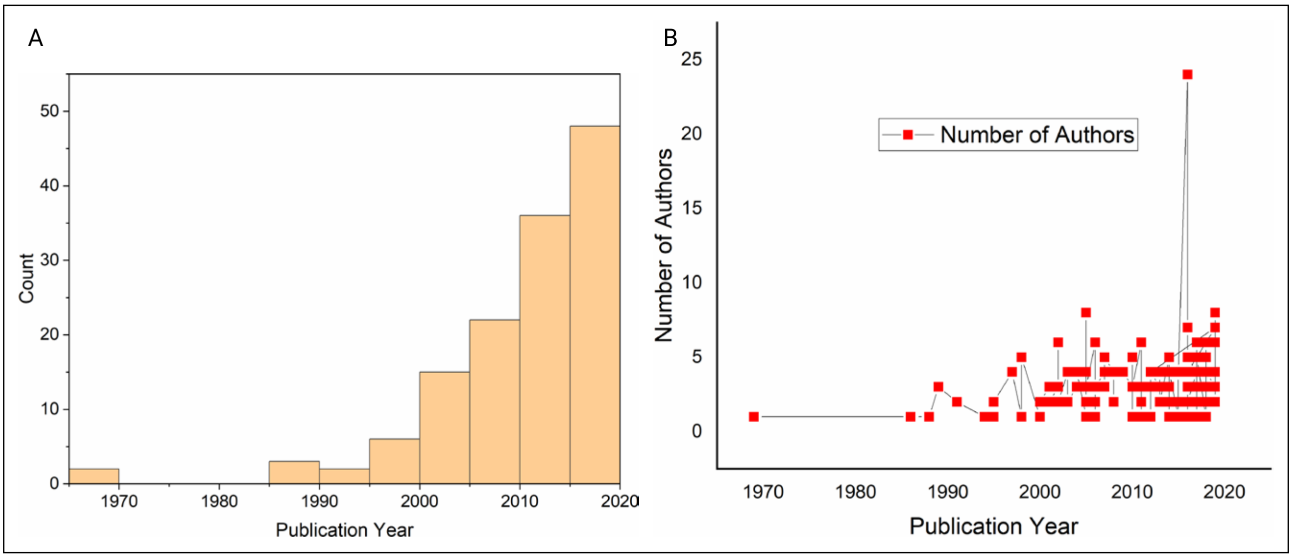

Figure 2. Trends in plant ecology research in Ethiopia; A, number of published articles per five-year interval; B, number of authors per publication in each year.

were not found. Furthermore, pollination ecology seems to be a neglected topic in the Ethiopian literature. A few articles have been published on pollination of crops such as coffee (*Coffea arabica*) by honeybees (*Apis mellifera*), but there have been no papers published on pollination ecology of indigenous and wild plants.

Descriptive/experimental studies

Out of the 134 articles reviewed, only two were experimental while the remainder were descriptive. One of these articles investigated the tree regeneration potential of four species namely *Juniperus procera*, *Ekebergia capensis*, *Prunus africana* and *Olea europaea* subsp. *cuspidata* under three conditions, i.e., along the interior and edge forest gradients, canopy cover, and grazing intensity (Wassie et al. 2009). The other article determined the floristic composition and soil seed bank richness using manure and livestock grazing as treatments (Woldu & Saleem 2000).

Plant ecological research on vegetation and land use types

Most of the plant ecological research articles in Ethiopia focused on the DAF and MAF vegetation types (Figures 3 & 4). Research on these vegetation types comprised about 52.6% of the articles. However, the woodlands (14.3%) i.e. *Acacia–Commiphora* woodland and bushland proper (ACB), and *Combretum–Terminalia* woodland and wooded grassland (CTW), desert and semi-desert scrubland (DSS) (2.3%), and the threatened Afroalpine (AA) and Ericaceous Belt (EB) (1.5%) received little attention. The Transitional Rain Forest (TRF) vegetation type was represented by only one article (Van Breugel, Friis & Demissew 2016). Nearly 8.3% of the studies covered more than one vegetation type. Church forests, grasslands/rangelands and area exclosures comprised 5.3%, 3.8% and 3.8% respectively. Apart from the natural vegetation types, other land uses have also been an area of plant ecological research. Plant ecology

Table 2. The number and percentage of articles published by thematic research topic in Ethiopian plant ecology between 1969 and 2019

Objectives	Number	Percentage of total
Floristic, structure, regeneration (count)	42	31.3
Vegetation–environmental–disturbance relationships OR carbon estimation	35	26.1
Floristic, structure, soil seed bank	28	20.9
Floristic (woody/herbaceous)	16	11.9
Vegetation–environmental–disturbance relationships, GIS & Remote Sensing	8	6.0
Theoretical approach/theory development or life form/functional traits or climate change/sustainability	5	3.7
Total	**134**	**100.0**

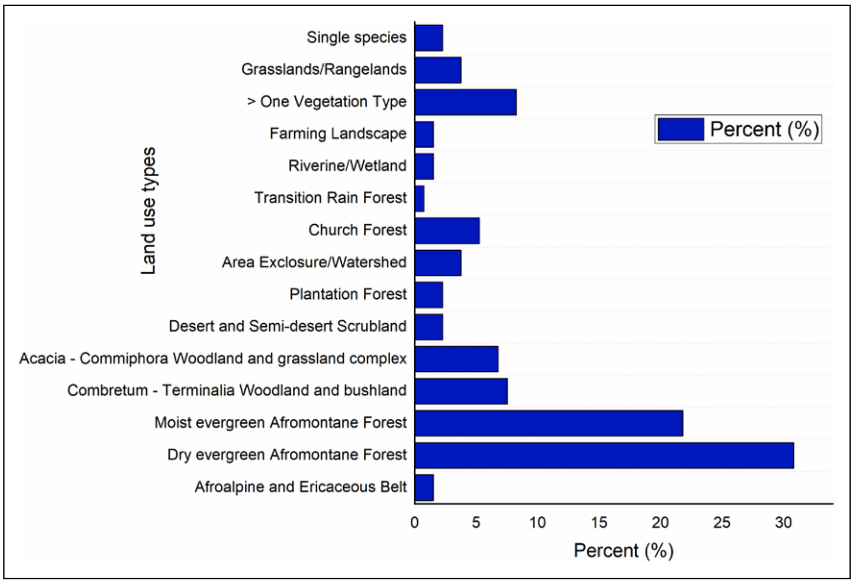

Figure 3. Percentage of publications covering different vegetation types or land use types in Ethiopia between 1969 and 2019.

research on farmland landscape and plantation forests comprised 1.5 and 2.3% respectively. About 2.3% of the studies were focused on single species. The absence of appropriate geographical coordinates make tracing some of the study sites challenging.

Plant community types

About 43% of the studies reported on plant community type analysis. The number of communities varied from two to nine with a mean of five communities per article. However, some articles did not follow the standard community naming (e.g. *Juniperus–Olea* community) while others showed some deviation in the characteristic species of vegetation types. For example, *Olinia rochetiana* is described as a characteristic species of the DAF (Friis, Demissew & Van Breugel 2010). However, this species was reported as a characteristic species of MAF. Furthermore, although *Erica arborea* is a characteristic species of the Ericaceous Belt, at least two articles reported it as a characteristic species of the DAF (Ayalew, Bekele & Demissew 2006; Yineger et al. 2008). Furthermore, a shrub/tree and herb (for example, *Albizia schimperiana–Hypoestes forskaolii*, *Hyparrhenia filipendula–Combretum molle*) were frequently

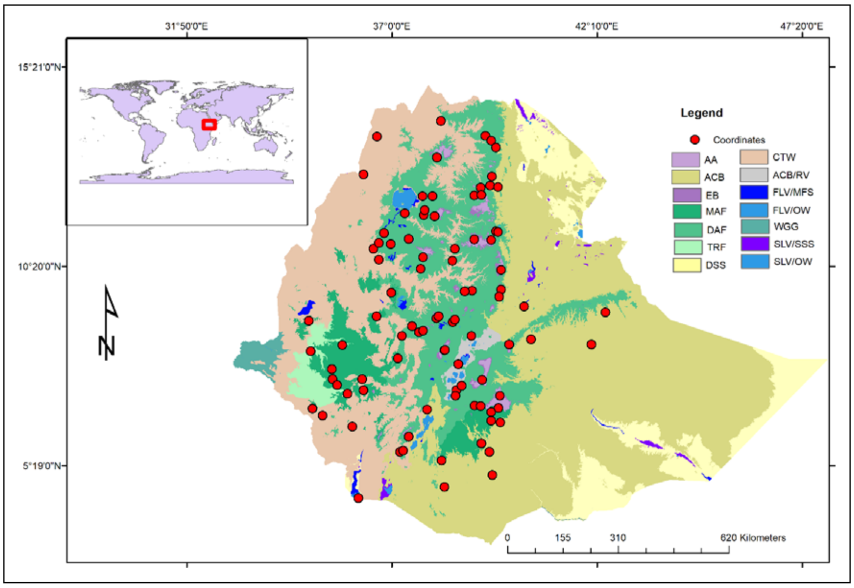

Figure 4. Map showing localities with coordinates covered by publications on plant ecology in Ethiopia between 1969 and 2019. Vegetation types shown (red dots) and the corresponding vegetation types (AA = Afroalpine Belt; ACB = *Acacia–Commiphora* woodland and bushland proper; EB = Ericaceous Belt; MAF = Moist evergreen Afromontane Forest; DAF = Dry evergreen Afromontane Forest; TRF = Transitional Rain Forest; DSS = Desert and semi-desert scrubland; CTW = *Combretum–Terminalia* woodland and wooded grassland; ACB/RV = *Acacia* wooded grassland of the Rift Valley; WGG = Wooded grassland of the Western Gambela region; FLV/MFS = Freshwater marshes and swamps, floodplains and Lake shore vegetation, FLV/OW = Freshwater Lake Vegetation – Open Water, SLV/SSS = Salt pans, saline/brackish and intermittent wetlands and salt-lake shore vegetation, and SLV/OW = Salt Lake Vegetation – Open Water). Base map from Van Breugel et al. (2015) and the vegetation classification system adapted from Friis, Demissew & Van Breugel (2010).

used to name a plant community. While this is not problematic in the concept of abstract plant communities, naming a plant community after indicator species of different strata (for example, herb (ground herbaceous layer) and tree (canopy)) could be challenging for conservation or management. Furthermore, if the taxa used to name a plant community are from the same stratum they should be separated by a n-dash (–), while those occurring in different strata are separated by a slash (/) and species that may occur with low constancy can be placed in parentheses (Dengler, Chytry & Ewald 2008). Some authors named plant communities after a weed such as *Achyrantes aspera* (Siraj et al. 2017). Overlap of plant community types between vegetation types were also reported in different articles. For example, *Arundinaria alpina* and *Maesa lanceolata–Brucea antidysenterica* communities were reported both from DAF and MAF (Bekele 1994; Yeshitela & Bekele 2003; Mewded, Negash & Awas 2019).

Methods employed by the studies

The selection of data collection and analysis methods were based on the availability of time, funding, expertise and objectives. In the present review 86 (64.2%) of the studies employed systematic sampling while a combination of sampling methods and plot-based data collection supported by GIS only accounted for six (4.4%) studies. The analysis of methods also revealed that more than 50% of the articles were descriptive or largely descriptive (Table 3).

Journal quartile of the articles published

Almost a quarter of the articles (24.6%) were published in the first quartile (top 25% of journals based on impact factor or impact index) and second quartile (top 25% to 50%) journals (Figure 5). The articles that were retrieved from African Journals Online (AJOL) and Addis Ababa Dissertation/Theses repository were not indexed although Momona Ethiopian Journal of Science (MEJS) is indexed in Web of Science and tracked for impact.

Recommendations forwarded by the studies

Most of the studies' recommendations were not based on the results of the research (51 articles, 38.1%,). For example, some floristic composition studies recommended establishment of a 'Natural Reserve' or 'Biosphere Reserve'. Although floristic study is part of establishing a biosphere reserve, proposing 'Natural Reserve' or 'Biosphere Reserve' based solely on a floristic list is far from the minimum requirement. In only 29 articles (21.6%) were the recommendations based on the results. In 22 articles (16.4%) the recommendations showed the gaps that were not covered by the research reported on. Several studies (32 articles or 23.9%) did not provide any recommendations.

Funding source reported

The funding for the articles reviewed was predominantly from international funders (58 articles or 43.3%) and the Ethiopian government (47 articles or 35.1%). The remaining articles' funding sources were either collaborative (11 articles or 8.2%) or the funder was not mentioned (18 articles or 13.4%). It is believed that international funding enables researchers to conduct a study with greater scope, but this is not reflected by the articles considered which were mostly descriptive.

Table 3. Sampling and analysis methods used in Ethiopian plant ecology publications (1969 to 2019)

Sampling method			**Analysis method**		
Description	**Frequency**	**Per cent (%)**	**Description**	**Frequency**	**Per cent (%)**
Systematic	86	64.2	Descriptive & community classification	34	25.4
Not mentioned	14	10.4	Descriptive	31	23.1
Preferential	14	10.4	ANOVA & Model	25	18.7
Stratified	6	4.5	Descriptive, community classification & ordination	24	17.9
Random	5	3.7	Ordination & GIS/Remote sensing	15	11.2
Combined	5	3.7	Descriptive, community classification, ordination & socio-economic	5	3.7
Plot & GIS	1	0.7			
Total	**134**	**100**	**Total**	**134**	**100**

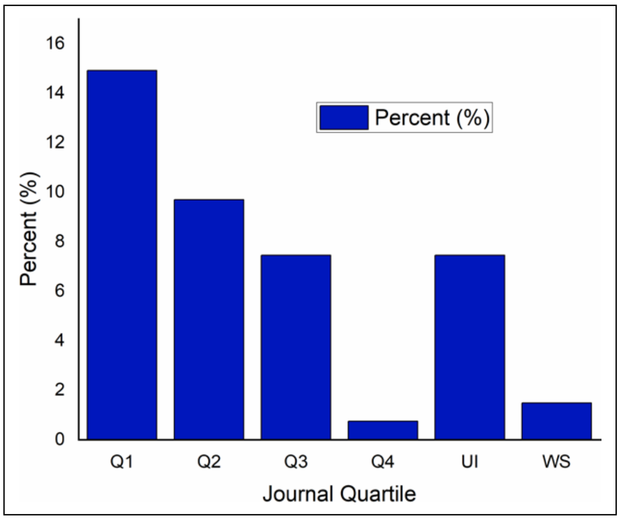

Figure 5. Journal quartile of the articles reviewed (Q1 = quartile 1, Q2 = quartile 2, Q3 = quartile 3, Q4 = quartile 4, UI = Unindexed, WS = indexed in Web of Science but no quartile value yet). The journal quartile value is obtained from Scimago (https://www.scimagojr.com/).

Discussion

Authorship and collaboration

The low number of plant ecological studies in the late 1960s was associated with the lack of trained manpower and political instabilities in the country. Apart from Haramaya and Gondar, which were colleges of agriculture and health science respectively, there has been only one university with a natural science programme, the so-called Haile Selassie I University, which has been known as Addis Ababa University since the early 1970s. Furthermore, most of the experts at the university were foreigners with limited knowledge about the vegetation of Ethiopia, which may explain the low number of plant ecology publications in the early 1970s.

In the early 1980s a flora project was funded by the Swedish International Development Corporation Agency (SIDA) and experts were trained in several disciplines including plant ecology, plant systematics and ethnobotany. A few of those trained are still staff members of Addis Ababa University. Furthermore, the number of universities in the country has increased from one in the 1960s to nearly 50 today. This has tremendously increased the capacity. Concurrently, the number of publications has risen steeply over the last five decades. In addition to the increased number of researchers, there has been an increase in the number of subjects due to new approaches and the development of new technologies from different disciplines which have influenced the increase in plant ecology research publications (Kim, Joo & Do 2018).

Globally, the decline of single-authored articles has been confirmed in various disciplines (Barlow et al. 2018). Similarly, in the present study, single-authored articles showed a declining trend (Figure 2B). This is mainly due to the fact that the research projects are either multidisciplinary or students and staff are included as authors, particularly in the case of publications based on theses or dissertations where the supervisor is included as an author.

Themes of the research topics

In the 21st century, research is supported by equipment for experiments, software for statistical analysis, and other applications such as GIS and remote sensing, which support field work. As a result of the availability of such technologies, the number of plant ecology articles published and the range of topics has dramatically increased globally (McCallen et al. 2019). In the present review, classical plant ecology themes were dominant over the last five decades in contrast to global contemporary topics such as microscale, macroscale and anthropogenic impacts (McCallen et al. 2019), which employ sophisticated techniques of analysis, including multivariate statistics and mathematical modelling (Kim, Joo & Do 2018). McCallen et al. (2019) identified nearly 50 thematic areas in ecological research. However, less than five thematic areas were covered in the articles reviewed in this study. Descriptive studies on plant community ecology focusing on floristic composition and community structure dominated the studies. However, the few studies on invasive species, fire ecology and species distribution modelling in the 21st century reveals that plant ecological research may be changing in Ethiopia. In line with the present study, a co-citation–based analysis study reported the dominance of community ecology research, but this was in the 1970s (Réale et al. 2020). This is, however, in contrast to a report by Carmel et al. (2013) in which single species research found to be dominant.

Ethiopia's natural environment is extremely degraded (Wassie 2020). As a result, most of the environment in the country is likely to be invaded by alien plants. Numerous plant species have been recognised as invasive in Ethiopia. Although most of them are exotic, there are few native plants, which have become invasive. Some of these invasive species appear to have become established in the desert and semi-desert scrubland at elevations lower than 1 000 m a.s.l. (e.g., *Parthenium hysterophorus* and *Prosopis juliflora*) and Afromontane forests at elevation above 2 500 m a.s.l. (personal observation), suggesting that protected areas in the lowlands and highlands are prone to invasive species. However, few studies (Shiferaw et al. 2019a, 2019b) investigated the distribution and impact of invasive species. The study of invasive species distribution and cover as well as reproductive and dispersal ecology is crucial for management or eradication. The impact of invasive species is profound in the Rift Valley.

However, studies on this topic, as well as in this ecosystem are extremely limited. Persistent environmental degradation and climate change are aggravating the impact of invasive species, which means that research in this field is a critical need.

Pollination, an often-mutualistic interaction, is at the core of ecological networks and plays a vital role in maintaining community stability and ecosystem function. Nevertheless, these interactions are threatened due to natural and anthropogenic disturbances leading to a global decline of pollinators. Plant–pollinator networks can potentially modify the population dynamics and the occupied range of a plant species (Pellissier, Alvarez & Guisan 2012). However, the contribution of pollination networks as driver of plant distribution and assemblage of plant communities has received little attention in Ethiopia. Thus, there is a need to characterise plant–pollinator interactions at large spatial scales and especially with respect to dynamic communities, whose compositions and patterns of relative species' abundance vary in time and space (Pellissier, Alvarez & Guisan 2012). In the Anthropocene, global warming is causing changes in species' fundamental and realised environmental niches. As a result, plants are shifting their ranges and phenology. This causes plant–pollinator mismatches, which leads to plant and pollinators diversity decline. Apart from the scant pollination studies on crops (Samnegård et al. 2014, 2016; Geeraert et al. 2020), particularly *Coffea arabica*, research on plant–pollinator networks in natural plant communities are absent in Ethiopia. This is identified as an important gap.

The limited number of articles based on experimental studies and advanced themes could be due to the lack of resources for experimental activities and limited expertise in these fields. Unlike the present study, Carmel et al. (2013) and Asselin and Gagnon (2015) revealed both observation and experimental studies shared almost equal contributions in their systematic reviews.

Although the Swedish organisation (SIDA) contributed to training experts in different fields, these were limited to the basic sciences. Hence, these experts have worked on descriptive research, and they encouraged the students they supervised to do their theses/dissertations on similar topics. Once the graduates are distributed to different universities, they follow the footsteps of their supervisors. As a result, redundancy of research focus occurs throughout the country.

Vegetation, land use and plant community types

Performing ecological research is not an easy task. Collecting ecological data from the field requires physical fitness as well as the ability to withstand harsh conditions and deal with other challenges associated with field work. Most of the plant ecological research was in either the DAF or MAF vegetation types. This could be due to forest being considered a high priority and these two vegetation types are dominant. In addition, DAF and MAF are found in an area which has a relatively suitable climate and so has the highest human populations, which means that these vegetation types are easily accessible. The high population does mean that these forests are also the most threatened (Woldu 1999) and so ongoing research is important.

The other important vegetation types attracted little attention, particularly, the Afroalpine and Ericaceous Belt, which are the main sources of freshwater for the downstream population. This could be due to the extreme cold and inaccessibility or the perceived low priority of these vegetation types. Similarly, there were few articles from drylands/lowlands vegetation types.

Journal quartile of the articles published

Journal Impact Factor (JIF) quartile is among the most widely used indicators to evaluate the importance or visibility of a journal in its field (Liu, Hu & Gu 2015). The reviewed articles were predominantly published in relatively high impact journals. Nevertheless, a significant number of studies were published in unindexed journals, and so it is not possible to track their impact.

Recommendations and source of funding

Plant ecological research publications often make recommendations based on empirical data and conclusions drawn. The recommendations may serve as guidance for natural resource managers and decision- and policy makers in conservation practices. Furthermore, highlighting research gaps could also have profound benefit. In the present study, most of the recommendations were not made based on the research results despite their relevance to decision makers. This shows either missed opportunities to help the relevant stakeholders or obscure research objectives.

Whether the funding source is governmental or international, the funders might have their own agendas. Often funders are interested in contributing to conservation decisions based on scientific evidence (Burivalova et al. 2019) to maximise the benefits of conservation, given the limited resources available (Game 2018). It is interesting that international funding dominated in the studies reviewed but the research topics investigated using international funding are more-or-less similar to the investigations conducted with Ethiopian government funding.

Monitoring of completed projects and incorporating research recommendations into policy and decision-making is poorly realised. For example, Teketay and Bekele (1995), Hundera and Deboch (2008) and Hundera et al. (2007) recommended Wof-Washa, Gurra Farda and Dodola forests as nature reserves. However, they are not yet designated as protected areas (UNEP-WCMC 2017). Furthermore, forest and woodland cover loss are reported even in protected areas (Nune, Soromessa & Teketay 2016; Arafaine & Asefa 2019), revealing lax policy and decision-making. This disconnect between research findings and recommendations and conservation practice could be due to the following reasons: i) the government is responsible for integrating the research outputs into policies; ii) complexity of socio-ecological systems (Miteva 2012); (iii) lack of funding for conservation operations (Ferraro & Pattanayak 2006); and iv) lack of trustworthy scientific studies.

Is plant ecology research growing up in Ethiopia?

There are debates on the progress of ecological research. Bringing Grace's (2019) question, 'Is ecology growing up?' to the Ethiopian perspective, if the context is the number of published studies, plant ecology research is definitely growing up. However, the quality of plant ecological research in Ethiopia is not growing up if the criteria applied are the research theme, the use of sophisticated technologies and the depth of study. This is excluding the land use/land cover change domain that focused on the change detection only. Plant community descriptive studies more-or-less dominated the plant ecology research thematically. This topic was the main focus of plant ecological research in the 1960s to 1970s in Europe and Northern America. Hence, although it seems like a negative perspective, plant ecology research in Ethiopia is still stuck in the 1970s.

Conclusions and future directions

This study systematically synthesised trends in plant ecology research in Ethiopia over the last 50 years. Descriptive plant community ecological studies dominated the plant ecology research thematically – most of them distributed in the DAF and MAF – while the Afroalpine and Ericaceous Belt, woodland (ACB & CTW), and desert and semi-desert scrubland (DSS) vegetation types got little attention. Hence, the following future directions are suggested to guide and improve plant ecology research in Ethiopia going forward.

Future plant ecology research should include the application of remote sensing in vegetation ecology, climate change and vegetation ecology, and plant functional ecology, vegetation temporal dynamics and experimental approaches should be considered.

Establishing a committee that comprises plant taxonomists, plant ecologists, geologists, geographers and GIS experts is recommended to investigate and map the plant community types at a national level. This is crucial to allocate conservation resources objectively otherwise, fragmented studies of plant community types of a particular sites will make conservation efforts increasingly challenging.

Recommendations from any research study, if available, should be based on empirical information to make policy and decisions justifiable. Funders such as government agencies, non-government organisations and others, including international agencies, are advised to provide resources to cover important topics such as invasive species ecology, application of GIS and remote sensing in vegetation ecology, and community interactions. Supervisors should also play a major role in helping postgraduate students identify contemporary ecological research areas such as pollination ecology.

The Ethiopian Ministry of Science and Higher Education (MoSHE) should establish a database both for completed and ongoing research projects i.e., project registration in addition to what exists at various universities. This would help to avoid project redundancy.

Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

KG (Samara University) inception, study design, data collection and analysis, and write-up. SD (Addis Ababa University) contributed to the project inception, data analysis and manuscript writing.

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Supplementary Material

Supplementary Table S1. Studies included in the systematic review and location where the study was carried out

Citation	Study area
Beals (1969). *Science New Series* 165, 981–985	Bati to Combolcha; Awash to Shashemene
Beals (1969). *Journal of Ecology* 57, 655–667	Erer-Gota Plain (Southern Afar, Danakil Depression)
Woldu (1986). *Vegetatio* 67, 3–16	Shewa
Demissew (1988). *Mountain Research and Development* 8, 243–247	Menagesha Forest
Woldu et al. (1989). *Vegetatio* 81: 189–198	Harena Forest
Woldu & Backéus (1991). *Journal of Vegetation Science* 2: 173–180	Shewa
Bekele (1994). *Journal of Vegetation Science* 5, 87–98	Jibat
Teketay (1995). *Mountain Research and Development* 15, 183–186	Dakata Valley
Teketay & Bekele (1995). *Feddes Repertorium* 106, 127–147	Wof Washa
Tekle et al. (1997). *Nordic Journal of Botany* 17, 48–493	Southern Wello
Demissew (1998). *Journal of Ethiopian Studies* 31, 159–192	Zonal
Carr (1998). *Plant ecology* 135: 135–163	Omo Valley
Egziabher et al. (1998). *Plant Biosystems* 132, 39–51	Adwa
Gebremedhin Hadera (2000). Thesis, AAU	Dess'a Forest
Tekle & Bekele (2000). *Biotropica* 32, 23–32	Southern Wello
Tekle (2001). *Applied Geography* 21, 275–300	Southern Wello
Woldu & Saleem (2000). *Agriculture, Ecosystems and Environment* 79, 43–52	Ginchi
Awas et al. (2001). *SINET: Ethiopian Journal of Science* 24, 213–228	Gambella
Senbeta & Teketay (2001). *Tropical Ecology* 42, 175–185	Menagesha Forest
Feoli et al. (2002). *Agriculture, Ecosystems and Environment* 91, 313–325	Adwa
Gashaw et al. (2002). *Nordic Journal of Botany* 22, 19–33	Gambella
Senbeta et al. (2002). *New Forests* 24, 131–145	Munessa-Shashemene Forest
Tesfaye et al. (2002). *Flora*197, 461–474	Harena Forest
Yeshitela & Bekele (2002). *SINET: Ethiopian Journal of Science* 25, 155–175	Sw Ethiopia
Asefa et al. (2003). *Land degradation and development* 14, 25–38	Hauzien District
Yeshitela & Bekele (2003). *Ethiopian Journal of Science* 2, 31–48	Masha-Anderacha Forest
Soromessa et al. (2004). *Tropical Ecology* 45, 209–221	Gamo Gofa Zone
Tesfaye etal. (2004). *Mountain Research and Development* 24, 354–361	Harena Forest
Abdiitana Tumtu (2005). Thesis. AAU	Awash National Park
Genene Bekele (2005). Thesis. AAU	Magada Forest
Leminih & Teketay (2005). *Forest Ecology and Management* 218, 60–73	Shashamane Forest Industry Enterprise
Mengistu et al. (2005). *Journal of Arid Environments* 60, 259–281	Biyokelala and Tiya
Senbeta et al. (2005). *Diversity and Distribution* 11, 443–452	Berhane-Kontir, Harenna, Maji, Yayu
Wassie et al. (2005) *Forests, Trees and Livelihoods*, 15, 349–373,	Gondar
Aerts et al. (2006). *Plant ecology* 187, 127–142	Geba Watershed
Ayalew et al. (2006). *SINET: Ethiopian Journal of Science* 29, 45–56	Denkoro Forest

Supplementary Table S1. Studies included in the systematic review and location where the study was carried out (continued)

Citation	Study area
Dereje Denu (2006). Thesis. AAU	Gurra Ferda
Senbeta & Denich (2006). *Forest Ecology and Management* 232, 68–74	Berhane-Kontir And Harenna Forest
Wassie & Teketay (2006). *Flora* 201, 32–43	Church Forest
Zegeye et al. (2006). *Flora* 201, 483–498	Islands Lake Ziway
Alelign et al. (2007). *Tropical Ecology* 48, 37–49	Peninsula Of Zegie
Hundera et al. (2007). *SINET: Ethiopian Journal of Science* 30, 1–12	Easter Ethiopia
Reubens et al. (2007). *Tropicultura* 25, 204–214	Dogua Tembien District
Gole et al. (2008). *Forest Ecology and Management* 255, 2138–2150	Yayu Forest
Hundera & Deboch (2008). *Ethiopian Journal of Educucation & Science* 3, 44	Gurra Ferda
Yineger et al. (2008). *SINET: Ethiopian Journal of Science* 31, 103–120	Bale Mountain
Lulekal et al. (2008). *Journal of East African Natural History* 97, 165–185	Mana Angetu
Tolera et al. (2008). *Agriculture, Ecosystems and Environment* 128, 52–58	Beseku-Ilala Peasant Association
Wassie et al. (2009). *Forest Ecology and Management* 257, 765–772	Gondar (Zonal)
Wassie et al. (2009). *Biotropica* 41, 110–119	Gondar (Zonal)
Didita et al. (2010). *Journal of Forestry Research* 21, 395–408	Delo Mana
Feyera Abdena (2010). Thesis. AAU	Chato Forest
Kreyling et al. (2010). *Diversity and Distribution* 16, 593–605	South Ethiopian Highlands
Schimitt et al. (2010). *Applied Vegetation Science* 13, 291–304	Bonga
Shambel Bantiwalu Bedanie (2010). Thesis. AAU	Sanka Meda
Wassie et al. (2010). *Journal of Vegetation Science* 21, 93–948	Gondar
Woldemicael (2010). *Momona Ethiopian Journal of Science* 2, 27–48	Hugumbirda-Grat-Khassu
Abiyu et al. (2011). *Mountain Research and Development* 31, 144–154	Tehuledere District
Dinkissa Beche Benti (2011). Thesis. AAU.	Menagesha Forest
Shambel Alemu Chengere (2011). Thesis. AAU.	Angada Forest
Wana & Beierkuhnlein (2011). *Journal of Tropical Ecology* 27, 289–304	Gughe-Amaro Mountains
Zegeye et al. (2011). *Journal of Forestry Research* 22, 315–328	Tara Gedam And Abebaye Forests
Adamu et al. (2012). *Journal of Forestry Research* 23, 599–607	Metema
Adamu et al. (2012). *Journal of forestry Research* 23, 391–398	Metema
Angassa (2012). *Land degradation and development*. http://dx.doi.org/10.1002/ldr.2160	Yabello And Dirre (Zonal)
Mekbib Fekadu (2012). Thesis. AAU	Awash Melka Kunture
Tessema et al. (2012). *Biotropica* 44, 211–219	Awash Naional Park
Burju et al. (2013). *Ethiopian Journal of Educucation & Science* 8, 11–32	Jibat
Fisaha et al. (2013). *African Journal of Ecology*. http://dx.doi.org/10.1111/aje.12071	Wof Washa
Gebrelibanos and Assen (2013). *African Journal of Ecology* 52, 292–299	Woodland
Gurmessa et al. (2013). *Science, Technology and Arts Research Journal* 2, 58–69	Komto Forest
Kebede et al. (2013). *Journal of Forestry Research* 24, 419−430	Wondo Genet
Kebede et al. (2013). *Biodiversity Research Conservation* 29, 63–80	Wondo Genet

Supplementary Table S1. Studies included in the systematic review and location where the study was carried out (continued)

Citation	Study area
Mohammed and Abraha (2013). *Ethiopian Journal of Science & Technology* 6, 33–45	Yegof Forest
Adem et al. (2014). *Journal of Forestry Research* 25, 319–328	Omo Valley
Assefa et al. (2014). *Ethiopian Journal of Biological Science* 13, 117–133	Chilimo
Dale et al. (2014). *SINET: Ethiopian Journal of Science* 37, 1–12	Borena Rangelands
Dibaba et al. (2014). *Momona Ethiopian Journal of Science* 6, 70–96	Sire Beggo in Gololcha District
Erenso et al. (2014). *International journal of biodiversity and conservation* 6, 382–391	Boda Forest
Gebrehiwot & Hundera (2014). *Momona Ethiopian Journal of Science* 6, 97–101	Belete Forest
Gedefaw & Soremessa (2014). *Science, Technology and Arts Research Journal* 3, 113–118	Tara Gedam
Mistire Yifru Feleke (2014). Thesis. AAU	Menagesha Forest
Senbeta et al. (2014). SINET: *Ethiopian Journal of Science* 37, 113–130	Bonga (Zonal)
Sileshi & Abraha (2014). *Momona Ethiopian Journal of Science* 6, 25–44	Hugumburda
Tadele et al. (2014). *Journal of Forestry Research* 25, 329–336	Zenegena Forest
Bruk Bedore Amado (2015). Thesis. AAU	Gera Forest
Getaneh Belachew Haile (2015). Dissertation. AAU.	Choke-Koso Ber Mountain Range
Kuma & Shibru (2015). *Journal of Botany*. http://dx.doi.org/10.1155/2015/963816	Humbo Carbon Project
Leul Kidane Woldemichael (2015). Dissertation. AAU	Hugumburda
Yirdaw et al. (2015). *Journal of Forestry Research* 26, 919–931	Rira Forest
Aerts et al. (2016). *Science of the Total Environment* 551–552, 404–414	Church Forest
Aynekulu et al. (2016). *Folia geobotanica*. http://dx.doi.org/10.1007/s12224-016-9247-y	Hugumburda
Berhanu et al. (2017). *Journal of Forestry Research* 28, 343–355	Kundisha
Kebede et al. (2016). *Acta Ecologica Sinica* 36, 392–400	Gedo Forest
Melese & Ayele (2016). *Journal of Forestry Research*. http://dx.doi.org/10.1007/s11676-016-0280-8	Ambo Forest
Tamene Yohannes (2016). Dissertation. AAU	Gergeda and Anbessa Forests
Van Breugel et al. (2016). *Ecosystems* 19, 369–386	National
Van Breugel et al. (2016). *Applied Vegetation Science*. http://dx.doi.org/10.1111/avsc.12220	National
Abreham Assefa Madebo (2017). Dissertation. AAU	GibeOmo Watershed
Gebregergis et al. (2017). *Journal of Forestry Research*. http://dx.doi.org/10.1007/s11676-017-0512-6	Tselemti District
Girma Nigussie Asresu (2017). Thesis. AAU	Guassa
Jara et al. (2017). *Agriculture, Ecosystems and Environment* 240, 92–100	Farmlandscape
Mesfin Woldearegay (2017). Dissertation. AAU	Bore-Anferara-Wadera Forest
Scull et al. (2017).*Land Degradation and Development* 28: 450–458	Debra Tabor (Zonal)
Siraj et al. (2017). *Applied Ecology and Environmental Research* 15, 245–262	Gamo Gofa Zone
Talemos Seta Shanka (2017). Dissertation. AAU	Boter-Becho Forest

Supplementary Table S1. Studies included in the systematic review and location where the study was carried out (continued)

Citation	Study area
Tesema and Belay (2017). *Journal of Arid Environments* 139, 76–84	Babile
Young et al. (2017). *Biotropica* 0, 1–9	Bale Mountain
Abiyou Tilahun Ayalew (2018). Dissertation. AAU	Wof Washa
Abunie & Dale (2018). *International Journal of Forestry Research*. https://doi.org/10.1155/2018/5302523	Yemrehane Kirstos Church Forest
Abyot Dibaba (2018). Dissertation. AAU	Gerba Dima Forest
Atsbha et al. (2019). *Heliyon* 5, e01120	Hugumburda
Berhanu et al. (2018). *Phytocoenologia* 48, 351–367	Awi Zone
Gebre et al. (2018). *Agroforest syst*. https://doi.org/10.1007/s10457-018-0226-6	Gergera Watershed
Gebrekiros & Tessema (2018). *Ecological Processes* 7, 9.	Kafta Humera And Tsegede (Zonal)
Gebremedhin et al. (2018). *Arid Land Research and Management* 32, 236–252	Dejena Sub-District
Girma et al. (2018). *Mountain Research and Development* 38, 143–152	Arsi Mountain
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Johansson et al. (2018). *Global change biology* 1–13.	Bale Mountain
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