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# The diversity and use of tropical fibre plants in Africa

BACHELOR'S THESIS

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# Declaration

I hereby declare that I have done this thesis entitled The diversity and use of tropical fibre plants in Africa independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 14.4.2023

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Petr-Simeon Filippi

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## Abstract

Fibre crops are important part of agriculture all around the globe. Nowadays, conventional agriculture focuses mostly on unsustainable cultivation of only few of them. This thesis was done as a literature review of fibre crops cultivated in Africa. At first it focused on major cash crops that make up for most of the total production. Later it described various issues that come with growing them, such as artificial fertilizer and pesticide use. It was also discussed how continuously worsening climate change could have negative impact on the production. The idea of using genetically modified fibre crops was included into the thesis as well. It was then focused on the underutilized fibre crops and how dome of them could play a role in improving the sustainability and help to stabilize the production for African small-scale farmers. The thesis provided table which included 38 species that are utilized at least to some extend on the African continent with basic general information about each of them. Also, suggested several species which do have some significant potential, that is not yet fully used. These species are suitable for deeper research in the future.



**Key words**: agrobiodiversity, agroecology, ethnobotany, industrial crops, natural fibres, textile, tropical crops, Africa

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## List of the abbreviations used in the thesis

**Bt – *Bacillus thuringiensis***

**GM – Genetically modified**

# 1. Introduction

## 1.1 Foreword

Fibre cells can be found in all plants around the globe. Plant fibres are mostly composed of cellulose and hemicellulos, very often with lignin and plant waxes. When plant is economically exploited for its fibre properties, it is called a fibre crop (Sorieul et al. 2016).

Plant fibres have played crucial role in human societies for millennia. The use of cellulosic fibres can be tracked down to China and the Middle East up to 10, 000 years ago. Different types of fibres have been used in different parts of the world. Flax was first used in the Middle East and Egypt, cotton in India, silk in China, hemp in Central Asia etc. It was to the extent that almost every civilization worldwide had cultivated some species of fibre crop for their use. Many of which are no longer in use today (Ramawat & Ahuja 2016).

After decades of synthetic fibres being preferrable, due to their low price and simple maintenance, nowadays, the trend is to go back to using organic clothing, mainly for environmental purposes, longer lasting wear and a more pleasant feeling while being worn. However, only a few fibre crops account for most of world´s production. According to FAOSTAT 2020 data, cotton itself covers around 80% (26 million tonnes) of the world´s natural fibre production and is still increasing its share of the market. It is followed by jute (3 million tonnes), flax (1 million tonnes), and coir (1 million tonnes). Annual production of other fibre crops is below a million tonnes (FAO 2021).

The vast majority of fibre crops are being produced in tropical and subtropical regions, making it a very important part of agriculture and income in certain countries. Notable ones being India, China, Pakistan, Turkey, Brazil, and Uzbekistan. If we look closer at Africa, on which this thesis is focused, economies where the exportation of natural fibres has some significant roles are in Egypt, Burkina Faso, Ivory Coast, Cameroon, Nigeria, Benin, and Tanzania. The biggest exporter, however, is Mali (FAO 2021). In Africa we also find many underutilized fibre crops, which could have some potential use for local communities in the future.

## 1.2. Location and Geographical Description of Africa

Africa as a continent is situated mostly on the African tectonic plate, also known as the Nubian plate. The easternmost part of the continent lies on the Somali plate. Africa is a relatively geologically stable continent, except for the border of the two plates. Huge subterranean forces there have created the Great Rift Valley, which is a geothermally active zone, that is slowly splitting the continent apart (Hardarson 2016).

African terrain is very diverse. The average elevation of the southern and eastern parts is very high with many highlands, high plateaus, and mountain ranges. The western and northern parts have a much lower elevation made up of mostly lowlands. One big exception is the Atlas Mountain range, the highest of Northern Africa. The highest peak of the continent is Mount Kilimanjaro with its peak at 5 895 metres above sea level, located on the border of Tanzania and Kenya. Also, along the Great Rift Valley Africa's biggest lakes - Lake Victoria being the biggest one – can be found (Rybová & Führmann Vízdalová 2009).

The continent lies between 37° 21' northern latitude and 34° 51' southern latitude, and 17° 33' western longitude and 51° 27' eastern longitude.

Its total area covers 30 370 000 $km^2$. The coastline is 26 000 kilometres long, however, in comparison Europe, which is three times smaller by its surface area, has a coastline over 32 000 kilometres long. This difference is due to the lack of deep indentations in the African continent's coastline (CIA 2023).

Fifty-four internationally recognized countries are classified as African. Fourty-four of them are mostly mainland nations and six are island nations. The biggest island is Madagascar, which is also the fourth biggest island on earth. Algeria is the biggest country by area, while Nigeria is the biggest by population. On the other hand, the archipelago of the Seychelles is the smallest and least populated African country (CIA 2023).


Figure 1: Physical Map of Africa (Geographic guide 2023)

### 1.2.1. Climate of Africa

So many different climatic zones appear in Africa that almost any climatic condition can be found there. It ranges from tropical in the equatorial lowlands to subarctic on the mountain peaks. The most important conditions which determine the climate are latitude, elevation, distance from the sea, and ocean currents (Rybová & Führmann Vízdalová 2009).

A tropical climate is found in the centre of the continent, so no typical seasons of the year occur there. From the Tropics of Capricorn and Cancer trade winds blow towards the equator, where it is completely calm. Around the two tropics, a subtropical climate can be found. The rest of northern Africa is considered to be subtropical. The southernmost tip, however, is technically considered as semi-moderate climatic zone. At the top of the tallest mountains is a semi-arctic climate, with some of the last African glaciers. These glaciers are thousands of years old, however, very soon, they will completely vanish. (CIA 2023)

The rate of precipitation is the highest in the central part of Africa around the tropical forests. On the other hand, the least among of precipitation is found around the Sahara Desert, making northern Africa the driest part (Rybová & Führmann Vízdalová 2009).

### 1.2.2. Ecosystems of Africa

In connection with climate zones, we come into contact with different types of ecosystems. The northernmost subtropical part of Africa mostly contains Mediterranean scrub. Followed up by the vast Sahara Desert on the way south, below the Tropic of Cancer lie dry Sahel grasslands. These grasslands then slowly transform into Northern African woodlands, that, in turn, transform into the tropical rainforest in the western half of the continent around the equator. The equatorial part in the east is much drier due to its mountainous terrain which creates rain shadow areas. This has created acacia woodlands and grasslands called Savannas. With some exceptions, these grasslands cover most of the way south to the Tropic of Capricorn. There, in the western part, the coastal Desert Namib is located. The Kalahari Desert and Karoo semi-desert are in the central part of southern Africa (Sayre et al. 2013). In the southernmost part, Veldt, Nama-Karoo, Albany thicket, and Fynbos ecosystems are found. These three types of ecosystems are endemic to South Africa and endangered due to their sensitivity to climate change (Skowno & Monyeki 2021).

Highland grasslands and artificially planted coniferous forests are found in the mountainous eastern part (van Wilgen & Richardson 2012).

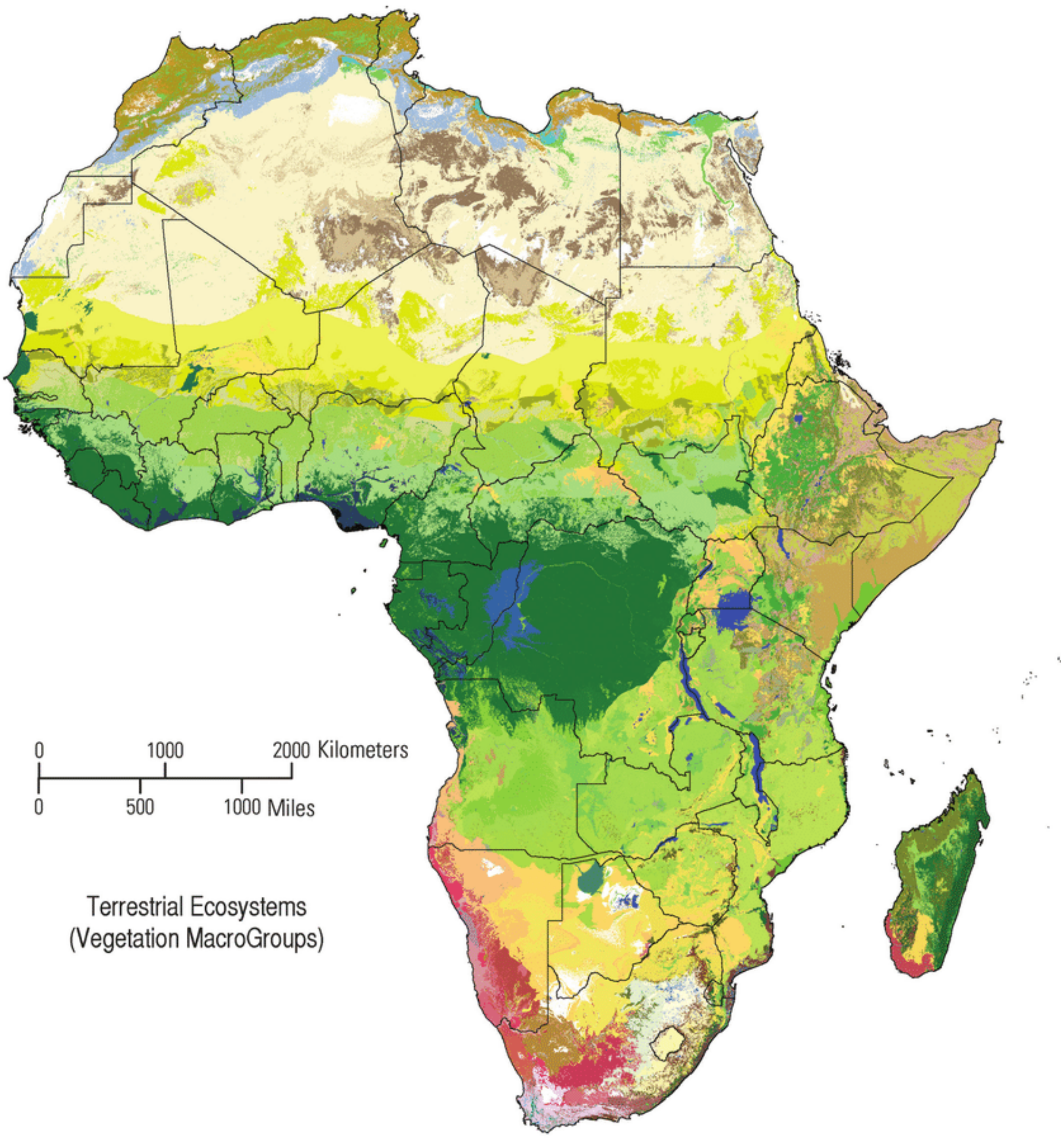


Figure 2: Terrestrial Ecosystems of Africa (Sayre et al. 2013)

### 1.2.3. Population of Africa

As of 2023, over 1,4 billion people live in Africa. Around 50% of them identify as Christian and 42% as Muslim, while the rest are mostly classified as followers of indigenous religions. The African population is rapidly growing. It has more than doubled in the past 30 years (CIA 2023). The growth comes with the price of famines, huge migration, and ethnic violence. However, it provides a large labour force for agriculture and the slowly growing industrial sector (Logan 1991).

### 1.2.4. Natural Biodiversity of Africa

More than 3 000 protected natural areas are located in Africa and this number is still growing. Unfortunately, with the enormous population growth, the nature suffers. Habitat destruction, such as deforestation and poaching, are continuously reducing the natural biodiversity. Together with the lack of funds and attention from the local governments, many species have become endangered. Another huge problem is the introduction of invasive species. Also, Africa faces soil degradation, physically and chemically (UNEP 2023).

## 1.3. Agrobiodiversity and Agriculture of Africa

African plant agrobiodiversity is still evolving, and new species are being introduced in order to increase yields. Traditional crops are crops that have been grown by local farmers for long periods of time are, for example, sorghum, maize, millets, casava, sweet potatoes, yams, amaranth, sesame, and cotton (FAO 2018)

Lately, genetically modified cultivars had been introduced, especially varieties of maize cultivars in order to be pest resistant and to face climate change better. Hand in hand goes the loss of species that are being planted because many farmers focus only to some cash crops. These are profitable in the short-term period, however, on a longer scale, it increases the risk of total crop failure. When any unexpected conditions occur, farmers with a slighter segment of crops are more vulnerable (FAO 2018). In the past few years, genetically modified crops started to be regulated in several African countries, one of the first to do so was Eswatini, also known as Swaziland, in 2012 by the Biosafety act (Harper 2022).

In the past years, oleaginous plants, such as rape and sunflower, have been increasingly planted, especially in the southern part of the continent. However, and more importantly, oil palm plantations were introduced. The primary threat to biodiversity is land conversion for agricultural purposes. In Indonesia and Malaysia, vast and still-growing oil palm plantations are destroying the natural environment for local fauna - the most famous example probably being the orangutans. Therefore, many people are afraid of something similar happening to the western and central part of Africa. It could possibly make way for the eradication of many endemic species of primates (Strona et al. 2018). On the other hand, even though the harvested area is still increasing, it is slowing down significantly. The predicted boom is not happening, for now (FAO 2021).

# 2. Aims of the Thesis

This bachelor’s thesis aimed to provide a review of the literature that has been published on major fibre plant species cultivated and used in Africa, as well as underutilised species which could potentially be used or play a significant economical role in the future.

This thesis summarized this specific group of useful plants. It also aimed to contribute to the identification of novel underutilised crop species for African agricultural and food systems. It included minor crops and wild plant species indigenous to Africa, as well as the possibility of promoting new agroecological systems over the currently quite unsustainable cultivation of major fibre crops, due to their high demand for industrial fertilizers and pesticides.

These new agroecosystems could possibly be more resilient to global climate change and bring new economic value to local communities.

# 3. Methodology

The thesis was, at first, focused on an overview of species already known and used, which play a crucial role in agriculture already - to show ecological issues which come with them, and make the production unsustainable in the long term. Later on, there was a focus on underutilised crop species which could possibly partially replace the current ones.

The target plant species were analysed according to their geographic origin and distribution, ethnobotanical importance, and economic value. The search for underutilised fibre crop species was done through different online databases.

A systematic and qualitative literature review was done mainly by using an electronic search on Web of Science, Scopus, PROTA4U, Google Scholar, JSTOR, ScienceDirect, SpringerLink, and Primo (search engine of Knihovna Antonína Švehly). A combination of key terms such as "Fibre Crops", "Africa", "Agriculture", "Use", "Ecology", “Fibre”, “Cultivated”, “Underutilised”, “Introduced”, “Production”, “Native”, “Agrobiodiversity”, “Agroecology”, “Ethnobotany”, “Industrial Crops”, “Natural Fibres”, “Textile”, “Tropical Crops”, and so on were used when searching for relevant information. Also, manual search of relevant literature, bibliographies, and textbooks, focused mainly on fibre crops and African agriculture was used.

# 4. Literature Review

## 4.1. Definition of Fibre Crops

As mentioned earlier, all plants contain plant fibres, however, not all the plants can be called fibre crops. For a plant to become a fibre crop it has to be economically exploited. That means, the fibres must be suitable for extraction and further use by humans (Sorieul et al. 2016).

Plant fibres can be distinguished according to the part of the plant from which the fibre is obtained. By this definition we have three different groups. The first one being seed fibres, collected from a plant seed (he most notable of this group is cotton. The second category is bast fibres, which are collected from the inner bark of a plant (for example, hemp, flax, or jute). And lastly, there are leaf fibres, collected from the plant leaves, for example, abaca (Rowell 2008)

## 4.2. Recent Production of Fibre Crops in Africa

According to FAOSTAT, the African continent is not classified as a big fibre crops producer. In the past five years, 25% of sisal was produced in Africa; making Africa a very important producer for the rest of the world. However, cotton is, by far, the most produced fibre crop on the continent by total number. Annually over two million tons a year are being produced, compared to only 80 thousand tons of sisal. Although, that is still less than 8% of the world´s total cotton production (FAO 2021).

Another quite significant fibre crop is kenaf, making around 5% of the world´s production. Around 1% of flax comes from Africa. All other fibre crop production stands for less than 1%, when compared to the rest of the world. The only exception is the "Other" fibre crop category, where Africa represents 10% of global production (FAO 2021).

## 4.3. Major Fibre Crop Species Cultivated in Africa

### 4.3.1. Introduced Species

Nowadays, cotton is the leading fibre crop worldwide, grown in more than 50 countries around the globe. Africa covers around 8% of the world´s total production (FAO 2021). The cotton seed coat is spun into yarn. Commonly huge irrigation systems are used by hand when growing cotton on a large scale. Around 50 different species of cotton are recognized, however, only four of them are cultivated (Khadi et al. 2010).

*Gossypium hirsutum* L., also known as Mexican cotton, is the most widely used cotton species. It originated in Southern Mexico in Central America (Fryxell 1979). It grows up to 150 centimetres in height and the plants have only a few or no vegetative branches. The flowers, of a pale-yellow colour, have large showy petals. The bolls are big and rounded. The seeds which can be used for oil production bear a coat of lint hairs and often a coat of fuzz hair as well (Berger 1969). *Gossypium hirsutum* L. is one of two cultivated tetraploid species.

The other one being *Gossypium barbadense* L., also known as Pima cotton, originally from Ecuador in South America. These two species alone make up for more than 90% of global cotton production (Khadi et al. 2010). *Gossypium barbadense* L. is a species which produces the finest quality lint. In Africa it is grown a lot by the Nile River in Egypt and Sudan, under irrigation. The plant is taller than its central American relative - it grows up to 270 centimetres tall. The flowers have a deep yellow colour with a red or purple spot at the bottom. The bolls are large, usually with less seeds than *Gossypium hirsutum* L. species has. The seeds can be used for oil production as well. The lint is almost silk like; it is longer and stronger than any other kind of cotton. That is why it is used for the finest textiles (Berger 1969).

The least cultivated species of cotton is *Gossypium arboretum* L., it is grown mostly in southern Asia where it originated. In Africa, it is grown mostly in Madagascar and coastal Tanzania. It is the tallest of all the species - it grows up to two metres or more in height. However, it is not suitable for massive and effective production (Berger 1969).

*Agave sisalana* Perrine, better known under the name of sisal, originates in Central America. It is the most important crop out of the leaf fibre group. It had first been introduced in Africa at the end of the 19th century, with its first plantings established in Tanganyika, nowadays Tanzania. Soon after it was brought to Mozambique, Madagascar, Kenya, and Angola. Later on, many more African countries started growing it as well (Oyen 2011a). Today over 1 quarter of world production comes from Africa (FAO 2021).

Sisal plant stalks usually grow up to 90 centimetres in height with a 38-centimetre diameter. Sharp leaves grow out of the stalk in a rosette-like shape. They are thick and full of moisture. Within 4 to 8 years after planting, the central stalk grows to the height of around six metres. Small yellow flowers then start to bloom to produce new seeds. The old plant completely dies after the flowering is completed, as with other *Agave* species. Sisal produces about 300 leaves during its productive period (Lock 1969).

Sisal fibre is relatively rough and strong; therefore, it is mostly used for products like ropes, rugs, footwear, or brushes. Sisal fibre on average contains 71% cellulose, 11% hemicelluloses, 10% pectin, and 8% lignin (Badrinath & Senthilvelan 2014).

Kenaf is a bast fibre obtained from stems of *Hibiscus cannabinus* L. The plant most likely originated in India. It has lower requirements for climate and soil conditions. Kenaf fibre is used for making sacks, ropes, rugs, and more. The waste can be used for paper production and building material (Valíček et al. 2002). The most important African producers of kenaf fibre are the Democratic Republic of Congo, Mozambique, Mali, and Nigeria (FAO 2021).

It grows from 2,4 to four metres tall. Cultivated varieties only flower when they are subjected to a certain amount of darkness due to their short-day nature. The best yields and fibre quality is provided during the flowering period. The flowers itself are of yellow colour and the leaves vary in shape (Berger 1969).

*Linum usitatissimum* L.*,* also known as flax, had been domesticated in the Fertile Crescent region. However, earliest evidence of its use as a textile comes from the Caucasus region, Georgia to be specific (Fu 2011). Africa produces about 1 to 1,5 % of the world's total production. The vast majority of it comes from Egypt, where the growing of flax has had a long tradition for millennia. Another two notable African producers are Angola and Togo (FAO 2021).

The plant usually grows about one metre in height. It has slender stalks and most of its branches grow close to the top. The actual fruits are small and dry. The textile, which is usually its primary use, is called linen. Sometimes, flax can also be harvested for its seeds. From them linseed oil is obtained. The flowers, growing from the stems, are usually blue and have five petals (Berger 1969). Another use comes from the processed waste material. It is used for making flax boards, which are used in the furniture industry (Kmošková & Kmošek 2017).

Flax stems, as a bast fibre, must undergo wide processing before it can be used as linen fabric. Linen is valued for its qualities, such as durability, lustre, strength, and resistance to attack of microorganisms. Constituents of flax fibres vary across a relatively wide range. Cellulose makes up from 64,57% up to 75,38%, hemicellulose from 12,97% to 26,07%, lignin from 4,78% to 7,44%, pectin 0,45% to 3,23%, and fats and waxes from 0,83% to 1,9% (Zommere et al. 2013).

Abaca, the fibre, which is obtained from the leaves of *Musa textilis* Nee*,* also known as Manila hemp, thanks to its place of origin, is a member of the banana family. Since abaca is the strongest of the cordage fibres, it is used for ropes and cables, especially for marine cordage because it is resistant to salt water (Berger 1969). Almost all of its production comes from Asia. In Africa there are only two exceptions: the biggest African producer is, surprisingly, Equatorial Guinea and the second is Kenya. These two countries make up for 0,4% of the world's production (FAO 2021).

The plant itself resembles the banana plant *(Musa × paradisiaca* L.*)* in appearance. It can reach four to eight metres in height. It grows from a rootstock that produces up to 25 fibreless stalks, each one of them produces 12 to 25 leaves. The flowers are usually of rose colour, and the plants are usually replaced after ten years of production (Vaughan 2011).

*Cochorus capsularis* L. and *Corchorus olitorus* L. are two cultivated species of jute. Its origins lay in present-day Bangladesh and India (Fondio & Grubben 2011). That is why these countries are still leaders in its production. Not more than 0,3% is being produced in Africa. The biggest African producers are South Sudan, Sudan, Egypt, and Zimbabwe (FAO 2021).

Jute is a bast fibre obtained from the stems. It is used for making rugs and carpets, but most importantly sacks and bags. Jute sacks are used are used for grain, tea, flour, vegetables, and much more. The jute plant grows up to 3,5 metres in height and has light green leaves and small bear yellows flowers (Fondio & Grubben 2011).

### 4.3.2. Native Species

*Gossypium herbaceum* L. is a cotton species native to Africa. It originated somewhere around present-day Sudan (Hutchinson 1954). It is grown mostly in the northern part of the African continent. However, it has lost its importance throughout the years, and kept only small portion of its former importance. (Jimu 2011a)

The plants are usually 60 to 180 centimetres tall and have thick and rigid stems. The leaves are flat, lobed and hairy and the flowers usually have a light-yellow colour. The bolls are rounded and two to three centimetres long. The seeds usually bear short fuzz and long lint hairs (Valíček et al. 2002).

## 4.4. Environmental Impact of Major Fibre Crops Cultivation

### 4.4.1. Vulnerability to Climate Change and Soil Degradation

The Gogwe region of Zimabwe is where cotton production is the most important part of its agricultural sector and internal immigrants are seeking a better life associated with cotton growing (Govereh & Jayne 1999). However, with lower precipitation and the increase of average annual temperature in southern Africa, yields of cotton are continuously lowering. That causes a hardship for local communities which are dependent on the cotton production in the area. New irrigation systems need to be built, however, that would put more pressure on the environment and is unimaginably expensive for the state of Zimbabwe nowadays (Gwinbi & Mundoga 2010).

Cotton can tolerate high temperature and drought to some extent; however, it is very sensitive to water availability during its flowering and boll formation (Ton 2011). It is expected that the variability of rainfall will significantly increase on the African continent throughout the current century, therefore, the probability that cotton production will be negatively impacted is very high (Adhikari et al. 2015).

In Togo, long-term experiments were done in savannah soils in cotton-cereal rotation systems. The main purpose of these experiments was to assess the productivity of cotton-based systems under different management. Four different crop rotations were used, cotton being the main part of each of them. During the 30-year experiment yields of all crops were continuously declining. Even though there were differences in between different crop rotations, a decline was recorded in each of them. The conclusion was made that without massive inputs of organic or mineral fertilizers, the soil was and still is being significantly depleted over time (Kintché et al. 2010).

### 4.4.2. Advantages and Disadvantages of Genetically Modified Fibre Crops

The term sustainable development sometimes relates to the usage of genetically modified organisms. Cultivation of GM crops started back in 1996. The main advantages that come with GM crops is resistance to insect pests, fungal, viral, or bacterial diseases, and tolerance to weeds and/or harsh climate conditions. All of this has the potential to lower the inputs of chemicals and fertilizers needed for cultivation and still increase production. In the future, genetically modified organisms are expected to be one of the options for environmentally sustainable agriculture while still providing food security (Ferry & Gatehouse 2009).

Cotton was the first genetically modified plant ever introduced that had been cultivated on the African continent. First in South Africa and then in Burkina Faso (Dowd-Uribe & Schnurr 2016). In the Republic of South Africa, GM cotton reduced the usage of insecticides and increased the profits of resource-poor farmers. On the other hand, it was not significant enough to have lifted them out of poverty. Another issue is that the pests could develop some kind of resistance. Therefore, it is seen as something that could be helpful and only further research will show its true potential (Morse & Mannion 2009).

However, the case of GM cotton in Burkina Faso differs a lot. This west African country is one of the biggest cotton producers in all of Africa, sometimes even ranked as number one, with highly regulated and organized production. Cotton farmers In Burkina Faso use relatively high inputs of fertilizers and other investments in comparison to most other African countries. The agrochemical company Monsanto started an experimental field trial in Burkina Faso for genetically modified insect resistant Bt cotton all the way back in 2003. Cotton produced in the country was seen as some of the finest quality cotton in Africa, second only to Egyptian Pima cotton, which is made from a completely different cotton species (Dowd-Uribe & Schnurr 2016). That was the reason why the local government wanted to introduce the traits through introgression into their local varieties, in the hope that it would keep the qualities they believed to be important (ISAAA Inc. 2018).

GM cotton suddenly became very popular and made up about 70% of all cultivated cotton in the country by 2013 (ISAAA Inc. 2018). Yields grew larger and it seemed like a story of success. However, the quality traits, which were the most important distinguishing factor of Burkinabè cotton, started to fall. The high quality of the cotton was a result of long-term breeding programmes which had been taking place for decades. It had a very high ginning ratio and was handpicked. Therefore, local companies could sell their premium product for a premium price (Dowd-Uribe & Schnurr 2016).

However, in the first few years after the commercial release, the ginning ration and staple length lowered a lot. Monsanto company tried to explain it by blaming it on an exceptional drought and other climatic conditions. Thanks to increased yields it was overlooked for a while. However, when all of these negativities persisted over a longer period of time, Burkinabè officials started to worry about it. Only 5 years after the commercial release, two thirds of the country’s total production were then classified as low-quality cotton. The turning point was when Burkinabè production reached an all-time high in yields but was unable to sell the cotton for a sustainable price (Dowd-Uribe & Schnurr 2016).

The government decided to get rid of the Bt cotton completely and did this by 2018, in the meantime replacing the plants with their own cultivars. Overall, it was a huge financial loss for the farming companies who had lost over 75 million US dollars during the single decade of cultivation. It was also a huge loss for Monsanto which hope to set an inspiring example which could have been the starting catalyst on the continent. The example of Burkina Faso has definitely put a big question mark over the idea of genetically modified crops in general (Luna & Dowd-Uribe 2020).

### 4.4.3. Negative Impact of Pesticide Use

Hand in hand with the increase in the world´s population the demand for the intensification of agricultural production grew. This is not achieved only by using more and more chemical fertilizers, but farmers are being encouraged to use pesticides to control pests which are lowering their production. The same innovations have also arrived in Africa. However, the overuse and misuse of pesticides has long-term negative effects. The most visible ones are to the environment. On the other hand, pesticides cause harm not only to the environment, but also to the health of local farmers and consumers of their products (Hendriks et al. 2019).

The study, which took part in the Great North region of the Ivory Coast, was focused on pesticide use practises, productivity, and farmers' health. The actual research was done in cotton-rice systems, which are the most common agricultural systems in the region. The Government Cotton Agency is the most important pesticide source for the farmers. It is supplying about 70-80% of all pesticides. The rest is supplied by the open market from chemical companies. The vast majority of all chemicals used in the fields is for cotton production; mostly insecticides, whereas herbicides are used less (Ajayi 2000).

The farmers do understand the basic need for careful application, like not to spray against the wind, for example. However, to save energy and time, they often spray when the wind speed is high. They take advantage of the ability to spray over larger number of cotton rows due to the wind, but this causes unwanted spraying behind the border of their field which contaminates the surrounding area. After questioning, pesticide applicators reported that in one out of five times, the use of insecticide sprays produce detrimental health symptoms in people affected - mostly headaches, skin rashes and coughing. Some people even had to take medication afterwards. This number is quite alarming. It shows the risk to less educated farmers of pesticide usage in developing countries (Ajayi 2000).

In Benin, farmers switched from subsistence farming to cash crop farming over recent years. In 2009, the main export crop was cotton which accounted for over 40% of the total exports (OECD 2009). With growing cotton production, the amount of insecticides needed for securing the yields grew. Insectivorous bats, natural predators of insects in this part of Africa, started to accumulate organochlorine - one of the components of these insecticides (Bayat et al. 2014). Bats were tested during 2008 and 2009 in several areas. The most concerning residue that was found was DDT. Its highest concentrations were found within the bats from the highly agricultural zone, suggesting that it was being illegally used in the cotton fields (Stechert et al. 2014).

Another example of the discovery of organochlorine residues, where they shouldn't be found, comes from Sudan, where blood samples of 96 people were taken. People came from areas which are known for intensive agriculture and overuse of pesticides, such as DDT in the past. Crops cultivated, usually under irrigation, in these areas were mostly cotton and sugar cane (Elbashir et al. 2015). Pesticide use in the country began in 1941 with a Bordeaux mixture and continued with chlorinated hydrocarbon and DDT (Abdebalgi & Mohamed 2007). Its peak was between the 1960s up until the beginning of 1980s, when DDT was internationally banned for use in agriculture. On average the fields had been sprayed 10 times per year for protection against pest infestation (Dabrowski 1997).

The results showed that levels of organochlorine in the blood samples were significantly higher in the areas where cotton was the main cash crop. With increasing distance from these cotton scheme areas, decreasing levels of organochlorine were seen. Some kind of residue was found in more than 90% of blood samples. It shows the impact, pesticides have even after decades of intensive use. Not only on human bodies but on the environment as well (Elbashir et al. 2015).

## 4.5. Underutilised Fibre Crop Species

### 4.5.1. Definition of Underutilised Crop Species

The term “underutilised crop” usually refers to a crop species whose full potential has not yet been realised. However, there is no definite classification. Some crops can be classified as underutilised in some countries, while, at the same time, are commonly planted and used in others. One example, *Vigna unguiculata,* also known as cowpea, is an important crop in sub-Saharan Africa and Eastern Asia, however, it is classified as underutilised in the Mediterranean region. Therefore, to some extent, the term is rather subjective (Padulosi & Hoeschle-Zeledon 2004).

Another term, which is often confused with “underutilised” is the term “neglected". The meaning is similar, but not exactly the same. “Underutilised” stands for crop species which were widely grown in the past but are no longer grown as much, usually being replaced with major cash crops. Neglected species, on the other hand, are species that are being cultivated in their places of origin by local traditional farmers. They remain inadequately described and, therefore, neglected by research at the same time (Padulosi et al. 2002).

The last term being used with a similar meaning is “orphan crops”. In short, it is a synonym for “neglected crops”. Orphan crops are usually not traded internationally but may have a significant role in regional food security. These crops have, oftentimes, only received a little attention from researchers, thus their potential has not been used to the fullest (Naylor et al. 2004).

For the purpose of this thesis the difference between underutilised, neglected, and orphan crops is negligible. This thesis will use the term “underutilised crops” to refer to each of the above-mentioned terms.

### 4.5.2. Potential of Underutilised Crop Species

Various crops have been used by mankind throughout its history. It is estimated that over 80 000 plant species have been used by humans at some point. These species were used for food, medicine, fibre, as well as many other purposes (Muthamilarasan et al. 2019). However, the number has decreased significantly. Nowadays, six plant species, including wheat, potato, sugarcane, soybean, rice, and maize, make up more than 75% of the world’s food production (Singh et al. 2022). Furthermore, over 95% of total food production in the world is covered by only 30 species (Shelef et al. 2017).

Underutilised crop species have the potential to make modern agriculture more sustainable. They are usually less sensitive to stressors, such as drought, thus underutilised crops could ensure more stable yields. These crops are especially suited to grow in poor soil and do not require as much irrigation or pesticide use. Another factor is the low financial input it takes to cultivate these crops. Together with various agricultural techniques and correct intercropping with major crops, underutilised crops could significantly benefit the future of agriculture (Garibaldi et al. 2017).

### 4.5.3. Underutilised Species with the Potential of Improving Sustainability

*Abroma augusta* (L.) L.f., Devil's cotton, is a species which most probably originated in India. It grows to be a two-to-four metre tall shrub when cultivated. When not cultivated it can grow to be up to 10 metres tall. The flowers can differ in colour from grey to yellow or purple. It is mostly used for its bast fibre, but the leaves and seeds are edible as well. The fibre reaches its optimal quality when the plant is flowering; this is the best time for harvesting. Extracted fibres are 0,5 to 2,5 metres long and are usually used for objects, such as ropes or fishing nets. It is mainly grown in India and Southeast Asia. The current distribution in Africa is not exactly known, however, it is certainly grown in the Democratic Republic of Congo and Uganda (Wabuyele 2011).

*Bombax buonopozense* P.Beauv. is a tree native to Western Africa. It grows up to 40 metres in height, with a straight bole with a grey-brown colour. The flowers are relatively small and red. The seed fibre cannot be spun, therefore, the kapok fibre of *Ceiba pentandra* is preferable and more widely known. The seed floss of *Bombax buonopozense* P.Beauv. is used to stuff pillows and mattresses, the wood can be used for all kinds of things, the leaves and young fruits are edible, and the bark is used for medicinal purposes. This species is very multifunctional. It is almost exclusively cultivated in its place of origin - from Guinea throughout the western coast of Africa to Angola. (Leung et al. 1968).

*Calotropis procera* (Aiton) R.Br. is a shrub or a small tree, usually two to three metres tall, although it can sometimes grow up to six metres in height. The stem is simple and only rarely branched, while its flowers are small and round. After the plant flowers, silky, white, three-centimetre-long seed fibre can be obtained (Kaur et al. 2021). This fibre has silk-like qualities and is seen as a potential substitute to silk. The species is to a high degree salt and drought tolerant and is able to grow in semi-desert conditions. It is seen as very adept for agroforestry systems in poor soils (Mathews 2018). The range of cultivation of this species covers central and northern Africa - more than 20 African countries in total - as well as southern and western Asia (Kaur et al. 2021).

*Crotalaria juncea* L. is a herb that grows up to 1,5 metres tall. The stem is branched only laxly and the bisexual flowers are a bright yellow colour and relatively small. The fruit is a hairy cylindrical pod. The most valuable part is its bast fibre of a relatively good quality, which is usually used for ropes, fishing nets, sacks, paper manufacturing, and footwear. The benefit of *Crotalaria juncea* is its usage as an intercrop. With major crops such as maize, sorghum, rice, cotton, tobacco, or sugarcane, it is sometimes grown to suppress weeds and prevent soil erosion (Maroyi 2011). *Crotalaria* *juncea* has also got the impressive quality of being used as a forage crop as 30% of its leaves are made up of protein. Thanks to its multifunctionality, the plant could potentially be cultivated in much larger amounts than it is today (Topcu & Ozkan 2019).

*Hyphaene thebaica* (L.) Mart., also known as Doum palm, is a tree that grows up to 20 metres tall. It is divided into two main branches which are then divided into between 8 and 16 leafy crowns. Freshly cut leaves contain about 20% fibre. The fibre is 40 centimetres long with slightly worse parameters than jute fibre. The fibre is used for making mats, bags, baskets, and coarse textiles. The quality is not excellent but it has quite a high yield. Sometimes, the leaves are dried and used as fodder for livestock during the dry season, while the fruits are also used as a forage. Another important trait is its tolerance to drought. This makes it a good option as a crop for dry regions of Africa, like Sudan or Eritrea (Soromessa 2011).

*Pavonia urens* Cav. can be found in two forms - a shrubby herb or a shrub that grows up to 3 metres tall. Its branches are hairy, bearing solitaire flowers of a white colour. The bast fibre of its bark is used for cordage, baskets, mats, as well as other products. The leaves can be cooked as a vegetable. The plant also has ornamental and medicinal value, particularly the roots which are used in traditional African medicine for curing stomach problems, other wounds, or impotence. *Pavonia urens* Cav. is currently found mostly in the wild, however, as it is easy to grow, it could be introduced into small-scale farming throughout the African continent (Kémeuzé & Nkongemeneck 2011).

*Raphia farinifera* (Gaertn.) Hyl. is a palm species distributed mainly in the southern part of tropical Africa. The tree grows up to 25 metres tall. The upper part is covered with leaf-bases, while its flowers are unisexual and the seed mesocarp is oily. The fibre is obtained from young leaflets, which is locally used for making a wide variety of products, such as mats, baskets, hats, footwear, and other textiles. In Madagascar, it is used for making floats for fishing nets. The fibre is of good quality and the yields are also relatively high and stable. The young terminal is cooked and eaten as palm cabbage. The tree can be tapped for sap and used for making palm wine, which can then be distilled into hard liquor. Roots of the tree are used locally as a painkiller (Jimu 2011). The fibre, after NaOH treatment, increases its cellulose level by 22% in comparison to untreated fibre. This increases its quality. The plant has the potential for further expansion (Fadele et al. 2019).

*Sida rhombifolia* L. is a herb, although it can perhaps be described as a shrublet, which grows to two to three metres tall. Its stems are densely covered with curly hairs. The plant bears tiny, white, bisexual flowers that turn into kidney-shaped seeds. The fibre that is extracted from the bark is white and very soft. It can even be spun with silk. It is weaker and finer than the fibre of jute but can be used as its substitute since the properties are similar. It is locally used for the making of nets, ropes, brooms, and textiles. The leaves and roots are used in local medicine for depressing the pressure of the smooth muscles. It also helps with asthma and bronchitis and the plant's leaf sap has antiseptic properties. The leaves can be cooked as a vegetable and used as fodder for livestock. It is another species which is easy to grow and could become increasingly popular in the future (Bosch 2011).

*Leptadenia pyrotechnica* (Forssk.) Decne. is a shrub that grows up to three metres tall. It is densely branched with round, yellow flowers and tiny fruits that contain many seeds. The plant has the potential to become economically significant because of its fibre. It can be used for making ropes or textiles when mixed with an additional type of fibre. It is also suitable for paper manufacturing. As a desert plant, *Leptadenia pyrotechnica* (Forssk.) Decne. is widely used for sand dune stabilisation (Sanogo 2011). It is a species that is adept for African countries suffering from global warming and desertification. Another of its uses comes from its medicinal properties (Abd-ElGawad et al. 2022).

*Urena lobata* L., also called Congo jute, is a shrub that grows up to one to 2.5 metres tall. Cultivated forms grow up to five metres in height and are poorly branched. Its flowers are a pink colour and its seeds are small. The fibre is of a good quality and it can serve as a substitute for jute. It is flexible, soft and lustrous. It is usually used for making ropes, nets, and strings, however, it has more uses, such as in sacks or paper manufacturing. The leaves can be eaten like a vegetable or be used as fodder for livestock. Different parts of the plant are used in traditional African medicine (N'danikou et al. 2011).

# 5. Conclusions

A general overview of fibre crops cultivation in Africa was presented in this thesis. The vast majority of production comes from major cash crops, such as cotton or sisal.

According to FAOSTAT, only about 10% of production comes from underutilised species.

However, hand in hand with the cultivation of the major crops comes ecological issues. Major crops are dependent on the usage of artificial fertilizers and various kinds of pesticides, which are, often, detrimental to the environment, affecting local fauna and flora. This unsustainable style of agriculture is depleting the soil and has already started to cause a decline in the production of these crops. With the current increase in global temperatures and climate change in general, the weather is becoming much more unstable, with a higher occurrence of extreme weather conditions on all sides. That has got a negative effect on the yields, especially making them unpredictable.

Genetically modified crops have not proven to be a solution yet. Their development is very difficult and expensive. The results of introducing genetically modified fibre crops to Africa were not really successful, however, this might change in the future.

A solution to improve sustainability could be the use of underutilised crops, since they do not require high inputs of fertilizers nor pesticides. It is unclear whether they could actually completely replace the major crops, although, they can help to stabilize the production of small-scale African farmers. Higher diversification would make them less vulnerable to unpredictable situations.

38 species were involved in this thesis; 28 of which could be considered underutilised in Africa. *Calotropis procera* (Aiton) R.Br. is an underutilised species with the potential to become utilised on a much larger scale in the future. It is suitable for very hot and dry regions and is relatively salt tolerant. It is seen as a perfect adept for agroforestry systems. It would be beneficial to continue research focused mainly on this species.

This thesis accomplished its original aim to provide a general overview of fibre crop species cultivated, at least to some extent, in Africa. It provided information about the negative and positive effects of the production of different species and proposed several underutilised species which could be useful in the future.

Table 1. - List of fibre crop species cultivated in Africa

| Scientific name | Family | Growth habit | Type of fibre | Fibre uses | Other uses | References |
|---|---|---|---|---|---|---|
| *Abroma augusta* (L.) L.f. | *Malvaceae* | shrub/tree | bast | ropes, nets, clothing | medicine, leaves and seeds as nutrition, ornamental use | 1 |
| *Agave sisalana* Perrine | *Asparagaceae* | acaulescent shrub | leaf | ropes, nets, sacks, industrial fabrics, mats, carpets, building panels | fencing, house construction, thatching | 2 |
| *Bombax buonopozense* P.Beauv. | *Malvaceae* | tree | seed | clothing, stuffing of mattresses and cushions | house construction, fodder for livestock, leaves and young fruits as nutrition, medicine | 3 |
| *Calotropis procera* (Aiton) R.Br. | *Apocynaceae* | shrub | bast, seed | ropes, nets, paper manufacturing, clothing, stuffing | medicine, arrow poisons | 4 |
| *Calotropis gigantea* (L.) W.T.Aiton | *Apocynaceae* | shrub/tree | bast, seed | nets, strings, clothing | medicine, ornamental use, leatherworking | 5 |
| *Chamaerops humilis* L. | *Arecaceae* | shrub/tree | leaf | rugs, sacks, stuffing, brushes | ornamental use | 6 |
| *Corchorus acutangulus* L. | *Malvaceae* | herb | bast | strings, ropes | leaves as nutrition, medicine | 7 |

Table 1. *(Continued)*

| **Scientific name** | **Family** | **Growth habit** | **Type of fibre** | **Fibre uses** | **Other uses** | **References** |
|---|---|---|---|---|---|---|
| *Corchorus capsularis* L. | *Malvaceae* | herb | bast | sacks, bags, carpets, fabrics, paper manufacturing | leaves as nutrition, medicine | 8 |
| *Corchorus olitorius* L. | *Malvaceae* | herb | bast | sacks, bags, industrial fabrics, strings | leaves as nutritive, medicine | 9 |
| *Crotalaria juncea* L. | *Fabaceae* | herb | bast | ropes, nets, bed linen, paper manufacturing, carpets | fodder for livestock, medicine | 10 |
| *Furcraea gigantea* (L.) Haw. | *Asparagaceae* | acaulescent shrub | leaf | ropes, clothing, tapestries, sacks, paper manufacturing | ornamental use, plant for green roofs in the tropics, medicine | 11 |
| *Gossypium arboretum* L. | *Malvaceae* | shrub/tree | seed | clothing, textile fabrics, paper manufacturing | seed oil, medicine | 12 |
| *Gossypium barbadense* L. | *Malvaceae* | shrub | seed | finest clothing, textile fabric, sewing thread, paper manufacturing | seed oil, ornamental use, bee forage, medicine | 13 |
| *Gossypium herbaceum* L. | *Malvaceae* | shrub | seed | clothing, textile fabric, paper manufacturing | seed oil, medicine | 14 |

Table 1. *(Continued)*

| Scientific name | Family | Growth habit | Type of fibre | Fibre uses | Other uses | References |
|---|---|---|---|---|---|---|
| *Gossypium hirsutum* L. | *Malvaceae* | herb/shrub | seed | clothing, textile fabric, sewing thread, paper manufacturing | seed oil, medicine | 15 |
| *Hibiscus cannabinus* L. | *Malvaceae* | herb | bast | ropes, industrial fabric, nets, paper manufacturing, mats | leaves and young fruits as nutrition, medicine | 16 |
| *Hyphaene compressa* H.Wendl. | *Arecaceae* | tree | leaf | baskets, rugs, chairs, brooms, hats | fruits as nutrition, local alcoholic beverage, house construction | 17 |
| *Hyphaene petersiana Mart.* | *Arecaceae* | tree | leaf | baskets, rugs, ritual clothing, hats | palm wine and liquor, fruits as nutrition | 18 |
| *Hyphaene thebaica* (L.) Mart. | *Arecaceae* | tree | leaf | mats, bags, baskets, ropes, industrial fabric | fences, house construction, fodder for livestock, medicine | 19 |
| *Leptadenia pyrotechtica* (Forssk.) Decne. | *Apocynaceae* | shrub | bast | ropes, nets, paper manufacturing | medicine, leaves as nutrition, dune stabilisation | 20 |

Table 1. *(Continued)*

| Scientific name | Family | Growth habit | Type of fibre | Fibre uses | Other uses | References |
|---|---|---|---|---|---|---|
| *Loudetia simplex* (Nees) C.E.Hubb. | *Poaceae* | herb | bast | ropes, baskets, hats | fodder for livestock, medicine | 21 |
| *Linum usitatissimum* L. | *Linaceae* | herb | bast | clothing, textile fabric, curtains, towels | linen oil, seeds as nutrition | 22 |
| *Lygeum spartum Loefl.* ex L. | *Poaceae* | herb | leaf | ropes, baskets, paper manufacturing, mats | fodder for livestock, soil rehabilitation | 23 |
| *Musa textilis* Née | *Musaceae* | herb | leaf | paper manufacturing, marine cordage, sacks, teabags, footwear | fodder for livestock, ceiling boards | 24 |
| *Pavonia urens* Cav. | *Malvaceae* | herb/shrub | bast | ropes, strings, baskets | roof rods, fodder for livestock, ornamental use | 25 |
| *Raphia farinifera* (Gaertn.) Hyl. | *Arecaceae* | tree | leaf | baskets, hats, industrial fabric, footwear, nets, bags | palm wine and liquor, oil, wax | 26 |

Table 1. *(Continued)*

| Scientific name | Family | Growth habit | Type of fibre | Fibre uses | Other uses | References |
|---|---|---|---|---|---|---|
| *Raphia hookeri* G.Mann & H.Wendl. | *Arecaceae* | tree | leaf | ropes, belts, brushes, paper manufacturing, baskets, bags | palm wine, palm cabbage, medicine | 27 |
| *Raphia vinifera* P.Beauv. | *Arecaceae* | tree | leaf | baskets, mats, hats, clothing | palm wine and liquor, medicine | 28 |
| *Sansevieria aethiopica* Thunb. | *Asparagaceae* | herb | leaf | ropes, bowstrings, twines, mats | ornamental use, medicine | 29 |
| *Sansevieria liberica* Gérôme & Labroy | *Asparagaceae* | herb | leaf | ropes, bowstrings, threads | ornamental use, medicine | 30 |
| *Sansevieria longiflora* Sims | *Asparagaceae* | herb | leaf | ropes, threads | ornamental use | 31 |
| *Sesbania bispinosa* (Jacq.) W.Wight | *Fabaceae* | shrub | bast | ropes, nets, sailcloth, sacks, mats, paper manufacture | natural gum, fodder for livestock, nutrition, medicine | 32 |
| *Sida cordifolia* L. | *Malvaceae* | herb/shrub | bast | ropes, baskets, brooms | leaves as nutrition, medicine | 33 |

Table 1. *(Continued)*

| Scientific name | Family | Growth habit | Type of fibre | Fibre uses | Other uses | References |
|---|---|---|---|---|---|---|
| *Sida rhombifolia* L. | *Malvaceae* | herb/shrub | bast | nets, toothbrushes, sacks, industrial fabric | leaves as nutrition, medicine, fodder for livestock | 34 |
| *Sparrmannia ricinocarpa* (Eckl. & Zeyh.) Kuntze | *Malvaceae* | shrub | bast | ropes, clothing, nets, industrial fabric | bee forage, fodder for livestock | 35 |
| *Themeda triandra* Forssk. | *Poaceae* | herb | leaf | baskets, thatching, paper manufacturing, ropes | fodder for livestock, medicine | 36 |
| *Typha domingensis* (Pers.) Steud. | *Typhaceae* | herb | leaf | mats, hats, baskets, paper manufacturing, thatching | leaves and stems as nutrition, fodder for livestock | 37 |
| *Urena lobata* L. | *Malvaceae* | shrub | bast | ropes, industrial fabric, carpets, nets, bags | leaves as nutrition, medicine | 38 |

1 (Wabuyele 2011), 2 (Lock 1969), 3 (Leung et al. 1968), 4 (Kaur et al. 2021), 5 (Jiofack Takofou 2010), 6 (Valíček et al. 2002), 7 (N'danikou & Achigan Dako 2011), 8 (Berger 1969), 9 (Berger 1969), 10 (Maroyi 2011), 11 (Vaughan G. 2011), 12 (Berger 1969), 13 (Berger 1969), 14 (Berger 1969), 15 (Berger 1969), 16 (Valíček et al. 2002), 17 (Beentje 1994), 18 (Coates Palgrave 1983), 19 (Soromessa 2011), 20 (Sanogo 2011), 21 (Oyen 2011b), 22 (Berger 1969), 23 (Valíček et al. 2002), 24 (Berger 1969), 25 (Kémeuzé & Nkongemeneck 2011), 26 (Jimu 2011b), 27 (Brink 2011), 28 (Russell 1965), 29 (Takawira-Nyenya 2011), 30 (Lewis 1986), 31 (Valíček et al. 2002), 32 (Uphof 1959), 33 (Bourobou Bourobou 2011), 34 (Bosch 2011), 35 (Beentje 1994), 36 (Lewis 1986), 37 (Lewis 1986), 38 (N'danikou et al. 2011).

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# Appendices

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