NATIONAL STRATEGIC ACTION PLAN FOR THE CONSERVATION AND SUSTAINABLE USE OF CROP WILD RELATIVES IN ZAMBIA – TECHNICAL BACKGROUND DOCUMENT

ZARI
Researching Soils, Crops and Water in Zambia

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LIST OF ACRONYMS

BCN	Biodiversity Community Network
CGIAR	Consultative Group for International Agricultural Research
CR	Critically Endangered
CSO	Central Statistics Office
CTDT	Community Technology Development Trust
CWR	Crop Wild Relative
EN	Endangered
FAO	Food and Agriculture Organization
GP	Gene Pool
ITPGRFA	International Treaty on Plant Genetic Resoources for Food and Agriculture
IUCN	International Union for Conservation of Nature
MAFF	Ministry of Agriculture, Food and Fisheries
MAL	Ministry of Agriculture amd Livestock
NPGRCs	National Plant Genetic Resources Centres
NSAP	National Strategic Action Plan
NT	Near Threatened
SADC	Southern Africa Development Community
SADC CWR	Southern Africa Development Community Crop Wild Relative Project
SDIS	SADC Documentation and Information System
SPGRC	SADC Plant Genetic Resources Centre
TG	Taxonomic Group
UNZA	University of Zambia
USDA	United State Department of Agriculture
VU	Vulnerable
ZARI	Zambia Agriculture Research Institute
ZAWA	Zambia Wildlife Authority

GOALS AND SPECIFIC OBJECTIVES OF THE NATIONAL STRATEGIC ACTION PLAN

The goal of the NSAP is to conserve and sustainable use of CWR to ensure their protection and guarantee their availability for use as a contribution to national food security and nutrition.

The objectives are:

I. To establish a network of active *in situ* conservation sites, to conserve the priority CWR taxa in the country.
II. Formulation and implementation of complementary *ex situ* conservation of CWR taxa;
III. Promotion of the sustainable use of CWR taxa.

The NSAP will establish better communication and coordination between various institutes and organizations engaged in *in situ* and *ex situ* conservation and land use management, at national, regional, and global levels.

1 NATIONAL CWR CHECKLIST

1.1 Type of CWR checklist

Two approaches namely, (i) the global and (ii) the national, were used for the generation of the Zambian checklist of Crop Wild Relatives (CWRs). Using the global approach, a list comprising 6914 genera extracted from Mansfeld's World Database of Agricultural and Horticultural Crops (Hanelt and IPK Gatersleben, 2001; IPK Gatersleben, 2003), which includes all types of cultivated taxa except for forestry and ornamental species, was obtained from the '*Crop and crop genus list for national CWR checklists and checklist prioritization'* prepared for the SADC CWR project (Kell unpublished). This list includes both accepted names and synonyms. This list of genera was matched with the genera in the checklist of Zambian vascular plants (Phiri, 2005) and the taxa within the matching genera were selected, resulting in a checklist of 3671 CWR taxa.

Using the global approach, a complete national checklist was generated. However, the national approach was used instead which, resulted in the development of a partial checklist of CWR taxa. The national checklist was produced after a first step of prioritizing the crops. This partial checklist was then further prioritized in order to obtain the priority CWR. The resulting list of priority CWR taxa was used for gathering occurrence data which subsequently formed the basis for carrying out spatial

analyses. The outputs arising from spatial analyses formed the basis of the selection of hotspot sites for consideration in the conservation and use of priority CWR taxa in the country.

1.2 Data sources to produce the CWR checklist

1.2.1 National flora checklist

The taxonomic backbone for the development of the national checklist of CWR was the checklist of Zambian vascular plants (Phiri, 2005). This national flora checklist was firstly digitized in order to be able to manipulate it and subsequently enable the matching of the digitized list with the crop genera. The national flora checklist consisted of a total of 6305 taxa.

1.2.2 List of crops or crop genera

The crops considered and described are those used to generate the national checklist of CWR using the national approach.

The list of national crops used in the generation of the checklist of CWR includes the Zambia Seed Technology Handbook developed by the Ministry of Agriculture, Food and Fisheries (MAFF, 1995), the database of Zambian National Plant Genetic Resources Centre and the Central Statistics Office (CSO) /Ministry of Agriculture and Livestock (MAL) Crop survey reports for the period from 2009 - 2014. The compilation generated a total of 107 crop taxa in 64 genera that are cultivated in Zambia.

The list of 107 compiled crops was subjected to the national stakeholders representing key national institutions for endorsement during the stakeholders' meeting held from 14-15 October 2014. The institutions represented during the stakeholders' meeting were Department of National Parks and Wildlife formerly Zambia Wildlife Authority (ZAWA), the University of Zambia (UNZA), Community Technology Development Trust (CTDT), Biodiversity Community Network (BCN) and the Zambia Agriculture Research Institute (ZARI). The list of compiled national crops was then prioritized by stakeholders based on three criteria, namely and by order of importance: (i) national socio-economic importance of the crops based on crop production and marketing statistics from the CSO/MAL Crop Survey Reports (2009-2014) and their importance for food security and industrial use through knowledge of key national experts involved in the process of prioritization of the national crops; (ii) the local cultural and use value of a particular crop including food and medicinal use values, and (iii) knowledge of occurrence of crop wild relatives in the country. Although some of the crops could not qualify based on the first criterion, they were included on the priority list because of their high cultural and use values in particular local communities and their potential to become of national socio-

economic importance in future. The agreement on the priority crops was reached upon by consensus among the experts attending the stakeholders' meeting. Based on this process a total of 59 priority crops belonging to 29 genera were finally selected and these are the crops that were subsequently used for the generation of the checklist of CWR. These crops included cereal, food legumes, vegetable, root and tuber, oil, fibre, pasture and forage and green manure crops. This list of crops includes both those that are native to Zambia and those that are introduced. Some of the crops on the priority list, such as maize (*Zea mays* L.), rice (*Oryza sativa* L.) and sorghum (*Sorghum bicolor* L.) for cereals, cowpea [*Vigna unguiculata* (L) Walp], and common bean (*Phaseolus vulgaris* L.) for food legumes, and cassava (*Manihot esculanta* L.) and sweet potato (*Ipomoea batatas*), are amongst the globally food security crops as reflected in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) from FAO (2001) and regional important crops as outlined in the Southern African Development Community Regional Agricultural Policy (SADC, 2013) and Southern African Development Community Agricultural Development Plans.

1.3 Generation of the national CWR checklist

The method used to generate the checklist of CWR is that of matching the genera of cultivated crops with the genera of the national flora (Phiri, 2005) in Microsoft Excel. Using this process, the generated list of 29 crop genera was matched with the genera in the digitized checklist of 6305 Zambian vascular plants and the taxa with the matching genera were selected. A total of 459 flora actually matched the crop genera and therefore it is these constituted a partial national CWR checklist. The generated CWR checklist was validated through broad national stakeholder consultation meeting that was held on 6 August 2015. The national stakeholders' that participated at this consultation meeting were from the University of Zambia (UNZA), Agriculture Consultative Forum, National Agricultural Information Services, Zambia Wildlife Authority, Department of Policy and Planning, Department of Forestry, Community Technology Development Trust, Biodiversiy Community Network, Ministry of Lands, Environmental Protection and Natural Resources, WorldFish Centre and Zambia Agriculture Research Institute representing policy makers, researchers, media, breeders and advocacy. There are plans to make the generated CWR checklist available online both on the national (www.zari.gov.zm) and regional (http://www.spgrc.org.zm/) websites.

1.4 Information documentation

In order to allow management and ease retrieval and manipulation of the priority CWR data, a database was created in Microsoft Excel.

1.5 CWR checklist and overview

On the basis of the prioritized 29 genera of cultivated crops and 6305 national flora, a total of 459 CWR taxa were generated (Appendix 1). The summary of the list of CWR genera and number of taxa generated for each genus, the associated common crop and the use value is provided (Table 1). These CWR taxa are divided into 12 families namely, Amaranthaceae, Asteraceae, Capparaceae, Convolvulaceae, Cucurbitaceae, Dioscoreaceae, Fabaceae, Lamiaceae, Malvaceae, Pedaliaceae, Poaceae and Solanaceae. Of these families, the main ones being Poaceae with 6 genera, Fabaceae with 4 genera and Cucurbitaceae with 3 genera. Out of the total CWR generated and according to Phiri (2005), 27 CWR taxa including mainly *Crotalaria* spp were endemic to Zambia representing about 6% of the total CWR taxa. A total of 139 CWR taxa, of which 30% have narrow distribution to the southern Africa and some of these are native to Zambia.

Table 1. List of Zambian CWR genera and number of taxa generated upon matching with selected crop genera with information on associated families, common crop and its use value. The list is organized according to alphabetical order of the CWR genus name.

Family	CWR genus	Number of CWR Taxa	Common crop	Use value
Amaranthaceae	*Amaranthus*	8	Amaranths	Human food
Poaceae	*Chloris*	2	Rhodes grass	Livestock fodder
Capparaceae	*Cleome*	5	Cats wiskers	Human food
Tiliaceae	*Corchorus*	9	Jute mallow	Human food
Fabaceae	*Crotalaria*	159	Sunnhemp	Human food
Cucurbitaceae	*Cucumis*	9	Melon, Cucumber,West Indian Gherkin	Human food
Dioscoreaceae	*Dioscorea*	16	Yam	Human food
Poaceae	*Eleusine*	2	Finger millet	Human food
Malvaceae	*Hibiscus*	34	False Roselle, Kenaf	Human food, Fibre
Convolvulaceae	*Ipomoea*	67	Sweet potato	Human food
Asteraceae	*Lactuca*	12	Lettuce	Human food
Cucurbitaceae	*Lagenaria*	3	Bitter gourd	Herbal medicine
Cucurbitaceae	*Momordica*	8	Momordica	Human food
Fabaceae	*Mucuna*	5	Velvet beans	Soil fertility improvement
Poaceae	*Oryza*	5	Rice	Human food
Poaceae	*Pennisetum*	10	Pearl millet	Human food
Lamiaceae	*Plectranthus*	29	Livingstone Potato	Human food
Pedaliaceae	*Sesamum*	6	Sesame	Human food
Fabaceae	*Sesbania*	11	Sesbania	Soil fertility improvement
Solanaceae	*Solanum*	14	African eggplant, Eggplant, Potato	Human food
Poaceae	*Sorghastrum*	6	Sorghum	Human food
Poaceae	*Sorghum*	4	Sorghum	Human food
Fabaceae	*Vigna*	35	Cowpea, Bambara groundnuts	Human food

2 PRIORITIZING THE CWR CHECKLIST

2.1 Prioritization criteria and process

Prioritization of CWR taxa for consideration in the development of the National Strategic Action Plan for their conservation were based on four criteria used the combination namely i) relative geographical distribution; ii) utilization potential for crop improvement i.e. gene pool and taxon group information; iii) Red List status; and iv) economic value of the associated crop species. The most common used prioritization concept, the gene pool (GP) concept (Harlan and de Wet, 1971) was largely used. As one of the prioritization criteria, data on red list status for each taxon was sourced from Bingham and Smith, 2002). The 1994 version of the IUCN Red List categories and criteria (IUCN 1994) were applied when compiling the regional plant red list data for the CWR taxa under consideration. The various other sets of data were compiled from various sources, including literature surveys and online databases (Crop Wild Relatives and Climate Change, 2013; Tropicos, 2011; USDA, 2011).

The process of prioritization of the generated CWR checklist entailed selection of a set criteria for prioritization of CWR taxa which was followed by compilation of data related to these criteria which included geographical distribution, potential for crop improvement (via gene pool and taxon group concepts), red list data and use value of the associated crop species for each taxon. Each taxon was assigned a score for each criterion as described and given in the document below and the sum of the scores used to assign the level of priority. For instance, a CWR species that is highly threatened due to its limited distribution (at country level) or crosses with ease with the cultigen was assigned a relatively higher score than the less threatened taxa and those in the tertiary gene pool. Thus, CWR species that were assigned the highest scores assumed a high priority status due to being threatened or considered highly important for food security and as such are considered high priorities for conservation action at the national scale.

(i) Relative distribution of crop wild relative

The CWR species were categorized based on whether they are endemic to Zambia, endemic to the SADC region, endemic to Africa, or cosmopolitan (i.e., found elsewhere in the world). The categories for relative distribution of priority CWR were scored as in Table 2. The CWR species that were known to be endemic to Zambia were assigned the highest score, followed by the species that were endemic to SADC region. However, those CWR taxa with wide occurrence at or near the global level were assigned the lowest score because due to their wide geographic distribution they were not threatened.

Table 2. Assignment of scores to categories on relative distribution of CWR

Distribution category	Assigned score
Country (endemic to Zambia)	4
SADC region (endemic to SADC region)	3
Africa (endemic to Africa)	2
World (cosmopolitan i.e. also found elsewhere in the world)	1

(ii) Utilization potential for crop improvement

Utilization potential for crop improvement is related to the ease of crossability with the related crop or potential use in crop improvement programmes. The Gene Pool (GP) concept (Harlan and de Wet, 1971) and the Taxon Group (TG) concept (Maxted et al., 2006), where each of these concepts were available, were used to define CWR utilization potential. The GP Concept categorizes CWR taxa based on their degree of relationship to and ease of crossing with the related crop species (Maxted et al., 2006). Based on GP concept, the checklist CWR taxa were assigned the following categories: primary (GP1b), wild or weedy forms of the crop that cross easily with the crop; secondary GP (GP2), less closely related species from which gene transfer to the crop is possible but difficult using conventional breeding techniques and tertiary GP (GP3), species from which gene transfer to the crop is impossible, or if possible, requires sophisticated techniques, such as embryo rescue, somatic fusion and genetic engineering. This information was sourced from the Harlan and de Wet Inventory (Vincent et al., 2013 and http://www.cwrdiversity.org/) and GRIN Taxonomy for Plants (http://www.ars-grin.gov/~sbmljw/cgi-bin/taxcwr.pl). The Taxon Group concept employs taxonomic hierarchy as a proxy for taxon genetic relatedness and thus potential crossability (Maxted et al., 2006). The CWR species that lacked this information were assigned the category 'unknown'. The scores assigned to the gene pool/taxon group categories are shown in Table 3.

Table 3. Scoring process of the Gene pool/Taxon group categories of the CWR taxa

Gene pool/Taxon Group category	Assigned score
Primary (GP1/TG1)	9
Secondary (GP2/TG2)	7
Tertiary (GP3/TG3)	3
Unknown	1

It should be noted that the assignment of scores to each of the categories took into account the closeness of the CWR to the cultivated crop. The ease of crossability of the plant species (CWR) to the cultivated crop as the case for those belonging to Primary GP (GP1), on one hand, were assigned the highest score of 9 because of their close biological relationship with the cultivated crops, gene transfer (crossability) from CWR to crop is possible without use of sophisticated techniques. GP3 (tertiary GP) plant species, on the other hand, were assigned a lower score of 3 owing to the fact that gene transfer to the crop is most difficult and generally possible by using sophisticated techniques such as embryo rescue, somatic fusion or genetic engineering. Alternatively, the taxonomic proximity where the TG concept could apply. In this case, TG1 taxa were more closely related to the cultivated crop than TG3 and therefore would be assigned comparatively a higher score.

(iii) IUCN Red List categories

The categories and criteria used in informing the red list status were the 1994 IUCN Red List Categories and Criteria. The 1994 categories of the red list status included: EX, EW, CR, EN, VU, LR-cd, LR-nt, LR-lc, DD, NE. In compiling the Red List category information in relation with the generated priority CWR, reference was made to the categorization according to Bingham and Smith (2002). In this regard, it should be noted that most of the taxa have been assessed at regional and global levels and none at national level. In part, this may explain the reason for most of the priority taxa generated being assigned the Not Evaluated category. The assignment of the scores for the red list status of priority CWR is as indicated in Table 4. It should be noted that species that are Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) categories were assigned with the high and equal score of 5 because according to (IUCN Red List Category and criteria, 2002) species that are assigned these categories are considered threatened. The Near Threatened (NT) category was assigned the score of 4. The Least Concerned (LC) and Lower Risk – Least Concern (LR-LC) categories were assigned the score of 3 and finally the Data Deficient (DD) and Not Evaluated (NE) categories were assigned the lowest

score of 1. Although the Red List categories of DD and NE are assigned low scores, this may not imply that the taxa falling under these categories are not priority for conservation. It is for instance necessary to undertake assessment on these taxa in order to establish their conservation status.

Table 4. Scoring process of the Red List categories of the CWR

Red List category	**Assigned score**
CR (Critically Endangered)	5
EN (Endangered)	5
VU (Vulnerable)	5
Near Threatened (NT)	4
LC (Least Concern)	3
LR-Lc (Lower Risk-Least Concern)	3
DD (Data Deficient)	1
NE (Not Evaluated)	1

(iv) Economic use value of associated crop species

The use category of the crop species associated with each priority CWR taxon in the checklist was used to assign indirect socio-economic value to the checklist taxa. Six economic use value categories were used and defined as follows: (i) human food; (ii) livestock fodder; (iii) soil fertility improvement; (iv) herbal medicinal; (v) fibre and (vi) utensils (Table 5). The assignment of scores provided a relative importance of the use value category with the higher score indicating a greater economic value of the taxon. In this regard, the use value category of human food was assigned the highest score because these priority CWR taxa contributed significantly as they were related to human food security which perhaps stand as a priority objective in national, regional and global human development policies and programmes. The use value categories of livestock fodder and soil fertility improvement follow in terms of assignment of scores as they are mutually supporting components, significantly contributing to sustainable agriculture.

Table 5. Categories and scores for the use value of crop species

Use value category	Assigned score
Human food	7
Livestock fodder	5
Soil fertility improvement	4
Herbal medicine	3
Fibre crop	2
Utensil	1

Priority ranking of CWR taxa

2.2 Priority CWR taxa

Following the scoring process described above, CWR species were ranked as high, medium and low based on score range given in Table 6. The CWR species were thus grouped as follows: i) species with scores in the range of 16–20 were in the high priority rank ii) those falling in the range of 10–15 were in the medium priority rank; and iii) the CWR species with a total score in the range between 4–9 were grouped in the low priority rank. Table 6 shows the number of species in each of the priority ranks. A total of 30 CWR taxa were placed in the group of high priority taxa (Table 6).

Table 6. Priority ranking of generated CWR taxa

Score range	No. of CWR taxa	Priority ranking
16–20	31	High
10–15	215	Medium
4–9	213	Low

The generated 30 prioritized CWR taxa belong to 6 families out of a total of 12 families associated with the CWR checklist taxa. These families with the number of CWR taxa in brackets are Fabaceae (9), Poaceae (9), Dioscorea (5), Cucurbitaceae (5), Solanaceae (2) and Convolvulaceae (1) (Table 7). Of the prioritized CWR taxa, 9 taxa belong to genus *Vigna*, 5 each belong to genera *Dioscorea* and *Cucumis*, 4 taxa belong to genus *Oryza*, 2 CWR taxa each belong to genera *Sorghum* and *Solanum* and a single

CWR taxon each belong to genera *Ipomoea* and *Pennisetum*. On the overall, most of the generated priority CWR taxa, 75%, were classified as primary or secondary relatives of the selected crop according to the genepool concept (Harlan and de Wet, 1971) (Figure 1). The active conservation of the CWR taxa of both of these two groups of genetic resources is important. However, this does not in any way suggest neglecting the CWR taxa in the tertiary and unclassified classes in terms of planning for their conservation because they may be harbouring the desired valuable traits that may not necessarily be available in the primary and secondary gene pool CWR taxa.

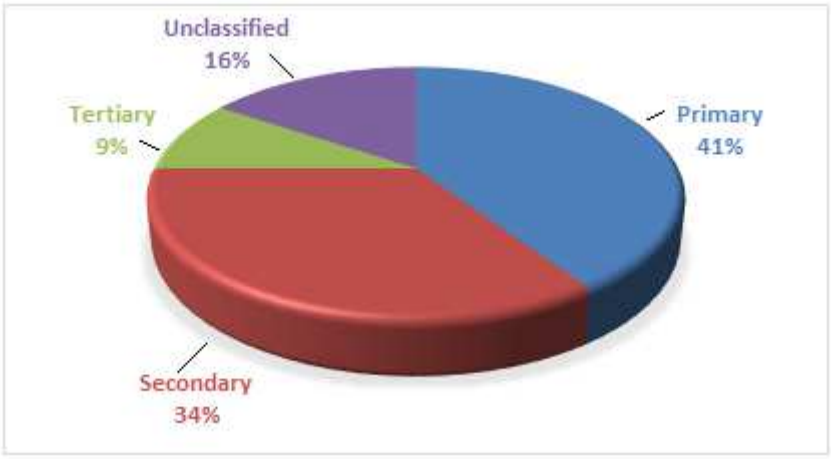

Figure 1. Classification of prioritized species according to the different genepool categories

Table 7. List of Priority CWR taxa with associated gene pool /taxonomic group

Family	Taxon and Author	Gene Pool/Taxon Group
FABACEAE	*Vigna unguiculata* (L.) Walp. subsp. *Tenuis* (E.Mey.) Marechal et al.	Primary
DIOSCOREACEAE	*Dioscorea dumetorum* (Kunth) Pax	Primary
DIOSCOREACEAE	*Dioscorea liebrechtsiana* De Wild. & T.Durand	Primary/Primary
DIOSCOREACEAE	*Dioscorea praehensilis* Benth.	Primary/Primary
POACEAE	*Oryza barthii* A. Chev.	Primary/Primary
POACEAE	*Oryza longistaminata* A. Chev. & Roehr.	Primary/Primary
POACEAE	*Sorghum verticilliflorum* (Steud.) Stapf	Primary
FABACEAE	*Vigna unguiculata* (L.) Walp. var. *spontanea* (Schweinf.) Pasquet	Primary
FABACEAE	*Vigna unguiculata* (L.) Walp. subsp. *dekindtiana* (Harms) Verdc.	Primary
CUCURBITACEAE	*Cucumis africanus* L.f.	Secondary/Tertiary/Tertiary
CUCURBITACEAE	*Cucumis myriocarpus* Naudin	Secondary/Tertiary/Tertiary
CUCURBITACEAE	Cucumis zeyheri Sond.	Secondary/Tertiary/Tertiary
DIOSCOREACEAE	*Dioscorea bulbifera* L.	Primary/Secondary
POACEAE	*Eleusine coracana* (L.) Gaertn. subsp. *africana*	Primary
POACEAE	*Eleusine indica* (L.) Gaertn.	Primary
FABACEAE	*Vigna radiata* (L.) Wilczek. var. *sublobata*	Primary/Secondary
CUCURBITACEAE	*Cucumis ficifolius* A. Rich	Secondary/Tertiary/Tertiary
CUCURBITACEAE	*Cucumis humifructus* Stent	Tertiary/Tertiary
DIOSCOREACEAE	*Dioscorea schimperiana* Hochst. ex Kunth	Secondary
CONVOLVULACEAE	*Ipomoea richardsiae* Verdc	
POACEAE	*Oryza brachyantha* Chev. & Roehr.	Secondary/Secondary
POACEAE	*Oryza punctata* Steud	Secondary/Secondary
POACEAE	*Pennisetum purpureum* Schumach.	Secondary
SOLANACEAE	*Solanum aureitomentosum* Bitter	Secondary
POACEAE	*Sorghum arundinaceum* (Desv.) Stapf	
FABACEAE	*Vigna multinervis* Hutch. & Dalziel	Tertiary
FABACEAE	*Vigna unguiculata* (L.) Walp. Subsp. *pawekiae* Pasquet	Secondary
SOLANACEAE	*Solanum incanum* L.	Secondary
FABACEAE	*Vigna haumaniana* R. Wilczek	
FABACEAE	*Vigna juncea* Milne-Redh	
FABACEAE	*Vigna phoenix* Brummitt	

The next stage in this process required undertaking diversity, *in situ* and *ex situ* gap analyses for purposes of identification key hotspot areas containing CWR and to identify key components of the Zambian CWR diversity not already conserved *ex situ* to make feasible, practical suggestions for the conservation of Zambian priority CWR taxa.

2.3 **Compilation of the CWR inventory for priority taxa**

The CWR inventory for priority taxa was developed by adding relevant data about the taxa on the prioritized national CWR checklist. The type of data used in the inventory included: nomenclature data and taxonomic descriptions, use, threat status and conservation status, socio-economic data, site and environment data. Various sources at national level and international as online databases were accessed for data and information for compilation of inventory of priority CWR taxa. These sources included the national herbaria at the University of Zambia, Mount Makulu Research station and the Forestry Department for herbarium specimen data; the national and the SADC Gene Banks through the digitized information and data on collected Zambian germplasm accessions; South African National Biodiversity Institute (SANBI) for the herbarium data; Global Biodiversity Information Facility (GBIF) (www.gbif.org) for the passport data from herbaria and genebanks from all around the world; Bioversity Collecting Mission Database (http://bioversity.github.io/geosite/), Bioversity Collecting Mission Database; EURISCO (http://eurisco.ipk-gatersleben.de/apex/f?p=103:1:30263504181871), access to ex situ PGR information in most European genebanks collected worldwide; GENESYS (https://www.genesys-pgr.org/welcome), passport, characterization and evaluation data from CGIAR Centres, EURISCO and GRIN; Germplasm Resources Information Network (GRIN), National Plant Germplasm System (NPGS) (http://www.ars-grin.gov/npgs/index.html), Passport, characterization and taxonomic information of PGR conserved by the United States Department of Agriculture (USDA); Germplasm Resources Information Network Canada (GRIN-CA) (http://pgrc3.agr.gc.ca/index_e.html), passport, characterization and taxonomic information of PGR Passport, characterization and taxonomic information of PGR; Kew Herbarium Catalogue (http://apps.kew.org/herbcat/gotoHomePage.do), Royal Botanic Gardens Kew worldwide specimen data Royal Botanic Gardens Kew worldwide specimen data; TROPICOS (http://www.tropicos.org/Home.aspx) , Missouri Botanical Garden worldwide specimen data; JSTOR Global Plants (http://plants.jstor.org/), large database of digitized specimens; African Plant Database (http://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php?langue=an), species distribution maps among other information; Missouri Botanical Garden Herbarium, herbarium data.

2.4 **Information documentation**

The datasets compiled for the CWR taxa inventory was basically managed and maintained in Microsoft Excel worksheet.

3 DIVERSITY ANALYSIS OF PRIORITY CWR

3.1 Compilation of occurrence data

The occurrence data of the priority national CWR taxa was compiled from a number of sources at national and global sources. The national sources of these data included national herbaria at the University of Zambia (UNZA) and Kitwe Forestry Research herbarium, the National Plant Genetic Resources Centre (NPGRC) database which in some cases was validated by maintained physical records as well as observational data from personal sources. The global sources of these occurrence data were mainly online sources which included the Royal Botanic Garden, Kew, African Biodiversity Conservation Innovation Centre, South African National Biodiversity Institute (SANBI) and the CGIAR centres including the International Centre for Tropical Agriculture (ICTA), International Institute of Tropical Agriculture (IITA) and International Rice Research Institute (IRRI).

3.2 Occurrence data quality verification and control and overview of data

Methodology:

Species occurrence data were examined in terms of quality of georreferencing data. The populated data records were checked for conformity with the requirement that data records should have geographic coordinates that were expressed in decimal degrees and that had information on locality description to allow for an evaluation of the quality of their geographic coordinates. Consequently, those occurrence data with the above-mentioned coordinate accuracy but no locality description were eliminated. In addition, based on the geographic coordinates, duplicate data were eliminated. A layer with the political boundaries of Zambia was sourced from the global sources and used to select those populations within the limits of the country and this enabled eliminating those records with erroneous coordinates. As an example those records resulting in plots falling in neighbouring countries were eliminated.

The occurrence data of the priority CWR taxa was comprehensively checked for duplicates, which were eliminated from the dataset that was finally used for subsequent analyses. In addition, the data was checked for spelling errors, formatted and standardized. The datasets were georeferenced with the aid of paper maps and through the application of google earth. Prior to spatial analyses using DIVA GIS version 7.5, the dataset were converted to text format prior to creation of shape files. Using DIVA GIS, a number of analyses were carried out, namely national individual priority genera distribution, priority species richness species, map of number of occurrences, rarefaction analysis, and complementarity analysis (based on Rebelo and Sigfrid 1992 and Rebelo 1994) of the priority CWRs.

Rarefaction analysis is a technique used to assess species richness from the results of sampling. It allows the calculation of species richness for a given number of individual samples, based on the construction of so-called rarefaction curves. Rarefaction analysis assumes that the individuals in an environment are randomly distributed, the sample size is sufficiently large, that the samples are taxonomically similar, and that all of the samples have been performed in the same manner. If these assumptions are not met, the resulting curves will be greatly skewed. The Complementarity Site Selection (abbreviated to Complementarity) procedure aims at identifying sets of grid cells that are complementary to each other, i.e. that capture a maximum amount of diversity in as few cells as possible. Instead of using richness, an adjustment can be made in which rare observations are given more weight. The procedure is based on the algorithm described by Rebelo (1994). The discussion below covers species, but any multi-state variable could be used for the analysis. The procedure used is less straightforward than it might seem. Whereas the selection of the first cell is easy – the cell with highest species richness (or a random choice between ties if there are any) – the choice of the next cell(s) depends on the previously selected cells. This is because the species in the cell with the second highest number of species may also be present in the first cell. This is a non-linear optimization problem. Rebelo (1994) developed a procedure that calculates an approximate optimal solution, and this has been implemented in DIVA. An iterative procedure is used. In each iteration the 'value' of each grid cell is calculated, based on the observations in that cell, and in relation to the observations in the cells already selected. If there are two or more cells with the same value, one is selected at random. Hence, this procedure can lead to slightly different results each time it is run. According to Petit et al. (1998) and Leberg (2002), the rarefaction method has been developed to compare richness among cells that have a dissimilar number of observations or samples. The rarefaction method recalculates the richness measured in the different cells as if a standard number of observations were made in each cell. Only cells with an equal or higher number of observations than the standardized number are included in the analysis; cells with fewer observations are excluded.

Results:

For the 30 priority CWR taxa, a total of 1,049 occurrence records was assembled. Of these records, 819 records were fully georeferenced and the remaining 230 records lacked georeferenced data and therefore were eliminated from the final dataset as they could not be used for subsequent analyses. However, of the fully georeferenced records 590 records with no duplicate passport data were used for spatial and other analyses. Two main sources of information and data of priority CWR taxa used in these analyses were the genebanks and herbaria. Of the two sources, the genebanks accounted for 67% of these records that were used for analyses and 50% (or 198) of these records out of the

genebank sources were obtained from the Zambian national genebank. The other genebank records were sourced from international genebanks that included the International Centre for Tropical Agriculture (ICTA), the International Institute for Tropical Agriculture (IITA) and the International Rice Research Institute (IRRI). A total of 195 records were obtained from the herbaria that included the Royal Botanical Gardens Kew, African Biodiversity Conservation and Innovations Centre, South African National Biodiversity Institute (SANBI), University of Zambia and Kitwe Forestry Research Herbarium. The number of records for each priority CWR taxon is provided (Table 8). Comparatively, *Oryza longistaminata* had the largest number of records (201), followed by *Eleusine coracana* subsp*. africana* with 145 records. The lowest number of recorded was obtained for *Cucumis zeyheri*, *Oryza punctata and Vigna phoenix* with a single record each (Table 8).

Table 8. Number of records for each priority CWR Taxon from genebanks and herbaria used in the analyses

CWR taxon	Genebank	Herbarium	Total
Cucumis zeyheri		1	1
Dioscorea bulbifera		4	4
Dioscorea dumetorum		13	13
Eleusine coracana subsp*. africana*	137	8	145
Eleusine indica subsp. *indica*	1	10	11
Oryza barthi	13	4	17
Oryza brachyantha	8	10	18
Oryza longistaminata	112	89	201
Oryza punctata		1	1
Pennisetum purpureum	5	3	8
Solanum aureitomentosum		4	4
Solanum incanum	1	3	4
Sorghum bicolor subsp. *verticilliflorum*	2	3	5
Vigna haumaniana	3	3	6
Vigna juncea	13	18	31
Vigna multinervis	6		6
Vigna phoenix		1	1
Vigna unguiculata subsp. *dekindtiana*	86	9	95
Vigna unguiculata subsp*. pawekiae*		2	2
Vigna unguiculata subsp*. spontanea*	3		3
Vigna unguiculata subsp. *tenuis*	5	9	14
Grand Total	395	195	590

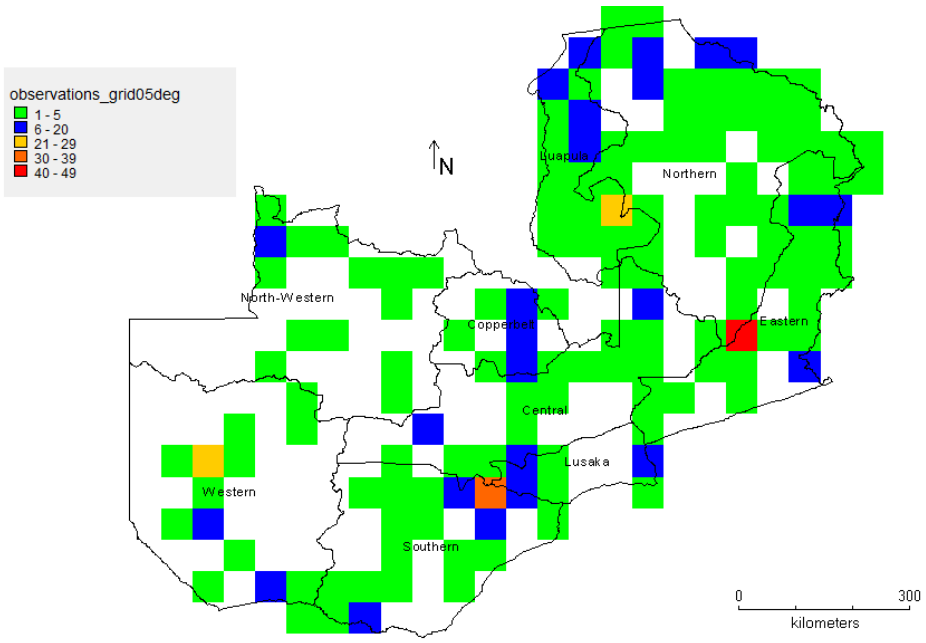

Figure 2. Number of observations recorded some regions of the country

The highest number of observations were recorded from Eastern province which was closely by Southern, Western and Luapula provinces (Figure 2). This could be attributed to the comparable highest frequency of sampling times in those regions. Despite the low number of observations, comparatively, Mbala district in the Northern Province had the highest species richness which was followed by South Luangwa in Eastern province, Lusaka Province and Mpongwe on the Copperbelt province (Figure 3). The Northwestern and Copperbelt Provinces are indicating high species richness based on the rarefaction method (Figure 4). These sites were least in terms of number of observations that were used for the analysis. South Luangwa in Eastern Province which, was highly sampled but comparatively had the lower species richness than Mbala in Northern province.

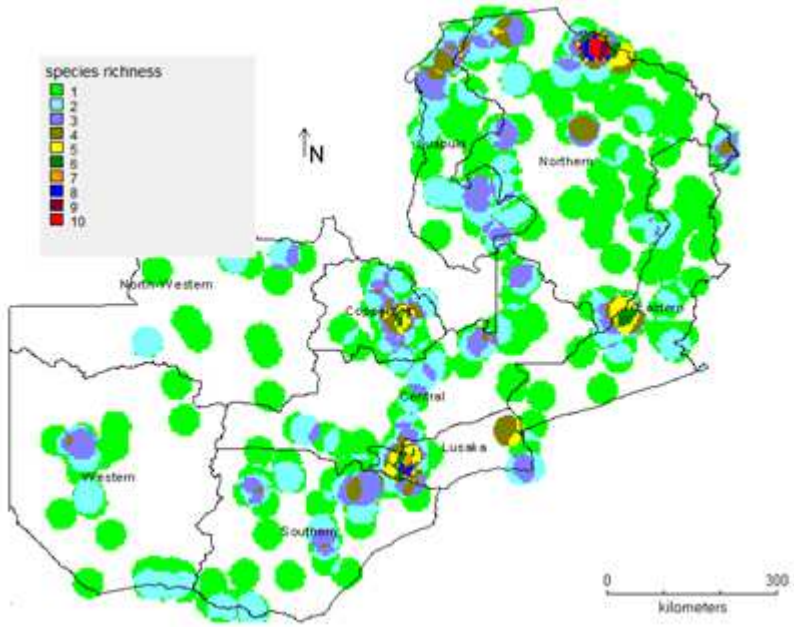

Figure 3. Species richness

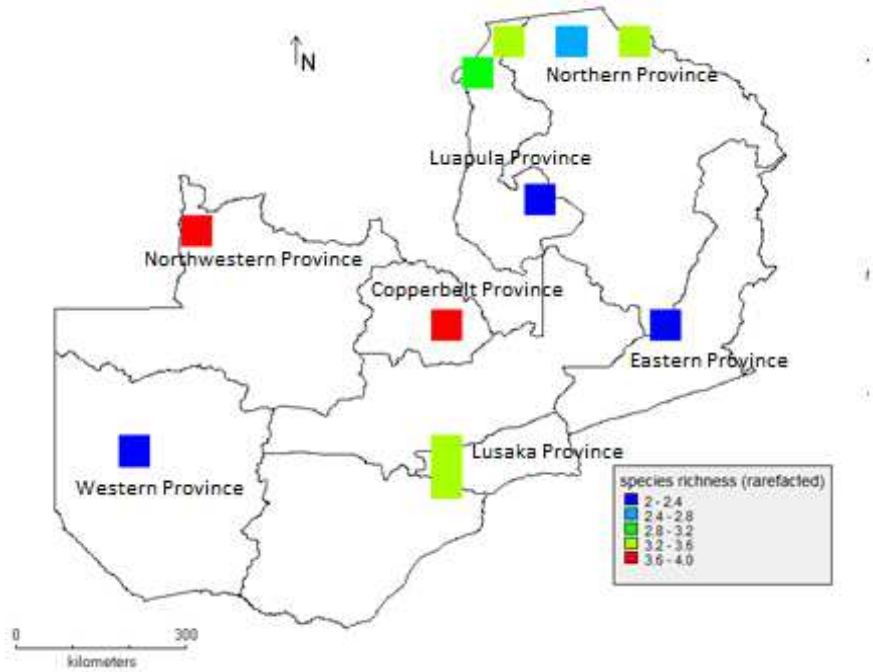

Figure 4. Species richness rarefacted accounting for sampling bias

3.3 **Distribution, hotspots and complementarity analyses**

Methodology:

Species distribution maps, hotspot areas where high high concentrations of proriority CWRs are found as well as complementarity analysis were undertaken.

Complimentarity analysis was undertaken as a basis for decision making on reserve selection. The idea of the complementarity analysis is to conserve as many taxa as possible in the minimum number of reserves (Rebelo and Sigfried 1992, Rebelo 1994). This analysis first selects the location with the highest species richness; subsequently it selects an additional location containing the highest species richness upon exclusion those species already present in previously selected locations from the analysis. The complementarity analysis was performed in DIVA-GIS version 7.5 using a 10 x 10 km grid. The type of layers used in these analysis were political boundaries of Zambia at country, province and district levels and these layers were obtained from the online global sources, such as www.gadm.org.

Results:

Analysis of Priority CWR Species Distribution

Separate priority CWR taxon distribution maps for *Oryza*, *Vigna*, *Eleusine*, and *Dioscorea* genera were obtained (Figures 5-8). A single combined distribution map was generated for *Cucumis*, *Pennisetum*, *Solanum*, and *Sorghum* genera (Figure 9). While *Oryza longistaminata* seems to be widely distributed in all the provinces of the country, while *O. barthii*, *O. punctata* and *O. brachyantha* have narrow distributions to particular regions of the country. Whereas *O. brachyantha* is narrowly restricted to the Northern region of Zambia i.e. Luapula and Northern Provinces, *O. barthii* and *O. punctata* have restricted distribution to the South Luangwa National Park in the Eastern region of the country (Figure 3).

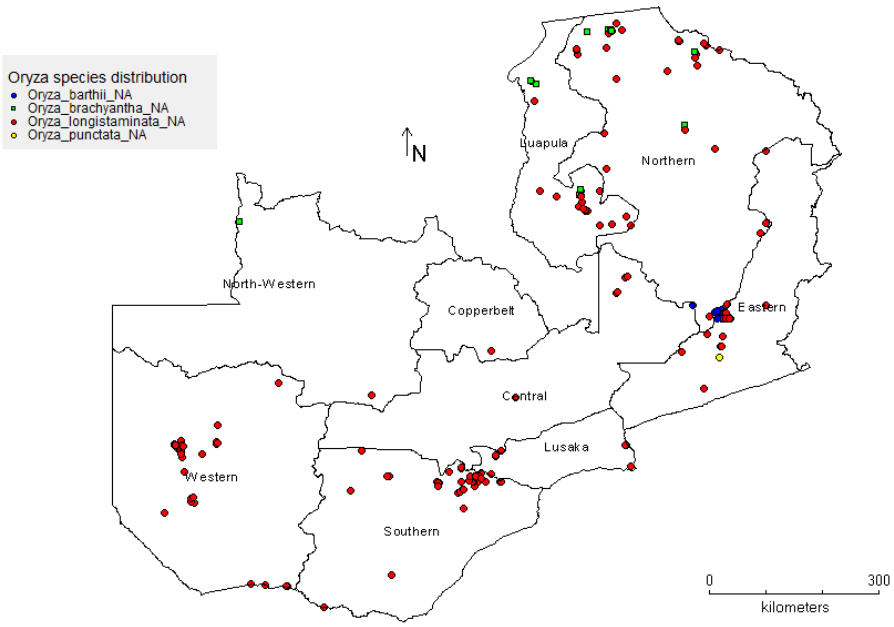

Figure 5. National distribution of priority *Oryza* species

Similarly, *Vigna juncea* has shown to have wide distribution across all the regions of Zambia, *V. haumaniana* and *V. multinervis* are restricted to South Luangwa in the Eastern province, *V. unguiculata* subsp. *dekindtiana* seems to have restricted distribution in Northern and Luapula Provinces and to some extent the Northwestern Province of the country (Figure 6).

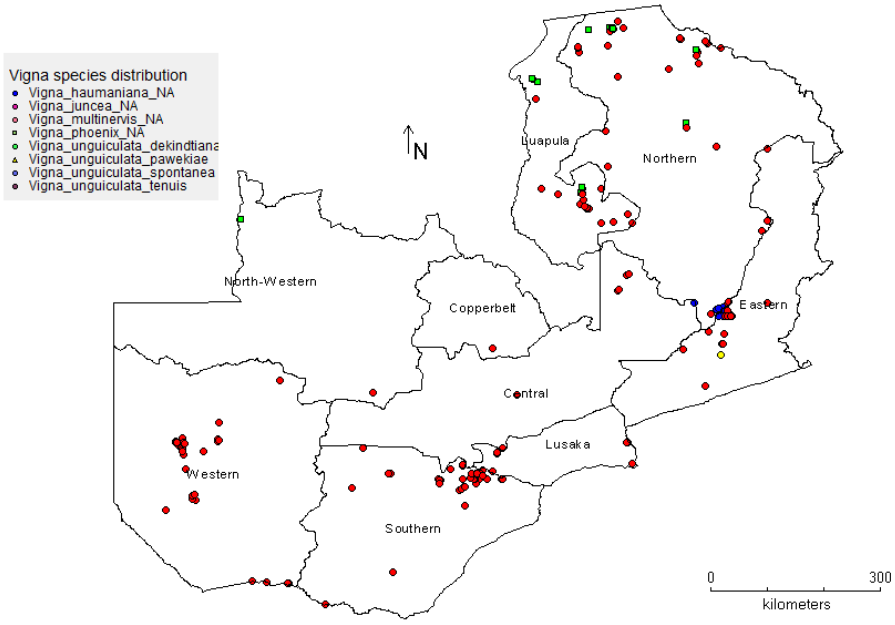

Figure 6. National distribution of priority *Vigna* species

Based on the occurrence data of *Eleusine coracana* subsp. *africana* and *E. indica*, the distribution of the two CWR taxa is restricted to the upper half of the country (Figure 7). The suitability map of the cultivated type, *E. coracana* subsp. *coracana,* follows the same distribution pattern as the two CWR taxa.

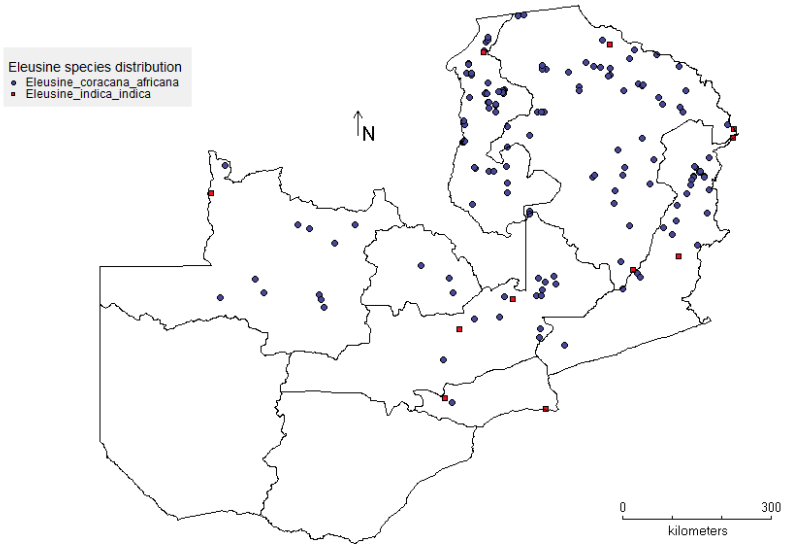

Figure 7. National distribution of priority *Eleusine* species

Based on the available occurrence data that was used in this analysis, distribution of *Dioscorea bulbifera* and *Dioscorea dumetorum* is restricted to the Northern, Central, Lusaka, Sothern and to some extent parts of Eastern Provinces of Zambia (Figure 8). However, perhaps this may not provide the complete picture in terms of distribution of the *Dioscorea* spp. This in part may be because the result obtained from the analyses was only based on available sources such herbaria voucher specimens and online sources whose observations may not have been of country wide coverage.

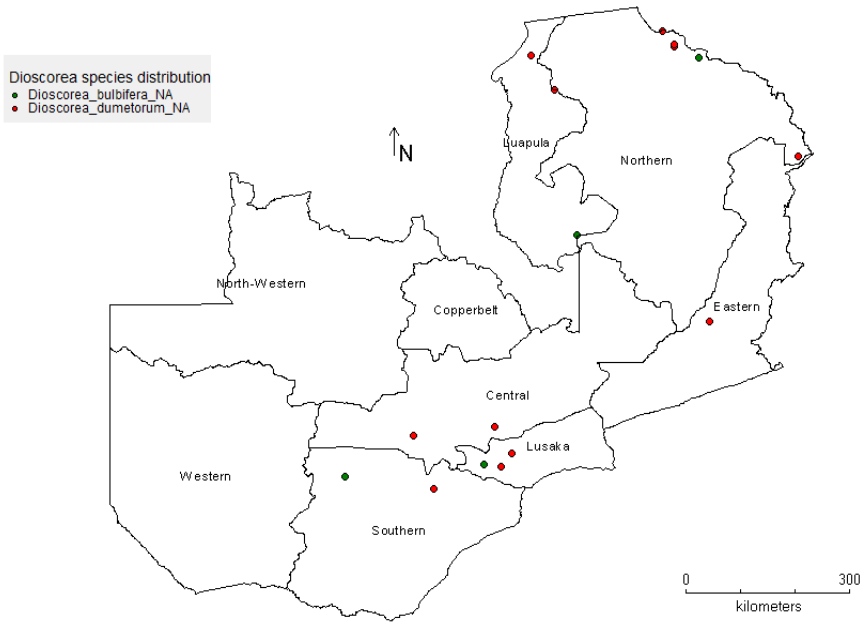

Figure 8. National distribution of priority *Dioscorea* species

The distribution of the remaining four priority CWR taxa indicated that *Pennisetum purpureum* was restricted to northern region of the country while the distribution of *Sorghum bicolor* subsp. *verticiflorum* was restricted to the Southern region of the country (Figure 9). *Solanum incanum* is evenly distributed between the Southern and Central regions of the country whereas *S. aureitomentosum* is restricted to the Northern region of the country. The distribution of *Cucumis zeyheri* is restricted to the Southern region of the country.

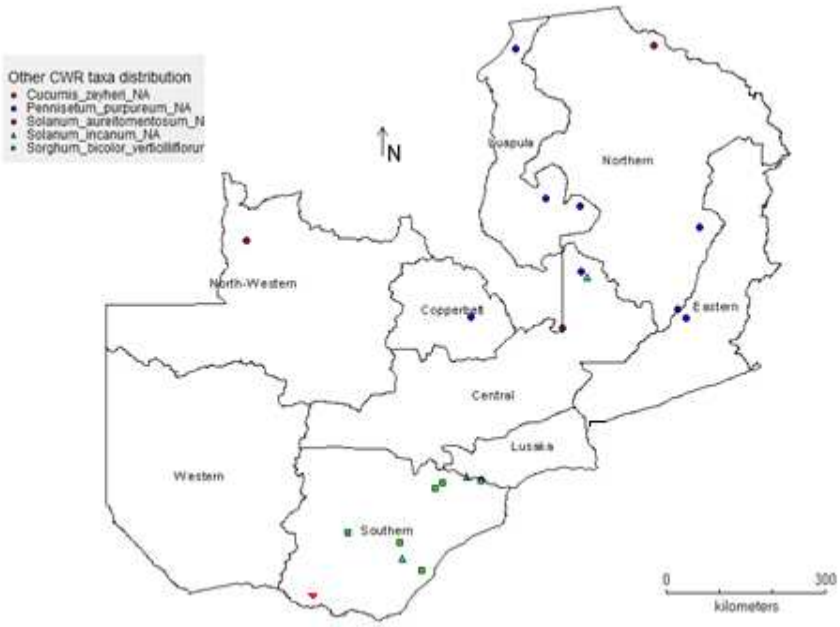

Figure 9. National distribution of *Cucumis*, *Pennisetum*, *Solanum* and *Sorghum* priority CWR taxa

Areas of increased species richness of priority CWRs

The priority CWR species richness analysis revealed six areas as the richest in number of species (Figure 10), where hotspots have been identified for the priority CWR based on the occurrence data gathered. Comparatively, four of these locations numbered 1-4 located in Northern, Eastern, Lusaka and Copperbelt seemed to be of the areas of highest species richness. The numbers in Figure 10 point to locations where the highest number of species are found or indeed the Provinces where locations of increased species richness are found as 1 (Northern Province), 2 (Eastern Province), 3 (Lusaka Province) and 4 (Copperbelt Province).

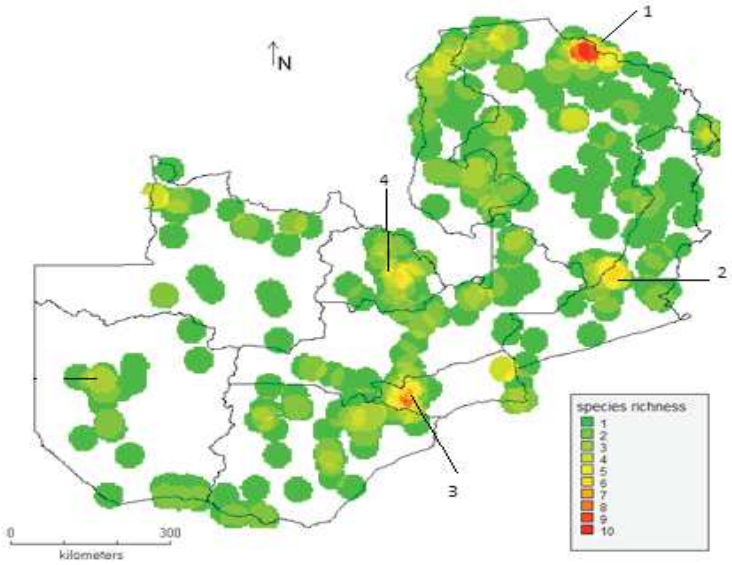

Figure 10. Sites for possible priority CWR species richness. Red areas encompass the highest number of CWR species.

Complementarity analysis at cell level 10 x10 km

Complementarity analysis at 10 x 10 km has established a total number of 13 cells in the network to conserve 21 out of the 30 priority CWR. (Figure 11). A total of 27 populations of those 21 priority CWR are covered by these complementary areas translating in 4.6% percent of the total number of populations.

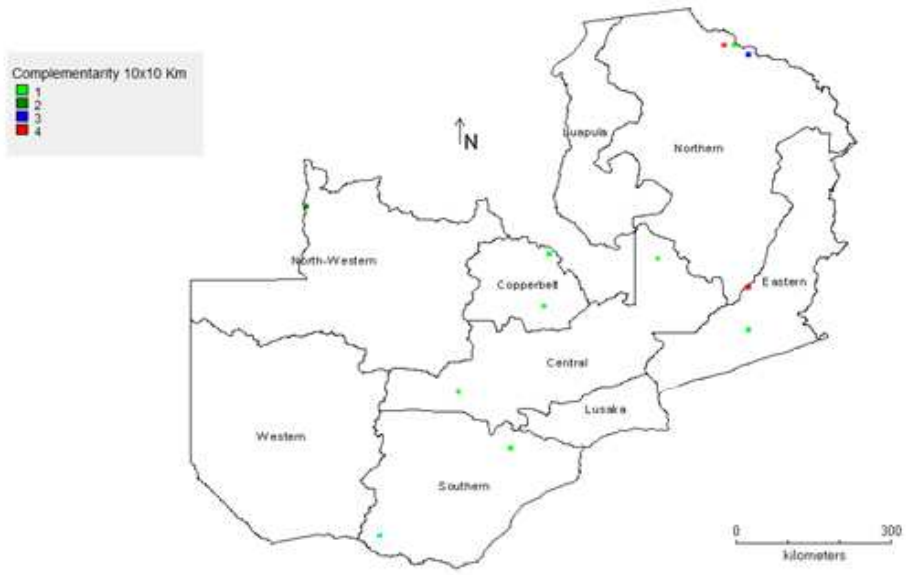

Figure 11. Complementarity sites for the priority CWR at cell level 10 x 10 km

3.4 Information documentation

The datasets compiled for the CWR taxa inventory was basically managed and maintained in Microsoft Excel worksheet.

4 GAP ANALYSIS OF PRIORITY CWR

4.1 *In situ* gap analysis

Methodology:

Currently, there are no conservation programmes in place in the country specifically targeting active *in situ* conservation of CWR species. While some CWR species may be occurring in some protected areas of the country such as national parks, game management areas, forest reserves and national Ramsar sites such as wetlands, planned conservation and monitoring activities on site do not take into account these CWR taxa. Therefore, presently there are no planned conservation and monitoring programs and activities in place for the CWR species occurring in the wild.

In this undertaking, the priority CWR taxa were assessed as not conserved *in situ* in comparison with those priority CWR taxa for which active *in situ* conservation measures are already in place; *in situ* gap analysis have identified the CWR taxa that occur within existing protected areas but are not actively conserved *in situ* as well as those that do not occur within the national network of protected areas. The data sources of priority taxon occurrence data used for *in situ* gap analysis are as the data collated in section 3.1.

Results: The gap analysis showed that there are nine (9) priority CWR taxa that do not occur within any of the existing protected areas of Zambia. These included the following crop wild relatives taxa *Cucumis zeyheri*, *Vigna unguiculata* subsp. *pawekiae* and *V. unguiculata* subsp. *spontanea.* These CWR taxa may be prioritized and targeted for conservation in the areas of their occurrence.

Out of the total of 30 priority CWR taxa generated, twenty one (21) of these CWR taxa (representing 67.7% of the total taxa) were covered in the protected area network of Zambia. The list of the priority CWR taxa covered in the protected areas of Zambia are *Oryza longistaminata, O. barthii, Pennisetum purpureum, Eleusine indica* subsp. *indica, Dioscorea dumetorum, Vigna haumaniana, V. juncea, Solanum aureitomentosum, D. bulbufera, V. unguiculata* subsp. *dekindtiana, E. coracana* subsp. *africana, V. juncea, V. multinervis, Sorghum bicolor* subsp. *verticiflorum, Solanum incanum, V. unguiculata* subsp. *tenius, O. punctata* and *V. phoenix* (Table 9). However, from the records used, the

CWR taxa that are not covered by existing protected area networks of Zambia are Cucumis zeyheri, Oryza punctata and Vigna phoenix.

Table 9. Priority CWR taxa occuring in each of the Protected Areas

Protected Area	Town	Province	Number of priority CWR Taxa	Name of priority CWR Taxa
Kafue National Park	Mumbwa	Central	4	*Oryza longistaminata, Oryza barthii, Pennisetum purpureum, Eleusine indica* subsp. *indica*
Nsumbu National Park	Mbala	Northern	4	*Dioscorea dumetorum, Vigna haumaniana, Vigna juncea, Solanum aureitomentosum*
Nsumbu National Park	Mbala	Northern	4	*Dioscorea bulbufera, Vigna unguiculata* subsp*. dekindtiana, Eleusine coracana* subsp*. africana, Dioscorea dumetorum*
West Lunga National Park	Mwinilunga	Northwestern	4	*Vigna juncea, Vigna multinervis, Oryza longistaminata, Eleusine indica* subsp. *indica*
Kafue National Park	Mazabuka	Southern	2	*Oryza longistaminata, Sorghum bicolor* subsp. *verticiflorum*
Kasanka National Park	Serenje	Central	2	*Oryza longistaminata, Solanum incanum*
Mienge Forest Reserve	Mpongwe	Copperbelt	1	*Vigna unguiculata* subsp. *tenius*
South Luangwa National Park	Katete	Eastern	1	*Oryza punctata*
Nsumbu National Park	Mbala	Northern	3	*Oryza longistaminata, Vigna unguiculata* subsp. *pawekiae, Vigna unguiculata* subsp. *dekindtiana*
Kafue National Park	Mumbwa	Central	2	*Vigna unguiculata* subsp. *dekindtiana, Vigna unguiculata* subsp. *spontanea*
Copperbelt Forest Reserve	Mufulira	Copperbelt	1	*Vigna phoenix*
Mosi Oa Tunya National Park	Livingstone	Southern	1	*Cucumis zeyheri*

However, these CWR taxa occurring in the protected areas are not presently targeted for active *in situ* management and monitoring activities. As such, in that regard, their actual status on site may not be known.

Zambia has a network of protected areas that include the national parks, game management areas, forest reserves and Ramsar sites. The country has a total of twenty one national parks (Figure 12), that have been designated for conservation of wildlife.

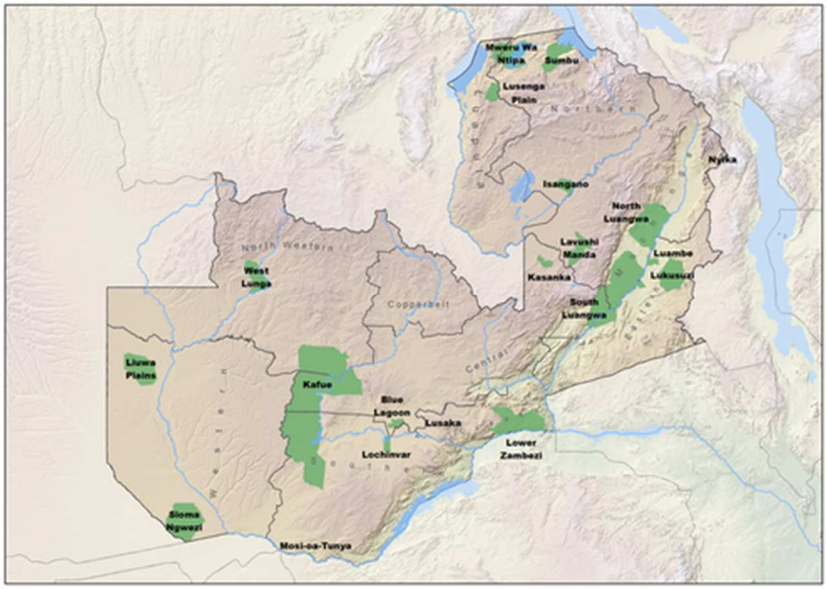

Figure 12. Network of National Parks of Zambia

In addition, the country also has one internationally recognized Ramsar site, the Barotse Floodplain in the western region of the country.

The existing national protected areas of Zambia cover a total of 222 occurrences out of a total of 590 population representing 37.6% of the total populations.

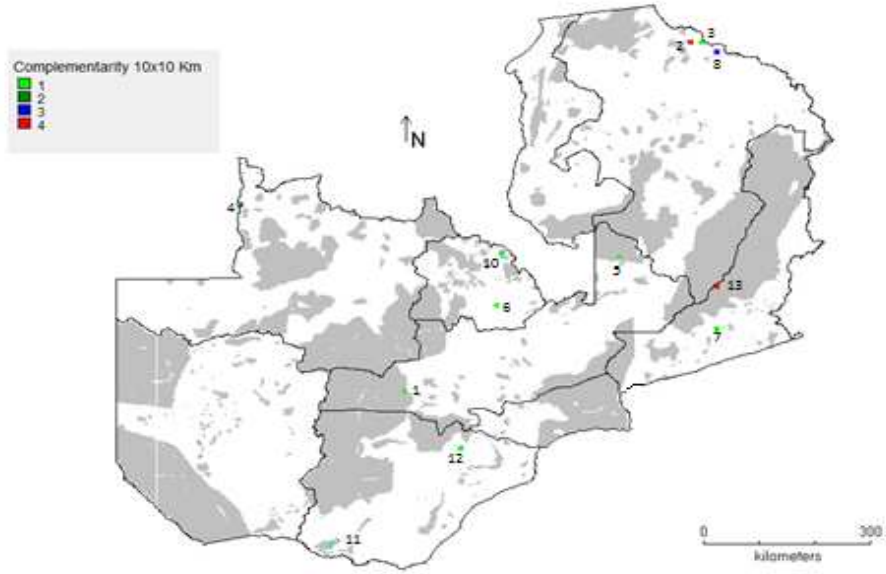

Figure 13. Complementarity of the Priority CWRs in the protected area network

From the complementarity analysis at 10 x 10 km as indicted in Figure 10, genetic reserves could be implemented in the Nsumbu National Park in Mbala covering cells numbered 2 and 3, in the South Luangwa National Park covering cell numbered 13, Kasanka National Park covering cell numbered 5 and Mosi-Oa-Tunya National Park covering cell numbered 11 (Figure 10) and to a variation of extent to which the populations of priority CWR taxa are covered in these protected areas (Table 10). However, there are proposed sites outside protected area that may be recommended for establishment of genetic reserve for conservation of priority CWR taxa. These include sites covering cells numbered 4 in Northwestern of the country at the source of Zambezi River and Cell numbered 8 occuring in Mbala district of the Northern Province. However, it will be necessary to undertake field surveys targeting the indicated sites to ascertain the feasility of this proposed conservation action.

Table 10. Number of populations for each priority taxon covered by existing protected areas

Priority CWR taxa	**Number of populations**	**Populations covered in protected areas**	**% of populations covered in protected areas**
Cucumis zeyheri	1	0	0
Dioscorea bulbufera	4	2	50
Dioscorea dumetorum	13	3	23
Eleusine coracana subsp. *africana*	145	34	23
Eleusine indica subsp. *indica*	11	4	36
Oryza barthii	17	17	100
Oryza brachyantha	18	8	44
Oryza longistaminata	201	102	51
Oryza punctata	1	0	0
Pennisetum purpureum	8	4	50
Solanum aureitomentosum	4	1	25
Solanum incanum	4	1	25
Sorghum bicolor subsp. *verticiflorum*	5	1	20
Vigna haumaniana	6	2	33
Vigna juncea	31	6	19
Vigna multinervis	6	3	50
Vigna phoenix	1	0	0
Vigna unguiculata subsp. *dekindtiana*	95	30	32
Vigna unguiculata subsp. *pawekiae*	2	1	50
Vigna unguiculata subsp. *spontanea*	3	1	33
Vigna unguiculata subsp. *tenius*	14	2	14

4.2 ***Ex situ*** **gap analysis**

Methodology:

The *ex situ* gap analysis was carried out by comparative analysis of the target taxa already in conservation in genebanks and the target taxa compiled from national herbaria, gene bank databases and online data sources (see section 3.1).

Results:

The *ex situ* gap analysis has indicated that a total of six (6) priority CWR taxa; *Dioscorea dumetorum*, *D. bulbifera*, *Cucumis zeyheri*, *Oryza punctata*, *Solanum aureitomentosum, Vigna unguiculata* subsp. *pawekiae* and *V. Phoenix;* are not conserved ex situ (Table 11). However, twelve (12) of the priority CWR taxa as shown in Table 11 with less than five accessions conserved in the genebank were under represented in *ex situ* collection and therefore there is urgent need for planned deliberate germplasm collection to be undertaken to conserve *ex situ* before these populations are extinct in the wild. These priority CWR taxa include *Eleusine indica* subsp. *indica*, *Solanum incanum**,** Sorghum bicolor* subsp*. verticilliflorum, Vigna haumaniana and Vigna unguiculata* subsp. *spontanea**.*** According to the gap analysis of the *ex situ* collections, there is an urgent requirement to consider germplasm collection of populations of those priority CWR taxa that are currently underrepresented in the *ex situ* collection. These CWR taxa include *Dioscorea dumetorum*, *Dioscorea bulbifera*, *Vigna unguiculata* subsp. *spontanea*, *Eleusine indica* subsp. *indica*, *Sorghum bicolor* subsp. *verticiflorum*, *Vigna haumaniana* and *Solanum incanum*. One of the compelling reason is that even if some of these priority CWR taxa may have been collected and conserved ex situ, they have fewer number of populations in the ex situ collection (Table 11). This is apparent for CWR taxa such as *Vigna unguiculata* subsp. *spontanea, Eleusine indica* subsp. *indica*, *Sorghum bicolor* subsp*. verticiflorum*, *Vigna unguiculata* subsp. *tenius*, *Pennisetum purpureum* and *Solanum incanum* which, have five and less number of populations in the *ex situ* collection (Table 11). The priority CWR taxa with more than five populations include *Oryza barthii, Oryza longistaminata, Oryza brychyantha, Vigna ungucuilata* subsp*. dekindtiana, Vigna juncea, Eleusine coracana* subsp. a*fricana and Vigna multinervis* (Table 11)***.***

Table 11. Gap analysis of the *ex situ* collections has indicated the number of accessions for each taxon in genebanks and the herbarium.

Taxon	***Ex situ* (Genebank)**	**Herbarium**	**Grand Total**
Cucumis zeyheri	0	1	1
Dioscorea bulbifera	0	4	4
Dioscorea dumetorum	0	13	13
Eleusine coracana subsp*. africana*	137	8	145
Eleusine indica subsp*. indica*	1	10	11
Oryza barthii	13	4	17
Oryza brachyantha	8	10	18
Oryza longistaminata	112	89	201
Oryza punctata	0	1	1
Pennisetum purpureum	5	3	8
Solanum aureitomentosum	0	4	4
Solanum incanum	1	3	4
Sorghum bicolor subsp*. verticilliflorum*	2	3	5

Vigna haumaniana	3	3	6
Vigna juncea	13	18	31
Vigna multinervis	6		6
Vigna phoenix	0	1	1
Vigna unguiculata subsp. *dekindtiana*	86	9	95
Vigna unguiculata subsp *pawekiae*	0	2	2
Vigna unguiculata subsp. *spontanea*	3		3
Vigna unguiculata subsp. *tenuis*	5	9	14
Grand Total	395	195	590

5 MONITORING CWR DIVERSITY

5.1 Development of monitoring plans for CWR

***In situ* conserved diversity:**

Zambia has not had an agenda for the active *in situ* conservation of CWR. Considering the inherent value of CWR taxa as sources of genes for introgression in the improved crop varieties in the light of the ever changing climate pattern and as a response to tackle biotic and abiotic stresses, it has become imperative that these biological resources should be actively conserved, managed and monitored in their natural habitats complemented by safety backup as *ex situ* collection for facilitated utilization.

While some of the priority CWR taxa may be occurring within protected areas, currently there are no planned activities in place for their active conservation. It is necessary to include the priority CWR taxa in the protected area management plan in order to prevent these populations from declining as a result of many factors occurring in those natural habitats. The proposed monitoring plan for the CWR taxa populations should focus on the monitoring of their genetic diversity and natural dynamics. Ample consideration should be given to implementing conservation plans for priority CWR taxa occurring both within protected area conservation and outside of protected area conservation. These species are under threat largely due to human driven activities. As these occur in close proximity to the homesteads of some inhabitants, a unique conservation plan outside protection areas will be required for priority CWR taxa that occur as weedy species on field margins and wastelands or even along highways. As the case for the genetic reserves, these sites will need a monitoring and management agreement and a regular interaction with the owners of the fields or homesteads.

It is necessary that for threatened CWR taxa, a regular monitoring schedule will be required to monitor population level and institution of rescue collection missions targeting those species. When planning

conservation of the CWR in the area, it is recommended to not follow the limitations of the grid but to follow the possible nature conservation area or reserve boundaries and look into which CWR taxa grow within the reserve and how to establish a genetic reserve within it by including the CWR taxa conservation in the maintenance and monitoring plan of the protected area.

The monitoring process of CWR populations whether they formally occur in recognised genetic reserves or an informal *in situ* conservation area, will have the same objectives and is likely to be implemented in a similar manner (Maxted et al., 2013), as follows:

(i) Identification and selection of the variables to monitor.

These variables may include the following parameters: demographic (population size, density, frequency, cover, structure, survival rate, growth rate, fertility rate, spatial structure); ecological (temperature, precipitation, solar radiation, cloud cover, soil structure, texture, pH, nutrients, salinity, redox potential, CEC); and anthropogenic (including social, economic, political and cultural threats and opportunities). At this stage, it is important to take into account parameters such as the life form and breeding system of the target taxon, as well as the resources available for monitoring.

(ii) Design of the sampling strategy.

The design of the sampling strategy involving making decisions on the type, size, number and positioning of the sampling units and the timing and frequency of sampling will be based on a review of the available literature on the monitoring of taxa with similar life forms and biological traits, as well as through consultation with conservation management experts. The monitoring plan could be designed in a way to enable detecting changes in the target population but distinguish between significant biological changes in the population that may negatively impact population health and normal seasonal variations that need not trigger changes in management actions.

(iii) Selection and positioning of the sampling units.

Sampling can be carried out using various methods: plot (or quadrat within areas of standard size), transect (banded transect or intercept - transects sample diversity within a defined distance either side of a central line, often 1m either side making a 2m wide transect, while the line intercept samples diversity that actually touches the line) methods or even monitoring of individual plants (or plant parts) for particular attributes (e.g. plant height, number of seeds per fruit). In an *in situ* conservation site, the plot method is most likely to be used with the establishment of permanent quadrats.

(iv) Positioning of sampling units.

The positioning of sampling units should be random and ideally distributed throughout the entire area of distribution of the population. Methods of random sampling will be used which include: simple random sampling, systematic sampling and stratified random sampling[95].

(v) Determination of the timing and frequency of monitoring.

Populations of CWR in genetic reserves should be surveyed regularly in order to detect any changes. Monitoring is commonly most effective when the target species is flowering or fruiting, as often then they can be easily identified. It also can be carried out when leaves are unusually coloured or about to fall, or when the surrounding vegetation does not obscure the target species or other particular character of the target taxon. Either way, it should be scheduled at the same phenological time each year to ensure the data are directly comparable between monitoring events. The frequency of monitoring (time between surveys) is usually dictated by the perception the researcher has during the first surveys. However, the frequency of monitoring will specifically depend on the life form, the expected rate of change, the rarity and trend of the target species, as well as on the resources available for monitoring. It can be as frequent as every month (e.g. rare or very threatened annuals) during several growing seasons, or annually (e.g. annuals) or less frequently (e.g. perennials). Generally, the monitoring in a newly established reserve is more frequent than in a wellestablished one. With time and experience, frequency of monitoring can be adjusted.

(vi) Implementation of a pilot study.

A pilot study should be carried out once the monitoring scheme has been designed in order to assess how efficient the experimental design is and whether the field techniques are efficient, before the implementation of a long term monitoring strategy.

(vii) Planned Data analysis.

The results of the pilot study should be analysed in order to detect possible problems with the monitoring design and field methodologies and if necessary adjust them to ensure that the scheme will detect changes that may indicate a decline in the size and/or genetic diversity of the population.

(viii) Adjustment of monitoring plan.

Frequently, refinement of the monitoring plan is needed. Sample size, position of sampling units, etc. may be inadequate to detect meaningful changes in the population so they need to be adjusted. However, changes to the monitoring regime may negatively impact data comparison, so any changes need to be considered, possible with the help of a statistician, before being implemented.

***Ex situ* conserved diversity:**

Primarily, identified priority CWR taxa that are not conserved *ex situ* in the national gene banks should be targeted for gap filling collection. In addition to conserving the collected priority CWR taxa in the natitional genebank, the duplicate samples should be duplicated at the Base collection of the SADC Plant Genetic Resources Centre (SPGRC). It is necessary to use recommended genebank standards for the conservation of these resources. As indicated by Parra-Quijano *et al.* (2012) in order to help detect genetically representative samples for the more widely distributed and non threatened CWR species, ecogeographical representativeness using ecogeographic land characterization (ELC) with the CAPFITOGEN tools can be used as a proxy.

The best management practices for the *ex situ* conserved priority CWR is to institute a programme of regular periodical monitoring of the germplasm accessions for their viability in storage. An interval of 3-5 years depending on the plant species and status of gene bank conservation facilities. When germination percentage falls below the recommended threshold level of 85%, the concerned accessions should be timely regenerated.

5.2 Information documentation

The SADC Documentation and Information System (SDIS) developed through the NORDIC supported SADC Plant Genetic Resources Project currently being used by the National Plant Genetic Resources Centres (NPGRCs) in the SADC region will be used for maintenance of passport and other data generated through active conservation of the priority CWR taxa. The data of the priority CWR taxa generated through this project will be publicly made available to users of priority CWR species such as breeders and other researchers, thereby supporting sustainable utilization of these resources. All possible channels such as the ZARI's and SPGRC's websites will be used for this purpose.

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7 APPENDICES

Appendix 1: Zambia CWR Checklist

FAMILY	TAXON and AUTHOR
AMARANTHACEAE	*Amaranthus dubius* Mart.ex Thell
AMARANTHACEAE	*Amaranthus graecizans* L. subsp. *syvestris*
AMARANTHACEAE	*Amaranthus hybridus* L. subsp. *cruentus*
AMARANTHACEAE	*Amaranthus hybridus* L. subsp. *hybridus*
AMARANTHACEAE	*Amaranthus lividus* L. subsp. *polygonoides*
AMARANTHACEAE	*Amaranthus spinosus* L.
AMARANTHACEAE	*Amaranthus thunberg* Moq.
AMARANTHACEAE	*Amaranthus viridis* L.
POACEAE	*Chloris pycnothrix* Trin.
POACEAE	*Chloris virgata* Sw.
CAPPARACEAE	*Cleome hirta* (Klotzsch) Oliv.
CAPPARACEAE	*Cleome macrophylla* Klotzsch) Briq. subsp. *macrophylla* var. *macrophylla*
CAPPARACEAE	*Cleome monophylla* L.
CAPPARACEAE	*Cleome rubella* Burch.
CAPPARACEAE	*Cleome rutidospermum* DC.
MALVACEAE	*Corchorus aestuans* L.
MALVACEAE	*Corchorus asplenifolius* Burch.
MALVACEAE	*Corchorus fascicularis* Lam.
MALVACEAE	*Corchorus olitorius* L.
MALVACEAE	*Corchorus pseudocapsularis* Schweinf.
MALVACEAE	*Corchorus saxatilis* Wild
MALVACEAE	*Corchorus schimperi* Cufod.
MALVACEAE	*Corchorus tridens* L.
MALVACEAE	*Corchorus trilocularis* L.
FABACEAE	*Crotalaria abbreviata* Baker f.
FABACEAE	*Crotalaria abscondita* Welw. ex Baker
FABACEAE	*Crotalaria aculeata* De Wild.
FABACEAE	*Crotalaria adamsonii* Baker f.
FABACEAE	*Crotalaria adenocarpoides* Taub.
FABACEAE	*Crotalaria alemanniana* Torre
FABACEAE	*Crotalaria alexandri* Baker f.
FABACEAE	*Crotalaria amoena* Welw. ex Baker
FABACEAE	*Crotalaria anisophylla* (Hiern) Welw. ex Baker
FABACEAE	*Crotalaria annua* Milne-Redh.
FABACEAE	*Crotalaria anthyllopsis* Welw. ex Baker
FABACEAE	*Crotalaria arcuata* Polhill
FABACEAE	*Crotalaria argenteotomentosa* R.Wilczek
FABACEAE	*Crotalaria argyrolobioides* Baker

FABACEAE	*Crotalaria axillaris* Aiton
FABACEAE	*Crotalaria axilliflora* Baker f.
FABACEAE	*Crotalaria axillifloroides* Baker f. ex R.Wilczek
FABACEAE	*Crotalaria barkae* Schweinf.
FABACEAE	*Crotalaria barnabassii* Dinter ex Baker f.
FABACEAE	*Crotalaria basipeta* R.Wilczek
FABACEAE	*Crotalaria baumii* Harms
FABACEAE	*Crotalaria becquetii* Baker f. ex R.Wilczek
FABACEAE	*Crotalaria bemba* R.Wilczek
FABACEAE	*Crotalaria bequaertii* Baker f.
FABACEAE	*Crotalaria blanda* Polhill
FABACEAE	*Crotalaria bongensis* Baker f.
FABACEAE	*Crotalaria bredoi* R.Wilczek
FABACEAE	*Crotalaria brevidens* Benth.
FABACEAE	*Crotalaria calycina* Schrank
FABACEAE	*Crotalaria campestris* Polhill
FABACEAE	*Crotalaria carsonii* Baker f.
FABACEAE	*Crotalaria caudata* Welw. ex Baker
FABACEAE	*Crotalaria cephalotes* Steud. ex A.Rich.
FABACEAE	*Crotalaria chirindae* Baker f.
FABACEAE	*Crotalaria chrysochloa* Baker f. ex Harms
FABACEAE	*Crotalaria chrysotricha* Polhill
FABACEAE	*Crotalaria cistoides* Welw. ex Baker
FABACEAE	*Crotalaria cleomifolia* Welw. ex Baker
FABACEAE	*Crotalaria comosa* Baker
FABACEAE	*Crotalaria confertiflora* Polhill
FABACEAE	*Crotalaria cornetii* Taub. & Dewèvre
FABACEAE	*Crotalaria crebra* Polhill
FABACEAE	*Crotalaria criniramea* Baker f. ex Polhill
FABACEAE	*Crotalaria cuspidata* Taub.
FABACEAE	*Crotalaria cylindrocarpa* DC.
FABACEAE	*Crotalaria cylindrostachys* Welw. ex Baker
FABACEAE	*Crotalaria debilis* Polhill
FABACEAE	*Crotalaria decora* Polhill
FABACEAE	*Crotalaria densicephala* Welw. ex Baker
FABACEAE	*Crotalaria deserticola* Taub. ex Baker f.
FABACEAE	*Crotalaria distans* Benth.
FABACEAE	*Crotalaria duboisii* R.Wilczek
FABACEAE	*Crotalaria egregia* Polhill
FABACEAE	*Crotalaria elisabethae* Baker f.
FABACEAE	*Crotalaria ephemera* Polhill
FABACEAE	*Crotalaria eurycalyx* Polhill
FABACEAE	*Crotalaria filicaulis* Welw. ex Baker
FABACEAE	*Crotalaria flavicarinata* Baker f.

FABACEAE	*Crotalaria florida* Welw. ex Baker
FABACEAE	*Crotalaria friesii* I.Verd.
FABACEAE	*Crotalaria gamwelliae* Baker f.
FABACEAE	*Crotalaria germainii* R.Wilczek
FABACEAE	*Crotalaria glauca* Willd.
FABACEAE	*Crotalaria glaucifolia* Baker
FABACEAE	*Crotalaria goetzei* Harms
FABACEAE	*Crotalaria goreensis* Guill. & Perr.
FABACEAE	*Crotalaria graminicola* Taub. ex Baker
FABACEAE	*Crotalaria grandistipulata* Harms
FABACEAE	*Crotalaria huillensis* Taub.
FABACEAE	*Crotalaria incana* L.
FABACEAE	*Crotalaria involutifolia* Polhill
FABACEAE	*Crotalaria ionoptera* Polhill
FABACEAE	*Crotalaria johnstonii* Baker f.
FABACEAE	*Crotalaria juncea* L.
FABACEAE	*Crotalaria kambolensis* Baker f.
FABACEAE	*Crotalaria kapiriensis* De Wild.
FABACEAE	*Crotalaria kerkvoordei* R.Wilczek
FABACEAE	*Crotalaria kipandensis* Baker f.
FABACEAE	*Crotalaria kipilaensis* R.Wilczek
FABACEAE	*Crotalaria kuiririensis* Baker f.
FABACEAE	*Crotalaria kwengeensis* R.Wilczek
FABACEAE	*Crotalaria laburnifolia* L.
FABACEAE	*Crotalaria lachnocarpoides* Engl.
FABACEAE	*Crotalaria lachnophora* Hochst. ex A.Rich.
FABACEAE	*Crotalaria lanceolata* E. Mey.
FABACEAE	*Crotalaria lasiocarpa* Polhill
FABACEAE	*Crotalaria laxiflora* Baker
FABACEAE	*Crotalaria lepidissima* Baker f.
FABACEAE	*Crotalaria leptoclada* Harms
FABACEAE	*Crotalaria limosa* Polhill
FABACEAE	*Crotalaria lukafuensis* De Wild.
FABACEAE	*Crotalaria microcarpa* Hochst. ex Benth.
FABACEAE	*Crotalaria microthamnus* Robyns ex R.Wilczek
FABACEAE	*Crotalaria minutissima* Baker f.
FABACEAE	*Crotalaria miranda* Milne-Redh.
FABACEAE	*Crotalaria modesta* Polhill
FABACEAE	*Crotalaria morumbensis* Baker f.
FABACEAE	*Crotalaria natalitia* Meisn.
FABACEAE	*Crotalaria nigricans* Baker
FABACEAE	*Crotalaria nuda* Polhill
FABACEAE	*Crotalaria nudiflora* Polhill
FABACEAE	*Crotalaria nyikensis* Baker
FABACEAE	*Crotalaria occidentalis* Hepper

FABACEAE	*Crotalaria ochroleuca* G. Don.
FABACEAE	*Crotalaria ononoides* Benth.
FABACEAE	*Crotalaria onusta* Polhill
FABACEAE	*Crotalaria orthoclada* Welw. ex Baker
FABACEAE	*Crotalaria pallida* Aiton
FABACEAE	*Crotalaria pallidicaulis* Harms
FABACEAE	*Crotalaria parvula* Welw. ex Baker
FABACEAE	*Crotalaria passerinoides* Taub.
FABACEAE	*Crotalaria peregrina* Polhill
FABACEAE	*Crotalaria pisicarpa* Welw. ex Baker
FABACEAE	*Crotalaria platysepala* Harv.
FABACEAE	*Crotalaria podocarpa* DC.
FABACEAE	*Crotalaria polysperma* Kotschy ex Schweinf.
FABACEAE	*Crotalaria polytricha* Polhill
FABACEAE	*Crotalaria praetexta* Polhill
FABACEAE	*Crotalaria prittwitzii* Baker f.
FABACEAE	*Crotalaria prolongata* Baker
FABACEAE	*Crotalaria pseudodiloloensis* R.Wilczek
FABACEAE	*Crotalaria pseudotenuirama* Torre
FABACEAE	*Crotalaria pygmaea* Polhill
FABACEAE	*Crotalaria quangensis* Taub.
FABACEAE	*Crotalaria quarrei* Baker f.
FABACEAE	*Crotalaria recta* Steud. ex A.Rich.
FABACEAE	*Crotalaria reptans* Taub.
FABACEAE	*Crotalaria rhodesiae* Baker f.
FABACEAE	*Crotalaria ringoetii* Baker f.
FABACEAE	*Crotalaria rogersii* Baker f.
FABACEAE	*Crotalaria senegalensis* (Pers.) Bacle ex DC.
FABACEAE	*Crotalaria sertulifera* Taub.
FABACEAE	*Crotalaria shirensis* (Baker f.) Milne-Redh.
FABACEAE	*Crotalaria simoma* Polhill
FABACEAE	*Crotalaria sparsifolia* Baker
FABACEAE	*Crotalaria spartea* Baker
FABACEAE	*Crotalaria sphaerocarpa* Perr. ex DC.
FABACEAE	*Crotalaria spinosa* Hochst. ex Benth.
FABACEAE	*Crotalaria stenoptera* Welw. ex Baker
FABACEAE	*Crotalaria steudneri* Schweinf.
FABACEAE	*Crotalaria streptorryncha* Milne-Redh.
FABACEAE	*Crotalaria subcaespitosa* Polhill
FABACEAE	*Crotalaria subcapitata* De Wild.
FABACEAE	*Crotalaria subtilis* Polhill
FABACEAE	*Crotalaria sylvicola* Baker
FABACEAE	*Crotalaria tabularis* Baker f.
FABACEAE	*Crotalaria tenuipedicellata* Baker f.
FABACEAE	*Crotalaria tenuirama* Welw. ex Baker

FABACEAE	*Crotalaria teretifolia* Milne-Redh.
FABACEAE	*Crotalaria trinervia* Polhill
FABACEAE	*Crotalaria tristis* Polhill
FABACEAE	*Crotalaria ulbrichiana* Harms
FABACEAE	*Crotalaria umbellifera* R.E.Fr.
FABACEAE	*Crotalaria unicaulis* Bullock
FABACEAE	*Crotalaria valida* Baker
FABACEAE	*Crotalaria vandenbrandtii* R.Wilczek
FABACEAE	*Crotalaria vanmeelii* R.Wilczek
FABACEAE	*Crotalaria variegata* Welw. ex Baker
FABACEAE	*Crotalaria virgulata* Klotzsch
CUCURBITACEAE	*Cucumis africanus* L.f.
CUCURBITACEAE	*Cucumis anguria* L.
CUCURBITACEAE	*Cucumis ficifolius* A. Rich
CUCURBITACEAE	*Cucumis hirsutus* Sond.
CUCURBITACEAE	*Cucumis humifructus* Stent
CUCURBITACEAE	*Cucumis metuliferus* E.Mey. ex Naudin
CUCURBITACEAE	*Cucumis myriocarpus* Naud. subsp. *myriocarpus*
CUCURBITACEAE	*Cucumis sacleuxii* Paill. & Bois
CUCURBITACEAE	*Cucumis zeyheri* Sond.
DIOSCOREACEAE	*Dioscorea asteriscus* Burkill
DIOSCOREACEAE	*Dioscorea baya* De Wild.
DIOSCOREACEAE	*Dioscorea bulbifera* L.
DIOSCOREACEAE	*Dioscorea cochleari-apiculata* De Wild
DIOSCOREACEAE	*Dioscorea dumetorum* (Kunth) Pax
DIOSCOREACEAE	*Dioscorea hirtiflora* Benth.
DIOSCOREACEAE	*Dioscorea hylophila* Harms ex Engl.
DIOSCOREACEAE	*Dioscorea liebrechtsiana* De Wild. & T.Durand
DIOSCOREACEAE	*Dioscorea mundii* Baker
DIOSCOREACEAE	*Dioscorea odoratissima* Pax
DIOSCOREACEAE	*Dioscorea praehensilis* Benth.
DIOSCOREACEAE	*Dioscorea preussii* Pax
DIOSCOREACEAE	*Dioscorea quartiniana* A.Rich.
DIOSCOREACEAE	*Dioscorea sansibarensis* Pax
DIOSCOREACEAE	*Dioscorea schimperiana* Hochst. ex Kunth
DIOSCOREACEAE	*Dioscorea sylvatica* Eckl.
POACEAE	*Eleusine coracana* (L.) Gaertn. subsp. *africana*
POACEAE	*Eleusine indica* (L.) Gaertn.
MALVACEAE	*Hibiscus acetosella* Welw. ex Hiern
MALVACEAE	*Hibiscus allenii* Sprang & Hutch.
MALVACEAE	*Hibiscus articulatus* Hoschst. ex A. Rich
MALVACEAE	*Hibiscus caesius* Garcke
MALVACEAE	*Hibiscus cannabinus* L.
MALVACEAE	*Hibiscus debeerstii* De Wild
MALVACEAE	*Hibiscus diversifolius* Jacq. subsp. *rivularis*

MALVACEAE	*Hibiscus dongolensis* Caill. ex Delile
MALVACEAE	*Hibiscus hiernianus* Exell & Mendonca
MALVACEAE	*Hibiscus lobatus* (Murr.) Kuntze
MALVACEAE	*Hibiscus ludwigii* Eckl. & Zeyh.
MALVACEAE	*Hibiscus mastersianus* Hiern
MALVACEAE	*Hibiscus mechowii* Garcke
MALVACEAE	*Hibiscus meeusei* Exell
MALVACEAE	*Hibiscus micranthus* L f.
MALVACEAE	*Hibiscus migeodii* Exell
MALVACEAE	*Hibiscus nigricaulis* Baker f.
MALVACEAE	*Hibiscus noldeae* Baker f.
MALVACEAE	*Hibiscus nyikensis* Sprague
MALVACEAE	*Hibiscus ovalifolius* (Forssk.) Vahl
MALVACEAE	*Hibiscus panduriformis* Burm f.
MALVACEAE	*Hibiscus physaloides* Guill. & Perr.
MALVACEAE	*Hibiscus platycalyx* Mast.
MALVACEAE	*Hibiscus praeteritus* R.A. Dyer
MALVACEAE	*Hibiscus rhabdotospermus* Garcke
MALVACEAE	*Hibiscus rhodanthus* Gürke apud Schinz
MALVACEAE	*Hibiscus richardsiae* Exell
MALVACEAE	*Hibiscus rostellatus* Guill. & Perr.
MALVACEAE	*Hibiscus schinzii* Gürke
MALVACEAE	*Hibiscus shirensis* Sprague & Hutch
MALVACEAE	*Hibiscus sidiformis* Baill.
MALVACEAE	*Hibiscus surettensis* L
MALVACEAE	*Hibiscus trionum* L.
MALVACEAE	*Hibiscus vitifolius* L.
CONVOLVULACEAE	*Ipomoea aquatica* Forssk.
CONVOLVULACEAE	*Ipomoea asarifolia* (Desr.) Roem. & Schult.
CONVOLVULACEAE	*Ipomoea barteri* Baker
CONVOLVULACEAE	*Ipomoea blepharophylla* Hallier f.
CONVOLVULACEAE	*Ipomoea bolusiana* Schinz
CONVOLVULACEAE	*Ipomoea cairica* (L.) Sweet
CONVOLVULACEAE	*Ipomoea chloroneura* Hallier f.
CONVOLVULACEAE	*Ipomoea chrysoch* Hallier f.
CONVOLVULACEAE	*Ipomoea chrysochaetia* Hallier f.
CONVOLVULACEAE	*Ipomoea coptica* (L.) Roth ex Roem. & Schult. Var. *coptica*
CONVOLVULACEAE	*Ipomoea coscinosperma* Hochst. ex Choisy
CONVOLVULACEAE	*Ipomoea crassipes* Hook.
CONVOLVULACEAE	*Ipomoea crepidiformis* Hallier f. var. *microcephala*
CONVOLVULACEAE	*Ipomoea crepidiformis* Hallier f. var *minor*
CONVOLVULACEAE	*Ipomoea decora* Hochst. ex Choisy
CONVOLVULACEAE	*Ipomoea dichroa* Hochst. ex Choisy
CONVOLVULACEAE	*Ipomoea eriocarpa* R.Br.
CONVOLVULACEAE	*Ipomoea fanshawei* Verdc.

CONVOLVULACEAE	*Ipomoea fulvicaulis* (Hochst. ex Choisy) Boiss. ex Hallier f. var. *fuvicaulis*
CONVOLVULACEAE	*Ipomoea fulvicaulis* (Hochst. ex Choisy) Boiss. ex Hallier f. var. *heterocalyx*
CONVOLVULACEAE	*Ipomoea fulvicaulis* (Hochst. ex Choisy) Boiss. ex Hallier f. var. *asperifolia*
CONVOLVULACEAE	*Ipomoea hederifolia* L.
CONVOLVULACEAE	*Ipomoea heterotricha* Didr.
CONVOLVULACEAE	*Ipomoea hochsteteri* House
CONVOLVULACEAE	*Ipomoea holubii* Baker
CONVOLVULACEAE	*Ipomoea humidicola* Verdc.
CONVOLVULACEAE	*Ipomoea involucrata* P.Beauv. subsp. var. *involucrata*
CONVOLVULACEAE	*Ipomoea kituiensis* Vatke
CONVOLVULACEAE	*Ipomoea lapathifoli*a Hallier f. var. *lapathifolia*
CONVOLVULACEAE	*Ipomoea leucanthemum* (Klotzsch) Hallier f.
CONVOLVULACEAE	*Ipomoea linosepala* Hallier f.
CONVOLVULACEAE	*Ipomoea linosepala* Hallier f. subsp. *alpina*
CONVOLVULACEAE	*Ipomoea mauritiana* Jacq.
CONVOLVULACEAE	*Ipomoea milnei* Verdc.
CONVOLVULACEAE	*Ipomoea obscura* (L.) Ker Gawl.
CONVOLVULACEAE	*Ipomoea ochracea* (Lindl.) Sweet
CONVOLVULACEAE	*Ipomoea oenotherae* (vatke) Hallier f.
CONVOLVULACEAE	*Ipomoea papilio* Hallier f.
CONVOLVULACEAE	*Ipomoea parasitica* (Kunth) G.Don
CONVOLVULACEAE	*Ipomoea pes-caprae* (L.) Sweet subsp. *brasiliensis*
CONVOLVULACEAE	*Ipomoea pes-caprae* (L.) Sweet
CONVOLVULACEAE	*Ipomoea pes-tigridis* L. var. *pes-tigridis*
CONVOLVULACEAE	*Ipomoea pes-tigridis* L. var. *strigosa*
CONVOLVULACEAE	*Ipomoea pileata* Roxb.
CONVOLVULACEAE	*Ipomoea plebeia* R.Br. subsp. *Africana*
CONVOLVULACEAE	*Ipomoea polymorpha* Roem. & Schult
CONVOLVULACEAE	*Ipomoea primatosyphon* Welw.
CONVOLVULACEAE	*Ipomoea protea* Britten & Rendle
CONVOLVULACEAE	*Ipomoea purpurea* (L.) Roth
CONVOLVULACEAE	*Ipomoea recta* De Wild.
CONVOLVULACEAE	*Ipomoea richardsiae* Verdc
CONVOLVULACEAE	*Ipomoea rubens* Choisy
CONVOLVULACEAE	*Ipomoea shirambensis* Baker
CONVOLVULACEAE	*Ipomoea shupangensis* Baker
CONVOLVULACEAE	*Ipomoea sinensis* (Desr.) Choisy subsp. *blepharosepala*
CONVOLVULACEAE	*Ipomoea sinensis* (Desr.) Choisy subsp. *sinensis*
CONVOLVULACEAE	*Ipomoea stenosiphon* Hallier f.
CONVOLVULACEAE	*Ipomoea tenuipes* Verdc.
CONVOLVULACEAE	*Ipomoea tenuirostris* Steud. & Chosy subsp. *tenuirostris*
CONVOLVULACEAE	*Ipomoea tuberculata* Ker Gawl. var. *odontosepala*
CONVOLVULACEAE	*Ipomoea turbinata* Lag.
CONVOLVULACEAE	*Ipomoea venosa* (Desr.) Roem. & Schult subsp. *stellaris*
CONVOLVULACEAE	*Ipomoea venosa* (Desr.) Roem. & Schult subsp. *venosa*

CONVOLVULACEAE	*Ipomoea verbascoidea* Choisy
CONVOLVULACEAE	*Ipomoea vernalis* R.E.Fr.
CONVOLVULACEAE	*Ipomoea welwitschii* Vatke ex Hallier f.
CONVOLVULACEAE	*Ipomoea wightii* (Wall.) Choisy subsp. var. *wightii*
ASTERACEAE	*Lactuca calophylla* C.Jeffrey
ASTERACEAE	*Lactuca homblei* De Wild.
ASTERACEAE	*Lactuca imbricata* Hiern
ASTERACEAE	*Lactuca inermis* Forssk.
ASTERACEAE	*Lactuca lasiorhiza* (O.Hoffm.) C.Jeffrey
ASTERACEAE	*Lactuca longispicata* De Wild.
ASTERACEAE	*Lactuca mwinilungensis* G.V.Pope
ASTERACEAE	*Lactuca praecox* R.E.Fr.
ASTERACEAE	*Lactuca schulzeana* Büttner
ASTERACEAE	*Lactuca schweinfurthii* Oliv. & Hiern
ASTERACEAE	*Lactuca setosa* Stebbins ex C.Jeffrey
ASTERACEAE	*Lactuca zambeziaca* C.Jeffrey
CUCURBITACEAE	*Lagenaria breviflora* (Berth.) Roberty
CUCURBITACEAE	*Lagenaria siceraria* (Molina) Standl.
CUCURBITACEAE	*Lagenaria sphaerica* (Sond.) Naudin
CUCURBITACEAE	*Momordica balsamina* L
CUCURBITACEAE	*Momordica boivinii* Baill.
CUCURBITACEAE	*Momordica cardiospermoides* Klotzsch
CUCURBITACEAE	*Momordica charantia* L
CUCURBITACEAE	*Momordica corymbifera* Hook f.
CUCURBITACEAE	*Momordica foetida* Schumach.
CUCURBITACEAE	*Momordica kirkii* (Hook.f.) C.Jeffrey
CUCURBITACEAE	*Momordica peteri* Zimmermann
FABACEAE	*Mucuna coriacea* Baker
FABACEAE	*Mucuna deeringiana* (Bort) Merr.
FABACEAE	*Mucuna glabrialata* (Hauman) Verdc.
FABACEAE	*Mucuna poggei* Taub.
FABACEAE	*Mucuna stans* Welw. ex Baker
POACEAE	*Oryza barthii* A. Chev.
POACEAE	*Oryza brachyantha* Chev. & Roehr.
POACEAE	*Oryza longistaminata* A. Chev. & Roehr.
POACEAE	*Oryza punctata* Steud
POACEAE	*Oryza schweinfurthiana* Prodoehl
POACEAE	*Pennisetum macrourum* Trin.
POACEAE	*Pennisetum pedicillatum* Trin.
POACEAE	*Pennisetum polystachion* (L.) Schult. subsp. *atrichum*
POACEAE	*Pennisetum polystachion* (L.) Schult. subsp. p*olystachion*
POACEAE	*Pennisetum purpureum* Schumach.
POACEAE	*Pennisetum setaceum* (Forssk.) Chiov.
POACEAE	*Pennisetum thunbergii* Kunth
POACEAE	*Pennisetum trachyphyllum* Pilg.

POACEAE	*Pennisetum typhodes* (Burm f.) Stapf & C.E.Hubb.
POACEAE	*Pennisetum unisetum* (Nees) Benth.
LAMIACEAE	*Plectranthus acaulis* Brummitt & Seyani
LAMIACEAE	*Plectranthus alboviolaceus* Gürke
LAMIACEAE	*Plectranthus betonicaefolius* Baker
LAMIACEAE	*Plectranthus buchananii* Baker
LAMIACEAE	*Plectranthus candelabriformis* Launert
LAMIACEAE	*Plectranthus caninus* Roth
LAMIACEAE	*Plectranthus comosus* Sims
LAMIACEAE	*Plectranthus cylindraceus* Hochst. ex Benth
LAMIACEAE	*Plectranthus equisetiformis* (E.A.Bruce) Launert
LAMIACEAE	*Plectranthus esculentus* N.E.Br.
LAMIACEAE	*Plectranthus flaccidus* (Vatke) Gürke
LAMIACEAE	*Plectranthus goetzei* Gürke
LAMIACEAE	*Plectranthus gracillimus* (T.C.E Fr.) Hutch. & Dandy
LAMIACEAE	*Plectranthus hjalmarii* (T.C.E Fr.) Hutch. & Dandy
LAMIACEAE	*Plectranthus kapatensis* (R.E.Fr.) J.K. Morton
LAMIACEAE	*Plectranthus laxiflorus* Benth.
LAMIACEAE	*Plectranthus luteus* Gürke
LAMIACEAE	*Plectranthus masukensis* Baker
LAMIACEAE	*Plectranthus mirabilis* (Briq.) Launert
LAMIACEAE	*Plectranthus modestus* Baker
LAMIACEAE	*Plectranthus neochilus* Schltr
LAMIACEAE	*Plectranthus nyikensi*s Baker
LAMIACEAE	*Plectranthus primulinus* Baker
LAMIACEAE	*Plectranthus stenophyllus* Baker
LAMIACEAE	*Plectranthus tetensis* (Baker) Agnew
LAMIACEAE	*Plectranthus tetragonus* Gürke
LAMIACEAE	*Plectranthus thyrsoideus* (Baker) B. Mathew
LAMIACEAE	*Plectranthus viphyensis* Brummitt & Seyani
LAMIACEAE	*Plectranthus zebrarum* Brummitt & Seyani
PEDALIACEAE	*Sesamum alatum* Thonn.
PEDALIACEAE	*Sesamum angolense* Welw.
PEDALIACEAE	*Sesamum angustifolium* (Oliv.) Engl.
PEDALIACEAE	*Sesamum calycinum* Welw. subsp. *baumii*
PEDALIACEAE	*Sesamum calycinum* Welw. subsp. c*alycinum*
FABACEAE	*Sesbania bispinosa* (Jacq.) W.Wight
FABACEAE	*Sesbania cinerascens* Welw. ex Baker
FABACEAE	*Sesbania coerulescens* Harms
FABACEAE	*Sesbania goetzei* Harms
FABACEAE	*Sesbania greenwayii* J.B. Gillett
FABACEAE	*Sesbania macrantha* Welw. ex E. Phillips & Hutch.
FABACEAE	*Sesbania microphylla* Harms ex E. Phillips & Hutch.
FABACEAE	*Sesbania mossambicensis* Klotzsch
FABACEAE	*Sesbania rogersii* E. Phillips & Hutch

FABACEAE	*Sesbania sesban* (L.) Merr.
FABACEAE	*Sesbania tetraptera* Hochst. ex Baker
SOLANACEAE	*Solanum aculeatissimum* Jacq.
SOLANACEAE	*Solanum anguivi* Lam.
SOLANACEAE	*Solanum aureitomentosum* Bitter
SOLANACEAE	*Solanum dasyphyllum* Schumach.
SOLANACEAE	*Solanum goetzei* Dammer
SOLANACEAE	*Solanum incanum* L.
SOLANACEAE	*Solanum lagascae* Roem. & Schult.
SOLANACEAE	*Solanum macrocarpon* L.
SOLANACEAE	*Solanum nigrum* L.
SOLANACEAE	*Solanum richardii* Dunal
SOLANACEAE	*Solanum rothii* C.H. Wright
SOLANACEAE	*Solanum taitense* Vatke
SOLANACEAE	*Solanum terminale* Forssk.
SOLANACEAE	*Solanum tettense* Klotzsch var. *renschii*
POACEAE	*Sorghastrum friesii* (Pilg.) Pilg.
POACEAE	*Sorghastrum fuscescens* (Pilg.) Clayton
POACEAE	*Sorghastrum incompletum* (J. Presl) Nash var. *bipennatum*
POACEAE	*Sorghastrum nudipes* Nash
POACEAE	Sorghastrum pogonostachyum (Stapf) Clayton
POACEAE	*Sorghastrum stipoides* (Kunth) Nash
POACEAE	*Sorghum arundinaceum* (Desv.) Stapf
POACEAE	*Sorghum bicolor* (L.) Moench subsp. *verticiflorum*
POACEAE	*Sorghum purpureosericeum* (Hochst. ex A. Rich.) Asch. & Schweinf.
POACEAE	*Sorghum versicolor* Andersson
FABACEAE	*Vigna antunesii* Harms
FABACEAE	*Vigna comosa* Baker
FABACEAE	*Vigna fischeri* Harms
FABACEAE	*Vigna frutescens* A. Rich.
FABACEAE	*Vigna gracilis* (Guill. & Perr.) Hook.f
FABACEAE	*Vigna haumaniana* R. Wilczek
FABACEAE	*Vigna heterophylla* A. Rich.
FABACEAE	*Vigna juncea* Milne-Redh
FABACEAE	*Vigna kirkii* (Baker) J.B. Gillett
FABACEAE	*Vigna longissima* Hutch.
FABACEAE	*Vigna luteola* (Jacq.) Benth
FABACEAE	*Vigna macrorhyncha* (Harms) Milne-Redh
FABACEAE	*Vigna monophylla* Taub.
FABACEAE	*Vigna multinervis* Hutch. & Dalziel
FABACEAE	*Vigna nuda* N.E.Br.
FABACEAE	*Vigna oblongifolia* A. Rich. var. *oblingifolia*
FABACEAE	*Vigna oblongifolia* A. Rich. var. *Parvifolia*
FABACEAE	*Vigna parkeri* Baker
FABACEAE	*Vigna parkeri* Baker subsp. *maranguensis*

FABACEAE	*Vigna phoenix* Brummitt
FABACEAE	*Vigna platyloba* Hierm
FABACEAE	*Vigna procera* Welw. ex Hiern
FABACEAE	*Vigna pygmaea* R.E.Fr.
FABACEAE	*Vigna racemosa* (G.Don) Hutch
FABACEAE	*Vigna radiata* (L.) Wilczek var. *sublobata*
FABACEAE	*Vigna radicans* Welw. ex Baker
FABACEAE	*Vigna reticulata* Hook. f.
FABACEAE	*Vigna richardsiae* Verdc.
FABACEAE	*Vigna triphylla* (R. Wilczek) Verdc.
FABACEAE	*Vigna unguiculata* (L.) Walp. var. *spontanea*
FABACEAE	*Vigna unguiculata* (L.) Walp. subsp. *dekindtiana*
FABACEAE	*Vigna unguiculata* (L.) Walp. subsp. *pawekiae*
FABACEAE	*Vigna unguiculata* (L.) Walp. subsp. *tenuis*
FABACEAE	*Vigna vexillata* (L.) A. Rich.
FABACEAE	*Vigna wittei* Baker f.