Master thesis

Suitable woody species for an unirrigated hardwood cutting propagation in the North-Bank Region of The Gambia

A preliminary study within the framework of the project “REUG“

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REUG
Research and Educational Programme on Unirrigated Methods of Tree Propagation in The Gambia

The present thesis arose with great support of Seffo Minteh, born in The Gambia and living in Vienna for more than 15 years. He untiringly fights for ethnic and gender equality, access to education, sustainable development and environmental protection in his country of origin. In 2018, we founded the project “REUG – Research and Educational Programme on Unirrigated Methods of Tree Propagation in The Gambia” in order to counteract ongoing land degradation and increasing loss of forest cover. In Seffo, I fortunately found a reliable, motivated and emphatic partner. And much more: A good friend.

REUG

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Abstract

Desertification is increasingly developing to a felt and visible problem threatening the production-base and the livelihood of the rural population within the small West African country The Gambia. The North-Bank Region located north of the main River Gambia and bordering to Senegal is especially affected. As a countermeasure against this problem, restoration and sustainable reforestation of resistant and durable forest areas are urgently required. However, the propagation of woody plants becomes more and more challenging. The success rate of frequently applied, generative reproduction techniques based on the utilisation of seeds gets increasingly reduced by low germination capacities and lack of seeds. Unirrigated vegetative propagation techniques by using hardwood cuttings are considered to be successful alternatives. Therefore, the main objective of this thesis was to identify occurring woody species which exhibit the most promising properties for a practicable and sustainable hardwood cutting propagation. To achieve this, two representative stocks of trees located close to the village of Farafenni were surveyed by using a raster model including 18 circular survey plots. Furthermore, all 53 determined woody species were assessed according their availability, social distribution within the stands, average height, trunk diameter, vitality and possible capability to adventitious root formation. This was done by applying a specifically developed evaluation system based on the principle of a decision tree. Consequently, *Azadrachta indica*, *Ficus capensis* and *Gmelina arborea* were classified as the most promising woody species in order to be further tested concerning their actual suitability for an unirrigated, practicable and sustainable propagation by the technique of hardwood cutting reproduction.

Keywords: hardwood cuttings, vegetative propagation, adventitious root formation, desertification, North-Bank Region, The Gambia

Kurzfassung

Desertifikation entwickelt sich in dem kleinen westafrikanischen Land Gambia zu einem ernsthaften Problem, welches die Lebensgrundlagen der ländlichen Bevölkerung zunehmend bedroht. Die Nord-Bank Region, die sich nördlich des Hauptflusses Gambia an der Grenze zum Senegal befindet, ist speziell von den negativen Auswirkungen dieser Prozesse betroffen. Um Desertifikation in dieser Region entgegenzuwirken, erscheinen die Förderung und die nachhaltige Aufforstung widerstandsfähiger und dauerhafter Gehölzbestände als die einzigen erfolgsversprechenden Gegenmaßnahmen und somit als dringend erforderlich. Die Vermehrung geeigneter Gehölze, welche derzeit hauptsächlich auf generativen Methoden basiert, stellt die örtlichen Bauern jedoch vor eine große Herausforderung. Aufgrund abnehmender Verfügbarkeit und oftmals schlechter Keimfähigkeit der gesammelten Samen sind deutlich höhere Aufwände und dennoch stetig abnehmende Erfolgsquoten zu verzeichnen. Unbewässerte vegetative Techniken der Gehölzvermehrung, speziell mittels Steckhölzern, könnten effektive Alternativen darstellen. Das Hauptziel dieser Arbeit war es folglich, jene örtlich vorkommenden Gehölzarten ausfindig zu machen, welche die erfolgversprechendsten Eigenschaften für eine praktikable und nachhaltige Steckholzvermehrung aufweisen. Um diese Auswahl treffen zu können, wurden zuerst umfangreiche Vegetationsaufnahmen in zwei unterschiedlichen Gehölzbeständen nahe der Ortschaft Farafenni durchgeführt. Diese Aufnahmen basierten auf einem Raster-Modell mit insgesamt 18 kreisförmigen Aufnahmeflächen. Anschließend wurden alle 53 nachgewiesenen Gehölzarten bezüglich ihrer Verfügbarkeit, ihrer sozialen Verteilung innerhalb der Bestände, ihrer durchschnittlichen Höhen, Stammumfänge, Vitalität und ihrer möglichen Fähigkeit zur Bildung von Adventivwurzeln bewertet. Diese Bewertung erfolgte mittels eines eigens erarbeiteten Bewertungssystems, welches nach dem Prinzip eines Bewertungsbaumes aufgebaut ist. Daraus resultierend gehen *Azadrachta indica*, *Ficus capensis* und *Gmelina arborea* als jene Gehölzarten hervor, welche die vielversprechendsten Eigenschaften besitzen, um weitführenden Tests bezüglich ihrer tatsächlichen Eignung für eine unbewässerte, nachhaltige und praktikable Vermehrung mittels Steckhölzern unterzogen zu werden.

Schlüsselwörter: Steckhölzer, vegetative Vermehrung, Adventivwurzelbildung, Desertifikation, Nord-Bank Region, Gambia

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1 Introduction

This thesis constitutes a preliminary study within the framework of the project "REUG – Research and Educational Programme on Unirrigated Methods of Tree Propagation in The Gambia" which was started in 2018.

1.1 Background

The Gambia is a small and generally underdeveloped Sahelian country (HARRY et al. 2019, p. 2) which heavily struggles with major environmental challenges like continuous loss of the vegetation cover, ongoing land degradation due to unsustainable cultivation techniques and the effects of climate change (HARRY et al. 2019, p. 2). Resulting processes of desertification lead to an ongoing destruction of the local population's existential basis and therefore induce a number of negative social and economic consequences (VERON et al. 2005, p. 752). By JEDDELOH (1979, p. 112-113), preferably closed stocks with an equal share of trees and shrubs constitute the most effective system of soil protection. Therefore, sustainable reforestation programs represent the key task for future generations. However, usually applied techniques of tree and shrub propagation based on generative reproduction become more and more difficult to implement (LAOULALI 2015, p. 1). Methods of vegetative propagation, especially by using "hardwood cuttings", are considered to be promising alternatives. In fact, there is scarcely scientific information about this topic in The Gambia.

The main objective of this thesis is to analyse biodiversity indices, classify regeneration capacities and quantify social structures within occurring tree populations in order to define general appropriate woody plant species for an unirrigated and sustainable propagation by hardwood cuttings.

1.2 Research questions

This thesis deals with the following main research questions:

1.) Which different woody species occur at the researched locality near the village of Farafenni and how are local tree populations structured?

2.) Which occurring woody species exhibit the most promising properties for an unirrigated and sustainable propagation by the method of hardwood cutting reproduction in order to be tested on rooting capacities within further field trials and monitoring programs?

1.3 Hypotheses

The main hypotheses are formulated as follows:

1.) Local tree populations are composed of different woody species which exhibit unequal abundances, growth habits, social-, size- and vitality class distributions. They furthermore differ in their natural reproduction capacities.

2.) Considering local conditions, some occurring woody species are better suited to be sustainably propagated by hardwood cuttings than others.

2 The Republic of The Gambia

The Republic of The Gambia is the smallest and one of the most densely populated countries of the African mainland. It exhibits a poor economic performance that adversely influences the living conditions of the local population. In Addition, a continuous loss of the vegetation cover, ongoing land degradation due to unsustainable cultivation techniques and the effects of climate change (Chapter 3.2.1) heavily burden on the country (HARRY et al. 2019, p. 2). As a result, irregular migration plays a significant role in Gambian society. Therefore, more than 35,000 Gambians arrived in Europe by irregular means between 2014 and 2018 (Iom.int).

2.1 History

At the end of the 15th century, the Portuguese first built settlements close to the Gambia River and started to trade with gold, cloths, and guns. They have also been the first who captured local inhabitants and sent them as slaves across the Atlantic and to Europe. By the 17th century, the English, Dutch and French were also trading in this area and made huge profits by slave trades. In 1820, The Gambia became a British protectorate. The British furthermore proclaimed it as a colony in 1886. In 1965, The Gambia finally announced its independence (LAMBERT 2019, p. 1).

2.2 Geographic position

The Gambia is a small and very narrow country in West Africa (Figures 1 and 2). It borders to Senegal and the Atlantic Ocean in the West and exhibits a total land area of about 10,000 km^2. The country extents over both sides of the River Gambia, the nation's namesake, which flows through the centre of The Gambia and empties into the Atlantic Ocean, where the capital city Banjul is located (SILLAH 2015, p. 17). According to FAO (2015, p. 9), the country can be subdivided into three major biological regions: “[…] (1) the marine system and coastal zone on the Atlantic Ocean in the west, (2) the east-to-west running River Gambia and related freshwater and estuarine ecosystems, and (3) the terrestrial ecosystems in the remaining stretches of land behind the coast and to the north and south of the river”. Despite its small size, The Gambia exhibits a remarkable biodiversity (SILLAH 2015, p. 17).

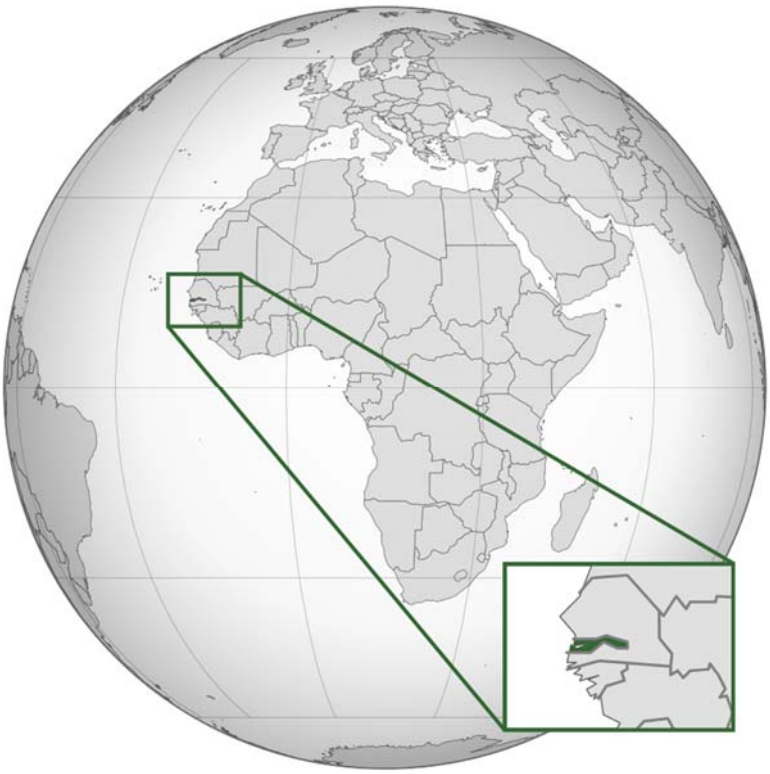


Figure 1: The position of The Gambia - orthographic projection with inset (FLAPPIEFH 2011)

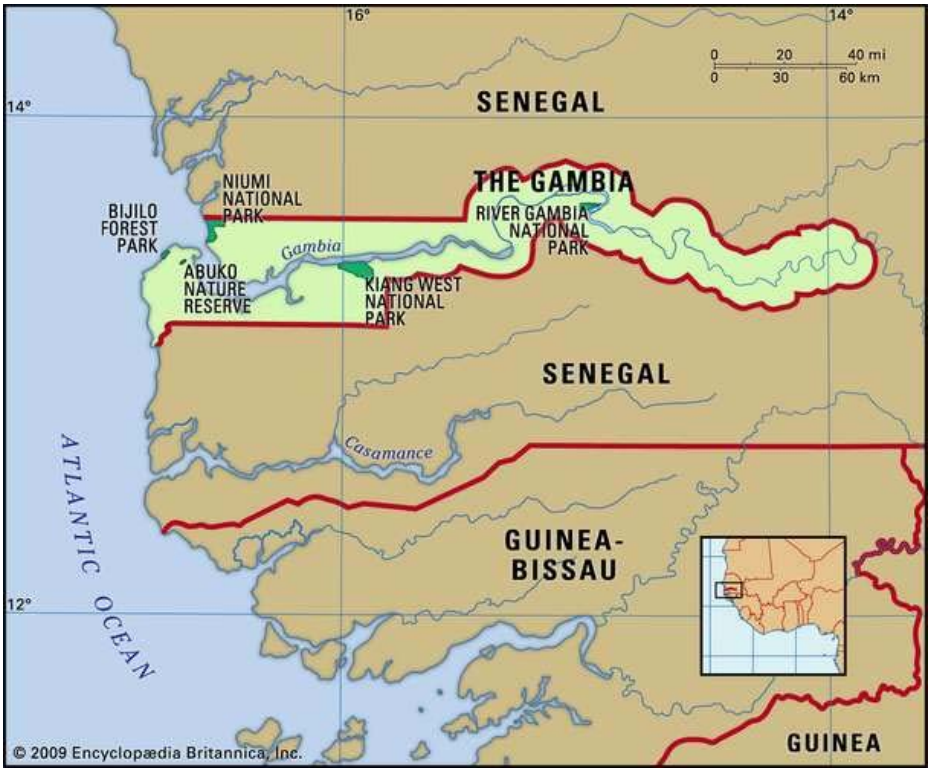


Figure 2: Borders of The Gambia (britannica.com)

2.3 Geology

The geology of The Gambia has its origin in the Tertiary and Quaternary periods. Nearly 53 % of its land area is covered with alluvial deposits along the river which date back to these times. The Gambia is generally low-lying and exhibits altitudes mostly below 60 m above sea level. The area immediately along the river and its tributaries is termed valley floor and makes up nearly 4,048 km^2 which constitutes 39 % of the land area. On this valley floor, especially the hydrology affects the soils and the occurring vegetation. Gambia's geomorphology is also closely connected to the main River Gambia. This river divides the country into two narrow segments which measure less than 30 km at the widest part. In the western third of the country, the river water is salty or brackish. As a result, the soils mainly consist of clay and are heavily impregnated with salt. In the upper freshwater areas of the river, the soils are often light alluvium and more fertile. Consequently, those soils have been used for the rice production for centuries. Most of the upland soils of The Gambia are sandy with a low nutrient content and a poor water holding capacity. The coastal beach complexes mainly consist of predominantly fine to medium grained sands with a significant amount of heavy minerals like ilmenite, rutile and zircon (SILLAH 2015, p. 17-18).

2.4 Climate

According to KINTEH (1999, p. 3), "[…] the country has a Sudano-Sahelian type of climate characterised by a long dry season from October to early June and a short rainy season from mid-June to early October". The mean air temperature is about 25 °C (UNCCD 2000, p. 23). The average annual rainfall ranges from 850 mm to 1200 mm, depending on the respective region. The relative humidity during the rainy season amounts above 70 % throughout the whole country and around 68 % along the coast and 41 % inland during the dry season. In the recent years, significantly decreasing rainfall and increasing temperatures have been recorded in The Gambia. Since 1951, there has been an average reduction of about 27% in the annual average rainfall including a reduction in the length of the rainy season and considerable increases in surface temperature. The Gambia is generally classified as a "net sink" for greenhouse gas emissions which means that the amount of greenhouse gases removing from the atmosphere is more than the amount emitting. Nevertheless, the country's climate is subjected to the influence of the global climate and its change. Therefore, hazards like torrential rainfall, storms, droughts and even cold spells are projected to become more widespread and to increase in frequency and intensity (SILLAH 2015, p. 19-20).

2.5 Socio-economic background

The total population of The Gambia is approximately 2.1 million (CENTRAL INTELLIGENCE AGENCY, 2019). According to SILLAH (2015, p. 32), the gross domestic product per capita in The Gambia amounts for USD 560, which ranks it among the least developed countries in the world. Its economy is characterised by its small size, a relatively narrow economic base and a low level of overall skills and literacy. The main sectors of the Gambian economy are agriculture, redistributive trade and tourism. Other areas like the construction and telecommunication have been expanding rapidly over the past years. However, agriculture and livestock production account for approximately 30 % of the gross domestic product per capita, employ around 70 % of the labour force and provide income for over 60 % of the rural population (SILLAH 2015, p. 32). The Gambian socio-demographic dynamics are characterised by a very high fertility rate of 6.04 and an annual population growth rate of 4.2 %. Due it's very high population density of 108 persons per km^2, The Gambia is one of the most densely populated countries within the African continent. This fact surely constitutes one of the key factors causing ongoing processes of desertification (Chapter 3). Furthermore, the age structure is very unusual. It is estimated that 80 % of the total population fall into the age bracket of 31 years and below, while 71 % are 24 years and younger. Therefore, the population density is certain to increase, regardless of short to medium term efforts to control it (SILLAH 2015, p. 32-34).

2.6 Societal structure

According to SEM (2017, p. 16), 58 % of the Gambian population live in cities and suburbs. The most densely populated areas are Banjul and Brikama located at the mouth of the Gambia River. They are also the centre of business and tourism. However, there is a high diversity of different ethnic groups allocated over the entire territory of the country. The prorated most frequent groups are the Mandinka, constituting about 34 % of the population, the Fula (24.1 %), the Wolof (14.8 %), the Jola (10.5 %), the Serahuli (8.2 %), the Serer (3.1 %), the Manjago (1.9 %), the Bambara (1.3 %) and the group of Aku (0.5 %). Since colonial times, English is the official language of The Gambia. In addition, many different local languages are spoken. But it is important to draw out that there is no perfect match between ethnic groups and languages as a significant part of the population is able to speak several languages (SEM 2017, p. 16-18).

> "The languages most frequently spoken in The Gambia are Mandinka (including Jahanka), Wolof, Fula (or Fulfulde, Peul, including Tukulor and Lorobo), Serahule (or Soninke Sarakole, Maraka), Jola (or Diola, including Karoninka), Serer (or Serere), Manjago (or Mandjak) and Aku (Creole, based on English)" (SEM 2017, p. 17-18).

2.7 Phytogeography

The vegetation of The Gambia represents a transition between the moist tropical rainfall in the South of the continent and the dry savanna in the North (DANSO 2001, p. 5-6). The two major vegetation types occurring are called Guinea Savanna and Sudan Savanna. On the banks of the Gambia River, large mangrove swamps consisting of the two main species *Rhizophora racemosa* and *Avicennia Africana* can be found. According to DANSO (2001, p. 6), the most frequent species within the western woodland areas are "[…] *Daniellia oliveri, Khaya senegalensis*, *Pterocarpus erinaceus, Terminalia albida, Parkia biglobosa, Prosopis africana, Piliostigma thonningii, Combretum micranthum* and *Bombax buonopozense"*. In riparian woodlands of the country, the vegetation is generally denser due to a higher water table. Under undisturbed conditions, individuals of those species can normally reach large dimensions. However, the most extensive undeveloped areas of The Gambia are classified as "disturbed woodlands" which are fairly open and exhibit a typical shrub understory with trees seldom taller than 15 m. The common woody species in these areas are *Combretum micranthum, Terminalia albida, Cordyla africana, Cassia sieberiana, Oxytenanthera abyssinica* and *Sterculia setigera* (DANSO 2001, p. 5-6).

2.8 State of forest habits

> "About one hundred years ago, most of the Gambian land territory was covered by dense and almost impenetrable forests although large forest areas on the north bank of the River Gambia have been already cleared for groundnut cultivation" (THOMA and CAMARA 2005, p. 1).

Those former forests were rich in wildlife and provided habitat for a variety of large mammals like hippopotamus, waterbucks, roans, servals, caracals, buffalos, giraffes, elephants and lions which are nowadays rare or even locally extinct (UNCCD 2000, p. 29). With the ongoing growth of the population, natural forest areas are increasingly destroyed by over-utilisation, bush fires and excessive transformation into agricultural areas (THOMA and CAMARA 2005, p. 1). As a result, secondary succession frequently takes place and affects lesser dense forests, a poor regeneration potential, a lower growth and an undesirable grass occupation (NGET 2010, p. 4). In addition, this process is accelerated by decreasing annual rainfalls. This development is not only of national importance but of sub-regional relevance as the River Gambia constitutes a natural barrier to the spread of desertification southwards the Sahara desert (THOMA and CAMARA 2005, p. 1). Based on the conclusions of the first national forest inventory of 1998 (TROTG 1998, p. 8), 43 % of the total land area, or about 505,300 hectares, were still classified as forest at this time. However, the last inventory implemented in 2010 (most updated data) only yields a percentage share of 26.6 % (NGET 2010, p. 41). This in an alarming decrease of 16.4 % within 12 years.

3 Desertification

More than one billion people live in arid and semiarid environments which make up more than 40 % of the global land surface. The rural population in these areas ultimately depend on the effective use of available natural resources (VERON et al. 2005, p. 752). However, increasing desertification has been ranked as a major environmental and social issue for the coming decades (HIGGINBOTTOM and SYMEONAKIS 2014, p. 9552).

3.1 Definition of desertification

In fact, there is still no universally agreed definition of desertification (FAROUK et al. 2009, p. 12). The term was rather marked by the French botanist and forest scientist André Aubreville in the late 1940s. He challenged the view that desertification describes the phenomenon of desert extension. In fact, the term derived from the Latin designation „desertus facere“, which can be interpreted as land degradation and desiccation as a result of continuous and excessive overuse of productive territories in arid, semiarid and dry sub-humid regions. Therefore, the process of desertification also takes place in dry-zones of Europe and all over the world, regardless of the occurrence of adjacent deserts (AKHAR-SCHUSTER and SCHMIEDEL 2012, p. 376). The United Nations Convention to Combat Desertification (UNCCD) defines desertification as“[…] land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities […]” (DOULA and SARRIS 2016, p. 216). VERON et al. (2005, p. 753) describe it as an extreme type and the final stage of land degradation which effects the development of local desert-like environmental conditions induced by unadjusted agricultural utilisation of land.

3.2 Causes of desertification

MÜLLER et al. (2006, p. 587) divide the factors which cause desertification into two main groups, defined as “natural climatic causes” (3.2.1) and “anthropogenic causes” (3.2.2).
It is important to underline that no single factor can be analysed one-dimensionally. It’s much more a complex causal network including various interdependencies and effects. Therefore, the following causes of desertification must be considered on a multi-level perspective in order to draw conclusions concerning consequences and possible solution approaches (BÖHM 2002, p. 17-18).

3.2.1 Natural or indirect anthropogenic causes

According to MÜLLER et al. (2006, p. 588-589), it is not necessarily correct to talk about "natural causes" of desertification. In many cases, those causes which directly affect main processes are closely interlinked to human activities (e.g. carbon emissions). Therefore, they are basically from natural origin but their current and future increasing expressions are anthropogenically influenced.

Global climate change:

New findings which are based on statistical data concerning climate changes of the last 3.8 billion years confirm a currently rapid increase of the global average annual temperature. This temperature rise inevitably causes massive environmental changes at our planet which significantly affect the life circumstances of plants, animals and human beings.
(WBGU 2008, p. 55). It is to be expected that extreme weather events like droughts, intense rainfalls and storms come up pronounced and more frequently in future. These conditions generally exacerbate the difficult situation in dry regions and therefore boost the below described key factors of desertification (WBGU 2008, p. 67-79).

Soil erosion by wind:

Wind erosion constitutes a key mechanism of progressing desertification. It's a phenomenon of extensive insufflation of fine, loose soil particles caused by continuously occurring wind gusts. These gusts physically remove the most fertile portion of the soil from fields and furthermore pollute the air, reduce seedling survival and growth and lower the marketability of many vegetable crops (FAROUK et al. 2009, p. 261). The effects of wind erosion are especially high in areas with a missing or just a weak vegetation cover (GÖTZE et al. 2015, p. 74).
Woody plants stabilise the upper soil layers and exhibit a weakening effect on insufflation of particles and the irretrievable loss of fertile top soil (GRAF et al. 2003, p. 2).

Fluvial erosion:

Fluvial erosion means the shift of soil particles by flowing water as well as the grinding effect on entrained solids above a channel bed. Its intensity is determined by the flow rate, the gradient, the flow velocity, the type and the size of transported particles and the resistance of affected soils. Fluvial erosion outside channel beds is called "denudation" and effects a linear concentration of surface runoff in grooves which finally develop to new, temporary flooded channels (DAVY and LAGUE 2008, p. 2-3).

Soil breaking and salinization:

Wrong irrigation techniques cause salinization and further breaking of affected soils. The main reasons are bad quality of used irrigation water, inefficient drainage systems, the rise in the groundwater level and the related transport of salt from deep to upper soil layers. In addition to a consequentially reduced fertility, water accumulations complicate the agricultural utilisation of affected soils (DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT 2015, p. 2).

3.2.2 Direct anthropogenic causes

The United Nations Convention to Combat Desertification (UNCCD) defines anthropogenically influenced degradation of land as a "[…] reduction or loss of biological or economic productivity and decreasing complexity of naturally or artificially irrigated cultivation areas, grassland, pastures, forestry areas and woods in consequence of land utilisation or processes which trace to human activity and settlement patterns" (UNCCD 1994, p .41).
According to latest findings, direct anthropogenic causes have stronger effects on desertification than natural climatic causes like droughts which induce mostly short-term but reversible degradation effects. However, if an over-utilisation of natural resources takes place, droughts speed up and increase man-made processes of degradation. Simultaneously, natural resources decrease and therefore provide incentives to unsustainable practices of soil management. Therefore, traces of desertification can frequently be found in densely populated, ecological unstable steppes and savanna-areas (BÖHM 2002, p. 13).

Destruction of the vegetation cover:

According to THALEN (1980, p. 51), the intense cultivation of soils goes hand in hand with a progressive destruction of local vegetation. The disappearance of often perfectly adjusted species causes significant changes of the affected ecosystems. Plants protect soils against erosion and dehydration and influence the surrounding microclimate in a positive way. In addition, a dense vegetation cover reduces the linear and planar water runoff and constitutes an irreplaceable habit for a great number of animal species. In semiarid areas, the local vegetation is perfectly adapted to the occurring precipitation variability. During rainy years, the agricultural utilisation (see below "Rain-fed agriculture") of endangered soils seems to be possible and promising. But in years with low precipitation, it becomes clear that the actual capacity is exceeded and a sustainable use does not take place. Therefore, grain growing areas extend in those apparently "humid" areas to compensate general stagnating or decreasing harvest yields. Furthermore, the agricultural usage displaces grazing fields to even dryer, unsuitable areas for sustainable livestock farming. Finally, a longer regeneration period and a far too large number of animals per hectare inevitably lead to massive overgrazing (THALEN 1980, p.51-53).

Another big problem concerning destruction of vegetation in semiarid areas is illegal and uncontrolled logging. The main reasons for this trend seem to be the high daily per capita consumption of wood and the constantly rising wood prices. The degradation of natural stocks of trees influences the soil moisture by decreasing shading and consequently boosts erosion and soil breaking (MENSCHING and IBRAHIM 1976, p. 87).

Rain-fed agriculture:

Rain-fed agriculture constitutes a practice of agriculture in which the water demand of crops can be covered by local rainfall. Irrigation is usually only applied under extreme conditions like long lasting droughts (SPEKTRUM AKADEMISCHER VERLAG 1999, p. 1). Due to progressive desertification, sustainable rain-fed agriculture seems to be hardly possible in many semiarid regions. This leads to a vicious circle, ending with the already described extensive destruction of the surrounding vegetation cover. Therefore, 47 % of the worldwide 457.74 million hectare farmed by rain-fed agriculture are acutely affected by desertification (DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT 2015, p. 2). This particularly applies to fields which are left unexploited during years of drought. Due to lack of vegetation, wind erodes fertile topsoil and furthermore elsewhere reduces the soil quality by deposing fine sand. The consequences are local plains, dunes and ditches of pure, unfertile quartz sediments (IBRAHIM 1992, p.77). Furthermore, soil fixing root networks are frequently pulled out in many areas of cultivation. Another problem is caused by the utilisation of modern ploughs which effects serious damages compared to traditional hoes and digging sticks. The negative effects resulting from increasing desertification processes especially become clear when looking at the engineered, “cash-crop” cultivation technique. This technique is based on monoculture plantations and a high employment of machines. It must therefore be classified as extremely unadjusted for prevailing conditions in vulnerable zones (BÖHM 2002, p. 13).

3.3 Consequences of desertification

The reduction of vegetation covers and the loss of fertile top soils lead to an ongoing destruction of the existential basis of the local population and therefore induce a number of negative social and economic consequences (VERON et al. 2005, p. 752).
Socio-economic consequences for a subsistence agriculture in less developed countries especially relate to a deterioration of the local utilization potential concerning rain-fed agriculture as well as pasture farming. If, for example, the harvest from millet cultivation decreases as a result of increasing droughts, not only the marketing of the crop but even the diet of the population gets endangered. In addition, the neglect of storage management during these periods aggravates the situation. As the market prices usually rise in times of crises, sufficient money for the purchase of aliments is often not available. Because of an oversupply, it furthermore gets very difficult for cattle breeders to sell their animals. As there are often no other income opportunities in poor regions of developing countries, hunger and poverty

increase and spread. Government aid is scarcely to be expected so that the international community has to react and enable food aid. But, in some regions which are severely affected by desertification, local development opportunities after drought events are disturbed, especially if foodstuff, which does not fit to the traditional diets, was delivered (UNCCD 1999, p. 7).

3.4 Desertification in The Gambia

The Gambia is geographically located within the Sahel region of Africa, which makes it vulnerable to droughts and land degradation (MINISTERY OF ENVIROMENT, CLIMATE CHANGE AND NATIONAL RESOURCES 2017, p. 3). Therefore, desertification is increasingly developing to a felt and visible problem threatening the production-base and the livelihood of the rural population (UNCCD 2000, p. 28).

Traces of desertification can especially be found in the North-Bank Region of The Gambia. The “River Gambia” serves as a natural buffer-zone which slows down the extension of desertification processes to the southern areas of the country (UNCCD 2000, p. 23).

According to UNCCD (2000, p. 28-29), the main triggers of desertification in The Gambia can be summarised as:

- The degradation of Gambian forest habitats as a result of commercial wood exploitation and in order to create agricultural fields.
- Environmental degradation as a result of unsustainable resource use, regular bush- and forest fires, decreasing fallow-periods in arable lands, overstocking and an uneven distribution of animals over the rangelands which diminishes the affected soil fertility, carrying capacities and stocking rates.
- An extraordinarily high population growth rate of 4.2 % per annum which complicates economic growth and decreases the national agricultural product self-sufficiency.

In addition, there is a significant correlation of desertification processes with the ongoing climate change in Sahelien countries like The Gambia (SILLAH 2015, p. 51). Especially the reduction of the vegetation cover directly leads to an impoverishment of the soils, a modification of the water cycle, the hydraulic balance and the energy balance which finally causes changes in the average air temperature. The resulting water scarcity in many regions of The Gambia does not only affect the environment and natural resources, but particularly complicates the food production, declines the health condition and the livability of the population. As a result, more than 60 % of The Gambian population was suffering from menace of food poverty in the year of 2015 (SILLAH 2015, p. 51-52).

The following Figure 3 presents a former forest habitat near the village of Farafenni which was cleared about 20 years ago. It is conspicuous that the fertile topsoil is almost completely eroded as a result of just a very patchy predominant vegetation cover.

Figure 3: Erosion at a former forest habitat near the village of Farafenni (own photograph 2019)

4 Vegetative propagation of woody plants in West African countries

According to LAOULALI (2015, p. 1), woody plants play an important socioeconomic role for rural populations in West Africa. Many species are used multifariously and are therefore subject to high anthropogenic pressure. For this reason, a regressive dynamic characterized by a generally lower regeneration capacity and a scarcity or absence of young individuals frequently takes place at affected areas. In principle, there are just a few known and practiced techniques to reproduce tropical woody species in West Africa. Generative reproduction by seeds is the most common method of propagating occurring trees and shrubs and is mainly applied in agroforestry and reforestation projects. However, the production of seedlings in nurseries gets increasingly reduced by low germination capacities and lack of seeds. Therefore, vegetative or asexual propagation techniques can be promising alternatives by offering the opportunity to rapidly overcome limitations like long generation times, irregular flowering, high default ratios and a generally high outlay and water consumption for the breeding of suitable seedlings (LAOULALI 2015, p. 1).

4.1 Principles of vegetative propagation

In contrast to generative (sexual) propagation of trees and shrubs which is implemented by nursing seeds, vegetative (asexual) propagation is generally based on the division and multiplication of living plant parts (SANDOR 2007, p. 4).
MUDGE and BRENNAN (1999, p.163) define vegetative propagation as “[…]regeneration of a new individual from a portion (ramet) of a stock plant (ortet) by processes involving mitotic (not meiotic) cell division, and subsequent regeneration of complementary cells, tissues, and / or organs or entire plants to replace those "missing" from the ramet.“
Therefore, vegetative propagated individuals are actually exact copies or clones of their mother plants. All ramets exhibit an identical genotype and tend to be uniform in shape and developmental behaviour (LIPENSKY 2010, p. 7).

4.2 Methods of vegetative propagation

4.2.1 Stock Division

Stock division is probably the simplest technique of vegetative plant propagation. A cluster of a mother plant's stock including sprouts and roots is partitioned off and pricked out at another spot. This method is based on the prerequisite that the mother plant exhibits several rooted stems. In the case of woody plants, stock division can only be implemented to propagate shrubs or multi-stem trees (SANDOR 2007, p. 9).

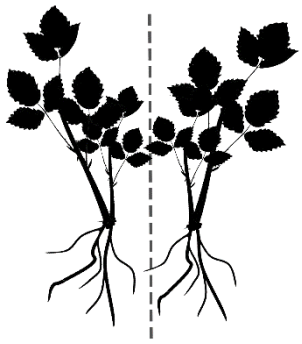


Figure 4: Principle of stock division
(own arrangement on the basis of SANDOR 2007)

4.2.2 Sucker Division

Some woody plant species exhibit "suckers". Those suckers are lateral shoots that develop from rhizomes and are located around the root neck or at roots close to the surface. Usually, they consist of one or several sprouts which are connected with the respective mother plant. Their root system is generally devised weakly or even missing. The process of propagation is implemented by cutting off those suckers and subsequently nursing them till they are grown to develop autonomously (MEGERSA 2017, p. 3).

Figure 5: Principle of sucker division
(own arrangement on the basis of MEGERSA 2007)

4.2.3 Runner Division

“Runners” are special types of sprouts which develop at the base of a respective mother plant. They usually try to get contact with the soil autonomously and form new root systems in order to develop to independent plants. By cutting off those runners and subsequently transplanting them to other spots, the propagation of suitable species can be implemented easily but usually in a low quantity (SANDOR 2007, p. 9-10).

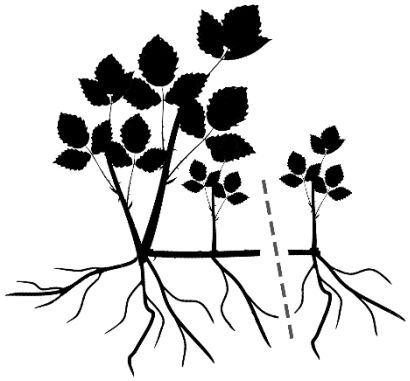


Figure 6: Principle of runner division
(own arrangement on the basis of SANDOR 2007)

4.2.4 Layering

The primary purpose of layering is to provide rooting of stems which are connected to the respective mother plant. To achieve this, stems are usually bend down into a trench and covered with soil. Depending on different techniques, the top parts of those stems are covered completely or left out for some centimetres. After developing enough roots to survive on their own, those new plants are cut off their mother plants in order to get pricked out at other spots (LERNER and DANA 2009, p. 2-3).

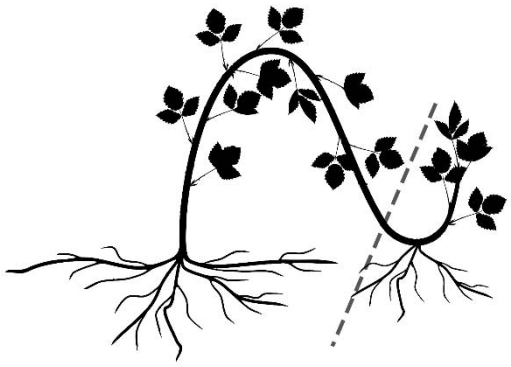


Figure 7: Principle of layering
(own arrangement on the basis of LERNER and DANA 2009)

4.2.5 Root Cuttings

This propagation technique is based on cutting off parts of roots of a mother plant. These cuttings should be 20 - 25 cm in length and 1 - 2 cm in diameter and be placed horizontally into the soil. The depth should not exceed 10 cm in order to enable a successful sprouting (SANDOR 2007, p. 16).

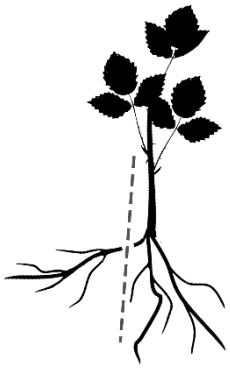


Figure 8: Principle of root cuttings
(own arrangement on the basis of SANDOR 2007)

4.2.6 Grafting

Techniques of grafting are quite complex and presuppose appropriate knowledge. They all function on the principle of matching the cambium of a scion to the cambium of a mother plant in order to create a fusion. Therefore, grafted plants are compounded organisms consisting of a rootstock (mother plant) and a twig or bud from a desired donor plant (scion). Vegetative propagation by grafting is commonly used to produce highly uniform selected genotype clones of fruit or nut trees (LIPENSKY 2010, p. 9).

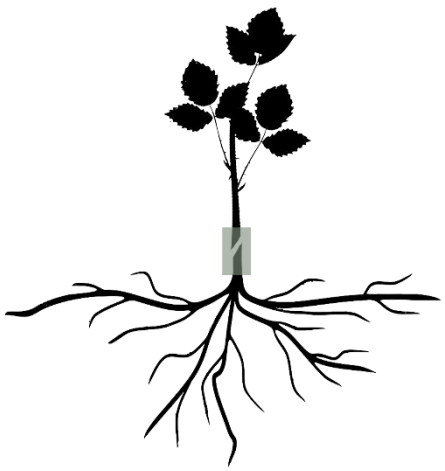


Figure 9: Principle of grafting
(own arrangement on the basis of LIPENSKY 2010)

4.2.7 Propagation by Stem Cuttings

Another opportunity to multiply woody plants is propagation by stem cuttings. A stem, twig or sprout section of a mother plant is cut off and transplanted into soil in order to develop roots and form an autonomous clone (LONGMAN 1993, p. 139). This property is based on the ability of adventitious root formation described in Chapter 4.4 (HARTMANN et al. 2010, p. 280). For this purpose, mostly soft- or greenwood cuttings, which are hardly lignified and in leaf, are used. However, a disadvantage is that these kinds of cuttings need to be irrigated, shaded and generally protected during the first weeks of development which makes the process of propagation quite time and labour-intensive (HARTMANN et al. 2010, p. 315). Hardwood cuttings which are leafless and possess larger diameters constitute a promising alternative. They are generally more resistant, exhibit a low default rate and don't dry up fast during dry periods (LONGMAN 1993, p. 140).

4.3 Hardwood Cutting Reproduction in The Gambia

Despite challenging environmental conditions in The Gambia (Chapter 2), hardwood cuttings may constitute an opportunity to propagate suitable woody species easily, successfully and time efficiently. According to ELIADES (2016, p. 1), their key-advantage compared to soft- or greenwood cuttings is "[…] that there isn't the initial requirement to provide a high humidity environment to stop the cuttings drying out before they root." This is due to a generally better water holding capacity which is based on a larger diameter, a well-advanced lignification of the cuttings and the missing of transpiring leaves. (HARTMANN et al. 2010, p. 322-323). Basically, different sizes of hardwood cuttings can be used. However, all of them have to be leafless and straight pieces of branches or stems that don't exhibit side branches and measure a diameter of at least 1 cm and a length of 15 cm or more (ELIADES 2016, p.1). Lengths and diameters may vary though depending on different species, respective propagation goals and occurring site conditions (HARTMANN et al. 2010, p. 344). Assessing the difficult circumstances in The Gambia, "live stakes", which are usually used in soil bioengineering issues, constitute the most promising variant. As illustrated in Figure 4, live stakes are usually 1.5 – 4 cm in diameter and 45 – 90 cm long. All side branches have to be clearly removed and the bark should be intact. Generally, young shoots with an age of 1 - 2 years provide the best results, while older and larger stems have a higher rate of mortality (LEWIS 2000, p.14-15). Live stakes are usually hammered into the soil. In order to facilitate this, the bottom end of the live stake should preferably be sharpened or cut in an acute angle (Figure 10). In this regard, it is important to always consider the natural growth direction of every single cutting. Furthermore, two-thirds to three-quarters of the length of a live stake should be installed into the soil which should be firmly packed around after installation. LEWIS (2000, p. 15) describes a basic rule: The less stem is exposed to air, the less moisture evaporates.

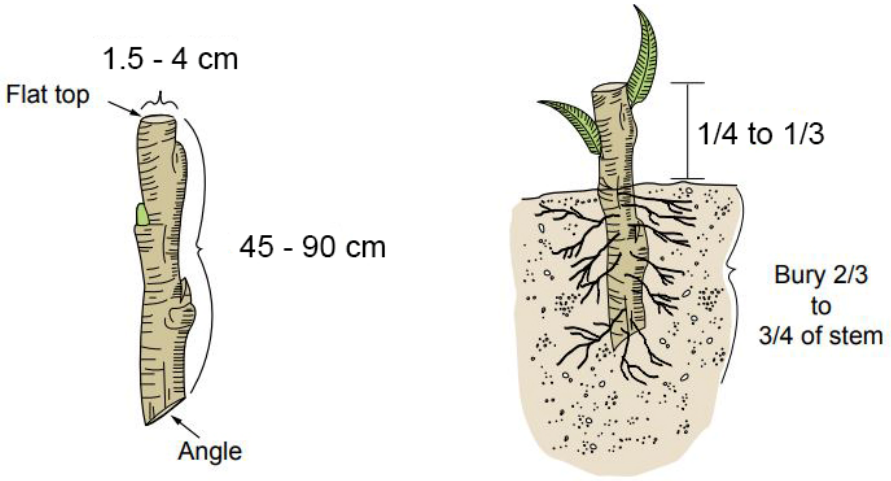


Figure 10: Dimensions of a live stake (own arrangement on the basis of LEWIS 2000)

Figure 11: Sharpened live stake of *Azadirachta indica* (own photograph 2020)

4.4 Adventitious root formation

The opportunity of woody plant propagation by using cuttings is based on the ability of adventitious root formation (HARTMANN et al. 2010, p. 281). According to STEFFENS and RASMUSSEN (2016, p. 603), "[…] adventitious roots are plant roots that form from any nonroot tissue and are produced both during normal development and in response to stress conditions, such as flooding, nutrient deprivation and wounding." They are essential for the durability under stress conditions, especially during periods of drought and nutrient deficiencies (STEFFENS and RASMUSSEN 2016, p. 603). Adventitious roots develop from "preformed or latent root initials" which are plant organs that generally lie dormant until favourable environmental conditions are reached (HARTMANN et al. 2010, p. 282).
In the case of propagation by hardwood cuttings, adventitious roots are mainly wound-induced. This means, that they especially develop as a response to wounding in preparing the cutting. HARTMANN et al. (2010, p. 283) define the following three steps of wound response and further four stages of adventitious root formation:

Steps of wound response:

Step 1: At first, the outer injured cells die and a necrotic plate is formed. The wound is sealed with a corky material (suberin) and the xylem may plug with gum. This plate protects the cut surfaces from desiccation and pathogens.

Step 2: Living cells behind this plate begin to divide after a few days and a layer of parenchyma cells form a callus which develops into a wound periderm.

Step 3: Particular cells placed close to the vascular cambium and phloem begin to divide and initiate the formation of adventitious roots.

Stages of adventitious root formation:

Stage I: De-differentiation of specific differentiated cells.

Stage II: Particular cells, which are located close to vascular bundles, become meristematic and develop into root initials.

Stage III: Subsequent development of root initials into organised root primordia.

Stage IV: Formation of the root primordia throughout different tissue of the stem.

Usually, adventitious roots in hardwood cuttings originate from the cambium or living parenchyma cells which are located in the young, secondary phloem. In some specific cases, they can also develop from vascular rays, primary phloem, callus, or lenticels (HARTMANN et al. 2010, p. 284).

5 Project area

Due its geographic position north of the River Gambia, the North-Bank Region is particularly affected by processes of desertification (UNCCD 2000, p. 23). On that account, there is an urgent need for action concerning research and education on effective and easily applied methods of tree propagation. This preliminary study within the framework of the "REUG" project has therefore been implemented in the Upper Baddibu district (Figure 12) which is part of the North Bank Division and extends from No Kunda to Polodi (SCHOONMARKER FREUDENBERGER 2000, p. 83). The process of vegetation survey (Chapter 6) took place near the biggest village of this district, Farafenni which is situated at one of the main highways of The Gambia. Its population, which counts about 30 thousand people, is mostly living of agriculture and commerce (REYNOLDS 2017, p. 1).
To provide an overview of the structure and the composition of the occurring stocks in order to define generally suitable wooden plant species for a propagation by hardwood cuttings, the overall project area consists of two different areas located within a distance of about 2 km (Figure 13). Those areas are defined as "project site" (A) and "reference area" (B).

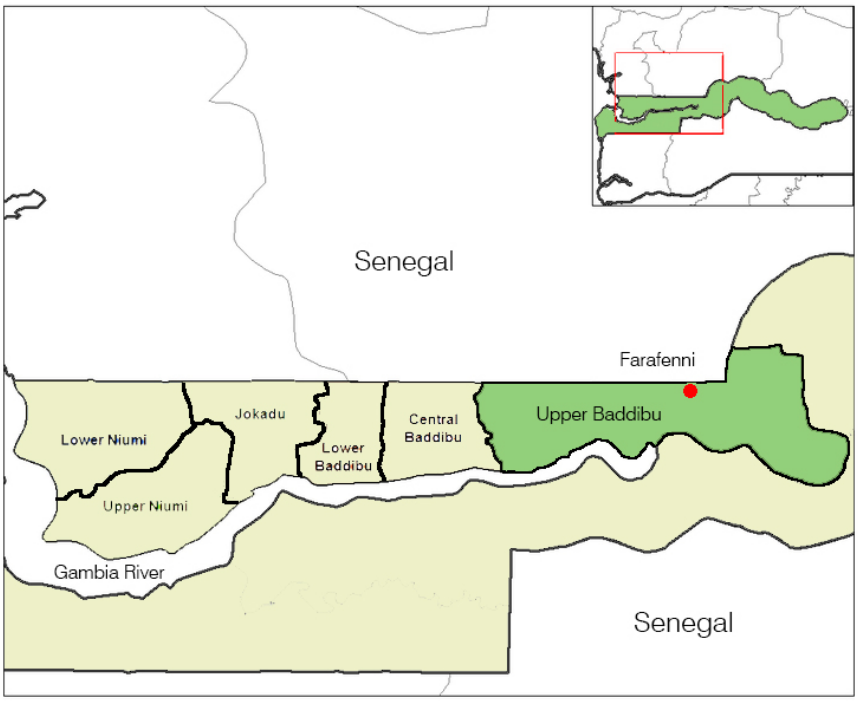


Figure 12: Position of Upper Baddibu district (own arrangement on basis of CIESIN 2015)

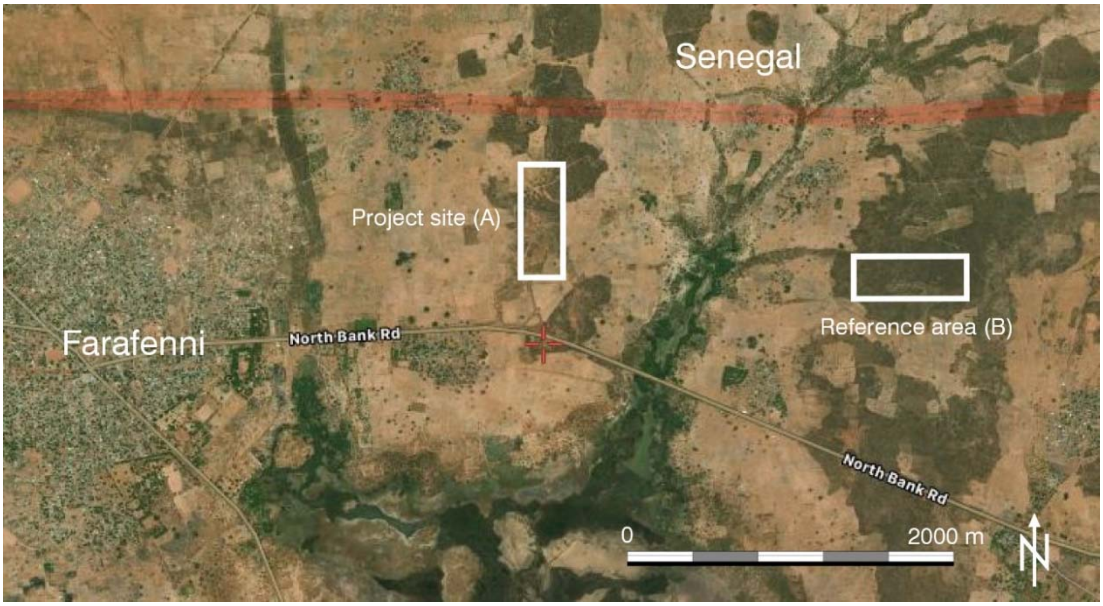


Figure 13: Position of the project site (A) and reference area (B)
(own arrangement on the basis of satellites.pro)

5.1 Project site (A)

The position of the project site (A) arose from its proximity to the test fields of the REUG project. Therefore, exact information about the condition of the occurring stock of trees was generated in order to carry out successful propagation tests. This site exhibits a typical Gambian stock of trees which is heavily impacted by anthropogenic interventions and ongoing secondary succession. It is conspicuous that big tree individuals are completely missing, which leads back to illegal logging of valuable single trees. As shown in Figure 14, the investigated stock of trees is additionally very patchy. There are even some bigger, treeless gabs which exhibit obvious traces of soil erosion.

Figure 14: Stock of trees at the project site (A) (own photograph 2019)

5.2 Reference area (B)

The reference area exhibits a stock of trees which is apparently less anthropogenically affected than the one at the project site. However, it is not a natural wood habitat like it would occur in this area of The Gambia. While the stock is denser and the number of trees is obviously higher than at the project site, there are also hardly any big tree individuals within the defined field (Figure 15). Currently, there are no visible traces of illegal logging and soil erosion at this site.

Figure 15: Stock of trees at the reference area (B) (own photograph 2019)

6 Applied Methods of the stock analysis

Usually, a stock of trees is analysed within the scope of a forest inventory. There is a large number of different techniques to implement such surveys. In general, all types of forest inventories aim to systematically generate information about forestry resources within a defined area (BRACK et al. 2004, p. 3). As a result, interferences concerning the current status of the forests, which often constitute the basis for further analysations, can be made. This findings are essential for the implementation of a sustainable forest management. Due to cost and time constraints, inventories are carried out using sampling techniques which are usually based on the selection of a subset from a population. By analysing those subsets, conclusions concerning the entire population can finally be drawn. The main factors determining the overall methodology are the objective and the size of the survey-area (BRACK et al. 2004, p. 3-5).

6.1 Austrian forest inventory

The Austrian forest inventory follows the methodology of classical inventories. Its task is to constantly monitor the condition of the overall Austrian wood areas with special focus on structural changes. In addition, it is used as an important tool for objective recordings concerning forest areas, calculation of timber stock, growth rates and resulting logging. Conclusions enable to manage forest areas in a sustainable manner and react to negative developments (SCHIELER and HAUK 2001, p. 1-2). The Austrian forest inventory is characterised by an equal distribution of survey units. Per survey unit, four observation plots form one tract (Figure 16). These tracts are evenly distributed over the total forest area of Austria within a distance of 3.89 km. Each crossing-point of tracts functions as the centre point of a circular survey plot with an area of 300 m² (r = 9.77 m). Within these plots, the tree stock is analysed by the method of angle-count sampling (SCHIELER and HAUK 2001, p. 3-4).

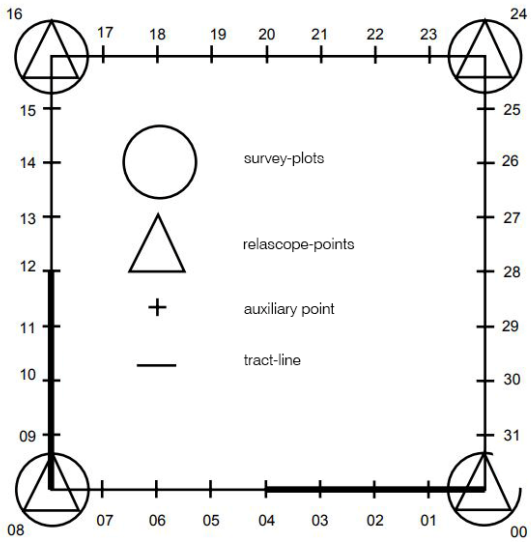


Figure 16: Survey-units of the Austrian forest inventory
(own arrangement on the basis of SCHIELER and HAUK 2001)

6.2 Requirements to the applied methodology

In contrast to classical forest inventories, the vegetation survey applied within this project did not focus on forestry interests. There was no need to collect data about timber stock or growth rates. It was much more about structural composition of a woody area and its physical format.

To achieve all objectives by means of a vegetation survey, a specific combination of scientific methods was needed to be designed. It was supposed to include all important factors in order to collect essential data for a target-oriented use concerning the subsequent research work.

Its target was to:

- determine woody plant species at the defined project area
- generate data about distribution of species
- generate data about the number of individuals
- generate data about physical expression of respective species
- generate data about layers and social structure of a stand
- generate data about natural reproduction capacities
- generate data about visible traces of human utilisation and effects of re-sprouting from cuts and stumps
- compare stands of different areas

As a consequence, the implementation of the vegetation survey was divided into two complementary parts which are explained in the following subsections.

6.3 Species determination – Part 1

The first part contained a general determination of tree and shrub species occurring at the researched locality. The aim was to identify the present species without consideration of quantity, position, structure, habit, traces of use or else. Furthermore, a separation respectively a clear allocation of indigenous and non-indigenous species was implemented.
The process of species identification and classification of their origin was primary conducted with the help of the book "*Woody Plants of Western African Forests: A Guide to the Forest Trees, Shrubs and Lianas from Senegal to Ghana*", composed by HOWTHORNE et al. (2000). It is well known as an indispensable field guide to the identification of all woody plants within the West African forest region. All occurring species were correctly designated (binary nomenclature) in a simple list. In addition, photographs were taken and collected in a suitable data-structure to use them in the following steps of the research work.

6.4 Stock analysis – Part 2

The second part of the vegetation survey aimed to compare (A) the tree and shrub stock at the defined project site with (B) an apparently little anthropogenically affected reference area. By clearly defined investigations, scientific information about composition, species richness and population structure under effects of human influences were gathered. This was not practiced by an area-wide mapping but rather by a statistical comparison. A convenient reference area (B) with approximately identical dimensions was selected on-site. It was expected to be much less disturbed by anthropogenic influence factors than the main project site.

6.4.1 Sampling design

The here described sampling design was oriented towards the publications "*Plant diversity and anthropogenic disturbances in the Sal (Shorea robusta C.F. Gaertn) forests of Bangladesh*" and "*Comparison of structural diversity of tree-crop associations in Peripheral and Buffer zones of Gachabari Sal forest area, Bangladesh*", which were composed by RAHMAN M. et al. (2009, 2007). In total, 18 circular plots (9 plots per area) with an approximately distance of 100 m from plot to plot were located (40 transects). As a consequence of forest gaps, it was necessary to position some plots in irregular distance. In this case, the next plot was taken at a maximum of 200 m (Figure 17). The total investigated area was about 40 hectare. The starting point of the first transect was fixed at the intersection of two roads. Each circular plot extended over an area of about 1257 m^2 at a radius of 20 m. The following parameters were investigated within each plot at both investigation areas:

- Total number of woody plant species occurring at the plot
- Abundance of each species
- Diameter at breast height (DBH) and height of each individual (≥ 5 cm DBH and ≥1.37 m height)
- Status of each registered tree or shrub (social class)
- Vitality class
- Visible traces of human utilisation
- Effects of re-sprouting from cuts and stumps

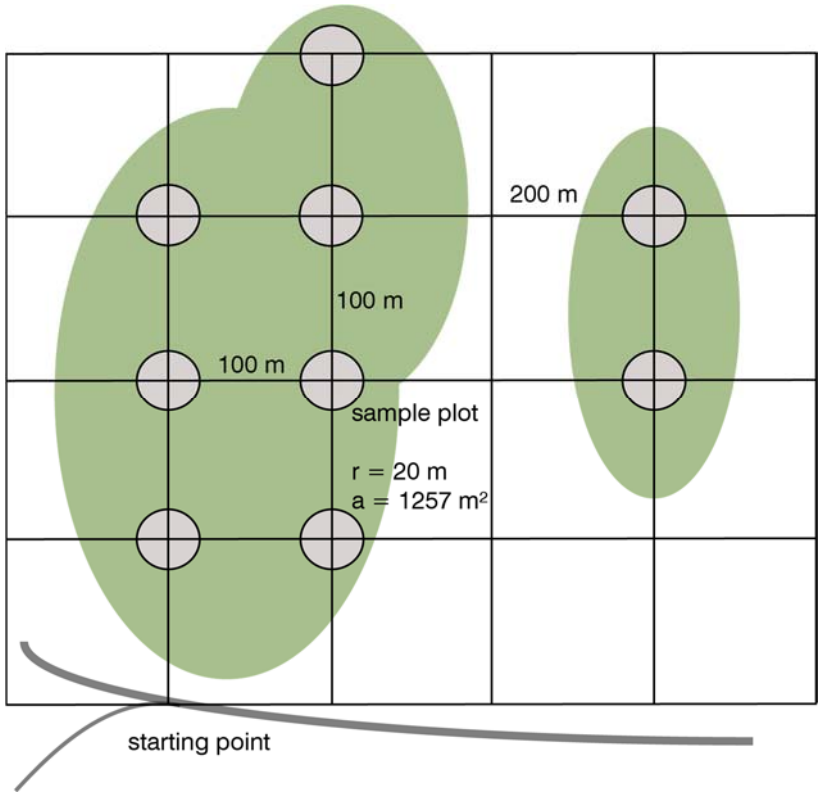


Figure 17: Schematic representation of the sampling design (own arrangement)

6.4.2 Main components of the stock analysis

The focus of the stock analysis was on the analysation of biodiversity indices, the classification of regeneration and the quantification of social-, height- and vitality classes of the examined tree and shrub population at the investigated areas A and B.

6.4.2.1 Species-area curve

By creating a “species-area curve” according to (RAHMAN 2009, p. 19) and based on the total number of plant species found at the different samples (circular spots), the probable maximum number of plant species from both study areas was estimated. Based on this curve, stand biodiversity of these areas can be compared. Furthermore, these curves illustrate the increasing total number of species in relation to the number of surveyed circular plots. The rise of the respective curve enables to draw conclusions concerning the proportion of the overall determined species in comparison to the possibly effective number of woody plant species at the site (RAHMAN 2009, p. 19).

6.4.2.2 Species richness and similarity coefficient (Jaccard Similarity Index)

The species richness describes the occurrence of different species at an investigated area (RAHMAN 2009, p. 22). The effective quantity of species is largely an arbitrary number which is needed to calculate the Similarity Coefficient by the method of Jaccard. The Jaccard Similarity Index is a commonly used approach in statistical analyses which compares the members of two sets (Figure 18) (ECKEY 2002, p. 221-233). The similarity of the sets is usually displayed as a percentage range from 0-100 %. However, it's easy to interpret and very sensitive to small samples sizes (ECKEY 2002, p. 221-234).

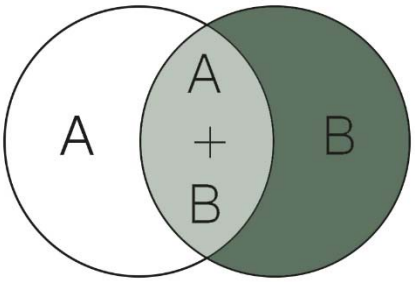


Figure 18: Similarity coefficient - overlapping in sets (own arrangement on the basis of ECKEY 2002)

The formula to calculate the Similarity Coefficient reads as follows:

*Jaccard Index = (the number of species in both sets) / (the number of species in either set) * 100*

The same formula in notation is: $J(X,Y) = |X \cap Y| \ / \ |X \cup Y| * 100$

Two sets that share all members would be 100 % similar to each other. The closer the index is to 100 %, the more similar the two sets are. If they share no members, they similarity is 0 % (ECKEY 2002, p. 221-233). In the context of this master thesis, the number of occurring species at area A, at area B and the number of species occurring at both areas (overlapping) were used to calculate the index. Based on RAHMAN (2009, p. 14), the following two growth forms and three stages of regeneration (progenies) were additionally classified and integrated in the analysation:

- Tree-species
- Shrub-species
- Saplings (≥1.37 m height but < 5 cm DBH)
- Large seedling (<1.37 m height and < 5 cm DBH)
- Small seedling (< 30 cm height)

6.4.2.3 Social classes of occurring major trees

According to CURTIS and MCINTOSH (1950, p. 434-455), social classes are important to define different tree layers and the structural pattern of a stand. As illustrated in Table 1, major trees (≥ 5 cm DBH) are classified according to their status as dominant, co-dominant, intermediate and suppressed, based on crown length, tree height, side branching and general level of canopy crown.

Social class	Indication
Dominant	Trees with well-developed crowns which may be crowded on the sides and reach above the general level of the layer. Higher than co-dominant trees.
Co-dominant	Trees with crowns which are generally smaller than those of the dominant trees and form the main layer of the canopy.
Intermediate	Trees with crowns partially below the general level of crown canopy. Their crowns are generally smaller than those of the dominant trees.
Suppressed	Trees with crowns entirely below the general level of the crown canopy.

Table 1: Classification of mature trees (own arrangement on the basis of RAHMAN 2009)

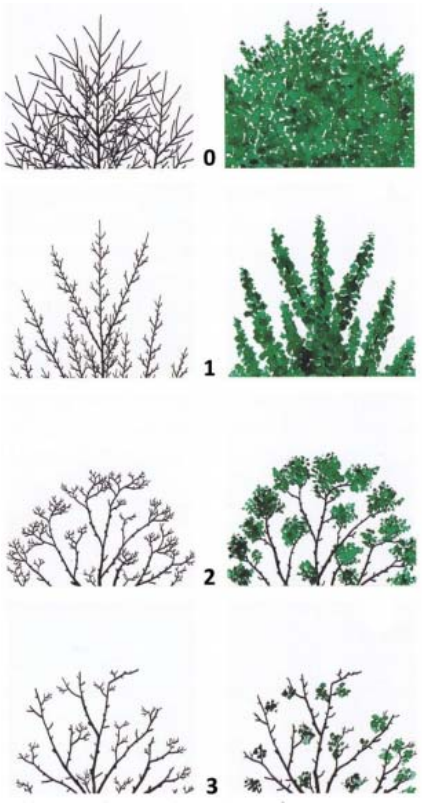
6.4.2.4 DBH and height class distribution

Data of all samples with DBH ≥ 5cm and a height ≥1.37 m was collected. The trunk diameters of investigated plants were classified as ≥ 5-10 cm, 10.1-15 cm, 15.1-20 cm, 20.1-25 cm and ≥ 25 cm. The height classes were defined as ≥ 1.37-5 m, 5.1-10 m, 10.1-15 m, 15.1-20 m and ≥ 20.1 m (PHILLIPS et al. 1959, p. 108). The results of the survey illustrate the size distribution of both tree and shrub stocks (area A and B) and permit conclusions regarding age-distribution and natural regeneration.

6.4.2.5 Vitality class differentiation

By examining the state of vitality of the different occurring species, conclusions concerning anthropogenic and climatic influences, individual stability and sustainability of populations can be drawn (JOHNSTONEA et al. 2013, p.18).

The vitality of each major tree was determined by a differentiation of the canopy structure of major trees at the respective sample. This differentiation was based on the key of vitality class distribution, composed by ROLOFF (2001, p.164-167). He structured the various state of canopies in four possible vitality classes:



— **Vitality class 0:** The upper third part of a canopy appears in an undamaged condition. The branching shows a homogeneous, netlike structure. The majority of the canopy consists of long shoots.

— **Vitality class 1:** The vitality of the tree appears slightly reduced. The upper third part of the canopy is not totally closed anymore, top-branches appear singular and rod-shaped.

— **Vitality class 2:** The vitality of the tree appears significantly reduced, which can be recognised by the sole existence of short shoots building the upper third of the canopy.

— **Vitality class 3:** The upper third of the canopy starts to disintegrate, the top part dies off and big branches break out. A skeletal structure with large hollow spaces is formed out.

Figure 19: Vitality class differentiation of trees (ROLOFF 2001)

6.4.2.6 Visible traces of human utilisation and effects of re-sprouting from cuts and stumps

In order to draw conclusions concerning the suitability of the occurring woody species for a propagation by hardwood cuttings, anthropogenic interventions and traces of utilisation within the respective stocks of trees were recorded. Decisive indicators were visible signs of logging or management interventions. Each determined major tree was examined of cutting-wounds, canopy cuttings and stem- and rootstock sprouting. These physical marks (Figure 20) were basically interpreted as indications for a good ability of adventitious root and sprout growing and additionally influenced the final valuation.

Figure 20: Effects of re-sprouting (own photograph 2019)

7 Development of a decision tree for the identification of potential species

In order to further test the actual suitability, which is beyond the scope of this thesis, a tree or shrub species needs to satisfy the following conditions: (1) As a fundamental prerequisite, the species needs to be available at the site. (2) Furthermore, a sufficient number of individuals split in an equal age- and size distribution is essential for a selection. (3) Additionally, relevant species have to react insensitively to several kinds of anthropogenic disturbances, especially periodic cutting of branches.

To evaluate the collected data of the vegetation survey, a particular model of decision-making was designed. Each recorded woody species ran through this process and was evaluated by its site-related characteristics. The goal of this evaluation-process was to seek out those species which exhibit the most promising properties for a successful series of tests regarding hardwood cutting reproduction.

7.1 Model of the decision-making process

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The whole evaluation-process was based on the basic concept of a decision tree. According to PLAPINGER (2017, p.1), a decision tree can be described as "[…] a predictive model based on a branching series of Boolean tests that use specific facts to make more generalized conclusions […]". It is usually compound of rules, nodes – representing attributes, branches and fields of actions. Each final decision is characterised by a chronology of paths starting from the root of the model to the respective nodes, until an action is reached. Decision trees are particularly convenient to manage large sets of rules and to illustrate the process of decision making in a transparent way (PLAPINGER 2017, p.1). To apply this method in the present case study, several adjustments were necessary.

7.2 Setup of the decision-making process

The evaluation of each existing species at project site A and reference area B was categorically following the principles of a trivial decision tree. This means, that if a prescribed criterion was satisfied or not satisfied in some way, the examined species followed the respectively defined path in vertical direction (Figure 21). This operation was replayed till the species has ran through all evaluation-criterions (Levels) and gets in its final position in the graphical display. A special feature of this modified decision tree is that all examined species additionally traversed three columns of suitability (horizontal direction).

The process of progression was just performed in one direction. This means that if a respective species didn't or just partially met selected criteria, it automatically took place in a sector of

“reduced suitable” or “unsuitable” species (drop-out-criteria). A repositioning in the sector of the potentially suitable species during the course of the ongoing process was not possible.

To ensure a better interpretation of the results, an additional evaluation chart is necessary. Within all criteria which are examined after a species passes the first three “drop-out-criteria”, the respective characteristics of species are rated with evaluation-points from 0 to 5.

This modified model of a decision tree includes the following components.

7.2.1 Horizontal components of the decision tree

The decision tree (Figure 21) contains three columns of suitability which are depicted in different colours (green, yellow and red). Seven criteria-levels are graphically positioned in the left (green) column. The path running through this column can just be followed by species which totally or at least mostly meet the examined criteria. If a woody species doesn’t meet any of the first three drop-out-criteria, it follows a branch in horizontal direction and gets positioned in the right (red) column. All species which reach this right column apply as not suitable for the following series of tests and get dropped out of the process of decision-making. If one of the characteristics (evaluation criteria) of a species is poorly evaluated, the species exits the left path and gets positioned in the middle (yellow) column. In this case, the species are classified as “reduced suitable” and continue the process. Species positioned in this middle column continuously follow just one vertical path. A repositioning in the left column during the course of the ongoing process is not possible. All those wood-species which finalise their path in the left column appear as the “most suitable” species to be tested for their qualities regarding hardwood cutting reproduction. Species completing the path within the middle column are classified as “second-choice-species”.

7.2.2 Vertical components of the decision tree

The examined species chronologically traverse a maximum of seven criteria-levels in vertical direction. The first three levels act as drop-out-criteria. This means that the examined species necessarily have to meet those criteria not to exit the process. Levels four to seven work as “evaluation criteria”. Within those four criteria, selected characteristics are evaluated by an evaluation chart. Depending on structural properties, which have been recorded during the vegetation survey on site (legend), the species get evaluation points from 0 to 5. The following basically applies:
The more evenly the distribution of the particular characteristics the more positive the evaluation and the more points are awarded. If certain characteristics of examined species get evaluated with 3 or more points, the decision tree can be continued by following the path in the left column. If they get evaluated with 2 or less points, the species leave this path and position in the middle column.

At the end of the process, after passing the four evaluation-levels, all evaluation points of each single species are added. Within the left and the middle column, species get ranked by their total score.

7.2.2.1 Criteria-levels for the evaluation

The seven criteria-levels focus on the following characteristics:

Level 1: Species occurs at project site A and reference area B

At Level 1, the occurrence and the geographic distribution of all species is checked. If species occur at the defined project area and the apparently little anthropogenically affected reference area, they follow the path vertically in the left column and reach Level 2. If species have just been documented at one of those two areas, they get positioned in the right column and are dropped out of the process in any case.

Level 2: Effects of re-sprouting from stumps, cuts and wounds

Furthermore, all remaining species are proofed concerning visible effects of re-sprouting from stumps, cuts and wounds (overall area = A+B).
At least one individual of a respective species has to feature these attributes. If there are no traces recognised, the respective species are qualified as not suitable and follow the path to the right column (exit).

Level 3: Abundance > 5 individuals / ha

At Level 3, the extrapolated number of individuals (major trees) per hectare of each examined species is considered. If the number is > 5 individuals, the respective species continue following the path in the left column and achieve Level 4. If the projection is ≤ 5, the species are dropped out and leave the decision tree.

Level 4: Social class distribution

Level 4 contains the first of four evaluation-criteria. It examines and evaluates in which social classes individuals of the respective species occur at the overall area. If species just occur in social class 4 (suppressed), they get evaluated with 0 points. If they are documented in social class 4 + 3 (intermediate) they receive 1 point. Species are evaluated with 2 points if they just occur in social class 2 (co-dominant) and with 3 points if they just occur in social class 1 (dominant). If the respective species have been found in social classes 2-4, they receive 4 points. The maximum of 5 points is awarded, if species occur in all five social classes.

Level 5: Height class distribution

Furthermore, all species get evaluated regarding the height class distribution of their individuals at the overall area. If species just occur in one height class, 0 evaluation points are awarded. If species are recorded in two height classes, they get 1 point, in three classes 2 points and in four classes 3 points. If species occur in all five height classes, they get evaluated with 4 points. The maximum score of 5 points is reached, if species occur in all five height classes and the distribution is almost equal (+/- 10 % difference).

Level 6: DBH class distribution

In the next step, the distribution of the trunk diameter was evaluated. The individuals of each respective species at the overall area were checked again. If the species just occur in one diameter class, they get 0 evaluation points. If species are recorded in two classes, they get 1 point, in three classes 2 points and in four classes 3 points. If species occur in all five classes, 4 points are reached. The maximum of 5 points is awarded, if species occur in all five diameter classes and the distribution is almost equal (+/- 10 % difference).

Level 7: Vitality class distribution

The last evaluation-criteria applied is located in Level 7. It proofs species regarding the vitality class distribution of their individuals at the overall area. If more than 50 % of the individuals of a respective species exhibit vitality class 3, 0 evaluation points are awarded. If 30-50 % occur in vitality class 3, 1 point is reached. If 30-50 % individuals in total exhibit vitality class 2 + vitality class 3 - 2 points, from 10-29 % - 3 points and from 5-9 % - 4 points are awarded. The maximum score of 5 points is reached, if $\leq$ 5 % of the individuals of a respective species in total occur in those two classes.

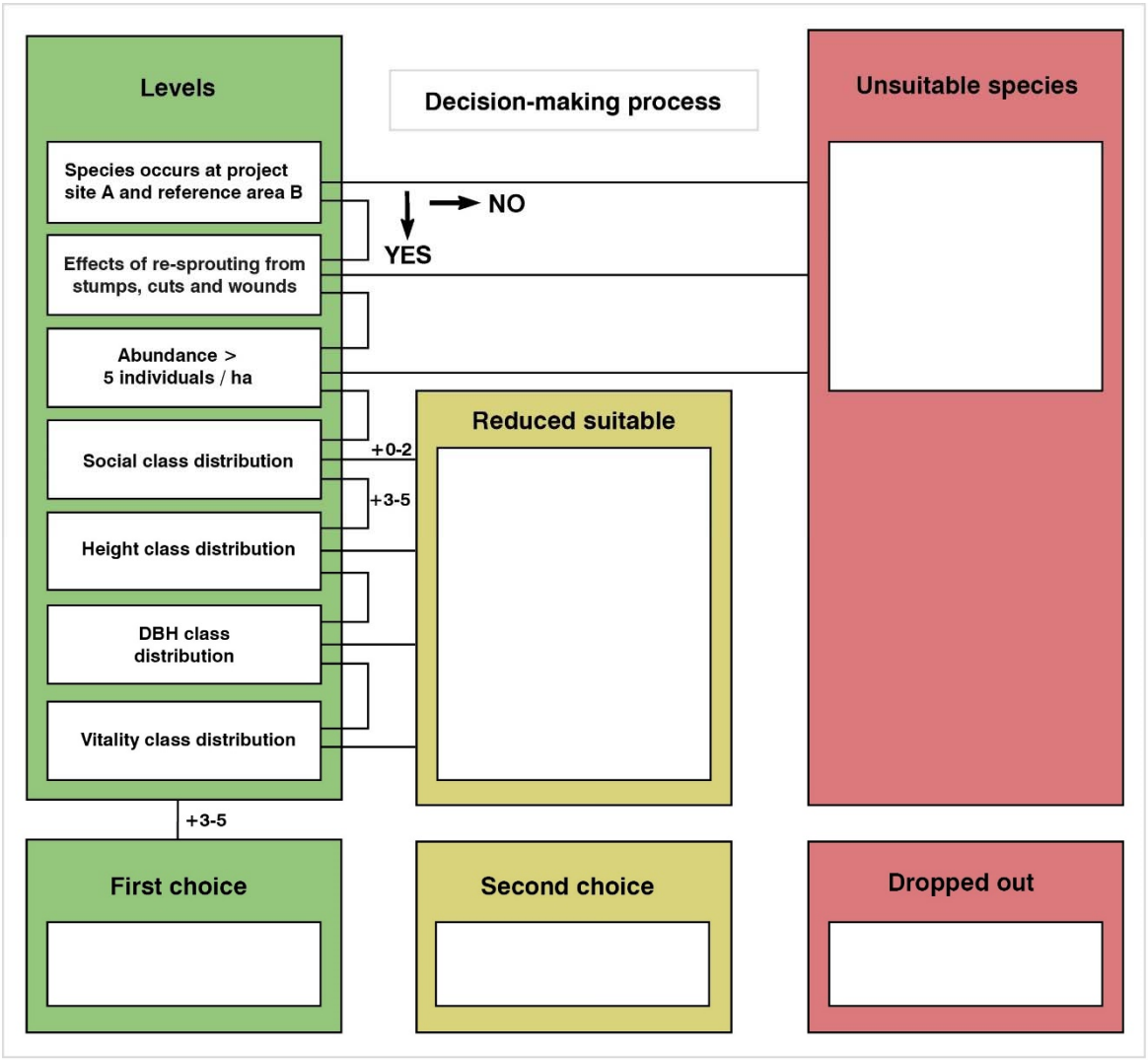

Figure 21: Schematic representation of the decision-making process

7.2.3 Sample size and calculation of individuals / ha

The process of decision making was based on the sum of surveyed data from the project area and the apparently little anthropogenically affected reference area. Exclusively at Level 1, the occurrence of the species was considered separately.

The number of individuals per hectare (Level 3) was calculated as follows:

The total surface area of both fields is about 40 ha (400,000 m^2). Each sample (circular plot) exhibits a radius of 20 m and a surface area of about 1256.6 m^2. The sum of all 18 circular plots consequently covers an area of about 22,619.3 m^2 which is about 5.7 % of the overall area. If 100 % (overall area) is divided through this percentage, a factor of 17.6 is obtained.

To calculate the number of individuals per hectare, the results of the multiplication finally have to be divided through 40 (40 ha overall area).

The resulting formula reads as follows:

$$\frac{(\text{individuals at area A} + \text{individuals at area B}) * 17.6}{40}$$

8 Results of the stock analysis

To provide an overview of the structure and the composition of the occurring stocks of trees at the overall project area (A+B), the collected data of the project site (A) was compared with the reference area (B). In addition, most of the parameters were merged for the following steps of analysis. This means that the received data of the survey plots at the project site were cumulated with the data of the reference area and analysed together. This type of analysis describes the average situation concerning species composition, size- and social class distribution and enables to draw conclusions concerning the general stability and sustainability of forest stands at the overall project area. Furthermore, stock structural information about single surveyed wood species can be obtained and used for the assessment of the potential use for a hardwood cutting reproduction.

8.1 Occurring species and their abundance

In total, a number of 53 different woody species were determined and recorded at the overall project area. According to HOWTHORNE et al. (2000), 32 of those species are native to The Gambia. By interviewing locals, the regional designation in the language of Mandinka could be assigned to 51 species. The abundance of each single species was calculated on basis of the projected overall area of about 40 ha (Chapter 7.2.3). The following Table 2 depicts an alphabetical list of all surveyed species and their abundance per hectare.

Scientific designation	Regional designation in Mandinka	Native / Non-native	Abundance / ha
Acacia faidherbia	*Baransango*	native	10,1
Acacia macrostachys	*Singoko*	native	1,3
Acacia polycantha	*Bambakogo*	native	0,9
Acacia seyal	*- unknown*	native	0,4
Adansonia digitata	*Baobab*	native	1,3
Allophyllus africanus	*Kutufingo*	native	4,4
Anacadium occidentalis	*Cashuwa*	non-native	4
Annona senegalensis	*Sunkung*	native	0,4
Artocarpus altilis	*Jackfruit*	non-native	0,4
Artocarpus heterophyllus	*Jackfruit*	non-native	0,4
Azadrachta indica	*Yirinding-Kunango*	non-native	16,3
Borassus aethiopum	*Sibo*	native	0,9
Calotropis procera	*Kipampam*	native	6,2
Carica papaya	*Papaya*	non-native	1,3
Cassia sieberiana	*Sinjango*	native	10,9
Casuarina equisetifolia	*Flower-Tree*	non-native	1,8
Ceiba pentandra var. caribaea	*Bantango*	native	0,9
Citrus reticulata	*Mandarin*	non-native	0,4
Cola cordifolia	*Taboo*	native	4
Combretum micranthum	*Kinkeliba*	native	1,8
Daniellia olivieri	*Santao*	native	3,1
Detarium senegalensis	*Tallo*	native	4,4
Diospyros mespiliformis	*Kukuwo*	non-native	2,2
Elaeis guineensis	*Tengo*	non-native	1,3
Erythrina senegalensis	*Ndolingo*	native	2,2
Eucalyptus camaldulensis	*Eucalyptus*	non-native	2,6
Ficus capensis	*Soto*	native	11,9
Ficus ingens	*Soto-Borama*	native	0,4
Ficus polita Vahl subsp. polita	*Yirinfang-soto*	non-native	0,4
Gmelina arborea	*Gmelina*	non-native	15,4
Heeria insignis	*Kankanao*	native	9,7
Icacina senegalensis	*Manankaso*	native	0,9
Lannea microcarpa	*Bembo-Kojo*	native	1,8
Lawsonia inermis	*Fuddan*	non-native	2,2
Lophira lanceolata	*Machecharo*	native	1,3
Mangifera indica	*Mango*	non-native	3,1
Manihot esculenta	*Cassava*	non-native	4,8
Morinda germinata	*Batio*	native	0,9
Moringa oleifera	*Moringa*	non-native	0,9
Nauclea latifolia	*Batio-Jongo*	native	10,1
Parinari macrophylla	*- unknown*	native	5,7
Persea americana	*Avocado*	non-native	0,4
Piliostigma thonningii	*Faro*	native	4,8
Prosopis africana	*Kembo*	native	1,3
Psidium guajava	*Biabo*	non-native	0,9
Pterocarpus erinaceus	*Keno*	native	2,2
Rauvolia vomitoria	*Bantang-Faro*	native	2,2
Sclerocarya birrea	*Salumplom*	native	1
Spondias mombin	*Ninkon*	non-native	2,6
Tectona grandis	*Gmelina*	non-native	5,7
Terminalia macroptera	*Wolo*	native	4
Vernonia amygdalina	*Doctor*	native	0,9
Ziziphus mauritania	*Tomborongo*	non-native	11
In total: 53 species			

Table 2: List of surveyed species (own arrangement)

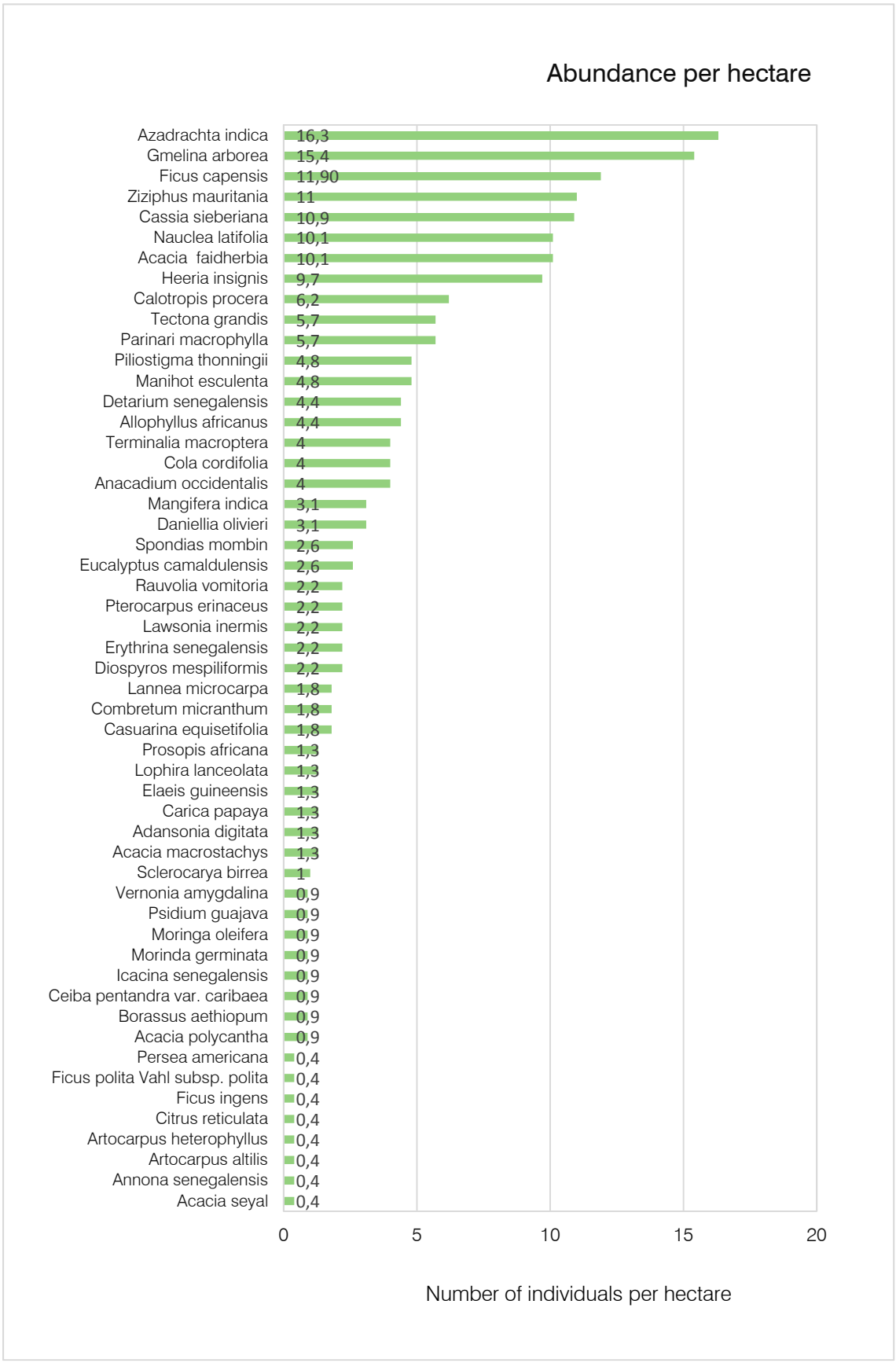

Figure 22: Abundance per hectare (own arrangement)

8.2 Species-area-curve

The total number of 53 different woody species were identified within 18 circular survey plots (Chapter 6.4.1). The plots no. 1 - 9 were investigated at the defined project site, the remaining numbers 10 – 18 at the reference area which was expected to be low disturbed by anthropogenic influence factors. The following species-area-curve (Figure 23) demonstrates the increasing number of documented species in relation to the number of surveyed circular plots. According to that, 48 species out of 53 (91 %) were already determined at plot no. 8. The total number of 53 species was reached at plot number 15.

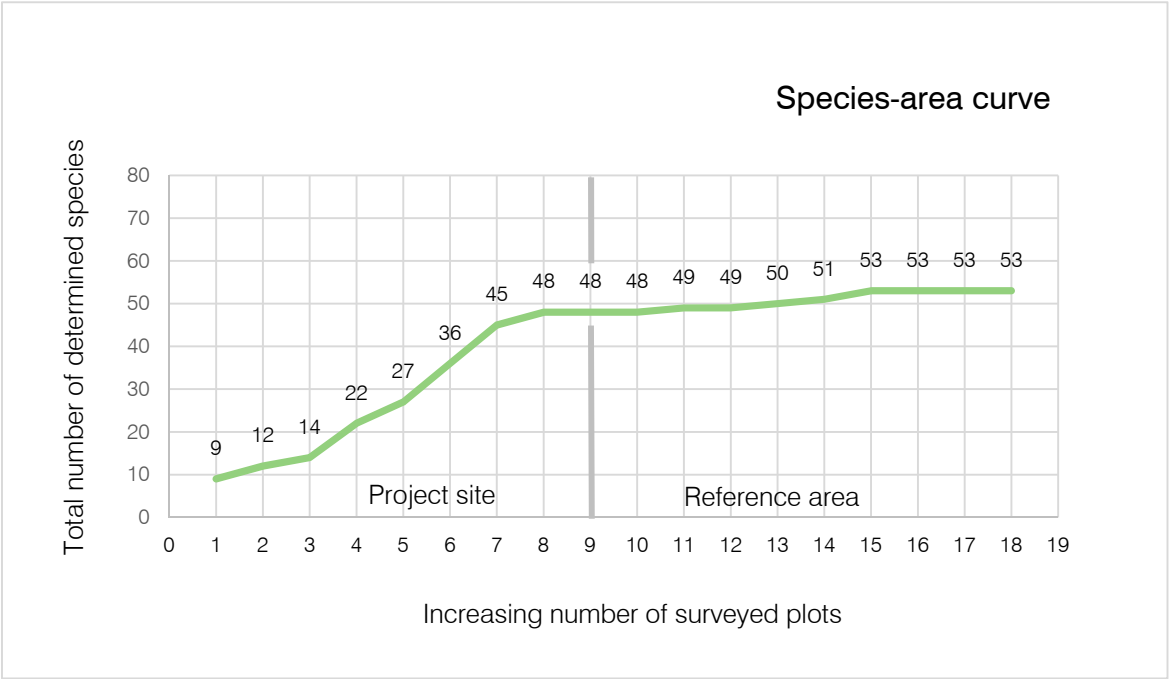

Figure 23: Species-area-curve (own arrangement)

8.3 Comparison of species at the project site and the reference area

The following matrix (Table 3) illustrates the respective numbers of the documented woody species at the project site (48 different species) and at the reference area (27 different species). The number of species which occur at both areas (shared members) amounts 22. The species-richness was analysed and calculated by the method of “Jaccard Similarity Index” described in Chapter 6.4.2.2. The formula to calculate this coefficient reads as follows: (the number of species in both sets) / (the number of species in either set) * 100. The resulting similarity coefficient amounts 42.

Species at the overall area	Species at the project site	Species at the reference area	Shared members
Acacia faidherbia	X	X	X
Acacia macrostachys	X		
Acacia polycantha	X		
Acacia seyal	X		
Adansonia digitata	X	X	X
Allophyllus africanus	X	X	X
Anacadium occidentalis	X		
Annona senegalensis	X		
Artocarpus altilis	X		
Artocarpus heterophyllus	X		
Azadrachta indica	X	X	X
Borassus aethiopum	X	X	X
Calotropis procera	X	X	X
Carica papaya	X		
Cassia sieberiana	X	X	X
Casuarina equisetifolia	X		
Ceiba pentandra var. caribaea	X		
Citrus reticulata	X		
Cola cordifolia	X	X	X
Combretum micranthum	X		
Daniellia olivieri	X	X	X
Detarium senegalensis	X	X	X
Diospyros mespiliformis	X		
Elaeis guineensis	X	X	X
Erythrina senegalensis	X		
Eucalyptus camaldulensis	X		
Ficus capensis	X	X	X
Ficus ingens	X	X	X
Ficus polita Vahl subsp. polita		X	
Gmelina arborea	X	X	X
Heeria insignis		X	
Icacina senegalensis	X		
Lannea microcarpa	X		
Lawsonia inermis	X	X	X
Lophira lanceolata	X	X	X
Mangifera indica	X		
Manihot esculenta	X		
Morinda germinata	X		
Moringa oleifera	X		
Nauclea latifolia	X	X	X
Parinari macrophylla		X	
Persea americana	X		
Piliostigma thonningii	X	X	X
Prosopis africana	X		
Psidium guajava	X		
Pterocarpus erinaceus		X	
Rauvolia vomitoria		X	
Sclerocarya birrea	X		
Spondias mombin	X	X	X
Tectona grandis	X	X	X
Terminalia macroptera	X	X	X
Vernonia amygdalina	X		
Ziziphus mauritania	X	X	X
Total number: **53**	Number at project site: 48	Number at reference area: 27	Shared members: 22
Jaccard Index: 22 / 53 * 100 = ≈ **42**			

Table 3: Comparison of the two areas and Jaccard Index (own arrangement)

8.4 Social class distribution

To distinct the proportions of the social classes within the stands, each tree with a DBH ≥ 5 cm was examined. As described in Chapter 6.4.2.3, the purpose was to characterise the different tree layers and their expressions. To achieve this, every single major tree was assigned to one of the four social classes “dominant”, “co-dominant”, “intermediate” and “suppressed” (according to CURTIS and MCINTOSH 1950, p. 434-455). Figure 24 illustrates the percentage distribution of those classes. Therefore, there is a relatively equal share of individuals assigned to the different social classes. Furthermore, Table 4 lists the detailed percentage social class distribution of all determined woody species. According to that, just a few species occur in all four classes. Most of them are just determined within two or three different social classes.

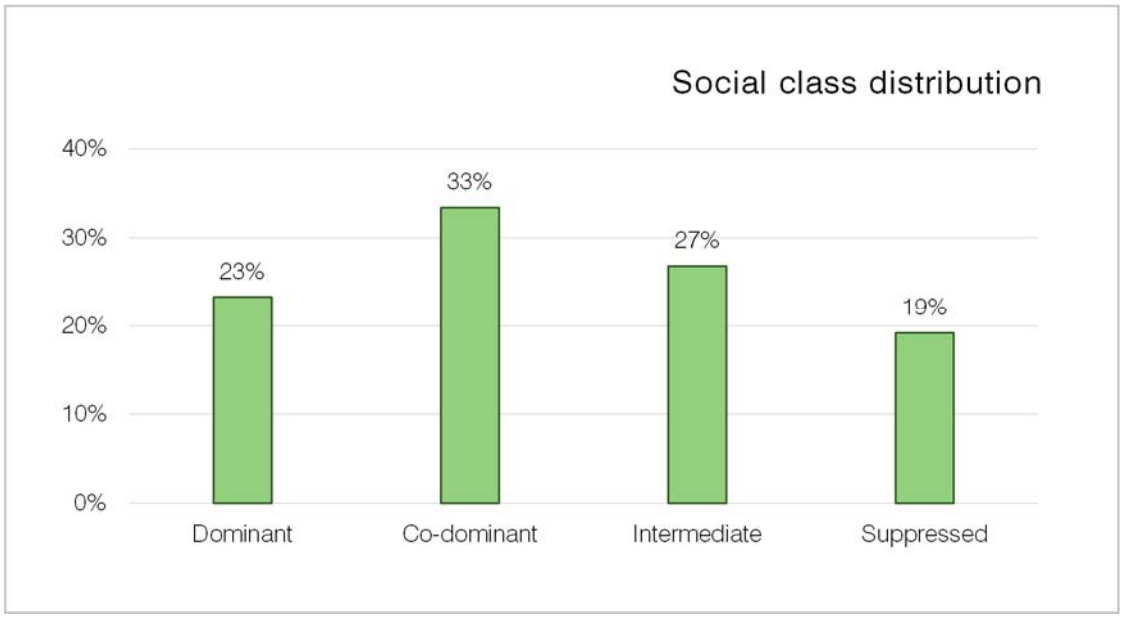

Figure 24: Social class distribution (own arrangement)

Species	% of dominant individuals	% of co-dominant individuals	% of intermediate individuals	% of suppressed individuals
Acacia faidherbia	-	13	17	70
Acacia macrostachys	-	100	-	-
Acacia polycantha	-	100	-	-
Acacia seyal	-	-	100	-
Adansonia digitata	100	-	-	-
Allophyllus africanus	-	30	10	60
Anacadium occidentalis	78	22	-	-
Annona senegalensis	100	-	-	-
Artocarpus altilis	*100*	-	-	-
Artocarpus heterophyllus	*100*	-	-	-
Azadrachta indica	*21*	17	45	17
Borassus aethiopum	*100*	-	-	-
Calotropis procera	*40*	40	7	13
Carica papaya	*100*	-	-	-
Cassia sieberiana	*7*	50	14	29
Casuarina equisetifolia	*50*	25	-	25
Ceiba pentandra var. caribaea	*50*	-	-	50
Citrus reticulata	*100*	-	-	-
Cola cordifolia	*56*	22	-	22
Combretum micranthum	-	100	-	-
Daniellia olivieri	-	-	-	100
Detarium senegalensis	*30*	-	-	70
Diospyros mespiliformis	*20*	80	-	-
Elaeis guineensis	*100*	-	-	-
Erythrina senegalensis	*40*	40		20
Eucalyptus camaldulensis	*100*	-	-	-
Ficus capensis	*55*	7	3	35
Ficus ingens	*100*	-	-	-
Ficus polita Vahl subsp. polita	*100*	-	-	-
Gmelina arborea	*8*	32	60	-
Heeria insignis	-	8	92	-
Icacina senegalensis	-	-	-	100
Lannea microcarpa	-	-	100	-
Lawsonia inermis	-	100	-	-
Lophira lanceolata	*100*	-	-	-
Mangifera indica	*50*	13	37	-
Manihot esculenta	-	100	-	-
Morinda germinata	-	100	-	-
Moringa oleifera	-	50	50	-
Nauclea latifolia	*21*	54	17	8
Parinari macrophylla	-	100	-	-
Persea americana	*100*	-	-	-
Piliostigma thonningii	*20*	60	-	20
Prosopis africana	-	60	40	-
Psidium guajava	*50*	50	-	-
Pterocarpus erinaceus	-	60	40	-
Rauvolia vomitoria	-	80	20	-
Sclerocarya birrea	-	100	-	-
Spondias mombin	*17*	17	66	-
Tectona grandis	*15*	23	-	62
Terminalia macroptera	-	33	-	67
Vernonia amygdalina	*50*	50	-	-
Ziziphus mauritania	-	19	69	12

Table 4: Social class distribution of respective species (own arrangement)

8.5 DBH and height class distribution

To describe the structure of the surveyed stock of trees more accurately, the DBH and the height of every documented tree were measured during the process of examination. Furthermore, every individual was assigned to one of five diameter and height classes. The diameter classes are defined as ≥ 5-10 cm, 10.1-15 cm, 15.1-20 cm, 20.1-25 cm and ≥ 25 cm, the height classes as ≥ 1.37-5 m, 5.1-10 m, 10.1-15 m, 15.1-20 m and ≥ 20.1 m (according to Chapter 6.4.2.4). The following Figures 25 and 26 visualise the percentage class distribution of all surveyed major trees. Therefore, there is an unequal share within both categories. Most of the examined individuals are assigned to the DBH class ≥ 5-10 cm and the height class ≥ 1.37-5 m.

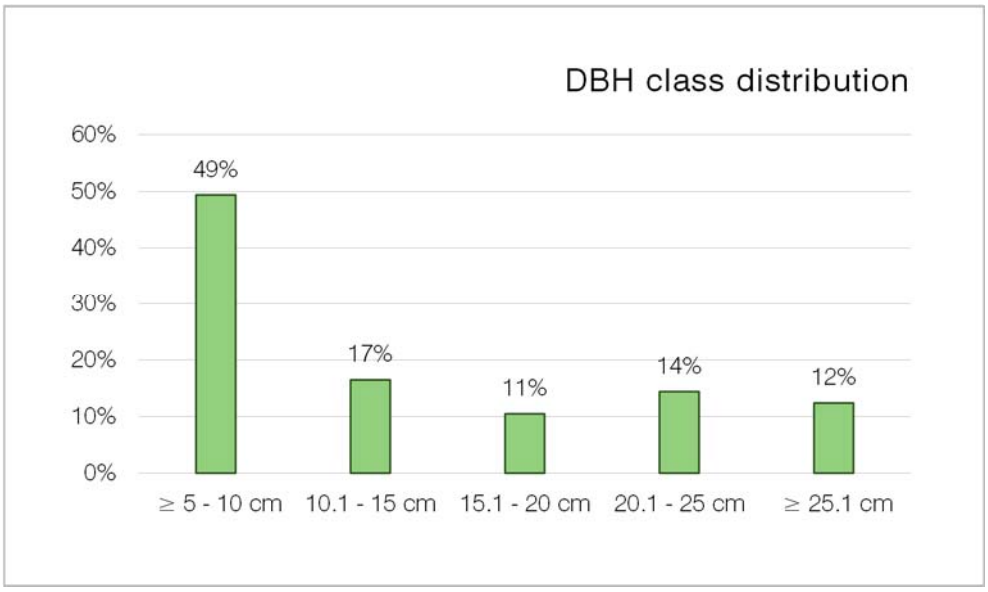

Figure 25: DBH class distribution (own arrangement)

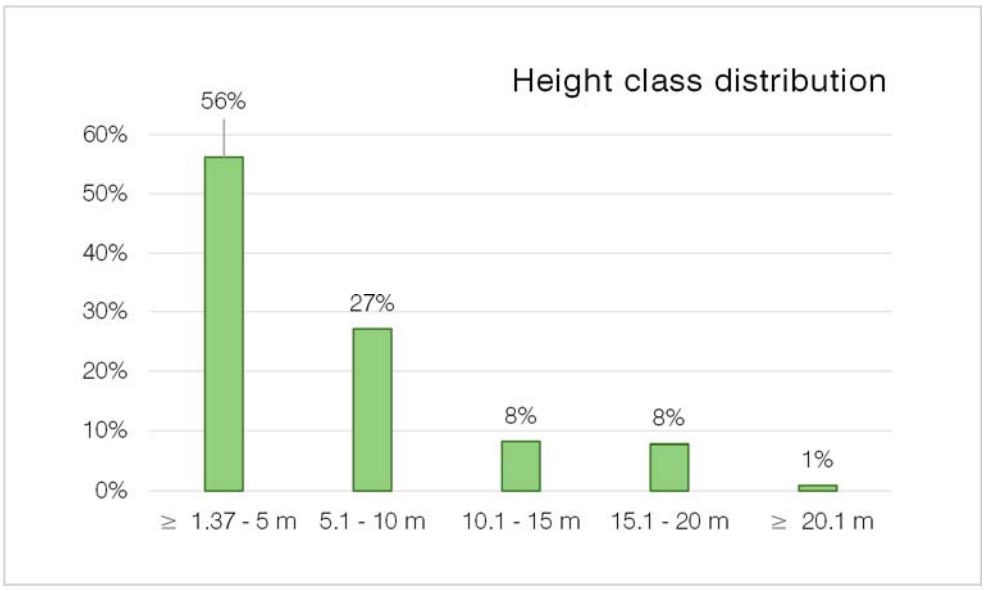

Figure 26: Height class distribution (own arrangement)

8.6 Growth-habit distribution

According to JEDDELOH (1979, p. 112-113), the distribution of different habits within a stand constitute an important factor regarding resistance against soil erosion. Figure 27 illustrates the percentage distribution of growth-habits at the overall project area. Therefore, 61 % of all recorded individuals are dendriform and 39 % are shrub-shaped.

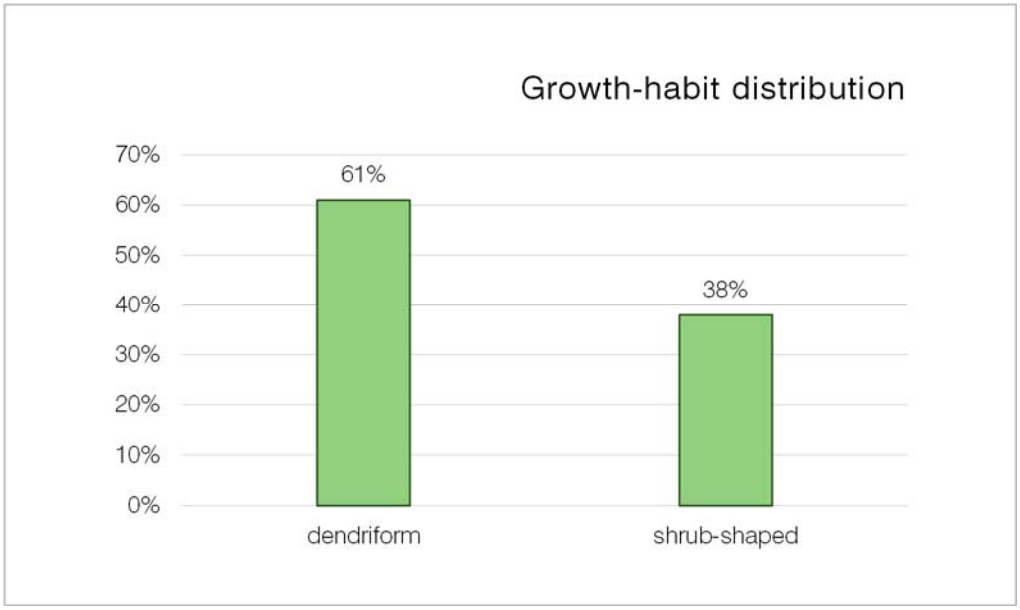

Figure 27: Growth-habit distribution (own arrangement)

8.7 Vitality class distribution

To evaluate the general state of health of the tree populations at the researched locality, the vitality of every surveyed tree was documented during the survey. Subsequently, the trees were attributed to vitality classes according to ROLOFF (2001, p.164), described in Chapter 6.4.2.5. Figure 28 below describes the percentage distribution of those vitality classes. Therefore, most of the recorded individuals are assigned to vitality class 1 (good condition). Only 0.3 % exhibit a bad vitality.

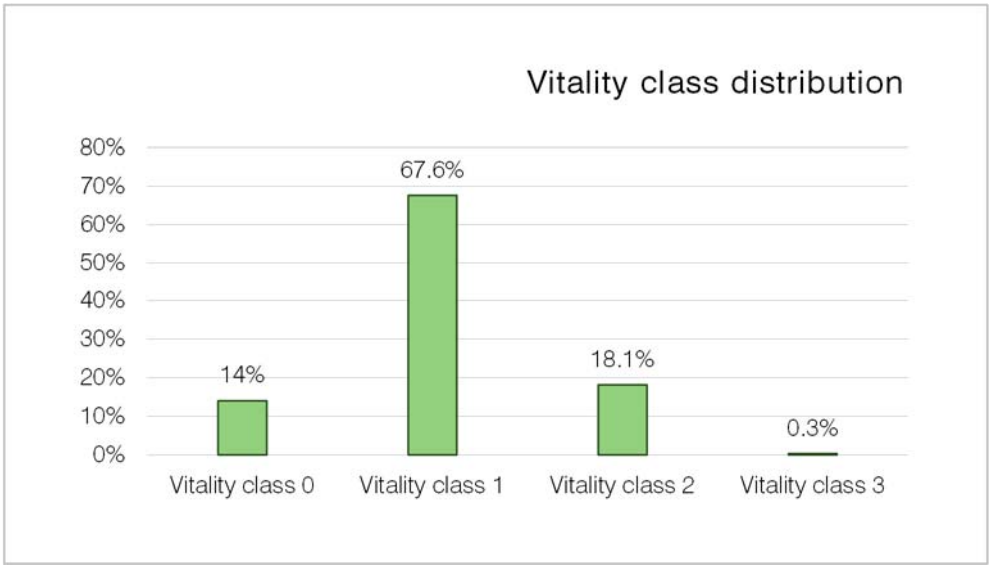

Figure 28: Vitality class distribution (own arrangement)

8.8 Natural reproduction

A further factor which enables to draw conclusions concerning stability and sustainability of individual woody species within a stock is their natural reproductive behaviour. In the course of the survey, all indications of natural reproduction at the circular plots were recorded. On this occasion, no distinction between generative and vegetative rejuvenation was made. All progenies were classified by their dimensions in the groups of „Small seedlings“ (all progenies $<$ 30 cm height) “Large seedlings“ (progenies $<$ 1.37 m height and $<$ 5 cm DBH) and „Saplings“ (all progenies $\geq$ 1.37 m height but $<$ 5 cm DBH). The results of the inventory were subsequently extrapolated to achieve a number of progenies per hectare. The following Figure 29 illustrates the reproductive behaviour of all determined wood species at the overall project area expressed as per hectare rates. Only 18 of 53 woody species exhibit natural reproduction. The highest number of progenies per hectare descent from *Gmelina arborea, Azadrachta indica* and *Ziziphus mauritania*.

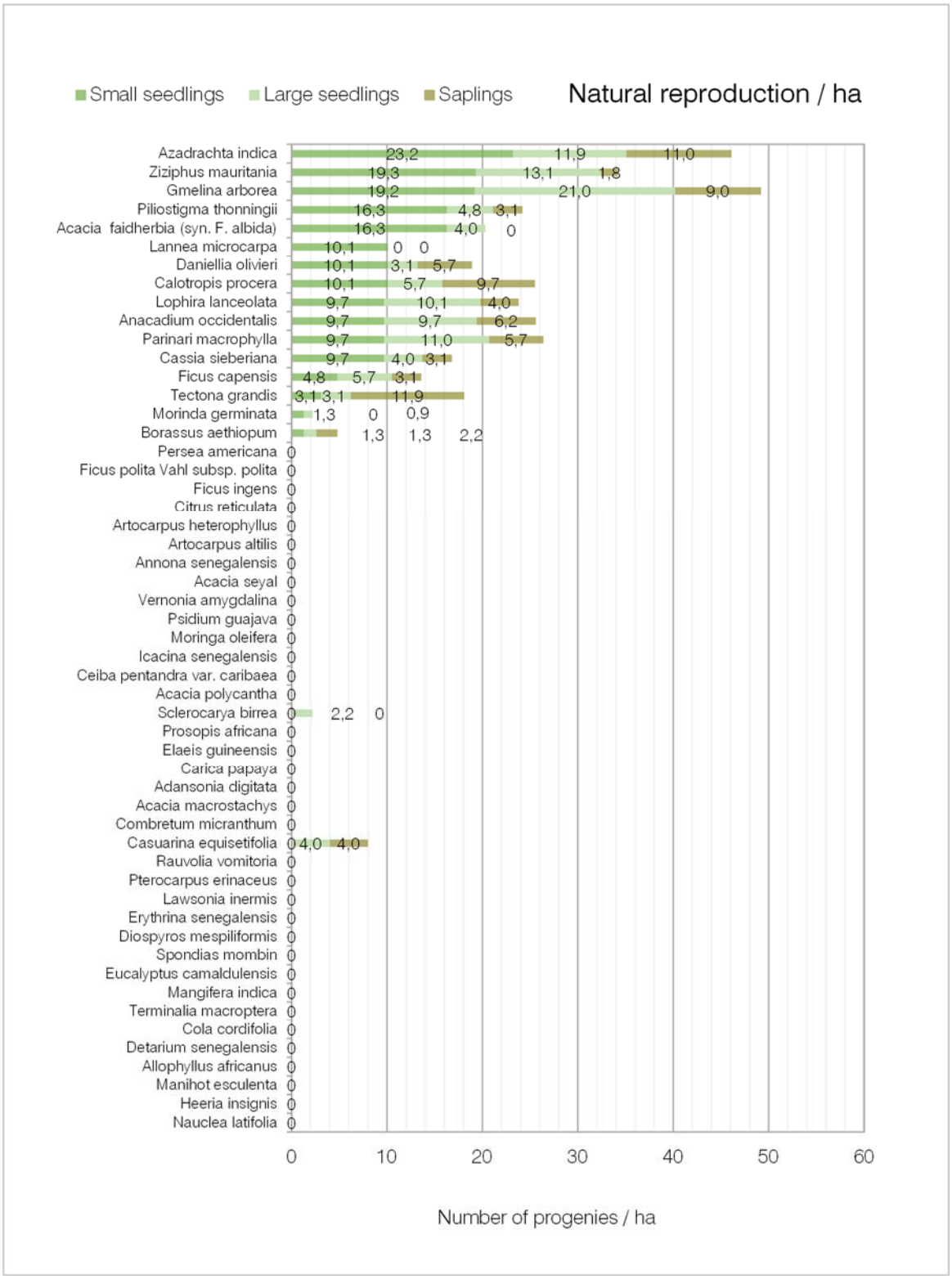

Figure 29: Natural per hectare reproduction (own arrangement)

9 Application of the decision tree for the identification of potential species

As described in Chapter 8.1, a number of 53 different woody species were determined at the overall project area. To evaluate those species in order to reach a promising selection concerning their suitability for a propagation by hardwood cuttings, each single species ran through the process of decision-making described in Chapter 7. Within Level 1, which includes a drop out criterion (species has to occur at the project site A and the reference area B), 31 species were already sorted out and positioned in the red column, which means that they are assessed completely unsuitable concerning the subsequent field tests. Within Level 2 (six species) and Level 3 (seven species), a total number of thirteen species were dropped from the process. Consequently, 44 species didn't pass the drop out criteria and therefore didn't receive further attention. *Acacia faidherbia, Azadrachta indica, Calotropis procera, Cassia sieberiana, Ficus capensis, Gmelina arborea, Nauclea latifolia, Tectona grandis* and *Ziziphus mauritania* remained in the process and were furthermore evaluated within the Levels 4-7, focusing the social class-, the height class-, the trunk diameter class- and the vitality class distribution of the respective species. At the end, only three woody species were still positioned in the green column. Rated and ranked by the total number of valuation points, *Azadrachta indica, Ficus capensis* and *Gmelina arborea* left the process of decision-making as the most promising species and were therefore classified as "First choice species". *Acacia faidherbia, Calotropis procera, Cassia sieberiana, Nauclea latifolia, Tectona grandis* and *Ziziphus mauritania* received an insufficient number of valuation points within at least one evaluation level. Consequently, they were positioned in the yellow column and classified as "Second choice species". The following Figures 30 – 32 illustrate the process of decision making.

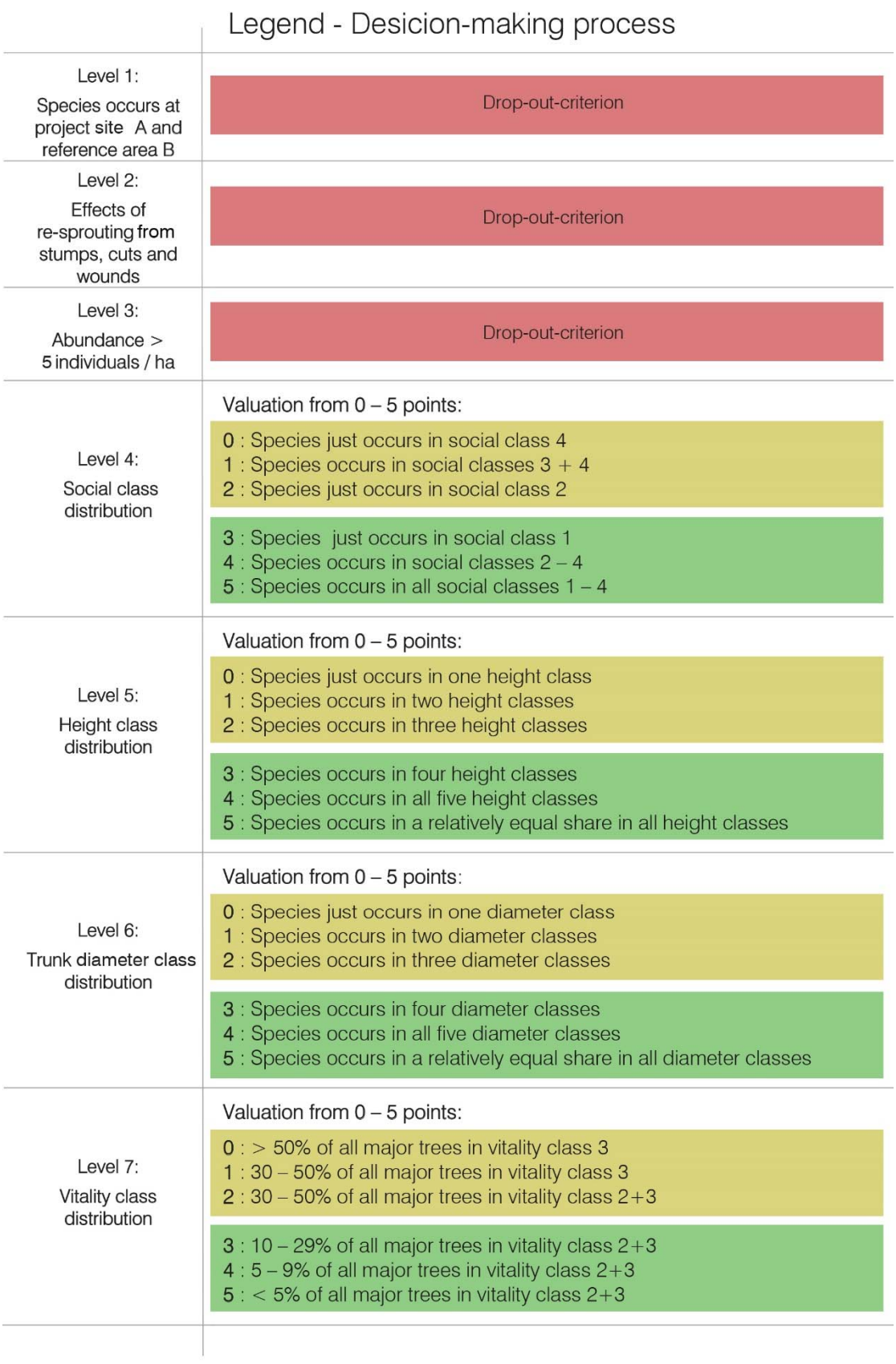

Figure 30: Legend of the decision-making process (own arrangement)

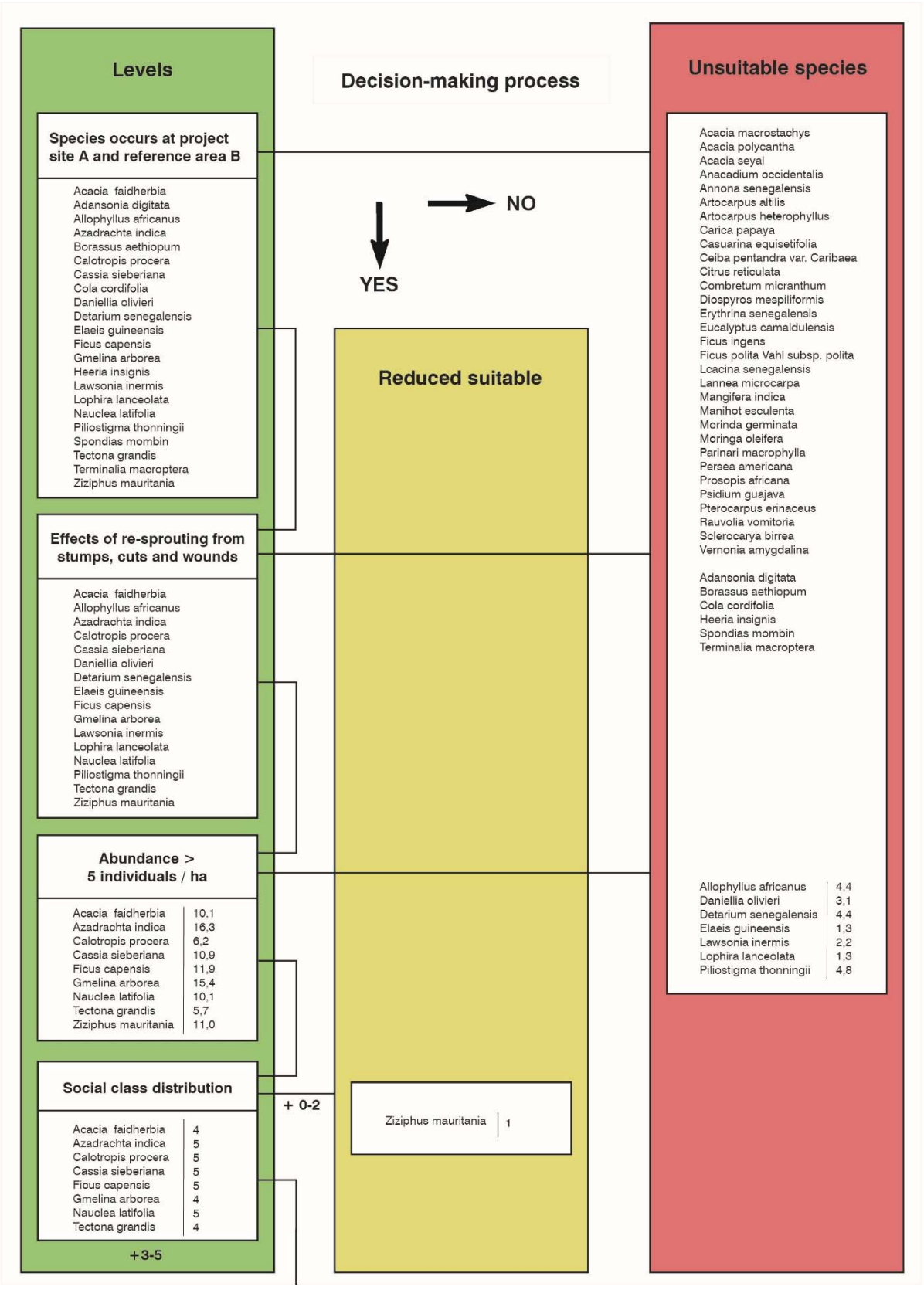

Figure 31: Decision-making process and identified potential species, page 1 (own arrangement)

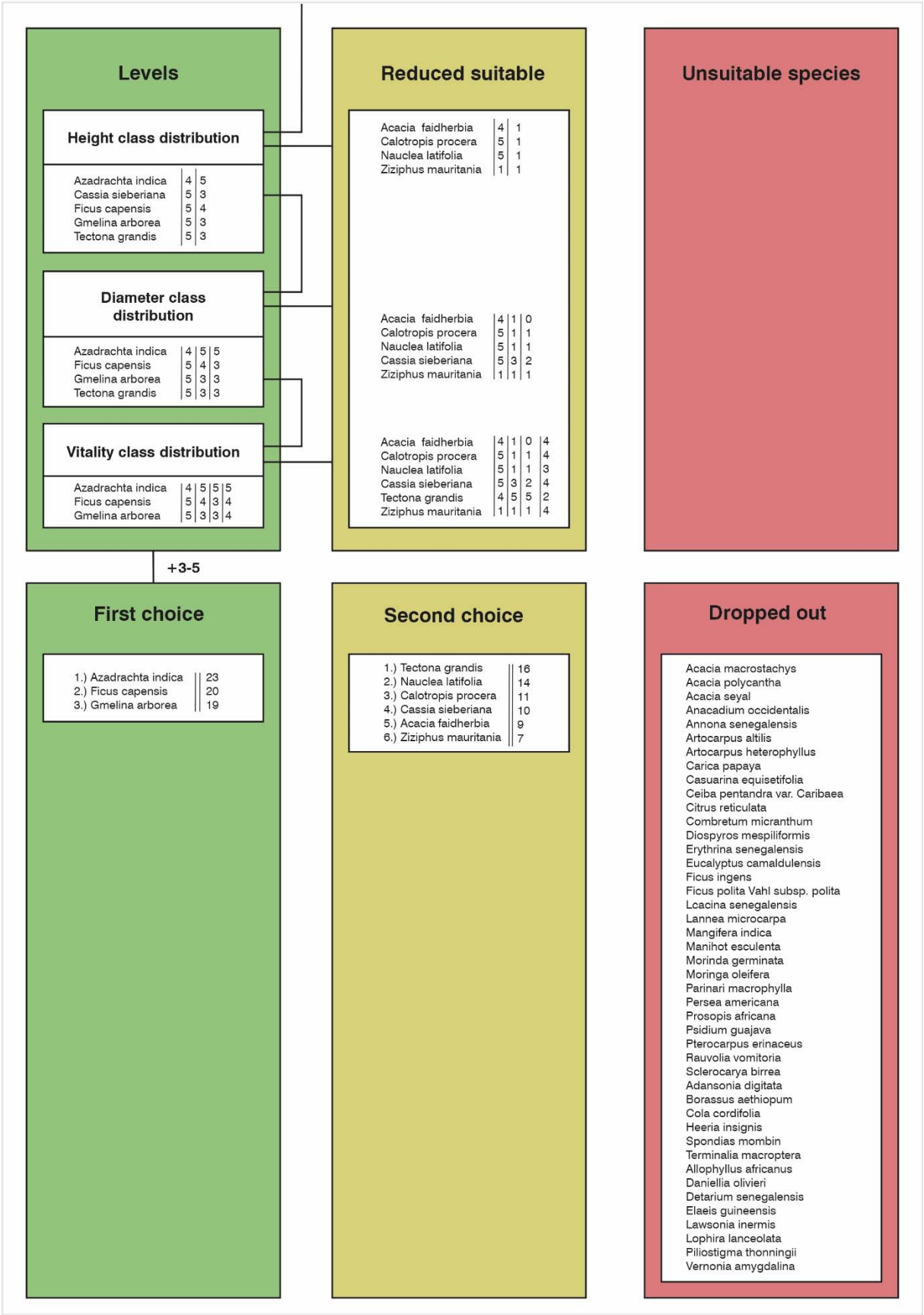

Figure 32: Decision-making process and identified potential species, page 2 (own arrangement)

10 Discussion

A short rainy season and increasing processes of desertification (Chapter 3.4) in the North-Bank Region of The Gambia present great challenges for the reproduction of occurring woody plants. Tree and shrub propagation by using hardwood cuttings may therefore be a serious alternative. Their key-advantage compared to soft- or greenwood cuttings is their higher resistance against dehydration, based on larger diameters above 1 cm and the lack of transpiring leaves (HARTMANN et al. 2010, p. 322-323). However, it is clear that not all of the occurring woody species possess the properties to be reproduced this way. Based on the data of the stock inventory, all species were evaluated using a specially created decision tree. The main results referring to the identified species with high potential for regional afforestation are interpreted as follows:

10.1 Occurring species and their abundance

The diversity of woody species within a stock provides information concerning stability and regenerative capacity of populations. In general terms, it can be said that the bigger the number of different occurring species at an area, the higher the resistance and resilience of a certain stock of trees (CHISHOLM et al. 2013, p. 1215). Furthermore, tree species composition can influence ecosystem properties through functional traits and interactions (HOOPER et al. 2005, p. 12). It has been shown that biodiversity increases productivity of a stand (LOREAU et al. 2001, p. 804). Additionally, it was recently suggested that biodiversity may be as important for productivity as the availability of growth-limiting nutrients in soil (TILMANN et al. 2012, p. 10395). It therefore appears that the presence of a variety of woody species and their abundance constitute important factors for a high resilience of a tree population. At the researched locality near the village of Farafenni, a total number of 53 different woody species were documented within the inventory of all circular plots at both areas (A+B). This appears to be a respectable value, especially when it is for example compared to the number of 65 occurring species at the whole forest territory of Austria (HAUK 2011, p. 18). By HOWTHORNE et al. (2000), 32 of those 53 species are native to The Gambia. This corresponds to a share of about 60 %. Considering the number of respective species per hectare, it appears that there is no equal share of individuals at the overall area. The main species *Azadrachta indica* (16.3 / ha, equalling 8.6 %), *Gmelina arborea* (15.4 / ha, equalling 8.1 %) and *Ficus capensis* (11.9 / ha, equalling 6.3 %) command about 23 % of all major trees at the investigated areas. Furthermore, just two documented woody species indicate an abundance of $\geq$ 15 individuals / ha, four species between $\geq$ 10 – 14.9 and three species between $\geq$ 5 – 9.9. Six species exhibit an abundance of $\geq$ 3 – 4.9 per hectare. The remaining 38 species only exhibit $<$ 3 individuals at one hectare of the overall project area. This means that the most 15 frequent species account for about 79 % of all individuals. It therefore appears that the biodiversity of the surveyed stock of trees seems to be quite high but a few species occur in a dominant way and constitute the majority of individuals.

10.2 Species richness and species area curve

The schematic representation of a species area curve (Chapter 6.4.2.1) illustrates the rising quantity of documented woody species depending on the increasing number of circular plots surveyed within the process of investigation (RAHMAN 2009, p. 19). At the first nine plots, which were surveyed at the project site, a number of 48 species out of 53 were already determined. That corresponds to a portion of about 91 %. At the furthermore eight plots recorded at the reference area, only five additional species were detected. The total number of 53 species was reached at plot number 15. The resulting course of this species area curve verifies that the conceived sampling design (Chapter 6.4.1) sufficiently captured the array of occurring woody species at both sites. Therefore, a higher number of effective occurring species cannot be ruled out, but appears rather unlikely.

10.3 Comparison of the survey areas and the similarity coefficient

As Table 3 in Chapter 8.3 visualises, 48 of the total 53 (A + B) woody species were determined at the project site (A), corresponding to about 91 %. This is astonishing, considering the fact that this area seems to be intensively used by human beings and appears significantly modified in relation to the defined reference area. Additionally, uncontrolled and illegal logging is happening. The investigated tree stock at the reference area (B) only consists of 27 different species. This is a share of about 51 %. The number of species determined both at the project site and the reference area (shared members) is 22. If those quantities are calculated by the method of Jaccard (according to ECKEY 2002, p. 221-233, described in chapter 6.4.2.2), a “Similarity Coefficient” of ≈ 42 is preserved. By ECKEY 2002 (p. 229), this means that the two investigated areas are similar to each other, but the similarity only amounts less than 50 % and must therefore be classified as “less similar”.

The higher number of species occurring at the project site (A) compared to the reference area (B) seems to be due to the following three factors:

- At first, there is a generally lower number of major trees per hectare (about 140 to 241 individuals) existing. This seems to lead to a sparse tree cover and a generally lower quantity of dominant individuals which enables natural reproduction and development of a high diversity.
- Secondly, it must be assumed that certain woody species are systematically supported or rather suppressed due to business interests.
- And thirdly, species which are usually used for the production of fruits or oil-products were recorded at this site. Those species like *Citrus reticulata* and *Elaeis guineensis* are obviously planted by locals, which is reflected by the fact that there are no indications of natural reproduction.

10.4 Social class, diameter and height class distribution of major trees

In order to analyse the age structure and the different layers of the tree stands, every investigated individual was assigned to a social class. Depending on several criteria described in Chapter 6.4.2.3, they were classified as „dominant“, “co-dominant”, “intermediate” and “suppressed” (according to CURTIS and MCINTOSH 1950, p. 434-455). To achieve a section of occurring trees at the overall project area (A+B), data of the two investigation areas were summarised and analysed together. Figure 24 (Chapter 8.4) demonstrates a relatively equal distribution of individuals assigned to the different social classes. Expectedly, the major share of individuals is attributable to the social class “co-dominant” (33 %). This can be explained by the generally existing number of individuals / ha. With an average of about 190 major trees / ha, there are inevitably group formations or rather areas with closed canopies. Furthermore, 23 % of individuals command a dominant status within the stands. This means that they either grow as solitaires or cover other members of the population. The big share of trees assigned to this social class confirms the impression received during the process of the survey. Therefore, there is a variety of canopy gaps and bare fields within both investigated areas. These gaps probably result from illegal logging. The remaining 46 % of major trees are attributable to the classes “intermediate” (27 %) and “suppressed” (19 %). This leads to the conclusion that there definitely was natural reproduction at these areas some time ago. The presence of all different tree layers within the stands can be interpreted as a positive feature concerning stability and regenerative capacity after possible calamities. Subordinated individuals, which exist numerously, can therefore replace losses, close gaps quickly and protect against dangerous processes of desertification described in Chapter 3.3, provided that there is no human interaction.
Assessing Table 4 (Chapter 8.4), which illustrates the social class distribution of respective species in detail, it is conspicuous that the frequently occurring species (Figure 22, Chapter 8.1) like *Azadrachta indica*, *Cassia sieberiana* and *Ficus capensis* often cover all four categories. It even seems that there is a connection between the number of individuals per hectare and their classification. It can therefore be concluded that species with a high abundance simply command a higher competitiveness regarding growth behaviour and sustainability.

The distribution of diameter classes indicates a different picture. Assessing Figure 25 (Chapter 8.5), it is obvious that nearly half (49 %) of all surveyed major trees exhibit a DBH ≥ 5-10 cm. However, there is a quite equal distribution of individuals categorised to the three remaining classes. 17 % are assigned to the class of DBH 10.1-15 cm, 11 % to DBH 15.1-20 cm, 14 % to DBH 20.1-25 cm, and 12 % exhibit a diameter at breast height of ≥ 25 cm.

The percentage height class distribution of the determined tree stocks illustrates an explicit decrease of individuals with increasing height. So, 56 % just exhibit a total height of ≥ 1.37- 5 m. 27 % are assigned to the class of 5.1-10 m, 8 % to the class of 10.1-15 m, also 8 % to the class of 15.1-20 m, and just 1 % of all surveyed trees at both investigation areas are ≥ 20.1 m in height.

Assuming that undisturbed growth conditions prevail at the researched areas, these results imply that the investigated tree stocks are relatively young and are composed of individuals with a low height and a small DBH. But the project site actually represents an “extreme location” with influential factors as described in Chapter 2.4. Therefore, a general reduction of growth, height and DBH can also be interpreted and taken into account as a possible adaption on these locational factors and especially on water shortage. Another reason for the high number of low and compact growing major trees at the investigated sites are species-specific characteristics. Many different species are simply small of habit with little diameters at breast height and a low maximal height. Additionally, one would expect that bigger trees were already felled by locals. This demonstrates that there were hardly no big individuals with knot free tree stems documented and the value of timber, as generally known, rises with increasing diameter and unscathed length. For the above mentioned reasons, it is very difficult to define and evaluate the age structure of the determined tree stocks by means of the applied methods and using non-destructive methods (eg. felling some individuals for further analyses). However, it can be assumed that the majority of occurring major trees might be middle aged (20-35 years).

10.5 Growth-habit distribution

During the stock survey, the growth forms of all major trees were classified into shrub-shaped and dendriform. This was done to get information about erosion-minimising effects of the surveyed tree stands. By JEDDELOH (1979, p. 112-113), preferably closed stands with an equal share of trees and shrubs constitute the most effective type of wind protection systems. Wind hitting mixed stands get disaggregated and deviated by above-ground plant parts. Consequently, wind speed gets significantly slowed down and loses its eroding effects. This weakening has further positive impact on dew formation, moisture content of near-surface air layers, temperature and growing conditions of progenies. Moreover, soil fertility gets promoted which can contribute to a rise of agricultural yields (GRUNERT et al. 1984, p.111).
Assessing the growth-habit distribution at the overall project area (Figure 27, Chapter 8.6), it is apparent that about two thirds (61%) of all recorded individuals exhibit a dendriform and about one third (39 %) a shrub-shaped habit. According to JEDDELOH (1979, p. 112-113), this distribution can be interpreted as a positive mixture regarding potentially erosion-minimising effects. But because of the generally light stocking coverage of just about 190 major trees / ha, hardly no positive influence can be assumed. The surveyed tree stands are simply too sparse and fragmented.

10.6 Vitality class differentiation

As described in Chapter 6.4.2.5, special attention was paid to the vitality conditions of all documented individuals. The differentiation was based on the key of vitality class distribution, composed by ROLOFF (2001, p.164-167). Proportionately, as illustrated in Figure 28 (Chapter 8.7), about 67.6 % of all recorded trees are attributable to vitality class 1. About 18.1 % are assigned to class 2 and about 14 % to class 0. Just 0.3 % exhibit a bad vitality and are therefore classified to class 3. This means that about 82 % are at least in a “good vitality condition”. The surveyed tree stands consequently make a healthy impression and no indications for negative influences on the vitality of the trees can be established.

10.7 Natural reproduction

To draw conclusions concerning natural reproduction of the different species within the stands, young progenies were additionally recorded during the survey. On this occasion, the focus was on different quantities of the occurring species. This collected data was meant to give information about reproduction capacities of the individual species under conditions prevailing at the site. The surveyed progenies were divided into three stages of regeneration defined as „Small seedlings“(all progenies $<$ 30 cm height), „Large seedlings“(progenies $\geq$1.37 m height but $<$ 5 cm DBH) and „Saplings“(all progenies $\geq$1.37 m height but $<$ 5 cm DBH). Furthermore, collected quantities were extrapolated in order to obtain the approximately number of progenies per hectare.

As illustrated in Figure 29 (chapter 8.8), there is no equal distribution of progenies within the stands. In total, just 18 of 53 different species exhibit at least one progeny within one of the stages of regeneration / ha. Of the remaining 35 species, no natural reproduction was established. 12 of the 18 reproducing species occupy all three stages. The five species with the highest number of progenies / ha are *Gmelina arborea* (49.2 / ha), *Azadrachta indica* (46.1 / ha), *Ziziphus mauritania* (34.2 / ha), *Parinari macrophylla* (26.4) and *Calotropis procera* (25.5 / ha). In general, this values seem to be low. Accordingly, it can be concluded that there is a very low reproduction rate of just a third of all determined species at the overall project area. Because of the small number of seedlings and saplings / ha and the usually natural high failure rate, it can be concluded that the surveyed tree stands currently produce hardly any progenies at the site. The essential reasons for this seem to be bad conditions for the development and germination of seeds which can be traced back to secondary succession and high anthropogenic pressure, increasing drought and processes of erosion. In addition, free ranging livestock is grazing all over the area. Therefore, it must be assumed that most of the shoots get grazed by free roaming cattle shortly after germination. Consequently, an undisturbed development of young plants is prevented.

10.8 Interpretation of the identified potential species for a propagation by hardwood cuttings

The evaluation and selection of potential suitable woody species for a sustainable propagation by hardwood cuttings is based on the basic concept of a decision tree (Chapter 7.1). In total, a number of 53 different species determined at the overall project area ran through this process. As described in Chapter 9, 31 species were already sorted out by fulfilling the first drop out criterion (availability at the project site and the reference area). This is a share of about 58 % and means that more than the half of all determined species didn't pass this first level. Furthermore, another 13 species (25 %) left the process within the subsequent two levels. In sum, a number of 44 or a percentage share of about 83 % of all surveyed woody species seems to be totally unsuitable for a sustainable hardwood cutting reproduction at the researched locality. The remaining 9 species (17 %) continued the validation phase which means that they seem to be at least reduced appropriated. Only the three species *Azadrachta indica, Ficus capensis* and *Gmelina arborea* fully passed the decision tree remaining in the green column and were therefore classified as "First choice species". This corresponds to a small share of just about 6 % which indicates that the decision-making process was construed and applied in a strict way in order to figure out just the most promising species. Of particular note is that those three species respectively exhibit the highest numbers of individuals occurring at the overall project area. It can therefore be concluded that they are especially competitive and resistant against difficult environmental conditions. In addition, it may be expected that natural ways of vegetative propagation (by root suckers, stolons etc.) are already applied successfully by those species.

11 Conclusions and answers to the research questions and hypotheses

The Gambia is a small and densely populated West African country struggling with a generally social and economic under-development. In addition, a continuous loss of the vegetation cover, ongoing land degradation due to unsustainable cultivation techniques and the effects of climate change heavily burden on the country (HARRY et al. 2019, p. 2). Another factor which strongly influences the stocks and the development of occurring plant species is the presence of a long dry season from November to May (Chapter 2.4) (UNCCD 2000, p. 23). In order to combat soil erosion and ongoing desertification, it appears absolutely necessary to stop the decrease in forest cover and additionally enable and support the development of new stocks of woody plants. To achieve this, several methods of tree and shrub propagation described in relevant literature appear suitable. In fact, there are just a few of them known and practiced in West Africa. Generative reproduction by seeds is the most common method of propagating occurring trees and shrubs and is mainly applied in agroforestry and reforestation projects. However, the production of seedlings in nurseries gets increasingly reduced by low germination capacities and lack of seeds. Therefore, vegetative propagation techniques can be promising alternatives by offering the opportunity to rapidly overcome limitations like long generation times, irregular flowering, high default ratios and a generally high outlay and water consumption for the breeding of suitable seedlings (LAOULALI 2015, p. 1). Hardwood cutting reproduction constitutes the most promising technique to propagate suitable woody species easily, successfully and time efficiently (Chapter 4.3). To define woody species which exhibit the most promising properties for a sustainable and unirrigated vegetative propagation, extensive vegetation surveys were carried out within the framework of this thesis. Data concerning the species richness, distribution of social-, height-, diameter- and vitality classes, visible traces of human utilisation and effects of re-sprouting from cuts and stumps of all different occurring woody species were recorded. By using a modified decision tree including previously defined drop-out- and valuation criteria, the most suitable species were defined. The main research questions and hypotheses of this thesis can therefore briefly be answered as follows:

Research question 1: **"Which different woody species occur at the researched locality near the village of Farafenni and how are local tree populations structured?"**

In total, a number of 53 different woody species were documented within the inventory of all circular plots at both areas (A+B). Chapter 12 includes portraits of all occurring species with detailed information about their origin, botanical classifications, site requirements, external characteristics and uses. However, there is no equal share of individuals, but a diverse distribution. The main three species (*Azadrachta indica, Ficus capensis* and *Gmelina arborea*) command about 23 % of all major trees. With a number of just about 190 major trees / ha, the local stands can be described as very sparse and fragmented. Although there is a relatively equal distribution of individuals within the social classes, the investigated tree stocks are

mainly composed of individuals with low heights and small DBHs and are therefore assessed to be relatively young. Furthermore, the occurring species exhibit a very low natural reproduction rate. Regarded holistically and in consideration of all results and diagrams, the surveyed tree stands are best described as highly instable at the researched locality.

Research question 2: "Which occurring woody species exhibit the most promising properties for an unirrigated and sustainable propagation by the method of hardwood cutting reproduction in order to be tested on rooting capacities within further field trials and monitoring programs?"

The stock inventory and species evaluation proofed *Azadrachta indica, Ficus capensis* and *Gmelina arborea* as the most promising woody species for an unirrigated and sustainable propagation by hardwood cuttings in the North-Bank Region of The Gambia. Further testing regarding their actual suitability is therefore recommended.

Hypothesis 1: "Local tree populations are composed of different woody species which exhibit unequal abundances, growth habits, social-, size- and vitality class distributions. They furthermore differ in their natural reproduction capacities."

The tree populations of the researched locality in the North-Bank Region of The Gambia contain a high diversity of woody species. They furthermore command fairly evenly distributed social structures with different quantities, growth habits and dimensions of the individuals. Although the natural reproduction capacities of all determined species appear to be very low, some species obviously exhibit a higher number of progenies than others. This hypothesis can therefore be confirmed.

Hypothesis 2: "Considering local conditions, some occurring woody species are better suited to be sustainably propagated by hardwood cuttings than others."

A sufficient availability at the researched locality, an equal structural distribution within the stands and an insensitive reaction to several kinds of anthropogenic disturbances - especially to periodic cuttings of branches - of the respective woody species are considered to be fundamental prerequisites for a sustainable propagation by hardwood cuttings. According to the results of the stock analysis and the specifically developed decision tree, the surveyed species exhibit individual characteristics and are therefore evaluated differently concerning their suitability. Consequently, this hypothesis can also be confirmed.

12 Portraits of the occurring woody species

Despite weak conditions concerning germination, development and sustainability of woody plants, a total number of 53 different species were documented at the overall project area. The following chapter portraits those species regarding their botanical classification, origin, distribution, site requirements, appearance markers and uses.
The information contained is mostly based on the two books „*Trees and Shrubs of the Sahel: Their Characteristics and Uses*“ by MAYDELL 1986 and “*Trees, shrubs and lianas of West African dry zones*” by ARBONNIER 2004. Additionally, trusted internet sources are quoted. The regional designations in the language of Mandinka were obtained by interviewing locals, especially local farmers. In order to receive a good quality of legibility, respective positions are quoted by superscript numbers and footnotes. All photographs used were specially recorded for this thesis. Some pictures show individuals located outside the overall project area. Due to inappropriately conditions or dense stocks, those individuals were just better suited to illustrate species-typical characteristics.

12.1 *Acacia faidherbia*

Synonyms: *Faidherbia albida*, *Acacia albida*[2], *Acacia gyrocarpa, Acacia leucocephala, Acacia saccharata*[1]

Family: Mimosaceae[2]

English designation: Apple-ring acacia, winter thorn[2]

Regional designation in Mandinka: Barasango[3]

Distribution: The species is distributed from South-Algeria to Transvaal and from Senegal to Somalia. It prefers the semiarid zone with annual rainfalls and occurs scattered beyond the valley to Syria, Lebanon, Israel and Yemen[1].

Site requirements: *Acacia faidherbia* is very adaptable. It can grow under precipitation of less than 300 mm up to 1800 mm and survives extended dry periods of even several years as well as several weeks of inundation. It is found in the Near East with average monthly winter temperatures of only 6 °C while tolerating daytime temperatures of over 40 °C in the Sahel and South Africa. Although a species of the alluvial plains, it is found at 270 m below sea level near the Dead Sea as well as at altitudes of up to 2700 m in the Sudan. *Acacia faidherbia* has no particular soil structure or nutrient requirements but demands a relatively high ground water table which must be reached by the taproot before height growth can begin[1].

Description: The species grows as a spiny tree which can reach a height of 20 m and a trunk diameter of more than 1 m. The crown is rounded and more or less dense. The bark is deeply fissured, cracked, fibrous, grey-brown and with pale brown slash[2]. The branches and twigs are characteristically light grey to whitish, with staggered, angular growth between the leaf axles. The species exhibits stipular, straight spines in axillary pairs. They are swollen at the base, up to 5 cm long and exhibit a light brown tip[1]. The leaves of *Acacia faidherbia* are alternate, bipinnate, blue-shagged green and exhibit 3-7 pairs of pinnae with 10-15 leaflets per pinna. The leaflets are oblong, linear, 3-6 mm long and 0.5-1 mm across. The flowering starts at the beginning of the dry season. The inflorescence, which is cream-white to yellow, appears as a spike at the base of a leaf. The fruit is an indehiscent pod which is 10-15 cm long and 1.5-3 cm across, thick, woody, swollen, curved into a semicircle, bright yellow to orange and contains 10-25 brown, more or less convex and elliptic seeds which are 9-12 mm in diameter[2].

Uses: *Acacia faidherbia* is a typical multipurpose tree which is appreciated and often actively protected by the local population. The leaves offer one of the best forage. The wood is used by the rural population for the manufacture of various tools and implements, including mortars, bowls and kitchen utensils. The thorny branches of this species are widely applied for fencing[1]. The medical application relates to fever, pneumonia, coughs and diarrhoea[2].

[1] MAYDELL (1986, p. 100-105)
[2] ARBONNIER (2004, p. 389)
[3] obtained by interviewing locals

Plate 1: Habit, branches and leaves of *Acacia faidherbia*

12.2 *Acacia macrostachus*

Synonyms: *Acacia macrostachya, Acacia suma sensu*[2]

Family: Mimosaceae[2]

English designation: No English designation known

Regional designation in Mandinka: Singoko[3]

Distribution: This species is common all over the southern Sahel and the Sudan-Savanna, including Burkina Faso, Senegal, The Gambia, Nigeria and Chad[1].

Site requirements: *Acacia macrostachus* prospers even on obdurate, skeletal or argillaceous soils, crustaceous, lateritic detritus, on eroded slopes and sandy soils[1]. It is often associated with *Combretum micranthum*, with which it often forms thickets in a banded mosaic[2].

Description: The species grows as a sarmentose shrub or small tree with an upright habit[1]. It exhibits thorns which are arranged all along the stems and small branches. They are about 1 cm long, bend downwards and brown. The bark is cracked or fissured, fibrous and brown with white-striped, red slash[2]. The leaves are bipinnate, alternate, with 20-30 pairs of pinnae and up to 5 cm long. Each possesses about 35-50 pairs of leaflets which are light green, 4-6 mm long and 1 mm wide[1]. The inflorescence is spiny and composed of 1-2 spikes. They are 5-12 cm long and more or less cylindrical. The numerous radially arranged flowers are yellowish. The fruit of *Acacia macrostachus* is as a narrow and oblong pod which is 7-12 cm long and 1.5-2 cm across. It exhibits 7-8 seeds which are brown, more or less flat, rounded and 7-8 mm in diameter[2].

Uses: The branch wood of *Acacia macrostachus* is used for fencing, in larger sizes as fuel. The gum is editable. In some regions, the seeds are boiled and consumed as a vegetable. In local medicine, the leaves and young shoots are used to treat gastrointestinal disorders, as an anthelmintic, to treat toothache and as an antidote for snakebites. It is said that large quantities of leaves eaten after a snakebite inhibit the poison's dispersion in the blood[1].

[1] MAYDELL (1986, p. 117)
[2] ARBONNIER (2004, p. 370)
[3] obtained by interviewing locals

Plate 2: Habit, branches and leaves of *Acacia macrostachus*

12.3 *Acacia polycantha*

Synonyms: *Acacia caffra var. campylacantha, Acacia campylacantha, Acacia catechu var. campylacantha, Acacia suma, Acacia erythrantha*[2].

Family: Mimosaceae[2]

English designation: No English designation known

Regional designation in Mandinka: Bambakogo[3]

Distribution: The species is distributed from Senegal to The Gambia, Cameron and as far as Sudan[2].

Site requirements: *Acacia polycantha* prefers sites with a high ground water table. It generally occurs solitarily and indicates eutrophic and fresh soils, but occasionally also prospers on stony slopes and compact soils[1].

Description: The species grows as a tree with a maximum height of up to 15 m. The twigs possess paired, axillary prickles which are curved like claws. Those prickles are brown with a black tip and exhibit a swollen base. The bark of the tree is ash-grey to yellowish with brown scales and black knots in the place of former leaves and thrones. The leaves are up to 25 cm long and exhibit 10-40 pairs of pinnae bearing 35-60 pairs of leaflets each. Those leaflets are 4-5 mm long and 1 mm wide[1]. The inflorescence appears as a fascicle of 1-3 dense spikes, is 4-13 cm long and placed in the axial of a leaf. The flowers are cream-white. The fruit is a flat, brown, oblong pod which is more or less coriaceous, glabrous, veined, 7-8 cm long and 1-2 cm across and approximately 3 mm thick. It contains 5-9 seeds which are brown, more or less convex and 7-9 mm in diameter[2].

Uses: The wood of *Acacia polycantha* is hard and durable but easy to polish. It is used for various applications, especially the manufacture of agricultural implements, poles, handles and wheels. Hardwood chips are applied in tanning and dyeing. The wood ashes give a salt substitute. Furthermore, the wood is good for fuel and charcoal. The gum is eatable and used as an adhesive and for treatment of new textile fibres. In local medicine, the roots of *Acacia polycantha* are applied to cure venereal diseases and to prepare an antidote for snakebites. The bark decoction is used against dysentery and gastrointestinal disorders[1].

[1] MAYDELL (1986, p. 131)
[2] ARBONNIER (2004, p. 374)
[3] obtained by interviewing locals

Plate 3: Habit, branches and leaves of *Acacia polycantha*

12.4 *Acacia seyal*

Synonyms: *Acacia stenocarpa, Acacia hockii*[1]*, Acacia flava var. seyal*[2]

Family: Mimosaceae[2]

English designation: White galled acacia[2]

Regional designation in Mandinka: unknown

Distribution: The species is typical for the African semiarid zones from Senegal across the entire Sahel to Sudan and Egypt. It also occurs in East Africa from Somalia to Mozambique and westwards to Namibia[1]. The distribution is irregular but sometimes in a high number of individuals or even in pure stands[2].

Site requirements: *Acacia seyal* requires annual rainfall of 250-1000 mm. It usually occurs on heavy clay soils, but can also be found on stony soils in plains, but generally not on slopes and hill tops. It often occurs at the base of hills or especially near river beds at lowland sites, on humus soils in valleys, beside waterholes and on low ground[1]. The species furthermore tolerates temporary flooding followed by periodic droughts[2].

Description: A small to medium-sized tree, reaching a height of 17 m and a stem diameter of 60 cm under favourable conditions. It develops a characteristic, umbrella-shaped crown. The bright green bark is covered with either a pale grey-green or rust-red, powdery coat. The slash is bright red, mottled and exudes a yellowish gum. The twigs exhibit many small, reddish glands and paired thorns at the leaf axils. The dark green leaves have 4-12 pairs of pinnae and 10-22 pairs of leaflets. The rachis is up to 8 cm long[1]. The inflorescence appears as a fascicle, is set at the base of a leaf and composed of 2-5 bright yellow, pedunculated glomerules which are 1.2-1.5 mm in diameter. The fruit is a narrow, more or less curved pod which is constricted between the seeds, pubescent and turning glabrous when touched. It is 7-20 mm long and 0.5-0.9 mm across, reddish brown and contains 6-10 brown, more or less rounded, flat seeds with a diameter of 7-9 mm[2].

Uses: The leaves, young shoots and pods are a valuable forage. Furthermore, the gum of *Acacia seyal* is traded in the Sudan under the name “Talh” and makes up to 10 % of the annual exported gum arabic. In Chad, the species is considered as the best fuelwood. For construction, poles of a medium size with forks at a height of 2-3 m are especially in demand. The pods and the bark contain tannin. The smoke of the wood is said to be particularly insect repellent. The bark, the leaves and the gum are used in local medicine for the treatment of haemorrhage, colds, diarrhoea, gastrointestinal disorders, jaundice, biliary diseases, syphilis, headaches, as an emollient, an astringent and for burns and ophthalmia[1].

[1] MAYDELL (1986, p. 131)
[2] ARBONNIER (2004, p. 374)
[3] obtained by interviewing locals

Plate 4: Habit, branches and leaves of *Acacia seyal*

12.5 *Adansonia digitata*

Synonyms: *Adansonia baobab, Adansonia situla, Adansonia sphaerocarpa, Adonsonia sulcata, Adansonia somalensis*[1]

Family: Bombacaceae[2]

English designation: Baobab[1]

Regional designation in Mandinka: Baobab[3]

Distribution: The species occurs in semiarid to subhumid Afrika south of the Sahara. It does not grow in moist tropical forests. Several varieties of the genus Adansonia exist on Madagascar and in Australia[1].

Site requirements: *Adansonia digitata* prefers areas with an annual rainfall of 100-1500 mm. There are no special requirements concerning the soil, but the species avoids seasonally inundated depressions. It is frequently associated with villages or occurs as a witness of former settlements[1].

Description: The Baobab exhibits a mighty trunk which can reach a diameter of 2-10 m with a girth of more than 20 m. Its maximal height is about 20 m. The crown and especially its branches resemble large roots when the tree has shed its leaves during the dry season. The tree's bark is smooth, about 2.5 cm thick, slivery grey or in parts nearly purple. The leaves of young individuals and the first leaves of the season are generally simple. Mature trees have long petioled, palmate leaves with 3-7 lanceolate leaflets which are brilliant above and pubescent beneath when they are young[1]. The solitary white flowers are 10-20 cm in diameter and are hanging at the tip of a 20-80 cm long pedicel. The fruit, which is well known as "monkey bread", has the shape of a capsule which is 20-40 cm long and 8-15 cm across. It is indehiscent, woody, pubescent, bronze-green to brown and may remain at the tree for a long time. At maturity, the fruit contains a great number of seeds immersed in a white floury pulp, mingled with reddish fibers[2].

Uses: Young leaves of the tree give a tasty spinach. Young sprouts and the roots of young plants are consumed like asparagus. At the beginning of the dry season, animals feed on fallen leaves which have a forage value. The seeds contain 15 % of oil and are eaten fresh or roasted. Pressed or dried and powdered, the fruit pulp provides a refreshing drink when dissolved in water or milk. The bark of lower parts of the stems can be removed to produce a valuable fibre for cordage, fishing nets, baskets, mats and clothes. Hollow trunks of old trees are used as grain stores, shelters, stables or even as tombs. It is remarkable that nearly every part of the plant has one or several uses in local medicine, especially to cure fevers, malaria, infections, insect bites and asthma[1].

[1] MAYDELL (1986, p. 149-153)
[2] ARBONNIER (2004, p. 196)
[3] obtained by interviewing locals

Plate 5: Habit, leaf and fruit of Adansonia digitata

12.6 *Allophylus africanus*

Synonyms: *Schmidelia africana, Allophylus cobbe*[1]

Family: Sapindaceae[1]

English designation: No English designation known

Regional designation in Mandinka: Kutufingo[2]

Distribution: This species is pantropical. It occurs from Senegal to Cameroon, in most cases scattered and locally gregarious[1].

Site requirements: *Allophylus africanus* grows at rocks, riverbanks and relatively drained soils[1].

Description: The shrub or small tree grows up to 2-4 m and exhibits a short bole and twisted, more or less erected branches. The bark is smooth, grey to dark brown and exhibits a yellow to pink, thin slash. The leaves are alternate, trifoliate and with subsessile leaflets which are pubescent beneath. They are 5-16 cm long and 2.5-7 cm across. The inflorescence appears as a 5-15 cm long raceme which is terminal or set in the axils of the last 3-4 leaves. The flowers are white to greenish, pedicellate and 6-8 mm in diameter. The fruit is an orange-red, globose berry with a diameter of 6-8 mm[1].

Uses: The roots are used in local medicine for the treatment of haemorrhoids, swellings and syphilis. The leaves are considered to reduce headache, anorexia and psychological disorders[1].

[1] ARBONNIER (2004, p. 477)
[2] obtained by interviewing locals

Plate 6: Habit, branches and leaf of *Allophylus africanus*

12.7 *Anacardium occidentalis*

Synonyms: *Anacardium occidentale*[1]

Family: Anacardiaceae[1]

English designation: Cashew tree[2]

Regional designation in Mandinka: Cashuwa[3]

Distribution: This species originates from the Northeast of Brazil and the Caribbean Islands. It was brought to other tropical countries by the Portuguese nearly 400 years ago and is thus one of the oldest cultivated tropical cash crops. Today it is planted all over the tropics, particularly in East Africa, Madagascar, West Africa and India. Plantations in Senegal, Mali and Burkina Faso have gained economic importance within Sahelian countries[1].

Site requirements: *Anacardium occidentalis* is very flexible with regard to climatic requirements. For an optimum production, a rainy season of 4-7 month with an annual rainfall of 1000-2000 mm is required. But the Cashew is very resistant to drought and will also grow under less favourable conditions, such as in Senegal and The Gambia. It prefers sandy, deep soils but does not tolerate indurated horizons. The species also grows on very poor, dry sites but bears no fruits under this conditions[1].

Description: An evergreen straggly shrub or tree of medium height up to 15 m, with a large and hemispherical crown which often reaches down to the ground. The leaves are alternate, 10-20 cm long and up to 15 cm wide, thick and leathery, glabrous and shiny with a prominent midrib and 12-20 lateral nerves[1]. The bark is rough, grey and exhibits pink slash. The inflorescence appears as a terminal, more or less dense cyme. The flowers are greenish, 7-9 mm in diameter and exhibit 5 sepals and 5 petals[2]. The fruit ("cashew nut") hangs on a stalk which is swollen to a fruit-like, red or yellowish body resembling a pepper pod called "cashew apple"[1].

Uses: The most important product of this tree are the tasty nuts which are of worldwide commercial interest. In some regions, young shoots of *Anacardium occidentalis* are used as a vegetable. The liquid of the nut shells is suitable for numerous industrial applications and applied as an insect repellent[1].

[1] MAYDELL (1986, p. 161-163)
[2] ARBONNIER (2004, p. 136)
[3] obtained by interviewing locals

Plate 7: Habit, branches and leaves of *Anacardium occidentalis*

12.8 *Annona senegalensis*

Synonyms: *Annona arenaria, Annona schrysophylla*[1]

Family: Annonaceae[1]

English designation: Wild custard apple[2]

Regional designation in Mandinka: Sunkung[3]

Distribution: The species is distributed within the entire semiarid to subhumid regions between Senegal and Sudan and southwards to the Guinea savanna[1].

Site requirements: *Annona senegalensis* grows on very diverse soil types of varying origins like stony soils, river banks, fallow land and even along the coast. It mostly occurs as a single shrub in the understory of savanna woodlands with annual rainfalls of over 600 mm[1].

Description: The species is a shrub with an irregular, open crown which grows up to 4 m[2]. It occurs rarely dendriform. The bark is smooth, grey-silvery and corrugated when old. Young stems are ferruginous, velvety to greyish and tomentose[1]. The leaves are alternate, widely ovate or oblong, 7-20 cm long and 6-12 cm across. The flowers are single or in groups of 2 to 3, yellowish, waxy, bell shaped and up to 2 cm in diameter[2]. The ovoid and pulpy fruit measures 4-7 cm and turns orange when ripe[1].

Uses: The greyish wood is used for poles and hoe handles. Furthermore, children like to eat the fruit as the fruit pulp is sweet. The wood ashes are added to chewing or snuff tobacco and used as a solvent for soap production. The leaves are used to fill pillows and mattresses. The greatest importance of *Annona senegalensis* lies in its application in local medicine. Especially the bark is applied for the treatment of worms, diarrhoea, gastro-enteritis and respiratory infections[1].

[1] MAYDELL (1986, p. 165-166)
[2] ARBONNIER (2004, p. 155)
[3] obtained by interviewing locals

Plate 8: Habit, branches and leaf of *Annona senegalensis*

12.9 *Artocarpus altilis*

Synonyms: *Artocarpus camansi, Artocarpus communis, Artocarpus incises, Artocarpus incisus var. non-seminiferus, Artocarpus incisus var. seminiferous, Artocarpus laevis, Artocarpus rima, Sitodium altile*[1]

Family: Moraceae[1]

English designation: Breadfruit[1]

Regional designation in Mandinka: Jackfruit[2]

Distribution: *Artocarpus altilis* is native to Papua New Guinea, Indonesia and the Philippines but nowadays occurs in several countries of the humid tropics[1].

Site requirements: The species prefers lowlands but tolerates altitudes of 650-1550 m above sea level. Its main sites are agricultural fields, gardens and plantations but it sometimes also occurs in secondary forests and next to roads[1].

Description: *Artocarpus altilis* is a tree which can grow up to 30 m. The trunk is straight, 5-8 m tall and 0.6-1.8 m in diameter. The leaves are alternate, ovate to elliptical in outline and 20-60 x 20-40 cm. They are mostly evergreen, shiny leathery and rough below. Young leaves are undivided, older ones are deeply pinnately cut into 5-11-pointed lobes. The inflorescences appears spongy, club-shaped and is 15-25 cm long and 3-4 cm across. The numerous small flowers are yellow to green. The fruit is cylindrical to globose, 10-30 cm in diameter, rind yellow-green and reticulately marked with 4-6-sided faces. Most of the cultivated breadfruits are seedless. Seeded ones are known as breadnuts. Breadnuts bear fleshy prickles. Their sweet pulp covers a large number of brown, flat seeds which measure a diameter of about 2.5 cm[1].

Uses: The species is often planted for its edible fruits and seeds, but the trees are also attractive for ornament and for shade. The fibrous bark of *Artocarpus altilis* was used to produce native cloths in former times. Its sap was frequently used to seal boats and as a chewing gum substitute. The light, quite firm, nicely grained wood is used for surf boards, canoes, furniture, carvings and in the construction of houses. In traditional medicine, especially the latex and the inner bark of the plant are applied to treat headaches and dysentery[1].

[1] Cabi.org (*Artocarpus altilis*)
[2] obtained by interviewing locals

Table 9: Habit, branches, leaves and fruits of *Artocarpus altilis*

12.10 *Artocarpus heterophyllus*

Synonyms: *Artocarpus brasiliensis, Artocarpus integrifolius, Artocarpus maxima, Artocarpus philippensis*[1]

Family: Moraceae[1]

English designation: Jackfruit[1]

Regional designation in Mandinka: Jackfruit[2]

Distribution: The species is native to India. It nowadays naturally occurs in many parts of the tropics. Large stocks can especially be in the South-East Asian region[1].

Site requirements: The species grows best in warm and humid climates with an altitude of about 1000 m. It is vulnerable to cold temperatures, droughts and flooding but exhibits a good salinity tolerance. It needs 1500 mm or more of annual rainfall and the dry season should not be too prominent. The tree can grow on different types of soil but performs best on deep, well-drained, alluvial and sandy or clay loam soils with pH 6.0-7.5[1].

Description: *Artocarpus heterophyllus* is a medium-sized, evergreen, monoecious tree which can grow up to 20 m. The crown is dense and conical in young and shaded trees but becomes rounded or spread in older age. New shoots, twigs and leaves are usually glabrous but occasionally short-haired and scabrid. The leaves are thin leathery, obovate-elliptic to elliptic, 5-25 cm long and 3.5-12 cm across. The green, solitary inflorescences exhibits an ellipsoid shape. It measures 3-8 cm x 1-3 cm and is composed of sterile and fertile flowers. The fruit is barrel- or pear-shaped, green, 30-100 mm long and 25-50 mm wide. The numerous seeds are brown, oblong-ellipsoid and about 2-4 x 1.5-2.5 cm[1].

Uses: The pulp of young fruits is commonly cooked as a vegetable. The seeds of *Artocarpus heterophyllus* are eatable when roasted or boiled. Young leaves offer a very good forage. Wood particles are sometimes used to dye silk and cotton fabrics. The latex of the plant offers a good caulking material and is frequently used to seal boats. The Wood is classified as a medium hardwood which is weather and termite resistant. It can be polished beautifully. In traditional medicine, the ash of burned leaves is applied against abscesses, ulcers and swellings[1].

[1] Cabi.org (*Artocarpus heterophyllus*)
[2] obtained by interviewing locals

Plate 10: Habit, inflorescences and leaf of *Artocarpus heterophyllus*

12.11 *Azadirachta indica*

Synonyms: *Antelaea aradirachta, Melia azadirachta, Melia indica*[1]

Family: Meliaceae[2]

English designation: Margosa, neem, nim tree[2]

Regional designation in Mandinka: Yirinding-Kunango[3]

Distribution: The origin of this species is the northeast of India. Nowadays, it is distributed in all tropical areas and in arid and semiarid regions[1].

Site requirements: *Azadirachta indica* is very drought and heat resistant and even grows with 150 mm of annual rainfall. The species has no particular site requirements and even tolerates slight salinity. It grows better than other species on dry, stony, shallow and nutrient deficient soils without groundwater contact but is intolerant to frequent inundation and lateritic outcrops[1].

Description: A small to medium-sized tree which can reach a maximum height of 15 m. It is generally evergreen but can cast its leaves under extreme conditions like long lasting droughts. The crown of *Azadirachta indica* is ovate to round. Its stem is frequently straight and smooth. The bark is brown-grey, of medium thickness and longitudinally fissured. The leaves are imparipinnate, 20-40 cm long and exhibit slim petioles. They consist of 7-17 pairs of alternate leaflets which are 6-10 cm long and 1-3 cm wide, ovate or lanceolate, coarse, bluntly dented, dark green and glabrous[1]. The inflorescence appears as a 10-20 cm long lax panicle and consist of numerous white, pedicellate single flowers with a diameter of 0.5-1.5 cm[2]. The fruit is an ellipsoidal drupe with one or rarely two seeds. It is 1.2-1.8 cm long, yellow when ripe and exhibits a thin cuticle. The fruit pulp is juicy[1].

Uses: The predominant function of this species relates to ornamental reasons. It is also a very common shade tree in court-yards, along roads and in parks. The wood is heavy and mainly used as fuel and charcoal. The leaves contain up to 15 % of protein and are used as fodder for camels, sheep and goats. The sap from upper branches and roots gets fermented and drunk. The flowers and the young buds get cooked as a vegetable. In northwest Nigeria, *Azadirachta indica* is used on degraded agricultural land for soil amelioration in order to improve the pH value and to make soil nutrients available for commercial crops. It has also been found out that the soil under neem trees is considerably more humid down to a depth of 30-120 cm during the dry season. Many parts of the plant, especially the oil is successfully applied against a number of different skin diseases[1].

[1] MAYDELL (1986, p. 173-175)
[2] ARBONNIER (2004, p. 353)
[3] obtained by interviewing locals

Plate 11: Habit, branches and leaf of *Azadirachta indica*

12.12 *Borassus aethiopum*

Synonyms: *Borassus flabfellifer var. aethiopum*[2]

Family: Palmae[2]

English designation: Borassus Palm, elephant palm, African fan palm[2]

Regional designation in Mandinka: Sibo[3]

Distribution: The species is distributed from tropical Africa to Senegal and The Gambia, to East and South Africa, throughout semiarid to subhumid regions[1].

Site requirements: *Borassus aethiopum* is very light-demanding and needs a high ground water table. It therefore prefers alluvial soils near watercourses, riverbanks and fertile agricultural sites. It tolerates seasonal inundation and prospers with an average of 800 mm of annual rainfall[1].

Description: The species is a typical fan-palm with a tall and straight bole which may attain a diameter of 60 cm. It can grow up to 20 m. The fan-shaped leaves are up to 3.6 m long. About 15-30 of them form the crown[1]. The male flowers are small and numerous, tightly set in the axil of a bract and exhibit 3 free external tepals and 3 internal tapals attached at the base. The female flowers are larger than the male ones and with fleshy, kidney shaped tepals[2]. The globose fruit can reach a diameter of up to 20 cm and turns orange to brown when ripe. The yellowish or white, oily and fibrous fruit pulp contains 3 kernels which measure about 8x8 cm and are brown and woody when ripe[1].

Uses: The sap, obtained by tapping the unopened inflorescence, contains up to 20 % of fructose and is processed into sugar or fermented and distilled as an alcoholic beverage. The oil-containing fruit pulp, the seeds and the starchy pitch are of local significance as a food. The leaves of *Borassus aethiopum* serve as thatch material for roofs and for plainting. Furthermore, a root decoction is given to newly born to treat respiratory ailments and asthma[1].

[1] MAYDELL (1986, p. 193-193)
[2] ARBONNIER (2004, p. 173)
[3] obtained by interviewing locals

Plate 12: Habit, leaves and fruits of *Borassus aethiopum*

12.13 *Calotropis pocera*

Synonyms: No synonyms

Family: Asclepiadaceae[2]

English designation: Swallow wort, Sodom apple[2]

Regional designation in Mandinka: Kipampam[3]

Distribution: The species is distributed in the entire Sahel, south and north of the Sahara, East Africa, the Arabian Peninsula, India[1], Latin America and the Caribbean[2].

Site requirements: *Calotropis pocera* grows on fields and swallow land, typically on extremely degraded soils near settlements, in Pakistan up to an altitude of 1300 m above sea level. It prefers sandy soils and sometimes forms pure stands[1].

Description: The species grows as a shrub and can reach a height of 5.5 m. The bark is fibrous, scaly, deeply fissured when old and grey to light brown. All parts of the plant contain a white latex which exudes when cut. The leaves are large, ovate, opposite, sessile, up to 30 cm long and 16 cm wide and greyish-green. Young leaves and shoots are white pubescent[1]. The inflorescence appears as an umbelliform cyme which is about 10 cm across and set in a leaf axil. The flowers are green-white and violet, 2-3 cm in diameter and exhibit 5 petals[2]. The fruit is green, ovoid and 10 cm in diameter. The fruit pulp is thick and spongy. The fruit contains numerous seeds which are surrounded by silky white floss[1].

Uses: The inner bark fibres of *Calotropis pocera* are very strong and resistant. They are frequently used to produce a binding material. The leaves and green fruits get eaten by goats and sheep, rarely by cattle and other livestock. The species is furthermore a very diversely used medicine plant. The latex is used for the treatment of Guinea worm blisters and scorpion stings. The twigs are applied for the preparation of diuretics, stomach tonics, anti-diarrhoea products ect.[1].

[1] MAYDELL (1986, p. 213-214)
[2] ARBONNIER (2004, p. 180)
[3] obtained by interviewing locals

Plate 13: Habit, leaves, flowers and fruit of *Calotropis pocera*

12.14 *Carica papaya*

Synonyms: No synonyms

Family: Caricaceae[1]

English designation: Papaya tree[1]

Regional designation in Mandinka: Papaya[2]

Distribution: The species is native to Central America, from Florida to Brazil. It is nowadays distributed in tropical areas all over the world[1].

Site requirements: *Carica papaya* is a water-demanding species which is commonly planted in vegetable gardens or near wells[1].

Description: The species grows as a small tree with a maximum height of 10 m. The trunk is greyish, straight, sometimes branched, often wider at the base, exhibits leaf scars, and is fibrous and more or less soft. The leaves are alternate, markedly petiolate, deeply notched and 30-50 cm long and wide. The male flowers are tubular, 5-lobed and yellowish. The female ones are solitary, positioned in leaf axils, subsessile, tubular, 5-lobed and about 5 cm in diameter. The fruit is a big freshly berry. It is almost globose, ovoid or pear-shaped and more or less angled. It contains a red to yellow pulp with numerous black seeds[1].

Uses: *Carica papaya* is a famous fruit tree. Furthermore, nearly all parts of the plant are used in traditional medicine. Especially the roots are applied to treat dysentery, tooth decay, whitlow and convulsions[1].

[1] ARBONNIER (2004, p. 248)
[2] obtained by interviewing locals

Plate 14: Habit, leaves and fruits of *Carica papaya*

12.15 *Cassia sieberiana*

Synonyms: *Cassia kotschyana*[1]

Family: Caesalpiniaceae[2]

English designation: Drumstick tree, African laburnum[2]

Regional designation in Mandinka: Sinjango[3]

Distribution: The species is distributed in the southern Sahel and in the Sudan savanna from Senegal to Sudan and Uganda[1].

Site requirements: *Cassia sieberiana* prefers well drained, humid soils in regions with at least 500 mm of annual rainfall. It also occurs on very dry sites, sometimes in groups.

Description: The species is a deciduouse tree with a maximal height of 20 m. The bark is dark grey to blackish and wrinkled with shallow vertical fissures and large, reddish, horizontally arranged lenticels[1]. The leaves are alternate, composite, paripinnate, 20-30 cm long and exhibit 5-9 pairs of opposite leaflets which are finely pubescent beneath and more or less shiny above. The inflorescence appears as a pendant raceme and is about 35 cm long. The flowers are long-pedicellate, bright yellow and about 5 mm in diameter[2]. The fruit is a cylindrical pod which is 40-80 cm long, dark green or brown, corky, transversally and contains numerous small seeds[1].

Uses: The hardwood is pale pink and darkening when exposed to light. It is used for cabinet work, turnery, carpentry, furniture, wheel work, pestles, mortars and tool handles. Furthermore, there a various medical uses. For example, the roots are applied to treat elephantiasis, leprosy, diarrhoea, haemorrhoids, dysentery and venereal diseases. The leaves are used to reduce fever, pleuritic, burns and ulcers[1].

[1] MAYDELL (1986, p. 225)
[2] ARBONNIER (2004, p. 214)
[3] obtained by interviewing locals

Plate 15: Habit, fruits and leaf of *Cassia sieberiana*

12.16 *Casuarina equisetifolia*

Synonyms: *Casuarina litorea*[1]

Family: Casuarinaceae[1]

English designation: Australian pine tree[1]

Regional designation in Mandinka: Flower-tree[2]

Distribution: The natural distribution of *Casuarina equisetifolia* extends along the sea coasts of eastern Asia. The species was brought to West Africa in 1925 and is nowadays mainly planted in gardens or along roadsides[1].

Site requirements: The species grows well on deep sandy soils and tolerates calcareous and slightly saline sites. It can withstand waterlogging for short periods, but its growth is inhibited by compacted soil layers. In its natural habit, annual rainfall varies between 200 - 700 mm, but plantation in other parts of the world have been successfully established with a little of 200-300 mm, if ground water is available[1].

Description: *Casuarina equisetifolia* is a tree which can reach a height of 25 m under favourable conditions and approximately 6-12 m in the Sahel. Not only the foliage, but also the shape resemble a conifer, which has occasionally caused confusion. The foliage consist of long needles which are actually modified branchless. The leaves are very small scales and look like whorls of tiny teeth. The male flowers are reduced. The female inflorescence develops into a small woody cone, which has break-like valves, containing a great number of tiny winged seeds[1].

Uses: In the Sahel, the species is mainly used for sand dune stabilisation. The strong network of lateral roots can help to reduce soil erosion. The wood, which is one of the hardest in the world, is heavy and difficult to saw. Posts are used for fencing, small utensils and for freshwater pilling and bridge construction. Furthermore, the wood is an excellent fuel due to its high specific gravity and calorific value. It splits easily and burns slowly with little smoke and few ashes[1].

[1] MAYDELL (1986, p. 227-228)
[2] obtained by interviewing locals

Plate 16: Habit and foliage of *Casuarina equisetifolia*

12.17 *Ceiba petandra var. caribaea*

Synonyms: *Bombax petandrum, Eriodendron anfractuosum, Ceiba thongii, Ceiba guinensis, Ceiba caribaea*[1]

Family: Bombacaceae[1]

English designation: Silk-cotton tree, Kapok tree[1]

Regional designation in Mandinka: Bantango[2]

Distribution: The species is distributed from Senegal to Cameron, Central America, West India and the Indo-Malay continent[1].

Site requirements: *Ceiba petandra var. caribaea* is mainly planted in villages of Sahelian, Sudanese and Guinean areas. It sometimes occurs in fringing forests and moist forests but is not resistant to bush-fires[1].

Description: The species is the tallest tree of the Sahel and can reach a maximum height of 60 m. The typical trunk exhibits large ribbed buttress roots at the base. The bark is variable smooth, often dark grey and sometimes green. The leaves are alternate, digitate, compound, and with 5-15 glabrous leaflets. The inflorescence appears as an irregular, dense panicle of small fascicles. The flowers are white and 3-4 cm in diameter. The corolla exhibits 5 petals and is attached at the base. The fruit is a spindle-shaped capsule which is 10-30 cm long, ochre to pale brown and with 5 valves. It contains black spherical seeds, which are embedded in a grey or white down[1].

Uses: Especially the down surrounding the seeds inside the fruits is used. Young women collect it at the beginning of the rain season and utilize it for the manufacture of mattresses, pillows and saddles[1].

[1] ARBONNIER (2004, p. 199)
[2] obtained by interviewing locals

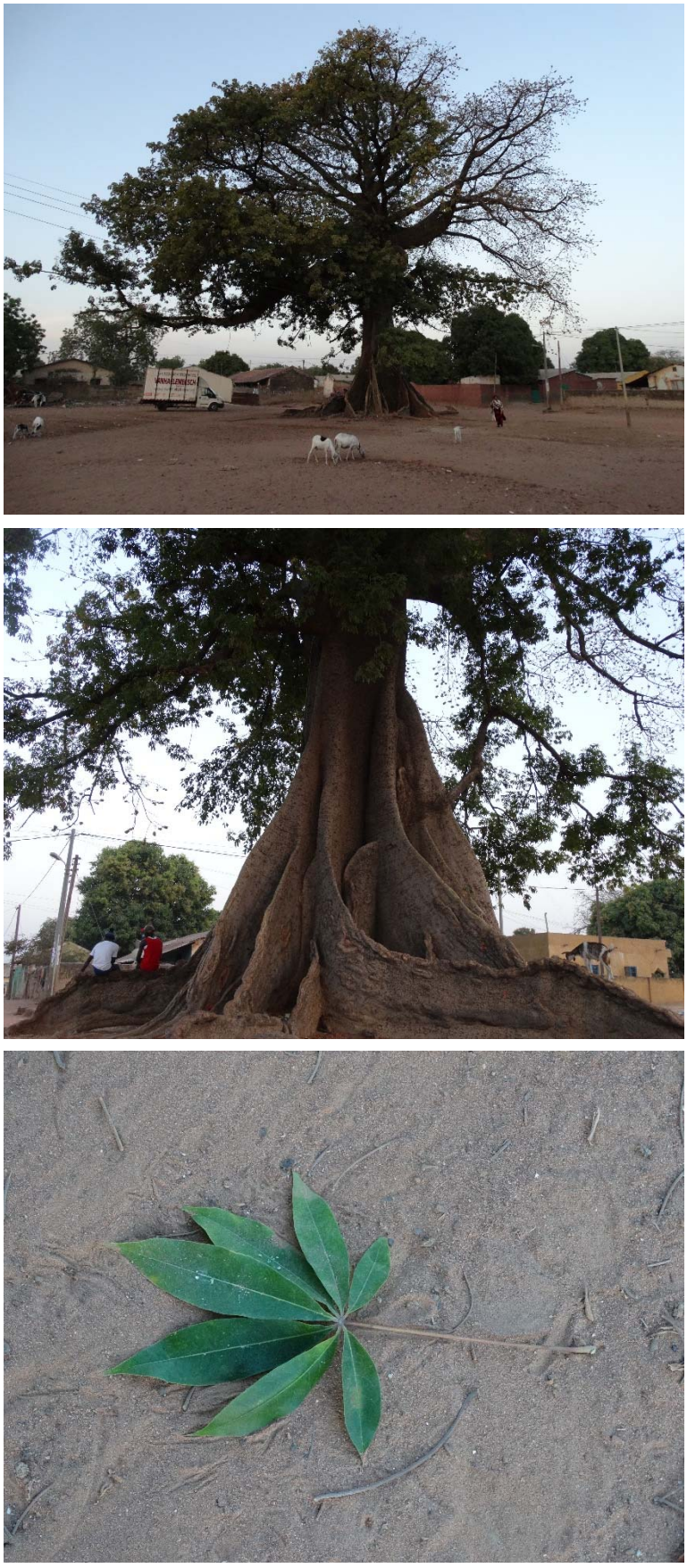

Plate 17: Habit, buttress roots and leaf of *Ceiba petandra var. caribaea*

12.18 *Citrus reticulata*

Synonyms: No synonyms

Family: Rutaceae[1]

English designation: Mandarin[1]

Regional designation in Mandinka: Mandarin[2]

Distribution: The species is probably native to Vietnam and nowadays distributed in America, tropical Asia and from Senegal to Cameroon[1].

Site requirements: *Citrus reticulata* is frequently planned in gardens and orchards in humid tropical areas and also in semi-arid or arid regions[1].

Description: The species is a small spiny tree with a dense crown. It can reach a height of 2-8 m. The bark is smooth, grey and exhibits yellowish slash. The evergreen leaves are unifoliate, compound, alternate, ovate to elliptic, 4-8 cm long and 1.5-5 cm across. The inflorescence appears as a short raceme of 1-7 flowers which is set in the axils of a leaf. The flowers are cream-white, fragrant, 1.5-2.5 cm in diameter and exhibit a cup-shaped calyx. The fruit is ovoid, 5-8 cm in diameter, depressed at both ends or pear-shaped and orange-yellow when ripe[1]

Uses: *Citrus reticulata* is primary planted as a fruit tree[1].

[1] ARBONNIER (2004, p. 470)
[2] obtained by interviewing locals

Plate 18: Habit, branches and leaf of *Citrus reticulata*

12.19 *Cola cordifolia*

Synonyms: *Sterculia cordifolia, Cola cordifolia var. puberula*[1]

Family: *Sterculiaceae*[1]

English designation: Mandinka cola, Mandingo kola[1]

Regional designation in Mandinka: Taboo[2]

Distribution: The species is distributed from Senegal to Burkina Faso and quite common in its area[1].

Site requirements: *Cola cordifolia* grows in Sudanese to Guinean savannas and dry forests. It is often planted at drained soils and tolerates temporary flooded areas[1].

Description: The species is a tree with a maximum height of 20 m, a dense crown and a short and squat bole which is often fluted and thickened at the base. The bark is grey-brown, fissured, peeling off in small scales, thick and fibrous. The pubescent leaves are alternate, suborbicular or with 3-7 more or less marked lobes, 8-35 cm long and 8-30 cm across. The inflorescence appears as a raceme which is branched and tomentose, about 6 cm long and set at the base of a leaf. The flowers are yellow, shortly pedicellate, apetalous, tomentose outside and 5-7 mm in diameter. The fruit is kidney-shaped, arranged in a star of 3-5 pieces, 10-15 cm long and covered with russet hairs[1].

Uses: The roots of *Cola cordifolia* are used as an aphrodisiac. The bark of the tree is applied to treat bronchitis, coughs and tuberculosis, headaches, blennorrhoea and haemorrhoids. The seeds are sweet and frequently eaten by children[1].

[1] ARBONNIER (2004, p. 489)
[2] obtained by interviewing locals

Plate 19: Habit, branches and leaf of *Cola cordifolia*

12.20 *Combretum micranthum*

Synonyms: *Combretum altum, Combretum floribundum, Combretum raimbaultii, Combretum parviflorum*[1]

Family: Combretaceae[2]

English designation: Kinkeliba[2]

Regional designation in Mandinka: Kinkeliba[3]

Distribution: The species occurs very frequently all over the Sahel. It often forms pure stands in Senegal, Niger, The Gambia, Burkina Faso, Niger and Sudan[1].

Site requirements: *Combretum micranthum* grows on dry sites, especially on sandstone, clay, laterite, crystalline rocks and on skeletal soils. It is an indicator for extremely unfavourable soils and needs an annual rainfall between 300 and 1500 mm[1].

Description: The species grows as a shrub and can reach a maximum height of 4 m. The brown-red, climbing branches may reach a length of 20 m. The leaves are alternate, shining light green when young and typically rust–coloured when mature. The leaves are variable in shape, mostly oblong-elliptic, up to 10 cm long, acuminate, and on the inner side with single tufts of hair in the axils[1]. The inflorescence appears as a spike-like axially raceme which is 3-5 cm long, sometimes fasciculate and with a scaly peduncle. The flowers are whitish and about 2 mm in diameter and exhibit a 4-petalled corolla. The fruit is a 4-winged samara which is brown when ripe, more or less glabrous and exhibits a reddish scaly seed[2].

Uses: In many countries, the leaves are used and traded as a tea. It is refreshing and has curative effects. The seeds are eatable. The wood is used for fuel, hut construction, basked manufacture and for furniture. The roots are applied to treat sterility, fever and sores and venereal diseases. The leaves are used as an antipyretic, diuretic, and for several diseases as yellow fever, hepatic disorders and disorders of the respiratory system[1].

[1] MAYDELL (1986, p. 237)
[2] ARBONNIER (2004, p. 261)
[3] obtained by interviewing locals

Plate 20: Habit, branches and leaves of *Combretum micranthum*

12.21 *Daniellia oliveri*

Synonyms: *Paradaniellia oliveri, Daniellia thurifera*[1]

Family: Caesalpiniodeae[1]

English designation: West African copal, African copaiba balsam[1]

Regional designation in Mandinka: Santao[2]

Distribution: The species is distributed from Senegal to Cameroon, as far as Sudan, Congo and Angola. It is locally common but the distribution is generally irregular[1].

Site requirements: *Daniellia oliveri* grows on any type of soil especially in Guinean and Sudanese savannas. It does not resist under cover[1].

Description: The species is a big tree which can grow up to 25 m. The crown is spreading and relatively dense. The bark is scaly, flanking of in large, more or less circular patches and grey with a white stripped, deep red slash. The leaves are alternate, paripinnate, 45-50 cm long and exhibit 4-9 pairs of opposite or subopposite leaflets. The inflorescence appears as a short axially panicle which can reach a length of 25 cm. The flowers are white or greenish-white and exhibit 4 sepals and 1-2 large petals. The fruit is an obovate, flat pod with 2 stiff papery valves. It is beige, 5-10 cm long and 2.5-5 cm across[1].

Uses: The bark of the tree is applied to treat migraine, headaches, stiffness, wounds, ulcers, skin diseases, tooth decay, leprosy, snake bites, menstrual disorders, hydrocele and tuberculosis. The wood of *Daniellia oliveri* is used to produce pestles and mortars, drums, beehives, drinking troughs and pirogues[1].

[1] ARBONNIER (2004, p. 217)
[2] obtained by interviewing locals

Plate 21: Habit and leaf of *Daniellia oliveri*

12.22 *Detarium senegalensis*

Synonyms: *Detarium heudelotianum*[1]

Family: Caesalpiniodeae[1]

English designation: Tallow tree[1]

Regional designation in Mandinka: Tallo[2]

Distribution: The species occurs from Senegal to Sudan and eastern Africa. It is locally common but the distribution is generally irregular[1].

Site requirements: *Detarium senegalensis* grows on moist lowlands and soils, especially in Sudano-Guinean forests and Sudanese fringing forests[1].

Description: The species is a tree which can reach a maximum height of 30 m. The crown is low and exhibits spreading, squat branches. The bark is finely fissured, blackish, and with small scales and deep red brown slash. The leaves are alternate, imparipinnate and exhibit 5-6 pairs of alternate or subopposite leaflets which are ovate, oblong or elliptic, 4-6 cm long and 2.5-3 cm across. The inflorescence appears as a lax axially raceme which is 10-15 cm long. The flowers are apetalous and exhibit 4 petals and 8-10 cream-white, prominent stamens. The fruit is an ovoid or globose drupe which is more or less flattened and 5-6 cm in diameter. It contains a large central stone embedded in a greenish, floury, fibrous, acidulous and sweet pulp[1].

Uses: The fruit pulp is eatable and rich in vitamin C. The fruits are especially collected and eaten by children. The roots of the tree are used to produce a perfume and a kind of birdlime. The wood is russet-brown, more or less fragrant and termite-resistant. The ashes of burned wood can be used to soften the taste of snuff tobacco[1].

[1] ARBONNIER (2004, p. 220)
[2] obtained by interviewing locals

Plate 22: Habit, leaf and fruit of *Detarium senegalensis*

12.23 *Diospyros mespiliformis*

Synonyms: *Diospyros senegalensis*[1]

Family: Ebenaceae[2]

English designation: West African ebony[2]

Regional designation in Mandinka: Kukuwo[3]

Distribution: The species is distributed from West Africa to Zimbabwe, Zambia, Angola, South Africa and Yemen. It is characteristic of tree savannas, particularly in Guinea and Nigeria and occurs up to an altitude of 1250 m in the mountains[1].

Site requirements: *Diospyros mespiliformis* grows on rocky soils. In the Sahel zone, it preferably occurs along seasonal watercourses and in swamps. It furthermore thrives well on heavy soils[2], red loam soils, loamy sands and termite mounds[1].

Description: The species grows as an evergreen tree which can reach a height of 12-15 m. Its crown is very branchy with dense foliage. The stem exhibits a black, wrinkled and finally scaly bark which later turns brown and corky. When the thin grey bark of the branches is scraped off, a bright red-brown layer appears. Young branches are usually green and tomentose. The leaves are up to 4x12 cm, oblong-ovate, short petioled and coriaceous[1]. *Diospyros mespiliformis* is a dioecious plant. The male inflorescence appears as a cyme of 3-9, is set in the axils of a leaf and measures 2-3 cm. The male flowers are white, corolla tube-shaped and covered with golden hairs. The female flowers are similar, but appear singular and are broader than long. The fruit is an ovoid drupe which measures 20-25 mm and is yellowish when ripe. It is pubescent and becomes glabrous when mature[2]. The fruit pulp is sweet and contains 4-6 chocolate brown seeds[1].

Uses: The fruit is eatable, either fresh or after drying. It is also used for the production of toffees and beverages. *Diospyros mespiliformis* yields a valuable ebony. It is very heavy, hard, brittle, decay and termite resistant. This much sought wood is especially suitable for turning and the production of cartwheels, canoes, tools, combs and drums. Furthermore, the leaf decoction is an extraordinary remedy for fever and otitis. The bark and the roots are applied to treat serious infections such as malaria, pneumonia, syphilis and leprosy.

[1] MAYDELL (1986, p. 255-256)
[2] ARBONNIER (2004, p. 284)
[3] obtained by interviewing locals

Plate 23: Habit, branches and leaf of *Diospyros mespiliformis*

12.24 *Elaeis guineensis*

Synonyms: *Elaeis nigrescens, Elaeis virescens*[1]

Family: Arecaceae[1]

English designation: African oil palm[1]

Regional designation in Mandinka: Tengo[2]

Distribution: The species is distributed from tropical Africa to central Africa, Senegal and Cameroon[1].

Site requirements: *Elaeis guineensis* grows in Sudano-Guinean to Guinean forests and savannas, especially on well-drained and moist soils, on termite mounts and flood-prone lowlands. The species is very popular and widely cultivated in gardens and on fields[1].

Description: *Elaeis guineensis* is a typical palm tree which can reach a maximum height of 20 m. The bole is regular, upright, grey and often covered with the remains of grey persistent leaf-petioles. The leaves are compounded, pinnate and 2-4 m long. The very numerous leaflets are up to 60 cm long and 1-3 cm across. The petiole is wide at the base, flattened above and convex beneath and exhibits prickly edges. The species is dioecious. The male flowers appear very numerous, are 5 mm long and set closely in the axil of a 3-lobed bract. The female flowers exhibit ovate external tepas and red internal tepas. The fruit is ovoid and more or less angular, 3-4.5 cm long, purple-black to orange and shiny. The spongy, fibrous and oily pulp surrounds a hard, brown stone called palm nut[1].

Uses: The fruits are used to produce a famous oil of considerable economic value. The leaves are applied to treat bronchitis, menorrhagia and blennorrhoea. The sap is often fermented to brew a beverage called palm wine[1].

[1] ARBONNIER (2004, p. 175)
[2] obtained by interviewing locals

Plate 24: Habit, leaves and leaflets of *Elaeis guineensis*

12.25 *Erythrina senegalensis*

Synonyms: No synonyms

Family: Fabaceae[2]

English designation: Coral tree[2]

Regional designation in Mandinka: Ndolingo[3]

Distribution: The species is only distributed in West Africa. It occurs in Senegal, The Gambia, Cameroon and Gabon[1].

Site requirements: *Erythrina senegalensis* grows frequently in Senegalese savannas but is also planted in settlements and gardens[1].

Description: The species is a shrub or small tree which can reach a height up to 6-7 m. The bark is thick, corky, bright and exhibits a yellow slash. The leaves are alternate, pinnate and set in triplets. The leaflets are ovate, 5-10 cm long and acuminate. The petiole measures 3-6 cm[1]. The inflorescence appears as an erect terminal raceme which is 16-30 cm long. The flowers are bright red, asymmetrical, 3-4 cm long and exhibit a glabrous, non-dentate calyx[2]. The fruits are thin pots which are strongly bend or twisted and 8-15 cm long[1]. They contain 5-9 smooth, shiny, ovoid bright red seeds which are 6-7 mm long[2].

Uses: *Erythrina senegalensis* is commonly planted as a hedge. The wood is without use, because it is very quickly infested by insects. In traditional medicine, the leaves are applied to treat all kinds of stomach disorders. The bark extracts are used to alleviate malaria, bronchitis, amenorrhoea, sterility in women, fever, rachitis as well as liver and gallbladder ailments[1].

[1] MAYDELL (1986, p. 261)
[2] ARBONNIER (2004, p. 316)
[3] obtained by interviewing locals

Plate 25: Habit, inflorescences and leaf of *Erythrina senegalensis*

12.26 *Eucalyptus camaldulensis*

Synonyms: *Eucalyptus rostrata*[1]

Family: Myrtaceae[2]

English designation: River redgum[2]

Regional designation in Mandinka: Eucalyptus[3]

Distribution: The species originates from Australia but is nowadays widely distributed all over the world, especially in the Mediterranean region, the Subtropics and in semiarid regions. It was first planted in Africa at about 1900[1].

Site requirements: *Eucalyptus camaldulensis* grows from sea level to approximately 600 m altitude with precipitations over 250 mm. It is able to tolerate a dry season of over 8 months and also thrives on poor and degraded soils[1].

Description: *Eucalyptus camaldulensis* is a big, evergreen tree which can reach a height of 20 m. It is deeply branched and frequently with spiral grain but can also exhibit long, straight boles. The bark is whitish to light brown, thin and typically peeling off in long strips. The leaves are alternate, lanceolate, grey-blue, dropping, glabrous and give off a strong scent when macerated[1]. The inflorescence appears as a pedunculated cyme which is 0.5-2.5 cm long, set at the base of a leaf and composed of 3-7 flowers. The flowers are pedicellate, apetalous, more or less rounded at the base and bear numerous whitish stems which are 4-6 mm long. The fruit is a hemispherical, woody capsule which is pedicellate, topped by a swelling and opening at the top in 4 triangular teeth[2].

Uses: The species is primarily planted for the fuelwood production, as windbreaks and as ornamental trees along roads. The timber is furthermore used for fence posts, poles for construction and for the production of tools. The essential oil contained in the leaves is used in the perfume industry and for medical applications[1].

[1] MAYDELL (1986, p. 263-264)
[2] ARBONNIER (2004, p. 418)
[3] obtained by interviewing locals

Plate 26: Habit, twigs and leaf of *Eucalyptus camaldulensis*

12.27 *Ficus capensis*

Synonyms: *Ficus sur*[1]

Family: Moraceae[2]

English designation: Bush fig[2]

Regional designation in Mandinka: Soto [3]

Distribution: The species is distributed all over Africa and is especially common at the southern rim of the Sahel[1].

Site requirements: *Ficus capensis* occurs in Sudanese to Guinean savannahs and fringing forests. It prefers moist but well drained soils[2].

Description: The species grows as a medium sized tree which can reach a height of up to 12 m[1]. Its crown is narrow and fairly dense. The bole is low branching and up to 1.5 m in diameter. The bark is smooth, rough and scaly, grey and exudates white latex. The leaves are alternate, spirally-arranged, more or less coriaceous, elliptic, oblong to ovate, 4-20 cm long and 3-13 cm across and pubescent or glabrous beneath. The flowers are very small and inconspicuous[2]. The fruits, called figs, are up to 5 cm in diameter, pear-shaped, smooth, reddish when mature and hanging in racemes on old branches or even on the stem[2].

Uses: The fruits and young aerial shoots of *Ficus capensis* are eatable. In Sierra Leone, the bark is used in the preparation of food. The leaves and the fruits are furthermore said to stimulate the milk production of cows. The wood is suitable for several applications provided the stem has been rebarked and dried before felling. In some regions, bast fibres and tannin are used. The species plays an important role in local medicine, in particular with respect to fertility. Certain parts of the tree are exclusively used as a treatment for women. In addition, positive effects on headache, bronchitis, dysentery, eye infections, rachitis, fever, oedema, sterility in women, complicated birth, leprosy, epilepsy, lumbago, poison antidote and venereal diseases are reported[1].

[1] MAYDELL (1986, p. 271)
[2] ARBONNIER (2004, p. 410)
[3] obtained by interviewing locals

Plate 27: Habit, bole, leaves and young fruits of *Ficus capensis*

12.28 *Ficus ingens*

Synonyms: *Ficus lutea, Ficus kawuri, Urostigma ingens, Ficus katagumica*[1]

Family: Moraceae[2]

English designation: No English designation known

Regional designation in Mandinka: Soto-Borama [3]

Distribution: The species is distributed in entire semiarid Africa, Kenia, South Africa and Yemen[1].

Site requirements: *Ficus ingens* occurs in Sudano-Guinean savannahs on any type of soil, but prefers sandy and gritty soils[2].

Description: The species grows as a deciduous tree and can reach a maximum height of 15 m. The branches are low and pendulous. The bark is scaly, grey-brown and exudes latex when cut. The leaves are characteristic long ovate, apiculate, glabrous and 8-15 cm long and 6-10 cm across. They exhibit 3-5 pairs of lateral nerves[1]. The flowers are very small and inconspicuous. The fruits, called figs, appear solitary or in pairs under or in the axil of a leaf. They are globose or ovoid, about 1 cm in diameter, more or less pubescent, often verrucous, wrinkled at the tip and reddish when ripe[2].

Uses: *Ficus ingens* is often preserved or planted for its shade. The bark of the tree is said to promote milk production in cows. The wood is yellowish, soft and light and not very resistant to insects. It is used as firewood and to produce pots, containers and cooking utensils. The latex presents a rubber substitute[1].

[1] MAYDELL (1986, p. 275)
[2] ARBONNIER (2004, p. 405)
[3] obtained by interviewing locals

Plate 28: Habit, branches and leaf of *Ficus ingens*

12.29 *Ficus polita Vahl subsp. polita*

Synonyms: No synonyms

Family: Moraceae[1]

English designation: No English designation known

Regional designation in Mandinka: Yirinfang-soto[3]

Distribution: The species is distributed from Senegal to Cameroon, as far as Sudan and Central Africa[1].

Site requirements: *Ficus polita Vahl subsp. polita* occurs in Sudanese to Guinean savannas and fringing forests. It grows on any type of soil but is generally planted[2].

Description: The species grows as an epiphytic shrub or tree and can reach a height of 12 m. The bole is usually short and squat. The crown is rounded and dense. Frequently, aerial roots are hanging from the trunk and older branches. The bark is smooth, grey to pale brown, with pale pink to reddish slash and exudes abundant white and very sticky latex. The leaves are alternate, spirally arranged, more or less coriaceous, glabrous, glossy above, elliptic or widely ovate, 5-20 cm long and 2-12 cm across and more or less cordate at the base. The flowers are very small and inconspicuous. The fruits, called figs, appear in a group of 2-4 in the axil of a leaf scar. They are 2.5-4 cm in diameter, glabrous or more or less puberulous and greenish-yellow when ripe[2].

Uses: *Ficus polita Vahl subsp. Polita* is often planted for its shade. The wood is a good fuel. Furthermore, the fruits are applied to treat diarrhoea[1].

[1] MAYDELL (1986, p. 275)
[2] ARBONNIER (2004, p. 405)
[3] obtained by interviewing locals

Plate 29: Habit, branches and leaf of *Ficus polita Vahl subsp. Polita*

12.30 *Gmelina arborea*

Synonyms: No synonyms

Family: Verbenaceae[1]

English designation: Gmelina, white teak[1]

Regional designation in Mandinka: Gmelina[2]

Distribution: The species is distributed in tropical areas in which there is a marked dry season of three to five months[1].

Site requirements: *Gmelina arborea* grows on many different types of sites but prefers deep and well drained soils[1].

Description: A tree which can reach a maximum height of 30 m. The bole is usually straight and up to 80 cm in diameter. The crown is dense. The bark is smooth, grey to pale beige and becomes more or less scaly on old trees. The stems are glabrous and green. The leaves are opposite, green, more or less glabrous above, glaucous and tomentose or pubescent beneath, elliptic or widely ovate, 15-25 cm long and 10-25 cm across. The Petiole is glabrous, 6-15 cm long and more or less channelled above. The inflorescence appears as a terminal raceme and is about 5-30 cm long. The flowers exhibit a yellow calyx with five triangular teeth. The fruit is an avoid drupe which is 2-3 cm long, yellow when ripe and turning dark brown when senescing[1].

Uses: The species is appreciated for its fast growth and is highly suited for reforestation. The timber is yellowish-white, semi-durable, easy to work and insect resistant. It is used to produce poles, sculptures, drums and boxboards. Furthermore, it is widely utilized in the match industry. The leaves of *Gmelina arborea* are applied in traditional medicine to treat diarrhoea, high blood pressure, malaria and insect stings[1].

[1] ARBONNIER (2004, p. 506)
[2] obtained by interviewing locals

Plate 30: Habit, branches and leaf of *Gmelina arborea*

12.31 *Heeria insignis*

Synonyms: *Ozoroa insignis, Anaphrenium abyssinicum, Ozoroa reticulata*[1]

Family: Anacardiaceae[1]

English designation: Gmelina, white teak[1]

Regional designation in Mandinka: Kankanao[2]

Distribution: The species is distributed in tropical Africa, from Senegal to Ethiopia and from Rwanda to Mozambique[1].

Site requirements: *Heeria insignis* grows in Sudano-Guinean savannahs on any type of soil[1].

Description: The species is usually shrub-shaped and can reach a height of 4 m. Its crown is lax. The bark is grey to pale brown, slightly fissured and exhibits a black-striped, pale yellow slash. The stems are slightly pubescent. The leaves are simple, opposite or alternate, arranged in whorls of three, oblong to narrowly ovate elliptic, 4-15 cm long and 1-5 cm across. The upper surface is dark green and exhibits prominent parallel nerves which intersect the margin of the blade. The inflorescence appears as a terminal and axillary panicle which is up to 15 cm long. The flowers are whitish, about 6 mm in diameter and exhibit 5 petals. The fruit is a vertically-flattened drupe which is up to 12 mm long, hard, bright black and often stays on the tree throughout the dry season[1].

Uses: The bark of *Heeria insignis* is commonly used as a tea substitute and applied in local medicine to treat colics. The sweet fruits are frequently collected and eaten by children. Furthermore, the crushed charcoal of this species is used for the production of gun powder[1].

[1] ARBONNIER (2004, p. 151)
[2] obtained by interviewing locals

Plate 31: Habit, branches and leaf of *Heeria insignis*

12.32 *Icacina senegalensis*

Synonyms: *Icacina oliviformis*[1]

Family: Icacinaceae[1]

English designation: False yam[1]

Regional designation in Mandinka: Manankaso[2]

Distribution: The species is distributed in tropical Africa, especially from Senegal to Nigeria and Sudan[1].

Site requirements: *Icacina senegalensis* grows best in tropical areas with a marked wet and dry season. It prefers sunny positions on light and sandy soils[1].

Description: The species grows as an erect, small woody herb or woody shrub. It exhibits a number of stems which can reach a height of 2 m. Furthermore, the plant develops a large tuber which is about 30 - 50 cm in diameter and 25-40 kg in weight. The edible fruit exhibits a sweet gelatinous pulp and turns red when ripe[1].

Uses: *Icacina senegalensis* is frequently applied in traditional medicine. The leaves are used for the treatment of numerous diseases. Taken internally, a decoction of the leafy twigs is used to alleviate internal haemorrhages, coughs and all chest affections, snake bites and feverish states. A decoction of the twigs and roots is given to adults in Senegal for general debility of an undiagnosed origin. The leaf-sap is sometimes used as a treatment for eye infections. The roots of *Icacina senegalensis* are considered to be tonic. A decoction is applied to treat dermatitis, headache, chest-complaints, kidney-troubles, senescence, debility and internal pain[1].

[1] Tropical.theferns.info
[2] obtained by interviewing locals

Plate 32: Habit, branches and leaf of *Icacina senegalensis*

12.33 *Lannea microcarpa*

Synonyms: *Lannea djalonica*[1], *Lannea barteri, Odina schimperi*[2]

Family: Anacardiacceae[1]

English designation: No English designation known

Regional designation in Mandinka: Bembo-Kojo[3]

Distribution: *Lannea microcarpa* is distributed from Senegal to Cameroon. The species is generally uncommon but can locally occur in a high abundance[2].

Site requirements: The species grows in Sahelo-Sudanese to Sudanese savannahs, on rocky soils in the eastern side of distribution area and on compacted to moist and deep soils in the West[2].

Description: *Lannea microcarpa* is a deciduous tree which can reach a height of 16 m and a stem-diameter of up to 50 cm. Its crown is hemispherical and very dense. The bark is white-greyish, sweet-scented, smooth, wrinkly on old trees, very fibrous and falling off in small scales. The leaves are alternate, imparipinnate, and generally do not exhibit more than 9 pairs of leaflets. The leaflets are ovate, acuminate, 6-10 cm long and tomentose[1]. The inflorescence appears as a terminal raceme which is studded with glandular dots and measures about 15 cm. The flowers are yellowish, about 4 mm in diameter and exhibit 4 petals. The fruit is an ellipsoid drupe which is about 1.4 cm long, glabrous, deep purple when ripe and exhibits 4 small teeth at the top[2].

Uses: The fibrous bark of *Lannea microcarpa* is used for the manufacture of ropes. The fresh fruits are edible and make a sweet beverage after cooking. The leaves are used as a forage exclusively for goats. Furthermore, the gum is soluble and edible. The wood is white and not durable. In traditional medicine, the bark and the leaves are used in traditional medicine to prepare a remedy against diarrhoea[1].

[1] MAYDELL (1986, p. 313)
[2] ARBONNIER (2004, p. 146)
[3] obtained by interviewing locals

Plate 33: Habit, and leaves of *Lannea microcarpa*

12.34 *Lawsonia inermis*

Synonyms: *Lawsonia alba*[1]

Family: Lythraceae[1]

English designation: Henna[1]

Regional designation in Mandinka: Fuddan[2]

Distribution: The species is native to Arabia and Iran but is nowadays widely distributed in subtropical and Mediterranean Africa, Madagascar, Asia and Australia[1].

Site requirements: *Lawsonia inermis* grows in Sudanese to Sahelian areas and prefers sandy soils. It is generally cultivated near houses since prehistoric times[1].

Description: The species grows as a very low branching and ramified shrub which can reach a height of 3-4 m. Its branches are spindly and the ends often become spiny. The bark is smooth, whitish, fibrous and exhibits pale pink slash. The stems are pale grey and quadrangular when young. The leaves are opposite, single, glabrous, elliptic or oblanceolate, 2-4 cm long and 0.5-1.5 cm across and exhibit a cuneate apex and a tapering-cuneate base. The inflorescence appears as a terminal panicle which measures 10-15 cm. The flowers are white or cream, glabrous, very fragrant and exhibit 4 sepals and 4 petals. The fruit of *Lawsonia inermis* is a spherical, indehiscent capsule with a diameter of about 5 mm. It is pale brown when ripe and contains numerous pyramidal seeds[1].

Uses: Especially the leaves release a mahogany-red or orange colour when crushed which is frequently used as a body colour, for colouring hair, fabrics and leather. The flowers are furthermore used as a perfume in cosmetics. The bark of *Lawsonia inermis* is sometimes applied to treat bronchitis and leprosy[1].

[1] ARBONNIER (2004, p. 352)
[2] obtained by interviewing locals

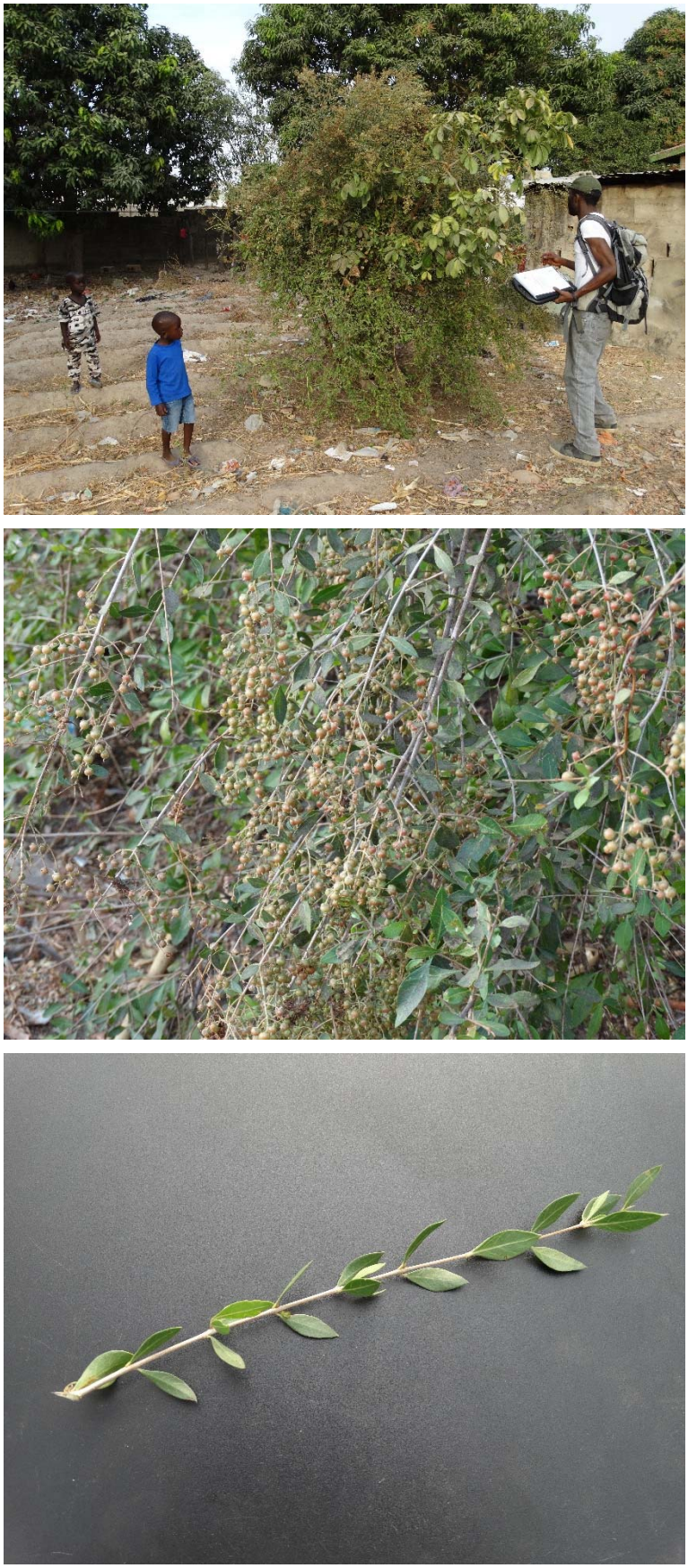

Plate 34: Habit, branches, fruits and leaves of *Lawsonia inermis*

12.35 *Lophira lanceolata*

Synonyms: *Lophira spatulata, Lophira alata, Lophira africana*[1]

Family: Ochnaceae[1]

English designation: Red oak, red ironwood[1]

Regional designation in Mandinka: Machecharo[2]

Distribution: The species is distributed from Senegal to Cameroon and far as Sudan. It usually occurs scattered but can locally be very common and gregarious[1].

Site requirements: *Lophira lanceolata* grows in Sudano-Guinean to Guinean savannahs and prefers average or stony soils. It is an invasive species which often recolonises fallow land at forest edges[1].

Description: The species grows dendriform and can reach a height of 10 m under optimal conditions. Its bole is straight or twisted and its crown narrow or slender. The bark is rough, pale brown to chestnut-coloured, flanking off in in small patches and exhibits a dark red slash. The stems are thick, corky, glabrous and russet-grey. The leaves of *Lophira lanceolate* are alternate, glabrous, glossy, narrowly oblong or oblanceolate, 10-45 cm long and 2-9 cm across. The inflorescence appears as a terminal panicle of fragrant flowers and measures about 15 cm. The flowers are white, about 3 cm in diameter and exhibit 5 sepals and 5 petals. The fruit is conical and more or less bombshell-shaped, woody, hard, 2.5 cm long and 0.8-1.2 cm across and red to chestnut-coloured when ripe[1].

Uses: An oil, obtained solely from the fruits, is frequently used as a body lotion. In traditional medicine, the whole plant is applied to treat leprosy. The timber of *Lophira lanceolate* is pink-coloured with a red core. It is very hard and heavy and is especially used to produce railway sleepers and mortars. Furthermore, it is valued for several kinds of construction works[1].

[1] ARBONNIER (2004, p. 426)
[2] obtained by interviewing locals

Plate 35: Habit, branches and leaves of *Lophira lanceolata*

12.36 *Magifera indica*

Synonyms: No synonyms

Family: Anacardiaceae[2]

English designation: Mango[2]

Regional designation in Mandinka: Mango [3]

Distribution: The species originates from India and the adjacent Southeast Asian region. Early explorers brought the tree to other regions such as East Africa in the 14th century and 200 years later to West Africa. Today, *Magifera indica* is cultivated in almost every tropical region but preferably in zones with a dry season[1].

Site requirements: *Magifera indica* has no particular soil requirements but tolerates neither stagnant water nor extended or frequent flooding. It grows well on deep, loamy-sandy and fresh, well drained soils but dislikes rocky soils, compact clays and calcareous soils[1].

Description: The mango tree can easily be recognised by its large, even dense and widely spread crown. It can reach a height of about 10 m. The bark is brown and smooth when young and almost black and rugose when old. The leaves are alternate, copper-coloured when young, tender and hang perpendicularly from the branches. They turn dark green when grown, are leathery, glabrous, lanceolate, 12-30 cm long and 3-5 cm wide[1]. The Inflorescence appears as a terminal panicle which measures 10-40 cm and exhibits about 1000 single flowers. The flowers are very small, yellowish to orange and exhibit 5 sepals and 5 petals. The fruit is an obliquely ovoid drupe which is very variable in size and colour. The pulp is fibrous in non-grafted varieties. The stone is wide, fibrous, more or less flat and exhibits lengthwise stripes[2].

Uses: *Magifera indica* is the most widely cultivated fruit tree of West Africa. Its fruits are eaten fresh or used for the manufacture of numerous products like jam, jelly, puree, juice and liquor. In local medicine, the fruit is applied to prevent scurvy[1].

[1] MAYDELL (1986, p. 225-227)
[2] ARBONNIER (2004, p. 149)
[3] obtained by interviewing locals

Plate 36: Habit, branches and leaf of *Magifera indica*

12.37 *Manihot esculenta*

Synonyms: No synonyms

Family: Euphorbiaceae[1]

English designation: Cassava, Tapioca, Manioc, Mandioca, Yuca[1]

Regional designation in Mandinka: Cassava[2]

Distribution: The species is native to South America. It is nowadays cultivated all over the tropics, especially in Mexico, Brazil, Colombia, Jamaica, Ghana, Madagascar, Paraguay, Fiji, and Sri Lanka[1].

Site requirements: *Manihot esculenta* grows in all well-drained tropical and subtropical areas where there is a warm humid climate. It requires a fairly well-spaced rainfall of about 1500 mm for an optimum growth. It does not tolerate frost and usually does not occur above 1100 m altitude. It grows best in well drained neutral to alkaline, quite permeable, sandy loams. The plant needs a lot of water, but does not tolerate consistent flooding[1].

Description: The species is usually shrub-shaped and can reach a height of up to 5 m. The leaves are deeply 3–7-parted with spatulate to linear-lanceolate acuminate lobes. They are 7.5-15 cm long, glabrous, glaucous beneath and minutely puberulent along the veins. The big roots are very woody and can reach a length of up to 2.5 m, a diameter of 10-15 cm and a weight of 40 kg under cultivation[1].

Uses: *Manihot esculenta* is primarily cultivated for the tubers which are used as a foodstuff. Tubers may be eaten raw, boiled, fried, or in baked goods. Young leaves are high in Vitamin B and are sometimes applied to treat beriberi. Furthermore, the Roots are used as fodder for livestock and as a source of alcoholic beverages or power alcohol[1].

[1] Hort.purdue.edu
[2] obtained by interviewing locals

Plate 37: Habit, branches and leaf of *Manihot esculenta*

12.38 *Morinda geminata*

Synonyms: *Morinda chrysorhiza*[1]

Family: Rubiaceae[1]

English designation: No English designation known

Regional designation in Mandinka: Batio[2]

Distribution: The species is distributed from Senegal to Togo, Cameroon, The Central African Republic and Congo[1].

Site requirements: *Morinda geminata* grows in tropical areas with moderate rainfall[1].

Description: The species is an evergreen shrub which can reach a height of 9 m. The bole is 12-40 cm in diameter[1].

Uses: In traditional medicine, *Morinda geminata* is used in a variety of applications. A decoction of fresh leaves is said to be an effective purgative. Dry leaves are applied to treat malaria. Furthermore, crushed roots are used to strengthen weakly babies[1].

[1] Tropical.theferns.info
[2] obtained by interviewing locals

Plate 38: Habit, branches, fruits and leaf of *Morinda geminata*

12.39 *Moringa oleifera*

Synonyms: *Moringa pterygosperma*[1]

Family: Moringaceae[2]

English designation: Never die, horse-radish tree[2]

Regional designation in Mandinka: Moringa[3]

Distribution: *Moringa oleifera* is native to Arabia and India. It nowadays occurs all over the tropics of the world, from South Asia to West Africa. It is especially common in parts of East Africa and South Africa[1].

Site requirements: The species grows in stream banks or in the savanna, but is mostly cultivated on fields and in home gardens. It is very drought-resistant and prefers very well drained soils with a high ground water table and an annual rainfall of 300-400 mm[1].

Description: The species grows as a tree or shrub which can reach a height of 5 m[1]. Its crown is low branching and spreading. The bark is smooth, grey to brownish, roughly lenticellate and exhibits green slash. The trunk exudes a white opaque gum which turns dark red when exposed to the air. The leaves are alternate, composite, bipinnate, imparipinnate, 30-70 cm long and exhibit 2-6 pairs of opposite leaflets. The leaflets are ovate to elliptic, 1-2 cm long and 0.5-1.5 cm across and shortly petiolate. The Inflorescence, which is 10-15 cm long, appears as a terminal raceme. The flowers are cream-white, pedicellate and exhibit 5 sepals and 5 unequal petals. The fruit is 30-50 cm long and about 2 cm across, elongated, linear and more or less beige to greyish when ripe. The seeds are spherical, black, 7-8 mm in diameter and exhibit 4 papery wings[2].

Uses: The species is one of the very valuable multipurpose trees of semiarid areas. Young fruits, flowers and leaves are frequently eaten as a vegetable. In traditional medicine, Moringa is used as a diuretic and to treat bladder and prostate ailments. Furthermore, the seeds contain a sweet, non-sticking oil which is used in the preparation of food and the manufacture of soaps[1].

[1] MAYDELL (1986, p. 335-337)
[2] ARBONNIER (2004, p. 417)
[3] obtained by interviewing locals

Plate 39: Habit, branches, inflorescence and leaf of *Moringa oleifera*

12.40 *Nauclea latifolia*

Synonyms: Mitragyna aifricana, Uncaria inermis, *Nauclea africana*[1], *Sacrocephalus latifolius, Sacrocephalus esculentus, Nauclea esculenta*[2]

Family: Rubiaceae[1]

English designation: African peach[2]

Regional designation in Mandinka: Batio-Jongo[3]

Distribution: The species is distributed from Senegal to Cameroon, as far as Sudan, tropical and southern Africa. It occurs scattered but can locally be very abundant[2].

Site requirements: *Nauclea latifolia* grows around pots and lowlands of Sudano-Guinean and Guinean savannas. It prefers moist and more or less well drained soils[2] and tolerates saline soils near mangrove forests[1].

Description: The species grows as a small tree or shrub and can reach a height of just 4-5 m. The bole is twisted and up to 30 cm in diameter. The crown is spreading and open. The branches are entangled, flexible and erect. The bark is cracked, dark grey-brown and exhibits fibrous reddish slash. The leaves are opposite, glabrous, bright green and greasy to touch above, broadly elliptic or suborbicular, 10-22 cm long and 7-15 cm across. The inflorescence, which is composed of numerous small white flowers, appears as a spherical ball which is arranged at the end of a branch and measures 3.5-4.5 cm in diameter. The fruit is a fleshy berry which is irregularly globose, 3-5 cm in diameter, red when ripe and contains a great number of small seeds immersed in a pink flesh with a strawberry-like scent[2].

Uses: The fruit pulp of *Nauclea latifolia* is frequently eaten fresh or dried[2]. Its wood is light brown, fine, easy to work but difficult to split. It is used for the manufacture of different utensils, for constructions, for ornamental work and as firewood. The flexible branches are sometimes used to plait fishing weirs. In traditional medicine, the leaves and the bark are used as a febrifuge[1].

[1] MAYDELL (1986, p. 333)
[2] ARBONNIER (2004, p. 463)
[3] obtained by interviewing locals

Plate 40: Habit, branches and leaf of *Nauclea latifolia*

12.41 *Parinari macrophylla*

Synonyms: *Neocarya macrophylla*[1]

Family: Chrysobalanaceae[1]

English designation: Gingerbread pulm[1]

Regional designation in Mandinka: unknown

Distribution: *Parinari macrophylla* is distributed from the coastal savannahs of Senegal to the woody savannahs of Mali, Niger and northern Nigeria[1].

Site requirements: The species grows in fringing forests and forest edges of Sudanese and Guinean lowlands. It prefers sandy soils[1].

Description: *Parinari macrophylla* is a shrub which can reach a maximum height of about 8 m. Its crown is open and the breaches are very twisted. The bark is fissured or rough, thick and brittle, blackish and exhibits a red slash. The stems are russet-brown and very pubescent. The leaves are alternate, ovate or elliptic, 10-25 cm long and 5-15 cm across, coriaceous and downy beneath. The inflorescence appears as an erect, terminal raceme which is up to 30 cm long and pubescent. The flowers are white, 12-20 mm in diameter and exhibit 5 petals. The fruit is an ellipsoid, glabrouse, yellowish-brown drupe which is 4-5 cm long and 2.5-3.5 cm across. The thick fruit pulp contains one hard stone[1].

Uses: The fruit pulp and the stone of *Parinari macrophylla* are eatable. The timber is hard and dark brown. It is very suitable for constructions and the manufacture of boats. In local medicine, the crushed roods are especially applied to heal circumcision wounds[1].

[1] ARBONNIER (2004, p. 251)

Plate 41: Habit, branches, fruits and leaf of *Parinari macrophylla*

13.42 *Persea americana*

Synonyms: *Laurus persea, Persea drymifolia, Persea gratissima, Persea nubigena, Persea persea*[1]

Family: Lauraceae[1]

English designation: Avocado[1]

Regional designation in Mandinka: Avocado[2]

Distribution: The avocado is native to southern Mexico. It is nowadays distributed in all parts of the tropics with suitable environmental conditions[1].

Site requirements: *Persea americana* prefers red clay, sand, volcanic loam, lateritic soils or limestone soils[1].

Description: The species grows as an erect tree which can reach a maximum height of 18 m. The trunk is short and the first branches are usually located close to the ground. The leaves are alternate, dark-green and glossy on the upper surface, whitish on the underside, variable in shape (lanceolate, elliptic, oval, ovate or obovate) and 7.5-40 cm long and 4-20 cm across. The small flowers are pale-green or yellow-green and borne profusely in racemes near the branch tips. They lack petals but have 2 whorls of 3 perianth lobes which are more or less pubescent. The pear-shaped fruit measures 7.5-33 cm x 10-15 cm wide. The single seed is oblate, round, conical or ovoid, hard and heavy, brown and about 4 cm in diameter[1].

Uses: *Persea americana* is especially planted for its famous and frequently exported fruits. Furthermore, the seeds yields a milky fluid which exhibits the taste of almond. They are also used to mark cotton and linen textiles. In local medicine, the leaves are chewed as a remedy for pyorrhoea. The seeds are sometimes cut in pieces, roasted, pulverized and given to overcome diarrhoea and dysentery. In addition, powdered seeds are believed to cure dandruff[1].

[1] Hort.purdue.edu
[2] obtained by interviewing locals

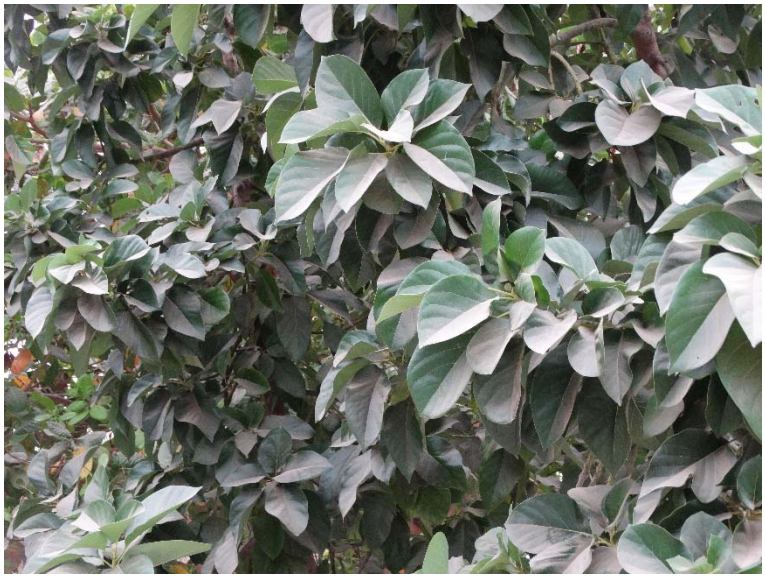

Plate 42: Habit, branches and leaf of *Persea americana*

12.43 *Piliostigma thonnigii*

Synonyms: *Bauchinia thonnigii, Bauchinia abyssinica, Bauchinia pyrrhocarpa*[1]

Family: Caesalpinioidae[2]

English designation: Camel's food[2]

Regional designation in Mandinka: Faro[3]

Distribution: The species occurs all over sub humid Africa, especially in tree savannahs, secondary forests and gallery forests[1].

Site requirements: *Piliostigma thonnigii* prefers cultivated soils but requires over 700 mm of annual rainfall[1].

Description: The species grows as an evergreen, dense shrub or tree which can reach a height of up to 10 m. The bole is twisted and spreading[1]. The bark of *Piliostigma thonnigii* is deep brown, fibrous and exhibits pink slash. The leaves are alternate, 2-ranked, coriaceous, pubescent beneath, bilobed and 7.5-15 cm long and 8-10 cm across. The inflorescence appears as an axillary or terminal panicle which is 10-25 cm long and exhibits ferruginous pubescence. The flowers are shortly pedicellate, cream white, exhibit 5 obovate petals and measure about 2.5-3 cm in diameter. The fruit is a woody, flat pod which is brown, sometimes twisted, cracked, 13-25 cm long and 2.5-5 cm across[2]. It is indehiscent and remains on the tree for a long time[1].

Uses: The inner bark is said to contain a gum swelling in water and is therefore used for caulking. The bark fibres are used to produce ropes and clothes. In local medicine, a decoction of dried leaves is especially applied to treat throat- and toothache[1].

[1] MAYDELL (1986, p. 351)
[2] ARBONNIER (2004, p. 229)
[3] obtained by interviewing locals

Plate 43: Habit, branches and leaf of *Piliostigma thonnigii*

12.44 *Prosopis africana*

Synonyms: *Prosopis oblonga, Prosopis lanceolata*[1], *Coulteria africana*[2]

Family: Mimosoideae[2]

English designation: Ironwood[2]

Regional designation in Mandinka: Kembo[3]

Distribution: The species is distributed from Senegal to Ethiopia, especially in the zone between the Sahel and the savanna forests[1].

Site requirements: *Prosopis africana* frequently occurs on fallow land with sandy clay soils[1].

Description: The species grows as a big tree which can reach a height of 20 m. Its bole is straight and measures up to 1.10 m in diameter. The crown is open and exhibits a drooping, pale green foliage. The bark is cracked, rough and grey to blackish in colour. The hard slash is reddish with a thick chocolate-brown rhytidome. The leaves are alternate, bipinnate, glabrous, 7-15 cm long and exhibit 2-4 pairs of opposite pinnae. Each pinnae is compound of 6-12 pairs of leaflets. The leaflets are oblong or lanceolate linear, 1.5-2 cm long and 0.5-0.8 cm across and exhibit an apiculate apex and a rounded base. The inflorescence appears as a dense, solitary spike which is set in the base of a leaf. It is cream-white to yellowish, 4-6 cm long and about 1.5 cm in diameter. The fruit is dark brown to blackish, hard and thick, woody, more or less cylindrical and glossy, 8-15 cm long and 2-3 cm across. It usually persists on the tree for a long time and contains approximately 10 seeds[2].

Uses: The very hard, heavy and durable wood is used to produce several kinds of tools and crafts. It is difficult to saw and cannot be nailed without pre-drilling. Young leaves and shoots are a much sought fodder towards the end of the dry season. In local medicine, the leaves are used for the treatment of head- and toothache as well as for various head ailments[1].

[1] MAYDELL (1986, p. 353-354)
[2] ARBONNIER (2004, p. 394)
[3] obtained by interviewing locals

Plate 44: Habit, branches and leaf of *Prosopis africana*

12.45 *Psidium guajava*

Synonyms: No synonyms

Family: Myrtaceae[1]

English designation: Guava[1]

Regional designation in Mandinka: Biabo[2]

Distribution: *Psidium guajava* is native to Brazil. In Africa, the species is distributed from Senegal to Cameroon[1].

Site requirements: The species is a fruit tree and therefore planted on any type of soil. In zones where average rainfall is less than 1000 mm, it prefers moist areas or near lowlands[1].

Description: *Psidium guajava* grows as a small shrub which just reaches a height of about 3-4 m. Its bole is twisted and its crown open. The bark is smooth, greyish, scaly, peeling off in thin grey to brown irregular scales and exhibits a pinkish slash. The stems are pubescent and more or less quadrangular and ripped. The leaves are opposite, sometimes sessile, 5-10 cm long and 3-8 cm across, pubescent above, more or less glaucous beneath, ovate or oblong and rounded at the base. The inflorescence appears as a solitary flower or as a 2-3-flowered cymne which is set in the base of a leaf. The flowers are pedicellate and about 2.5 cm in diameter. They exhibit a 4-lobed calyx, a white 4-petalled corolla and many yellow and white stamens. The fruit of *Psidium guajava* is globose or pear-shaped, smooth or rough, fleshy, 6-10 cm long and 3-5 cm across and yellowish when ripe. It contains a great number of hard, more or less flat, small seeds embedded in a yellowish-white to dark salmon pink flesh[1].

Uses: The species is especially planted for its fruits and as a shadow-tree. The fruits are rich in vitamin C and used in local medicine to treat digestive disorders[1].

[1] ARBONNIER (2004, p. 423)
[2] obtained by interviewing locals

Plate 45: Habit, branches and leaf of *Psidium guajava*

12.46 *Pterocarpus erinaceus*

Synonyms: *Pterocarpus angolensis, Pterocarpus echinatus*[1]

Family: Fabaceae[2]

English designation: Senegal rosewood tree[2]

Regional designation in Mandinka: Keno[3]

Distribution: The species is distributed from Senegal to Gabon, Chad, Benin, Togo, Nigeria, Cameroon, The Central African Republic and Sudan[1].

Site requirements: *Pterocarpus erinaceus* grows on shallow and gravelly soils in areas with an annual rainfall of 700-1200 mm. It can occur individually, in groups or in open stands[1].

Description: The species is a tree with a maximum height of 8-12 m. The bole is straight and cylindrical and can reach a diameter of up to 1 m. The crown is rounded and open. The bark of *Pterocarpus erinaceus* is blackish, cracked and exudes a reddish translucent resin which becomes hard quickly. Its stems are densely pubescent but become glabrous and grey when older. The leaves are alternate, imparipinnate and exhibit 3-5 pairs of alternate leaflets. The leaflets are finely pubescent, 6-11 cm long and 3-6 cm across, ovate to elliptic and rounded at the base. The inflorescence appears as a 10-20 cm long lax panicle which is set at the end of a branch. The flowers are golden-yellow, 10-12 mm long, asymmetrical, fragrant, pedicellate and exhibit crinkled petals and a pubescent calyx with 5 short teeth. The fruit is a flat samara which is 4-7 cm in diameter, surrounded by a membranous, circular wing, more or less pleated and persisting on the tree for a long time[2].

Uses: *Pterocarpus erinaceus* exhibits a yellowish sapwood and a dark brown veined core wood which is heavy and durable. It is especially used to manufacture cabinet works, turnery, mortars, musical instruments, sculptures and tool handles. In local medicine, the bark is applied as a powerful astringent[2].

[1] MAYDELL (1986, p. 361)
[2] ARBONNIER (2004, p. 324)
[3] obtained by interviewing locals

Plate 46: Habit, branches and leaf of *Pterocarpus erinaceus*

12.47 *Rauvolia vomitoria*

Synonyms: No synonyms

Family: Moraceae[1]

English designation: Sandpaper tree[1]

Regional designation in Mandinka: Bantang-Faro[2]

Distribution: The species is distributed from Senegal to Cameroon and Yemen [1].

Site requirements: *Rauvolia vomitoria* grows in Sudanese and Guinean fringing forests, especially on well drained soils[1].

Description: The species occurs as a shrub or a tree with a maximum height of up to 20 m. The bark is smooth and grey and exhibits a green slash which sometimes exudes a translucent, more or less liquid sap. The stems are more or less thick, scabrid, greyish and pubescent. The leaves of *Rauvolia vomitoria* are alternate, almost 2-ranked, 7-22 cm long and 3.5-7.5 cm across, entire or more or less denticulate, coriaceous, elliptic, ovate and scabrid on both sides. The infructescence appears solitary or in pairs under the axil of the leaves, usually on old, more or less leafless branches. The fruits are globose or obovoid, pedunculated, 1-2 cm in diameter, pubescent, scabrid and red or purplish when ripe[1].

Uses: The rough leaves of *Rauvolia vomitoria* are used to polish wooden and metal objects[1].

[1] ARBONNIER (2004, p. 403)
[2] obtained by interviewing locals

Plate 47: Habit, branches and leaf of *Rauvolia vomitoria*

12.48 *Sclerocarya birrea*

Synonyms: *Pouparita birrea*[1], Spondias birrea[2]

Family: Anacardiaceae[2]

English designation: No English designation known

Regional designation in Mandinka: Salumplom[3]

Distribution: The species is a tree of the Sahel and open, dry savanna ecosystems with rather wide distribution from Senegal to East Africa and Sudan[1].

Site requirements: *Sclerocarya birrea* grows on sandy or stony soils and on lateritic crusts[1].

Description: The species is a tree with a maximum height of 12 m and a trunk diameter of 0.8 m. The crown is relatively dense and rounded. The bark is scaly grey, more or less silvery and exhibits fibrous, spongy, reddish slash. The stems are brown-grey and pubescent when young. The leaves are alternate, imparipinnate, divergent, distributed at the end of very thick stems, up to 40 cm long and exhibit 10-15 pairs of opposite or subopposite leaflets. *Sclerocarya birrea* is a dioecious species. The female flowers are pedicellate, reddish or greenish and about 7 mm in diameter. The male flowers are about 5 mm in diameter and exhibit 4 pink or greenish petals. The fruit is a thick-skinned, globose drupe which is 3-3.5 cm long, glabrous, yellow when ripe and contains a thick stone[2].

Uses: The wood of *Sclerocarya birrea* is used for the manufacture of mortars, bowls and differnt local crafts. The fruit pulp of the species has a pleasant acid taste. It is used for the preparation of a beverage or can be eaten fresh. In local medicine, a bark decoction is used to treat dysentery, toothache and infections[1].

[1] MAYDELL (1986, p. 369)
[2] ARBONNIER (2004, p. 153)
[3] obtained by interviewing locals

Plate 48: Leaves and fruits of *Sclerocarya birrea*

12.49 *Spondias mombin*

Synonyms: *Spondias lutea, Spondias oghihee*[1]

Family: Anacardiaceae[1]

English designation: Hog plum, Ashanti plum[1]

Regional designation in Mandinka: Ninkon[2]

Distribution: The species is native to America but is nowadays distributed in tropical regions all over the world[1].

Site requirements: In Africa, *Spondias mombin* occurs in Guinean forest-bordering savannahs or Sudanese savannahs. Furthermore, it is frequently cultivated in villages on any type of soil[1].

Description: The species grows as a tree and can reach a maximum height of 15 m. Its trunk is up to 50 cm in diameter and exhibits small buttresses around the foot of older trees. The crown is hemispherical and relatively open. The bark is deeply marked with longitudinal fissures and thick rough crests, pale brown and exhibits red slash with white stripes. The stems are glabrous or hairy and silver-grey in colour. The leaves of *Spondias mombin* are alternate, imparipinnate, rather clustered at the end of stems, up to 60 cm long and exhibit 5-8 alternate or opposite pairs of leaflets. Those leaflets are oblong-elliptic, asymmetrical, 7-13 cm long and 3.5-5 cm across, glabrous and rounded at the base. The inflorescence appears as a 10-20 cm long, lax terminal panicle. The flowers are red to white, 3-5 mm in diameter and exhibit a 5-lobed calyx and a 5-petalled corolla. The fruit is an elliptic or ovate drupe which is 25-35 mm long and 15-20 mm across, yellow when ripe and with a more or less acidulous pulp[1].

Uses: *Spondias mombin* is frequently planted for its sweet and tasty fruits. They are eaten fresh or used for the production of drinks, alcohols or jams. In traditional medicine, especially the leaves are applied to treat high blood preassure[1].

[1] ARBONNIER (2004, p. 154)
[2] obtained by interviewing locals

Plate 49: Habit in dry season, flowers and young fruits of *Spondias mombin*

12.50 *Tectona grandis*

Synonyms: No synonyms

Family: Verbenaceae[1]

English designation: Teak[1]

Regional designation in Mandinka: Gmelina[2]

Distribution: The species is native to south-east Asia. In Africa, it is distributed from Senegal to Cameroon, tropical Africa and Madagascar[1].

Site requirements: *Tectona grandis* is a pantropical species which is extensively used in forestry plantations in areas where the dry season ranges from 3 to 7 months with a minimal rainfall of 750 mm per year. It grows at different types of sites but prefers well drained soils[1].

Description: The species grows as a big tree which can reach a height of 50 m under optimal conditions. Its bole, which is up to 1.5 m in diameter, is straight in pure stands but often branching low down when solitary. The crown is open and rounded. The bark is fissured and finely scaly, grey to pale brown and exhibits a fibrous slash which turns sooty-brown outside and orange beneath. The stems are pubescent, rectangular in cross section and pale brown. The leaves are opposite, pubescent, scabrid and more or less russet beneath, broadly elliptic or suborbicular, 25-60 cm long and 20-30 cm across. The inflorescence appears as a terminal corymb with opposite branches and is about 30-70 cm long. The flowers of *Tectona grandis* are about 5 mm in diameter, white and exhibit a pubescent calyx and a 6-petalled corolla. The fruit is globose, hard and hairy, 1-1.5 cm in diameter and yellowish to brown when ripe[1].

Uses: *Tectona grandis* offers a very valuable wood. It is suitable for shipbuilding, scaffolding, woodwork and cabinet work and therefore exported all over the world. The young leaves are used as a henna substitute to colour skin, fabrics and pottery[1].

[1] ARBONNIER (2004, p. 509)
[2] obtained by interviewing locals

Plate 50: Habit of a young individual and leaves of *Tectona grandis*

12.51 *Terminalia macroptera*

Synonyms: *Terminalia chevalieri, Terminalia suberosa, Terminalia adamauensis, Terminalia elliotii, Terminalia dawei*[1]

Family: Combretaceae[2]

English designation: No English designation known

Regional designation in Mandinka: Wolo[3]

Distribution: *Terminalia macroptera* occurs widespread in Africa but especially from Senegal to Uganda and Cameroon[1].

Site requirements: The species grows on fresh soils, also with periodic flooding, on riverbanks and waterholes in depressions with a high ground water table. The annual rainfall needs to be between 700-1500 mm. It can also often be found at termite mounds and on compact soils[1].

Description: *Terminalia macroptera* is a tree which can reach a height of 15 m under optimal conditions. Its short, squad bole can reach a diameter of 1 m. The crown is spreading and open. The bark is deeply cracked, brown to blackish and exhibits slash which is brown above and more or less orange beneath. The stems are glabrous, grey-brown and turn corky when ageing. The leaves of *Terminalia macroptera* are alternate, spirally arranged, 15-35 cm long and 6-16 cm across, usually sub sessile, glabrous and narrowly ovate to elliptic. The inflorescence appears as an axially raceme which is spike-like, 8-20 cm long and glabrous to pubescent. The flowers are apetalous, yellowish-white in colour and exhibit a 5-lobed calyx. The fruit is an oblong to oblong- elliptic samara which is glabrous, 8-10 cm long and 2.5-4 cm across. It exhibits a single wing around the seed which turns brown when ripe and persists on the tree for a long time[2].

Uses: The wood of this species is hard, light brown or yellowish, coarse, very durable and termite-resistant. It is suitable for the manufacture of carts, boats and tools. Furthermore, it yields an excellent charcoal. The leaves are used to obtain a black, shiny textile colour. Extracts of the roots are used in human and veterinary medicine. A leaf decoction is applied to treat hepatitis, ringworm and skin diseases. The young shoots are said to reduce headache, fever and depressions[1].

[1] MAYDELL (1986, p. 393)
[2] ARBONNIER (2004, p. 276)
[3] obtained by interviewing locals

Plate 51: Habit, branches and leaf of *Terminalia macroptera*

12.52 *Vernonia amygdalina*

Synonyms: *Vernonia senegalensis*[1]

Family: Asteraceae[1]

English designation: No English designation known

Regional designation in Mandinka: Doctor[2]

Distribution: *Vernonia amygdalina* occurs all over tropical Africa, especially from Mali to Cameroon. It is often planted[1].

Site requirements: The species grows in Guinean and Sudanese forests and savannahs, fallow land at forest edges or along river banks, usually on drained and moist soils[1].

Description: *Vernonia amygdalina* is a 1-5 m high shrub with spreading, upright branches. The bark is grey, more or less scaly, lenticellate and exhibits slash which is brown above and greenish-yellow beneath. The stems are pubescent with brown-grey hairs. The leaves of *Vernonia amygdalina* are alternate, 10-18 cm long and 3-7 cm across, more or less pubescent and narrowly ovate or obovate. The inflorescence appears as a terminal corymb which is 8-12 cm across and composed of a great number of flowers. The flowers are white to pink and 5-6 mm in diameter. The fruit is a capitulum of achenes which are finely pubescent, glandular and topped by a beard-like white or russet pappus[1].

Uses: The roots are very powerful and used for abortions and to treat venereal diseases and colds. The leaves are bitter and used as an additive in local beers and as food for convalescence. Furthermore, crushed leaves yield a good soap[1].

[1] ARBONNIER (2004, p. 186)
[2] obtained by interviewing locals

Plate 52: Habit, inflorescence and leaf of *Vernonia amygdalina*

12.53 *Ziziphus mauritania*

Synonyms: *Ziziphus jujuba, Ziziphus orthacantha*[1]

Family: Rhamnaceae[2]

English designation: Jujube tree, Indian jujube[2]

Regional designation in Mandinka: Tomborongo[3]

Distribution: *Ziziphus mauritania* is native to South and Central Asia but is nowadays widely distributed in semiarid Africa and the Mediterranean region. It frequently occurs in the Sahel[1].

Site requirements: The species tolerates great heat and an annual rainfall of only 150-500 mm. It has no specific soil requirements and grows on sand, gravel, fields, riverbanks and waterholes[1].

Description: *Ziziphus mauritania* grows as a spiny scandent shrub or small tree which can reach a height of 4-5 m. Its crown is rounded with drooping branches. The bark is grey to brown, barely fissured and exhibits pink to reddish slash. The stems are tomentose, whitish and characteristically zigzagging. The thorns, which are about 1.8 cm long, are set in pairs in the axils of a leaf. The leaves of *Ziziphus mauritania* are alternate, elliptic, ovate or suborbicular, 1.3-7 cm long and 1-4 cm across, blade green and shiny above and greyish and pubescent beneath. The inflorescence appears as a tomentose or woolly fascicle which is 2-4 cm across and composed of 3-8 flowers. The flowers are pedicellate, yellowish, 3-4 mm in diameter and exhibit a 5-toothed calyx and a 5-petalled corolla. The fruit is a globose drupe which is 1.2-1.5 cm in diameter, brownish or purple when ripe and with a large stone embedded in a whitish and more or less floury pulp[2].

Uses: The fruits of this species are eatable. The fruit value of the fruit pulp is close to that of bananas and of special importance because it can be made available in times of food scarcity. The dried fruit pulp is often pounded and pressed into small cakes or used as a floury meal. It contains much vitamin A and C. In addition, young leaves are added as a vegetable to couscous and soups. In local medicine, bark decoctions are used to treat colics, venereal diseases and intestinal infections[1].

[1] MAYDELL (1986, p. 402)
[2] ARBONNIER (2004, p. 440)
[3] obtained by interviewing locals

Plate 53: Habit, branches, leaves and fruits of *Ziziphus mauritania*

Glossary

The subsequent glossary is based on the book "*Woody Plants of Western African Forests: A Guide to the Forest Trees, Shrubs and Lianas from Senegal to Ghana*", composed by HOWTHORNE et al. (2000).

Term	**Definition**
Acuminate	Apex of leaf tapering very gradually at tip.
Alternate	Leaves arranged one by node, alternate *leaflets* occur singly along the *rachis* of compound leaves.
Apetalous	Without *petals*.
Axis	Main stem or channel from which braches or other parts arise.
Bipinnate	Leaves with two orders of branching, the first order being *pinnate*, usually with small leaflets.
Blade	The flat, usually green photosynthetic part of a leaf.
Bract	Leaf-like structure at nodes of inflorescence.
Corolla	Petals as a whole, especially when they are united or form a tube.
Corymb	A flat inflorescence with different sizes of flower pedicels.
Cyme	A branched Inflorescence without main axis. At the basis of the flower, subsequent flowers develop from braches below it.
Deciduouse	All leafs of the plant falling in one season, mostly applying to certain tree species.
Denticulate	With small triangular teeth.
Drupe	Fruit with a central stone, usually one-seeded. Surrounded by a fleshy part.
Fascicle	Cluster or bundle of flowers arising from the same spot.
Ferruginous	Rust- coloured.
Fibrous	With obvious fibres.
Fissured	With elongated deep cracks or splits.
Glabrous	Hairless.
Glands	Permanent multicellular structure on leaf, distinct from surrounding tissue of various types.
Glandular	Covered with secretory or excretory *glands*.

Glaucous Dusty, non-shiny surface.

Globose Almost spherical, ignoring fine details.

Glutinous Slightly sticky to touch, like a thick, viscous liquid.

Imparipinnate *Pinnate* leaf with leaflets that are not all paired (leaflets either *alternate* or opposite except for a solitary terminal leaflet).

Indehiscent Not splitting open at maturity.

Inflorescence Branched set of two or more, often many flowers.

Kernel Inner, soft part of a nut or a fruit stone.

Lanceolate Lance-sharped.

Leaflet A simple leaf which is part of a compound leaf.

Monoecious Male and female flowers are separated but located at the same plant.

Oblong 1.5 - 2 times as long as wide.

Opaque Murky, not possible to see through.

Palmate Arranged like fingers on a hand, with more than three (often 5) lines radiating from main axis.

Panicle A branched *inflorescence* with more than one flower per branch.

Pappus Fine hairs next to the apex of the fruit.

Paripinnate *Pinnate* with opposite leaves, always in pairs.

Pedicel Stalk of a single flower or fruit.

Pedicellate With a *pedicel*.

Peduncle The common stalk of an *inflorescence*, below the first branches, leading to more than one flower.

Perianth The non-reproductive part of the flower, and structure that forms an envelope surrounding the sexual organs, consisting of *sepals* and the corolla *petals*.

Petal One of the members of the inner ring of *perianth,* especially if brightly coloured.

Petiole To the stem.

Petiolule Stalk attaching a leaflet to the axis of a compound leaf.

Pinnate Compound leaf with leaflets attached to only one axis.

Pod Dry, usually flattened fruit with seeds in one line.

Prickle Sharp, conical or pyramid-like, broad based outgrowth from epidermis, mostly easy to remove.

Pubescent Hairy, but neither densely, nor roughly.

Raceme *Inflorescence* without a terminal flower. The lowest flowers are usually more developed.

Rachis Central axis of a *pinnate* leaf after first leaflet(s).

Rectangular Box-like, 4-sided, longer than wide.

Reticulate Arranged like strings in a net.

Rugose With a creased surface.

Samara Simple dry fruit, *indehiscent.*

Sarmentose With long *stolons*.

Scabrid Rough to touch, like sand paper.

Sepal One of the lobes of the outer parts of the *perianth,* especially if leaf like.

Spike Unbranched *inflorescence*, individual flowers without stalks.

Spiny Sharp, needle-like projection from below bark.

Stipular Leaf-like.

Stolon An aerial shoot which roots at the nodes.

Suborbicular Nearly circular or orblike.

Subsessile Having a very small stalk.

Tepal One of the segments of the *parianth*, used when the *parianth* is not differentiated into *sepals* and *petals.*

Translucent Letting light through, but murky and not transparent.

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