Hohenheim Working Papers on Social and Institutional Change in Agricultural Development

Working Paper 007-2021

Edible weeds and food and nutrition security in the face of the herbicide revolution. A case study from Zambia

Thomas Daum, Alysha Vehre, Carolin Schweizerhof, Christoph Schunko

Universität Hohenheim

January 2021

Hohenheim Working Papers on Social and Institutional Change in Agricultural Development (007-2021)

Edible weeds and food and nutrition security in the face of the herbicide revolution. A case study from Zambia

Authors Details

Thomas Daum (University of Hohenheim, Germany)

Alysha Vehre (University of Natural Resources and Life Sciences, Vienna, Austria)

Carolin Schweizerhof (University of Hohenheim, Germany)

Christoph Schunko (University of Natural Resources and Life Sciences, Vienna, Austria)

Corresponding Author

Thomas Daum (thomas.daum@uni-hohenheim.de)

Suggested citation: Daum, T., Vehre, A., Schweizerhof, C., Schunko, C. (2021). Edible weeds and food and nutrition security in the face of the herbicide revolution. A case study from Zambia. Hohenheim Working Papers on Social and Institutional Change in Agricultural Development. 007-2021. University of Hohenheim.

Title Picture Credit: Alysha Vehre

Download this working paper from our homepage: https://490c.uni-hohenheim.de/en/75736

Abstract

Herbicides are on the rise across the developing world. Herbicides may come with several advantages, for example, they may help to improve yields, thereby contributing to food and nutrition security. However, they may negatively affect environmental and human health. In the quest to assess the trade-offs of herbicide use, one aspect has received limited scientific attention: the role of edible weeds, which can be key elements of rural food baskets, yet are also the targets that herbicides are designed to eradicate. Using a quantitative survey with 158 households and a range of qualitative methods such as field walks, focus group discussions, and stakeholder interviews, this study examines the role of edible weeds for rural diets in Zambia and explores how herbicides affect the consumption of edible weeds. The results suggest that edible weeds are an integral part of rural diets in Zambia, in particular during the "hunger months", emphasizing their contribution to food and nutrition security. While the unfolding herbicide revolution poses risks to the availability of edible weeds, herbicide use did not (yet) affect the consumption of edible weeds, likely because still few households use herbicides, and herbicides are sprayed only on a fraction of the plots. Long-term herbicide users are, however, slightly less likely to consume edible weeds. Given the potential trade-offs between herbicides, edible weeds, and food security, this topic should continue to be monitored. Policymakers should pay more attention to potential trade-offs concerning food and nutrition security when promoting the use of herbicides.

Key Words

Agrochemicals, ethnobotany, food systems, intensification, nutrition-sensitive agriculture

Acknowledgments

We are grateful for the financial support from the "Program of Accompanying Research for Agricultural Innovation" (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ). Alysha Vehre and Carolin Schweizerhof are very thankful for additional financial support from the Stiftung fiat panis for the field research. We are grateful for excellent and dedicated research assistance from a team around Fabiano Tembo from Kachele Research Solutions. We thank all the farm families for participating in the study.

1. Introduction

The use of herbicides is on the rise in many developing countries (Haggblade et al. 2017, 2017b, Rodenburg et al. 2019, Seneshaw et al. 2017, Tamru et al. 2017). Haggblade et al. (2017) refer to this phenomenon as the “herbicide revolution”, which is, according to them, driven by “a flood” of cheap herbicides from Asia and the leading agrochemical companies discovering emerging markets. Herbicides may come with advantages. As weeds compete with crops for soil nutrients, they may help to raise yields (Rodenburg et al. 2019), thereby contributing to food security (Nyanga et al. 2012). Also, they may reduce the labor burden associated with manual weeding, which is often done by women and children (Gianessi 2013, Nyanga et al. 2012, Timmons 2005). However, herbicides may also have negative effects on environmental and human health (Antle & Pingali 1994, Bonner & Alavanja 2017, Haggblade et al. 2017, Williamson et al. 2008). While many advantages and disadvantages of agrochemicals have been well explored, one aspect has received limited scientific attention: the linkage between herbicide use and the consumption of edible weeds and, subsequently, food and nutrition security.

The Oxford Dictionary defines a weed as “a wild plant growing where it is not wanted and in competition with cultivated plants”. In this study, weeds are considered leafy plants that grow in or on the edges of fields and have not been planted on purpose. Self-seeding weeds are generally considered undesirable plants from the human perspective (Maroyi 2013). Herbicides, sometimes also referred to as weedicides, are “a substance that is toxic to plants, used to destroy unwanted vegetation” (Oxford Languages), and are specifically designed to eradicate weeds. Yet, several studies show that some plants that would be eradicated by herbicides are more than an agricultural foe and constitute a considerable share of rural food baskets in developing countries (Cruz-Garcia & Price 2012, Maroyi 2013, Hillocks 1998), in particular in times of crisis when the main crops fail (Shava et al. 2009).

As a subcategory of wild plants, which are well-known to be beneficial for many rural households (Badimo et al. 2015, Bharucha & Pretty 2010, Harris & Mohammed 2003, Mavengahama et al. 2013, Ojelel & Kakudidi 2015, Ong & Kim 2017), edible weeds may play a role for food and nutrition security. However, unlike other wild plants, which grow outside of farmers’ fields, the consumption of edible weeds may be affected by herbicide adoption. This is because, in contrast to manual weeding, herbicides are less selective and allow ‘clean weeding’ (Hillocks 1998). Increased use of herbicides may thus cause edible weeds to disappear from food baskets.

This study explores the role of edible weeds for food and nutrition security in the face of the herbicide revolution, focusing on the Eastern and Southern Provinces of Zambia, which ranks 113th out of 117 countries according to the Global Hunger Index (von Grebmer et al. 2019). In Zambia, 37% of the population are food insecure, 40% of the children are stunted and nearly half of the population experiences seasonal hunger (Mwanamwenge & Harris 2017). Moreover, deficiencies of Vitamin A, B12, Folate, Iron, and Iodine are prevalent across Zambia (Chapoto et al. 2018). Herbicide adoption in Zambia is low compared to the world average, however, their use is on the rise: around 14% of farm households use herbicides (Chapoto & Zulu-Mbata 2016).

The study first analyzes the consumption patterns and perceptions related to edible weeds and their role for the food and nutrition security of smallholder farmers. The study then explores to what extent households use herbicides and how their adoption affects the consumption of edible weeds. While this study focuses on two provinces in Zambia, its findings are important for many developing countries given that worldwide, more than 820 million people suffer from hunger, and close to two billion people suffer from hidden hunger, which is a lack of sufficient micronutrients (Global Nutrition Report 2020).

2. Literature review and conceptual framework

2.1. Effects of herbicides

Herbicides may come with several advantages such as reducing manual weeding, which is time-consuming, physically demanding, and often detrimental to the farmer's health and well-being (Gianessi 2013, Haggblade et al. 2017b, Tamru et al. 2017). Using herbicides, farmers may free up time to expand their cultivated land, cultivate kitchen gardens, and for off-farm work, etc. (Gianessi 2013, Haggblade et al. 2017b, Tamru et al. 2017). Women and children who often take a large share of the weeding burden may have time for childcare and educational activities, respectively (Tamru et al. 2017). Herbicides may help farmers to achieve higher yields. Manual weeding is associated with the risk of not being able to remove weeds quickly enough to prevent competition with the main crop for nutrients, water, and light, which can lead to lower yields (Gianessi 2013, Oerke 2006). With better weed control, the effects of fertilizer may also increase (Haggblade et al. 2017). Lastly, herbicides may allow a shift to minimum tillage as part of conservation agriculture, which can help to reduce soil erosion and soil carbon losses, etc. (Haggblade et al. 2017).

However, herbicides can also have drawbacks, most notably on human health when substances are not carefully handled and no protective equipment is used (Antle & Pingali 1994, Bonner & Alavanja 2017, Haggblade et al. 2017, Pingali & Marquez 1996, Rodenburg et al. 2019, Williamson et al. 2008). There can also be negative environmental effects, particularly on rivers and groundwaters (Bonanno et al. 2017, Gianessi 2013, Naylor 1994), insect populations (Pleasants & Oberhauser 2013), and soil biota (Lekberg et al. 2017). There are also concerns about the growth of herbicide-resistant weeds (Heap 2014). Effects on human and environmental health may be particularly adverse in the absence of adequate public monitoring and regulatory capacity, which is the case in many African countries (Haggblade et al. 2017).

The effects of herbicide adoption on food and nutrition security are unclear. In areas where edible weeds are a part of rural diets, herbicides may reduce food and nutrition security because edible weeds are destroyed. Food and nutrition security may also decline when herbicides eradicate edible weeds which are fed to animals that provide livestock products such as meat, milk, and eggs, for direct consumption or cash for food when sold on markets. However, when herbicides enable area expansion by addressing labor bottlenecks and contribute to higher crop yields (Gianessi 2013, Haggblade et al. 2017b, Oerke 2006, Tamru et al. 2017), this may help households to access more calories, however, not necessarily more micronutrients. Nutrition security may rise when farmers use the land to cultivate additional crops (or produce fodder for animals) and can therefore sell more crops - using the additional income to buy nutritious food from markets. As noted above, herbicides may also reduce the time needed for weed control (Gianessi 2013, Haggblade et al. 2017b, Tamru et al. 2017), thereby allowing households to pursue off-farm activities, whose income can be used to buy food from markets.

2.2. Edible weeds and food security

As a way to combat hunger and malnutrition, wild edible plants, including edible weeds, have been used around the globe to supplement diets (Cruz-Garcia & Price 2011, Nyaruwata 2019, Addis et al. 2005, Madamombe-Maduna et al. 2008). For example, Maroyi (2013) found that in Zimbabwe, edible weeds were used as a “survival strategy”, playing an important role in the daily diets of households and also being preserved for future food security (Maroyi 2013). In Thailand, edible weeds were discovered to be important for food and nutrition security amongst rice farmers (Cruz-Garcia & Price 2011). Edible weeds may also be used as fodder, medicine, and income and are considered to be important contributors to agro-ecosystems through the maintenance of biodiversity and the prevention of soil erosion (Vieyra-Odilon & Vibrans 2001, Maroyi 2013, Cruz-Garcia & Price 2012, Mavengaham et al. 2013).

The reliability of edible weeds in times of food scarcity is partly due to their hardiness and drought tolerance. Weeds, like Amaranthus sp., can be found in poor soils and water-scarce environments making them likely to be still accessible even when exotic crops, like maize, have failed (Alemayehu et al. 2014, Dzerefos et al. 1995). Considered to be high in minerals and nutrients, edible weeds can contribute to a more varied and healthy diet (Rapoport et al. 1995, Harris & Mohammed 2003). Food insecurity consists of not only the lack of food but also the lack of essential nutrients to be healthy. Nutrient deficient diets have resulted in high occurrences of anemia, especially among women and children, and can have irreversible effects on the physical and mental development of children (Mofya-Mukuka & Mofu 2016, Fanzo 2012). The consumption of edible weeds may help to treat and prevent some dietary diseases, like anemia (Mofya-Mukuka & Simoloka 2015).

Despite the potential health benefits, little attention is given to edible weeds in the context of food security. Edible weeds are weeds, and they are not differentiated by the researchers and extension workers who advocate for their removal from fields (Vorster et al. 2007, Shakleton 2003). While farmers can be selective during manual weeding, the use of herbicides may entirely eradicate all weeds from the field, including edible weeds (Mavengahama et al. 2013, Joala et al. 2016).

3. Study Site and Methods

3.1 Study sites

Zambia has a population of 18 million, of which 56% live in rural areas (World Bank 2020). 78% of rural households earn less than 1.25 USD per day (IAPRI 2015). Maize is the most important staple food and covered 54% of the cultivated area in 2015/16 (Chapota et al. 2018). Other crops grown are groundnuts (peanuts), soybeans, sunflowers, seed cotton, mixed beans, and cassava. In recent years, persistent droughts and the fall armyworm (Spodoptera frugiperda) have led to crop failures (Chapota et al. 2018). The government has taken measures to increase agricultural productivity, in particular, the Farmer Input Support Program (FISP), which provides farmers with subsidized inputs such as fertilizers and herbicides (Kuteya et al. 2016). Various stakeholders such as the Conservation Farming Unit and the Ministry of Agriculture and Livestock promote conservation farming, which can trigger the use of herbicides (Goeb 2013).

The study focuses on the Eastern Province and the Southern Province. Here, agriculture is predominantly carried out by smallholders who own less than five hectares, constituting 96% of agriculture in the Eastern Province and 87% in the Southern Province (Chapoto et al. 2016). Most fieldwork is done with animal power or by hand: the share of farms using mechanization is 0.5% in the Eastern Province and 1% in the Southern Province (Chapoto et al. 2016). Weed control is mainly done by hand and to a large extent by women (Beuchelt

& Badstue 2013, Nyanga et al. 2012). Herbicides are used by 4% of households in the Southern Province and 5% in the Eastern Province – compared to the national average of 14% (Chapoto et al. 2016). The Eastern Province offers good climatic and ecological conditions for agricultural production and is known as Zambia's food basket, whereas the Southern Province has large areas that are less favorable for agricultural production because of prolonged droughts (Department of Energy Zambia 2017). Previous studies suggest that different weed varieties grow in the two provinces (Nguni & Mwila 2007). To gain insight into both the consumption of edible weeds and the current and potential future adoption of herbicides, these two provinces were perceived as particularly useful.

3.2. Methods and sampling

The study followed a mixed-method research design, including a quantitative household survey (see 3.2.1) as well as qualitative methods such as focus group discussions (FGD), field walks, and stakeholder interviews (see 3.2.2). Data was collected during the 2018/2019 growing season from December 2018 to March 2019. Fieldwork was carried out during the rainy season when most edible weeds were growing, in order to collect and identify each specimen.

3.2.1. Quantitative methods: household surveys

The research was conducted in the Eastern and Southern Provinces. 158 farming households in eight camps and eight districts were randomly selected to obtain an unbiased representation of smallholder farmers (see Figure 1). A camp refers to an agricultural camp, which is composed of multiple villages within a designated area, as defined by the Zambian Ministry of Agriculture. One accessible camp was randomly selected from each district. Due to heavy rains, some camps and households were inaccessible and had to be excluded from random sampling.

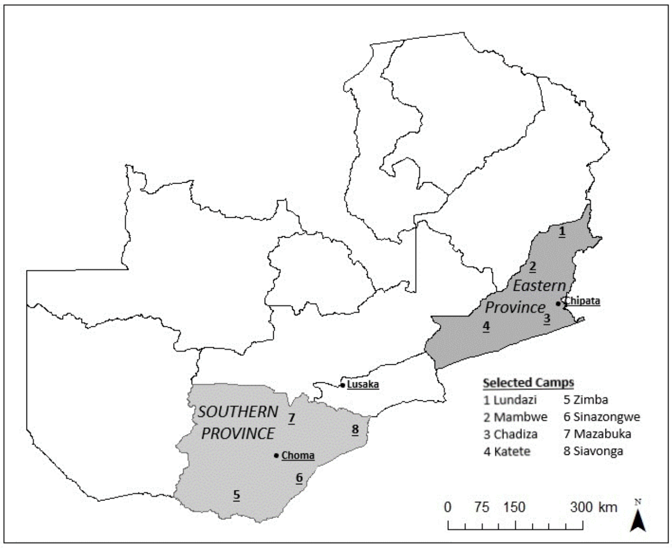

Figure 1: Location of camps for fieldwork.
Source: Authors, Geodata © OpenStreetMap

In the camps, lists of farm households were obtained from the camp officers, with the aim of including all farm households within the camp. This might have led to some bias as the lists did not always contain all of the farming households in a given area and may have overrepresented farmers that are part of farmer groups, cooperatives, and recipients of the Farmer Input Support Program (FISP). From the household lists, 20 households were randomly selected for each camp. 158 households were interviewed (Table 1).

Selected provinces	Selected districts	Total camps	Accessible camps	Selected camps	Total households	Accessible households	Selected households	Interviewed households
Eastern Province	*Lundazi*	44	39	*Vuu*	600	116	20	19
	Mambwe	13	5	*Mpomwa*	2900	800	20	19
	Chadiza	16	13	*Mlolo 2*	3818	357	20	20
	Katete	20	14	*Vulamkoko*	1870	1870	20	20
Southern Province	*Zimba*	13	11	*Mayoba*	1821	393	20	20
	Sinazongwe	22	15	*Malima*	2100	1300	20	20
	Mazabuka	22	19	*Ngwezi B*	283	283	20	20
	Siavonga	10	7	*S. Gwena*	322	106	20	20
Total	8	160	123	8	13714	5225	160	158

Table 1: Household sampling process

In each household, the head of the household and the individual responsible for food were interviewed. In single-headed households, which constituted 46 households, this could also be the same person. A total number of 270 respondents were interviewed. The survey was divided into two parts. The first part was addressed to the head of the household and the second part to the person responsible for food in the household. Questions about the household's demographics and agricultural activities were addressed to the head of the household. However, questions about edible weeds, their availability, consumption, and use were addressed only to the person responsible for food. Some sections were the same for both persons, such as questions about the perception of herbicides and edible weeds. The interviews were conducted with a paper survey by research assistants who were fluent in the local language and had received extensive training in the use of the survey before the fieldwork (Mayer 2012). Written and verbal consent was obtained from each respondent. Either the second or third author was present at each interview to clarify possible questions. After the data collection, the data were digitalized and screened for completeness and inconsistencies. The data was analyzed with Microsoft Excel (2016) and STATA.

To better understand the link between the herbicide revolution and the use of edible weeds, an ordinary least squares (OLS) regression was performed with edible weed consumption (average number of days consumed per month) as the dependent variable and two different independent variables for herbicide use (the share of the land on which herbicides are used, and the years of herbicide adoption) while controlling for additional covariates. These covariates, which may equally affect the consumption of edible weeds, were selected based on economic theory and include demand-size factors that may influence the interest of households in the consumption of edible weeds (gender, age, household income, as well as a dummy for the province, which captures socio-cultural and agronomic-climatic differences) and supply-side factors that influence the prevalence of edible weeds (the share of the land kept fallow, and the use of conservation agriculture). Robust standard errors were used to account for heteroscedasticity and pairwise correlation coefficients were done to detect and avoid multicollinearity.

3.2.2. Qualitative methods: Focus groups, field walks, stakeholder interviews

In each camp, two FGDs were conducted (in total 16) by the second author and a trained research assistant who helped with the translation and moderation (Chambers 2004). The participants for the FGDs were selected with the help of the respective camp officer, who was asked to identify persons who met the given criteria. For the first FGD in each camp, 6-10 women with very good knowledge of edible weeds were invited to participate. Thematically, the first FGD focused on edible weeds, their availability and use, but also on information sources and knowledge transfer on the topic of edible weeds. A seasonal calendar was used to structure and document the information collected on the availability and consumption of edible weeds (Chambers 2004, Narayanasamy 2009). The method of listing was used to capture the various sources of information on edible weeds (Chambers 2004, Narayanasamy 2009). For the second FGD in each camp, 6-10 people of mixed gender were selected who indicated that they had knowledge on herbicides. In this FGD the topic of weed control and the use of herbicides was discussed. This included the use of pro-contra lists (Chambers 2004) for herbicide use and the mind-mapping method (Chambers 2004, Crowe & Sheppard 2012) to collect information on weed control.

14 field walks - 1-2 in each camp - were conducted to identify the plant species reported by their local names in the household survey and the focus group discussions. Individuals in the camp who were perceived to be especially knowledgeable about the identification and usage of the edible weeds were asked to act as local guides and to locate the plant individuals, corresponding to local plant names, in areas around the community: in communal lands, agricultural fields, gardens, pathways and around households. The guide directed the third authors along with a reseach assistant to point out the edible weeds and describe the typical uses and collection methods for each. After this, a plant would be collected to be used as a voucher specimen for later identification. Voucher specimens were collected in the vegetative stage, flowering stage, or in the stage when the guide would typically collect the plant to be used. Each collected plant was tagged with the local name, date, and GPS coordinates, etc. (British Columbia Ministry of Forests 1996). Samples were collected with the permission of the landowner and/or household head.

In addition to voucher specimen collection, photographs were taken of plant species (Baskauf and Kirchoff 2008). Each plant species was photographed with a white background behind the individual plants to make its features more distinguishable, along with photographs of its habitat. The photographs aided identification in conjunction with collected voucher specimens. Plant species corresponding to 38 local plant names were not collected nor photographed because the plants were unavailable at the time of the field walks or because the plants did not grow in agricultural fields and were therefore irrelevant to the study. In total, 112 plant individuals were photo-documented and 76 plant individuals were collected as voucher specimens. The voucher specimens and photographs were identified by the botanist in the department of the biological sciences of the University of Zambia (UNZA) and stored in the university's herbarium. The botanist made the identifications utilizing Flora Zambesiaca (Flora Zambesiasca) and selected the scientific names based on "The Plant List" (The Plant List 2010) and the Angiosperm Phylogeny Group (Chase et al. 2016). The identifications were later cross-referenced with the World Flora Online for consistency (WFO 2020).

4. Results

4.1 Uses and perceptions of edible weeds

The 158 households listed a total of 26 edible weed species from 15 families that are consumed, mostly from the Amaranthaceae family (Amaranthus sp.), the Asteraceae family (Bidens pilosa and Bidens schimperi), and Corchorus olitorius from the Malvaceae family. Other weeds grow in the fields but are collected considerably less frequently. On average, households consumed 3.5 different weeds (arithmetic mean) with each household consuming at least one, and at most ten different weeds. Weeds are mostly eaten fresh, but nine types were also preserved for later use, in particular C. olitorius and Bidens sp. and some plants are not only collected as “weeds” but but intentionally grown (e.g. Amaranthus sp.).

Scientific Name	Voucher Number	Family	Collected Last Farming Season			Preserved Last Farming Season	Cultivated Current Farming Season
			Eastern Province n=78	Southern Province n=80	Total n=157	n=157	n=157
Amaranthus sp.	*22253, 22223, 22256, 22257*	Amaranthaceae	84%	91%	88%	10%	10%
Corchorus olitorius L.	*22270*	Tiliaceae	81%	76%	78%	61%	0%
Bidens sp.	*22258, 22261*	Asteraceae	90%	40%	64%	52%	0%
Ceratotheca triloba (Bernh.) Hook.f.	*22216*	Pedaliaceae	23%	38%	31%	22%	1%
Cleome gynandra L.	*22265*	Cleomaceae	10%	25%	18%	10%	3%
Hibiscus cannabinus L.	*22277*	Malvaceae	25%	1%	13%	1%	3%
Cleome monophylla L.	*22211*	Cleomaceae	0%	9%	4%	3%	0%
Cucumis c.f. *anguria* L.	*22217*	Cucurbitaceae	4%	1%	3%	1%	0%
Jacquemontia tamnifolia (L.) Griseb	*22229*	Convolvulaceae	0%	4%	2%	0%	0%
Portulaca oleracea L.	*22245*	Portulacaceae	0%	4%	2%	0%	0%
Alternanthera sessilis (L.) DC.	*22235*	Amaranthaceae	0%	3%	1%	0%	0%
Commelina benghalensis L.	*22214*	Commelinaceae	0%	3%	1%	0%	0%
Commelina africana L. var. *lancispatha* C.B. Clarke	*22230*	Commelinaceae	0%	3%	1%	0%	0%
Crotalaria c.f. cleomifolia Welw. ex Bak.	*22273*	Fabaceae	3%	0%	1%	1%	0%
Euphorbia oatesii Rolfe	*22276*	Euphorbiaceae	3%	0%	1%	0%	0%
Tithonia diversifolia (Hemsl.) A. Gray	*22215*	Asteraceae	0%	3%	1%	0%	0%
Aerva leucura Moq.	*22248*	Amaranthaceae	1%	0%	1%	0%	0%
Ormocarpum kirkii S. Moore	*22280*	Fabaceae	1%	0%	1%	0%	0%
Sesamum c.f. *angolense* Welw.	*22281*	Pedaliaceae	1%	0%	1%	0%	0%
Solanum nigrum L.	*22219*	Solanaceae	0%	1%	1%	0%	0%
Tribulus sp. L.	*22224*	Zygophyllaceae	0%	1%	1%	0%	0%
Tricliceras longepedunculatum (Mast.) R. Fernandes var. *longepedunculatum*	*22283*	Passifloraceae / Turneraceae	1%	0%	1%	0%	0%
Unidentified Edible Weeds	na	na	9%	25%	17%	8%	1%

Table 2: Edible weeds collected, preserved, and cultivated in the research area

All of the households collected edible weeds from within their fields. Based on arithmetic mean, households gathered 79% of the edible weeds from their agricultural fields, 17% from around the field edges, and 5% outside of their agricultural land (eg. forests, communal lands, and other farmers' fields). The households reported collecting 68% of the available edible weeds. For 26% of the reported weeds, all available plant individuals were harvested, however. The primary reason for not collecting everything available was simply because more was not needed. Households also mentioned not having enough time, plants becoming too mature to be collected, and disliking certain types of edible weeds as reasons for not collecting specific edible weeds. Six households intentionally left edible weeds for regrowth or to allow others to collect them as well.

Edible weeds are eaten for a variety of reasons, such as tradition (52% of 270 respondents), to supplement diets (51%), and taste/preference (46%). Edible weeds are typically used as a relish alongside the main staple food, a hard-maize porridge called nshima (Picture 2). For this, the plants are chopped into thin pieces (Picture 1) and cooked with oil, onion, and sometimes tomato, green pepper, or groundnuts.

Picture 1-4.
Picture 1: Cutting of edible weeds for cooking. Picture 2: Typical dish with nshima (right plate) and a relish (left plate) of different edible weed varieties (Amaranthus sp., Hibiscus cannabinus L. and Impwa). Picture 3: The edible weed "Bondwe" from the leafy Amaranthaceae family being sold in a supermarket in the capital Lusaka. Picture 4: Bondwe sold in a mix with soy pieces.
Source: Authors

Edible weeds were consumed throughout the entire year, but mostly during the rainy season from December to March when the weeds are most abundant (Figure 2). The peak of edible weed consumption corresponds with the "hunger months" when the previous year's harvests have dwindled – typically between November and March. For example, 26% and 28% of the households described their food security situation as bad or very bad in January and February, respectively. In these months, households eat edible weeds 18-22 days per month. According to the respondents, the consumption of edible weeds is of particular importance during food scarcity (87% of respondents).

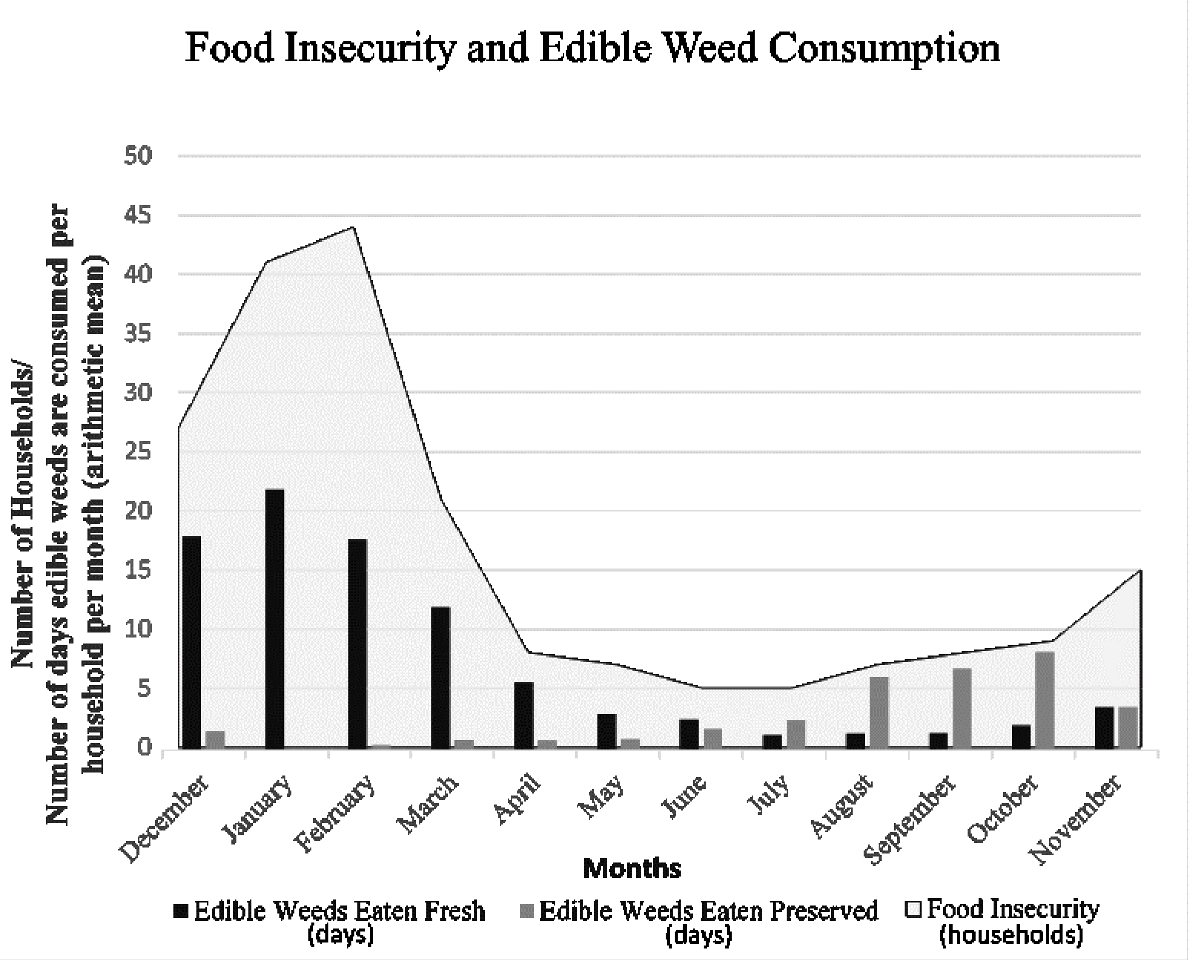

Figure 2: Food insecurity and edible weed consumption.
The line graph represents the number of households that experienced food insecurity per month (n=159). The bar graph shows the arithmetic mean of the number of days that edible weeds were consumed per household in each month either fresh or preserved (n=157).

Edible weeds are mostly eaten fresh but also preserved through drying. This process is done by laying the weeds out in the sun on a tarp so that the weeds can be stored and saved for later use. Some edible weeds, such as *B. pilosa*, *C. gynandra*, *B. schhimperi,* and *C. olitorius* were blanched before drying. Edible weeds were preserved by 137 (87%) of the households, who preserved between one and five different types of plants. Nearly all of the households who preserved edible weeds (99%) did so to ensure food security in the future. Preserved edible weeds were consumed mostly from August to October.

Perceptions of the nutritional value of edible weeds differed widely. In the focus group discussions, some respondents referred to them as “stomach fillers”, while others described them as very nutritious and referred to their health benefits. For example, it was stated that *Amaranthus* sp. can be used to treat anemia. 74% of respondents found edible weeds to have very high or high nutritional value. In contrast, 18% assessed them to have low value or no value at all. The use of edible weeds for food was not commonly viewed as “food for the poor”. Although 21% of the persons responsible for food viewed edible weeds as food for low-income households, 77% opposed this mentality. When asked about the availability of each reported edible weed used over time, the households perceived 38% of all 550 reported edible weeds as more available, 30% as less available, and 32% with no change compared to five years ago. Regarding consumption, 33% of the households consumed more, 39% were eating less and 28% reported consuming certain edible weed species more and others less compared to five years ago.

44% of the households eating fewer weeds attributed this to declining availability, however, they knew little about the reasons for this decline (nine households suggested droughts, one household suggested herbicide use). 34% of households eating fewer edible weeds attributed this to taste reasons or because they preferred other foods. Households eating more edible weeds over time listed a need to supplement diets due to a lack of other food, taste/preferences, and, conversely to those eating fewer edible weeds, having more edible weed plants available as the primary reasons. Households also listed making a dietary change to either increase dietary diversity or increase the level of nutrition in the household.

For 84% of the participants in the household survey, the most important source of information on edible weeds was within the family. In the focus group discussions and the household survey it was stated that, from an early age, children are taken to the field and given instructions on which plants are edible and how they are prepared. According to the result of the survey, the female respondents talked with significantly more people about edible weeds ($r_{pearson} = 0.2147$, $p < 0.000$) and significantly more people asked the female respondents about edible weeds ($r_{pearson} = 0.1321$, $p = 0.03$).

4.2. Use of and perceptions on herbicides in Zambia

On average, households owned 5.3 ha of land, out of which 1.2 ha was left fallow, and 2.8 ha was cultivated (all arithmetic means) (Table 3). The median of the land area owned was 3.6 ha, the median of the land area allowed was 0.5 ha and the median area of land cultivated was 2 ha. The amount of land owned by the farmers is large compared to other smallholder farming setting, however, Zambia is more land-abundant than many other African countries. Households collected edible weeds on 1.8 ha or 54% of the cultivated land. 34% of the sampled households used herbicides for weed control, with an arithmetic mean of 1.7 l/ha (SD=1.4). On average, herbicides were used on 0.75 ha per household translating to 23% of the cultivated fields being sprayed. Herbicide-using households sprayed on average 58% of their fields (arithmetic mean). Households also collected edible weeds on plots that were sprayed with herbicides: on 0.5 ha or 72% of the sprayed fields.

Land use and herbicide application	Arithmetic mean and median per households (n=157)		
	M	SD	Median
Land area owned (ha)	5.3	5.4	3.6
Land area fallowed (ha)	1.2	1.9	0.5
Land area cultivated with crops (ha)	2.8	2.2	2.0
Land area where edible weeds are collected (ha)	1.8	1.6	1.2
Land area where no herbicides are used and no edible weeds are collected (ha)	0.8	1.2	0.4
Land area where herbicides are used (ha)	0.8	1.6	0
Land area where herbicides are used and edible weeds collected (ha)	0.5	1.4	0

Table 3: Land use and herbicide application

52% of the 55 herbicide-using households adopted them less than two years before the study and 83% of the herbicide-using households started using herbicides less than five years before the study, suggesting a trend towards more herbicide use within the study areas (Figure 3). In addition to a growing number of herbicide-using households, the number of herbicide products per household has risen, suggesting that households already using herbicides are adopting multiple products (Figure 3). 73 herbicides were reported by the households, of which 20 could be identified. The most common types were glyphosate as well as atrazine in a mixture with mesotrione, nicosulfuron, or cyanazine and mesotrione.

The majority of the 159 sampled household heads stated that herbicides are easily accessible (62%) and 69% stated that herbicides are more accessible than five years ago. Households showed a high interest in the use of herbicides with 62% wanting to start using herbicides or including more herbicides into their agricultural practices. Among the top reasons for using herbicides were weed pressure and a desire for more effective weed control (mentioned by 95% of households), a reduction of labor (28%), and improving yields (8%).

17% of households were not interested in adopting herbicides or using more, including 10% who were highly opposed to the use of any herbicides. The primary reason for not using herbicides was due to financial reasons (herbicides being viewed as expensive or not affordable to households), which was listed by 60% of 104 households that were not using herbicides. Concerns about the overall health and vitality of the farm including crop, animal, and soil health were mentioned by 9% of the households (n=104). 3% of households explicitly stated that they did not use herbicides because of the effect that it might have on edible weeds (n=104). Additional reasons for not using herbicides were not needing them, health concerns for the household members, and not having sufficient knowledge about herbicides.

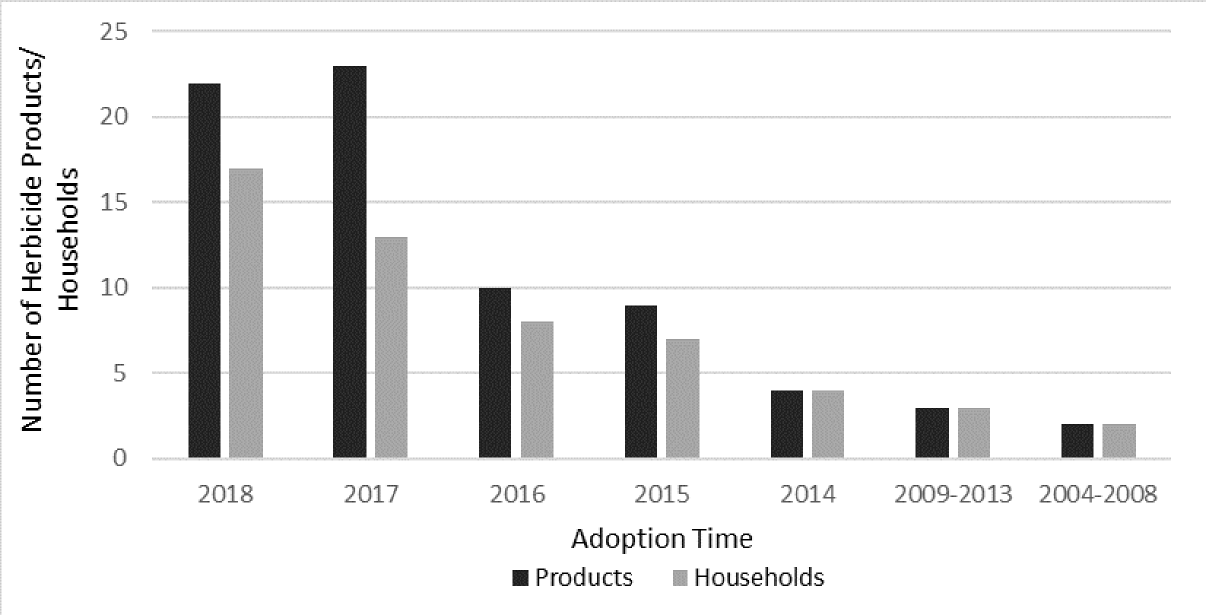

Figure 3: Herbicide adoption over time.
Number of adopted herbicide products (f=73) and number of households adopting herbicides (n=55).

In 68% of 55 households using herbicides, the male head was responsible for the decision to use herbicides (Table 4). However, the person who is responsible for preparing food, including the use of edible weeds, is typically a woman (see 4.1.). In all of the households with a female head where herbicides were used, the female head decided to use them. But only three female heads eventually took on the task of spraying. In households with a male head, it was always a man who took over the task of spraying. The study found a lack of formal information (e.g. from the public extension) on herbicides in the research area. As a result, 53% of all 270 respondents felt inadequately informed about herbicides.

	Person responsible for …		
	… decision to use herbicide	**… preparation of herbicide**	**… application of herbicide**
Male head of the household	68%	74%	74%
Single male-headed household	11%	7%	3%
Single female-headed household	11%	3%	4%
Child of the head	-	5%	10%
Others	10%	11%	9%

Table 4: Decision making and responsibility on herbicide application
(n=55, 100%, f=73 herbicides)

The peak times of herbicide application (Figure 5) overlap with the peak time of edible weed collection (see section 4.1). Herbicide-using households began to spray their fields as early as November but 84% of households applied herbicides in December and 65% in January.

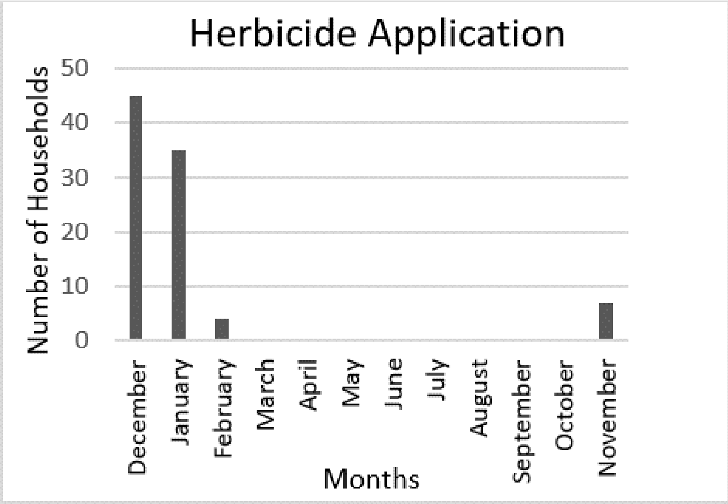

Figure 4. Timing of herbicide application.
The number of households that applied herbicides in each month of the previous farming season (n=55).

Safety concerns arose during the interviews concerning herbicide application. The majority of the 272 respondents perceived herbicides to be potentially hazardous to the health of the person applying them (58%). 89% of respondents agreed that it is important to wear protection when applying herbicides, however, safety procedures were often only followed partly. Among the 96 respondents from the 55 households that applied herbicides, 73% believed that herbicides were potentially harmful. Boots and gloves were the most commonly used protective gears according to the respondents, used respectively by 65% and 60% of the households applying herbicides (n=55). Overalls were worn by 43% of households followed by long pants (41%), long shirts (39%), masks (32%), and eye protection (25%). The integrity of the gear used came into question as some households described fashioning gloves out of plastic bags, and masks out of mosquito nets. As a result, it is uncertain how many respondents who claimed to use protective gear used officially recommended protective gear.

4.3. How does the herbicide revolution affect the use of edible weeds?

To empirically explore trade-offs between the herbicide revolution and the use of edible weeds, table 5 shows the results from ordinary least squares (OLS) regressions with edible weed consumption as a dependent variable and the use of herbicides and other covariates as explanatory variables. In the first model (1), the share of land sprayed with herbicides is used as a proxy for herbicide use. In the second model (2), the years of herbicide use is used as a proxy for herbicide use.

The first model (1) shows that the use of herbicides, indicated by the share of land sprayed with herbicides, is not correlated with the consumption of edible weeds (Table 5). The correlation may not be significant because the overall use of herbicides in the study area is still limited: only 34% of the households used herbicides and these households sprayed on average only 58% of their farmland. Potential trade-offs may therefore not yet be pronounced, as even households using herbicides can still access edible weeds from their non-sprayed plots and from outside their farms. When respondents, including household heads and individuals responsible for food, were asked about the relation between herbicide use and edible weed availability, 46% said that less edible weeds are available because of herbicides, while 26% disagreed. The second model (2) shows that the number of years of herbicide use is negatively correlated with the consumption of edible weeds at the 10% level (Table 5).

Variable	**Edible weed consumption (days per month)**	
	Model (1)	**Model (2)**
Province (Southern)	8.58 (1.91)***	8.83 (1.96)***
Gender (Female)	-1.10 (1.46)	-1.12 (1.46)
Age (Years)	-0.10 (0.08)	-0.10 (0.08)
Total income (ZMK)	-0.00 (0.00)	-0.00 (0.00)
Share of fallow land (%)	1.70 (3.12)	2.26 (3.07)
Share of land herbicides used (%)	-2.02 (2.30)	-
Length of herbicide use (Years)	-	-0.53 (0.29)*
Conservation agriculture (Yes)	-4.31 (1.93)**	-4.65 (2.00)**
Constant	7.88*	8.16*
Observations	*157*	*157*
R-squared	*0.18*	*0.19*

Table 5: Ordinary least squares regression explaining edible weed consumption (average days eaten per month) and herbicide use (n=157)
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Edible weeds are consumed by different types of households, regardless of the gender and age composition, and wealth of the household (Table 5). Households in the Southern Province consume edible weeds significantly more often than households in the Eastern Province. Households practicing conservation agriculture, consume significantly fewer edible weeds. Conservation agriculture aims to minimize soil disturbance and to have a continuous soil cover, which may explain why such households refrain from removing weeds from the field.

5. Discussion and conclusion

This paper has shown that edible weeds are an integral part of the daily diets of the surveyed farm households in Zambia, in particular during the “hunger months”, when last year's harvests dwindle, emphasizing their contribution to food and nutrition security (see also Cruz-Garcia & Price 2012, Maroyi 2013, Hillocks 1998). Edible weeds may play an especially important role for food-insecure regions and the more than 820 million people who are without adequate access to food and nutrition, approximately half of which reside in rural areas (FAO et al. 2020). Sub-Saharan Africa is one of the areas most affected by food insecurity, with over half of the population experiencing moderate to severe food insecurity (FAO et al. 2020).

Edible weeds are consumed by households regardless of wealth, and the age, and gender of the household head, underscoring how embedded they are in the food culture. In both provinces studied, households consumed similar species, in particular *Amaranthus sp. L.*, *Corchorus olitorius L.,* and *Bidens sp.*, but households in the Southern Province consumed edible weeds significantly more often. This may reflect socio-cultural differences, but may also be explained by prolonged droughts, which have affected yields in the Southern Province (IFRC 2019). In this case, edible weeds may buffer against shocks and enhance the household's resilience (Shava et al. 2009).

Although the contribution of wild edible plants to food security is well acknowledged (Badimo et al. 2015, Bharucha & Pretty 2010, Harris & Mohammed 2003, Mavengahama et al. 2013, Ojelel & Kakudidi 2015, Ong & Kim 2017), edible weeds are rarely addressed explicitly. However, edible weeds provide not only calories but also nutrients (Rapoport et al. 1995). This may be of particular importance in countries such as Zambia, where rural diets are heavily centered on maize and contain few nutrient-dense foods such as meat, dairy, and vegetables (Mwanamwenge & Harris 2017). *Amaranthus hybridus*, for example, contains high levels of vitamin A, iron, zinc, and protein, and *Bidens pilosa* is frequently used in Zambia to treat anemia, suggesting a high level of iron (Mofya-Mukuka & Simoloka 2015).

The paper has shown that the herbicide revolution, which is gaining momentum across the developing world (Haggblade et al. 2017), is also unfolding in the study areas in Zambia. While this poses risks to the availability of edible weeds, which are mostly collected on cultivated plots, herbicides do not (yet) seem to affect the consumption of edible weeds when measured as the share of plots being sprayed with herbicides. This is because still few households use herbicides, and herbicides are sprayed only on a fraction of the cultivated land. However, there is some evidence that households using herbicides for longer periods consume fewer edible weeds and many households themselves perceived trade-offs between herbicide use and edible weed availability. Interestingly, close to 50% of the respondents perceived that less edible weeds are available because of herbicides – however, only 3% explicitly stated that they did not use herbicides because of their effect on edible weeds. Given the potential trade-offs between herbicides, edible weeds, and food security, this topic should continue to be carefully monitored. Instead of using cross-sectional data, which is a limitation of this study, future studies may use longitudinal data for this. There is also a need for studies on the potential health effects among households applying herbicides and still collecting edible weeds, which may potentially be contaminated with toxic chemicals.

While households can be expected to be rational decision-makers, decisions on the adoption of herbicides can be associated with various difficult-to-make trade-offs. Herbicides may contribute to higher agricultural production (Haggblade et al. 2017) but their adoption can undermine the consumption of edible weeds, making their overall food and nutrition effects ambiguous. Trade-offs may also occur regarding dietary diversity and seasonality. While the use of herbicides may enhance harvests and thus access to calories, access to micronutrients can be undermined when edible weeds become unavailable, and the additional revenues from increased harvests are not used to buy nutritious food. Moreover, edible weeds may help to buffer food supplies over time, as they mitigate “hunger months”. Manoeuvring between the potential trade-offs between herbicides and edible weeds may be hampered by gender roles: in most households, men decide on herbicide adoption, but women are responsible for food preparation.

Overall, the paper suggests that policymakers and development partners should pay more attention to potential trade-offs concerning food and nutrition security when promoting the use of herbicides. Similar to safeguarding for environmental and human health effects – an aspect that is largely neglected as the limited use of safety equipment in the study areas indicates – policymakers should also safeguard for negative food and nutrition effects. Ultimately, it is a decision of the respective farmers and the societies at a large to which extent they want to use herbicides, but informed decisions should be made acknowledging all potential trade-offs, including those regarding edible weeds and food and nutrition security.

6. References

Addis, G., Urga, K., & Dikasso, D. 2005. Ethnobotanical Study of Edible Wild Plants in Some Selected Districts of Ethiopia. Human Ecology, 33(1), 83-118.

Alemayehu, F., Bendevis, M., Jacobsen, S.E. 2014. The Potential for Utilizing the Seed Crop Amaranth (Amaranthus spp.) in East Africa as an Alternative Crop to Support Food Security and Climate Change Mitigation. Journal of Agronomy and Crop Science. 201.

Antle, J. M., & Pingali, P. L. 1994. Pesticides, productivity, and farmer health: A Philippine case study. American Journal of Agricultural Economics, 76(3), 418-430.

Ayanlade, A., Radeny, M., Morton, J. F., Muchaba, T. 2018. Rainfall variability and drought characteristics in two agro-climatic zones: An assessment of climate change challenges in Africa. Science of the Total Environment. 630. 728-737.

Badimo, D., Lepetu, J., & Teketay, D. 2015. Utilization of edible wild plants and their contribution to household income in Gweta Village, central Botswana. African Journal of Food Science and Technology, 6 (7), 220-228.

Beuchelt, T. D., & Badstue, L. 2013. Gender, nutrition- and climate-smart food production: Opportunities and trade-offs. Food Security, 5(5), 709–721.

Bharucha, Z., & Pretty, J. 2010. The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences, 365 (1554), 2913-2926.

Bonanno, A., Materia, V., Venus, T., and Wesseler, J. 2017. The plant protection products (PPP) sector in the European Union: A special view on herbicides. European Journal of Development Research.

Bonner, M. R. & M. C. R. Alavanja 2017: Pesticides, human health, and food security. Food and Energy Security 6(3).

Chambers, R. 1994. The origins and practice of participatory rural appraisal. World Development, 22(7), 953–969.

Chapota, A., Chisanga, B., & Kabisa, M. 2018. Zambia Agriculture Status Report 2017. Indaba Agricultural Policy Research Institute (IAPRI).

Chapoto, A., Zulu-Mbata, O., Beaver, M., Chisanga, B., Kabwe, S., Kuteya, A. N., … Sitko, N. 2016. Rural Agricultural Livelihoods Survey 2015 Survey Report. (February). Retrieved November 27, 2020, from http://agriprofocus.com/upload/post/RALS_2015_Survey_Report__Finalv-_edited1456827249.pdf

Chase, M. W., Christenhusz, M. J. M., Fay, M. F., Byng, J. W., Judd, W. S., Soltis, D. E., Mabberley, D. J., Sennikov, A. N., Soltis, P. S., Stevens, P. F. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society, 181(1), 1–20.

Crowe, M., & Sheppard, L. 2012. Mind mapping research methods. Qual Quant 46, 1493–1504

Cruz-Garcia, G. S., & Price, L. L. 2012. Weeds as important vegetables for farmers. Ethnobotany of Wild Plants, 81 (4), 397-403.

Cruz-Garcia, G. S., & Price, L. L. 2011. Ethnobotanical investigation of 'wild' food plants used by rice farmers in Kalasin, Northeast Thailand. Journal of Ethnobiology and Ethnomedicine, 7(33).

CSO. 2019. Demographic and Health Survey: Key Indicators Report 2018. Retrieved November 27, 2020, from https://www.zamstats.gov.zm/phocadownload/Demography/ZDHS Key Indicator Report 2018.pdf

Department of Energy Zambia. 2017. Environmental and Social Management Framework: Zambia Electricity Service Access Project. Retrieved November 27, 2020, from http://documents.worldbank.org/curated/en/439551494596125878/pdf/SFG3353-REVISED-EA-P162760-Box402909B-PUBLIC-Disclosed-5-16-2017.pdf

FAO, IFAD, UNICEF, WFP, & WHO. 2019. Transforming food systems for affordable healthy diets. Rome, FAO.

Flora Zambesiaca. Kew, UK. Kew Royal Botanic Gardens.

Gianessi, L. P. 2013. The increasing importance of herbicides in worldwide crop production. – Pest management science, 69(10), 1099-1105. doi:10.1002/ps.3598

Global Nutrition Report 2020. Action on equity to end malnutrition. Bristol, UK: Development Initiatives.

Goeb, J. 2013. Conservation Farming Adoption and Impact Among First Year Adopters in Central Zambia (No. 80). Retrieved from http://www.iapri.org.zmandhttp//www.aec.msu.edu/fs2/zambia/index.htm

Haggblade, S., Smale, M., Thériault, V., & Assima, A. 2017b. Causes and consequences of increasing herbicide use in Mali. The European Journal of Development Research, 29(3), 648-674.

Haggblade, S., Minten, B., Pray, C., Reardon, T. & D. Zilberman 2017. The Herbicide Revolution in Developing Countries: Patterns, Causes, and Implications. – The European Journal of Development Research 29: 533–559.

Harris, F., & Mohammed, S. 2003. Relying on nature: wild foods in northern Nigeria. Journal of the Human Environment, 32(1), 24–29.

Heap, I. 2014. Global perspective of herbicide - resistant weeds. Pest management science, 70(9), 1306-1315.

Hillocks, R. J. 1998. The potential benefits of weeds with reference to smallholder agriculture in Africa. Integrated Pest Management Reviews, 3 (3), 155-167.

IAPRI. 2015. Rural Agricultural Livelihoods Survey: 2015 Survey Report. Indaba Agricultural Policy Research Institute (IAPRI), Lusaka.

IFRC. 2019. Emergency Appeal Zambia: Drought (Food Insecurity). International Federation of Red Cross and Red Crescent Societies, Geneva.

Joala, R., Zamchiya, P., Ntauzai, C., Musole, P., & Katebe, C. 2016. Changing agro-food systems: The impact of big agro-investors on food rights - Case Studies from Mozambique and Zambia. Retrieved November 27, 2020, from http://www.plaas.org.za/plaas-publication/book-agrofood-systems-joala

Kuteya, A. N., Lukama, C., Chapoto, A., & Malata, V. 2016. Lessons Learnt from the Implementation of the E-voucher Pilot Key Points. In Policy Brief Number (Vol. 81). Retrieved from http://www.iapri.org.zmorhttp//www.aec.msu.edu/fs2/zambia/index.htm

Lekberg, Y., Wagner, V., Rummel, A., McLeod, M., & Ramsey, P. W. 2017. Strong indirect herbicide effects on mycorrhizal associations through plant community shifts and secondary invasions. Ecological Applications, 27(8), 2359-2368.

Madamombe-Maduna, I., Vibrans, H., & López-Mata, L. 2008. Diversity of coevolved weeds in smallholder maize fields of Mexico and Zimbabwe. Biodiversity and Conservation 18, 1589–1610.

Maroyi, A. 2013. Use of weeds as traditional vegetables in Shurugwi District, Zimbabwe. Journal of Ethnobiology and Ethnomedicine, 9 (1), 60-70.

Mayer, H. O. 2012. Interview und schriftliche Befragung: Grundlagen und Methoden empirischer Sozialforschung. Walter de Gruyter.

Mofya-Mukuka, R., & Simoloka, A. 2015. Forest Resources for Rural Household Food and Nutrition Security: The Case of Eastern Province of Zambia. IAPRI Working Papers 102. Indaba Agricultural Policy Research Institute, Zambia.

Mofya-Mukuka, R., & Mofu, M. 2016. The Status of Hunger and Malnutrition in Zambia: A Review of Methods and Indicators. Lusaka: IAPRI.

Mavengahama, S., McLachlan, M., & de Clercq, W. 2013. The role of wild vegetable species in household food security in maize based subsistence cropping systems. Food Security, 227-233.

Mwanamwenge, M., & Harris, J. 2017. Agriculture, Food Systems, Diets and Nutrition in Zambia. Discussion Paper: IIED/Hivos.

Narayanasamy, N. 2009. Participatory rural appraisal: Principles, methods and application. SAGE Publications India.

Naylor, R. 1994. Herbicide use in Asian rice production. World Development 22, 1, 55-70.

Nguni, D., & Mwila, G. 2007. Opportunities for Increased Production, Utilization and Income Generation from African Leafy Vegetables in Zambia. African Journal of Food, Agriculture, Nutrition and Development, 7(4), 1–16.

Nyanga, P. H., Johnsen, F. H., & Kalinda, T. H. 2012. Gendered Impacts of Conservation Agriculture and Paradox of Herbicide Use among Smallholder Farmers. International Journal of Technology and Development Studies, 3(1).

Nyaruwata, C. 2019. Contribution of Selected Indigenous Vegetables to Household Income and Food Availability in Wedza District of Zimbabwe. Acta Scientific Agriculture 3(3), 170-188.

Ojelel, S., & Kakudidi, E. K. 2015. Wild edible plant species utilized by a subsistence farming community in Obalanga sub-county, Amuria district, Uganda. Journal of Ethnobiology and Ethnomedicine, 11(1), 7.

Ong, G. H., & Kim, Y. D. 2017. The role of wild edible plants in household food security among transitioning hunter-gatherers: evidence from the Philippines. Food Security, 9 (1), 11-24.

Pingali, P.L. and Marquez, C.B. 1996. Herbicides and rice farmer health: A Philippine study. In R. Nayler (ed.) Herbicides in Asian Rice: Transitions in Weed Management. Los Banos, Philippines: International Rice Research Institute.

Pleasants, J. M., & Oberhauser, K. S. 2013. Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population. Insect Conservation and Diversity, 6(2), 135-144.

Rapoport, E.H., Raffaele, E., Ghermandi, L., & Margutti, L. 1995. Edible weeds: A scarcely used resource. Bulletin of the Ecological Society of America, 76, 163-166.

Rodenburg, J., Johnson, J. M., Dieng, I., Senthilkumar, K., Vandamme, E., Akakpo, C., ... & Bassoro, I. 2019. Status quo of chemical weed control in rice in sub-Saharan Africa. Food Security, 11(1), 69-92.

Seneshaw, T., Minten, B., Alemu, D., & Bachewe, F. 2017. The Rapid Expansion of Herbicide Use in Smallholder Agriculture in Ethiopia: Patterns, Drivers, and Implications. The European Journal of Development Research, 29 (3), 628-647.

Shava, S., O'Donoghue, R., Krasny, M. E., & Zazu, C. 2009. Traditional food crops as a source of community resilience in Zimbabwe. International Journal of African Renaissance Studies, 4(1), 31-48.

Soko, J. J. 2018. Agricultural Pesticide Use in Malawi. Journal of Health and Pollution, 8(20), 181201.

Timmons, F. L. 2005. A History of Weed Control in the United States and Canada. Weed Science, 53 (6), 748-761.

von Grebmer, K., Bernstein, J., Mukerji, R., Patterson, F., Wiemers, R., Chéilleachair, N., Foley, C., Gitter, S., Ekstrom, K., and Fritschel, H. 2019. 2019 Global Hunger Index: The Challenge of Hunger and Climate Change.Bonn: Welthungerhilfe, and Dublin: Concern Worldwide.

Vieyra-Odilon, L., Vibrans, H. 2001. Weeds as crops: The Value of Maize Field Weeds in the Valley of Toluca, Mexico. Economic Botany 55(3), 426-443.

Vorster, I. H., Jansen van Rensburg, W., Van Sijl, B., & Venter, S. L. 2007. The Importance of Traditional Leafy Vegetables in South Africa By. African Journal of Food, Agriculture, Nutrition and, Development.

Williamson, S., Ball, A., & Pretty, J. 2008. Trends in pesticide use and drivers for safer pest management in four African countries. Crop protection, 27(10), 1327-1334.

World Bank. 2020. World Development Indicators. World Bank, Washington. Retrieved July 04, 2020, from https://databank.worldbank.org/reports.aspx?source=world-development-indicators

Social and Institutional Change in Agricultural Development
Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)
Universität Hohenheim
Wollgrasweg 43 | 70599 Stuttgart | Deutschland
T +49 (0)711-459-23517 | **F** +49 (0)711-459-23812
E regina.birner@uni-hohenheim.de | https://490c.uni-hohenheim.de/en