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Review

African Leafy Vegetables: A Review of Status, Production and Utilization in South Africa

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Received: 7 November 2017; Accepted: 19 December 2017; Published: 22 December 2017

Abstract: African leafy vegetables (ALVs) are mostly gathered from the wild, with few selected species being cultivated, usually as part of a mixed cropping system in home gardens or smallholder plots. They have important advantages over exotic vegetable species, because of their adaptability to marginal agricultural production areas and their ability to provide dietary diversity in poor rural communities. Despite their significance in food and nutrition security, there is limited availability or access to these crops leading to underutilisation. The objective of this review was to document the state of utilisation and production of ALVs in South Africa. A qualitative systematic approach review of online sources, peer reviewed papers published in journals, books and other publications was conducted. There is lack of suitable production systems, innovative processing, and value-adding techniques that promote utilisation of ALVs. Furthermore, there is a perception that ALVs are food for the poor among the youth and urban folks, while, among the affluent, they are highly regarded as being nutritious. To promote ALVs from household consumption and commercialisation, further research on agronomy, post-harvest handling, storage and processing is required in South Africa.

Keywords: drying; nutritional value; packaging; promotion; water use

1. Introduction

African leafy vegetables (ALVs) are defined as plant species which are either genuinely native to a particular region, or which were introduced to that region for long enough to have evolved through natural processes or farmer selection [1]. There are many names by which indigenous leafy vegetables are known by different authors including wild vegetables [2], African leafy vegetables [1], and traditional leafy vegetables [3,4]. In South Africa, they are called *imfino* in isiZulu and isiXhosa, *morogo* in Sesotho and *miroho* in tshiVhenda [5]. South Africa faces challenges of food insecurity at household levels due to nutrient deficiencies such as vitamin A, iron, zinc, and vitamins C [6]. Studies have shown that ALVs can contribute to addressing gaps in nutrition through offering healthy and affordable nutrient dense alternatives. Some ALVs are rich in compounds such as vitamins, minerals, anti-oxidants and even anti-cancer factors needed to maintain health and fight off infections [7]. This would be particularly beneficial for poor rural communities who cannot afford to purchase vegetables.

Most smallholder communities live in marginal areas where crops struggle to survive and face challenges of water scarcity. African leafy vegetables offer alternatives to such communities because they are tolerant to abiotic stresses such as drought and heat stress [8]. According to the Department of Agriculture Fisheries and Forestry [9], ALVs are tolerant to drought, pests and diseases. They are also adapted to low input agriculture than exotic vegetables such as Swiss chard [5,10]. Thus, ALVs are a potential food source for poor people living in marginal areas and practising low input agriculture. Despite their abundance, they remain underutilised due to various constraints, including perception, processing, distribution and marketing, as well as nutritional information [11].

South Africa also faces challenges of water scarcity [12] and population growth [8]. Inclusion of ALVs in cropping systems can contribute to climate change adaptation, the environment, and employment creation in poor rural communities [13]. It is therefore worthwhile to identify the policy, socio-economic and institutional conditions that hinder/promote utilisation and production of the ALVs. Availability of such information will give specific direction and guidance in research, production and marketing of ALVs. The objective of the study was to analyse factors that have influence in the use and production of the ALVs to identify research needs. This study is expected to contribute to a broader scientific knowledge of important constraints and drivers in promoting ALVs. The goal of this paper is to critically review the status of utilisation and production of ALVs with a view to identifying research gaps that will facilitate scaling up their production in South Africa. The following questions are explored.

(1) What is the status of production and utilisation of ALVs in South Africa?
(2) What can be done to promote production and utilisation of ALVs in South Africa?
(3) What are potential gaps and research priorities for future research of ALVs in South Africa?

Methods Used for Literature Search

A qualitative systematic approach was adopted for the current review. The search included online sources, peer reviewed papers published in journals, books and other publications such as popular articles. Published literature from universities, national research institutions, in the form of student theses, conference proceedings, working papers, and project reports was also considered. A comprehensive search was conducted using various search engines such as Google, MSN, Scopus etc., using the following terms: "indigenous leafy vegetable" or "African leafy vegetables" or "production or promoting ALVs" or "nutritional value of ALVs"; the search was limited to South Africa and the period 1994–2017.

Approximately 480 were retrieved of which ~10% were peer reviewed. Through an analysis of the content of returned entries, papers were screened based on relevance to South Africa. The records were furthered filtered to ~300 and classified according to topics such as biodiversity (20%), nutrient content (38%), production and utilisation (32%), marketing (2%) and postharvest handling and processing (8%). The entries were further classified in terms of category of research, as surveys, field trials or laboratory experiments. Most studies from returned entries were as follows: based on household surveys (55.0%), literature reviews (10.0%), field trials (15.0%), and laboratory experiments (25.0%). The observation for such a variation of returned entries within the topics selected can be attributed to the magnitude of research attention given to each category by the research community in South Africa. For example, there is little information of ALVs available on marketing, postharvest, field trial etc. resulting in less returned entries in comparison to other areas in this paper. Putting entries into categories gave each entry an equal opportunity to be screened or filtered. Within the mentioned categories above, the papers were filtered based on relevance to the subject under study. This also considered geographical locations of the entries to represent all areas where possible and variation in crop species covered. In cases where many entries reported on the same issue, the most suitable rated entry was selected to reduce repetition. This reduced entries to ~167. These articles were further screened for research methodology, whether the study involved actual data, literature review, appropriate sampling technique, or data analysis or statistical techniques. An overall rating of suitability of articles was assigned as poor or satisfactory. Only articles with ratings of satisfactory were selected for review. From this, 74 articles were considered relevant and included in the review.

2. Current Status of Utilisation and Production of Leafy Vegetables

2.1. Diversity of ALVs

South Africa has more than 100 different species of ALVs that have been identified; however, few groups of leafy vegetable species are still utilised [1]. These include *C. olitorius* (jute mallow), *Amaranthus cruentus* (pigweed), *Citrullus lanatus* (bitter melon), *Vigna unguiculata* (cowpea), *Cleome gynandra* (spider plant), *Cucurbita* spp. (pumpkin) and *Brassica rapa* subsp. *chinensis* (non-heading Chinese cabbage). The local names, distribution and ecology of major African leafy vegetables in South Africa have been documented [1,14].

Amaranth is one of the most common ALVs in South Africa. Amaranth belongs to the *Amaranthaceae* family and is an extremely variable, erect to spreading herb (Figure 1b). Different species of amaranth are available all over South Africa [1,6,14]. These include: *Amaranthus thunbergii*, *A. greazicans*, *A. spinosus*, *A. deflexus*, *A. hypochondriacus*, *A. viridus* and *A. hybridus* [1,6,14]. The various amaranth species are tolerant to adverse climatic conditions, but prolonged dry spells induce flowering and decrease leaf yield [1,6,14]. Amaranth is a C4 plant that grows optimally under warm conditions (day temperatures above 25 °C and night temperatures not lower than 15 °C), bright light and adequate availability of plant nutrients. Hence amaranth is mainly grown in summer. Amaranth is rarely cultivated in South Africa because as with many other African leafy vegetables people believe the plants will grow naturally [1,6,14].

Corchorus belongs to the Tiliaceae family and is an erect annual herb that varies from 20 cm to approximately 1.5 m in height (Figure 1a). The stems are angular with simple oblong to lanceolate leaves that have serrated margins and distinct hair-like teeth at the base. Different *Corchorus* species are available in South Africa, namely *C. asplenifolius*, *C. trilocularis, C. tridens* and *C. olitorius* [1,6,14]. *Corchorus* prefers warm, humid conditions and performs well in areas with high rainfall (600 to 2000 mm) and high temperature (30 °C during the day and 25 °C at night). In South Africa it grows in summer. Despite the abundance of species and having a potential for development as a crop, *Corchorus* is still considered a wild species and has never been cultivated.

(**a**) (**b**)

Figure 1. (**a**) *Corchorus olitorius*; (**b**) *Amaranthus cruentus* growing under commercial production in the trial at Roodeplaat in 2012 summer season.

Cleome (Figure 2b) belongs to the Capparaceae and it is an erect herbaceous herb, branched and rather stout [1,6,14]. Different Cleome species exist such as *C. monophylla* and *C. hirta* with *Cleome* *gynandra* most widely used as a leafy vegetable in South African gardens [1,6,14]. Cleome does tolerate a degree of water stress, but prolonged water stress hastens flowering and senescence. It grows in summer and does not grow well when the temperature drops below 15 °C. Cleome is not formally cultivated in South Africa although it is among the group of African leafy vegetables that has good potential for development as a crop [1,6,14].

(**a**) (**b**)

Figure 2. (**a**) *Vigna unguiculate*; and (**b**) *Cleome gynandra* growing under commercial production in the trial at Roodeplaat in 2012 summer season.

Vigna unguiculata is a leaf and pulse crop that belongs to the Leguminosae family (Figure 2a). It is an annual or perennial herbaceous plant with tri-foliate leaves [1,6,14]. Different varieties exist, varying from prostate indeterminate types to erect, determinate, low-branching types. The varieties mainly used as a leafy vegetable are the spreading, prostrate types. Various subspecies of *Vigna unguiculata* are found in the wild in the eastern parts of the KwaZulu-Natal, Mpumalanga and Limpopo Provinces. These subspecies include: *Vigna unguiculata* subsp. *dekindtiana* var. *dekindtiana, V. unguiculate* subsp. *dekindtiana* var. *huillensis, V. unguiculata* subsp. *rotracta, V. unguiculata* subsp. *stenophylla, V*. *unguiculate* subsp. *tenuis* var. *ovata,* and *V. unguiculata* subsp. *unguiculata*, with *Vigna unguiculata* subsp. *unguiculata* the most commonly found [1,6,14]. *Vigna unguiculata* is widely cultivated in summer for its seeds and as a fodder crops. Its use as a leafy vegetable has not received much attention [1,6,14].

Brassica rapa L. subsp. *chinensis* (Figure 3). belongs to the Brassicaceae, an annual, flowering, leafy vegetable, in which the leaves form a rosette [1,6]. It originates in China and found its way from Asia into Africa as a result of trade between two continents [1,6]. Vhembe District in Limpopo Province is the centre of origin of the cultivation of *Brassica rapa* L. subsp. *chinensis* in South Africa, where an informal seed multiplication and distribution system is being maintained by selected producers. It is primarily grown during the dry winter months, making it reliant on irrigation for its water requirements. Different landraces have been reported in South Africa which have been given local names as *dabadaba* and *lidzhainthi* being most commonly grown, followed by *tshikete* and *mutshaina wa u navha* [6]. Its cultivation by South African smallholders has been rapidly spreading from Vhembe District to many parts of the Limpopo, Mpumalanga and Gauteng Provinces.

Figure 3. *Brassica rapa* L. subsp. *chinensis* growing under commercial production in the trials at Roodeplaat in 2013 winter season.

Other ALVs species available in South Africa include *Cucurbita* family. *Cucurbitaceae* (pumpkin and relatives) are almost all vine like, annual, herbaceous plants. The most popular cucurbit species are *Citrullus lanatus* (Figure 4b), *Cucumis melo*, and *Cucurbita pepo*, *C. maxima* and *C. moschata* [1,6,14]. *Cucurbita maxima* (Figure 4a) and *C. pepo* are drought tolerant and require relatively little water, but they respond positively to irrigation when conditions are very dry most heat tolerant type of pumpkin and it is also fairly drought tolerant. They are grown in summer.

(**a**) (**b**)

Figure 4. (**a**) *Cucurbita spp*; (**b**) *Citrullus lanatus* growing during summer season at Roodeplaat in 2012 season.

2.2. Utilisation

Previous studies have tried to quantify the frequency of utilisation of ALVs in South Africa [2,15–17]. Their use has remained low despite their nutritive value and potential economic use. Van Rensburg et al. [10] reported that the utilization of indigenous leafy vegetables is declining in favour of exotic vegetables. Even at present the utilisation is still variable [1]. This is because they are not cultivated but mostly gathered from cultivated fields, fallowed land and the veldt [14,18]. Women are the major custodians in the gathering of wild vegetables [1,19]. The low levels of utilisation are also attributed to perception that they are food for the poor and hard times among the youth and urban folks [20–23]. The loss of indigenous knowledge also causes low utilisation [21]. This supports the view that the youth do not have enough knowledge of wild species to collect in wild; with the tendency of mixing wild vegetables with poisonous species [14].

2.3. Production

The occurrence and extent of cultivation of leafy vegetables in South Africa has been presented in Table 1. *Amaranthus cruentus*, *Cleome gynandra* and *Corchorus olitorius* as shown in Table 1 are still considered wild species and thus have never been considered for large-scale commercial production [24]. *Vigna unguiculata* is widely produced mainly for grain and as a fodder crop (Table 1). Its production as a leafy vegetable for human consumption is not widespread and has received limited research attention [24]. *Citrullus lanatus* and *Cucurbita* species are often grown as an intercrop with maize covering the soil surface which helps to control weeds [20,25,26] and for their fruits (Table 1). Some of the ALVs indicated in Table 1 such as *Brassica rapa* subsp. *chinensis* are already cultivated but the wide diversity in agronomic practices used indicate the absence of sound agronomic guidelines for these crops [27].

Table 1. African leafy vegetable commonly harvested from the wild or obtained through cultivation in South Africa.

African Leafy Vegetable	Harvested from Wild	Cultivated	Growth Season	References
Abelmoschus esculentus Moench.		✓	Summer	[6,8,14]
Amaranthus spp.	✓		Summer	[1,6,8,14]
Bidens spinosa L.	✓		Summer	[6,8,14]
Brassica rapa L. subsp. *chinensis*		✓	Winter	[1,6,8,14]
Chenopodium album L.	✓		Summer	[6,8,14]
Citrillus lanatus		✓	Summer	[6,8,14]
Cleome gynandra L.	✓		Summer	[1,6,8,14]
Corchorus olitorius L.	✓		Summer	[1,6,8,14]
Cucumis melo L.		✓	Summer	[1,6,8,14]
Cucurbita spp.		✓	Summer	[1,6,8,14]
Galinsoga parviflora Cav.	✓		Summer	[6,8,14]
Momordica balsamina L.	✓		Summer	[6,8,14]
Portulaca oleracea L.	✓		Summer	[6,8,14]
Solanum retroflexum Dun.		✓	Winter	[1,6,8,14]
Vigna unguiculata (L.) Walp.		✓	Summer	[1,6,8,14]

Harvesting of ALVs without cultivation is unsustainable in that people have no control over availability as shown in Table 1. Others argue that these ALVs are only needed in small quantities and the naturally occurring amounts should be adequate. However, if the increase in promotion and consumption of these species is not matched with propagation or cultivation, this could lead to an unsustainable increase in harvesting from the wild or extinction of species in South Africa [14,28]. An alternative to this utilisation approach is the integration of African leafy vegetables in cropping systems [29]. Therefore, there is need to conduct more agronomic studies to generate basic production guidelines for these crops that will enable to match supply with demand. These agronomic studies will explore the planting dates appropriate for farmers to get better prices. Studies on various harvesting methods should be conducted alongside nutritional studies to ascertain the best time or different stages of harvesting.

Some agronomic studies aiming to develop optimal cultivation practices for improved yield in South Africa have indicated the possibility of improved production. Agronomic considerations such as nitrogen [8,27,30,31] and manure application [8,32] have reported improved production. However, further studies still need to be conducted on the effects of manure and nitrogen on the quality of

ALVs in terms of bioactive compounds and quality parameters. It is after such studies that some of the nitrogen rates can be adapted by farmers. Similar reports have been made on improved production due to agronomic factors such as planting date [27,33] irrigation management [34,35] and plant density [24,36]. Promoting cultivation of ALVs would increase their availability and accessibility to consumers and possibly generate household income for rural households [37]. There is still a need to investigate the relationship between water use, crop production and quality in terms of macro and micronutrient.

2.4. Marketing of Leafy Vegetables in South Africa

The marketing of leafy vegetables in South Africa is still low and limited to dried products [20,38]. Their marketing and distribution is mainly through street vendors [38,39]. Despite their perceived quality, ALVs are rarely found in supermarkets and upmarket groceries in South Africa. The rare presence of stocking of ALVs in supermarkets has greatly contributed to their reduced consumption. This is due to decreased availability and their low status among some South African community. At the time of this research, there is no coordination of leafy vegetable production and marketing. Those who are already consuming these vegetables have not increased their demand for same, due to lack of improved presentation and availability from steady and reliable sources. The opening up of market outlets for ALVs in supermarkets and groceries can be achieved through training of farmers in modern production techniques, quality control and standardization of selling units, and then linking the farmers to the markets. According to Matenge et al. [22], marketing messages such as "old-fashioned but new" or "traditional but more convenient" might reach both younger and older consumer markets. For successful promotion of these crops there should be vertical integration that must be achieved through institutional linkages between the producers and the supply outlets. Linking up of the various market actors will lead to increased supply as well as increased efficiency in the chains.

2.5. The Role of the Private and Public Sector in Promoting ALVs

Research of ALVs in South Africa has been ignored for a long time by policy makers and researchers although it is currently attracting interest [9]. The Agricultural Research Council (ARC) Vegetables and Ornamental Plants (VOPI) is one of the major role players involved in research and training of indigenous vegetables in South Africa. Indigenous crops research is since 1994 an existing research focus area for ARC-VOPI [18]. It has created awareness within the scientific community through publications, presentations, posters, workshop and conference attendance. The ARC-VOPI in collaboration with the International Institute of Plant Genetic Resources Institute, (IPGRI) has made efforts in promoting wild vegetables [18]. There are also current efforts being done by ARC-VOPI to promote different ALVs through compilation of important literature on the production, subsequent research collaboration with universities and farmer engagements. However, long term partnership and funding by governments and private sector is a key driving force behind the increased production of ALVs in South Africa.

Water Research Commission (WRC) has also been a major role player in promoting ALVs through research funding. Some of the funded WRC scoping studies have tried to document water use efficiency of selected ALVs, and then use these with nutritional values to estimate nutritional water productivity [35,40]. This is necessary as it will give insight on how increasing ALVs production and diversity can be linked to addressing nutritional outcomes. Most of the water use efficiency data used in these studies were benchmarks estimates and from various sources [35,40]. This is because there is limited published data on most ALVs and there is no literature on water use of some of the ALVs such as in South Africa. Despite its efforts in scaling up research, WRC should direct mostly of its research in agronomy to determine potential yield and water use efficiency to accurately calculate nutritional water productivity in South Africa.

The Medical Research Council as a role player has focused on the use and nutritional value of ALVs among rural households among other projects. The South African Department of Agriculture, Forestry and Fisheries (DAFF) is a key role player at policy level in promoting the value of ALVs [9]. At present, the current food security policy guiding research, production and marketing of agricultural produce is quite broad and lacks specific direction for the promotion of ALVs. At the time of this research, there is notably no formal or commercial seed production which is a prerequisite for sustaining the production trend. Discussions with colleagues from ARC-VOPI breeding department cited that there are no registered varieties of ALVs at present under the Department of Agriculture. According to Venter et al. [18], efforts should be made to ensure government agencies are supportive of ALVs initiatives in current and future projects. Extension service in South Africa is not well facilitated to work properly and, on the other, even if it were, there would be a need for some basic training since training college curricula rarely cover ALVs. This is because Agricultural education in both commercial and communal areas is aimed at cash crop production [29].

All South African universities are role players in promoting use of ALVs. Universities have been partners on nutritional and consumption studies, thus helping to strengthen the capacity in the scientific community on ALVs [18]. From the discussion arising from Symposium on the Water Use and Nutritional Value of Indigenous and Traditional South African Underutilised Food Crops for Improved Livelihoods conducted in Pretoria in 2014, one of the challenges is research funding. Lack of funding in some South African universities towards research of ALVs results in fewer field studies conducted and in the case where they are conducted, it is in small plots or backyard field leading to poor results. Another challenge is that researchers are focusing on their areas of interest or interesting studies with few dealing with basic agronomic studies that require extensive field work.

Promoting home-grown or small-scale food production is explored as a feasible contributor to food and nutrition security for the rural poor in South Africa [41]. Improved research funding, combined with public education and dissemination of information is required. Since the target is promoting home-grown or small-scale food production there is constant need for community feedback sessions, interaction with farmers and scientists. According to van Rensburg et al. [1], the active promotion, use and conservation of ALVs will ensure that the status of these crops is enhanced, specifically their contribution towards sustainable nutrition as well as sustainable production in South Africa.

3. Nutritional Value

South Africa faces Vitamin A and Iron deficiencies, while utilisation of ALVs is documented to alleviate malnutrition. In such cases one would expect an increased uptake of such species. However, there is a decreased tendency in the utilization of ALVs due to limited knowledge of the nutritional content [21]. African leafy vegetables are increasingly recognized as possible contributors of both micronutrients and bioactive compounds to the diets [42]. They contain nutrients such as calcium, iron and vitamins A and C, fibre and proteins [14]. They are a valuable source of nutrition in rural areas and they contribute substantially to protein, mineral and vitamin intake together with fibre; they also add diversity to the diet. African leafy vegetables should therefore be included in the diet to overcome various nutritional problems such as iron and vitamin A deficiency [14]. The minerals and vitamins found in ALVs exceed the levels found in exotic vegetables such as cabbage; they are also compatible to use with starchy staples because they contain ascorbic acid, which enhance iron absorption [2].

Studies on the antioxidant properties of these vegetables also revealed that they are good dietary sources of antioxidants such as flavonoids, tannins and other polyphenolic constituents [43]. Phenolic compounds are secondary metabolites in plants which exhibit a wide range of physiological properties, such as anti-allergenic, anti-atherogenic, anti-inflammatory, anti-microbial, antioxidant, anti-thrombotic, cardio protective and vasodilatory effects [44]. Many phenolics, such as flavonoids, have antioxidant properties that are much stronger than those of vitamins C and E. Flavanols and flavonoids have been found to possess antioxidant and free radical scavenging activity in vegetables [45]. One way to promote nutritional uptake of ALVs in South Africa is childhood exposure and education on ALVs at primary school level by incorporating these products into school feeding programmes [22].

Our literature research has indicated that few studies have been conducted on the nutritional composition of wild vegetables in South Africa [3,21,42,46]. However, most of these studies have been based on the collection of plant samples from the wild. Hence, variations in soil and climatic conditions might have influenced the chemical composition of the crop species. Studies comparing the superior nutrient composition of wild vegetables to conventional vegetables such as cabbage (*Brassica oleracea* var. *capitata*) and Swiss chard [2,3,47,48] are documented in South Africa. In some cases, these studies have been conducted in separate soils or samples purchased from the market to conduct tests, hence there are needed to conduct studies in the same field environment to reach meaningful comparison. More controlled experiments on aspects such as effect of soil type, effect of fertiliser amount and type, and age of harvesting on the nutritional composition of ALVs still needs urgent attention. The amounts of nutrients reported for the same species from different studies vary widely [13]. Possible cause to such is variation in the age of plant material used and variations in protocols of analysing the bio compounds from one lab to the other [14]. Therefore, there is need to conduct studies with standardised assays or protocols to make comparisons and to consider the age of plants materials used.

4. Drought Tolerance and Resilience

African leafy vegetables could make a positive contribution to world food production because they adapt easily to harsh or difficult environments [49]. The input required for growing them is lower compared with other crops, and they are highly resistant to pathogens thus requiring fewer chemicals and pesticides [49]. They are considered low input crops, which are more tolerant to abiotic and biotic stresses as compared to exotic vegetables [50,51]. The notion that ALVs grow in the wild or adverse environments could mean they have various strategies/mechanisms to deal with drought stress. Drought stress is defined as the moderate loss of water which results in stomatal closure and limitation of gas exchange [52]. A plant may escape, avoid, and/or tolerate stress. Drought tolerance has been defined as the plant's capacity to maintain metabolism under water stress [53]. Drought avoidance involves crop responses such as stomatal regulation, enhanced capture of soil moisture through an extensive and prolific root system [54,55]. Studies conducted elsewhere have shown that cowpea [56] and Amaranth [57] are tolerant to adverse climatic conditions. Few studies conducted in South Africa have also shown that leafy vegetables are drought tolerant. Neluheni et al. [58] showed that reasonable yield in Amaranth can still be obtained even at lower moisture availability. Slabbert et al. [59] in screening for drought tolerance showed that the six major indigenous leafy vegetable could maintain higher relative water content and leaf area compared to *B. vulgaris.* var. *cicla*.

Studies have shown that not all African leafy vegetables are tolerant to water stress. *Brassica rapa* subsp. *chinensis* has been shown to require adequate availability of soil water for optimum growth [34]. Neluheni et al. [58] reported that stress tolerant in amaranth depends on the specie with *A. graezizans* tolerant than *A. cruentus*. This concurs with previous researchers elsewhere who reported that drought tolerance in amaranth depends on the species [26,60]. Farmers can still choose species that are drought tolerant. Therefore, ALVs can act as a substitute for other cultivated crops to alleviate nutrient deficiencies by increasing nutrient supplies [37]. Therefore, there is needed to breed for drought resistant varieties and to conduct irrigation trials throughout the year to ensure continuous availability remains to be established in South Africa.

5. Water Use of ALVs

South Africa is a water stressed country [12] and irrigated agriculture takes place under water scarcity. According to Annandale et al. [61], in the next two to three decades, water availability is likely to drop below benchmark of 1000 m^3 person $year^{-1}$. One way to deal with inadequate availability of water is to utilise crops that are tolerant to water stress [6]. African leafy vegetables can be exploited to contribute towards food and nutrition security without upsetting the existing burden on water shortages [6]. The promotion of production of ALVs in South Africa include addressing the notion of "more crop per drop", thus the production of more food per millimetre of water used. This is necessary despite ALVs being drought tolerant, with low water requirement, poor water management could upset the existing water burden once these crops are commercilised. Therefore, to optimise the amount of water, Water use efficiency (WUE) and Water productivity should be known with considerable precision. WUE is defined as mass of dry matter produced per unit volume of water evapotranspired expressed in kg m^{-3}. Studies conducted on water use efficiency indicate that black nightshade (*Solanum nigrum*) and cleome (*Cleome gynandra*) among other crops have low water use and high water use efficiency compared to Swiss chard [41]. Water use efficiencies obtained in South Africa substantially differs with those published international [40]. Therefore, there is need to conduct more studies as little local research has been published on water use efficiency of ALVs in South Africa.

Crop water productivity is the amount of water required per unit total biomass or specified biomass produced expressed in kg m^{-3} [62]. A study conducted to determine the water requirements of selected ALVs in South Africa showed that adequate amount of water is needed to produce marketable yield [35]. Highest water productivity was obtained at deficit irrigation which indicates that production of ALVs is possible in water scarce areas. However, deficit irrigation compromised the leaf quality as observed by Beletse et al. [35]. This study was conducted under a rain shelter and in one locality, hence need to conduct more field trials in different regions in South Africa.

Furthermore, in promoting production in South Africa, researchers need to shift from emphasizing production per unit area towards maximizing nutritional content per volume of water consumed, the nutritional water productivity (NWP) as defined by Renault and Wallender [63]. According to Mabhaudhi et al. [64] South African benchmarked values of macronutrient water productivities indicates that indigenous leafy vegetables such as Amaranth and pumpkin leaves are efficient in terms of water consumed per protein produced. Dark green vegetables are efficient protein synthesizers and high efficient iron accumulators [40]. The sets of nutritional water productivity (NWP) values were calculated using the equation of Renault and Wallender [63]. It should be noted that the values were calculated using the same trials hence the influence of the environment on water productivity and nutrient contents questions the reliability of the results [40]. There is limited published information on nutritional water productivity (NWP) in South Africa [40]. Therefore, there is need to conduct systematic research in the determination of yields, water use efficiencies and nutritional water productivity under a range of production environments in South Africa.

6. Post-Harvest Handling and Storage of ALVs

The main constraint to increased production, marketing and consumption of ALVs is the high perishability in the fresh form [42]. Another major constraint is that they are seasonal produced mainly in summer [19]. A study by Modi et al. [21] in South Africa at Ezigeni, KwaZulu–Natal observed that the availability of wild vegetables suddenly declined in May and became scarce between July and August and only increased as the season progressed from August to October. Therefore, there is a need to develop and promote appropriate processing techniques to minimize post-harvest losses and ensure regular supplies of leafy vegetables from the production areas to consumers in peri-urban and urban centres.

6.1. Cooling and Storage

Post-harvest losses of leafy vegetables are generally caused by poor handling and storage conditions after harvest. Cooling extends shelf life by reducing the rate of physiological change (i.e., rate of respiration and transpiration) and retarding the growth of spoilage microorganisms. In most cases, if these vegetables are not sold within 24 h after harvest, the likelihood of deterioration is imminent. Some farmers have tried to sprinkle water and leave them in the open overnight. However, problems of disease development and thus microbiological contamination still hamper their effort.

Temperature is the most important environmental factor that influences the deterioration of harvested commodities [65]. Higher temperatures accelerate physiological deterioration and quality loss. Elsewhere, Nyaura et al. [66] reported that ascorbic acid declined by 88% in vegetable amaranth when kept at room temperature after four days of storage while the lowest loss was observed at 5 °C (55% loss) after 23 days of storage. Based on this study, it is suggested that shelf life extension and nutrient preservation of vegetable amaranth can be achieved through storage at temperatures of 5 °C. A study conducted in South Africa on Baby Spinach (*Spinacia oleracea*), a member of the *Amaranthaceae* family showed that storage period and temperature have different effects on Mg, Fe, Zn, phenolics, antioxidant activity, flavonoids carotenoids, and vitamin C [67]. Baby Spinach leaves stored at 4 °C maintained good quality for 4–6 days as compared with those stored at 22 °C such as a retail store [67]. There is limited information on storage temperature on ALVs. Information on various ranges of storage temperatures for small holders farming and commercialisation of leafy vegetables in South Africa needs urgent research attention.

6.2. Packaging

According to Matenge et al. [22], there is need to improve the image of ALVs to improve acceptability, preference and consumption by younger consumers, thereby presenting food product developers and marketers with the opportunity to make more acceptable ALVs product available. Proper packing is essential to protect ALVs against spoilage and microorganism decay, preserve their quality and provide convenience of handling [68]. At present ALVs are simply uprooted or cut at the stems, sometimes washed, then tied into bunches and presented in the market. African leafy vegetables would fetch better prices if there were innovative ways of presenting them in the markets because packaging would attract the attention of consumers. This conforms to the findings of Mampholo et al. [68] that appearance of the product plays a major role in influencing the consumer acceptance. Voster et al. [19] reported that some farmers packaged dried leafy vegetables products to increase shelf life in South Africa.

The knowledge of appropriate packaging for ALVs is still limited. Recent studies conducted in South Africa on *A. cruentus* and *S. retroflexum* [69] and on *Brassicas chinensis* [68] indicates that modified packaging can reduce postharvest losses and retain the overall quality and bioactive compounds on the retailer's shelf during marketing. These studies have focused on modified packaging and research still need to be conducted on various low-cost packaging techniques for small holder farmers in South Africa. Furthermore, the effect of pre-harvest or agronomic practices on postharvest and shelf life still needs urgent research needs. At the time of this research there is no pre-cut, branding or packaging of fresh ALVs in the South African formal market. Packaging and instructions on how to prepare the ALVs would assist potential customers who do not know how to cook them.

6.3. Drying

Drying is a way of processing leafy vegetables to make them available during periods of short supply [42]. Drying is a post harvesting process that can promote availability of leafy vegetables to farmers especially those who cannot afford packaging. Drying reduces microbiological activity through reduced moisture content in food. There are several methods of drying leafy vegetables that have been reported elsewhere which include sun drying, solar drying, vacuum drying, oven drying, and dehydrofreezing [70].

In South Africa, drying is the major method of processing leafy vegetables to make them available during periods of scarcity [19]. Whilst drying solves the problem of perishability, it does not satisfy the needs of a large population of consumers; particularly urban dwellers who prefer freshly harvested vegetables [42]. Voster et al. [19] reported that there are two main methods of preserving indigenous leafy vegetables in South Africa. These include sun drying of fresh leaves and sun drying of blanched leaves. Both these methods transform the leafy vegetable into dry products that have long shelf lives [19]. Van Averbake et al. [27] reported that electrification of the rural areas has introduced the new preservation technology, of freezing of leaves. Various drying methods have been reported elsewhere to affect quality parameters such as texture, flavour, colour, and bio-compounds of leafy vegetables.

However, there are limited published data on the effect of various drying methods on the quality of indigenous leafy vegetables in South Africa. Such information is necessary to establish suitable drying methods for cultivated leafy vegetables within South Africa. There is a need to develop and promote locally appropriate processing techniques and ensure regular supplies of leafy vegetables from the production areas to consumers in peri-urban and urban centres.

6.4. Cooking

Cooking induces significant changes in chemical composition affecting concentration and nutrient bioavailability [71]. Various cooking methods are used based on convenience and taste preference rather than nutrient retention. Some cooking methods may oxidize antioxidants [72] and affect the vegetable nutrient retention. It is therefore important to choose a cooking method that leads to optimal nutrient retention and bioavailability [73]. Cooking for a longer time leads to a higher loss of most of the nutrients especially if cooking water is discarded since most nutrients leach into it [71,73]. The choice and age of plant harvested influences the quality of the leafy vegetable.

Voster et al. [74] reported that young growing and tender leaves are used in the preparation of vegetables dishes in South Africa. Petioles and in some cases young tender stems are also included but old, hard stems are discarded [74]. The leafy vegetables dishes are prepared from a single species or form a combination of different species [6]. Cooking methods vary through boiling, to steaming [6]. The recipes used to prepare the vegetables tend to be similar among people belonging to a particular cultural group, limiting culinary diversity [19]. At the time of this research there was less published data retrieved on the recommended cooking methods and diversified recipes for various ALVs in South Africa.

Smith and Eyzaguirre [42] reported that ALVs are indispensable ingredients in soups or sauces that accompany carbohydrates or staples. The crucial component of the leafy vegetable promotion strategy will be through recipes developments to show ways of preparing these food ingredients. The recipes should encourage the use of the ALVs in preparing foods other than accompanying sauces to ensure that the vegetables are used daily, thus increasing the opportunities for their consumption. To promote these crops, the developed vegetable products can be consumed as snacks or accompany a beverage thus broadening the consumption habits. Value addition through product development will help address the issue of perishability and fluctuating supply of the vegetables on the market. There is need for research in the development of diversified recipes that are nutrient-dense and for alternative uses of these indigenous vegetables. Awareness creation, coupled with the development of brochures on how to prepare ALVs—as well as informing the potential consumers of where to find them—will help to extend demand even to those who do not know much about these vegetables. The demonstrations of proper cooking methods will result in increased utilization in ALVs species, some of which have an unpleasant taste (e.g., African night shade)—a factor which has been detrimental to acceptance by some people.

7. Conclusions

In South Africa, there is a decline in consumption of ALVs partly because of low availability and poor perception. Low availability is because production continues to be on small scales and they are considered wild species hence have never been commercialised. They are obtained by means of collection rather than cultivation hence they face threats of over-exploitation. Promotion of conservation and collection of genetic resources and germplasm exchange needs urgent attention. There is need to develop support policies for seed systems for both the public and private sectors. Although neglected and underutilised in South Africa, ALVs offer unique opportunities to diversify farming systems, ensure food security and alleviate poverty, while increasing income and improving human health. Some of the challenges hindering promotion of ALVs include lack of sound agronomic information due to limited research, shortage of seeds as currently there are no registered varieties for most of ALVs and lack of value-adding technologies. For leafy vegetables to move from underutilised crops to commercial-level production there is a need to generate production information as has been done on major crops. Public education in production, conservation and marketing through workshops and seminars is also key to their promotion. Increased research on production, nutrition, processing and marketing still requires attention. Promotion of ALVs needs engaging of policy-makers who will incorporate it into government policies and programmes. Furthermore, policy makers can influence curriculum development at schools and universities to integrate ALVs into the educational curriculum. There is need to develop joint programmes among government, private sectors and NGOs to promote ALVs. ALVs are part of the region's cultural heritage and are rich in nutrients, e.g., vitamin A and iron. Therefore, there is need to promote the cultivation and utilisation of ALVs by farmers, especially women and other vulnerable groups. Successful promotion should result in ALVs forming part of the daily staple diet of South Africans.

Acknowledgments: The authors acknowledge funding from the South African department of Rural Development.

Author Contributions: Innocent Maseko, Tafadzwanashe Mabhaudhi and Samson Tesfay did the initial conceptualisation of the paper. Innocent Maseko then led the write-up of the paper and all authors then reviewed and approved of the paper prior to publication.

Conflicts of Interest: The authors declare no conflict of interest.

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