Trees, shrubs and lianas of West African dry zones

Michel Arbonnier

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Preface

Our French-speaking colleagues have already had the pleasure of using this book. A first version was prepared and released in 2000; an expanded version was subsequently compiled and made available in 2002. I welcomed those versions, recognising the broad expertise put into their preparation and the various improvements and additions from which the expanded version benefited. They were indeed of great relevance for those professionals involved in studying, characterising and using tree and shrub species in the Sudano-Sahelian region in research, conservation and development work.

Now English-speaking professionals studying or active in conservation and development activities in these regions have their own version of Trees, shrubs and lianas of West African dry zones. *I am confident that they will join me in welcoming the new book and commending the authors and editors of this important new contribution to the conservation, management and development of dryland natural resources in Sudano-Sahelian countries, no matter what language they are familiar with. This document significantly expands and supports our knowledge of and familiarity with the steppes, savannahs and woodlands of Sudano-Sahelian areas of Africa. The authors have provided ample scientific information on the species, their distribution, their uses and their role in the development and conservation of the ecosystems they belong to. A set of excellent pictures succeeds in setting these species in the context of their landscapes and natural biophysical environment.*

We have here a very useful tool, which will ensure a better understanding of Sudano-Sahelian ecosystems and landscapes. Its contribution is essential at a time when both the conservation of the biological diversity of drylands and the control of land degradation in these areas are rapidly growing in priority and importance. The expanded programme on forest biological diversity under the Convention on Biological Diversity, in particular the specific programme on Mediterranean and dry tropical and subtropical regions, and the implementation of the UN Convention to Combat Desertification, now further supported by the GEF's Operational Programme 15 on Land Degradation, will call for increasing expertise on the drylands and in particular on development and conservation issues in Sudano-Sahelian areas. These tasks will undoubtedly benefit considerably from this work, as it will surely contribute to increasing knowledge of and expertise on Sudano-Sahelian drylands.

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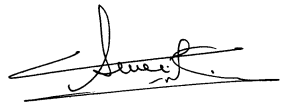

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I should first like to thank the members of the Scientific Advisory Committee, who showed considerable interest in this work, checked certain determinations and gave us their comments, corrections and suggestions:
– Professor Laurent Aké Assi, Professor of Botany at the University of Abidjan, Côte d'Ivoire;
– Dr Paul Bamps, Honorary Head of Department at the Jardin Botanique National de Belgique;
– Dr André Gaston, Doctor of Ecology, Doctor of Science, research coordinator at the Institut National Agronomique Paris-Grignon, France;
– Professor Sita Guinko, Professor of Botany and Plant Biology, Vice-Chancellor of the University of Ougadougou, Burkina Faso;
– Dr Bernard Roussel, tutor at the Ethnobiology-Biogeography Laboratory, Muséum National d'Histoire Naturelle de Paris, France.

This book would not be complete without the field information given to me, which guided my surveys and enabled me to identify sites and collect a large number of species. I would particularly like to thank the following people, in chronological order:
– in Senegal, Mr Boubou Bathily, who encouraged me to make considerable use of his botanical knowledge, while he was head of the reforestation project in the central East of the country. His observations and comments helped me to recognize numerous species;
– in Cameroon, Dr Satabie, Director of the National Herbarium, and Dr Gaston Achoundong and his family, for their hospitality and the unforgettable discussions we had during our surveys in the bushlands of northern Cameroon. Mr Seny Bourcar, Director of the Institut de Recherche Agronomique's Maroua Centre, also encouraged and facilitated our work;
– in Burkina, Messrs Ouétian Bognounou, ethnobotanist, Louis Sawadogo, researcher, and particularly Youssouf Outtara, botanist-technician at the Institut de l'Environnement (INERA), as well as Mr Adama Diallo, botanist at the Centre National des Semences Forestières (CNSF), Dr Sié Kambou, researcher at CNSF, for his drawings of flowers, and Ms Hortense Bakouan for her drawings of fruits, for the determination keys;
– in Mali, Mr Abdoulaye Sow, consultant botanist in Bamako;
– in Niger, Mr Bonaventure Somé, meteorologist at the regional agro-hydro-meteorological monitoring centre Agrhymet, who was kind enough to provide temperature and rainfall figures for the Sahel.

Lastly, I am particularly grateful to some of my CIRAD colleagues, including:
– Philippe Daget, for his advice on pastoralism and the documents he found for me;
– Christian Didier, for the information he provided on fruit trees;
– Pascal Danthu and Dominique Louppe, for finding and providing me with photos;
– François Besse, who devoted a good deal of time and energy to preparing and following the book's publication.

This work is a translation of the second edition of the original French book *Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest*, improved by the comments made by readers of the first edition, in particular Professor Laurent Aké Assi, who checked the determinations of certain herbaria. I should also like to thank the following:
– Mr Michel Baumer for his observations concerning the growth habit of certain species and the map of climatic sectors in tropical Africa;
– Dr A. Thiombiano, who noticed that the illustrations of *Terminalia glaucescens* and *T. laxiflora* were inverted;
– Mr Marc Pignal, for facilitating my studies the herbarium held by the Muséum National d'Histoire Naturelle in Paris.

We should particularly like to thank:
– Anouchka Golay, Diego Gonzalez and Sylvie Margueritat, who translated the major part of the descriptions of the different species, with the support of our colleagues Jean César, Pierre Poilecot and Bernard Toutain;
– Helen Burford (CIRAD), who translated the introductory texts and glossaries;
– Alexandra Wortley (University of Oxford), PhD, who edited the English translation;
– Laurence Rodriguez (CIRAD), who was in charge of page make-up, and Monique Loubet (CIRAD), who read the proofs.

Description of the guide

This practical guide to identifying the trees, shrubs and lianas of the dry zones of West Africa is a translation of the first popular work available in French on the subject. It was governed by several basic principles in terms of content and form, with the aims of: responding to the needs of amateur botanists, agronomists, pastoralists or nature lovers with a good sense of observation; using common botanical or technical terms to facilitate understanding of the descriptions; presenting a brief, up-to-date summary of how each species is used; and offering a concise, practical guide suitable for use in the field, which can be consulted without the use of a microscope.

To this end, around half of the guide is given over to illustrations of the species described. Moreover, there are four types of illustrated, simple keys—leaves, flowers, fruit and thorns or spines—, a few keys relating to plant families, and comparative tables for certain genera, such as *Ficus* or *Terminalia*, to facilitate species identification.

Current uses in agropastoralism (fodder, live hedges…), traditional pharmacopoeia (either human or veterinary), or for industrial, domestic (construction, carpentry, tool handles, etc.) or culinary (packaging, gum) purposes are also listed.

Limitations of the guide

The first rule is: one page per species. This was an arbitrary decision. Half the page is given over to the description and the other outside half to illustrations, which are thus the first thing the reader sees on thumbing through the book.

This choice meant that I had to be concise when describing the plant and indicating its uses, particularly by using abbreviations and pictograms. Some species are very common or highly economically important, and it would have been logical to give more information about them. In fact, those species have mostly already been described in many works and have also been studied in depth relatively recently. It would therefore have been tedious to provide a comprehensive description. However, I have made a few exceptions for fruit trees (mango and citrus species) that have undergone genetic selection—for fruit size and quality, growth or disease resistance—and which have been distributed in rural areas in clonal form for several decades. Such species are described on a double page. On the other hand, there are some species that have rarely been used traditionally, if at all, and in this case the description is shorter and is supplemented with illustrations.

Determination keys

The determination keys are intended for two types of users: inexperienced and experienced botanists.

The four types of keys given at the start of the book were drawn up for inexperienced users. To facilitate identification, the simplified illustrations are sufficiently explicit in themselves.

Experienced botanists can refer to the keys or to the tables in the text. These are either before the first species in the genus concerned, such as *Combretum*, *Ficus* or *Lannea*, or within the text relating to the species of the genus, such as *Cordia*, *Grewia* or *Vernonia*.

Choice of species

The choice of the species covered was governed by several criteria. Rare or highly localized species were generally excluded. For certain Guinean species found in the gallery forests or coastal savannahs, the choice was more difficult and may seem arbitrary. In general, species were chosen if they were relatively common and widespread, and have frequently been used traditionally. Lastly, a few of the most common parasitic plant species (Loranthaceae) were added.

Descriptions of species

English names and local names

It was impossible to give an English name for each plant, since they do not always have one.

Similarly, I decided not to list local names for each species, for practical reasons:
– the limitations of the book, which comprises descriptions of over 350 species plus the four determination keys, a glossary of botanical terms and a lexicon of pharmacopoeia terms;
– economy. It will be easier to produce a leaflet in black and white listing the local names in each region, rather than one in colour, which would also be much more costly. Thus readers in Senegal will not have to buy the many pages listing the local names used in Cameroon, and vice versa;
– the lack of available information, since the glossaries available in the most commonly spoken languages are very sketchy, and in some cases do not even exist;
– the difficulty of transcribing vernacular languages correctly. This would mean calling upon a large number of linguists and using specific typographic characters, as many of the transcriptions available are incomplete and give little information on the phonetics of each name;

– the complexity of certain languages as a result of their broad vocabulary. For a given species, there may be a different name for the tree, its leaves, its flowers, its fruits and even each part of its fruits (flesh or seed).

Synonymies

Most of the synonymies were taken from *Flora of Tropical West Africa*, by Hutchinson and Dalziel (1954–58) and *La pharmacopée sénégalaise traditionnelle*, by Kerharo and Adam (1974). Updates were drawn from two works, *Enumération des plantes à fleurs d'Afrique tropicale*, by Lebrun and Stork (1991–97) and *The Plant Book, a Portable Dictionary of the Vascular Plants*, by Mabberley (1997). However, some names were deliberately not updated, so as not to confuse botanists who are used to the old names, since new names do not provide any additional botanical information.

Only those synonymies that correspond to the geographical zone in question are quoted. For conciseness, I did not feel it was worth mentioning names corresponding to species from eastern or southern Africa or from the rainforests of central Africa.

For instance, the botanical classification chosen for the species *Loeseneriella africana* is the one given by Lebrun and Stork (1992). It is therefore classed among the Hippocrateaceae, although it has also been classed in the family Celastraceae (Mabberley, 1997).

The botanical names I did not change include:
– *Combretum fragans* and *Terminalia glaucescens* (Combretaceae), which became *Combretum adenogonium* and *Terminalia schimperiana* in 1986, but which botanists continue to refer to by their old names;
– *Malacantha alnifolia* (Sapotaceae), for which Lebrun prefers *Pouteria alnifolia*. Like Mabberley, I think the genus *Pouteria* applies to American species, while *Malacantha* is still valid for those from Africa.

On the other hand, I followed Lebrun and Stork's and Mabberley's recommendations in restoring *Flueggea virosa* (Euphorbiaceae) to its original name. The genus *Securinega* is still valid for *Securinega flexuosa*, which originated in the Solomon Islands.

Choice of presentation

All the descriptions follow the same sequence: plant growth habit, bark—external and internal appearance and exudate, latex or resin, if relevant—, branches, thorns, stipules, leaves, petioles, venation, inflorescences, flowers, infructescences, fruits and lastly the seeds, if they are unusual or are of particular relevance in describing the species.

Growth habit, crown shape. The habit described corresponds to the natural shape of the trunk and crown. This depends on two main factors: the environment and how the species is used.

In open natural environments—open savannah, parks or orchards, roadsides, etc.—, trees are relatively far apart. There is no competition for light, and they tend to develop a broad crown and short trunk. Conversely, in closed environments—gallery forests or woodland—where there is considerable competition with neighbouring trees, trees tend to develop longer trunks in an attempt to capture light and gain a place in the canopy formed by the surrounding trees. Crown spread is hindered by neighbouring crowns. In other instances, trees may develop in a forest but become isolated when the forest is felled for planting, in which case they retain their slender growth habit but the crown develops and gradually expands.

In Africa, and particularly in the dry zones covered in this guide, trees are subject to several types of attack, from man, animals and bush fires. Tree shape is often substantially modified as a result of pruning and of the management method chosen.

For instance, the candle-like growth habit of backyard baobabs, which are thinned for most of the year, differs considerably from that of the impressive baobabs found in village squares, which are intended to provide fruit and shade. The same goes for the red-flowering silk-cotton trees *(Bombax)*, which generally grow straight and tall in forests but which look more like large candelabras, with short trunks, when grown near villages, since they are cut, either for their leaves, which are fed to livestock, or for their flowers, which are used as a condiment.

This deformed growth habit thus concerns all the fodder species cut to feed livestock, but also trees planted in avenues or near houses, which are often pollarded to ensure denser shade and with a view to using the branches as construction posts or fence posts.

Bark. The bark descriptions correspond to non-altered trees that have not been affected by bush fires (blackened, burnt and sometimes split bark) or repeated stripping for traditional medicine (which causes formation of peripheral cankers or calluses), or occasional pruning with a machete, as is the case with roadside trees in towns. On such trees, we advise observing bark high up in the tree, which will not have suffered either fire or pruning damage.

Flowering and fruiting

The section "Flowering and fruiting" primarily concerns flowering, which is described according to field observations and information drawn from the bibliography or from herbaria.

Flowering. This section gives the flowering period, which cannot accurately be pinpointed in terms of the months concerned. In particular, the numerous field observations available show that the flowering period of a given species can vary significantly, as it is affected by numerous factors:
– the geographical location of the plant, since the study zone ranges from the Atlantic coast (Mauritania and Senegal) to Lake Chad (west-east gradient), and covers an annual isohyet range of 400 to 1 500 mm (north-south gradient). Flowering dates are often staggered between the East and the West, even if the sites are on the same isohyet;
– interannual rainfall variability at a given site: early or late flowering as a result of temporal and spatial variations in the north-south progression of the humid tropical front. Moreover, we observed that in unexpected droughts during the rainy season, some trees flowered again, outside their normal flowering period. This type of exceptional flowering, which rarely results in fruit, was not taken into account;
– topography and soil type. For instance, water availability varies considerably depending on whether a tree is on a rocky slope or a loamy lowland site.

This guide pinpoints flowering in relation to the four seasons recognised by the inhabitants of the study zone. The respective lengths of these periods vary from one region to another:
– the first part of the dry season, or the cold dry season, in which the nights gradually become cold or at least cool;
– the second part of the dry season, or the hot dry season, in which both diurnal and nocturnal temperatures are high;
– the rainy season, corresponding to the first rains, when wet monsoon episodes alternate with dry periods, characterized by high air and soil humidity and the lowest diurnal temperatures of the year;
– a transitional period between the rainy and dry seasons, which in fact corresponds to the end of the rainy season.

Fruiting. The fruiting period is not systematically described. It is given only for fig trees, in which flowering is difficult to observe, or if it occurs at a surprising, characteristic time, for instance when the tree has been thinned, out of season, or if the fruits ripen before flowering has finished. However, a characteristic fruit colour or shape can enable rapid identification of the plant, and this information is included in the description of the growth habit.

Leaves. Some plants, such as Euphorbiaceae, only have leaves for a short time each year, in which case this unusual characteristic is mentioned before the section on "Flowering".

Uses

There are two main reasons why I chose to indicate how the different parts of each plant are used. The first was to make the guide more interesting for non-specialists in botany and to highlight the local knowledge that exists in Africa. The second was to stress that some species that are apparently of no particular interest can be used for rural development, notably by preserving or cultivating them.

Five types of uses are covered, each introduced by an icon:
– ✚ proven uses in pharmacopoeia (chemically-tested therapeutic properties);
– ✜ traditional pharmacopoeia (identified medicinal uses, untested chemical properties);
– ❋ food and culinary uses;
– Ψ agricultural, pastoral and veterinary uses;
– ❑ domestic, craft and industrial uses.

These uses are listed without distinguishing between either the methods or the regions involved, or the ethnic groups concerned. This was primarily to ensure conciseness, but also due to the fact that the methods relating to a given use often vary considerably from one region to another and that this information was not always given in the works I used as sources for this guide.

Pharmacopoeia

From the strict point of view of modern medicine, the information given obviously has to be used with caution. However, some species, and how they are used, have been the object of thorough scientific studies and precise chemical and physiological analyses (in vitro or in vivo pharmacodynamics). These proven pharmacological uses are classed under the icon ✚. Other pharmacological uses are classed under ✜, and will undoubtedly be good starting points for future research.

The different uses are therefore listed without judging their scientific and pharmacological merits (efficacy of the plant in treating a given disease) or their therapeutic effect (psychological effect, cultural function, religion, witchcraft, etc.). For further information, please refer to books specifically on pharmacology.

Medical treatments depend upon how nature, the body and disease are perceived, which varies substantially from one society to another and often differs significantly from the prevailing concepts of modern Western medicine (Roussel, 1997, pers. comm.). For instance, in most of the therapeutic practices that make up what we call traditional medicine, witchcraft and religion systematically play a major role and it is not worth trying to distinguish between healthcare and ritual. Likewise, the concept of disease covers psychological, social or metaphysical as well as physiological conditions. Identifying diseases, establishing nomenclature and choosing the corresponding treatments relies on a form of reasoning that is specific to a given cultural situation and is sometimes difficult to transfer elsewhere (Roussel, 1997, pers. comm.).

It is true that symptom-based treatments often follow simple, relatively universal rules, such as the doctrine of signatures, according to which red things are used to treat the blood, bitter things to bring down a fever and yellow things to treat the liver. However, diseases are still generally seen as a sign of divine intervention, enchantment or a curse. Treatments therefore refer to complex cosmological structures and religious contexts that bear no direct relation to the physicochemical properties of the plants used (Roussel, 1997, pers. comm.).

Lastly, the medicinal uses quoted in this guide were drawn from works on fields as diverse as botany (Aubréville, 1950; Irvine, 1961; Berhaut, 1971–79), plant and forest ecology (Thies, 1995) or medical anthropology, ethnology (Adjanohoun et al., 1979; Malgras, 1992; Ehya Ag Sidiyène, 1996) and pharmacology (Kerharo and Adam, 1974; Pousset, 1989; Nacoulma-Ouédraogo, 1996). Some of this work was done some time ago, such as the remarkable compilations produced by Dalziel (1937), while other works are much more recent (Burkill, 1985–95). The wide range of disciplines, and changes in medical and ethnological scientific thinking mean that the data gathered are not always homogeneous and are often difficult to compare. This heterogeneity is clearly reflected in the vocabulary used to refer to diseases and the corresponding treatments. For this reason I felt it necessary to compile a glossary giving the meanings I intended for the medical and pharmacological terms used.

If I have the necessary information, I specify whether treatments are prepared with one or more parts of the plant in question, and whether other ingredients are used in the preparation.

For instance, for *Combretum fragrans*, "**Stems** + **Fruit** Pain" means that a mixture of stems and fruits is used to treat pain. However, "**Roots, Bark** Stomach aches" means that either the roots or the bark are used to treat stomach aches, depending on what the traditional practitioner prescribes. The choice, in this case roots or bark, may also show that the treatment varies depending on the region, season or local traditions. Each part, in isolation, has the same function. Moreover, they may be combined, depending on local practices and the availability of the different parts of the plant.

If other ingredients are used in the preparation—extracts of another plant, palm oil, salt, iron or any other substance—, this is pointed out by $^{+}$. For instance, in the case of *Haematostaphis barteri*, "**Bark** Trypanosomiasis^{+}" indicates that the person who provided the information does not only use bark to treat the disease.

The same goes for other uses: "**Leaves** + **Stems** + **Flowers** Blue dye^{+}" in relation to *Saba comorensis* indicates that it is a combination of leaves, stems and flowers, plus other ingredients, that is used to make blue dye.

Food uses

Uses in the human diet are given for every part of the plant, whether it is used for its fruits—fresh, dried or fermented—, as a cooked, grilled, boiled or raw vegetable, or as a condiment, spice or drink, for all or part of the year. Reference is made to the fact that some plants are only eaten during food shortages. They may also be used to replace other products that are now widely sold, such as salt or sugar, but which are expensive in the region or are temporarily unavailable due to a stock shortage or limited shelf-life.

Agricultural, pastoral and veterinary uses

These uses include:
– fodder;
– avenues of trees, shade or ornamental trees, orchards (fruit trees) or hedges;
– crop fertilization (green manure), soil improvement (fallow), soil stabilization and protection (dunes, ravines and living hedges);
– veterinary medicine;
– apiculture.

Seasonal grazing and the season in which the plant is actually used are not mentioned in relation to use as fodder. Livestock feed use depends on the climatic conditions (dry or rainy season) and possible choices between several herbaceous or woody, which may vary considerably in terms of quantity and quality. Moreover, cattle do not have the same preferences as goats, sheep or camels. Cattle prefer herbaceous plants but may eat tree leaves if fresh grass is in short supply, while camels prefer leafy branches. The term "livestock" refers to any type of animal.

"Veterinary medicine" does not distinguish between proven and unproven treatments. Much less pharmacological research has been carried out in the field of veterinary medicine than in human medicine. Moreover, the books I consulted very rarely make this distinction either.

Domestic and technological uses

Domestic, craft and industrial uses primarily include:
– domestic uses such as construction, tool handles, ropes, perfumes, colourings for tattoos, and above all firewood and charcoal;
– technological uses, for both crafts—carpentry and cabinet-making, sculpture, tannery, dyes, glues, fishing and hunting tackle, musical instruments—and industry—pharmaceuticals, perfumes and cosmetics, varnishes and paints.

Related species

Some related species are morphologically similar. In such cases the illustrated keys are not sufficiently precise to distinguish unequivocally between these species. This section stresses the criteria specific to each species and thus mentions the characters that need to be observed particularly closely to avoid confusion.

Abbreviations and symbols

In the determination keys

* Presence of thorns or spines.
° Presence of white or colourless latex.
• Presence of coloured latex.
G Creeping plant.
ip In part.

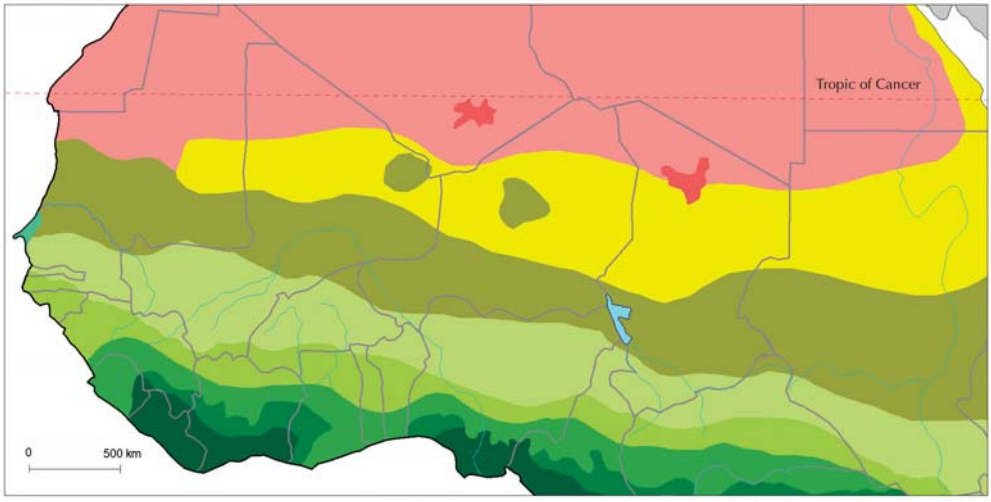
To help with determination using the keys, morphological characters specific to certain species or genera are marked. For instance, *Ancylobotrys*°G means that the genus is a creeper (G) and secretes latex (°); *Capparis** that the genus *Capparis* has thorns; *Strychnos*ip* that some species of the genus have thorns in the flora concerned—one species (*S. spinosa*) has thorns while the other species quoted (*S. innocua*) does not; and *Vitex madiensis*ip is quoted for the criterion "digitate compound leaves with three leaflets" and also for that of "digitate compound leaves with more than three leaflets", since the species has leaves with three to five leaflets and therefore partly satisfies both criteria.

In the species notes

\+ Plant used in association with other ingredients.

Synonymies that are only partly applicable (because the samples collected were incorrectly determined) are marked ip.

Climatic zones in tropical Africa



Saharan zone
- Saharan sector
- Saharo-montane sector

Sahelian zone
- Saharo-Sahelian sector
- Sahelian sector

Sudanian zone
- Sahelo-Sudanian and Sudanian sector
- Sudano-Guinean sector

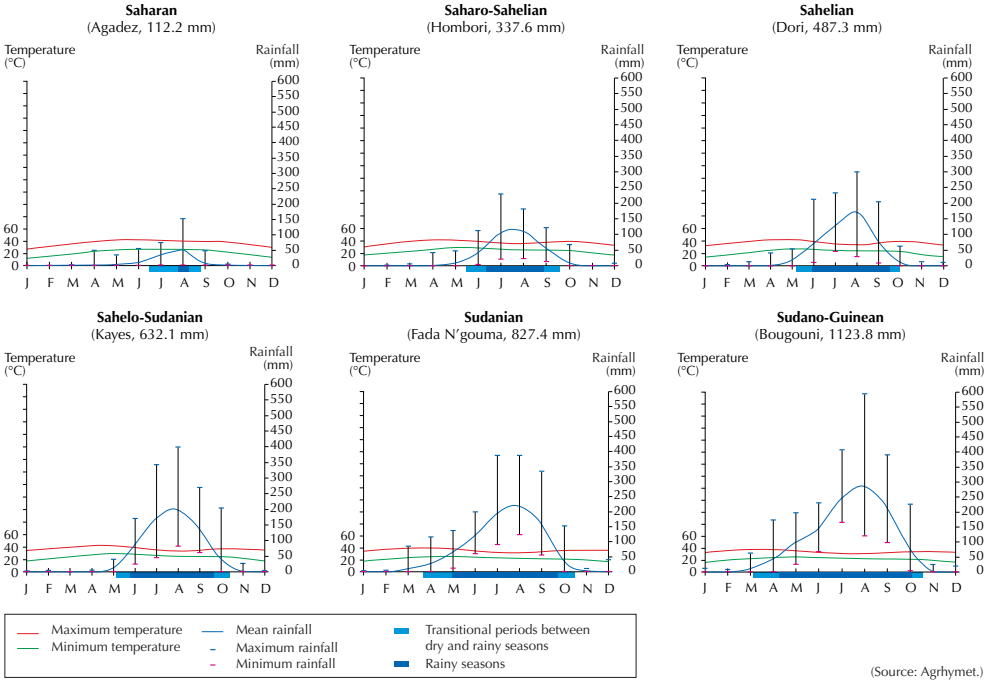
Subguinean zone
- Subguinean sector

Central African zone
- Peri-forest sector

Forest sector
- Semi-deciduous forest district
- Evergreen forest district

(Sources: Aubréville, 1950; Trochain, 1970; Zohary, 1973.)

Climatic features of West African dry zones from 1961 to 1990



(Source: Agrhymet.)

The dry zones of West Africa

Climate

The dry zones of West Africa, between Dakar and Lake Chad, have only one rainy season, during the hottest part of the year, which lasts from one to five months.

The low relative humidity results in very severe insolation and generally high air and soil temperatures. Rainfall is extremely variable, in terms of both distribution in time and space and intensity, which varies between 1 and over 200 millimetres per hour. These variations apply to the spatial distribution of rainfall, which is highly irregular, but also its temporal distribution, ie frequency—the rains may be early or late and occur daily or interspersed with dry periods lasting several days—and its abundance, or daily quantities.

The ombrothermal climagrams on the previous page demonstrate this variability in rainfall patterns, observed over the period 1961 to 1990. The data used in these charts are the monthly mean minimum and maximum temperatures and minimum, mean and maximum rainfall levels. For instance, for Hombori in Mali, where the mean rainfall figure for July is 107.4 millimetres, the recorded figure was 23.1 millimetres in 1982 and 229.9 in 1975. For Kayes, where the mean rainfall figure for August is 196.0 millimetres, the figure was 80.2 millimetres in 1983 and 396.6 in 1989.

The climate is linked to the advance of the intertropical front, the interface between two air masses, one hot and humid and the other cold and dry, which travels between two extremes.

In January, there is an anticyclone in the centre of the Sahara, on the 30th parallel. The Harmattan blows from the Northeast. In July, the anticyclone is replaced by a depression, and moist winds blow in from the Atlantic to the Southwest.

From North to South, the zone has Saharan, Saharo-Sahelian, Sahelian, Sahelo-Sudanian, Sudanian and Sudano-Guinean sectors.

However, in the field, the borders between these climatic regions are very vague. Local conditions linked to the relief—mountains, hilltops or slopes, lowlands or riverbeds—and soil quality—from permeable sands to compacted clays and hardpans in particular—play a major role in rainwater distribution and storage.

Types of vegetation

Saharan sector

In the Saharan sector, where rainfall is both very low and irregular, the soils are generally skeletal, comprising sand (shifting or fixed dunes) covered with varying amounts of coarse stones or pebbles (regs). The shrubby vegetation is concentrated in patches in depressions corresponding to drainage channels. It primarily comprises *Acacia tortilis raddiana* and *A. ehrenbergiana*, *Balanites aegyptiaca*, *Maerua crassifolia*, *Salvadora persica* and *Leptadenia pyrotechnica*.

The temperatures in the mountainous zones are tempered by the altitude, the climate is less arid and the flora is Mediterranean, Sahelian or Sahelo-Sudanian. The dominant species are *Acacia tortilis raddiana*, *A. laeta*, *Boscia senegalensis*, *Maerua crassifolia* and *Grewia tenax*, which are often mixed.

Trees are concentrated in and around the depressions surrounding waterholes and wells. Some species grow at the edge, on rocks *(Tamarix*, *Ficus cordata)*, while others stay near the water *(Anogeissus leiocarpus*, *Bauhinia rufescens)*.

Saharo-Sahelian sector

The Saharo-Sahelian sector is primarily characterized by shifting or fixed dunes alternating with sandy or bare depressions on rocky soils.

On the fixed dunes, the bushy vegetation is sparse and takes the form of steppe, with *Cenchrus biflorus* (a grass) and *Guiera senegalensis*, dominated by *Balanites aegyptiaca*, *Acacia tortilis raddiana*, *A. ehrenbergiana*, *Combretum glutinosum* and *C. micranthum*, *Boscia senegalensis* and *Leptadenia pyrotechnica*.

The main species on the rocky soils of the depressions are *Acacia tortilis raddiana* and *Cordia sinensis*, dominated in places by *Hyphaene thebaica*.

Sahelian sector

In the Sahelian sector, the vegetation changes from North to South, from bushy or wooded steppe to strips or patches of bush. These bush areas comprise alternating wooded zones or thickets and almost bare zones or areas with only grass cover. This grass cover is generally patchy and primarily comprises annual species, as it is occasionally affected by bush fires.

The shrubby steppes with *Cenchrus* and *Aristida* (grasses) are mainly dominated by *Acacia ehrenbergiana, A. senegal* and *A. tortilis raddiana, Piliostigma reticulatum, Balanites aegyptiaca* and *Leptadenia pyrotechnica*, with a few scattered species in depressions, such as *Combretum glutinosum, Sclerocarya birrea* and *Lannea acida*.

The strips and patches of bush primarily comprise *Combretum micranthum*, which is by far the dominant species. It is mixed with *Acacia ataxacantha* and *A. macrostachya, Combretum nigricans, Piliostigma reticulatum, Boscia senegalensis, Guiera senegalensis,*

Grewia flavescens, Commiphora africana, Pterocarpus lucens and *Gardenia sokotensis*.

Near temporary ponds, the thickets are primarily dominated by *Mitragyna inermis, Acacia ataxacantha* and *A. macrostachya*, mixed with *Celtis integrifolia, Crataeva adansonii* and lianas such as species of the genus *Cissus* or *Tinospora bakis*.

Multipurpose trees have grown or been planted in villages and around sandy depressions: *Acacia tortilis raddiana, Azadirachta indica, Faidherbia albida, Ficus* sp., *Hyphaene thebaica, Phoenix dactylifera, Prosopis juliflora* and *Tamarindus indica*.

Sahelo-Sudanian sector

There is a mosaic of different types of vegetation in the Sahelo-Sudanian sector. The species found are governed by the relief and soil type:
– shrubby steppes with *Acacia laeta, A. macrostachya, A. senegal* and *A. tortilis*, *Combretum glutinosum, C. nigricans* and *C. micranthum, Guiera senegalensis, Sclerocarya birrea, Balanites aegyptiaca, Piliostigma reticulatum* and other acacias;
– wooded savannahs with *Anogeissus, Acacia senegal* and *A. seyal, Combretum* sp., *Sclerocarya birrea, Sterculia setigera* and *Stereospermum kunthianum*;
– occasional copses and thickets, either around former termite nests, around which *Balanites aegyptiaca, Diospyros mespiliformis, Ficus* sp. or *Tamarindus indica* grow, or under large trees. They comprise *Combretum aculeatum, Feretia apodanthera* and *Grewia* sp., which are colonized by a range of lianous species, such as *Acacia erythrocalyx, Leptadenia hastata, Capparis* sp., *Cissus* sp. and *Saba senegalensis*;
– localized gallery forests near watercourses or around ponds, which are sometimes flooded and which have a specific type of vegetation. These areas, which are often degraded by local people, farmers or herdsmen, primarily comprise *Acacia nilotica, A. polyacantha campylacantha* and *A. seyal, Crataeva adansonii, Diospyros mespiliformis* and *Mitragyna inermis*;
– agroforestry parks, ie natural forests adapted by man. These include fruit species—*Adansonia digitata, Cordyla pinnata, Lannea microcarpa, Parkia biglobosa, Sclerocarya birrea, Vitellaria paradoxa* and *Ziziphus mauritania*. Multipurpose trees—*Acacia nilotica, Azadirachta indica, Cassia sieberiana, Celtis integrifolia, Faidherbia albida, Ficus* sp. and *Pterocarpus erinaceus*—are also found;
– smallholdings planted with fruit species, in lowland areas—*Annona squamosa, Mangifera indica, Psidium guajava* and *Punica granatum*. Living hedges primarily comprise *Acacia nilotica, Euphorbia balsamifera* and *E. tirucalli, Jatropha* sp., *Lawsonia inermis* and *Thevetia neriifolia*. Avenues of trees or ornamental plantings include *Albizia lebbeck, Azadirachta indica* and *Khaya senegalensis*, and the woods planted by smallholders *Acacia senegal, Azadirachta indica, Eucalyptus camaldulensis, Prosopis juliflora* and *Ziziphus* sp.

Sudanian sector

The Sudanian sector is covered by grass 20 centimetres to 1.5 metre tall, which is regularly affected by bush fires. There are also various types of savannah vegetation.

The shrubby or wooded savannahs on rocky or hardpan soils include trees such as *Acacia dudgeoni* and *A. macrostachya, Combretum glutinosum* or *C. nigricans, Lannea velutina, Piliostigma reticulatum* and *Terminalia avicennioides*. These dominate the bushes, including *Acacia ataxacantha, Combretum micranthum* or *C. nioroense, Gardenia* sp. and *Grewia bicolor* or *G. flavescens*, which are often mixed with scrambling shrubs such as *Acacia erythrocalyx, Saba senegalensis* or *Sarcostema viminale*. The grass cover primarily comprises annual grasses that are not often affected by bush fires. The different soil types of varying depths are dominated by species such as *Acacia dudgeoni* and *A. seyal, Anogeissus leiocarpus, Bombax costatum, Burkea africana, Combretum* sp., *Crossopteryx febrifuga, Detarium microcarpum, Parkia biglobosa, Piliostigma thonningii, Terminalia* sp., *Vitellaria paradoxa* and *Ximenia americana*. The perennial grasses, such as *Andropogon* sp. and *Pennisetum* sp., are regularly affected by bush fires.

The wooded savannahs and open forests comprise *Anogeissus leiocarpus, Combretum* sp., *Detarium microcarpum, Isoberlinia doka, Parkia biglobosa, Pterocarpus erinaceus, Terminalia* sp. and *Vitellaria paradoxa*.

The gallery forests are concentrated in depressions, where the dominant trees prevent grass growth. They are not generally affected by bush fires and comprise trees between 15 and 30 metres tall, such as *Acacia polyacantha, Afzelia africana, Berlinia grandiflora, Ceiba pentandra, Daniellia oliveri, Dialium guineense, Erythrophleum suaveolens* and *Khaya senegalensis*. There are also bushy shrubs between 4 and 10 metres tall, such as *Flacourtia flavescens, Keetia venosa, Rytigynia senegalensis* and *Sarcocephalus latifolius*, and scrambling shrubs—*Baissea multiflora, Combretum paniculatum, Gymnema sylvestre, Loeseneriella africana, Opilia celtidifolia, Paullinia pinnata, Saba senegalensis* and *Tetracera alnifolia*.

The riparian stands, which are occasionally flooded, comprise characteristic species, including arborescent species such as *Breonadia salicina, Cola laurifolia, Cynometra vogelii, Garcinia livingstonei, Keetia cornelia, Pterocarpus santalinoides, Syzygium guineense*

guineense and *Vitex chrysocarpa*, small trees or bushes such as *Ficus capreifolia, Hymenocardia heudelotii, Mimosa pigra, Salix subserrata, Sesbania sesban* and *Ziziphus spina-christi microphylla*, and numerous lianas, including *Gymnema sylvestre, Paullinia pinnata* and *Taccazea apiculata*.

The agroforestry parks, developed from the existing vegetation, primarily comprise fruit trees—*Adansonia digitata, Ficus* sp., *Lannea microcarpa, Parkia biglobosa, Sclerocarya birrea* and *Vitellaria paradoxa*—and multipurpose trees such as *Azadirachta indica, Borassus aethiopum, Cassia sieberiana, Ceiba pentandra, Eucalyptus* sp., *Faidherbia albida* and *Senna siamea*.

Fallow areas are dominated by the tall trees of the agroforestry parks, under which regrowth often comprises the species found in bush areas on hardpans, particularly *Acacia macrostachya, Combretum glutinosum* or *C. nigricans, Piliostigma reticulatum* and *Terminalia avicennioides*, mixed with bushes such as *Acacia ataxacantha* and *A. erythrocalyx, Combretum glutinosum, C. micranthum, Gardenia* sp., *Grewia* sp., *Guiera senegalensis, Saba senegalensis* and *Ziziphus mauritania*.

Ornamental planting includes *Albizia lebbeck, Crescentia cujete, Delonix regia, Ficus* sp., *Terminalia catappa* and *T. mantaly,* and living hedges *Acacia nilotica, Agave sisalana, Euphorbia balsamifera, E. kamerunica* and *E. tirucalli, Jatropha* sp., *Lawsonia inermis, Parkinsonia aculeata, Thevetia neriifolia, Ziziphus abyssinica* and *Z. mauritania*, while the woods planted by smallholders generally comprise multipurpose, short-life-cycle species—*Azadirachta indica, Eucalyptus camaldulensis, Gmelina arborea, Khaya senegalensis* and *Tectona grandis*.

Sudano-Guinean sector

The Sudano-Guinean sector is a mosaic of different types of vegetation, ranging from copses or patches of forest between 3 and 8 metres tall on fissured hardpans, to dense gallery forest dominated by trees some 30 to 40 metres tall, with a multitude of types of transitional vegetation in between.

The copses on hardpans, are very similar to the Sudanian vegetation, and primarily comprise:
– dominant trees or shrubs such as *Acacia macrostachya, Combretum* sp., *Crossopteryx febrifuga, Ficus abutilifolia* and *F. cordata, Lannea velutina* and *L. acida, Pachystela pobeguiniana* and *Terminalia* sp.;
– twining shrubs or bushes, such as *Combretum micranthum* or *C. nioroense, Feretia apodanthera, Gardenia aqualla* and *G. sokotensis,* and *Sericanthe chevalieri*;
– climbing species such as *Baissea multiflora, Cissus* sp., *Landolphia heudelotii, Opilia celtidifolia* and *Saba senegalensis*.

The open forests comprise trees whose crowns are virtually continuous, under which the plants and grasses are relatively sparse, and the wooded savannah is made up of widely-spaced trees under which the grasses are tall (particularly *Andropogon* sp.) and are often affected by bush fires. The species that grow here are dominant trees, sometimes in almost pure stands: *Anogeissus leiocarpus, Burkea africana, Combretum* sp., *Daniellia oliveri, Detarium microcarpum, Isoberlinia doka, Lophira lanceolata, Parkia biglobosa, Pseudocedrela kotschyi, Pterocarpus erinaceus, Terminalia glaucescens* and *T. mollis,* and *Uapaca togoensis*. There are also shrubs such as *Crossopteryx febrifuga, Entada abyssinica* and *E. africana, Gardenia erubescens* and *G. ternifolia, Maranthes polyandra, Parinari curatellifolia, Pavetta crassipes, Pericopsis laxiflora, Securidaca longepedunculata, Strychnos spinosa* and *S. innocua, Vitex madiensis* and *V. simplicifolia*. Lastly, there are more or less scrambling shrubs, including *Baissea multiflora, Landolphia* sp., *Loeseneriella africana, Opilia celtidifolia, Saba senegalensis, Smilax anceps* and *Strophanthus sarmentosus*.

Gallery forests are found in depressions or damp areas. They primarily comprise a mixture of species found in the dense, semi-deciduous Guinean forests (not covered in this work) and open forest species. The crowns of the dominant trees and the branches of the trees on the edge of these forests are generally tangled and covered in creepers. The forests contain trees some 20 to 40 metres tall, such as *Afzelia africana, Albizia zygia, Berlinia grandiflora, Ceiba pentandra, Cola cordifolia, Daniellia oliveri, Detarium senegalense, Dialium guineense, Elaeis guineensis, Erythrophleum suaveolens, Guibourtia copallifera, Khaya senegalensis, Malacantha alnifolia* and *Lecaniodiscus cupanioides*, trees between 8 and 20 metres tall and bushy shrubs from 3 to 10 metres tall—*Flacourtia flavescens, Ochna sp., Olax subscorpioides, Sarcocephalus latifolius, Vernonia colorata* and *Voacanga africana*—, and scrambling shrubs such as *Baissea multiflora, Gymnema sylvestre, Lonchocarpus cyanescens, Opilia celtidifolia, Paullinia pinnata, Saba senegalensis* and *S. comorensis, Santaloides afzelii, Smilax anceps, Tetracera alnifolia* and *Uvaria chamae*.

Riparian stands, which are sometimes flooded, comprise arborescent species such as *Breonadia salicina, Cola laurifolia, Cynometra vogelii, Ficus asperifolia* and *F. trichopoda, Garcinia livingstoniana, Margaritaria discoidea, Pterocarpus santalinoides, Pheonix reclinata, Raphia sudanica, Rytigynia senegalensis, Syzygium guineense guineense* and *Vitex chrysocarpa*.

The bushy species include *Ficus capreifolia, Hymenocardia heudelotii, Mimosa pigra, Sesbania sesban* and *Ziziphus spina-christi microphylla*. Lastly, there are numerous herbaceous and woody lianes similar to those found in Guinean areas.

The agroforestry parks are similar to those in the Sudanian sector, with the addition of *Blighia sapida, Borassus* aff. *flabellifer* and *Elaeis guineensis*. Fruit trees are also often planted in orchards, including various varieties of mango, citrus and cashew trees.

Ornamental planting includes *Albizia* sp.*, Blighia sapida, Delonix regia, Pithecellobium dulce, Terminalia catappa* and *T. mantaly* and the live hedges *Agave sisalana, Jatropha curcas* and *J. gossypiifolia,* and *Thevetia neriifolia*. The woods planted by smallholders are primarily *Azadirachta indica, Eucalyptus camaldulensis, E. citriodora* and *E. tereticornis, Gmelina arborea, Senna siamea* and *Tectona grandis*.

Fallow areas are colonized by herbaceous species intermingled with the species that were there previously, which have thrown out stool shoots or suckers, primarily Combretaceae—*Albizia zygia, Crossopteryx febrifuga, Daniellia oliveri, Hymenocardia acida, Lophira lanceolata, Pericopsis laxiflora, Piliostigma thonningii* and *Trema guineensis*—, and ruderal plants or plants that indicate exhausted soils, particularly *Guiera senegalensis*.