

# Diversity of cocoyam-based agroforestry systems in Benin, West Africa

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## Research Article

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# Abstract

Cocoyam-based agroforestry systems in Benin remain poorly characterized, despite their ecological and cultural importance to local livelihoods. Limited documentation of associated plant species and traditional management practices constrains efforts toward the sustainable use of this neglected crop. This study explored the species diversity, domestication levels, and ethnobotanical knowledge related to cocoyam-associated plants across six agro-ecological zones and seven departments of Benin.

Data were collected using semi-structured interviews across the region of the field study. Species diversity associated with cocoyam production was listed in accordance to an inventory based on the flora of Benin through 56 farm units, commonly called agroforestry systems; on the flora of Benin IUCN online database; on the Red List of threatened plant species in Benin; on the Biodiversity Atlas for West Africa; and on the online database of the Plant Resources of Tropical Africa. Meanwhile, the domestication status was assessed using six levels ranging from wild (level 0) to fully cultivated species with pest and disease management (level 5). Species prioritization was determined using eight criteria (native status, economic and ethnobotanical value, global and national distribution, *in situ* and *ex situ* conservation status, legislation, and threat assessment) combined across four prioritization methods (point scoring, weighted point scoring, compound ranking, and binomial ranking). A super-prioritization of these methods was applied to identify the highest-priority species for conservation.

In total, 48 species representing 26 families and 41 genera were documented. The Bar Land Zone showed the highest diversity (85.18% of families), followed by the Fisheries (66.66%) and Food Crops (20%) zones. The Leguminosae family dominated, followed by Rubiaceae, Anacardiaceae, Meliaceae, and Musaceae. Level 5 species were the most represented (23 species). Leaves were the most used plant part (27%), followed by wood (25%) and fruits (20%), primarily for therapeutic (25%), nutritional (18%), and craft (10%) purposes, reflecting the multifunctional value of these plants in rural communities.

Twelve plant species (*Vitellaria paradoxa*, *Morinda lucida*, *Khaya senegalensis*, *Parkia biglobosa*, *Albizia zygia*, *Rauvolfia vomitoria*, *Anogeissus leiocarpa*, *Sarcocephalus latifolius*, *Vitex doniana*, *Cola nitida*, *Caesalpinia bonduc*, and *Newbouldia laevis*) were prioritized for domestication and conservation for sustainable valorization of agrobiodiversity in Benin.

## 1. Introduction

Agroforestry systems are widely recognized as sustainable land-use strategies that integrate trees or shrubs with crops or livestock, fostering ecological and socio-economic interactions among components (FAO 2023). These systems play a crucial role in national economies by supporting smallholder livelihoods, enhancing socio-economic resilience, and delivering important environmental benefits (Leakey and Prabh 2017; Castle et al. 2021). Through crop diversification, agroforestry increases productivity, ensures year-round harvests, reduces food and income insecurity, and provides additional revenue streams for farming households (Mariel et al. 2021; Hajjar et al. 2021). Empirical studies further show that farmers adopting cash-crop agroforestry are better able to meet household needs, including education and living standards (Llopis et al. 2020; Iiyama et al. 2014), while also producing valuable resources such as fruits, fodder, and medicinal products (Thevs et al. 2022). Beyond economic value, agroforestry delivers sociocultural benefits, including improved landscape aesthetics and the demarcation of farmland (Gassner & Dobie 2022). Collectively, these attributes position agroforestry as a cornerstone for sustainable development and natural resource preservation (Smith & Mbow 2014; Castle et al. 2021).

Agroforestry practices are among the oldest farming systems globally, often associated with smallholder farmers operating with limited technology and resources in environments unsuitable for monoculture. Agroforestry can take multiple forms, including agrosilvicultural systems (trees combined with crops), silvopastoral systems (trees with livestock), and agrosilvopastoral systems (integration of trees, crops, and livestock). These systems are particularly relevant in regions facing population growth and rising food demand. The global population is projected to reach 9.1 billion by 2050 (UN, 2013), with Africa experiencing the fastest demographic increase (Mounthford & Rapport 2016). This demographic pressure necessitates intensified agronomic research on neglected and underutilized species, such as cocoyam (*Xanthosoma sagittifolium* (white cultivar) and *Colocasia esculenta* (Red cultivar)), which offer potential as alternative food sources and climate-resilient crops.

Cocoyam-based agroforestry involves integrating cocoyam cultivation with trees and other crops, thereby enhancing biodiversity, improving soil fertility, and diversifying household income. Despite its potential, cocoyam remains largely neglected in research and development programs, and guidance on profitable production systems in tropical contexts is limited. Yet, orphan crops such as cocoyam are increasingly recognized for their importance in addressing local food and livelihood challenges (Borelli et al. 2020). They contribute to sustainable food systems by promoting dietary diversity, strengthening the resilience of underutilized cropping systems, and expanding cultivation into new agro-ecological zones (Mabhaudhi et al. 2019; Jamnadass et al. 2020; Ulian et al. 2020). In Africa, cocoyam plays an important role in household food security, particularly in traditional home gardens where root crops serve as staple carbohydrate sources.

Given these considerations, studying cocoyam-based agroforestry is essential for both conservation and sustainable use. Such systems not only support the preservation of a multi-use, threatened species, but also provide insights into the diversity of associated non-timber forest products that enhance rural livelihoods. The present study aims to fill this gap by documenting cocoyam-based agroforestry systems in Benin. Specifically, it seeks to: (i) assess the diversity of species associated with cocoyam cultivation; (ii) identify domestication strategies applied to these associated species; and (iii) determine priority species for domestication and conservation.

## 2. Methodology

### 2.1. Study area

This study was conducted in the Republic of Benin, located between the latitudes of 6°10' N and 12°25' N and the longitudes of 0°45' E 3°55' E. Benin is characterized by three major climatic zones. The southern region is relatively humid (varying between 75% and 95%), with two rainy seasons and an annual rainfall amount ranging from 1.100 to 1.400 mm. In southern Benin, the climatic zone is classified as sub-equatorial, characterized by relatively high and stable humidity throughout the year. In contrast, the northern region experiences a single rainy season and a markedly drier climate, with relative humidity dropping to between 20% and 30% during the dry season and rising to moderate levels, ranging from 50% to 70%, during the rainy season (Vodounhè et al. 2012). The annual rainfall varies between 800 and 950 mm, with a tropical dry climate. Average annual temperatures vary between 26°C and 28°C in southern localities, and can exceptionally reach 35°C to 40°C in northern localities (Adomou 2005; Akoegninou et al. 2006). The vegetation in the south is characterized by evergreen and semi-deciduous forests, degraded due to urban expansion, commonly referred to as Guinean-Congolese, while the north is characterized by savannahs, woodlands, and shrub savannahs, recognized under the category of Sudanian vegetation (Akoegninou et al. 2006). For ecological and agricultural purposes, Benin is divided into eight agro-ecological zones. However, this study was carried out specifically across six representative agro-ecological zones—namely, the Depression Zone, South Borgou Crop Zone, West Atacora Zone, Central Cotton Zone, Fisheries Zone, and Bar Land Zone. Among these, the West Atacora Zone and the South Borgou Crop Zone were the two zones covered in the northern region, while the other five zones are located in the southern parts of the country (Fig. 1). This selection ensured that the study encompassed the main ecological gradients, land-use systems, and socio-economic contexts across Benin. The survey of agroforestry systems was conducted across these socio-economic zones (Adja, Aïzo, Fon, Holli, Nago, Tori, Goun, Gourmantché, Otamari, Ditamari, Natimba, Mahi, Ouémé) and the social structure (royal families and others) to capture both environmental variability and cultural diversity in resource management.

### 2.2. Sampling

Surveys of the species diversity associated with cocoyam cultivation were carried out in 16 municipalities throughout six agro-ecological zones. These municipalities were selected based on their agricultural status and the agro-ecological zone of interest according to cocoyam production. Specifically, 34 villages (2 or 3 per municipality) were selected randomly based on criteria such as accessibility and the agroforestry practice associated with cocoyam cultivation adopted by farmers, with the assistance of staff members of the Communal Cells of the Territorial Agency for Agricultural Development. This resulted in a total of 56 agroforestry systems. Each agroforestry system was considered as a sampling unit defined as a household-managed field or plot where tree and/or herbaceous plants and crops are integrated. The information collected on the species associated with cocoyam cultivation was as follows: their name (vernacular in local or vulgar languages); and the number of trees and/or

herbaceous plants and crops integrated within each farm unit, in accordance to the methods used by Houndjo Kpoviwanou et al. (2024). The socio-demographic factors of each cocoyam farmer (i.e., gender, age, origin, social background, level of education, number of years of farming activity), the level of domestication and the differences, as well as their knowledge on the use of the species associated with cocoyam cultivation, were obtained by surveying the farmers in their farm unit. Field surveys were conducted and flora inventories gathered in each farm unit and each agro-ecological zone, with the support of the owners using the flora of Benin (Akoègninou et al. 2006), the IUCN online database (IUCN 2018), the Red List of threatened plant species in Benin (Neuenschwander et al. 2011), the Biodiversity Atlas for West Africa (Sinsin et al. 2010), and the online database of the Plant Resources of Tropical Africa (PROTA 2018).

## **2.3. Data collection and analysis**

### **2.3.1. Diversity of plants species associated with cocoyam**

For each unit within the agroforestry system, the geographical coordinates were recorded, as well as the identity of the owner. The inventory focused on the cultivated crops and the associated trees, including the tree or crop's identify (species and family), the individual number of trees, and information on the use of the tree.

Data analysis involved calculating the relative frequency of each associated tree family within each agro-ecological zone using the following formula: Relative frequency (%) = (Number of occurrences of the family / Total occurrences of all families) × 100. Additionally, species diversity per family, the number of individuals per species, and the agro-ecological zone for each agroforestry system were recorded. All calculations were performed using Microsoft Excel, while R software (version 4.3.0) was employed to generate graphs illustrating the plant diversity associated with cocoyam.

### **2.3.2. Identification of the use and domestication strategies for the tree species associated with cocoyam**

Data were collected through individual questionnaire surveys focusing on harvested plant parts—such as bark, wood, leaves, flowers, fruits, and roots—and their respective uses, including food, medicinal, and medico-magical purposes. In addition, the mode of use and domestication level were assessed using the model developed by Vodounhè et al. (2012), which defines six domestication levels from wild (Level 0) to fully cultivated species with pest and disease management (Level 5).

### **2.3.3. Priority species to be combined with cocoyam**

The process of prioritization in this study involved ranking plant species associated with cocoyam, wherein the literature was searched to collect data regarding the species origin, its economic value, its ethnobotanical value, its global and national distribution, its conservation status (*in situ* and *ex situ*), existence of legislation, and threat assessments for prioritization purposes. The criteria used for prioritization of wild plant species were adapted from Brehm et al. (2008a, 2010). Scientific papers, the flora of Benin (Akoègninou et al. 2006), the IUCN online database (IUCN, 2018), the Red List of threatened plant species in Benin (Neuenschwander et al. 2011), the Biodiversity Atlas for West Africa (Sinsin et al. 2010), and the online database of the Plant Resources of Tropical Africa (PROTA, 2018) were used as complementary data. (Brehm et al. 2008a). To identify priority plant species associated with cocoyam cultivation for conservation, we adopted the approach proposed by Brehm et al. (2010) and subsequently applied by Idohou et al. (2012) to crop wild relatives in Benin. Eight criteria were considered: (i) native status, (ii) economic value, (iii) ethnobotanical relevance, (iv) global distribution, (v) national distribution, (vi) *in situ* and *ex situ* conservation status, (vii) legal framework, and (viii) threat status according to the IUCN Red List.

The prioritization process combined four complementary methods: Point Scoring Procedure (PSP); Point Scoring Procedure with Weighting (PSPW); Compound Ranking System (CRS); and Binomial Ranking System (BRS). In PSP, each inventoried species was assigned a score for each criterion (Table 1), and the overall score was obtained by summing the individual values. Species with higher overall scores were considered to have greater conservation priority. PSPW followed a similar procedure but incorporated criterion-specific weights (Table 1). Table 1 shows the weighting according to PSP, and the weights (%) of each criterion to the PSPW method, refer to the appendix. CRS was based on ranking species according to each criterion, with ranks subsequently combined into a composite score (Table 2) (refer to the appendix). BRS relied on a set of binary (yes/no) questions, where

positive answers (yes = 1) were systematically given precedence over negative ones (no = 0). Combinations of different criteria achieved different orders of importance (Table 3) (refer to appendix).

Table 1  
Weighting according to PSP (Point Scoring Procedure) and weights (%) of each criterion to the PSPW method  
(adapted from Brehm et al., 2010).

| Criteria                                                                                                                                                                                                      | Evaluation of criteria                                                                                                                                                                   | Score attribution PSP                                                         | (PSPW) Weight of Criteria (%) |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-------------------------------|
| Origin of the species                                                                                                                                                                                         | (a) Aboriginal; (b) introduced; (c) existence of doubt about the origin of the species; (d) no data                                                                                      | (a) 4 ; (b) 3 ; (c) 2 ; (d) 1.                                                | 15                            |
| Economic value (in millions of ton)                                                                                                                                                                           | (a) > 2M; (b) 1.75M < P < 2M; (c) 1.5M < P < 1.75M; (d) 1.25M < P < 1.5M; (e) 1M < P < 1.25M; (f) 0.75M < P < 1M; (g) 0.5M < P < 0.75M; (h) 0.25M < P < 0.5M; (i) P < 0.25M; (j) no data | (a) 9; (b) 8; (C) 7; (d) 6; (e) 5; (f) 4; g (3); (h) 2; (i) 1; (j) 0.         | 10                            |
| Ethnobotanical value                                                                                                                                                                                          | (a) food (b) medicinal (c) cultural / cultural, (d) ornamental fodder (f) other (g) no data                                                                                              | (a) 6 ; (b) 5 ; (c) 4 ; (d) 3 ; (e) 2 ; (f) 1 (g) 0                           | 20                            |
| Global distribution                                                                                                                                                                                           | (a) East / West / North / South / Central Africa; (b) all Africa (c) World; (d) no data                                                                                                  | (a) 6 ; (b) 5 ; (c) 4 ; (d) 3 ; (e) 2 ; (f) 1 ; (g) 0                         | 15                            |
| National distribution                                                                                                                                                                                         | (a) 1 (b) 2 (c) 3 (d) 4 (e) 5 (f) 6 (g) 7 (h) 8 (i) 9 (j) 10 (k) no data                                                                                                                 | (a) 10; (b) 9; (c) 8; (d) 7; (e) 6; (f) 5; (g) 4; (h) 3; (i) 2; (j) 1; (k) 0. | 75                            |
| Conservation status                                                                                                                                                                                           | (a) In situ (b) ex-situ (c) other or (d) no data                                                                                                                                         | (a) 4 ; (b) 3 ; (c) 2 ; (d) 1.                                                | 10                            |
| Legislation                                                                                                                                                                                                   | (a) international (b) national, (c) local or (d) no data                                                                                                                                 | (a) 4 ; (b) 3 ; (c) 2 ; (d) 1.                                                | 75                            |
| Threat Assessment                                                                                                                                                                                             | Expected (a) ;NE (b); DD (c), LC (d), NT (e),VU (f),EN (g) CR (h) EW (i) ,, EX(j).                                                                                                       | (a) 1; (b) 2; (c) 3; (d) 4; (e) 5; (f) 6; (g) 7, (h) 8, (i) 9;(j)10           | 15                            |
| Attribution of Scores CR: critically endangered; EN: in danger; VU: vulnerable; NT: near-threatened; LC: minor concern; DD: Insufficient data; NE: Not rated; EW: extinct in the wild, EX: extinct, Expected. |                                                                                                                                                                                          |                                                                               |                               |

Table 2  
Ranking allocation to the sub-criteria for each criterion

| Criteria                                                                                                                                                                                                                                                                                                                                                                                            | Rank of sub-criteria |                |                                                     |                  |                |                |                  |                  |           |         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------|-----------------------------------------------------|------------------|----------------|----------------|------------------|------------------|-----------|---------|
|                                                                                                                                                                                                                                                                                                                                                                                                     | R1                   | R2             | R3                                                  | R4               | R5             | R6             | R7               | R8               | R9        | R10     |
| Origin of the species                                                                                                                                                                                                                                                                                                                                                                               | Aboriginal           | Introduced     | existence of doubt about the origin of the species; | no data          | -              | -              | -                | -                | -         | -       |
| Economic value (in millions of ton)                                                                                                                                                                                                                                                                                                                                                                 | > 2M                 | 1,75M < P < 2M | 1,5M < P < 1,75M                                    | 1,25M < P < 1,5M | 1M < P < 1,25M | 0,75M < P < 1M | 0,5M < P < 0,75M | 0,25M < P < 0,5M | P < 0,25M | No data |
| Ethnobotanical value                                                                                                                                                                                                                                                                                                                                                                                | 6                    | 5              | 4                                                   | 3                | 2              | 1              | No data          | -                | -         | -       |
| Global distribution                                                                                                                                                                                                                                                                                                                                                                                 | 1 region             | 2 region       | 3 region                                            | 4 region         | All Africa     | World          | No data          | -                | -         | -       |
| National distribution                                                                                                                                                                                                                                                                                                                                                                               | 1                    | 2              | 3                                                   | 4                | 5              | 6              | 7                | 8                | 9         | 10      |
| Conservation status                                                                                                                                                                                                                                                                                                                                                                                 | In situ              | Ex situ        | Others                                              | No data          | -              | -              | -                | -                | -         | -       |
| Legislation                                                                                                                                                                                                                                                                                                                                                                                         | International        | National       | Local                                               | No data          | -              | -              | -                | -                | -         | -       |
| Threat Assessment                                                                                                                                                                                                                                                                                                                                                                                   | CR                   | EN             | VU                                                  | NT               | LC             | DD             | NE               | -                | -         | -       |
| CR: critically endangered; EN: in danger; VU: vulnerable; NT: near threatened; LC: minor concern; DD: Insufficient data; NE: Not rated. Ri = rank I the lower the rank of species, the higher the priority of the species. jRi = the number (j) of time where rank i appear for a given species. The lower the rank sum for a species, the higher the priority. It should be noted that $\sum jR_i$ |                      |                |                                                     |                  |                |                |                  |                  |           |         |

Table 3  
Definition of prioritization criteria according to the BSR (Binomial Ranking System) method

| Criteria                            | Evaluation of criteria | Binomial ranking |
|-------------------------------------|------------------------|------------------|
| Origin of the species               | Existence              | Yes (1) No (0)   |
| Economic value (in millions of ton) | Existence              | Yes (1) No (0)   |
| Ethnobotanical value                | Existence              | Yes (1) No (0)   |
| Global distribution                 | -                      | Yes (1) No (0)   |
| National distribution               | -                      | Yes (1) No (0)   |
| Conservation status                 | Existence              | Yes (1) No (0)   |
| Legislation                         | Existence              | Yes (1) No (0)   |
| Threat Assessment                   | Existence              | Yes (1) No (0)   |

Each method produced a sub-list of eight priority species. The frequency of occurrence of species across the different sub-lists was then recorded to calculate an overall score for each. A super-ranking of the four methods was performed, which allowed us to identify the species with the highest overall scores and designate them as top-priority for conservation. In cases where two or more species had equal scores, cultural significance and socio-economic considerations were used as tie-breakers.

## 3. Results

### 3.1. Diversity of agroforestry species

A total of 56 farm units in agroforestry systems were surveyed, revealing 48 trees or herbaceous species associated with cocoyam, across 26 families and 41 genera. Species diversity varied across the 6 agro-ecological zones, with the Bar Land Zone exhibiting the highest richness (32 species), followed by the Fisheries Zone (26 species), Central Cotton Zone (8), West Atacora Zone (5), and both the Food Crop and Depression Zones with 4 species each. The *Musa* genus was the most represented, with 3 different species (*Musa sapientum*, *Musa acuminata*, *Musa paradisiaca*), while legumes were the most dominant family, with 7 species.

Regarding the family diversity, the Bar Land Zone was the most diversified, with 23 families, followed by the Fisheries Zone, with 18 families, and the Central Cotton Zone, with 6 families (Fig. 2). Within the identified families, Leguminosae exhibited the highest species diversity, with 7 species, followed by Rubiaceae, Anacardiaceae, Meliaceae, and Musaceae (Fig. 3). Furthermore, more than 10 other families were represented by only a single species.

### 3.2. Species diversity according to the two cocoyam cultivars (red and white) found in the different agro-ecological zones

The red cultivar of cocoyam was associated with greater species diversity, with species such as *Moringa oleifera* and *Saccharum officinarum* more frequently found in its vicinity, while these species were almost completely absent around the white cultivar. Some species, including *Vernonia amygdalina* and *Tectona grandis*, were commonly associated with both cultivars (Fig. 4).

#### Caption

*Vernonia amygdalina* (VERN), *Tectona grandis* L.f. (TECT), *Spondias mombin* (SPON), *Musa sapientum* (MUSA), *Anacardium occidentale* (ANAC), *Nauclea latifolia* (NAUC), *Elaeis guineensis* (ELAI), *Citrus sinensis* (L) (CITR), *Artocarpus altilis* (ARTO), *Carica papaya* L. (CARI), *Newbouldia laevis* (NEWB), *Parkia bigomosa* (PARK), *Vitex domiana* (VITE), *Vitellaria paradoxa* (VITE), *Azadirachta indica* (AZAD), *Melia azedarach* (MELI), *Moringa oleifera* (MORI), *Musa paradisiaca* (MUSP), *Psidium guajava* (PSID), *Cocos nucifera* (COCU), *Rauvolfia vomitoria* (RAUV), *Jatropha multifida* (JATR), *Annona squamosa* (ANNO), *Morinda citrifolia* (MORI), *Khaya senegalensis* (KHAY), *Gmelina arborea* (GMEL), *Crescentia cujete* L. (CRES), *Leucena leucocephala* (LEUC), *Saccharum officinarum* L. (SACC), *Cassia alata* (CASS), *Morinda lucida* (MORI), *Acassia auriculiformis* (ACAS), *Annona muricata* (ANNO), *Anthocleista schweinfurthii* (ANTH), *Persea americana* (PERS), *Theobroma cacao* (THEO), *Citrus aurantifolia* (CITR).

### 3.3. Species use recorded in association with cocoyam

Different organs were used from the plant species in association with cocoyam cultivars. The utilization of leaves was the most commonly recorded (27%), followed by wood (25%), and fruits (20%) (Fig. 5). Moreover, species associated with cocoyam were primarily utilized for therapeutic purposes (25%), followed by food (18%), and craft-related uses (10%) (Fig. 6).

### 3.4. Level of domestication of species in association with cocoyam

Among the 48 species recorded, 23 were at the highest domestication level (Level 5), followed by 8 species receiving some care (Level 2), 7 under selective cultivation (Level 3), 5 well cultivated and reproduced (Level 4), 4 wild species (Level 0), and 1 merely spared during fieldwork (Level 1).

Caption: Merely spared during fieldwork, MSF (Level 1); Wild species, WS (Level 0); Well cultivated and reproduced, WCR (Level 4); Under selective cultivation, USC (Level 3); Species receiving some care, SRC (Level 2); Highly cultivated with selection, HCS (Level 5).

## 4. Species prioritization in association with cocoyam

### 4.1. Prioritization using the PSP and PSPW methods

PSP identified a list of priority plant species associated with cocoyam for conservation, revealing *Vitellaria paradoxa* to have the highest score of 93 from the Sapotaceae family, followed by *Elaeis guineensis* with a score of 90 from the Arecaceae family, and *Morinda lucida* with a score of 70 from the Rubiaceae family. Meanwhile, their scores according to PSPW were 9.6, 7.9, and 7.37, respectively, with the same ranking (Table 4) (refer to the appendix).

Table 4  
PSP and PSPW prioritization method scores.

|                                 |                        | Total score |      |
|---------------------------------|------------------------|-------------|------|
| Scientific Name                 | Scientific Name Family | PSP         | PSPW |
| <i>Vitellaria paradoxa</i>      | Sapotaceae             | 93          | 9.6  |
| <i>Elaeis guineensis</i>        | Arecaceae              | 90          | 7.92 |
| <i>Morinda lucida</i>           | Rubiaceae              | 74          | 7.37 |
| <i>Anacardium occidentale</i>   | Anacardiaceae          | 68          | 6.45 |
| <i>Parkia biglobosa</i>         | Leguminosea            | 66          | 6.25 |
| <i>Cola nitida</i>              | Sterculiaceae          | 64          | 6.17 |
| <i>Rauvolfia vomitoria</i>      | Apocynaceae            | 62          | 5.67 |
| <i>Newbouldia laevis</i>        | Bignoniaceae           | 61          | 5.62 |
| <i>Caesalpinia bonduc</i>       | Leguminosea            | 54          | 5.12 |
| <i>Vernonia amygdalina</i>      | Asteraceae             | 52          | 5.07 |
| <i>Sarcocephalus latifolius</i> | Rubiaceae              | 52          | 5.05 |
| <i>Albizia zygia</i>            | Leguminosea            | 51          | 4.9  |
| <i>Anogeissus leiocarpa</i>     | Combretaceae           | 45          | 4.32 |
| <i>Spondias mombin</i>          | Anacardiaceae          | 43          | 4.11 |
| <i>Khaya senegalensis</i>       | Meliaceae              | 41          | 4    |
| <i>Vitex doniana</i>            | Laminiaceae            | 39          | 3.85 |
| <i>Annona squamosa</i>          | Annoceae               | 33          | 3.77 |
| <i>Crescentia cujete L</i>      | Bignoniaceae           | 28          | 2.99 |
| <i>Jatropha multifida</i>       | Euphorbiaceae          | 26          | 2.77 |

## 4.2. Prioritization according to the CRS method

According to the rank scores derived from the CRS prioritization method (Table 5), *Jatropha multifida* was the highest priority, with a rank score of 19, followed by *Crescentia cujete* and *Vitex doniana*, with an equal score of 21, and *Anogeissus leiocarpa*, with a score of 23.

Table 5  
Rank scores derived from the CRS prioritization method.

| Scientific Name                 | Rank of Sub criteria | Total of Score |
|---------------------------------|----------------------|----------------|
| <i>Jatropha multifida</i>       | R1-3R2-R3-3R5        | 19             |
| <i>Crescentia cujete</i> L      | R1-3R2-2R3-2R6       | 21             |
| <i>Vitex doniana</i>            | R1-3R2-R3-2R5        | 21             |
| <i>Anogeissus leiocarpa</i>     | 2R1-2R2-R4-2R5       | 23             |
| <i>Spondias mombin</i>          | R1-2R2-2R3-R4-R5     | 26             |
| <i>Annona squamosa</i>          | 2R1-2R2-R3 -2R5-R7   | 26             |
| <i>Albizia zygia</i>            | 2R1-2R2-2R4-2R5      | 26             |
| <i>Rauvolfia vomitoria</i>      | 3R1-R2-2R3-R5        | 27             |
| <i>Vernonia amygdalina</i>      | 2R1-2R2-R3-2R5       | 28             |
| <i>Newbouldia laevis</i>        | 2R1-2R2-R3-2R5       | 28             |
| <i>Caesalpinia bonduc</i>       | R1-3R2-R3-R4-3R5     | 28             |
| <i>Sarcocephalus latifolius</i> | 4R1-R2-2R5-R6        | 30             |
| <i>Morinda lucida</i>           | 3R1-2R2-2R5-R6       | 31             |
| <i>Cola nitida</i>              | 3R1-2R2-R3-R4-2R5-R9 | 34             |
| <i>Parkia biglobosa</i>         | 4R1-R2-R4-R7-R8      | 39             |
| <i>Khaya senegalensis</i>       | 5R1-2R2-2R3-R4       | 39             |
| <i>Anacardium occidentale</i>   | 3R1-5R2-R3-R4        | 45             |
| <i>Elaeis guineensis</i>        | 5R1-R2-R4-2R5-R10    | 45             |
| <i>Vitellaria paradoxa</i>      | 6R1-2R2-2R3-2R4-R8   | 65             |

### 4.3. Prioritization according to the BRS method

According to the binomial prioritization method (Table 6), *Vitellaria paradoxa* (Sapotaceae) and *Anacardium occidentale* (Anacardiaceae) ranked highest, with equal scores of 8, followed by *Spondias mombin* (Anacardiaceae) and *Rauvolfia vomitoria* (Apocynaceae), each scoring 7.

Table 6  
The scores of the BRS prioritization method.

| Scientific Name                 | Scientific Family Name | Total of Score |
|---------------------------------|------------------------|----------------|
| <i>Vitellaria paradoxa</i>      | Sapotaceae             | 8              |
| <i>Anacardium occidentale</i>   | Anacardiaceae          | 8              |
| <i>Spondias mombin</i>          | Anacardiaceae          | 7              |
| <i>Rauvolfia vomitoria</i>      | Apocynaceae            | 7              |
| <i>Annona squamosa</i>          | Annonaceae             | 7              |
| <i>Parkia biglobosa</i>         | Leguminosae            | 7              |
| <i>Elaeis guineensis</i>        | Arecaceae              | 7              |
| <i>Cola nitida</i>              | Sterculiaceae          | 7              |
| <i>Khaya senegalensis</i>       | Meliaceae              | 7              |
| <i>Vernonia amygdalina</i>      | Asteraceae             | 6              |
| <i>Newbouldia laevis</i>        | Bignoniaceae           | 6              |
| <i>Anogeissus leiocarpa</i>     | Combretaceae           | 6              |
| <i>Jatropha multifida</i>       | Euphorbiaceae          | 6              |
| <i>Caesalpinia bonduc</i>       | Leguminosae            | 6              |
| <i>Albizia zygia</i>            | Leguminosae            | 6              |
| <i>Vitex doniana</i>            | Lamiaceae              | 6              |
| <i>Morinda lucida</i>           | Rubiaceae              | 6              |
| <i>Sarcocephalus latifolius</i> | Rubiaceae              | 6              |

## 5. Super-prioritization

All four methods identified priority species for conservation. The combined results highlight *Vitellaria paradoxa* (Sapotaceae) as the top priority, followed by *Morinda lucida* (Rubiaceae), *Khaya senegalensis* (Meliaceae), *Rauvolfia vomitoria* (Apocynaceae), and *Albizia zygia* (Leguminosae) as the top five species for domestication and conservation. The list of these species is presented in Table 7

Table 7  
Combination of the four prioritization methods (PSP, PSPW, CRS, BRS).

| Scientific Name                                                                                                                      | Scientific family name | PSP | PSPW | CRS | BRS |
|--------------------------------------------------------------------------------------------------------------------------------------|------------------------|-----|------|-----|-----|
| <i>Vitellaria paradoxa</i>                                                                                                           | <i>Sapotaceae</i>      | X   | X    | X   | X   |
| <i>Morinda lucida</i>                                                                                                                | <i>Rubiaceae</i>       | X   | X    | X   | X   |
| <i>Khaya senegalensis</i>                                                                                                            | <i>Meliaceae</i>       | X   | X    | X   | X   |
| <i>Rauvolfia vomitoria</i>                                                                                                           | <i>Apocynaceae</i>     | X   | X    | X   | X   |
| <i>Albizia zygia</i>                                                                                                                 | <i>Leguminoseae</i>    | X   | X    | X   | X   |
| <i>Parkia biglobosa</i>                                                                                                              | <i>Leguminoseae</i>    | X   | X    | X   | X   |
| <i>Anogeissus leiocarpa</i>                                                                                                          | <i>Combretaceae</i>    | X   | X    | X   | X   |
| <i>Sarcocephalus latifolius</i>                                                                                                      | <i>Rubiaceae</i>       | X   | X    | X   | X   |
| <i>Vitex doniana</i>                                                                                                                 | <i>Lamiaceae</i>       | X   | X    | X   | X   |
| <i>Cola nitida</i>                                                                                                                   | <i>Sterculiaceae</i>   | X   | X    | X   | X   |
| <i>Caesalpinia bonduc</i>                                                                                                            | <i>Leguminoseae</i>    | X   | X    | X   | X   |
| <i>Newbouldia laevis</i>                                                                                                             | <i>Bignoniaceae</i>    | X   | X    | X   | X   |
| Notes: PSP, Point Score Procedure; PSPW, Point Score Procedure with Weighting; CRM, Compound Rank Method; BRS, Binomial Rank Method. |                        |     |      |     |     |

## 6. Discussion

### 6.1. Diversity, use, and domestication strategies of plant species in association with cocoyam

The floristic diversity observed in cocoyam-based cropping systems in Benin, encompassing a total of 48 associated species, confirms the agroecological richness previously reported in traditional or integrated farming systems (Baudron, 2024). This diversity reflects the complex interactions among ecological factors, farming practices, and socio-economic dynamics. As highlighted by Esquivel et al. (2021) and Guinet et al. (2023), variability in agroecological contexts strongly influences the composition and structure of agroecosystems. Areas characterized by high rainfall and fertile soils tend to support greater species richness, while degraded or low-rainfall zones exhibit more limited floristic assemblages.

The dominance of *Musa* species in taro associations underscores their nutritional, economic, and cultural importance, as confirmed in several African studies (Akouègnon et al. 2014 ; Tchoma et al. 2020). Likewise, the strong representation of Fabaceae reflects their ecological plasticity and functional role in soil fertility—traits identified by Houéhanou et al. (2016) as key determinants of agroforestry sustainability. However, the association of taro with high-value forest trees (*Vitellaria paradoxa*, *Khaya senegalensis*, *Parkia biglobosa*, etc.) raises concerns about potential conflicts over land use in contexts of increasing pressure on woody resources (Camille 2021).

From a socio-economic perspective, agroforestry emerges as a critical lever for rural resilience by enhancing food security, income diversification, and economic stability (Schroth et al. 2011 ; Sagastuy & Kause 2019 ; Ruf 2018). Such systems facilitate adaptation to land degradation and climatic variability while promoting carbon sequestration and biodiversity conservation. The effectiveness of these practices, however, depends on contextual factors such as land availability, planting density, and canopy size, which influence competition and the productivity of associated crops (Yousefi et al. 2024).

The analysis of plant uses highlights the multifunctionality of associated species : leaves, wood, and fruits are the most exploited organs, primarily for medicinal, nutritional, and artisanal purposes (Agbodjento et al. 2023 ; van Noordwijk et al. 2022). These findings support those of Winara et al. (2022), who emphasized that plant diversity simultaneously contributes to

household nutrition, health, and livelihoods. The predominance of medicinal uses, as previously noted by Talukdar et al. (2020) and Adjatin et al. (2012), underlines the central role of traditional knowledge in the local management and domestication of plant resources.

Analysis of domestication levels reveals a gradient of human intervention ranging from wild to fully cultivated species (Vodounhê et al. 2012). This diversity of statuses illustrates a progressive and adaptive domestication process shaped by local needs, resource availability, and the socio-cultural value of species (Gbedomon et al. 2017 ; Brown, 2018 ; Locqueville et al. 2023). The coexistence of wild and domesticated forms within the same agroecosystem confirms the pivotal role of smallholder practices in *in situ* biodiversity conservation (Adjatin et al. 2012 ; Salako et al. 2018).

However, the overexploitation of woody species and the growing pressure on plant resources may threaten ecological sustainability. As emphasized by Donovan (2017) and Turner-Skoff & Cavender (2019), the multiple benefits derived from trees may paradoxically encourage overuse, leading in some cases to the depletion or local disappearance of certain species (Nuenschwander et al. 2010). These results call for the implementation of sustainable management strategies and community-based conservation mechanisms integrating the ecological, economic, and cultural dimensions of domestication.

In summary, the diversity and structure of plant associations in taro-based systems reflect a dynamic balance between production, conservation, and the sustainable use of plant resources. Recognizing farmers' knowledge and supporting local domestication initiatives appear to be key levers for strengthening agroecological resilience and food security in tropical contexts.

## 6.2. Prioritization of species in association with cocoyam

In recent years, increasing attention has been devoted to the conservation and prioritization of wild plant species in Benin. Previous studies have focused on non-timber forest products (Vodouhê et al. 2009), wild edible plants (N'Danikou et al. 2011), crop wild relatives (Idohou et al. 2013), neglected and underutilized species (Dansi et al. 2012), and woody species. However, none have specifically addressed plant species associated with cocoyam (*Colocasia esculenta*) cultivation. Conservation measures targeting these associated species are essential to ensure their long-term availability in cocoyam-producing agroecological zones. Given the increasing threats posed by human activities, land-use change, and environmental degradation, enhancing the sustainability and effectiveness of conservation actions is urgent, as species currently considered of low concern may become highly threatened in the near future (Agbani et al. 2018).

In this study, we applied the prioritization framework developed by Brehm et al. (2010) and successfully implemented by Idohou et al. (2012) to identify cocoyam-associated species requiring conservation attention across different agroecological zones. Twelve priority species were identified and ranked by importance : *Vitellaria paradoxa*, *Morinda lucida*, *Khaya senegalensis*, *Parkia biglobosa*, *Albizia zygia*, *Rauvolfia vomitoria*, *Anogeissus leiocarpa*, *Sarcocephalus latifolius*, *Vitex doniana*, *Cola nitida*, *Caesalpinia bonduc*, and *Newbouldia laevis*. These species were subsequently assessed for domestication and conservation potential.

According to Abessika et al. (2024), *V. paradoxa* and *K. senegalensis* face high and continuous exploitation pressures due to the demand for shea butter and khaya wood, limiting their natural regeneration. Both species are widely recognized as conservation priorities in West Africa (Vodouhê et al. 2011 ; Sop et al. 2013 ; Assogbadjo et al. 2012 ; Lokonon et al. 2019 ; Hounsou-Dindin et al. 2022) and are listed as Vulnerable on the IUCN Red List for Benin (Adomou et al. 2011). *P. biglobosa* is similarly threatened by habitat loss and poor regeneration resulting from agricultural expansion and deforestation (Boffa, 1999), despite its recognized importance in traditional agroforestry systems (Sopkon, 1999 ; Yabi et al. 2013).

Medicinal species such as *M. lucida* and *R. vomitoria* are subject to intense harvesting, which hampers their development and regeneration (Laila, 2019). Likewise, *A. leiocarpa* and *A. zygia* are considered vulnerable due to overexploitation, habitat degradation, and the high value of their timber, with unsustainable harvesting exceeding reforestation efforts (Ouédraogo et al. 2017 ; Kouassi et al. 2018). *C. nitida* and *N. laevis* are overharvested for their medicinal and ritual significance, while *V. doniana* suffers from excessive harvesting of its leaves, fruits, and wood, limiting regeneration (N'Danikou et al. 2015). Although *C. bonduc* and *S. latifolius* currently show greater adaptability to tropical environments, continued exploitation could eventually endanger these species.

These findings highlight the need for strategies that promote both the development and protection of these valuable indigenous resources to prevent further biodiversity loss. Species prioritization revealed a tendency among farmers to favor multipurpose species, particularly those associated with cocoyam cultivation, as they meet multiple subsistence needs. Farmers generally value species offering several uses because they maximize returns on labor invested in resource collection. As the abundance of high-value plants increases, less-valued species tend to be neglected (Gaoue et al. 2017). Similar patterns have been reported in Mali (Faye et al. 2010), Togo (Padakale et al. 2015), and Tanzania (Wagner et al. 2019), where preferred agroforestry species provide multiple products and services, contributing significantly to household income. Farmers' preferences, however, often vary with social class and farming experience (Moore et al. 2014).

There is no single standardized method for developing conservation priority lists, as each approach depends on its specific objectives. The framework used in this study is methodologically flexible and integrates multiple ecological and socio-economic criteria. Unlike approaches applied by Teso et al. (2012), Crespo (2016), and Khoury et al. (2013) in Spain, Venezuela, and the United States, respectively, it requires substantial data and time due to its complexity and the variety of indicators considered. Moreover, data scarcity for many wild and underutilized species remains a limiting factor.

The results derived from this method may not fully reflect local perceptions of conservation priorities, as scientific assessments often differ from community-based evaluations. Such discrepancies can undermine the acceptance and effectiveness of conservation measures (N'Danikou et al. 2011). To address this gap, it is essential to integrate local knowledge systematically into the prioritization process through participatory approaches that combine scientific and community perspectives. This inclusive strategy can produce co-constructed priority lists, strengthen local ownership of conservation initiatives, and enhance the long-term sustainability of implemented actions.

## 7. Conclusion

This study assessed the diversity of agroforestry systems based on cocoyam, identifying 48 associated with cocoyam across 26 families and 41 genera throughout 6 agro-ecological zones. The species *Colocasea esculenta* was associated with greater species diversity, which was in contrast to *Xanthosoma sagittifolium* with lower diversity. These plant species associated with cocoyam cultivation provide various parts for use (leaves, root, bark, fruit, etc.) and many reasons for use. The most commonly used part by farmers in the study area is leaves, followed by wood and fruit. The highest level of domestication was level 5 of the species highly cultivated with some selection by farmers. Twelve priority species were identified for conservation, including *Vitellaria paradoxa*, *Morinda lucida*, *khaya senegalensis*, *Rauvolfia vomitoria*, *Albizia zygia*, *Parkia biglobosa*, *Anogeissus leiocarpa*, *Sarcocephalus latifolius*, *Vitex doniana*, *Cola nitida*, *Caesalpinia bonduc*, and *Newbouldia laevis*, for sustainable management through targeted conservation efforts. Farmers should maintain agroforestry practices to enhance the diversity of resources obtained from agro-ecosystems and to contribute to the conservation of endangered species in natural habitats with cocoyam and contributing to their sustainable use. This study revealed that most Territorial Agencies for Agricultural Development lack data on cocoyam cultivation and producers. We recommend that Communal Cell Chiefs integrate cocoyam into their local development plans to improve data availability and support. Given its importance, large-scale cocoyam production should be encouraged. Further research is needed to assess the impact of associated species on cocoyam and to compare their behavior in different ecosystems. Lastly, the cooking difficulty of the white cultivar, especially in northern regions, warrants laboratory analysis and regional trials to better understand and address the issue.

## Declarations

## Conflicts of Interest

The authors declare that they have no conflict of interest.

## Author Contribution

Aboudou Hack Arouna: Conceptualization, Methodology, formal analysis validation, writing –original draft, writing-review & editing, visualization; Aboudou Hack Arouna, Delphin Demahou Sobakin, Padonou Elie Antoine and Mouritala Sikirou: Formal analysis, data curation Padonou Elie Antoine and Bruno Agossou Djossa: Validation and Review of the manuscript, Bokon Alexis Akakpo and Ghislain Comlan Akabassi: Review of the manuscript. All authors have read and agreed to the published version of the manuscript.

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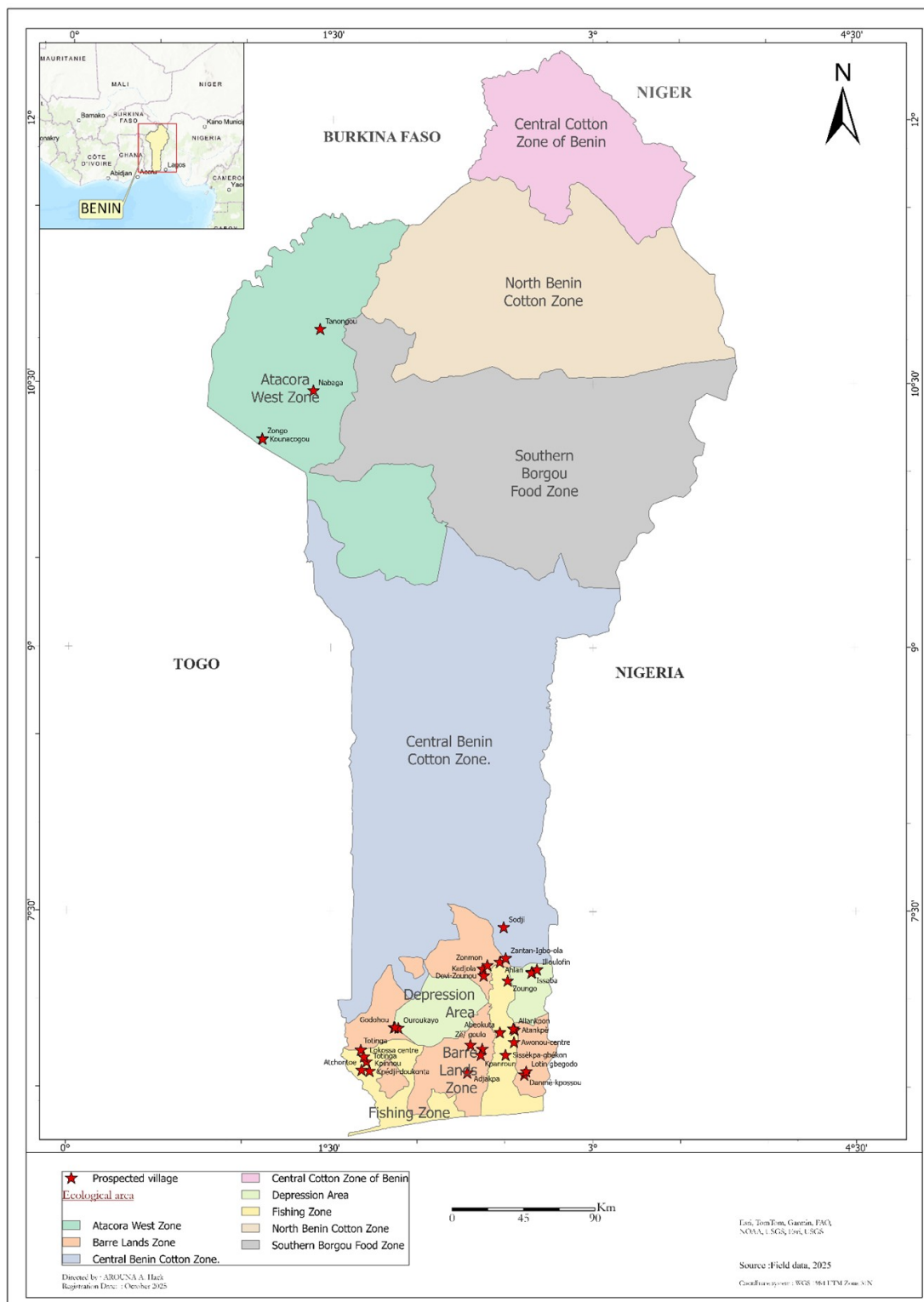
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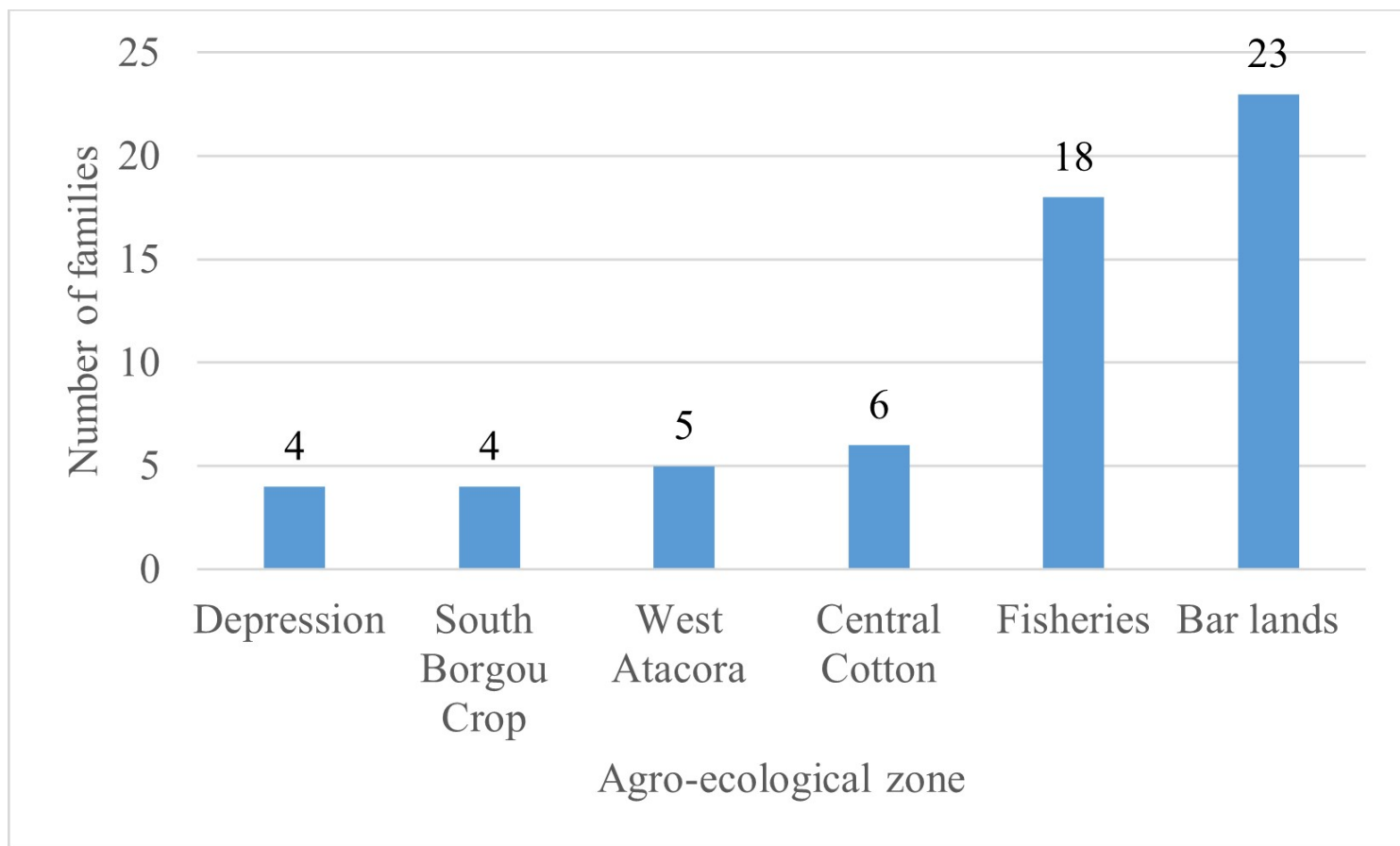
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## Figures



**Figure 1**

Geographical locations of the villages surveyed in the different agro-ecological study zones.



**Figure 2**

Diversity of families according to the six agro-ecological zones.

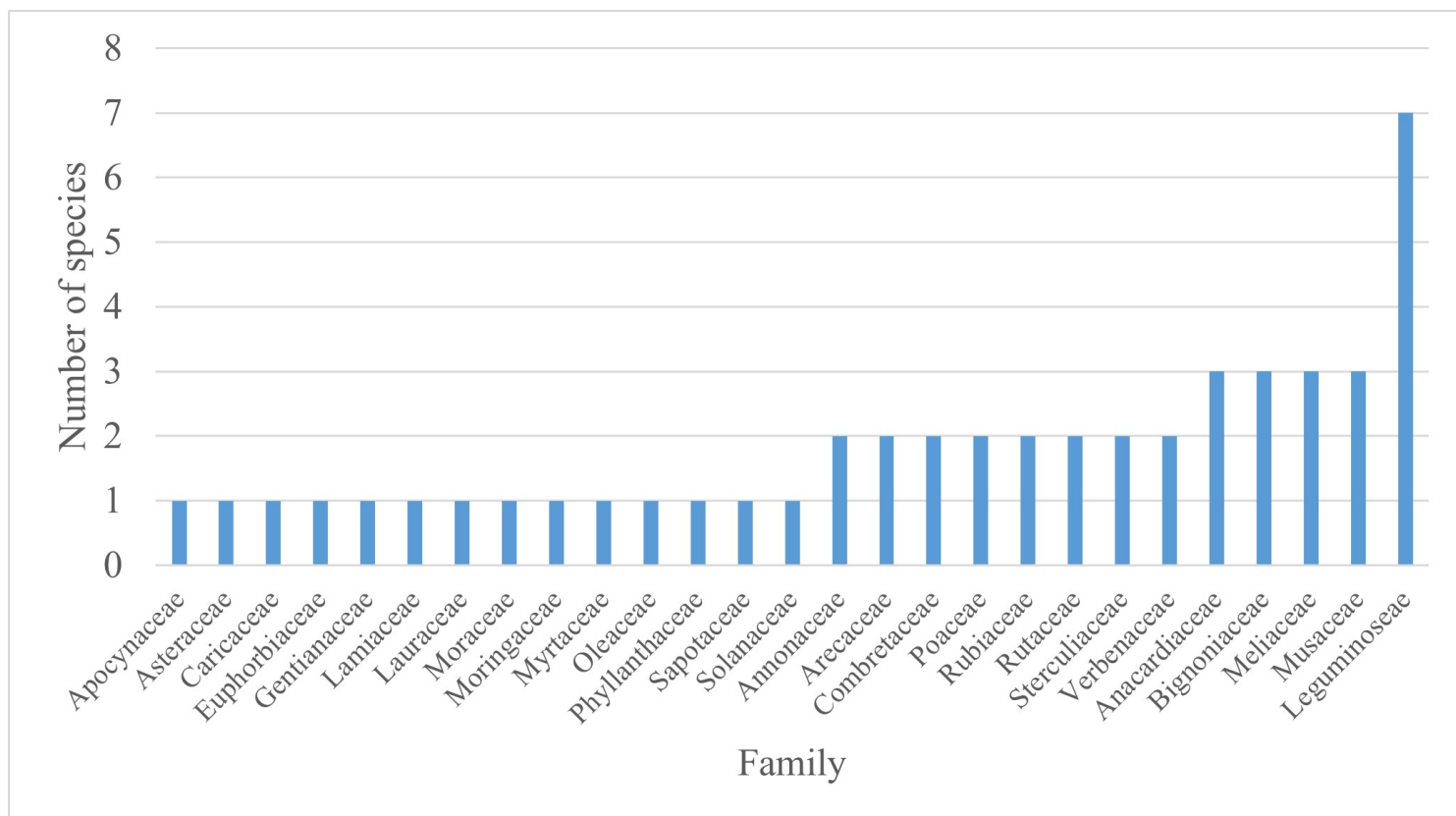


Figure 3

Species diversity by family.

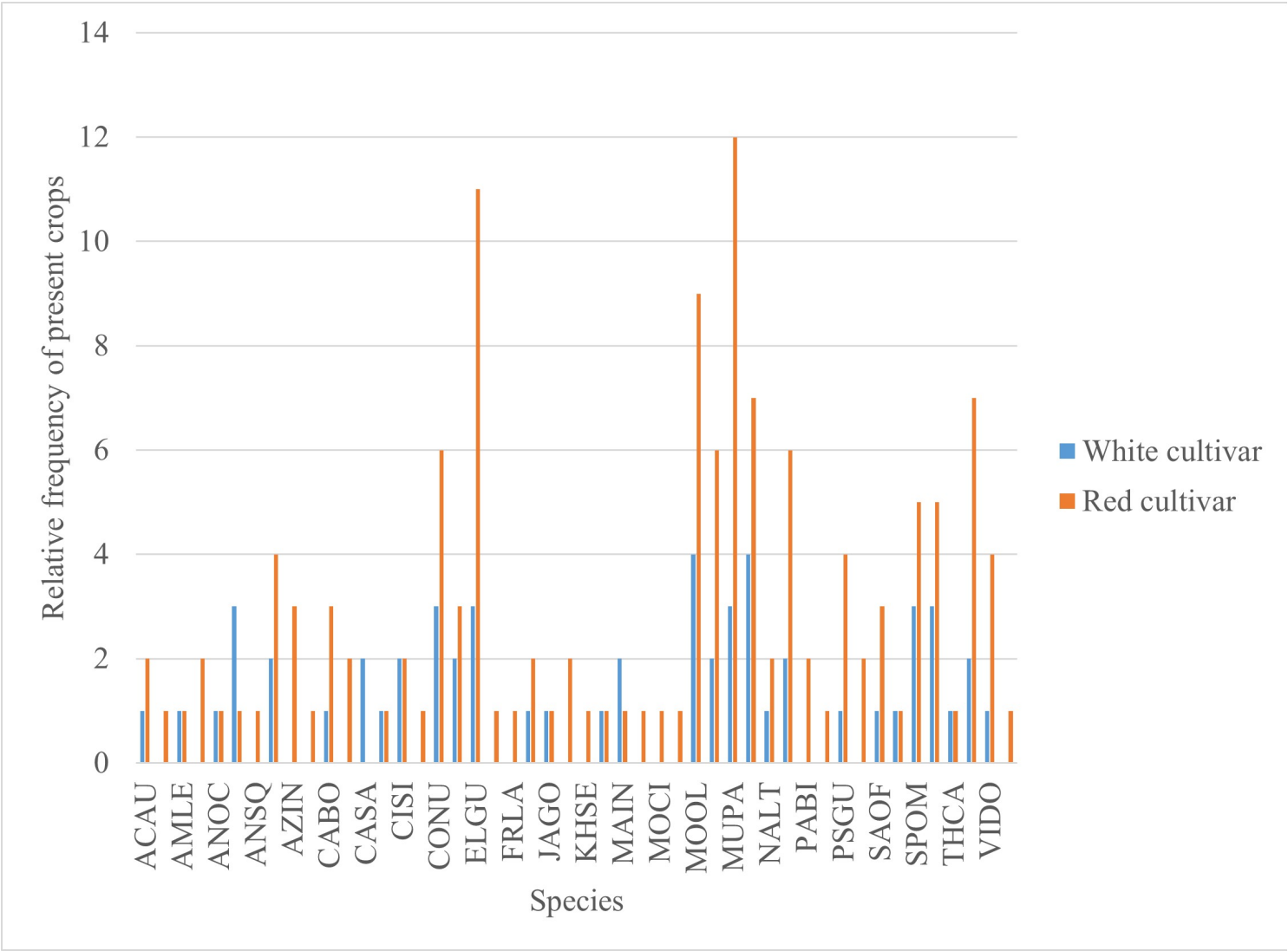
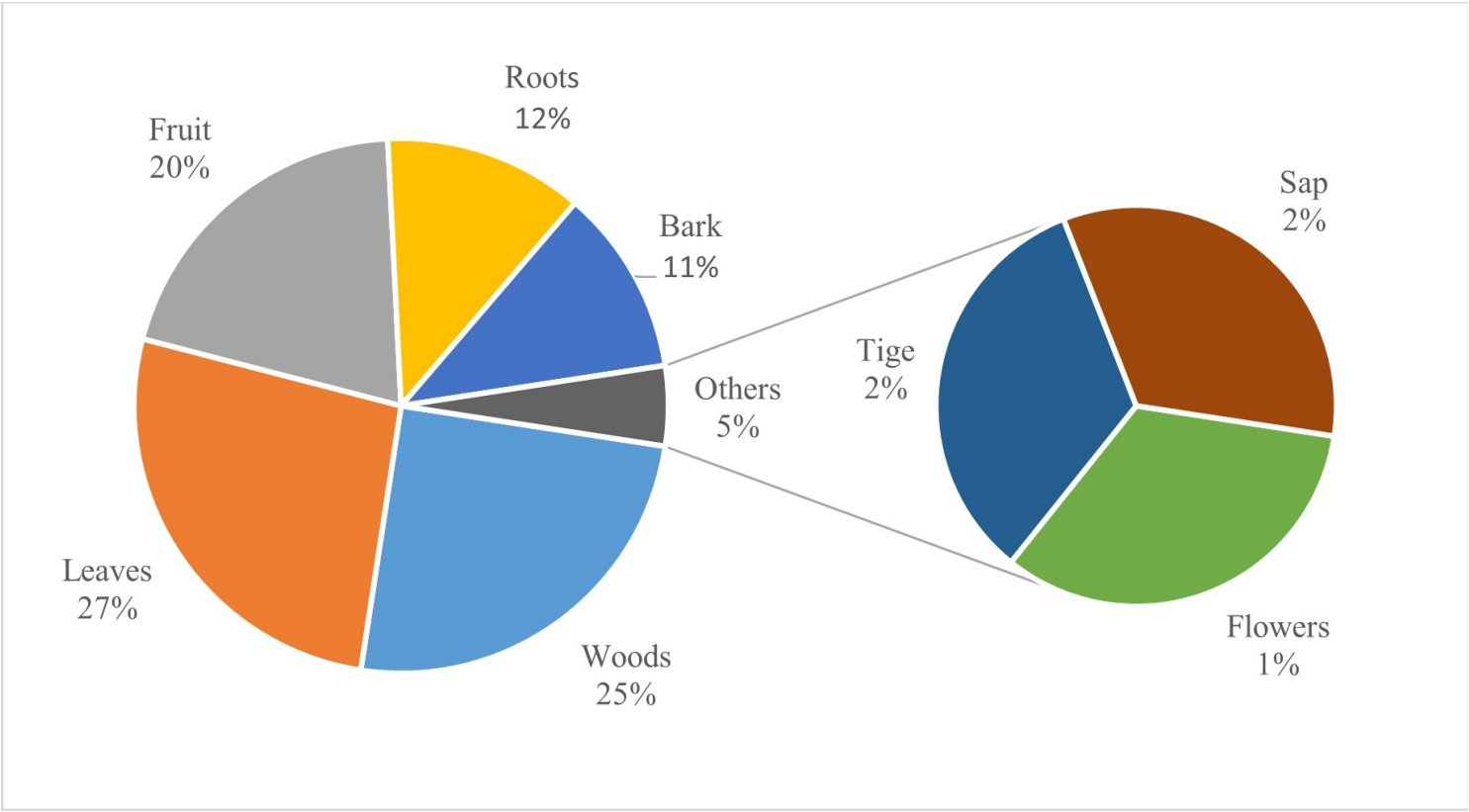
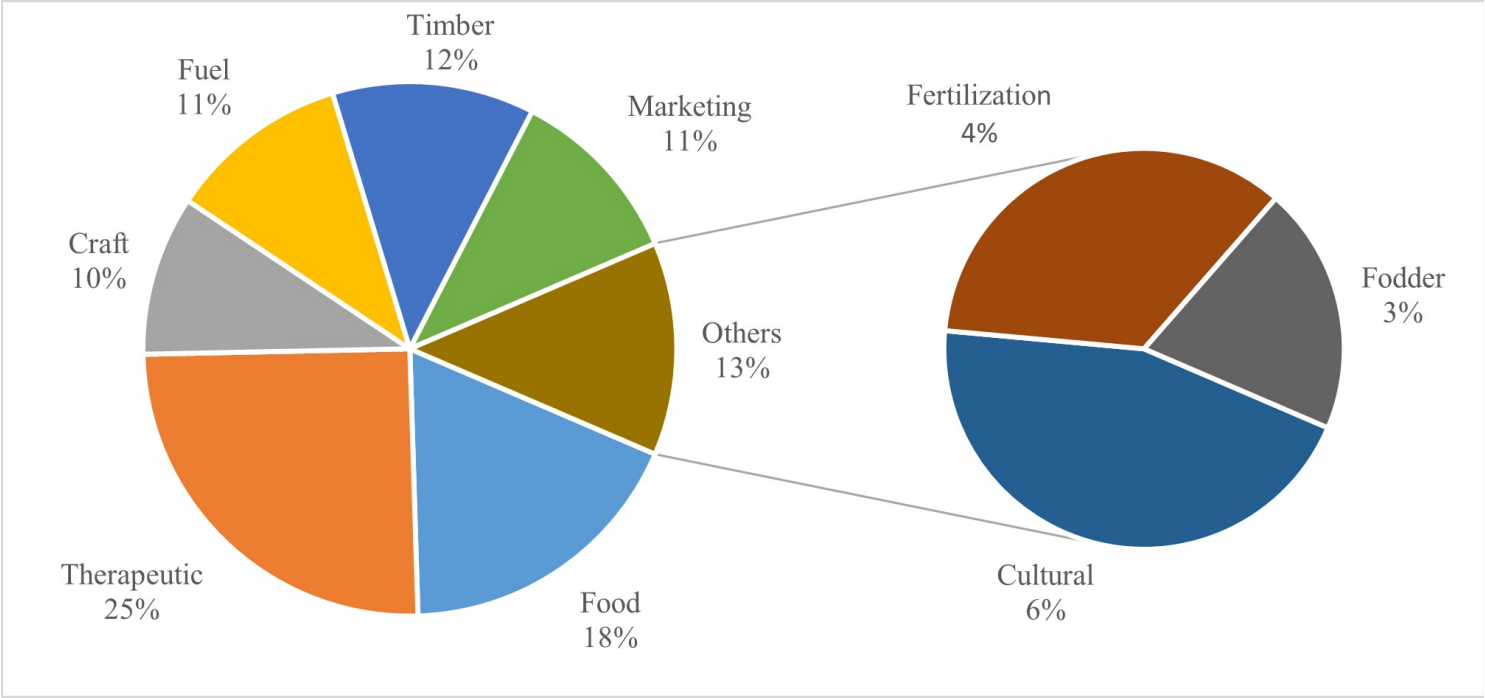


Figure 4

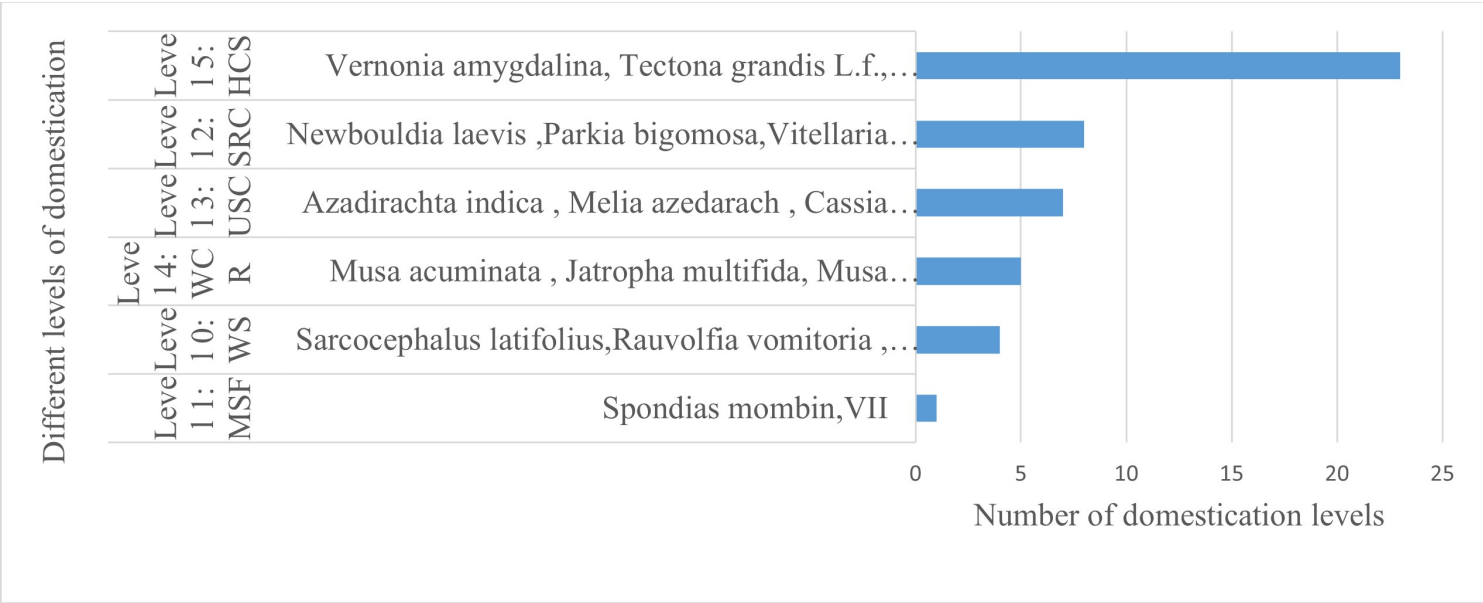
Species in the presence of red and white cocoyam cultivars.



**Figure 5**  
Parts of the species used in association with cocoyam.



**Figure 6**  
Reasons for using species in association with cocoyam.



**Figure 7**

Level of domestication of species.