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The Status of Vegetables Research in Malawi, Capacity, Progress, Gaps, and Way Forward—A Scoping Review

Dickson Mazibuko[1,2], Hiromu Okazawa[3*], Hiroko Gono[4], Sarvesh Maskey[3]

[1]Graduate School of Agro-Environmental Science, Tokyo University of Agriculture, Tokyo, Japan
[2]Faculty of Basic and Applied Sciences, University of Malawi, Zomba, Malawi
[3]Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
[4]Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Tokyo, Japan
Email: dmazibuko@unima.ac.mw, *h1okazaw@nodai.ac.jp

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Abstract

Vegetables are key to nutrition and economic security, especially for developing societies. Research in vegetables has been historically key. From early domestication efforts to modern-day breeding and value addition, research has enabled vegetable productivity to support the nutritional and economic needs of societies. Impactful research, however, requires competent research capacity and a guiding framework, in a continuously changing socio-climatic world. Vegetable research appraisal in Malawi, especially regarding capacity, focus, and a guiding framework, is lacking. By using 5 search engines and 506 analyzed publications, this review sought to first examine the existing research capacity in Malawi and assess the vegetable research focus in terms of both value chain analysis themes and specific vegetable tax. This approach allowed for the isolation and flagging out of key emerging issues from existing research that positively contextualize future vegetable research direction in Malawi. It has been found that Malawi has adequate institutional and expertise capacity to further vegetable research. The identified challenges include local funding and infrastructural capacity to leverage donor funding. Three key emerging issues of climate change, modeling, and biofortification in vegetable crops have been identified. It is suggested that, with Malawi facing the climate change challenge, research focus in these areas, will enhance not only nutritional and economic security, but also overall climate change readiness. Key to climate change readiness is the involvement of indigenous vegetable production. As a package, vegetable cultivation can play a critical role in contributing to the achievement of pillar 1 of the Malawi vision 2063, which seeks to leverage agricultural productivity and commercialization with a focus on climate change resilience.

Keywords

Agroecology, Biofortification, Climate Change, Malawi, Research, Vegetables

1. Introduction

1.1. Vegetable Research: A Historical Perspective

The importance of vegetables has been ably documented over time, as sources of human nutrition [1], where they play a key role in reducing risks from the non-communicable disease [2], household economy, and enhancement of local and national food security. The attainment of such a status for vegetables in society stems from research that dates to vegetable identification and domestication thousands of years back. Domestication as long-term research (experiment) [3], is thought to have begun about 12,000 years ago [4] and led to modern-day agriculture as science. Gepts [3] posits that agriculture as an innovation evolved independently in geographically disparate regions (referred to as centers of origin) that shared similar ecosystems and species pools that allowed for the identification of taxa predisposed to domestication. Placing man on a scale of her relationship with plants, Harris *et al.* [5] recognize four stages: effortless wild plant procurement, cultivation, domestication, and labor-intensive agriculture. Vegetable migration from centers of origin into new locales has been coupled with adaptions to novel destination habitats [6]. These various vegetable adaptions have supported breeding efforts for various desirable traits that support modern-day vegetable production.

Vegetable consumption in different countries is itself determined by the cultural and ethnic origins [7] of the resident peoples in a country or society. Various vegetables have, thus, tended to accrue variable levels of importance depending on the ethnic and cultural composition of a locale in which they exist or have been introduced. The arrival of new vegetables in novel geographic ranges has spurred research (crude or advanced) by humans attempting to improve the palatability and acceptability of various vegetables, leading to diversity in recipes [8], parts of plants utilized, and cultivation approaches for various vegetables.

Vegetable research has, thus, been and shall remain a key component of vegetable production and utilization within human societies. The diversity in vegetable crops in general, and diversity in consumed diversity specifically, has entailed variable research attention. Indigenous vegetables, irrespective of their importance [9], currently fall at the lower end of the research priorities [10].

1.2. Modern-Day Vegetable Research

The magnitude, focus, and target species of vegetable research in any country are to a greater extent determined by human capital or capacity (in terms of expertise), funding availability, and the actual or perceived importance of a given vegetable species. Such research determinants could lead to skewed attention in research where other vegetable species are either neglected [10] or receive minimal research attention. The emergence of universal global threats to agriculture in general, and particularly to vegetables, has led to some un-written consensus on the research agenda. Global climate change and climatic variability call for some standardized research agenda for agricultural [11] crops and vegetables. Climate change is envisaged to facilitate new pathogen emergence, frequent drought episodes, pollinator shifts, soil degradation, and general water scarcity. These events have a direct bearing on vegetable productivity and consequently affect the provisions humans obtain from their cultivation.

This review, thus, seeks to contextualize vegetable research in Malawi by overall seeking to determine the status of research from 1990 to date. Specifically, this review set out to: 1) Determine the national research capacity (human (collaboration), funding); 2) Research focus *i.e.* themes and crops; 3) Identify existing calls to research and emerging issues; 4) Propose future vegetable research that focuses on, emerging global issues and that aligns with change and Malawi's vision 2063. It is hoped that such a review would help guide the overall research agenda aimed at enhancing diversifying vegetable consumption base, economic productivity, and climatic resilience.

2. Methodology

2.1. Approach

A scoping review approach was used to acquire and synthesize information on research on vegetables in Malawi. Existing evidence shows no wholistic review has been done on this topic. Some studies summarized specific issues [12] [13] within the broader framework of vegetables in Malawi and while other authors reviewed specific vegetable species as in [14] [15].

The study used a combination of five search engines and databases: Google scholar: a free web search engine that indexes the full text or metadata of scholarly literature in diverse disciplines; AGRIS (FAO): a database indexing articles and other publications in the area of food and agriculture; CABI Direct: CAB Direct is reference source incorporating leading bibliographic databases CAB Abstracts and Global Health; Scopus: an Elsevier's abstract and citation database for life sciences, social sciences, physical/health sciences; and Mendeley: a reference manager with an article search option. The Boolean search approach was used in searching all the databases listed above.

2.2. Review Period

The target articles were those published between 1990 and 2022. The base year was thus chosen to coincide with inception of the World Wide Web (www) in the 1990s [16]. This review has been based fully on articles published and traceable online. It is recognized that there exist publications, especially conference proceedings, project report, and academic thesis that are not available online. These do not form part of this review.

2.3. Database Search Approach

Several search terms were used in the process of identifying relevant papers. These included "Vegetables" and "Malawi". The intention was to capture only those articles that dealt with Malawian vegetables. Each search term was used/repeated across all search engines and databases used in this study. A more refined search, using specific vegetable names (Scientific English and sometimes local) was also used, for example, "*Manihot esculenta*" and "Malawi" OR "Cassava". The specific search approach was also repeated across all search engines/databases used in this review. The "term" Malawi was maintained in all search terms to ensure that the results/hits were confined to works on Malawi as much as possible. To ensure exhaustive analysis of search hits, the time frames for the searches was limited to a decade span (1990-1999, 2000-2009, 2010-2019, and 2020-2022), except for CAB-direct where such categorization was not possible, and a manual separation of search results (into respective decades) was done. These decadal demarcations also enabled a decade-based review of the topic.

2.4. Article Qualification Criteria

The criterion for selecting relevant papers was two pronged. The selected papers had to fit two criteria: 1) The title should have both the term "vegetable" or "vegetable name" and the name "Malawi"; 2) the terms "Malawi" and "vegetable" ("vegetable name") appearing either in the article title or in the accompanying (search) text. Papers were screened by title and abstract to identify full-text reports that were relevant to the objectives of this review. Further criteria for article inclusion required articles whose focus was on any vegetable (or a group of vegetables) in Malawi published between 1990 and 2022. Articles whose research took place outside Malawi and used Malawian germplasm were included if they were addressing a research issue relevant to Malawi.

2.5. Data Analysis

For each publication, the following attributes were recorded: year of publication, study site (Malawi or elsewhere), vegetable taxon/taxa studied, type of publication (journal article, conference proceedings, thesis, and project reports), research theme, emerging issues, call to research (suggested areas of further research), source of research funding (international funder, local funder or a combination), First author institutional affiliation, Nature of collaboration (where two or more authors co-publish, and collaborating institutions). During assessment of research themes, the article abstracts, and conclusions were read, and a determination was made into the theme a particular research fell under. For each article, the above 13 attributes were entered into Microsoft excel spreadsheet. Tallies for each theme were generated and later used for various computations and chart production.

Qualitative data was tabulated in Microsoft word.

3. Research Output Overview

Vegetable research in Malawi has been on the increase during the review period. Figure 1 shows the increase from about 95 publications (traceable online) in the decade 1990-1999 to about 197 by the end of 2019. Specifically, journal articles and academic thesis have shown a steady increase. Noteworthy is the decline in the Conference Proceedings (CPs). While CPs were common in the nineteen nighties and two thousands, there has been a decline in this publication category lately.

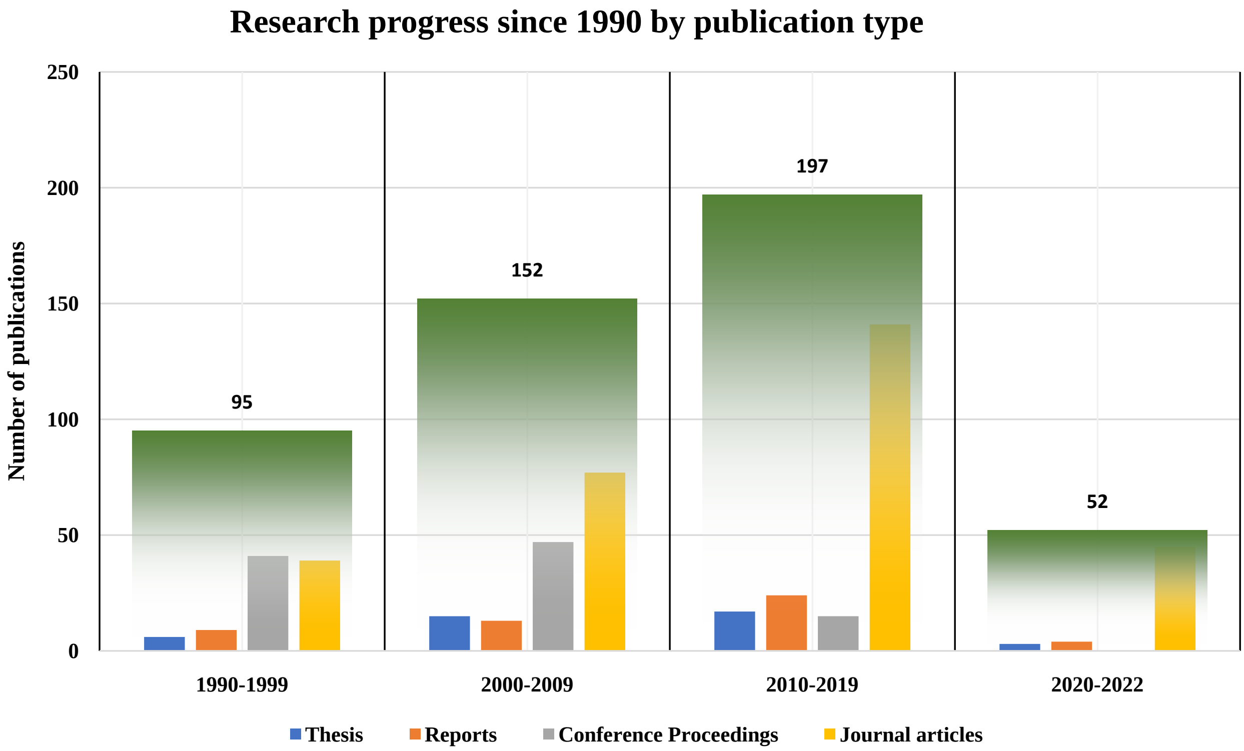

Figure 1. Progress of vegetable research in Malawi since 1990, giving the total number of publications and type of publications.

The decline in conference proceedings corresponds with an increase in both journal publications. The decline could have a bearing on the actual amount of research done and yet untraceable online. Conference proceedings used to be (and still are) a way of dissemination of findings without the rigor required for journal publication of the same results. This review thus provides a picture of research in vegetables, sorely based on published and traceable literature. There exist potentially more unpublished research is on bookshelves as reports. This notwithstanding, this work still captures the wider picture of the vegetable research story in Malawi.

4. Vegetable Research in Malawi: Capacity

Research capacity in this article is categorized into four themes namely, funding capacity, expertise capacity, institutional capacity, and collaboration capacity. It has been reasoned that where these four critical facets coexist, meaningful research is possible.

4.1. Funding Capacity

In the case of vegetable research in Malawi for the past 30+ years, funding has been available mostly from international funding institutions. Of the 497 articles screened for funding source, 211 declared source of funding. Approximately, eighty different funding institutions have been involved. Figure 2 shows research funding contribution by different stakeholders. The Malawi government has been directly involved in funding vegetable research via its agricultural research stations and Agri-based universities mainly Lilongwe University of Agriculture and Natural Resources (LUANAR). A small proportion (7%) of sole government finding was also made directly available for research.

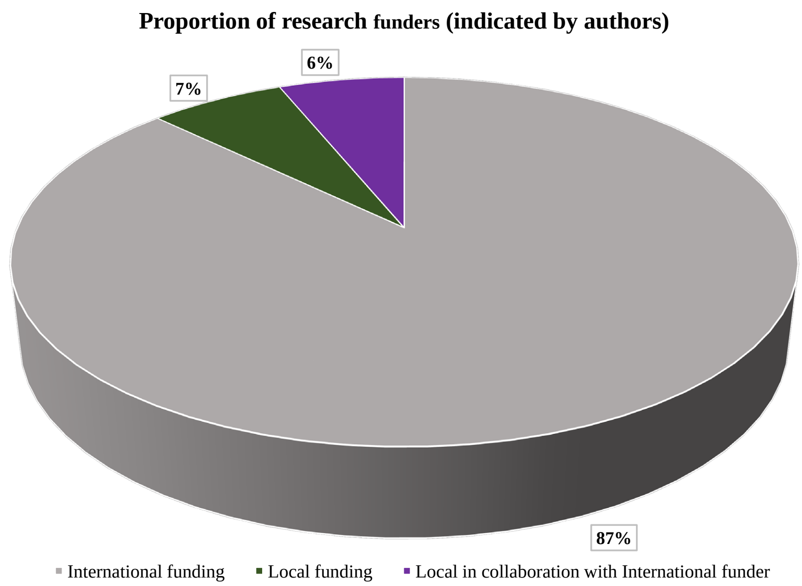

Figure 2. Funding sources for the various vegetable researches in Malawi. The data here is from authors that indicated the source of funding (20% of all publications).

There exists a need to augment the current vegetable research funding capacity, where the government and other local stakeholders become involved. With the existing global financial challenges partly emanating from the COVID-19 pandemic, international funding could potentially decline as nation states focus on rebuilding their economies.

4.2. Human/Expertise Capacity

This review has shown the existence of robust expertise that constitutes a critical mass in vegetable research. From the assessed publications, expertise exists in most key areas such as vegetable agronomy, molecular biology, breeding, plant pathology and extension. The contribution of these experts is evident in publication in all areas of vegetable production including crop and yield improvement, pest and disease control, genetic characterization and diversity assessments, and climate change related research in moisture and drought tolerance and nutrient cycling and use efficiency. Such intellectually equipped expertise can spearhead vegetable research and need recognition as an asset to national research agenda.

4.3. Institutional Capacity

Institutionalization of research in Malawi has been a part of government agenda both prior to and after independence. The government has a total of eleven research stations: three major and eight minor stations. The establishment of most of these research stations dates prior to independence except Kasinthula and Lunyangwa (http://dars.mw/index.php/research-stations/). After independence, the new Malawi government inherited these stations and subsequently restructured their mandates. In terms of vegetable research, according to ISNAR [17], Bvumbwe research station was a major station mandated for horticulture research. Chitala was for roots, tubers, beans, and peas; Kasinthula for irrigated agriculture (horticulture); and Lunyangwa for roots and tubers. It should be noted that research mandates across research stations is currently blurred, as various stations are involved is diverse research themes (**Figure 3**).

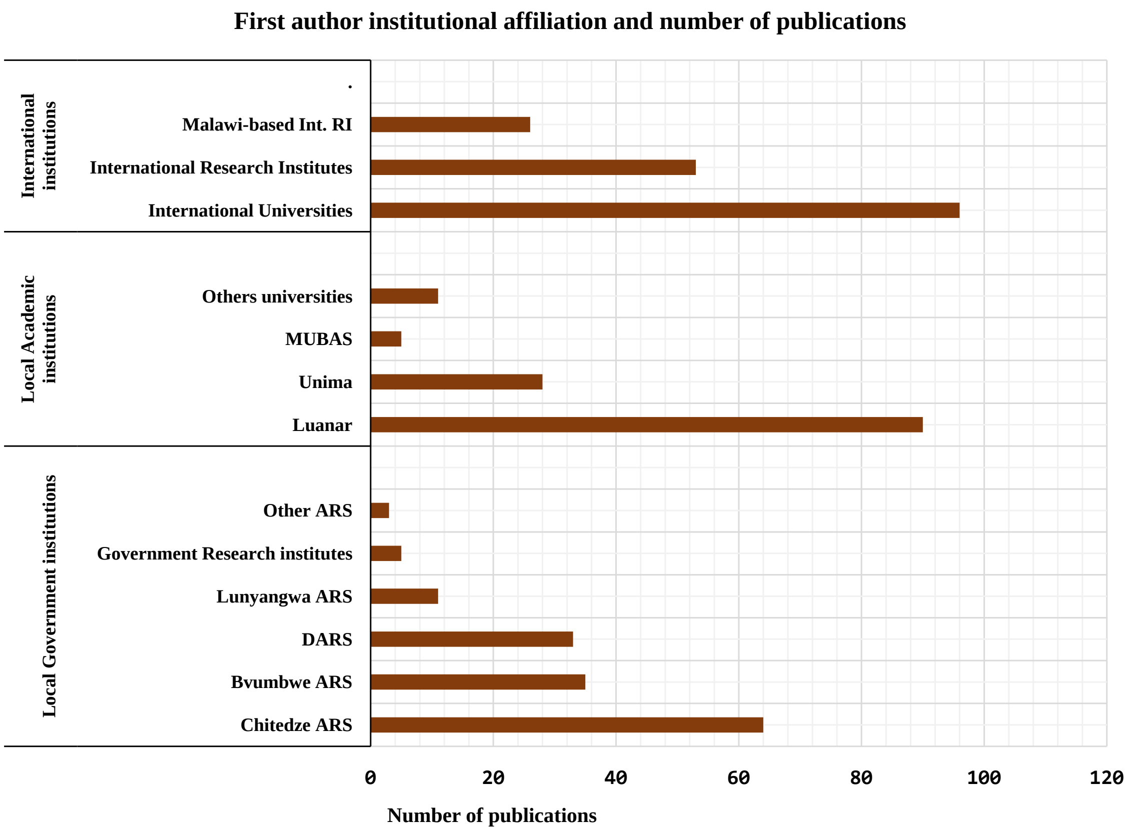

Figure 3. Number of publications from both local and international institutions as obtained from first author affiliation (RI: Research Institute; ARS: Agricultural Research Station; DARS: Department of Agricultural Research Services; MUBAS: Malawi University of Business and Applied Sciences).

Vegetable research reviewed here has been spearheaded by government research stations (Chitedze, Bvumbwe, and Lunyangwa) at a combined 33% of total research. Academic research institutions contributed about 29% to vegetable research. Of these, LUANAR has, by far, been the most active contributing 67% of all university's contribution. This emanates from LUANAR's mandate that is clearly Agri-based. The participation of international research institutions and institutes is evident in Malawi's vegetable research with ninety-eight publications led by authors affiliated with international universities.

In terms of institutional capacity, it is prudent to posit that there is adequate institutional capacity to spearhead vegetable research in Malawi. There however exist institutional challenges that need resolving to ensure the institutions involved are capacitated to deliver. These include adequate funding, and state of the art laboratories, and adequately trained technicians to run laboratories, among others.

4.4. Collaboration Capacity

Collaborative research has been around for a long time. However, for a long time, research was assigned to specific institutions or even departments. Recently,

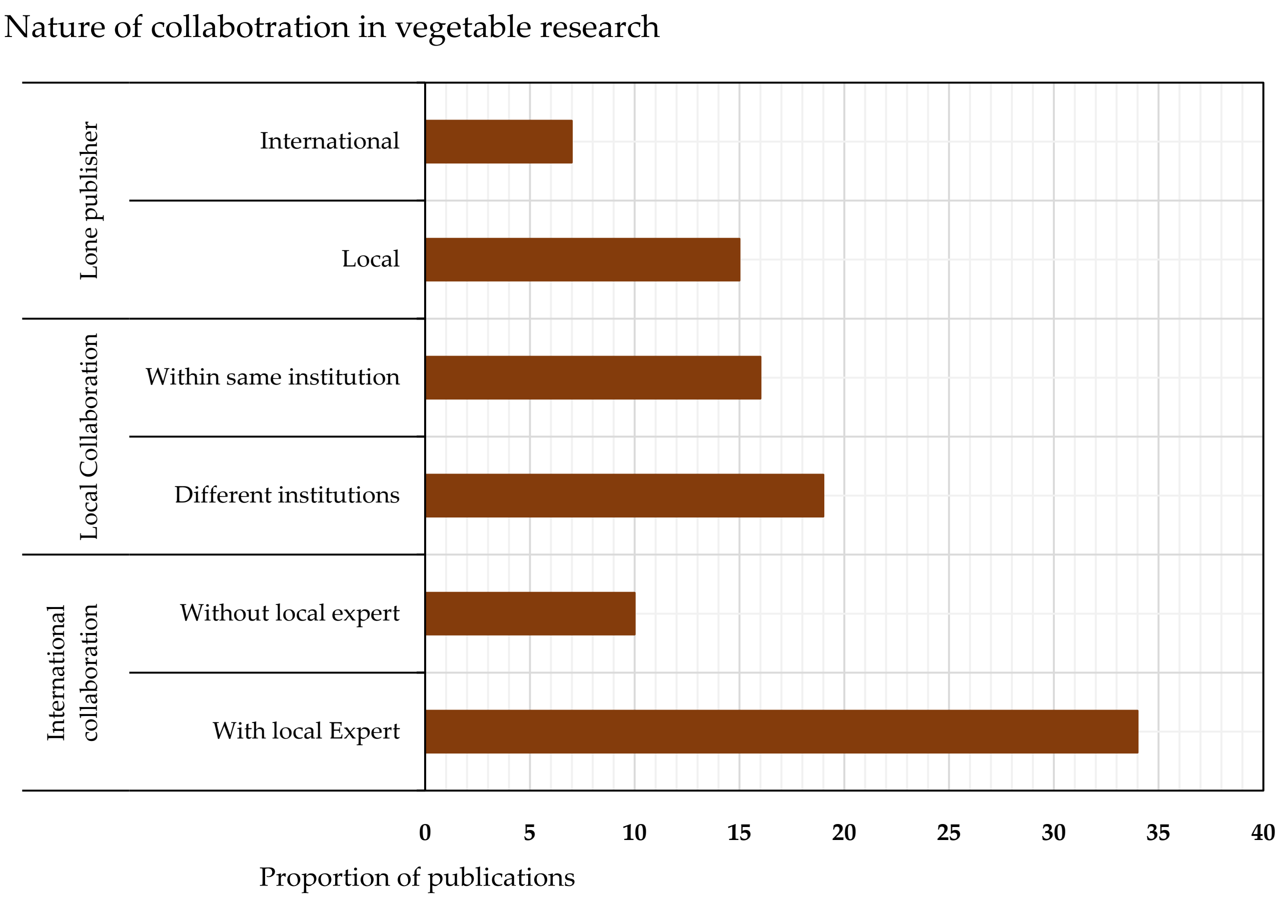

Figure 4. Nature of collaborations among various institutions (both local and international (IC: International Collaboration; LC: Local Collaboration; LPs: Lone Publishers).

an innovative approach where departments/disciplines/institutions come together in what is termed multidisciplinary research has emerged. This contemporary approach reduces the need for expanded expertise capacity [18] by incorporating such a resource from other institutions and disciplines. The vegetable research and publications in Malawi since 1990 has been via multidisciplinary collaboration between international institutions and experts and local ones.

Most vegetable research (79%) in Malawi has been via collaboration 44% with international and 27% with local experts. Collaboration in research was also reflected in publications where 34% of local experts co-authored published papers (**Figure 4**). Overall, there exists a strong collaboration culture in vegetable research. In countries where limited funds are dedicated to research, collaboration is known to save funds. Bansal et al. (2019) observes that where government research funds are inadequate for universities (which is the case in Malawi) compared to small government institutions, there tends to be the consequence of separating education from research in universities. Collaboration, irrespective of known challenges [19] ensures the linkage of diverse expertise and institutions leading to production of quality research outputs. Collaboration can play a role in solving this challenge and aid in ensuring the production of breakthrough research.

5. Vegetable Research in Malawi: Areas of Focus

The review sought to document issues that dominate vegetable research in Malawi. Particularly as regards diversity of taxa, and thematic areas (that constitute the entire value chain).

5.1. Taxa Studies

Of the reviewed articles, twenty-nine different vegetable species had been researched on. Vegetable research in Malawi has not been even in terms of crop coverage. Greater focus seen to have been on *Manihot esculenta* for root vegetables, *Cajanua cajan* for seed-based, *Brassica* sp. for leafy vegetables, and *Alium cepa* for spices. Most attention has been to roots/tuber and seed-based vegetables while leafy vegetables and spices got the least attention (**Figure 5**). The abundant research in *Manihot esculenta* can partly be explained by the search for starch products that utilize cassava starch for industrial purposes, spearheaded by Cassava Adding Value for Africa (CAVA) project, and early efforts to use *Cajanus cajan* as an agroforestry species (nitrogen fixation) but also export of its non-vegetable seeds.

Further, the research is seen to have focused on non-native vegetable species irrespective of earlier calls [20] to bring indigenous vegetable research and cultivation to the front. For example, of the studied taxa, 71% are non-native (exotic) species. Introduced species get confused with indigenous or native and are noted here. **Figure 5** shows species specific research focus and **Table 1** gives a summary of the studied species including their regions of origin and thus their rightful residence status in Malawi.

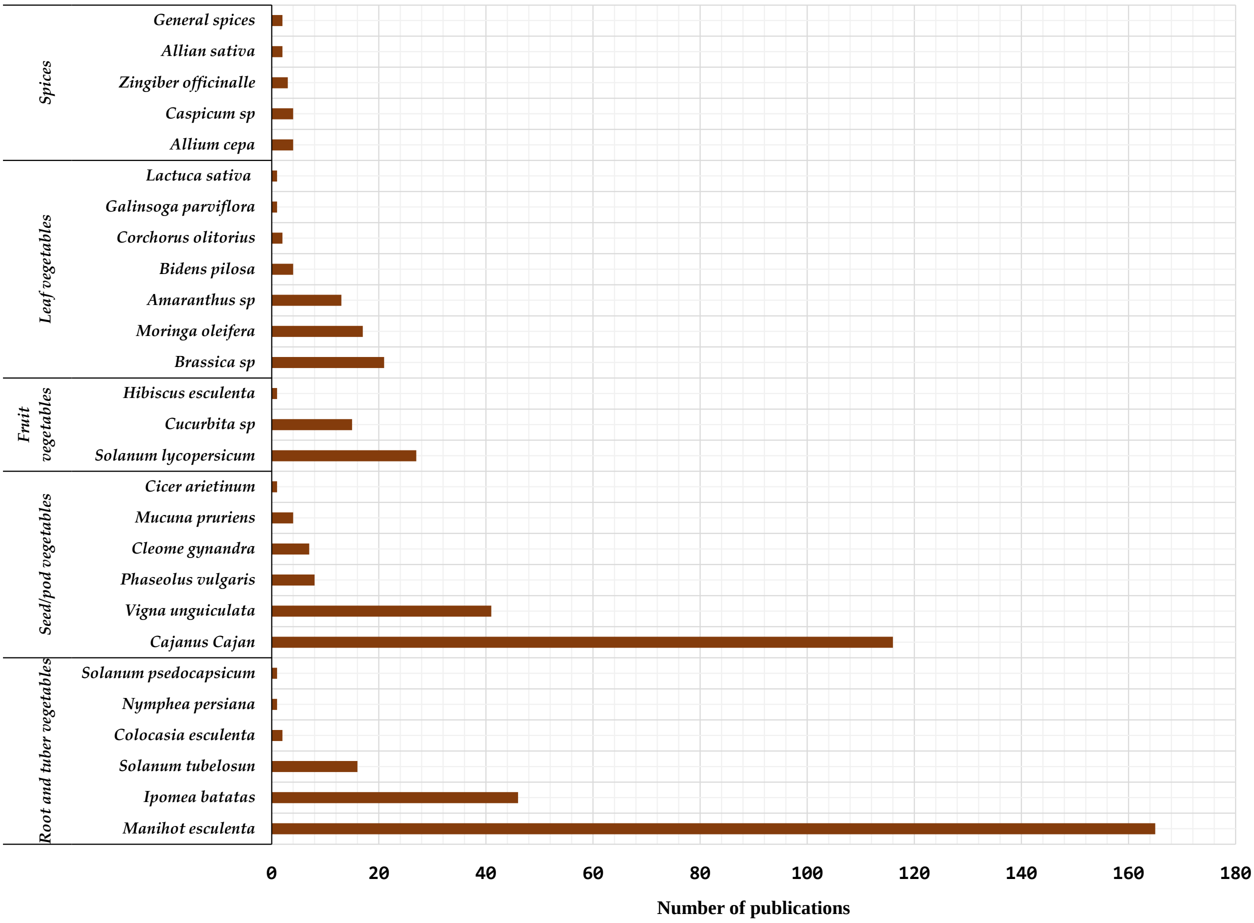

Figure 5. Amount of research (as evidenced from number of publications) into various vegetables species grouped into five categories.

Table 1. A listing of vegetable taxa researched in Malawi, most of which are introduced vegetable and erroneously referred to as indigenous. The table thus includes residence status of the researched taxa in Malawi (as determined from the published native range). Non-Indigenous Vegetables (NIVs) *i.e.* those that were introduced and exist just in cultivated form without wild populations, Indigenous/Native Vegetables (IVs), and Naturalized Vegetables (NVs).

Family	Botanical name	Local name(s)	Plant part used as vegetable	Residence status in Malawi	Published native range
Malvaceae	*Abelmoschus esculentus*	Thelele lobala	Leaves and fruits	Indigenous	South Asian, Ethiopian and West African [21]
Amaryllidaceae	*Allium cepa* L.	Anyezi	Leaves and bulb	Non-indigenous vegetable	Middle East [22]
Amaryllidaceae	*Allium sativum*	Galiki	Tuber	Non-indigenous vegetable	Northern China [23]
Amaranthaceae	*Amaranthus retroflexus* L.	Bonongwe	Leaves	Indigenous	Africa, Asia, America [24]
Amaranthaceae	*Amaranthus* sp	Bonongwe	Leaves	Indigenous	Africa, Asia, America [24]
Asteraceae	*Bidens pilosa*	Chisoso	Leaves	Indigenous	South America [25]. Cosmopolitan to global tropics

Continued

Brassicaceae	*Brassica napus* L.	Tanaposi (Mpiru)	Leaves	Non-indigenous vegetable	Mediterranean region (Europe) [26]
Brassicaceae	*Brassica oleracea* var. capitata L.	Kabichi/abichi	Leaves	Non-indigenous vegetable	Europe [27]
Brassicaceae	*Brassica rapa* var. rapifera	Repu	Leaves	Non-indigenous vegetable	China [26]
Brassicaceae	*Brassica rapa*	Repu	Leaves	Non-indigenous vegetable	China [26]
Brassicaceae	*Brassica rapa* subsp. chinensis	Chinise	leaves	Non-indigenous vegetable	Southern China [23]
Brassicaceae	*Brassica oleracea*	Kabichi	Leaves	Non-indigenous vegetable	Mediterranean region (Europe) [26]
Fabaceae	*Cajanus cajan*	Nandolo	Seeds	Non-indigenous vegetable	India and south Asia [28]
Solanaceae	*Capsicum annuum*	Tsabola/ Kambuzi/Piripiri	Fruit	Non-indigenous vegetable	Central America [29]
Fabaceae	*Cicer arietinum*	Chana	Seeds	Indigenous	West Africa [30]
Cleomaceae	*Cleome gynandra*	Luni	Leaves	Indigenous	Africa and Asia [31]
Araceae	*Colocasia esculenta*	Masimbi (Tum.)	Tuber	Non-indigenous vegetable	Southeast Asia [32]
Malvaceae	*Corchorus olitorius*	Denje	Leaves	Indigenous	Africa (Egypt) and the middle East [33]
Cucurbitaceae	*Cucurbita maxima*	Maungu	Leaves and fruits	Non-indigenous vegetable	North America [29]
Cucurbitaceae	*Cucurbita moschata*	Dzungu (Maungu)	Leaves and fruits	Non-indigenous vegetable	North America [29]
Cucurbitaceae	*Cucurbita pepo*	Dzungu (Maungu)	Leaves and fruits	Non-indigenous vegetable	North America [29]
Asteraceae	*Galinsoga parviflora*	Mwamunaligone	Leaves	Non-indigenous vegetable	Andes region in South America [34]
Convolvulaceae	*Ipomea batatas*	Mbatata, Kholowa	Root tubers	Non-indigenous vegetable	South and Central America [29]
Asteraceae	*Lactuca sativa*	Letesi	Leaves	Non-indigenous vegetable	South-West Asia [35]
Euphorbiaceae	*Manihot esculenta*	Chinangwa	Leaves and root tubers	Non-indigenous vegetable	Brazil [29]
Molingaceae	*Moringa oleifera*	Chammwamba	Leaves	Non-indigenous vegetable	North-West India [36]
Fabaceae	*Mucuna pruriens*	Kalongonda	Seeds	Non-indigenous	Northeast and Eastern India [37]

Continued

Nymphaeaceae	*Nymphaea petersiana*	Nyika	Tubers	Indigenous	Africa, India and Australia [38]
Fabaceae	*Phaseolus vulgaris*	Nyemba	Leaves and fresh seeds	Non-indigenous vegetable	North and Central America [39]
Solanaceae	*Solanum tuberosum* L.	Mbatatesi	Tubers	Non-indigenous vegetable	Peru [29]
Solanaceae	*Solanum lycorpesicum*	Matimati (Tomato)	Fruits and leaves	Non-indigenous vegetable	South and Central America [29]
Solanaceae	*Solanum nigrum*	Msaka	Leaves and fruits	Indigenous	Africa, Cosmopolitan [40]
Fabaceae	*Vigna unguiculata*	Khobwe, Nkhunde (Tum.)	Leaves and seeds	Indigenous	Eastern and Southern Africa [41]
Zingiberaceae	*Zingiber officinale*	Jinja	Tubers	Non-indigenous vegetable	South-East Asia [42]

5.2. Thematic Areas

Theme categorization in this review was based on what it takes to get the most out of vegetable production enterprise via the improvement of the value chain. This starts from growth/propagation issues, then processing of the vegetable before marketing and consumption. A fifth category, diversity and genetic characterization have been included due to its relevance in decisions regarding what must be propagated. Figure 6 shows the proportion of reviewed research under the various categories/themes.

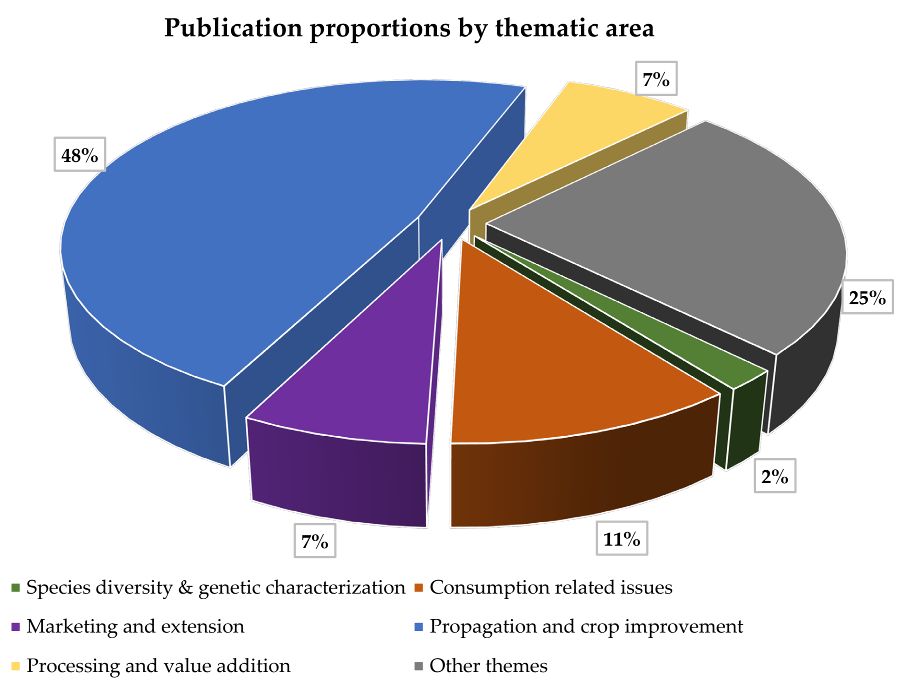

Figure 6. Vegetable research thematic categorizations, showing proportion of publication for each of the five thematic areas.

Most publications, 48%, dealt with issues of propagation and crop improvement. This is not surprising as most agricultural enterprises seek to maximize production by using improved cultivars. Crop improvements seek to improve yield, pest resistance, and tolerance of environmental factors, among others. This review notes that extensive research on *Cajanus cajan* was for its role in crop and soil improvement theme. This research however deals with crop improvement as a nitrogen source in agroforestry or mixed cropping technologies. The use of *Cajanus cajan* as a vegetable has not received enough attention, prompting researchers to sound a reminder that *C. cajan* crop is a vegetable [43], beyond its use as a soil amendment plant. The second major research effort was on vegetables issues that could not clearly fit in the four pre-determined themes, 25%. This research included works where two or more themes featured in the work. Research into vegetable processing, value addition and marketing are cooperatively very minimal. This observation shows that vegetables in Malawi are produced for consumption with minimal processing and value addition. Processing and value addition are processes known to increase returns on agricultural production to the farmer, creating employment and boosting industrialization [44]. If vegetable production is to become more profitable, and claim space in the local economy, future research should focus on processing and value addition. **Figure 7** depicts the current research focus and a missed opportunity from enhanced research into value addition and promotion of marketing. Vegetable production is more productive with value addition unlike when it is consumed straight from the farm.

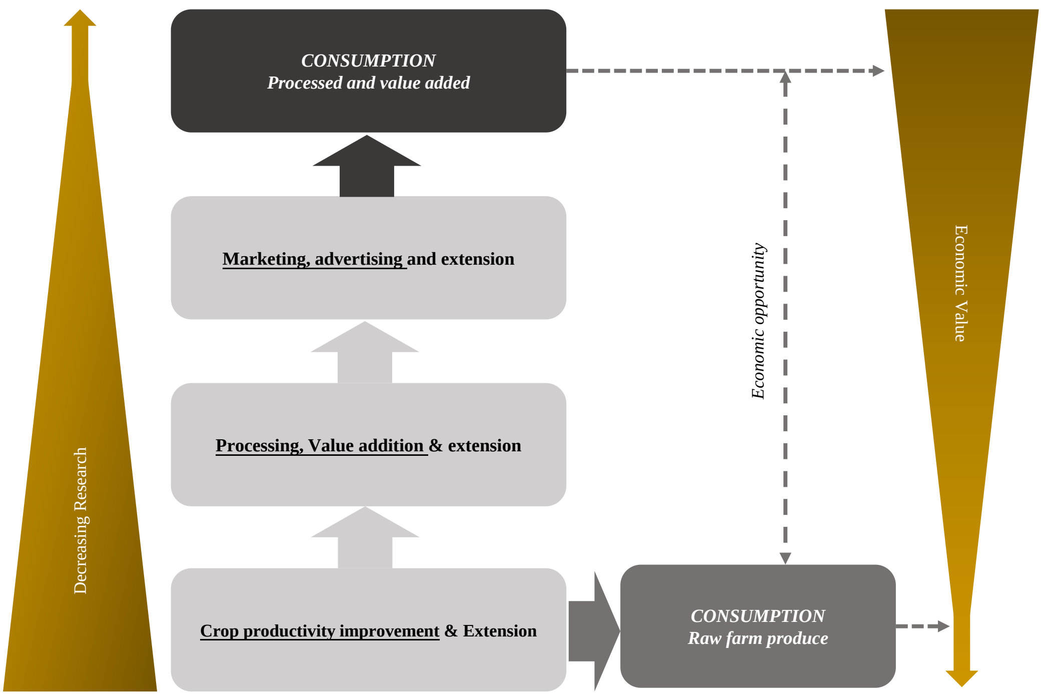

Figure 7. Conceptualization of the current vegetable research trends (focused much on crop productivity) and supporting raw consumption; revealing a missed opportunity of higher economic returns from processing and value-addition to vegetables.

The review further shows that research on marketing and processing is confined to just two vegetables *Manihot esculenta*, and *Moringa oleifera*. The processing of the vegetables however is not associated with their vegetable utility but other uses such as commercial starch production and water purification purposes, respectively. For most vegetables, especially green leafy vegetables, little has been done in areas of processing and value addition, marketing and even consumption.

6. Vegetable Research in Malawi: Gaps and Emerging Issues

Most authors did not state areas for further research but provided just the summaries of their study findings. About 20% of authors provided directions for future research. The future research directions ranged from verification of their findings (via methodological or change of experimental setting), to proposition of entirely new research. As regards future research directions, they are as diverse as their authors. The two key calls for research that keep surfacing are those regarding vegetable marketing and promotion of indigenous vegetables production. The latter is indicative of the importance of IVs in the broader vegetable production scheme. The urgent yet old need for IVs includes the need for inventory production [20] [45] [46]; the need for nutritional assessments [46] [47] [48] and cultivation promotion [49]. In an era of climate change, IVs will have a key role and a call to their inventories, nutrition assessment, cultivation and their participation in marketing need to be sustained.

6.1. Emerging Issues: Biofortification

Irrespective of their importance to human health, vegetables are rarely cultivated in prime lands, being largely relegated to fridges and in mixed cropping. This limits the amount of nutrients that eventually a given vegetable provides to consumers. Biofortification provides a way of production of nutritious vegetables under various soils with variable inherent nutrient levels. With climate change, projected to impact negatively on soil nutrients [50], biofortification promises to be a viable adaptation strategy.

Biofortification is a modern technology having emerged in the 1990s [51] primarily aimed at combating micronutrient malnutrition or "hidden hunger". Biological fortification uses three approaches: transgenic biofortification, agronomic biofortification and breeding [52], transgenic biofortification (where genes conferring a desirable trait are transferred from one crop to another), agronomic biofortification (where nutrients are added to temporarily improve nutritional status of a crop) and breeding (where existing genotypic traits within a crop are utilized to breed for desired attributes). Of the three existing biofortification approaches, the transgenic approach has been the most researched [52] in the case of vegetable crops. In an era of climate change, where soil nutrient depletion is predicted [53], biofortification is a promising approach. In Malawi this is a novel approach with biofortification of maize [54] and vegetables [55] [56] being one of the first researches in this area. Going forward, cognizant of the debate regarding pros and cons of the various approaches, local researchers need to agree on the approach that best suits the country and its biodiversity.

6.2. Emerging Issues: Modelling

Crop modelling, due to its predictive ability, is and will continue to be an invaluable in vegetable production. Elsewhere, modelling has been used to assess evapotranspiration and water demand [57], water use and irrigation demand [58], and post-harvest behavior of fresh vegetables [59]. By being able to project future climate scenarios, modelling allows for better preparedness, for horticulturalists as they aim to ensure a consistent supply of vegetables under various climatic scenarios. For Malawi, the modelling of various aspect of vegetable growth is an area that is yet to be adequately explored.

6.3. Emerging Issues: Climate Change

The climate change challenge in agriculture and associated issues cannot are not "emerging." Globally, there has been comprehensive climate change research in agriculture [60] covering impacts, prediction, adaptation, and mitigation among other issues. While some research on climate change on agriculture in Malawi has been done [61] [62], vegetables have not been the focus. In this study, just under 2% of the total publications dealt with some elements of climate change in vegetable production. Thus, as far as vegetable cultivation in Malawi is concerned, climate change is an emerging issue requiring research attention.

6.4. Emerging Issues

Emerging issues in the context of this review, refer to new research areas in vegetable production in Malawi, with longer term relevance. The four issues identified as emerging are biofortification, modelling, and climate change.

7. Vegetable Research in Malawi: Proposed Future Directions

Research into vegetables is on the increase in Malawi. However, there is need to broaden the research focus in terms of both species studied and research support to various aspects of the value chain. More research remains to be done to address gaps regarding optimal growth requirement, adaptation to existing agroecological zones, breeding aspects and the promotion of consumption aimed at spurring utility values and increasing their sphere in Malawi's food systems. Any advances in research need to be contextualized with the reality of climatic change and variability where indigenous vegetables could play a particularly critical role.

7.1. Vegetable Research in a Changing Climate

To successfully mitigate and adapt to the impact of climate change on vegetable cultivation, there must be defined areas of readiness, envisaged here as encompassing ecosystem, crops and society at large. These need to be driven by some deliberate vegetable research agenda. The conceptual framework in **Figure 8** shows vegetable research role in promoting vegetable production in a changing climate. Vegetable research needs focus and facilitate the readiness of society, ecosystems, and crops.

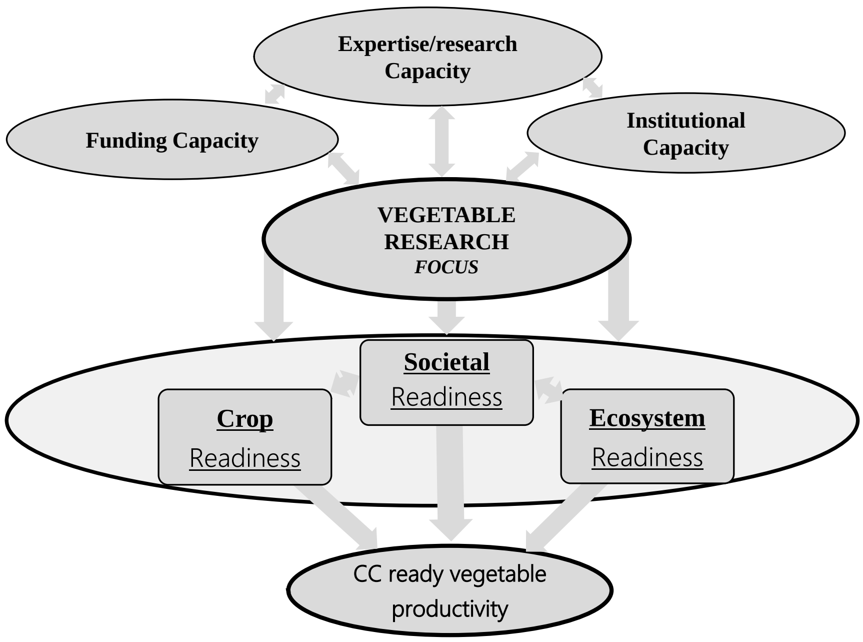

Figure 8. Schematic diagram showing a proposed wholistic vegetable research approach in Malawi in the face of Climate Change (CC), showing interlinkages of three key determinants.

Ecosystems Readiness: This aspect includes all efforts aimed at enhancing ecosystems resilience to climatic variability [63] enabling it to provide all the necessary services supporting vegetable cultivation and agriculture. Key to ecosystem readiness is issues of conservation of pollinators, and identification of geospatial dynamics of pests, disease vectors, and pathogens. The general maintenance of ecosystems health where biophysical linkages are sustained, would be key in supporting horticulture in a changing climate.

Crop Readiness: This approach entails ensuring resilient to climate change. It can be realized, in part by improving climate variability-tolerant traits in plants, conventional breeding, and genetic manipulation [64]. Key to crop readiness is increasing the cultivated crop-base [65]. This ensures production security as a diversified agronomic base act as a safety net in times of crop failure. In the case of Malawi, the promotion of use and cultivation of indigenous vegetables is key to the diversification effort.

Societal Readiness: This is where farmers and all stakeholders, understand and own the climate change challenge, and are ready and willing to avert, or adapt to its impacts. It is argued [66] that the current efforts to climate change largely ignore socioeconomic component. The current approach to climate change technology promotion seems to indicate a "lack of ownership", by farmers of the climate change challenge. Discussing drivers of dis-adoption of conservation agriculture, [67] points at unfulfilled and delayed expectations and delay in technical support and extra financial resources needed to support CA as some dis-adoption drivers. Delays in CA benefits are due to the long time it takes to improved soil fertility [68].

In the Southern African region, climate change research has dealt with different components of the three key readiness facets [63] [69] [70] [71]. In Malawi, however, climate change research especially on vegetable crops is lagging. More needs to be done however to consolidate the existing gaps. **Table 2** provides some key climate change impacts [72] [73] and proposed areas that require research attention in Malawi as a part of climate change preparedness.

Table 2. Proposed research areas for vegetable research focus to ensure "climate change readiness" in Malawi.

Predicted climate change impact	Impact on vegetable cultivation	Key potential research areas
Pollinator decline	Reduced fruit/seed set. Reduced yield for fruits/seed-based vegetables [74]	• Pollinator diversity assessments • Creating crop-pollinator matches • Documentation of key pollinator refugia • Development of pollinator conservation strategies
New emerging vegetable diseases	Various, some yet unknown [75]	• Understand vector biology of existing diseases • Predict vector geographical shifts with climate change
Increase in droughts and number of dry days	Reduced yield, Impact on pest cycles [76]	• Determination of drought tolerance for different vegetables taxa • Determination of optimal water requirements for various vegetables • Breeding for drought tolerance
Increase of heat waves	Increased water demand Increase in labor needs	• Determination of optimal water requirements for various vegetables
Soil fertility decline and degradation	Reduced vegetable productivity	• Feasibility of vegetable "conservation cultivation" • Exploring suitable biofortification approaches • Feasibility of composting and other manure yielding enterprises
Fragmented and small land holdings	Reduced vegetable output	• Designing and testing technologies that maximize vegetable yield on small land holdings e.g. intercropping

7.2. Revitalizing Research in Indigenous Vegetables

Indigenous Vegetables (IVs) have recently received renewed research attention [77] due to their role in human health, as protective foods, addressing issues of malnutrition and non-communicable disease prevalence [78]. Indigenous vegetables are also a source of income aiding in poverty reduction, and as stapple foods in lean seasons [79] in Malawi. **Table 3** provided a list of indigenous vegetables in Malawi and how they are utilized in other countries. From an agronomic perspective, indigenous vegetables are better suited for low-input systems, and for marginal environments [80]. The reduced reliance on indigenous vegetables s in most African societies is attributable to the green revolution that came with improved crop species that produced superior yield. This led to loss (in extinction terms and usage) of indigenous land races of several plant taxa that existed [81] [82]. Currently, globally, and regionally, there is resurgence of interest in indigenous vegetables. According to [80], this resurgent interest is a result of our improved knowledge regarding linkages between agriculture and environment, noted limitations of the green revolution, the need for diversified diets, and rapid climate change.

Table 3. A collection indigenous vegetables species recommended for further research by [20](†) and other Malawi's important indigenous vegetables documented by [80](⁑) and [84](⁋). Note that the term native in the current context refers to species whose origin can be traced to Africa in general and not Malawi directly. Included are advances in research (on the species) within the region. This review supports the previous calls for research into these indigenous vegetable taxa.

Botanical family	Botanical name	Residence status in Malawi	Published geographic range	Advances in research on the species elsewhere	Plant part used
Malvaceae	*Abelmoschus esculentus*⁑	Native	Tropical Africa, South Asia and Mediterranean Basin [85] [86]	All aspects of growth, value addition, marketing and consumption [87]	Leaves and fruits
Passifloraceae	*Adenia cissampeloides*†	Native	Senegal to Cameroon and Angola [88]	Categorized as underutilized [89] and thus offers diverse research concepts	Leaves
Fabaceae	*Afzelia quanzensis*†	Native	African savannah [90]	Not records of this species as a vegetable (could have been a mis-entry)	A forest tree known for its durable wood
Fabaceae	*Albizia antunesiana*†	Native	DR Congo east to Kenya, and south to Namibia and South Africa [91]	Not known/popular as a vegetable but as a medicinal plant species [92]	Roots and leaves
Amaranthaceae	*Amaranthus lividus*†,	Native	Cosmopolitan, Mediterranean region, Senegal, Ethiopia, South Africa [91]	Basic agronomy, value addition and Value chain analysis [93]	Leaves
Pedaliaceae	*Ceratotheca sesamoides*⁑	Native	Africa, south of the Sahara [91]	Comparatively well studied. Its growth, chemical composition, and marketing [94]	Leaves

Continued

Solanaceae	*Solanum lycopersicum* var. cerasiforme[*]	Non-native	Andean region of South America [95]	All aspects are well studied species [96]. An appropriate taxon for replication research	Fruits (and leaves in the case of Malawi)
Fabaceae	*Chrotalaria brevidens*[*]	Native	Nigeria, Ethiopia, and Southern Tanzania [91]	Well studied [97]. In Malawi, this remains an under-studied taxon	Leaves
Cucurbitaceae	*Citrullus lanatus*[*]	Non-native	India, Pakistan, and Afghanistan [91]. Africa [98]	Adequately studied but not widely developed and considered underutilized in the region as reviewed by [98]	Leaves (fresh and dried) and Fruits (pulp and seeds)
Malvaceae	*Corchorus trilocularis*[†]	Native	Africa and India [99]	The species is under-researched in the region. Still wild and rarely grown	Leaves and flowers
Cucurbitaceae	*Cucumis metuliferus*[*]	Native	Tropical and subtropical Sub-Saharan regions of Africa [91]	Well studied elsewhere [100]	Fruits (pulp, peel and seeds)
Cucurbitaceae	*Cucumis sativus*[*]	Non-native	Himallaya region of Asia [91]	All aspects studied are well reviewed by [101]	Fruits (pulp, peel and seeds)
Malvaceae	*Hibiscus physaloides*[†]	Native	Southern Africa [102]	No traceable publications on this species as a vegetable. Could have been a misidentification	___
Malvaceae	*Hibiscus sabdariffa* (L.)[*]	Native	Africa (Sudan) [91]	This plant has had extensive studied (its uses and economic applications) e.g. [103] [104]	Leaves fruits and petals
Brassicaceae	Local rape[†] (*Brassica juncea*)	Non-native	Middle East then China and India [105]	The species adequately studied regarding growth nutritional composition and other aspects [106]	Leaves
Cucurbitaceae	*Luffa cylindrica*[*]	Native	Africa or Asia [107]	The species is well studied regarding growth nutritional composition and other aspects [108]	Young shoots, leaves, flower bugs, and seed
Cucurbitaceae	*Momordica balsamina* (L.), *Momordica foetida*[*] in Malawi	Native	Africa, South of the Sahara [96]	Well studied as a vegetable. It is still considered underutilized with economic potential	Leaves and young fruits
Fabaceae	*Phaseolus lunatus*[*]	Non-native	Andean region of South America [109]	There is little research on the species [110] but not as on Phaseolus vulgaris. More still needs studying	Fruits and leaves
Portulacaceae	*Portulaca oleracea*[*]	Native	A tropical vegetable suspected of African origins [111]	Still considered as underutilized and with a lot of potential as reviewed in [112]	Young leaves and stems
Pedaliaceae	*Sesamum angustifolium*[*]	Native	Africa (Uganda Kenya and Tanzania) [91]	Not adequately studied in the region. Room for research exploitation	Leaves
Malvaceae	*Hibiscus acetosella*[⁋]	Native	Africa [113]	Not much studied and offers room for more research	Leaves
Pedaliaceae	*Sesumum angolense*[⁋]	Native	Africa and India [114]	Limited research in Malawi	Leaves. Others as an oil source

Indigenous plants are key to climate change adaptation strategies. Inherent in some indigenous vegetables are low water demands thus enabling them to tolerate drought stress; in addition, they grow successfully on soils that are low in fertility due to their low nutrient demands [83] and can grow well in marginal lands to which vegetable cultivation has largely been relegated. In addition, indigenous vegetables are adapted to existing climatic fluctuations and have better chances of coping with climatic variabilities. Indigenous vegetables also provide a wider gene stock for resilient gene harvesting for breeding programs. Generally, of the many impacts of climate change, drought has received the greatest research attention. Indigenous vegetables offer an alternative ground for other climate change impacts such as cold tolerance, new diseases, and other weather-related phenological changes that accompany climatic variability.

8. Conclusions

Vegetable production in Malawi is a promising enterprise. With relevant partnerships in research, vegetables have the potential to claim a key role in the national economy and further enhance their contribution to the insurance of a healthy society. The existing institutional research with capacity is robust donor community, if augmented with local funding, which can help ensure adherence to the national research agenda. The vegetable research focus is currently skewed, from two perspectives: First, more focus has been on vegetable crop improvement and propagation at the expense of key issues of value addition, marketing, and consumption. Secondly, except for *Manihot esculenta* and *Cajanua cajan*, most vegetables have not received enough research attention. Further, the existing agroecological approaches need broadening to fully encompass the understanding of the suitability for a wider range of vegetables. In Malawi, there exists a need to acquire technical infrastructure such as laboratories and high-standard greenhouses, to support the existing skilled professionals and drive sustainable research. In a projected changing climate for the country (and the world), any advancement in vegetable research in Malawi needs to ensure full readiness, where indigenous vegetables have a key stake.

At the national level, there is a general commitment to promoting agricultural approaches that aim at averting adverse climatic variability [115]. Horticulture in general and vegetable cultivation in particular fall within pillar 1 (Agricultural Productivity and Commercialization) of the Malawi vision 2063. Vegetable production is likely to play a key role in ensuring the availability and consumption of diverse diets, as alluded to under vision enabler 5 of Malawi's vision.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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