Genet Resour Crop Evol (2016) 63:1397–1409
DOI 10.1007/s10722-015-0327-2

RESEARCH ARTICLE

Agro-biodiversity and challenges of on-farm conservation: the case of plant genetic resources of neglected and underutilized crop species in Ghana

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Received: 31 March 2015 / Accepted: 21 September 2015 / Published online: 7 October 2015

Abstract Neglected and underutilized crop species (NUS) are important genetic resources for nutrition, food security, medicine, management of agricultural risk and income generation for rural communities in Ghana. Little is known about their diversity, farmers' management practices and safety of NUS conserved on-farm while these are prerequisites for developing strategic action plans to ensure their conservation and thus their continued utilization. This study was designed to (1) assess the diversity, forms of consumption and management practices of NUS in Ghana, (2) investigate constraints of on-farm conservation of NUS and the linkage between cultural practices in traditional farming systems and the safety of the NUS conserved on-farm in Ghana. A survey involving 1800 respondents was carried out in nine (9) farming villages of Ghana using participatory research appraisal tools. Seventy-two NUS species were identified on farmers' field. The grouping of these species into major commodity crops suggests high diversity of NUS genetic resources in Ghana which could be used to further enhance nutrition and food security. The high market value of some of the NUS species suggest that they are well known and consumed. Mass use of systemic weedicides by farmers, activities of herdsmen and lack of knowledge on conservation of seeds and tubers are the main factors reported by farmers as the cause of genetic erosion of NUS on their farms. These findings create an urgency to collect and conserve genetic resources of NUS in Ghana to promote their utilization and breeding of improved varieties.

Keywords Agrobiodiversity · Farming systems · Genetic resources · Neglected and underutilized species · On-farm

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Introduction

Globally, approximately 7000 plant species have been used in the history of humanity to meet food needs (Prescott-Allen and Prescott-Allen 1990). Of these cultivated plant species only 30 are considered to be main crops that feed the world. Only 3 major species: rice, wheat and maize supply almost 50 % of our worldwide calory need. Together with six other species (sorghum, pearl millet, potato, sweet potato, soybean, sugarcane and sugar beet), they supply 75 % of the world's energy needs (Padulosi et al. 1999; Magbagbeola et al. 2010; FAO 2010). There are numerous cultivated plant species with exclusively regional or local importance and referred to as minor species, orphan crops or neglected and underutilized species (NUS) (Dansi et al. 2012). The genetic diversity of NUS, landraces and their wild relatives constitutes a very important part of agricultural biodiversity. While their potential may not be fully realized at national level, they are of significant importance locally, being highly adapted to marginal, complex and difficult environments and contributing significantly to diversification and resilience of agro-ecosystems (Padulosi et al. 2011). NUS play a crucial role in the food security, nutrition and income generation of the rural poor (Magbagbeola et al. 2010; Nyadanu et al. 2014a, b). Many neglected and underutilized crop species are nutritionally rich (Padulosi et al. 1999; Johns and Eyzaguirre 2006; Ghane et al. 2010, Dansi et al. 2012; Nyadanu and Lowor 2014). In many rural communities, NUS complement major staples in diets and are a fall-back option if staple crops fail. In marginal environments, where poverty and food insecurity is most prevalent, NUS are often central to farmers' strategies for mitigating climatic change and economic risks (Padulosi et al. 2013). While these crops continue to be maintained by cultural preferences and traditional practices, they remain inadequately characterized and neglected by research and conservation (Dansi et al. 2012). Many NUS have never seen a gene bank. The global genebank system for conserving agricultural biodiversity *ex situ* comprises more than 1740 genebanks and over 7.4 million crop samples (FAO 2010). These collections focus primarily on staple and commodity crops and their wild relatives. Many NUS are poorly represented and Ghana is of no exception (Aboagye et al. 2007, 2010), their conservation and continued evolution largely depends both on their use on-farms and their conservation in healthy wild ecosystems. The alarming decline of NUS genetic resources and the traditional knowledge associated with them has far-reaching implications for the future of agriculture. This decline inhibits natural evolution and adaptation of crop species, reduces future options for breeding improved cultivars and reduces the resilience of agro-ecosystems and their ability to adapt to risks, including climate and emergence of new pests and diseases (Padulosi et al. 2011; Dansi et al. 2012).

In-situ and on-farm conservation of crops and their wild relatives is an important strategy for plant genetic resources conservation. A large number of wild plant species growing in farming environments is consumed or otherwise used by local people worldwide (Shackleton et al. 1998; High and Shackleton 2000; Ogle et al. 2003; Price 2006; Dansi et al. 2008; Msuya et al. 2008; Price and Ogle 2008; Achigan-Dako et al. 2010). These genetic resources embedded in NUS and wild relatives, represent a very important part of the gene pool of domesticated species, which are invaluable to the continued evolution and adaptation of these species. In spite of such efforts, the conservation of NUS and their wild relatives *in situ* and on-farm depends to a large extent on prevailing agricultural production systems for their safety.

Many studies have concentrated on on-farm conservation of NUS (Altieri and Merrick 1987; Einarsson 1994; Morse and McNamara 1994; Hammer et al. 1997; Wood and Lenne 1997; Maxted et al. 2002). However, limited attention has been given to the link between management practices of farmers and safety of conserved species on-farm.

Understanding factors that influence the diversity and management practices of NUS is fundamental to their conservation as well as how individuals make decisions in the management of these resources (Winterhalder and Goland 1997; Hilderbrand 2003). It is also crucial for understanding the dynamics of traditional farming systems and the rationale of farmers in the management of wild food resources (Winterhalder and Goland 1997; Avouhou et al. 2012).

The objectives of this project were therefore to assess the diversity and forms of consumption, and linkage between cultural practices in traditional farming systems and the safety of NUS conserved on-farm in Ghana.

Materials and methods

The study area

The study was conducted in Ghana (Fig. 1) situated in between the latitudes 4° and 12°N and longitudes 4°W and 2°E (Ghana Geographical Association 2012) with a

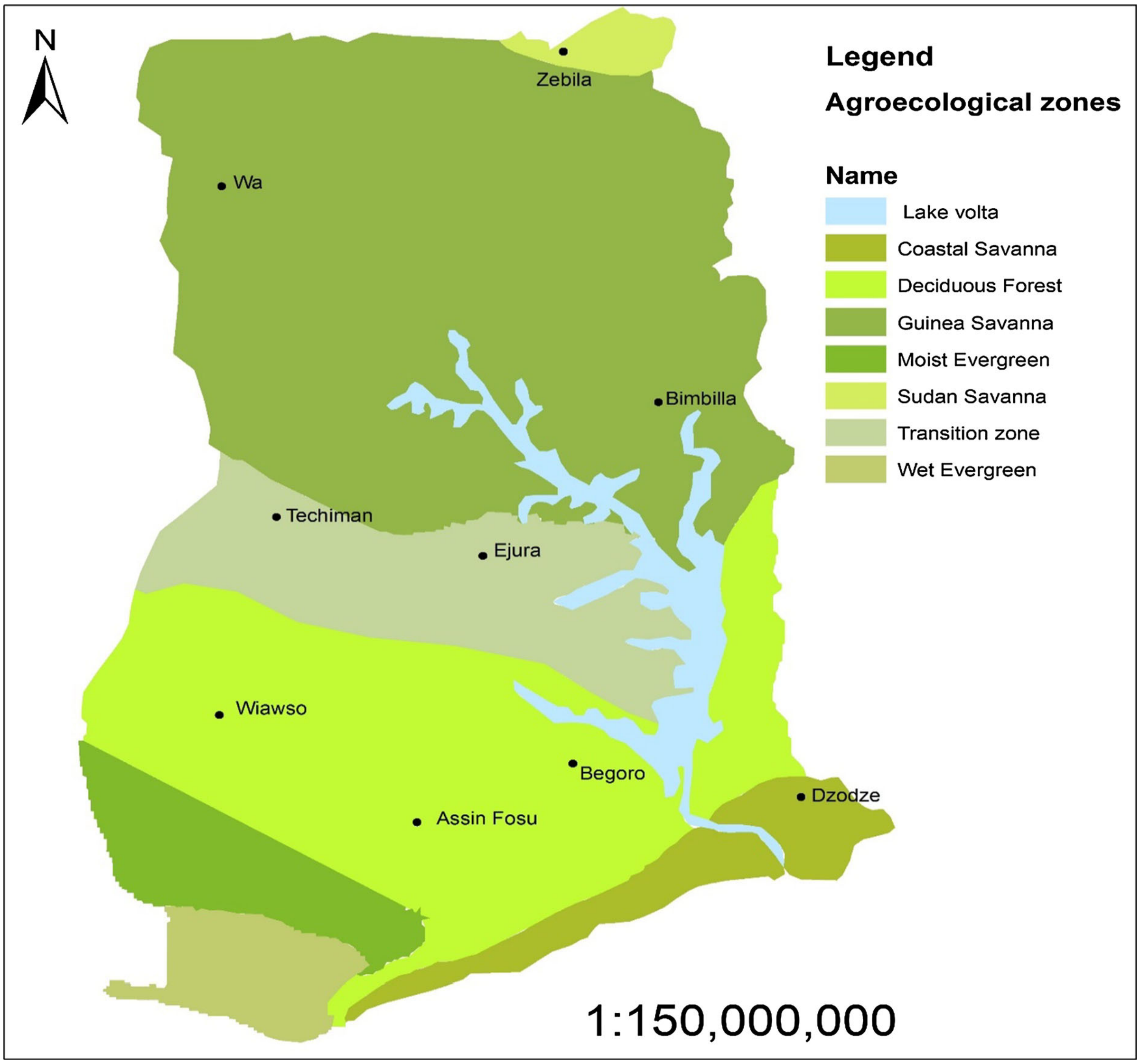

Fig. 1 Ghana map showing the geographical location of the towns surveyed

total land area of 238,535 km^2 and a population of 25.9 million (Ghana Statistical Service 2013), the country is partitioned into 10 administrative regions and several ethnic groups. Rainfall declines from 2100 mm in the south to 1100 mm in the North characterised by unpredictable and irregular rainfall pattern. Mean annual temperatures range from 21 to 28 °C with a relative humidity between 77 and 85 %. The southern and middle belts of the country consist of coastal scrub and grassland, moist semi-deciduous forest, rain forest, strand and mangrove zones vegetation types and the northern parts are made up of Guinea savanna and Sudan savanna vegetation types.

Towns and villages surveyed

Nine (9) farming towns were randomly selected in diverse regions, agro-ecological (coastal, forest, transitional and guinea savanna) zones for survey. These were: Dzodze, Assin Foso, Ejura, Begoro, Bimbilla, Techiman, Wiawso, Wa and Zebila (Fig. 1). Dzodze is located in the coastal zone of Ghana. The ewes are the predominant ethnic group in this area and their occupation is mainly farming. The dominant land use is forests and plantations. Begoro, Wiawso and Assin Foso are located in the forest zone. Many ethnic groups are found in this zone including asantes, akyems, and fantes. The principal occupation of the tribes are farming and trading. Ejura and Techiman are located in the transitional zone of Ghana. The Bonos, Ahafos, asantes and many northern tribes are found in this zone and crop farming and rearing of animals are the major source of their livelihoods. Dominant land use in annual food and cash crops. Bimbilla is found in the Sudan Savanna zone and Wa is found in the guinea savanna zone of Ghana. Dagomba, Dagati, Frafra, Mamprusi, Sisala, Kusasi, are the main tribes in this zone. The major occupation is crop farming and rearing of animals. There is little mechanized farming, but bullock farming is practiced more in this zone than the others. The bimodal rainfall in the coastal, forest and transitional zones give rise to major and minor growing seasons. In the guinea savanna zone, the unimodal distribution of rainfall results in a single growing season. The rainfall determines largely the type of agricultural enterprise in each zone. Figure 1 shows the geographical zones and the towns in which the surveys were carried out.

Data collection and analysis

Data were collected during expeditions from the different towns and villages through the application of Participatory Research Appraisal tools and techniques such as direct observation, individual interviews, focus groups and field visits using a questionnaire (Dansi et al. 2008, 2010). Two hundred (200) randomly selected farmers and agricultural officers were interviewed per town. In the villages, interviews were conducted with the help of translators from the area. Data collected were related to the socioeconomic characteristics including level of education, occupation, mode and size of land acquisition of the respondents. Data was also collected on constraints of on-farm conservation of NUS. Through discussion and visits to major agrochemical shops in the various towns, some key information was recorded on systemic herbicides used in farming systems in Ghana that can contribute to loss of NUS genetic resources. In each town, during the focus groups, the names of NUS species cultivated and consumed were identified, the various management practices used in the village, the market value based on selling prices (low, medium, high). Their forms of consumption, market value and management in traditional farming systems were also documented using individual interviews.

Data were analyzed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different levels.

Results

Socio-economic characteristics of respondents

Except for the Fulani who specialize on rearing animals, crop farming is the main activity in the towns and villages surveyed in this study. More than 70 % of households depend on farming activities as the sole mean of subsistence. Land is generally inherited and farm size ranges from 1 to 100 ha. Maize was the predominant crop followed by cassava, yam, cowpea, groundnut, millets and sorghum. In the northern parts of the country, households generally experience seasonal food shortages during a period of the year such as the beginning of the rainy season when food shortage is most acute as households have exhausted previous year's harvest but the harvest of the new season has not commenced. Gathering and domestication of wild plants are important activities as a source of food supply in these areas. The main system of farming is traditional. The hoe and cutlass are the main farming tools. Most food crop farms are intercropped. After crop harvest all members of the community have the right to graze their livestock on any farmland and grazing land (natural pastures) is communally owned. Women were more involved in cultivation, caring and marketing of NUS species. This was particularly evident in the transitional and guinea savanna zones where women cultivate indigenous vegetables like *Corchorus*, kenaf and *Amaranthus* species among major staple crops cultivated by their husbands. These crops mature early and therefore serve as early source of income for management of home while waiting for the major crops to mature.

Biodiversity of NUS in Ghana

Seventy-two NUS species were identified based on the information gathered from the 1800 respondents. The botanical names, organs and forms of consumption, market value and management practices of the species are summarized in Table 1. Among the 72 crop species, 21 were indigenous vegetables, 8 were root and tuber crops, 7 were cereals, 12 were legumes and 24 were edible wild fruit trees. Within each category of NUS some species, the market value ranges from low to high. The species that have high market value are patronized and eaten in many local dishes. They were often cultivated by the respondents or maintained in their farms during land preparation. However, the species with low market value were not cherished by the respondents and were harvested usually from the wild. Among the indigenous vegetables for instance, *Solanum aethiopicum*, *Solanum nigrum*, *Curcurbita maxima*, *Cucumeropsis edulis*, *Corchorus olitorius*, *Solanum macrocarpon*, *Talinum triangulare*, *Amaranthus cruentus* were of high market value (frequently patronized by consumers). Similarly, *Colocasia esculenta*, *Xanthosoma sagittifolium*, *Ipomoea batatas*, *Dioscorea cayenensis* among the root and tuber crops were of high market value. Among the cereals the most important were *Sorghum bicolor* and *Pennisetum glaucum,* among the legumes it was *Vigna subterranea* and within the fruit tree species *Dialium guineense*, *Irvingea gabonensis*, *Adansonia digitata*, and *Parkia biglobosa* ranked high (Table 1). Figure 2 shows pictures of some of the NUS according to their grouping into commodity crops.

Constraints of conservation of NUS crops

Table 2 shows constraints that farmers encounter in conserving and preserving neglected and underutilized crop species on their farms. The extent of challenges of conserving NUS on-farm varies from one town to another and from one region to another. In general, 12.17 % of farmers mentioned grazing animals as one of the causes of loss of NUS crops in their farms. In terms of individual towns surveyed, Ejura, Zebila and Wa recorded the highest number of respondents for grazing animals as a constraint of conserving genetic resources of NUS on-farm. Invariably, a high number of respondents was recorded for spraying of weedicides inducing loss of genetic resources of NUS in all the towns surveyed in each region representing 68.4 % of total respondents (Table 2). Table 3 shows the commonly used weedicides in Ghana. The active ingredient of most of these weedicides is glyphosate. In traditional farming systems in Ghana where weedicides are not used, useful plants such as cocoyam (*Xanthosoma sagittifolium, Colocasia esculenta*) emerge after clearing the land. Figure 3 shows emergence of cocoyam plant in a farm where systemic weedicides were not used. Other constraints reported by the respondents as challenges of on-farm conservation of underutilized crop species were: limited financial support, lack of knowledge on reproductive biology, lack of technical skills on storage and conservation, inadequate labour and planting materials, inadequate rainfall and seedling viability (Table 2). Among these constraints, lack of knowledge on conservation and storage techniques were reported by a high number of respondents as a challenge to NUS conservation representing 24.3 % of total respondents (Table 2).

Discussion

The use and importance of NUS species vary among the ethnic groups surveyed suggesting the link between NUS species and the food and medicinal culture of the various towns surveyed. The cultural, social and gender context of most NUS is fundamentally different among ethnic groups. Realising the cultural traditions, religious beliefs, the custodians of these crops is important. In many cases it mainly women who care for, cultivate and market NUS. This suggest that in developing value chains for these crops, a gender perspective is critical.

The grouping of these NUS species into major commodity crops suggests high diversity of NUS genetic resources in Ghana which could be used to further enhance nutrition and food security. The mode of consumption of some of the NUS species is as a pot herb and medicinal uses. These findings agree with the results of Keatinge et al. (2011) who reported that alternative strategies based on diverse local food crops can provide a valuable and sustainable complement to other means of tackling malnutrition. Many NUS are rich in micro- and macro-nutrients (Yehouenou et al. 2010; Dansi et al. 2012; Adjatin et al. 2013; Nyadanu and Lowor 2014; Nyadanu et al. 2014a; Nyadanu and

Table 1 Biodiversity of NUS in Ghana, forms of consumption and management practices

Species	Family	Organs/forms of consumption	Market value	Practices
Indigenous vegetables				
Amaranthus cruentus L.	Amaranthaceae	Leaf (vegetable and medicine)	High	rc
Amaranthus hybridus L.	Amaranthaceae	Leaf (vegetable and medicine)	High	rc
Basella alba L.	Basellaceae	Leaf (vegetable and medicine)	Low	rw
Celosia argentea L.	Amaranthaceae	Leaves (vegetable)	Low	rwc
Corchorus olitorius L.	Malvaceae	Leaves (slimy soup)	High	rc
Cleome gynandra L.	Cleomaceae	Leaves (vegetable and medicine)	Low	rw
Cucumeropsis edulis Hook. f.	Curcurbitaceae	Seeds (soups and stews)	High	rc
Curcurbita maxima Duchesne	Curcurbitaceae	Fruits (vegetable)	High	rc
Justicia tenella (Nees) T. Ander.	Acanthaceae	Leaf (vegetable)	Low	wr
Langenaria siceraria (Mol.) St.	Curcurbitaceae	Fruit (young fruit harvested and used as vegetable)	Low	wr
Sechium edule (Jac.) Sw.	Curcurbitaceae	Fruits (vegetable)	Low	wr
Sesamum radiatum Schum. et Thonn.	Pedaliaceae	Leaf (vegetable and medicine)	Low	wrc
Solanum aethiopicum L.	Solanaceae	Fruits (vegetable)	High	c
Solanum macrocarpon L.	Solanaceae	Leaves (vegetable and medicine) fruits (in sauce)	High	rc
Solanum nigrum L.	Solanaceae	Fruits (vegetable)	High	wr
Solanum torvum Swartz	Solanaceae	Fruits (vegetable and medicine)	Medium	wr
Talinum triangulare (Jacq.) Willd.	Talinaceae	Leaf (vegetable and medicine)	High	wr
Telfaria occidentalis Hook. f.	Curcurbitaceae	Leaf (vegetable), seed (vegetable)	Low	wr
Trichosanthes cucumerina L.	Curcurbitaceae	Fruit (vegetable and medicine)	Low	wrc
Vernonia amygdalina Delile	Asteraceae	Leaf (vegetable and medicine)	Low	w
Vitex doniana L.	Lamiaceae	Leaf (vegetable), fruit (eaten fresh)	Medium	wr
Root and tuber crops				
Colocasia esculenta (L.) Schott	Araceae	Leaf (vegetable), tubers (eaten boiled or fried)	High	c
Dioscorea bulbifera L.	Dioscoreaceae	Tubers (eaten boiled)	Low	C
Dioscorea cayenensis Lam.	Dioscoreaceae	Tubers (staple food, eaten boiled)	High	c
Dioscorea dumetorum L.	Dioscoreaceae	Tubers (staple food, eaten boiled)	Low	c
Dioscorea praehensilis L.	Dioscoreaceae	Tubers (staple food, eaten boiled)	Low	c
Ipomea batatas (L.) Lam.	Convolvulaceae	Leaves (vegetable), tubers (eaten boiled)	High	rc
Solenostemon rotundifolius (Poir.) J.K. Morton	Lamiaceae	Tubers and leaves (eaten boiled or fried and medicine)	Low	rc
Xanthosoma sagittifolium (L.) Schott.	Araceae	Leaves (vegetable), tubers (eaten boiled or fried)	High	wrc
Cereals				
Digitaria exilis (Kippist) Stapf	Poaceae	Grains (eaten boiled)	Low	c
Eleusine coracana Gaertn.	Poaceae	Grains (eaten boiled)	Low	c
Eragrotis tef (Zucc.) Trotter	Poaceae	Grains (eaten boiled)	Low	rc
Oryza glaberrima Steud.	Poaceae	Grains (eaten boiled)	Low	wrc
Pennisetum glaucum (L.) R. Br.	Poaceae	Grains (eaten boiled)	High	rc
Setaria italica (L.) P. Beauvois	Poaceae	Grains (eaten boiled)	Low	rc
Sorghum bicolor (L.) Moench	Poaceae	Grains (eaten boiled)	High	rc

Table 1 continued

Species	Family	Organs/forms of consumption	Market value	Practices
Legumes				
Cajanus cajan (L.) Millsp.	Fabaceae	Seed (eaten boiled), leaves (animal fodder)	Low	rc
Canavalia ensiformis (L.) DC.	Fabaceae	Seed (eaten boiled)	Low	rc
Canavalia gladiate (Jacq.) DC.	Fabaceae	Seed (eaten boiled)	Low	rc
Cassia occidentalis L.	Fabaceae	Seed (medicine)	Low	wr
Centrocema pubescens Benth.	Fabaceae	Seed (eaten boiled) and medicine, leaves as fodder)	Low	w
Crotalaria L. spp.	Fabaceae	Seed (eaten boiled and medicine)	Low	w
Macrotyloma geocarpum (Harms) Maréch. et Baud.	Fabaceae	Seed (eaten boiled)	Low	w
Mucuna pruriens (L.) DC.	Fabaceae	Leaves (animal fodder and soil enrichment)	Low	rc
Phaseolus lunatus L.	Fabaceae	Seed (eaten boiled)	Low	rc
Pueraria phaseloides (Roxb.) Benth.	Fabaceae	Seed (eaten boiled)	Low	w
Vigna subterranean (L.) Verdc.	Fabaceae	Seed (eaten boiled)	High	c
Edible wild fruits				
Adansonia digitata L.	Malvaceae	Leaf (vegetable), fruit (commercial juice)	High	wr
Artocarpus altilis (Parkinson) Fosberg	Moraceae	Fruit (eaten fresh)	Low	rw
Borassus aethiopicum Mart.	Arecaceae	Fruit (eaten fresh and boiled with fresh maize)	Low	rw
Chrysophyllym albidum G. Don	Sapotaceae	Fruit (eaten fresh)	Low	rw
Cola millenii Schott et Endl.	Malvaceae	Fruit (eaten fresh and medicine)	High	rw
Dacryodes klaineana Vahl	Burseraceae	Fruit (eaten fresh)	Low	rw
Dialium guineense Willd.	Fabaceae	Fruit (pulp eaten when dry)	High	wrt
Diospyros vignei F. White	Ebenaceae	Fruit (eaten fresh)	Low	rw
Diospyros soubreana F. White	Ebenaceae	Fruit (eaten fresh)	Low	rw
Drypetes chevalieri Vahl	Putranjivaceae	Fruit (eaten fresh)	Low	rw
Irvingea gabonensis (Aubry-Lecomte ex O'Rorke) Baill.	Irvingiaceae	Fruit (eaten fresh)	High	wrc
Heisteria parvifolia Sm.	Olacaceae	Fruit (eaten fresh)	Low	rw
Morinda morindiode L.	Rubiaceae	Fruit (eaten fresh)	Low	rw
Parkia biglobosa (Jacq.) R.B. ex G. Don f.	Fabaceae	Seed (condiment), fruit (pulp eaten fresh and drinks)	High	rw
Salacia cornifolia Hook. f.	Celastraceae	Fruit (eaten fresh)	Low	rw
Sclerocarya birrea (A. Rich.) Hochst.	Anacadiaceae	Fruit (eaten fresh)	Low	rw
Synsepalum dulcificum (Schumacher et Thonn.) Daniell.	Sapotaceae	Fruit (eaten fresh)	Low	rw
Uvaria chamae P. Beauv.	Annonaceae	Fruit (eaten fresh)	Low	rw
Ximenia americana L.	Olacaceae	Fruit (eaten fresh)	Low	rw

Observed management practices: *w* gathered from the wild, *r* retained on-farm when weeding, *t* transplanted from the wild, *c* cultivated

Aboagye 2014) and could therefore be used to reduce the "hidden hunger" which leads to poor health conditions for millions of Africans (Saka and Msonthi 1994; Saka et al. 2007). For example, around 50 million African children are at risk of vitamin A deficiency, the continent's third greatest public health concern after HIV/AIDS and Malaria (Aguago and Baker 2005; Black et al. 2008). Many small-scale farmers make use of the plant diversity present in their surroundings. This includes use for home

Fig. 2 Pictures of some selected NUS grouped according to their commodity groups Indigenous vegetables: **a** *Amaranthus* species (*Amaranthus cruentus*); **b** Turkey berry (*Solanum torvum*) Root and tuber crops: **c** frafra potatto (*Solenostemon rotundifolius* Pair); **d** Cocoyam (*Xanthosoma saggittifolium*). Cereals; Legumes, **e** pigeon pea (*Cajanus cajan* (L.) Millsp.); **f** Bambara groundnut *Vigna subterranean* (L.) Verdc.); **g** Fonio (*Digitaria exilis*); **h** Sorghum (*Sorghum bicolor*) Edible wild fruits; **i** African locust bean (*Parkia biglobosa*); **j** African black velvet tamarind (*Dialium guineense*)

Table 2 Variability and importance across surveyed villages of NUS; on-farm conservation constraints identified in Ghana

No.	Constraints	Village surveyed (number of responses)									% of responses
		Dzodze	Assin Fosu	Ejura	Begoro	Bimbilla	Techiman	Wiawso	Wa	Zebila	
1	Grazing animals and fire caused by herdsmen	12	21	46	17	21	16	9	32	45	12.2
2	Spraying of weedicides	159	172	143	193	102	164	128	95	75	68.4
3	Lack of cash	43	11	8	26	18	22	17	32	48	12.5
4	Lack of knowledge on reproductive biology	5	13	18	27	15	11	25	16	2	7.3
5	Lack of knowledge on preservation and storage techniques	33	26	54	29	48	89	49	67	43	24.3
6	Lack of labour	11	27	8	19	26	17	18	25	18	9.4
7	Lack of seeds and planting materials	28	41	2	17	19	13	11	7	17	8.6
8	Lack of water	17	27	18	11	32	26	15	22	25	10.7
9	Land	32	27	17	35	19	11	9	11	16	9.8
10	Seedling mortality and survival	32	17	22	11	17	18	22	25	21	10.3
11	Cutting of forests	5	9	11	19	2	17	20	4	15	5.7

consumption, as dietary sources during crises, provision of medicines, as well as provision of additional sources of income through road side and local market sales.

The high market value of some of the NUS species suggests that, they are well-known and consumed. However, the observation of low market value for many NUS species in this study indicates that their potential value has not been recognized by many consumers. Many of them are noted as part of cultural food of some ethnic groups in Ghana and were considered to be old-fashioned and unattractive in comparison to modern crops. Similar findings were reported by Quaye et al. (2009) who indicated preference and marketability of traditional leafy vegetables (TLVs) in Ghana. Different ethnic groups specialize in the sale of TLVs that are highly marketable in their respective communities. There is a need to promote their utilization and upgrade their value chains in order to make them acceptable and known to all consumers.

In general, majority of these NUS species are in the wild and farmers retain them during cultivation of their lands. Many of these NUS species have not been conserved *ex situ* making them vulnerable to genetic erosion that will hamper domestication and breeding, and their evolution could be affected. Biodiversity of crop species holds the key to adapting to climate change through the collecting and conservation of germplasm or the breeding of new cultivars that can withstand biotic and abiotic stresses.

The variation in constraints of on-farm conservation of NUS species across the towns surveyed suggest differences in management practices in these zones. The coastal and forest zones use slash and burn as a cultural practice in land preparation and therefore bush burning was predominant. Likewise farmers in the savanna and transitional zones rear cattle and use bullocks in farming and therefore the high number of respondents in Ejura who stated grazing as a constraint to conservation of NUS species on-farm was expected as large number of herdsmen or cattle are reared in these areas in Ghana. This finding highlights the need to regulate activities of nomadic herdsmen in Ghana. Tonah (2006) also reported that activities of herdsmen cause loss of crops and worsened farmer-herder relationship in the Volta basin of Ghana. Okoli and Atelhe (2014), Ofem and Bassey (2014), de Haan (2002), Ingawa et al. (1999) also reported similar findings in Nigeria. Furthermore, susceptibility of farmers' fields to erosion (land degradation) which occurs as a result of grazing by animals of herdsmen lead to crop loss.

Table 3 Herbicides commonly used in Ghana

Herbicide-trade name	Active ingredient	Mode of action
Tackle®	360 g/glyphosate	S
Rival®	360/glyphosate/L	S
Frankosate	41 % glyphosate in the form of 480 g/L isopropylamine salt	S
Conti-quat 24 SL gramozone	24 g paraquat Dichloride per Litre soluble concentrate	NS
Superb 2,4-D Amine salt	720 g/L	S
Adwuma Wura	480 g/glyphosate/L in the form of 480 g/L isopropylamine salt	S
Sarosate®	360 g/L glyphosate in the form of 480 g/L	S
Kum Nwura	41 % glyphosate/L in the form of 480 g/L	S
Rendo	Isopropylamine salt of N-phosphono Methyl), glycine(Glyphosate)	S
Glyphader 480	480 g/L isoprolamine salt of Glyphosate	S
Propacal Plus 560EC	360 g propanil and 200 g 2,4D isobutylate/L	S
Weedout®	41 % glyphosate/litre in the form of 480 g/litre isopropylamine salt	S
Orizo plus	360 g propanil and 200 g 2,4-D/L	S
Alligator 400EC	Pendimethaline 400 g/L	S
Sunphosate 360SL (Glyphosate)	360 g glyphosate/L in the form of 480 g/L isopropylamine salt of soluble liquids	S
Adom 480SL	480 g/L glyphosate/L in the form of 480 g/L Isopropylamine salt	S
NicoGan 40 (OD)	Nicosulfuron 40 g/L	S
Nico Plus Nicosulfuran 40 OD	40 g/L micosulfuran as an oil based Dispersin concentrate	S
San-2.4D Amine	720 g of Dimethyl Lamine salt of 2.4 Dichlorophenoxy acetate/L	S
Terbulor 500 EC	333 g/L of metolachlor 167 g/L of Terbytryn	S

S systemic, *NS* non-systemic

Fig. 3 A traditional farming system where no weedicides were used. *Arrow indicates* the cocoyam plants which were not intentionally planted

The high percentage for spraying of weedicides as a constraint in all the towns surveyed suggest that use of weedicides is currently a predominant cultural practice in farming systems in Ghana.

Farmers in their quest to increase size of farm lands, use systemic weedicides to control weeds. Most of the weedicides used are non-selective and are systemic. Systemic chemicals kill NUS and their seed banks in the soil and therefore causes genetic erosion of these species. Glyphosate which is the active ingredient of most of these weedicides inhibits enzyme action in the synthesis of amino acids and translocation to growth points. The suicidal effect of these weedicides on on-farm conservation of NUS is evidenced by lack of sprouting of useful plants like cocoyam, taro and other indigenous vegetables after land clearing in farming systems where these chemicals are being used. The lack of training on improved methods of conservation expressed by respondents suggests the need to train farmers on improved methods on conserving genetic resources of NUS in Ghana. Central to these issues is the recognition that if crop genetic resources of NUS are to be conserved successfully and sustainably on-farm, such an outcome should be the result of farmers' production activities directed to improve their livelihood (conservation through use). This means that on-farm conservation efforts must be carried out within the framework of farmers' livelihood needs (Sthapit et al. 2010). Depending upon available resources and government commitment, selection of on-farm conservation sites should identify least cost conservation sites that are ranked in terms of richness of genetic diversity and where the private benefit that farmers obtain from growing genetically diverse varieties is the greatest. The crop genetic resources which have both low farmer utility and public value will be difficult to conserve on-farm. This finding is in agreement with reports of Hay and Probert (2013) who stated that in order to ensure effective on-farm conservation of crops, it is important to motivate and train farmers on techniques of handling recalcitrant seeds and ensuring safety of seeds. Farmers' ability to manage NUS species on-farm will be strengthened if the research and development institutions can build upon the traditional knowledge and practices of farmer seed and germplasm management systems. This requires strengthening their social seed networks and policy supports that promote farmer-to-farmer seed exchange systems. Over recent years, advances have been made in understanding the seed ageing process, that is, the reactions that take place within the seeds leading to decline in vigour and eventual loss of ability to germinate. Much of the damage that accumulates in seeds during storage is attributed to oxidation by reactive species (Hendry 1993; Bailly 2004; Kranner et al. 2010). Longevity of seeds depends on temperature and moisture relationship (Gold 2008; Hay et al. 2008). Most peasant farmers use indigenous methods like storing of seeds in cloths and other traditional materials which causes the seeds to lose viability easily. Bennett-Lartey and Oteng-Yeboah (2008) also reported lack of skilled personell as one of the main constraints of conserving genetic resources of crops in Ghana.

Conclusion

This study revealed that there is a great biodiversity of NUS grown or cultivated in Ghana and conserved in farmers' fields. These species contribute to nutrition, food security, medicine and income generation of the rural poor. Unfortunately many NUS cannot be found in gene banks leading to continuous loss of their genetic resources. Mass use of systemic weedicides by farmers, activities of herdsmen and lack of knowledge of conservation of seeds and tubers of NUS are the main factors reported by farmers as the cause of genetic erosion of NUS on their farms. These findings create an impetus/stimulus to collect genetic resources of NUS in Ghana, conserve them *ex situ* and to characterize and evaluate them to enhance their utilization and genetic improvement.

Acknowledgments We express our sincere thanks and gratitude to all farmers, agricultural officers and students of College of Agriculture Education, University of Education, Winneba who provided information and assisted during the survey.

Compliance with ethical standards

Conflict of interest This research article is an account of our own research and has not been published elsewhere. Work of other researchers which served as references has been duly acknowledged.

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