Chapter 11
Potentials of Indigenous Fruit Trees in Enhancing Nutrition, Income and Biodiversity Conservation in African Agroforestry

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Abstract Indigenous fruit trees are in abundance as wild in the forests of Africa and play very significant role in food, nutrition, income and livelihood security of millions of people, especially the poor in Africa. Many species have been identified for their potential in meeting the nutritional requirement, value addition, income generation and biodiversity conservation when domesticated from the wild. The chemical composition of some of these species have been analysed and found to be rich in nutritional value and show potential for processing as juice, jelly, jam, edible oil and alcoholic beverages. Their uses as fodder, timber and making small tools and medicinal value have been documented but many of these remain underutilized and have potential for domestication and may be explored further when cultivated using proper propagation techniques. These may also play a vital role as sources of commercial products and mitigating climate change by sequestering carbon. Potential of some of the most preferred trees, challenges for their domestication and research needs have been discussed in this article.

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11.1 Introduction

Indigenous fruit and medicinal trees play a significant role in the food, nutrition, health and incomes of millions of people in Sub-Saharan Africa (Akinnifesi et al. 2008a; Jamnadass et al. 2011; Leakey and Akinnifesi 2008, 2017). Many of these species also provide products with great potential for processing and marketing (Ham et al. 2008). Some species produce fruits out of season and this creates opportunities for the development of cultivars which will extend the season of availability. The 'Noel' cultivar of *Dacryodes edulis* in Cameroon (Leakey et al. 2002) is a good example. There is also a great potential to develop them into tree crops for commercialization through clonal propagation (Leakey and Akinnifesi 2017; Leakey et al. 2017). The role of underutilized fruit and medicinal tree species in combating hunger, malnutrition, disease and poverty becomes more apparent as concerns of climate change and food security increase.

Nevertheless, almost all indigenous fruit tree species are still in a wild or semi-domesticated state and therefore, have remained neglected and underutilized. The reasons for the long neglect of indigenous fruits and failure to domesticate them have been variously identified as due to: (1) lack of information and reliable method for measuring the contribution to rural economy, livelihoods of communities and ecological services; (2) low production incentives relating to markets and technology (e.g. lack of cultivar development); (3) bias in favour of large-scale agriculture and conventional forestry; (4) colonial interventions that left a profound legacy of neglect of smallholder farm production in favour of estate farm producers and European export product trading interests and (5) weak interface between private sector actors, researchers and extension staff in tree products (Akinnifesi et al. 2008b). Although planting of indigenous fruit trees is not a common practice, they are selectively retained when farmers are clearing the land for agriculture (Teklehaimanot 2008; Kalinganire et al. 2008). In other parts of the continent, indigenous fruit trees are continuously being destroyed by an ever-increasing population and demands for new farmlands, human settlements, wood for fuel and construction and forest conversion to agriculture (Teklehaimanot 2008). Indigenous fruit tree species have also not benefitted from positive agricultural or forestry policies, research and extension development (Campbell 1987; Leakey et al. 2017). Most National Agricultural Research Institutions (NARIs) focus on improvement of staple food crops, but research interest on indigenous fruit trees has been lacking. The scientific and development community started to pay attention to underutilized crops only in the 1970s. Even then, the number of international and national programmes involved with indigenous fruit trees has remained very small. Lack of attention to indigenous fruit trees has been compounded by the misconception that they are abundant in the forest. This has been aggravated by the limited understanding of the genetic variability, reproductive biology, propagation techniques, field management requirements, value addition and marketing (Akinnifesi et al. 2006). However, the importance of commercial products from indigenous fruit trees is steadily gaining recognition in both developing and developed country markets (Akinnifesi et al. 2006). As a result, interest in domestication has increased, and a farmer-driven and market-led process is now being implemented in many parts of Africa (Leakey et al. 2003; Simons and Leakey 2004; Akinnifesi et al. 2008a, b, c, d). The indigenous fruit tree domestication efforts aimed at promoting the cultivation of species with economic potential as new cash crops, and providing incentive to subsistence farmers to plant trees on their farms (Akinnifesi et al. 2008b). The low-technology options are more appropriate if the participatory approach to domestication is the preferred strategy. In this case, farmers vegetatively propagate their best trees to create selected cultivars (Leakey and Akinnifesi 2017).

The early history of indigenous fruit tree domestication has been detailed elsewhere (Leakey et al. 2005; Akinnifesi et al. 2008a, b). According to Leakey et al. (2017), more than 420 research papers involving more than 50 tree species have been published on tree domestication over three decades (1992–2012). The first decade was characterized by species assessment, germplasm improvement and dissemination of propagation techniques. The second decade included characterization of genetic variation using morphological and molecular techniques, product commercialization, adoption and impact and farmers' rights, nutrition and composition of marketable products. The third decade focused on the research that underpin agroforestry tree domestication and scaling up, as well as commercialization (Leakey et al. 2017). This chapter briefly describes the human uses and functions of indigenous fruit and nut trees in general, nutritional values of priority species, current research and trends in domestication and commercialization of priority species including more recent developments.

11.2 Human Uses in Different Regions of Africa

Indigenous fruit trees have many uses; primary among them are the edible fruits and nuts. The fruits may be eaten fresh, dry or processed into alcoholic beverages, jam, juice and jellies (Maghembe et al. 1998; Akinnifesi et al. 2008a; Ham et al. 2008; Dagar et al. 2020). Traditional fruits like marula (*Sclerocarya birrea*), monkey oranges (*Strychnos cocculoides, S. spinosa*), bird plum (*Berchemia discolor*), baobab (*Adansonia digitata*), *Diospyros* spp., *Grewia* spp., manketti (*Sciniziophyton rautanenii*), mobola plum (*Parinari curatellifolia*), *Uapaca kirkiana, Vangueria infausta* and many others have become part and parcel of the life of rural population. Ripe fruits of many of the species are consumed as such since immemorial times. For example, marula (*S. birrea* subsp. *coffra*) is known and consumed by humans in southern Africa for millenia (Walker 1989). Monkey oranges are other delicious fruits in Kwango and Caprivi regions in southern Africa. Fruits of *Annona senegalensis, Diospyros mespiliformis, Friesodielsia obovata, Parinnari* *curatellifolia, Securinega virosa, Syzygium cordatum, S. guineense, Vangueria infausta, Vangueriopsis lanciflora, Ximenia americana, Ziziphus mucronata* and *Z. mauritiana* are among many others which are consumed raw when ripe and are highly nutritious.

Depending on their seasonal occurrence, the trees provide an additional dietary supplement during hunger periods in the agricultural cycle. For example, in southern Africa, at least one species is ripe every month, including during the traditional periods of hunger in the agricultural cycle, which occurs in January–February every year (Akinnifesi et al. 2004). Fruits of some of the species appear even in unusually dry periods, and are thus, particularly valuable sources of food and nutrition during emergency periods of food shortage, such as famine, droughts and war (Jama et al. 2007; Teklehaimanot 2008). Because of drought, *Berchemia discolor* is one of the most preferred fruit trees in Katma Mulilo region of Namibia, and *S. rautanenii* (manketi) has been the tree of difficult times in Kavango region. *Balanites aegyptiaca*, prominent in dry regions on all types of soils, is very useful tree bearing highly nutritive fodder and fruits consumed both when ripe and dried. Many parts of the plant are used as famine food in Africa; the leaves are eaten raw or cooked, the oily seed is boiled to make it less bitter and eaten mixed with cereals, and the flowers are also consumed. The tree is considered valuable in arid regions because it produces fruit even in dry period. The fruit can be fermented for refreshing drinks. The seed cake is used as animal feed. Thus, the local communities in drylands heavily rely on these (indigenous fruit trees) resource as emergency food and fodder for livestock. For example, *Cordeauxia edulis* is sometimes the only food left for the nomads during droughts in the arid areas of eastern Ethiopia and Somalia (Teklehaimanot 2008).

Dried kernels or nuts of some species are consumed raw or roasted or made into porridge. For example, dried kernels of marula, manketti; dried fruits of bird plum, *D. mespiliformis, P. curatellifolia*; arils of *Guibourtia coleosperma*; and roasted seeds of *Kigelia africana, Bauhinia thonningii* and *Schotia afra* are consumed making porridge; and dried fruits of *Grewia flava, G. flavescens* and *G. retinervis* are soaked in water, mashed and eaten as porridge. Cooking a mixture of pounded eembe, marula kernels, water and salt makes a traditional cake/bread. Fruits of marula, monkey orange and eenkwiyu (*Ficus sycomorus*) are used in making traditional jam; fruits of *Ximenia caffra* make a tart jelly; fruits of *Grewia* spp mixed with fresh milk to make a kind of yoghurt. Rural people most commonly use manketti and marula oils as edible and a kind of cooking oil is extracted from the fruit of nonzwe (*Ochna pulchra*), which can be stored for about a year.

Most of the fruits mentioned above (marula, manketti kernels, bird plum, monkey orange, *Grewia flava, G. bicolor, Dialium engleranum, Diospyros mespiliformis, Parinari curatellifolia, Garcinia livingstonei* and *Ziziphus mucronata*) are extensively used for preparing alcoholic drinks, which now is also being explored commercially. Fruits of *Adansonia digitata, Syzygium guineense, Dialium engleranum* and arils and red skin of *Guibourtia colosperma* make a kind of refreshing beverage. Young fruits of makami palm (*Hyphaena petersiana*), a sap exuded from spadix of makami palm and wild date palm (*Phoenix reclinata*) is converted into an alcoholic drink. Fruits of *Rhus lancea* pounded with water are fermented for a kind of beer.

Indigenous fruits are also a source of oil for use in cosmetic products (e.g. *Sclerocarya birrea*, *Adansonia digitata*, *Ximenia caffra*) and fuel for cooking, medicinal products, fodder, fibre, timber, saps and resin. Where products and markets have been developed effectively, indigenous fruits have become sources of household incomes and revenue for national economies, as has been documented for several indigenous species such as *Sclerocarya birrea* in South Africa and *Uapaca kirkiana* in Zimbabwe (Akinnifesi et al. 2008a). For example, the fruit pulp and oil of *Adansonia digitata* have gained formal international market in the EU and USA hence an income generation for millions of rural farmers (De Smedt et al. 2011). More than 70 species of indigenous fruit tree species, besides having edible fruits or nuts, have one or more medicinal and other minor uses such as crafting and thatching, fencing, tools and dug-out canoes among local communities (Table 11.1).

In addition, most tree species provide shade, modulate the microclimate, reduce surface run-off, improve water storage, increase soil fertility, carbon sequestration and conserve biodiversity (Bayala et al. 2006, 2014; Teklehaimanot 2008). These effects can increase opportunities for associated crops to thrive especially during drought years. By reducing air temperature, solar radiation and wind velocity, trees decrease potential evapotranspiration under their crown canopies resulting in higher soil moisture contents than in open areas without tree cover. For example, Grouzis and Akpo (1997) recorded temperatures lower by 6 °C under *Balanites aegyptiaca* tree crowns than in direct sunlight. Similarly, Bayala et al. (2014) reported a reduction in the maximum daily temperature by an average of 1–2.5 °C and an increase in the minimum air humidity by up to 5%, with stronger differences on hotter and drier days. Soil temperature was also substantially reduced by at least 5 °C under crowns of *Adansonia digitata* and *Vitellaria paradoxa* (Belsky et al. 1989; Jonsson et al. 1995). Jonsson et al. (1995) found significant reduction in wind speed under *Vitellaria paradoxa* trees compared with the open. Significantly, higher soil moisture has been reported under tree crowns of *B. aegyptiaca* and *V. paradoxa* than in the open (Boffa 1999).

One of the most important functions of indigenous fruit trees on farmland is their contribution to soil organic carbon (SOC), which plays a key role in improvement of soil physico-chemical properties. Mature trees have often been cited as hot-spots of SOC and islands of fertility in drylands (Bayala et al. 2006; Takimoto et al. 2009). SOC is known to contribute to the provision of important supporting ecosystem services including nutrient inputs, enhancement of internal flows and reduction of nutrient losses. Thus, indigenous fruit trees on farmland can play a critical role in Sub-Saharan Africa where loss of SOC is becoming the most limiting factor for soil ecological functions, crop growth and production. In addition, N fixing species such as *Vitex doniana* and *Cordeauxia edulis* may increase soil N availability. However, empirical data are lacking on the amount of N fixed by these tree species and conditions that promote N fixation. Studies based on soil chemical analysis beneath some of the species have shown a common pattern of superior soil fertility under tree canopies than in areas distant from the trees (Bayala et al. 2002; Boffa 1999). For

Table 11.1 Fruit, ethnomedicinal and other minor uses of indigenous fruit trees of Africa

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Adansonia digitata (Bombacaceae)	Baobab, mabuyu, muyu, mukuya	1, 2	Bark as rope and floor mats; light wood for boats; bark used fever, body pain; root used to treat impotency; leaves in kidney and bladder problems, diarrhoea, asthma; fruit made into a drink used to treat fever and scorbutic complaints (Apr–Oct)[b]
Allanblackia floribunda (Cluciaceae)	Tallow tree	3, 5, 7	Wood minor tools; seed oil for soap making; bark and leaf decoction for asthma, bronchitis, diarrhoea, dysentery, toothache (most of the year)
Ancylanthos bainesii (Rubiaceae)	Guwaiadjoadjoa	1	Root infusion for eye pain, headache, chest pain and cough (Oct–Dec)
Annona senegalensis (Annonaceae)	Wild custard apple, mulolo, mukonogwa	1	Roots for dizziness and claimed to cure madness (Oct–Dec)
Annona stenophylla (Annonaceae)	Duih	1	Roots for tooth pain (Feb–March)
Azanza garckeana (Malvaceae)	Snot apple Moneko	1	Inner bark fibre for ropes; fruit without seeds chewed as gum (Feb–Sep)
+*Balanites aegyptiaca* (Zygophyllaceae)	Desert date	1, 5, 7	Seed as famine food; leaves good fodder; bark decoction used as spasmolytic, antodote to arrow poison; leaves in worm infection, liver and spleen disorders; fruit in dysentery and constipation; seed in tumour and wounds, as laxative, in stomach ache, fever, to treat syphilis, haemorrhoid, jaundice, yield cortistone drug (April–June)
Bauhinia petersiana (Caesalpineaceae)	White bauhinia, koffiebeeskloa	5	Leaves as remedy for common cold, seed used substitute to coffee (Feb–May)
Bauhinia thonningii (Caesalpineaceae)	Camel's foot, monkey bread	5	Bark as fibre; green fruit as soap substitute; all parts medicinal (June–Sept)
+*Berchemia discolor* (Rhamnaceae)	Bird plum, embee, voelpruim, mukumba, muzinzia	1, 2, 3, 4, 6	A dye from inner bark; good forage and firewood (Jan–May)
Carissa edulis (Apocynaceae)	Simple spined num-num	1, 3	Root and fruit as flavouring; root to relieve pain in arthritis, rheumatism, as vermifuge (Oct–Dec)
Cassine aethiopica (Celastraceae)	Kooboo-berry	1	Bark infusion as drench for worm infestation in calves (June–Jan)
	Transvaal saffron wood	1	Bark infusion to relieve stomach ache and fever; wood for cattle trough,

(continued)

Table 11.1 (continued)

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Cassine transvaalensis (Celastraceae)			spoons, ladles and tobacco pipes (Jun–Nov)
Chrysophyllum caimito (Sapotaceae)	Star apple	1, 3	Bark medicinal (Feb–Apr)
Cordeauxia edulis (Caesalpiniaceae)	Vehib	1, 2, 5	Leaves yield red dye and are medicinal (June–July)
+*Dacryodes edulis* (Burseraceae)	African plum, bush butter, safou	1, 2, 5, 7	Fodder; seed oil in food industry, as medicinal in yellow fever, diarrhoea, anaemia, skin diseases, wounds (Nov–Mar)
Detarium microcarpum (Fabaceae)	Detar, Bambara, ntamajalan	1, 3, 6	All parts medicinal, root used as mosquito repellent (Sep–Jan)
Dialium engleranum (Caesalpiniaceae)	Kalahari pod berry, nonsimba, nonsisibe, muhamani	2, 4, 6	Attracts bees; crushed wood as disinfectant; root decoction for dysentery; cooked bark for stomach ache; leaf infusion for cough and chest pains (Dec–June)
Diospyros batocana (Ebenaceae)	Sand jackal berry, mufumbo	1	Hard wood for spoons and small carvings; leaves as enema (overdose fatal) (Sept–Feb)
+*Diospyros mespiliformis* (Ebenaceae)	Ebony diospyros, muchenje, mupako	1, 4, 6	Wood to make canoes, furniture, flooring, stamping blocks; bark, twigs and leaves remedy for ringworm, leprosy, wounds, fever and dysentery (Apr–Sept)
+*Dovyalis caffra* (Salicaceae)	Kei-apple		Root and thorn used in chest pain, amenorrhoea; bark and root in rheumatism (Dec–May)
Ehretia rigida (Boraginaceae)	Puzzle bush	1	Powdered roots applied to cuts and to treat gall-sickness in cattle (Oct–Jan)
Erythrococca menyharthii Euphorbiaceae	Northern red berry	1	Leaves used as vegetables, fodder; medicinal (Dec–Jan)
Euclea divinorum (Ebenaceae)	Diamond-leaved euclea, magic guarri	1	Wood for minor tools; bark yields brown dye; fruit taken as aperient and used in brewing beer and make a purple ink (Oct–Dec)
Euclea pseudebenus (Ebenaceae)	Ebony tree, ebbeboom, trawib	1	Wood timber, fire wood; root infusion for head ache and toothache (Feb–May)
Euclea undulata (Ebenaceae)	Common guarri, thicket euclea	1	Root remedy for tooth ache and heart ailments, is purgative; bark for head ache; leaves good fodder (Apr–Oct)

(continued)

Table 11.1 (continued)

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Ficus carica (Moraceae)	Domestic fig, ng/kchau	1, 6	Leaves fodder, fruit medicinal (Apr–May)
Ficus sycomorus (Moraceae)	Sycomore fig, katema, mukuyu, muchaba	1	Infusion of bark and latex used for chest and glandular complaints, diarrhoea and inflamed throat (July–Dec)
Flacourtia indica (Flacourtiaceae)	Flacouria, goewerneursprium	1, 2	Root decoction for body pain; dry leaves tonic and used for asthma and decoction to treat screw-worm in cattle (Jan–June)
Friesodielsia obovata (Annonaceae)	Bastard dwaba berry	1, 2, 3, 5, 6	Wood for small tools; root decoction used for treating stomach-ache, infertility in women and as an antidote for snakebite
+*Garcinia kola* (Cluciaceae)	Bitter kola	1, 5, 6, 7	Fruit and seed in body pain, fever, asthma, cough, throat infections and tuberculosis (July–Sept)
+*Garcinia livingstonei* (Cluciaceae)	Mangosteen, Imbe, mukwananga, mungindu, mutungwa	1, 6	Root used as aphrodisiac; Leaf and flower extracts show antibiotic properties (Nov–Dec)
Grewia avellana (Tiliaceae)	Muchaba, mundumdu	1, 6	Root remedy to sore eyes, diarrhoea and stomach ache (Sep–Oct)
Grewia bicolor (Tiliaceae)	Bastard, false brandy bush, kapopo	1, 6	Plant fibre for ropes, twigs for bows and arrows; fruits for local drink *machao* and *epoaka*; roots for chest complaints (Mar–June)
Grewia falcistipula (Tiliaceae)	Gloai, gloach	1	Roots part of other drug used as contraceptive (Mar–June)
Grewia flava (Tiliaceae)	Brandy bush, wilderosyntjie	1, 4, 6	Bark fibre for baskets; twigs nused as tooth brush; heavily browsed by game and stock (Dec–Apr)
Grewia flavescens (Tiliaceae)	Donkey berry	1	Roots for stomach troubles (Mar–June)
Grewia schinzii (Tiliaceae)	Zambezi raisin, omushe, mutulu	1, 3, 6	Fruit used to make a beer and to treat heart burn (Apr–June)
Grewia tenex (Tiliaceae)	Small leaved white cross-berry	1	Plant for bone fracture and tissue healing; fruit for promoting fertility in women and as a special diet to pregnant women and anaemic children (Feb–June)
Grewia villosa (Tiliaceae)	Mallow raisin	1, 2	Root to treat body pain, wounds, syphilis; dry fruit for stomach ache (Apr–May)
Guibourtia coleosperma (Caesalpiniaceae)	False mopane, nonsivi, mushibi, muzauli,	4, 5, 6	Wood for furniture, tools, crafts, firewood; bark yields a dye; bark and leaves to treat cough and healing wounds (May–July)

(continued)

Table 11.1 (continued)

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Hexalobus monopetalus (Annonaceae)	Shakama plum	1, 2, 5	Wood for timber; bark fibre; fruit extract shows bioactive anti-fungal activities (Dec–Apr)
Hyphaene petersiana (Arecaceae)	Itala palm, makami	1, 2, 6	Branches for furniture, tools, crafts, firewood; leaf fibre for mats, baskets and ropes; leaves as thatching material; root and kernel for dry cough (Sep–Oct)
Irvingia gabonensis (Irvingiaceae)	Bush mango	1, 3, 7	Wood as timber; leaves as fodder; kernels used as condiment, in sauces, cakes, seed oil in soaps; bark as medicinal in hernia, yellow fever, dysentery, diarrhoea, antidote to poison (Apr–Jul; Sep–Oct)
Kigelia africana (Bignoniaceae)	Sausage tree, worsboom, munguh	5, 6	Wood for making boxes and dugout canoes; bark and fruit in stomach ailments; powdered fruit for dressing ulcers and sores (Dec–June)
+*Mimusops zeyheri* (Sapotaceae)	Transvaal red milk wood	1	Bark to treat ulcers, wounds; leaves to treat diabetes; root to treat syphilis, stomach ache, gynaecological disorders (Apr–Sep)
Myrica serrata (Myricaceae)	Lauce leafy berry, lauce-leaved wax-berry	1	Branches to get fat rich in fatty acids; fruit rich in vit C and with stem and leaves produce aromatic oil (Apr–Oct)
Ochna pulchra (Ochnaceae)	Peeling plane, peeling bark ochna	1, 7	Wood for kitchen utensils; Seeds yield un-pleasant smelling poisonous oil, in Zambia it is used for cooking and soap making; bark used to treat burns, wounds and diarrhoea (Jan–March)
Olea europaea (Oleaceae)	Wild olive	1	Bark infusion relieves colic; leaf decoction used for sore throat (Mar–July)
Oncoba spinosa (Flacourtiaceae)	Snuff box tree, mulangu	1	Drying seed oil for varnishes; root used in dysentery and bladder complaints (Apr–Jul)
Pappea capensis (Sapindaceae)	Indaba tree, doppruim	1, 3, 6	Seed oil for soap making and lubrication and edible with mild purgative action, remedy for ringworm and to restore hair; bark used to treat venereal diseases; root infusion given to cattle as a purge; leaf infusion to cure sore eyes (Feb–July)
+*Parinaria curatellifolia* (Chrysobalanaceae)	Mobola plum, mubula	1, 4, 6	As a hot fomentation from bark used to treat pneumonia, cataracts, earache; leaves applied in dislocated and broken bones, wound healing and pneumonia (Oct–Jan)

(continued)

Table 11.1 (continued)

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Parkia biglobosa (Mimosaceae)	Nere	2, 5	Leaves good fodder; seed used as spice and medicinal, fruit rich in vitamin C
Phoenix reclinata (Arecaceae)	Wild date palm, chisonga, mukapakapa	1, 6	Leaves as thatching material, sap from spadix make intoxicating drink (Feb–Apr)
Salvadora persica (Salvadoraceae)	Mustard tree, regte mosterd boom	1	Leaves fodder; Seed oil used in soap making (Sept–Feb)
+*Schinziophyton (Ricinodendron) rautanenii* (Euphorbiaceae)	Manketti, mongongo, nongongo	4, 5, 6	Wood for canoes, carving, crafts and utensils; bark for stomach pain, diarrhoea and helpful drink for pregnant women who feel sick (Feb–Sept)
*Schotia afra (*Caesalpiniaceae)	Karoo boer-bean	5	Bark to treat heart burn and hangovers (Oct–March)
+*Sclerocarya birrea* (Anacardiaceae)	Marula, maroela, mulula, muongo	1, 2, 3, 5, 6	Bark to treat dysentery, diarrhoea and to prevent malaria, given to pregnant women to have a child of desired sex; leaves in intestinal and constipation problems (Feb–March)
Securinega virosa (Euphorbiaceae)	Snow berry, katoma	1	Root infusion with a meat broth is taken in malaria and considered effective in snakebite; bark for treatment of diarrhoea and pneumonia (Dec–March)
+*Strychnos cocculoides* (Loganiaceae)	Cork bark monkey orange, maguni	1,2, 3, 6	Roots of young tree given to children to treat stomach ache, also given in cold, cough; bark decoction and juice of unripe fruit used in stomach pain, malaria; unripe fruit pounded in water used in snakebite and swellings and juice applied to treat ear pain. (Mar–Sept)
Strychnos pungens/ spinosa (Loganiaceae)	Spine-leaved monkey orange, tha, matu	1,2,3,6	Used as above (July–Dec)
Strychnos spinosa (Loganiaceae)	Spiny monkey orange, groen klapper	1, 2, 3	Roots in cough, gonorrhoea, malaria; pounded leaf applied for healing wounds and neck pain (Mar–Sept)
Syzygium cordatum (Myrtaceae)	Water berry/lily, umdoni, mutuya	1, 2, 6	(Nov–Apr)
+*Syzygium guineense* (Myrtaceae)	Woodland water berry, water peer	1, 6	Wood for dug-out canoes; root infusion to bathe a patient with serious illness; bark in chest complaints (Nov–Apr)
+*Tamarindus indica* (Fabaceae)	Tamarind	1, 2, 3	Wood in timber; leaves fodder; fruit medicinal

(continued)

Table 11.1 (continued)

Species (Family)	English/African name	Fruit uses[a]	Medicinal and other minor uses and fruit availability[b]
Uapaca kirkiana (Rubiaceae)	Wild loquat/medlar		Root and bark used in dysentery, indigestion and intestinal problems; leaves used as fodder (Jan–Apr)
+*Vangueria infausta* (Rubiaceae)	Wild medlar, mubilo, ibbu, guri	1,4	Root a remedy for malaria, roundworm, chest pain and pneumonia; leaves applied in animals to tick bite spots and wounds (Jan–Apr)
Vangueriopsis lanciflora (Rubiaceae)	False wild medlar, muhole, mumbole	1, 2, 6	Wood for making utensils, charcoal and as wood fire; root and bark used to purify blood and heart ailments and dysentery (Sept–Jan)
+*Vitellaria paradoxa* (Sapotaceae)	Shea, karite	5, 7	Butter prepared from nut used in chocolates, pharmaceuticals (Jun–Aug)
Vitex doniana (Lamiaceae)	Bluck plum	1	Leaves as fodder and are medicinal; seed oil used in skin creams
Vitex mombassae (Lamiaceae)	Smell-berry vitex, poerabessie	1	Wood for tool handles, fuel; root decoction for diabetes, infertility and as antiemetic; fruit rich in vit C (Jan–June)
Vitex pavos (Lamiaceae)	Chocolate berry	1	Root for stomach ailments; bark to treat threadworm, skin problems; leaf decoction as appetiser (Feb–June)
Ximenia americana (Olacaceae)	Small blue sour plum, mulutulua	1, 6	Seed oil used to soften leather and as cosmetic; inner root bark to treat wounds and in infant maladies (Dec–Feb)
Ximenia caffra (Olacaceae)	Large sour plum, musambya	1, 3	Leaf decoction in inflamed eyes; seed oil for chapped feet and wounds; roasted and mashed seed applied to hair for colouring dark black and straighten it (Dec–Jan)
+*Ziziphus mauritiana* (Rhamnaceae)	Ber	1, 2, 3, 7	Fire wood; charcoal; leaves good fodder; bark medicinal
+*Ziziphus mucronata* (Rhamnaceae)	Buffalo thorn, mukalu	1, 6	The stock and game browse the leaves and fruit; root decoction for treating diarrhoea, coughing blood and tuberculosis; leaf paste used to cure boils and other skin infections (Mar–Aug)

Source: Compiled by Dagar (2003) from various sources, mainly Palgrave (1983), Leger (1997), Ayuk et al. (1999b), and Omotayo and Aremu (2020)

[a] Fruit uses depict as: 1 = fruit consumed when ripe, 2 = fruit juice or refreshing beverage, 3 = used in jam, jellies, 4 = stored dry and made into porridge, 5 = seed edible, ground into meal, 6 = alcohol, 7 = edible seed oil

[b] In parenthesis months indicating the period of availability of fruits in wild

example, Bayala et al. (2002) found higher SOC, total phosphorus (P) and potassium (K) under *Vitellaria paradoxa* and *Parkia biglobosa* crown than in the open in the Sahel. Similarly, Belsky et al. (1989) recorded higher soil N, P, K and calcium (Ca) contents under crowns of *Adansonia digitata* than in the open area in East Africa. Improvement in microclimatic conditions under trees can enhances soil microbial activity, organic matter decomposition and soil physical characteristics. For example, Belsky et al. (1989) reported 35–60% higher soil microbial biomass-carbon, lower bulk density of top soil, and higher water infiltration rates under *Adansonia digitata* crowns than in the open. Trees can intercept wind-blown soil particles and deposit them in the soil by throughfall and stemflow. Species such as *Balanites aegypitica, Cordeauxia edulis*, *Tamarindus indica* and *Ziziphus mauritiana* may play an important role in intercepting dust as they retain their leaves during dry season when most soil laden winds prevail in drylands. For example, according to Roose and co-workers (cited in Boffa 1999) rainwater collected under *Vitellaria paradoxa* canopies had higher concentrations of N, P, K, C, Ca and Mg than in the open. The inclusion of indigenous fruit trees in production systems can reduce the risks inherent to monocultures of staple food crops, such as insect and disease outbreaks, soil nutrient depletion and reliance on a single crop for income (Haq et al. 2008). Some species have mystical and religious significance in some societies and are used for spiritual ceremonies (Haq et al. 2008).

In the following sections, examples of the human uses of indigenous fruit trees will be illustrated using selected priority species in different parts of Africa. These species have been identified based on farmer participatory selection for a particular uses, producers and consumers. In most cases, trees providing food particularly edible fruits and nuts dominated farmers' choices among species. In addition to fruits, some also provide edible leafy vegetables and medicinal products, timber and animal fodder. For brevity, we will focus on selected species that were chosen by farmers for their fruits and nuts, and we will describe the priority species in each region of Africa.

11.2.1 West and Central Africa

The humid tropical region of West and Central Africa includes the Congo Basin which is the world's second largest continuous rainforest after the Amazon. Over 70 species of indigenous fruit trees have been identified and efforts in domestication are on-going (Franzel et al. 2008; Leakey et al. 2017). Systematic work started in 1998 initially focusing on species in the humid lowlands of Cameroon and Nigeria (Tchoundjeu et al. 2008). The work progressively expanded into Equatorial Guinea and Gabon in 2002, the Democratic Republic of Congo and Ghana in 2004.

Priority species for domestication have been jointly identified by researchers and farmers following a priority setting carried out in Cameroon, Gabon, Ghana and Nigeria (Franzel et al. 1996). There was considerable variability among farmers' priority species within and between the countries surveyed. However, three species ranked among the top four in at least two of the countries. All three were important as both food and cash earners. Ten underutilized indigenous fruit trees of Africa having food nutritional security, reported by Omotayo and Aremu (2020) have also been included among priority species explained below.

Irvingia gabonensis (bush mango) is a large evergreen tree belonging to the family Irvingiaceae. It is widely distributed in moist semi-deciduous forests in West and Central Africa. Its geographical distribution covers Angola, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea-Bissau, Liberia, Nigeria, Senegal, Sierra Leone, Sudan and Uganda. This tree is prized for its large kernels, which are used as a condiment in soups known as 'ogbono' in Nigeria. In addition, the fruits of some varieties are eaten fresh. The kernel is also used in preparing sauces and cakes. The kernel is also used for medicinal purposes and as a source of oil for making soap (Ayuk et al. 1999a). This species is an important component of regional trade in West Africa. It is also a source of timber, poles and fodder. The bark is used in the treatment of various ailments such as hernia, yellow fever, dysentery, diarrhoea, and as an antidote for poisons. Farmers usually preserve this tree on farms as a shade tree for crops such as coffee and cocoa and to restore soil fertility (Ayuk et al. 1999a).

Dacryodes edulis (bush butter or prune, safou) belongs to the family Burseraceae. It is found in humid tropical climates with geographic distribution covering nearly all of the western coast of Africa across to Uganda (Ayuk et al. 1999b). It has been known to occur in Angola, Benin, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic of Congo (DRC), Equatorial Guinea, Gabon, Ghana, Liberia, Nigeria, Sierra Leone, Togo and Uganda. It is now widely planted by farmers in Nigeria, Cameroon and DRC, and in association with coffee and cocoa in some countries (Schreckenberg et al. 2002). The fruit is eaten raw, boiled or roasted and is an important food during its brief fruiting season. The fruit pulp yields about 48% edible oil. The fruits have very high cash value because they are sold widely in most countries of Central Africa. The oil is used widely in cosmetic and food industries. The kernel can be used as fodder for sheep or goats. The tree is also a source of many herbal medicines including the treatment of yellow fever, diarrhoea and anaemia (Ayuk et al. 1999b). It has also long been used in the traditional medicine of some African countries to treat various ailments such as wound, skin diseases, dysentery and fever. Ajibesin (2011) provides a comprehensive review of the ethnomedicinal uses of products from this tree, its chemical constituents and the biological effects.

Chrysophyllum cainito (star apple) belongs to the family Sapotaceae. It is widely distributed in the tropical rain forest and coastal region of West Africa (Nigeria, Niger, Cameroon and Cote d'lvoire and East Africa (Uganda). The flesh fruit is eaten especially as snack and relished by children. The fruits are also processed into jams and jellies. The bark, foliage and fruits are also used in traditional medicines (Houessou et al. 2012). The African star apple is produced commercially in West Africa.

Garcinia kola (bitter kola) belongs to the family Clusiaceae. It is found in moist forests throughout West and Central Africa including Cameroon, Ghana, Nigeria and Sierra Leone. The species is one of the most important trees valued in West Africa. The seeds are widely traded in West Africa. Every part of the plant has some medicinal uses. The seeds have pharmacological uses in treating asthma, coughs, poisoning, vomiting, throat infections, bronchitis and hepatitis (Abu et al. 2013). Experimental studies have confirmed antibacterial, anti-hepatoxic, antioxidant, anti-inflammatory and hypoglycaemic properties of its extracts (Abu et al. 2013). The extracts from seed and dry powered seeds have been made into tablets, cream and tooth paste. *Gacinia kola* seeds are also used as dietary food supplement, as flavour enhancer in the beverage industry and also as hop substitute in several indigenous alcoholic drinks.

Garcinia livingstonei (Imbe), is also important and preferred tree of tropical African nations including Uganda, Swaziland, South Africa, Somalia, Angola and Congo. The fruits are harvested for local use. The powdered root is used as an aphrodisiac and the fruit is said to be fermented into a pleasant alcoholic beverage which could help in improving health (Omotayo and Aremu 2020).

Allanblackia floribunda, a tree belonging to the family Clusiaceae, is an oil tree producing unique vegetable oil that comes from the seeds in tropical Africa. Although fruits are still mostly wild harvested, but there is a potential international market for its oil. Oil from the seeds has been extracted for generations and used for cooking or soap making, but a new use has been found because its oil melts and solidifies at temperatures just right for making margarine – similar to palm oil but easier to process. However, *Allanblackia* tree is considered vulnerable on the IUCN Red List of Threatened Species.

Balanites aegyptiaca syn *B. roxburghii*, a small tree belonging to family Zygophyllaceae (commonly known as balanite or desert date), is prevalent in all African regions including Northern Eastern, Central and Southern Africa, and also the Sahel-Savannah region across Africa, especially in West African countries including Mali, Benin, Senegal, Nigeria and Burkina Faso. It can be found in many kinds of habitat, tolerating a wide variety of soil types, from sand to heavy clay; and climatic moisture levels, from arid to subhumid. It is relatively tolerant to biotic pressure including fire and regenerates quickly from root-stock (https://en.wikipedia.org/wiki/Balanites_aegyptiaca - cite_note-fao-7). It has been cultivated in Egypt for more than 4000 years and is a good agroforestry tree as it fixes nitrogen and the foliage is rich in nitrogen contents and being spiny in nature forms good fence. As stated earlier, it is a very useful during famine. Its desert date fruit, mixed into porridge is given to nursing mothers. Date used to treat worm infection and liver and spleen disorders (Omotayo and Aremu 2020). A bark decoction is used as an abortifacient. The seed contains 30–48% non-volatile oil and all parts contain saponins.

11.2.2 The Sahel Region

The Sahel region, a semi-arid area stretching from Niger to Senegal, is characterized by high temperatures throughout the year and unpredictable rainfall patterns. This region is characterized by parklands, the principal agricultural system where a mixture of trees and shrubs are managed by farmers together with staple food crops, such as millet and sorghum. A number of indigenous fruit trees and shrubs provide fruits, leafy vegetables, nuts, oil and condiments that complement staple food crops in the local diet. In a survey conducted across Senegal, Mali, Burkina Faso, and Niger, a total of 59 indigenous fruit tree species were identified (Franzel et al. 2008). Out of these priority species (Table 11.2) were identified through participatory approaches for domestication. These species were preferred by farmers because of their nutritional, medicinal and income-generating values (Kalinganire et al. 2008).

Adansonia digitata (common name: baobab), a member of the family Bombacaceae, is indigenous to Africa where it is found in many countries (Kamatou et al. 2011). It occurs widely across the Sahel in savannahs of Sub-Saharan Africa. It is an emblematic and culturally important tree. It is often referred to as 'arbre a palabre', meaning the place in the village where the elders meet to resolve problems. Its leaves, bark, fruit pulp, seed and roots are used for medicines. The sun-dried fruit pulp is eaten either raw or added to sauces. Juice, rich in vitamin C, is prepared from the fruit pulp. A fermented baobab seeds known as *Maari* is part of the local diet in Burkina Faso (Parkouda et al. 2012, 2015). The leaves are used as vegetable consumed with cereal-based meals. Seeds are also used in soups or roasted and consumed as snacks (Sidibé and Williams 2002). The plant parts are used to treat various ailments such as diarrhoea, malaria and microbial infections. Baobab has numerous biological properties including antimicrobial, antiviral, anti-oxidant and

Table 11.2 List of the four most preferred priority indigenous fruit tree species in selected regions (adapted from Akinnifesi et al. 2009a)

Region	Rank 1	Rank 2	Rank 3	Rank 4
West Africa (Cameroon, Ghana and Nigeria)	*Irvingia gabonensis* (Bush mango)	*Dacryodes edulis* (African plum)	*Chrysophyllum cainito* (star apple)	*Garcinia kola* (bitter kola)
Sahel (Burkina Faso, Mali, Niger and Senegal)	*Adansonia digitata* (baobab)	*Tamarindus indica* (tamarind)	*Vitellaria paradoxa* (shea)	*Ziziphus mauritiana* (ber)
East Africa (Ethiopia, Kenya, Sudan and Uganda)	*Adansonia digitata* (baobab)	*Tamarindus indica* (tamarind)	*Ziziphus mauritiana* (ber)	*Sclerocarya birrea* (marula)
Southern Africa (Malawi, Tanzania, Zambia and Zimbabwe)	*Uapaca kirkiana* (wild loquat)	*Strychnos cocculoides* (monkey orange)	*Parinari curatellifolia* (mabula)	*Ziziphus mauritiana* (ber)

anti-inflammatory activities amongst others (Kamatou et al. 2011). The global demand for baobab seed oil and fruit pulp by the food and beverage, nutraceutical and cosmetic industries has increased dramatically in recent years (Kamatou et al. 2011).

Detarium microcarpum (detar) is a small leguminous tree of family Fabaceae that occurs widely in the Sahel region including Senegal, Mali, Burkina Faso, Cameroon, Chad, Nigeria and Sudan. It also occurs in the drier areas of Benin, Cameroon, Central African Republic, Gambia, Ghana, Guinea, Nigeria and Togo. Its fruits are consumed raw or cooked, or processed into cakes. The pulp is used to make an alcoholic beverage and in the preparation of couscous (Kalinganire et al. 2008). Seeds are dried, ground and used as fragrance. Mosquito repellent is prepared from the roots, while medicines are prepared from the seeds, fruits, leaves, roots and bark.

Parkia biglobosa (Néré) is a deciduous leguminous tree (family Mimosaceae) that occurs naturally across 15 countries in West Africa, parts of central Africa (Central African Republic and Republic of Congo) and parts of East Africa (Ethiopia, Sudan and Uganda) (Hall et al. 1997). It is the dominant species in the parklands, and it is managed in association with groundnuts, maize, millet and leafy vegetables (Bayala et al. 2002). As a legume, its seed are rich in protein, lipids, carbohydrates and minerals while the fruit pulp is high in carbohydrates and Vitamin C. The fresh fruit pulp is fermented into a beverage. In addition, the flowers are consumed. Its seeds are ground into a spice or condiment locally called ‘soumbala’, which is an important source of protein that is added to soups and stews throughout the Sahel. The species is considered as a commodity of local and regional trade in sub-Saharan Africa, especially in Benin, Burkina Faso, Cote d’Ivoire, Mali and Nigeria and is also a valuable source of fodder. Its branches are usually lopped by farmers and fed to livestock, especially in the dry season when good quality feed is scarce.

Tamarindus indica (tamarind) is a leguminous species (Family Fabaceae) indigenous to Africa. It probably originated in East Africa, but now naturalized in many countries in the Sahel and West Africa and the Indian sub-continent. Farmers commonly cultivate it in parklands in the arid and semi-arid zones of West Africa. In the Sahel, the fruit pulp is used primarily for sauces, porridge and juice. In Kenya, the fruit pulp is also used to tenderize meat, but this practice is unknown in the Sahel. Tamarind can be used as snacks, sauces, confectionery, drinks, jam, ice cream, wine, coffee-substitute, pectin, food stabilizer, dye, animal fodder, glue, edible oil and medicine. Tamarind is also a valuable timber species used in making furniture, tool handles, charcoal, and fuel wood. In addition, the leaves, flowers, root, bark, fruit pulp and seeds are an important source of herbal medicines (Bhadoriya et al. 2011).

Vitellaria paradoxa (Karité) is an indigenous African species belongs to the family Sapotaceae. It is abundant across the savanna between the equatorial rain forest and the Sahel. Its natural range extends from eastern Senegal to the high plateau of Uganda. There are two sub-species of *V. paradoxa* subspecies *paradoxa*, which occurs in the Sahel, produces a solid fat or butter while the Eastern Africa subspecies *nilotica* produces a liquid oil, which contains most of the therapeutic substances found in shea-butter. Nilotica shea-butter is softer and more fragrant than West African shea-butter. The fruits are not eaten fresh, but seeds are used as nutritious food condiment. The tree's main product is the shea butter extracted from the nuts. In addition to local uses, shea butter is exported for use in chocolate products and pharmaceuticals industries in European and other markets. Shea kernel is a very important export commodity and contributes significantly to the generation of revenues to many countries in the region. Annual exports to Europe are about 40–75,000 tons, with another 10–15,000 tons sold to Japan (Kalinganire et al. 2008). Mature fruits are eaten fresh and flowers are made into fritters.

Ziziphus mauritiana (ber) belongs to the family Rhamnaceae. Its origin is believed to be in Southeast Asia but it is naturalized in many parts of Africa. In the Sahel its main use is the fruit pulp, which is consumed fresh or dry, and also prepared into a juice. In addition, leaves are used for fodder, and the leaves, roots and bark are used for medicinal purposes. The wood is used for handles, kitchen utensils, firewood and charcoal. Among the selection criteria are plant vigour, early fruit set, sweet fruits, resistance to pests and disease, small seeds, big and round fruits, good fruit conservation, less thorns, high fruit, large canopy with many branches for greater fruit production. The tree can be propagated by budding and grafting techniques. Top grafting is the most popular technique for propagating this species in the Sahel.

11.2.3 East Africa

Dry lands cover 70% of the Eastern Africa region making it one of the driest in the world. Over 50 species of indigenous fruit trees occur in East Africa playing a crucial role in the diets of local people. The fruits of many of these species are important as a source of income during the late dry season and early wet season, when stocks of cereal crops usually are low (Teklehaimanot 2008). *Carissa edulis*, *Parinari curatellifolia*, *Sclerocarya birrea*, *Tamarindus indica* and *Ziziphus mauritania* were identified as national priority species for domestication (Jama et al. 2007; Teklehaimanot 2008). In a more recent priority setting conducted in Ethiopia, Kenya, Sudan, Tanzania and Uganda resulted eight priority indigenous tree species for domestication. These included *Adansonia digitata*, *Balanites aegyptiaca*, *Cordeauxia edulis, Sclerocarya birrea*, *Tamarindus indica, Vitelaria paradoxa*, *Vitex doniana* and *Ziziphus mauritania* (Teklehaimanot 2008). Recently, Omotayo and Aremu (2020) also included *Garcinia livingstonei, Strychnos spinosa, Uapaca kirkiana* and *Vangueria infausta* among priority species of East Africa.

Adansonia digitata (baobab) of family Bombacaceae occurs in semi-arid, deciduous savannahs in Ethiopia, Somalia, Eritrea, Sudan, Kenya, Tanzania, Central Africa Republic and Congo. The most important benefit of baobab is derived from its fruits. The fruits are used in porridges and as snacks particularly for children (Jama et al. 2007). Seeds are also eaten fresh, dried or roasted. Fresh and dried leaves, which are rich in vitamin A, are cooked and eaten as a vegetable (Teklehaimanot 2008). The pod contains a very nutritious pulp, which is rich in vitamin C (Table 11.3), calcium, potassium, phosphorous, iron and protein. The dry

Table 11.3 Nutritional composition of the fruit pulp of priority indigenous fruit trees of Africa

Species	Country	Energy (KJ 100 g^{-1})	Protein (%)	Fat (%)	Vitamin C (mg 100 g^{-1})	Vitamin A (μg)	Iron (mg 100 g^{-1})	References
Adansonia digitata	Malawi	1480	3.1	4.3	179.1	21	58	Saka et al. (2008)
	Kenya	1214	2.2	0.8	270	–	7.4	Jama et al. (2007)
	Botswana	–	1.3		141.3	–	0.1	Amarteifio and Mosase (2006)
Annona senegalensis	Namibia	329	1.7	1.5	18.2	–	0.7	Saka and Msonthi (1994), Keya et al. (2000)
Balanites aegyptiaca	Kenya	1151	5	0.1	35	–	–	Teklehaimanot (2008)
Berchemia bicolor	Namibia	305	–	3.5	50.3	–	2.2	Saka and Msonthi (1994), Keya et al. (2000)
Chrysophyllum cainito	Nigeria	–	9.8	15.0	–	–	1.3	Arotupin et al. (2016)
Cordeauxia edulis	Ethiopia	446	13.3	11.6	–	–	–	Teklehaimanot (2008)
Detarium microcarpum	Mali	–	4.9	–	3.2	–	–	Kalinganire et al. (2008)
Diospyros mespiliformis	Namibia	210	1.4	0.5	24.6	–	1.0	Saka and Msonthi (1994), Keya et al. (2000)
Garcinia livigstonii	Namibia	258	0.8	0.3	5.4	–	0.3	Saka and Msonthi (1994), Keya et al. (2000)
Parinari curatellifolia	Malawi	1517	3	1.5	10.4	357	1.0	Saka et al. (2008)
	Tanzania	–	0.7	0.7	60.7	–	–	Saka et al. (2008)
	Namibia	533	1.6	0.5	70.9	–	0.9	Saka and Msonthi (1994), Keya et al. (2000)
Schinziophyton routanerii	Namibia	1410	7.8	0.5	27.0	–	2.5	Saka and Msonthi (1994), Keya et al. (2000)
Sclerocarya birrea	Malawi	–	–	–	–	35	1.7	Saka et al. (2008)
	Kenya	–	4.7	–	160.8	–	21.8	Saka et al. (2008)

	Kenya	225	3.6	0.5	194	–	–	Teklehaimanot (2008)
	Botswana		3.7	–	128.3	–	0.07	Amarteifio and Mosase (2006)
	Namibia	225	1.5	1.0	194	–	0.5	Saka and Msonthi (1994), Keya et al. (2000)
Strychnos cocculoides	Malawi	1390	11.5	6	22.9	22	60	Saka et al. (2008)
	Tanzania	–	0.47		46.2	–	–	Saka et al. (2008)
	Botswana	–	3.8	4.7	38.0	–	–	Saka and Msonthi (1994), Keya et al. (2000)
	Namibia	308	0.7	0.1	6.7	–	0.2	Saka and Msonthi (1994), Keya et al. (2000)
Tamarindus indica	Kenya	1490	4.1	1.6	9	–	–	Teklehaimanot (2008)
	Kenya	285	2	0.2	8	–	–	Jama et al. (2007)
Uapaca kirkiana	Malawi	1897	17	22.9	16.8	–	43	Saka et al. (2008)
	Tanzania	–	–	6.03	98.7	–	–	Saka et al. (2008)
Vangueria infausta	Malawi	1456	1.8	1.1	16.8	–	451	Saka et al. (2008)
	Tanzania	–	0.01	5.19	93.7	–	–	Saka et al. (2008)
	Botswana		3.0	–	67.7	–	0.09	Amarteifio and Mosase (2006)
	Namibia	498	1.4	4.3	4.7	–	1.1	Saka and Msonthi (1994), Keya et al. (2000)
Vitellaria paradoxa	Kenya	393	4.13	–	–	–	–	Teklehaimanot (2008)
Vitex doniana	Malawi	1445	5.7	2.6	19.6	175	285	Saka et al. (2008)
	Tanzania	–	0.26	0	98.7	–	–	Saka et al. (2008)
	Kenya	1459	2.6	29.6	1000	–	–	Teklehaimanot (2008)
Vitex mombassea	Tanzania	–	0.03	18.8	111	–	–	Saka et al. (2008)
Ximenia americana	Namibia	556	2.8	0.8	69.7	–	1.3	Saka and Msonthi (1994), Keya et al. (2000)

(continued)

Table 11.3 (continued)

Species	Country	Energy (KJ 100 g^{-1})	Protein (%)	Fat (%)	Vitamin C (mg 100 g^{-1})	Vitamin A (μg)	Iron (mg 100 g^{-1})	References
Ximenia caffa	Namibia	374	1.9	1.5	68.2	–	0.5	Saka and Msonthi (1994), Keya et al. (2000)
Ziziphus mauritiana	Malawi	1588	4.1	9.5	13.6	35	–	Saka et al. (2008)
	Namibia	1198	3.2	0.6	–	–	0.7	Saka and Msonthi (1994), Keya et al. (2000)
Ziziphus mucronata	Namibia	659	3.8	0.5	42.6	–	1.0	Saka and Msonthi (1994), Keya et al. (2000)

pulp is mixed with water to produce beverages. Coloured pulp is sold as sweet in many kiosks and supermarkets in Eastern Africa (Teklehaimanot 2008). Oil extracted from the seeds is often used for cooking. Bath oil, lotions and creams have also been developed from the oil for the cosmetic industries.

Balanites aegyptiaca, an indigenous African species as described earlier, has edible pulp and a hard woody endocarp enclosing an edible oil-rich seed (Table 11.3). Its young leaves are edible. The seeds are also rich in protein and energy. Local communities in drylands of Eastern Africa heavily rely on this resource as emergency food and are regular rural market commodities. Oil is extracted from the kernels are used for cooking and medicine. Commercially, *B. aegyptiaca* is a potential source of ingredients for the manufacture of cortisone and corticosteroid drugs (Teklehaimanot 2008).

Carissa edulis (simple spined num num), a small tree of family Apocynaceae is found distributed from Senegal to West Cameroons. Fruits and roots are consumed. These are used in sauces, condiments and spices as flavouring agents. Traditionally decoctions of roots are used as pain killer, chest complaints, in arthritis, rheumatism and to treat malaria. Root is useful in treatment of a variety of diseases including sickle cell anaemia, toothache, ulcer, worm infestation, epilepsy, and inflammation The fruits help in the treatment of dysentery. Various alkaloids such as saponin, flavonoids, tannins, anthraquinones and cardiac glycosides have been reported from root and fruit (Teke and Kuete 2014).

Cordeauxia edulis (yehib) is an indigenous leguminous shrub of family Fabaceae, mainly found in Ethiopia and Somalia. It produces a tasty edible nut of high nutritional and economic value. The nuts are rich in fatty acids and eaten fresh, dried, roasted or cooked. The nuts are sold on local markets in Ethiopia and Somalia. Leaves are infused as tea. Leaves also contain a brilliant red dye, cordeauxiaquinone that stains the hands and is used in dyeing of fabrics. Cordeauxiaquinone is also used medicinally to stimulate hemoponsis. The plant has attracted considerable interest as a potential food crop for arid areas (Teklehaimanot 2008). However, it is listed as one of the most threatened tree species by IUCN (1998).

Sclerocarya birrea (marula) is an indigenous African species belonging to the family Anacardiaceae, widely distributed across the Sub-Saharan Africa stretching from Senegal to Ethiopia in the north, southward to Natal in South Africa, and eastward to Namibia, Angola and southern Democratic Republic of Congo. Three subspecies of *S. birrea* are recognized: *S. birrea* subsp. *caffra*, *Sclerocarya birrea* subsp. *multifoliolata* and *Sclerocarya birrea* subsp. *birrea.* While *S. birrea* subsp. *multifoliolata* occurs in Tanzania, *S. birrea* subsp. *birrea* occurs through West, Northeast and East tropical Africa. *S. birrea* subsp. c*affra* is the most ubiquitous and occurs in East tropical Africa (Kenya, Tanzania), southern Africa (Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Swaziland Zambia and Zimbabwe). Kenya and Tanzania have higher genetic diversity of *Sclerocarya birrea* than other countries in the region. This species plays a very significant role in the diet and culture of people in many countries where it occurs. The fruit pulp is eaten fresh, boiled to a thick black consistency for sweetening porridge or fermented to make alcoholic drinks of both local and commercial value (Jama et al. 2007). The fruit is also used to make juice, jam, jellies and as a cosmetic agent. The kernels yield highly stable oil useful for cooking and manufacturing cosmetics. Butter is also extracted from the kernels, which is used for the production of cosmetics by cosmetic industries in Europe and USA (Teklehaimanot 2008). The leaves and bark have medicinal properties (Jama et al. 2007). The fruit *S. birrea* makes high value liquor, 'Amarula' in South Africa and is marketed worldwide.

Tamarindas indica (tamarind) is thought to have originated from Eastern Africa, from where it spread to Asia and Central and South America. The edible pulp is consumed fresh and used to make syrup, juice concentrates and exotic food specialities like chutney, curries, pickles and meat sauces. The fruit pulp contains high amount of vitamin C and sugar and is a much-valued food ingredient in many Asian and Latin American recipes. The seed is also a good source of protein and oil.

Vitellaria paradoxa (shea tree) of family Sapotaceae has been identified as a priority in Ethiopia, Sudan and Uganda. Both fruits and seeds of *V. paradoxa* are edible. The fruit is consumed fresh and sold on local markets. The oil is primarily used as a source of cooking fat. Shea butter is used by chocolate and cosmetic manufacturing industries worldwide. In Eastern Africa, shea has become an export commodity to a very small extent only in Uganda since 1990. However, the shea butter in Sudan and Ethiopia has never had access to the export market and still remains a source of household cooking fat by local communities (Teklehaimanot 2008).

Vitex doniana (African olive or Black Plum) belongs to family Lamiaceae. The ripe fruit of this species is edible and extensively traded locally. The oil extracted from the dried seeds of *V. doniana* is used for skin cream, resin and paint production. The leaves provide cattle feed, while other parts of the tree are used in traditional medicines (Teklehaimanot 2008).

Ziziphus mauritania (Ber or Jujube) of family Rhamnaceae produces fruits with high sugar content and a high level of vitamin C, phosphorus and calcium. The fresh fruits are mostly liked by children and eaten raw. Dried fruits are sold on local markets in Kenya and Sudan (Teklehaimanot 2008). The fruits are also boiled with rice and millet and stewed or baked or made into jellies, jams, chutneys or pickles (Jama et al. 2007). Oil is also extracted from its seeds.

11.2.4 Southern Africa

Indigenous fruit tree species are important sources of vital nutrients and income to rural households in southern Africa (Akinnifesi et al. 2008a, b). Several studies have confirmed that wild fruits from the miombo woodlands are the major sources of coping with seasonal food shortages in Zimbabwe, Zambia, Malawi, Mozambique and Tanzania (Akinnifesi et al. 2008a, b, c, d; Dagar et al. 2020). Although over 60 species of indigenous fruit trees have been cited from southern Africa, the following are among the top most ranked for research and development in southern Africa (Table 11.2):

Uapaca kirkiana (sugar plum, masuku or mahobohobo) is a member of the family Phyllanthaceae. This species occurs naturally in southern, central and eastern Africa including Angola, Democratic Republic of Congo (DRC), Burundi, Tanzania, Malawi, Mozambique, Zambia and Zimbabwe. Extensive pure stands are often found on sandy or gravely soils with good drainage (Chirwa and Akinnifesi 2008) but with low exchangeable cations, organic matter and nutrients. Traditionally wood is used for carpentry and charcoal making. Fruit is a delicacy and consumed raw. The fruit juice is mixed with sorghum meal to form a thin, orange-flavoured porridge. Root infusion is used to treat indigestion and dysentery. The leaves are used as repellent to cockroaches. The bark is used as medicine against dysentery and indigestion. Leaves are used as fodder for cattle and help against dysentery and intestinal-related problems (Omotayo and Aremu 2020).

Some of its products have become commercialized at local, regional and international levels. Examples of commercial alcoholic beverages from *U. kirkiana* fruits include wine and Chikoto beer. The fruits are set between January and February, and mature in August and November. Another notable importance of *U. kirkiana* is its association with ectomycorrhizal fungi that form mushrooms, some of which have a significant impact on the livelihoods of communities where it occurs. Sileshi et al. (2007, 2008) have reported the impact of fertilizer application and pest management in this commercial species. Amanita, *Cantharellus, Lactarius* and *Russula* constitute the most common genera of fungi which typically form ectomycorrhizae. It also hosts the edible bug *Encosternum delegoruri* in Malawi and Zimbabwe.

Strychnos cocculoides (monkey orange) belongs to the family Loganiaceae and widely occurs in Central and Southern Africa (Chirwa and Akinnifesi 2008). The fruit is rich in sugars, essential vitamins, minerals, oils and proteins. The ripe fruit is eaten fresh or is used to prepare a non-alcoholic drink (Saka et al. 2008). The seeds contain strychnine, which is a toxic substance. The fruit is used to make a dye that provides protection from insects and for colouring trays and containers. The roots are chewed to treat eczema while its decoction is used as a cure for gonorrhoea by local communities. The fruit is used in making eardrops, and a fruit preparation is mixed with honey or sugar to treat coughs. Ground leaves are used to treat sores and when soaked in water, the drained liquid is used as a spray for vegetables to repel insects such as aphids and scales. The wood is suitable for construction, making tool handles and building materials.

Strychnos spinosa (natal orange) is widely distributed in tropical and subtropical Africa in almost all regions bearing sweet-sour fruits consumed raw when ripe and making juice, jelly and beverages. The plant is used for snakebites, venereal disease, increasing the flow of breastmilk in lactating mothers, and enhancing physical strength. The roots are prepared as tea and use against cold symptoms, cough, gonorrhoea, and malaria (Omotayo and Aremu 2020).

Parinari curatellifolia (Mbola plum), a member of the family Chrysobalanaceae, is a large evergreen tree indigenous to Africa. Its known distribution covers 37 countries across Africa. In southern Africa it occurs in woodland and wooded grasslands. It produces edible fruit with 88% carbohydrates and rich in vitamin C. The fruit may be eaten raw or made into a porridge. It is also made into a refreshing non-alcoholic drink. The oil-rich seeds (with 38% oil content) are pounded and used for making soup. In addition, it is a source of charcoal, timber and medicinal products.

Vangueria infausta (wild medlar) of family Rubiaceae is widely distributed in tropical Africa including Uganda, Kenya, Tanzania, Malawi, Mozambique, Zimbabwe, Namibia, Botswana, Swaziland and South Africa. The fruit is relished when ripe, used in puddings and even stored dry and the roasted seeds are consumed. Traditionally, it is used against gastro-intestinal disorders, malaria, pneumonia, cough, menstrual problems, parasitic worms, chest complaints, snake bites, infertility, fever, candidiasis and abdominal pains.

Ziziphus mauritiana (*Jujube*) as described above under Sahel and East Africa. It has been among the top preferred indigenous fruits widely consumed and traded fruit in southern Africa (Akinnifesi et al. 2006).

Ziziphus mucronata (buffalo thorn) is a small to medium size tree native of southern Africa. The ripen fruits are deep brown to red colour and are eaten when ripe and are found from February to August. The leaves are good fodder. The flowers bloom from October to April and attract honey bees. The leaves are edible and can be cooked as vegetable. The seeds can be roasted and ground as a substitute for coffee and the fruit are used to prepare a type of local beer (*ombike*). The wood is used for making implements and also as fuelwood. The leaves bark and roots are used medicinally for respiratory complaints and skin infections, and chest and stomach disorders. In east Africa, roots are said to be used for treating snake bites.

11.3 Nutritional Value

Recent analyses involving more than 3000 indigenous African species show their fruits are generally more nutritious than their exotic counterparts (Cernansky 2014; Akinnifesi 2017). Fruits and nuts from indigenous trees are a good source of energy, carbohydrates, protein, fats, vitamins and minerals (Table 11.3; Stadlmayr et al. 2013). The health benefits of fruits are also mediated through their antioxidant capacity (Vertuani et al. 2002). Proximate analysis (i.e. analysis of nutrients in which the gross components such as carbohydrate, proteins, fat, etc.) of fruits and seeds have been done for some species. However, fruits were mainly analysed for macronutrients and minerals and vitamins, mostly vitamin C (Stadlmayr et al. 2013). The lack of uniformity in methodology and incomplete reporting makes comparison of results across studies very difficult. In this section, we will focus on analysis of carbohydrate, proteins, fat and vitamin contents of fruits, nuts and seeds of the priority species. Since substantial compositional differences exist within a species, we provide information per country for priority species. For more detailed information, we refer the reader to Stadlmayr et al. (2013), who provide a general review of the literature.

11.3.1 Carbohydrate Content

Many fresh fruits are important sources of carbohydrates. Across a range of studies, the average carbohydrate contents were 74.9 g 100 g^{-1}in *Adansonia digitata* fruit pulp, in *Balanites aegyptiaca* dried fruit, 60.4 g 100 g^{-1}in *Tamarindus indica* fruit pulp, 28.7 g 100 g^{-1}in *Uapaca kirkiana* 68.8 g 100 g^{-1} fruit (Stadlmayr et al. 2013). On the other hand, *Ziziphus mauritiana* fruit pulp had very low carbohydrate content (8.3 g 100 g^{-1}). Nuts and seeds are also sources of carbohydrates. For example, seeds of *Irvingia gabonensis* contain 24–26% carbohydrate and the energy content is 641.1 KJ 100 g^{-1}; of *Cordeauxia edulis* carbohydrate 63.9%, energy 1666 KJ (Ejiofor et al. 1987; Adeniyi et al. 2014). *Chrysophyllum cainito* fruits contain 26–30% carbohydrate (Amusa et al. 2003; Arotupin et al. 2016). Besides these, Keya et al. (2000) while reporting chemical composition of veld fruits and vegetables, reported 86.8% carbohydrate in pulp of *Berchemia bicolor*, 81.7% in *Sclerocarya birrea*, 75.0% in fruit of *Schinziophyton rautanerii,* 25.0% in fruit (79% in peel) of *Vangueria infausta,* 28.9% in fruit of *Parinari curratellifolia,* 28.5% in *Ximenia americana* (energy 556 KJ 100 g^{-1}), 60.9% in fruit of *Z. maurtiana* (energy 1198), 34.4% in fruit of *Z. mucronata* (energy 659), 68.8% in flesh plus peel of *Grewia retinervis* (energy 1250), 42.1% in flesh plus peel of *G. avellena* (energy 851) and 67.0% in flesh plus peel of *G. bicolor* (energy 1302). The seeds of *Cordeauxia edulis* are also rich in fatty acids. Different parts of the fruit (peel, pulp, cortex, mesocarp, endocarp, etc.) contain different amount of carbohydrate and other mineral contents as reviewed by Dagar et al. (2020).

11.3.2 Protein Content

The protein content of the fruit pulp is highly variable, but the values reported for many species (Table 11.3) are higher than for commercial fruits such as orange (0.7 g 100 g^{-1}), mango (0.6 g 100 g^{-1}), grape (0.5 g 100 g^{-1}), banana (1.2 g 100 g^{-1}) and papaya (0.6 g 100 g^{-1}) (Rathore 2009). For example, *Chrysophyllum cainato* fruits with 8.8–9.8% protein (Amusa et al. 2003; Arotupin et al. 2016) contain 10 times more protein than those fruits. The seed of some species are rich in proteins. For example, *Irvingia gabonensis* seeds contain 7.4% protein (Ejiofor et al. 1987). The seeds of *Adansonia digitata* from Malawi*, Parinari curatellifolia* from Tanzania and *Sclerocarya birrea* from Kenya were reported to be 28.7%, 47%, and 33% protein, respectively (Saka et al. 2008). Seeds of *Cordeauxia edulis* contain protein 10.8% protein. *Adansonia digitata* seeds contain high amount of essential amino acids such as lysine and tryptophan (Osman 2004). Since lysine is limited in many cereals, *Adansonia digitata* seed protein holds high potential for fortifying cereal dominant diets (Osman 2004).

11.3.3 Fat and Oil Content

Although the fat content of the fruits and seeds varies widely with species, it is generally comparable or much higher than most commercial fruits (Table 11.3). For example, *Dacryodes edulis* fruits are 48% fat, while *Chrysophyllum albidum* fruit pulp is 14–17% fat (Amusa et al. 2003; Arotupin et al. 2016). The seed kernels of *Adansonia digitata*, *Parinari curatelifolia* and *Sclerocarya birrea* have been reported to contain 20–75% fat, which is comparable to those of leguminous seeds such as soybean (12–40%) (Saka et al. 2008; Thiong'o et al. 2002). According to Ejiofor et al. (1987), seeds of *Irvingia gabonensis* contain 53% fat, while Adeniyi et al. (2014) reported 10% fat, which is lower than in soybean seeds.

11.3.4 Vitamins

Vitamin C (ascorbic acid) was the predominant vitamin reported for most indigenous fruits; other vitamins were rarely reported (Stadlmayr et al. 2013). Although there is considerable variation within and between species, indigenous fruits are rich in vitamins (Table 11.3). The vitamin C levels of the edible parts of some species are superior to those of exotic and domesticated fruits. *Adansonia digitata*, *Sclerocarya birrea* and *Irvingia gabonensis* are rich sources of vitamin C, as they contain more than 30% of the nutrient reference value of 60 mg vitamin C per 100 g food (Stadlmayr et al. 2013). The fruit pulp of *Adansonia digitata* represents the most important natural sources of vitamin C, while the leaves are characterized by thigh content of provitamin A (Vertuani et al. 2002). According to a number of studies (cited in Kamatou et al. 2011; Stadlmayr et al. 2013), the vitamin C contents of *Adansonia digitata* fruit pulp across Africa (126–509 mg per 100 g) are 3–5 times higher than the vitamin C content of oranges (50–70 mg per 100 g). The vitamin C content of *Sclerocarya birrea* fruit pulp (85–319 mg per 100 g) is 2–4 times higher than those reported for fresh oranges or orange juice (Saka et al. 2008). Leakey (1999) reported high vitamin C content in the Nigeria population (403 mg per 100 g) that was twice as much as that of the Botswana population. Thiong'o et al. (2002) also reported Vitamin C content of 90–300 mg per 100 g in Kenyan populations of *Sclerocarya birrea*. The vitamin C content of 49–65 mg per 100 g reported for *I. gabonensis* (Stadlmayr et al. 2013) is comparable with the vitamin C content of oranges. The daily adult requirement of vitamin C is 45–80 mg per 100 g which implies that only 50 g of the edible part of indigenous fruits is sufficient to supply the body requirement of the vitamin. It is argued that without this valuable contribution many children who are most vulnerable and the chief consumers would be affected by dietary deficiencies (Makombe 1993). The indigenous fruits could also be a good source for the malnourished and people living with HIV/AID in Africa. The Vitamin A levels varied from 21 μg per 100 g in *Adansonia digitata* to 337 μg per 100 g in *Parinari curatellofolia* (Table 11.3).

11.3.5 Minerals

The fruits and seeds of indigenous fruits are also good sources of minerals especially iron (Table 11.3), calcium, magnesium, phosphorus, potassium, sodium, zinc and copper. However, high variability in mineral contents exists among and within the species (Stadlmayr et al. 2013). Across several studies iron values were high in dried fruit of *Balanites aegyptiaca* (13.8 mg per 100 g), *Uapaca kirkiana* (11.8 mg per 100 g) compared to other species (Stadlmayr et al. 2013). The Recommended Daily Allowance (RDA) of iron for 7–10-year-old children is 23 mg. Consumption of 1 kg of some of the raw fruits per day will give the child the recommended level of iron intake (Lutham 1997). This is lower than for commercial fruits for which more than 10 kg are required to meet the RDA.

11.3.6 Antioxidants

Carotenoids, flavonoids and polyphenols are the main phytochemicals with antioxidant capacities in fruits. Antioxidant capacity was not reported for most species except for *Adansonia digitata, Irvingia gabonensis*, *Garcinia kola* and *Dacryodes edulis* (Stadlmayr et al. 2013; Terashima et al. 2002). *Adansonia digitata* has a particularly high anti-oxidant capacity mainly because of it is high vitamin C content which is equivalent to 6 orange per 100 gm. According to Vertuani et al. (2002) *Adansonia digitata* fruit pulp had higher antioxidant capacity than fresh fruit pulp of strawberries, kiwi fruit, oranges and apples. Indeed, the integrated antioxidant capacity of *Adansonia digitata* fruit pulp (11.1 m mol g^{-1}) was 10 times more than that of orange fruit pulp (0.3 m mol g^{-1}) on a fresh weight basis (Vertuani et al. 2002). *Garcinia kola* seed is believed to contain flavonoids, with antioxidant capacity (Terashima et al. 2002).

Research on the nutritional, anti-nutritional and medicinal values of indigenous fruits has been on-going. However, this is occurring in an uncoordinated manner. In most cases, the analyses and reports are incomplete. Authors often focused on analysis of one or a few nutrients, and as can be seen in Table 11.3, our knowledge of the nutritional values is limited.

11.4 Fruit Trees and Agricultural Income

11.4.1 Income Generation

As discussed above, fruits of many trees such as marula, bird plum (eembe), monkey oranges, baobab (*Adansonia digitata*) and *Kigelia africana* are sold in market or along road sides as such or by transforming these into juice or jam and cake. Dry fruits of bird plum are frequently available in small markets even offseason. Gwary et al. (2000) conducted a survey and found that in north-central region of Namibia, 82% of the respondents claimed to get cash income from selling indigenous fruits or their products. The sold products were *Strychnos cocculoides* (54% of all households), false mopane (*Guibourtia coleosperma*, 46%) and *kashipembe* (46%), manketti nuts (21%), *Strechnos pungens* (7%) and *Dialium engleranum* (7%). Kalaba et al. (2009), in their survey found that in Zambia fruits of *Uapaca kirkiana* are collected and sold in local market by 74% of respondents, and of *Anisophyllea boehmii* by 71% followed by fruits of *Strechnos cocculoides* by 50%, *Parinari curatellifolia* by 30% and rest by sailing the small quantity of other fruits. Results of many such surveys from other regions are also available indicating products from marula, bird plum, *Hyphaene petersiana, Ziziphus maurtiana, Z. mucronata*, and *Diospyros mespiliformis* showing the importance of the indigenous fruits in meeting the livelihood requirements. Besides cash income, there are so many socio-economic advantages of these trees as these are the source of fuel, timber, agricultural implements, refreshing drinks and medicine.

Some active research has been undertaken in manketti and *Ximenia* oil and potentials of *Adansonia digitata* and *Kigelia africana* oils have been explored. In Kavango region in North Namibia, manketti (*S. rautanenii*) and Devil's claw (*Harpagophytum zeyheri*) are sold in local markets and *kashipembe* (alcohol) is the most important use of the manketti nuts (Vincent 1998). The process of oil extraction from nuts has been perfected by local people. Many of these have gone for commercial purpose. Research efforts are needed to find commercial uses of species such as *Diospyros mespiliformis* and *Parinari curatellifolia* fruits, which are already consumed, stored and transformed in various products by the rural people. Barion et al. (2001) indicated that it is possible to use dried bird plum fruit for making commercially acceptable country-wine. For commercial exploration, the species must be domesticated at farm level so that the required product is available in sufficient quantity. Thus, it is clear that above-mentioned fruits are helping in income generation of the rural people and have commercial potential and need domestication.

Omotayo and Aremu (2020) while reviewing studies revealed that the trading of fruits collected from the wild is a profitable enterprise and fruit collection is an efficient labour allocation strategy and its returns to labour are considerably higher than that of crop production. For example, the collection of *Uapaca kirkiana* generated an average of $50 in Zimbabwe and $78 for *Sclerocarya birrea* in South Africa (Akinnifesi et al. 2007). Furthermore, studies in Malawi, Tanzania, and Zimbabwe found that the percentage of net profit of indigenous fruit products reached 28% with higher profits being obtained in locations that are close to the markets (Akinnifesi et al. 2007). In South Africa, communities collectively harvested about 2000 Mg of *Sclerocarya birrea* fruits and earned $180,000 annually, representing more than 10% of average household income in the communities (Ham 2005). In addition, the members of a popular southern African Natural Products Trade Association reported gross revenue of $629,500 from the sale of fruit tree products. The key fruit tree products were obtained from *Sclerocarya* *birrea* and *Adansonia digitata* that generated $126,420 and $44,120, respectively (Akinnifesi et al. 2007). Based on a recent market projection, the potential market of *A. digitata* was valued at $960 million. Thus, the availability of market near to product collection is must and moreover, there is need to domesticate the important fruit trees on the farm for getting better managed product rather than collection alone from the wild.

11.4.2 Trends in Commercialization

Despite the importance of indigenous fruits to African consumers, relatively little success has been made in commercialization of their products. Trade in indigenous fruits is poorly developed and lags far behind the trading of exotic fruits. Only a couple of indigenous fruit products have made it onto the international market. ‘Amarula Cream’, made from the fruits of *Sclerocarya birrea* by the Distell Corporation in South Africa is probably one of the best-known examples (Ham et al. 2008). The Amarula Cream is sold in 63 countries and it is presently the second best-selling cream liquor in the world (Akinnifesi et al. 2006).

Another good example of successful commercialization is the seed oil of *Allanblackia floribunda*. The seed of this species yields oil widely used by local people in Tanzania. The oil was produced at commercial scale between 1972 and 1984 with involvement of local state-owned and community-led organizations in Tanzania (Mpanda et al. 2014). After a collapse of production, the business was revived in 2004 due to renewed interest in international markets. An ambitious programme was initiated to select productive germplasm and develop technology for earlier production of newly planted trees linking East and West African production areas to a major global supply chain (Mpanda et al. 2014).

The commercialization of *Dacryodes edulis* in Central Africa is another example. The fruit is exported mainly to the USA, Europe and also other countries within the region. The total export of its fruit from Cameroon was estimated at 93,995 Mg in 2007/2008 (Anonymous 2010).

Adansonia digitata is being exported to European and US markets as natural product by PhytoTrade. According to Sanchez et al. (2010) it is becoming a billion-dollar industry for Africa and creating employment opportunities for over 2.5 million households.

11.5 Challenges

11.5.1 Post-harvest Losses

Unlike exotic fruits, which are normally harvested according to specified methods and harvesting time, indigenous fruits are often collected using crude methods such as by knocking the fruit down with sticks, throwing objects to dislodge fruit, shaking the stem or branches, climbing the trees, and picking fruit up from the ground following abscission. These methods often cause excessive bruising, thus reducing the shelf life, quality and market value of the fruits and also damage the tree (Kadzere et al. 2004; Kalaba et al. 2009). The indigenous fruits that are affected the most include marula, *Uapaca kirkiana* and *Anisophyllea boehmii* due to their delicate outer covering when the fruit is fully ripe. In an attempt to reduce post-harvest losses of fruit, the local people use baskets called *museke* to transport these fruits to market. The basket allows the air to circulate through thereby avoiding fruit rot. Some rural people prefer harvesting fruit that are not yet fully ripe. The main injuries that the fruits sustain are abrasion injuries, impact injuries and compression injuries. These considerable losses of fruits reduce the quantity and quality of fruit available for consumption and sale. Fruit collectors often collect fruits that have fallen to the ground after abscission, which would leave only a limited consumption period and increase the chances of mechanical damage during the transport process. Methods for post-harvest handling of indigenous fruits are also poorly developed. The fresh fruits that are being marketed in urban centres go through a long handling chain before reaching the final consumer. Crude harvesting, packaging and transport activities decrease the shelf life of indigenous fruits dramatically and lead to spoilage and waste. Thus, fruits are subjected to post-harvest losses, both in quantity and quality. Saka et al. (2004) reported that fresh fruit incur direct or indirect nutrient and general quality loss from the field to the consumer. In quantifying the degree of fruits lost, Hughes and Haq (2003) reported post-harvest losses of fruit to be between 40% and 60%. These losses are attributed to a lack of knowledge in fruit handling and marketing.

11.5.2 Challenges in Processing and Value Addition

As in most products in Africa, indigenous fruits are often traded as raw materials or semi-processed raw materials. There are many problems along the supply and processing chains of indigenous fruits, and commercialization activities are in their infancy. Commercial companies are also processing fruit products with limited success (Ham et al. 2008). The reasons for this include lack of machinery to undertake processing, lack of skills to undertake research and development on fruit processing, lack of skills to run processing facilities, lack of finance to establish processing facilities, high maintenance costs for spare parts that have to be imported, high unit costs of running small processing facilities (Ham et al. 2008). While commercially viable processing requires a reliable supply of raw materials, uniformity and reliable quality of products, the situation is less than ideal for most indigenous fruits. As a result, cottage industries have failed to thrive. A case in point is the Mulunguzi winery in Malawi, which at one time produced wine from *Syzygium owariense*, *Uapaca kirkiana* and *Tamarindus indica*. Enterprises that processed and exported *Ziziphus mauritiana* and *Sclerocarya birrea* were initiated in Zambia but collapsed partly due to irregular supply of raw materials (Akinnifesi et al. 2009a, b). Access to technologies that meet processing and market requirements is also limited in areas where most indigenous fruit. Local small-scale processors, the majority of which are women, face a variety of problems including lack of skills, access to information and credit. Commercial processors also experience problems related to government support and technology information.

11.5.3 Challenges in Marketing

The lack of capacity to market fresh produce among local producers and the loss in quality during storage and transportation to the final market is a major limitation. Farmers often have to wait for traders before harvesting, which presents a particular problem during peak production periods and results in losses throughout the market chains. The lack of uniformity in quality is also a serious constraint. A basket of fruits usually comes from many different trees and as a result, wholesalers do not pay a good price (Leakey et al. 2002). Product quality and consistency of quality are major factors in the successful marketing. For many small-scale producers, consumer requirements remain unknown. Fruit markets also lack the necessary infrastructure and support systems to function optimally.

11.5.4 Other Challenges

There are some other inherent challenges which include inadequate baseline data on biochemical and food-related nutritional properties of fruit of individual indigenous fruit tree in relation to agro-climatic distribution of these trees; indiscriminate and illegal logging; lack of knowledge about the economic importance of different products hence the level of acceptability and accessibility of indigenous fruits; lack of policies regarding preference of local species rather than exotics creating insidious domination and preference for the exotic fruit tree species; inadequate knowledge on effective harvesting and storage technique as well as processing facilities; inadequate research facilities, priorities and support to innovations; and lack of political will and policies regarding promotion of domestication of indigenous fruit trees, value addition, creation of storage facilities and handling of market issues in favour of poor farmers.

11.6 Biodiversity Conservation

11.6.1 Indigenous Fruit Tree Diversity

Agrobiodiversity is the foundation of African agriculture, providing food, nutrition, and health and livelihood needs. Of the 20,000 plant species producing edible products, only 0.5% have been domesticated as food crops, although potential to develop new crops through participatory tree domestication has been a subject of intensive research in the tropics (Leakey et al. 2017). Harnessing the diversity of indigenous fruit trees may contribute to improved Africa's diet, nutrition and health, while reducing genetic erosion and extinction (Akinnifesi 2017).

One notable characteristic of wild tree species is their enormous genetic variability. Information on phenotypic and genetic variation is a prerequisite for the domestication and improvement of indigenous fruit trees. However, this has been studied only in a handful of the priority species such as *Adansonia digitata* (De Smedt et al. 2011; Munthali et al. 2012) and *Uapaca kirkiana* (Mwase et al. 2006). Therefore, investment is need in research for many of the species.

11.6.2 Overexploitation, Loss of Habitat and Ethno-Ecological Knowledge

There is a growing concern that increased interest in commercialization of products from the wild might cause over-exploitation. For example, in eastern Zimbabwe, where baobab bark is harvested for craft purposes, the trees are in danger of destruction in the short term as a result of harvesting and trade arrangements (Dovie 2003). Overexploitation combined with lack of natural regeneration, droughts and land clearing for agriculture, mining and infrastructure pose threats to baobab tree populations (Sanchez et al. 2010). Wild populations and the genetic diversity of many other species (e.g. *Cordeauxia edulis*) are threatened by increased clearing of forest for farms. This stresses the need for conservation strategies for wild populations and the need for planting on farmland. In many areas other indigenous fruit trees are undergoing losses due to habitat alteration through monocrop agriculture and cutting of trees for construction, fuelwood and charcoal (Teklehaimanot 2008). Much of the knowledge on indigenous tree species also remains with the local people, while scientific information on their uses and products remains inadequate (Haq et al. 2008).

11.7 Research Needs

A key research need is in the area of tree ecology and management. Such information can inform decision on where to cultivate desired species of trees. It is important to determine suitability of sites using either experimentation or modelling for large scale plantations. For example, a recent modelling study by Sanchez et al. (2010) identified areas highly suitable for wider cultivation of *Adansonia digitata* in Africa. Such information is urgently needed for scaling up the cultivation of other priority species as tree crops. Significant information is also needed on tree spacing, training, pruning, pest and disease management as well as harvesting, post-harvest management and value addition.

Another priority area for research is product and enterprise development. The narrow production period of some indigenous fruit trees results in the simultaneous ripening of all fruits. This often causes a glut in the market and low prices, followed by relative scarcity and high prices. Processing of fresh fruits immediately after harvesting may reduce losses. There has been relatively little work on product development and market standards. Hence, new innovative research and development efforts are needed to bring about improvements in marketing and small-scale enterprises. Research on processing, value addition, quality assurance and certification of products are also necessary for product development.

A third priority area for research is tree-crop interactions involving indigenous fruit trees. The planting of indigenous fruit trees on farmland can improve the productivity and sustainability of agriculture because trees are capable of increasing water and nutrient use efficiency of the systems. However, information is scanty on the ecological functions of such trees. Many of the areas where indigenous trees are managed in areas that are normally characterized by poor soil fertility and aridity. As discussed in Sect. 11.2, the influence of trees on microclimate and soil fertility plays a crucial role in the production of associated crops in these drylands. This has been traditionally exploited by farmers to sustain crop production especially in the parklands. However, problems such as shading and competition for water and nutrients remain subjects of scientific research. Although most studies on tree–crop interactions have focused on tree-cereal combinations, the results demonstrate that trees have highly variable effects on yields of the associated crops. Their effect on grain yields of cereals was found to be variable (Bayala et al. 2014). Yields of leguminous crops such as cowpea, groundnut and pulses were less affected by trees. On the other hand, tuber yields of the root crops *(e.g., Colocasia esculenta*) were improved under trees compared to the treeless monoculture plot (Bayala et al. 2014).

Empirical studies (reported in Boffa 1999) and analyses indicate reduction in yields of cereal crops due to the competition between the trees and the annual crops (Bayala et al. 2008, 2012). For example, Boffa (1999) reported reduction in sorghum and millet yield under *Vitellaria paradoxa*. Similarly, analyses by Bayala et al. (2012) revealed reduction in cereal yields under *Adansonia digitata*. Competition for light, nutrients and water between the trees and the crops were found to be the most important factor in yield reduction. However, the yield losses from the cereal crops are compensated for by fruit yield. Although in the short-term crop yields may be reduced due to competition, in the long-term favourable soil conditions are provided by the indigenous fruit trees (Bayala et al. 2002). These tree–crop interactions have been a subject of research only under a few species such as *Adansonia digitata*, *Parkia biglobosa* in the Sahel (Bayala et al. 2012; Sanou et al. 2012). Planting dwarf trees or crown pruning may reduce the shading effect, and its role as a management tool for reducing competition has also been studied. For example, studies on the pruning of *Parkia biglobosa* and *Vitellaria paradoxa* in the Sahel (Bayala et al. 2002, 2008) show that totally pruned trees give higher millet yields than due to effects of large tree crowns on photosynthetically active radiation (PAR). In the short-term millet yield could be improved by crown pruning, but long-term effects may depend on the ability of the trees to maintain soil fertility and on how quickly the trees recover from pruning (Bayala et al. 2002). While crown pruning may reduce competition, this must be balanced by the species ability to recover and produce fruits. Generally, slow recovery of crown in pruned trees is the most desirable characteristic in order to avoid the negative effect of tree shade on adjacent crop (Bayala et al. 2008). However, our understanding of when and where crop–tree interactions lead to increases in soil fertility or result in yield reduction is still limited. Hence, researchers need to generate more information on the attributes of the species and the processes that are involved in making each of these practices beneficial or not. This may be achieved through a combination of experimentation and process modelling. Valuing the contribution of indigenous fruit trees to the national economy is also long overdue. This can help in redirecting investments in research and development.

Research efforts are also needed to develop desired clones through tissue culture. This becomes more important for trees such as marula (being unisexual) to ensure large number of female trees. Investments in research are needed for genetic improvements in fruit quality, productivity and other desired traits in most preferred and economically important fruit trees.

11.8 Policies and Incentives

Beyond the basic research, enabling conditions, such as governance, gender synergies, secured land tenures, investment, proper and cheap financial support, markets for agroforestry inputs and sales of the products. This requires appropriate policy initiatives supporting political, social, cultural, economic and ecological factors to address the livelihood security of the poor (Kuyah et al. 2020). The guidelines formulated by FAO (2013) provide good fodder for developing suitable agroforestry-related initiatives including related to fruit trees, which include creation of awareness of the benefits of agroforestry systems among all stakeholders at local and global level; resolving unfavourable regulations and legal restrictions related to harvesting and marketing the produce and developing mechanism for interactions among the farming community and other stake holders at national and global level; securing of the land – use policy and land tenure issues at local level; strengthening the agroforestry policies that take into account the role of trees in rural development; organization of intersectoral coordination for better policy coherence and synergies; develop protocols at national and global level to pay the farming community and other agroforestry-dependent stake holders to pay suitably for the environmental services rendered by the agroforestry systems; strengthening of farmers' access to markets for agroforestry products (including fruit juice, oil, medicines, dairy and poultry products) and ensuring suitable prices for agricultural commodities; ensuring gender empowerment encouraging women-folk in sharing agroforestry benefits; and engaging good governance of rural activities such as skill development, creation of self-help groups and mass tree plantations.

The agroforestry policy must recognize the potential of indigenous, traditional and improved agroforestry practices to reduce poverty, enhance productivity, while also making agricultural landscapes more resilient to the risks of climate change. The comprehensive policy must intend to address the increasing demand for timber, food, fuel, fodder, fertilizer (adopting fertilizer trees) and fibre, while at the same time creating employment opportunities and generating income. India has become first nation to develop National Agroforestry Policy in 2014, which envisages the development of a National Agroforestry Mission/Board with an initial investment of approximately USD 33 million, to coordinate agroforestry-related activities in the country and the policy document highlights the climate change mitigation and adaptation benefits of agroforestry and it is assumed that the agroforestry plan will help increase the area under agroforestry from 25 to 53 million ha (NAP 2014). The main strategies of implementation of the policy (which can successfully be implemented in other nations including in Africa with minor modifications) may include: (1) Establishment of institutional set up (such as AF Mission or Board formation) at national level to promote agroforestry; (2) establishment of simple regulatory mechanism for harvesting, transiting and marketing of AF produce; (3) developing sound data base and information system; (4) invention in research, extension and capacity building; (5) improving farmers' access to quality planting material; (6) providing institutional credit and insurance cover for adopting agroforestry; (7) facilitating increased participation of industries dealing with AF products, mainly in rural areas at the sites of production of a particular commodity and encouraging farmers' cooperative or self-help groups; (8) strengthening farmers' access to markets for AF products and ensuring to them the profitable prices for their produce; (9) incentives to farmers for adopting AF practices; (10) promoting sustainable AF for renewable biomass-based energy and (11) suitable payment of agroforestry services to those who adopt the agroforestry practices.

11.9 Conclusions and Prospects

Through the propagation and cultivation of indigenous fruit trees on farm, opportunities exist for developing indigenous fruit trees as horticultural crops and for wider commercialization of their products. Past research has identified priority species for

R & D in many parts of SSA. Appropriate domestication strategies and protocols for vegetative propagation have also been developed for some of the priority species. Very few cases of active promotion and successful commercialization have been documented in Africa. The challenge is to develop superior ideotypes for the market, which can be done through clonal propagation. This will require more strategic research tailored at consumer needs and preferences. More research is also needed to develop appropriate field management practices. Tree crops for the future that will emerge from the domestication of indigenous fruits should aim at meeting farmer needs and market demand; creating or expanding market opportunities through superior germplasms and products, and development of market ideotypes.

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