PROTA

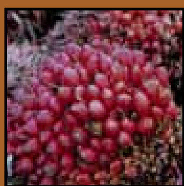
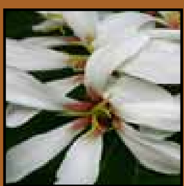
Vegetable oils of Tropical Africa

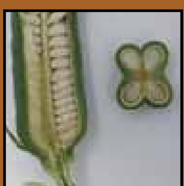
Conclusions and recommendations based on PROTA 14: 'Vegetable oils'









Plant Resources of Tropical Africa

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Conclusions and recommendations
based on PROTA 14: 'Vegetable oils'

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PROTA Foundation
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1. Introduction

1.1 About this booklet

The PROTA handbook volume, PROTA 14: *Vegetable oils* was published in September 2007. Following the format of earlier handbooks, PROTA 14: *Vegetable oils,* comprises a series of in-depth reviews on valuable (oil-producing) plant species in tropical Africa. The information is available in English and French, and reviews are freely available online (www.prota.org). The books and CD-ROMs can be obtained from PROTA's distributors and offices.

Vegetable oils are important in human nutrition, providing energy and essential fatty acids and facilitating absorption of fat-soluble vitamins. They constitute about 80% of the world's supply of natural oils and fats, the remainder being of animal origin.

In addition to their edible uses, vegetable oils are also used in products such as soap and cosmetics, household commodities such as candles, lamp fuel and paint, and an array of industrial applications, notably lubricants. The use of vegetable oils for biodiesel has assumed global importance in the quest for renewable alternatives to fossil fuels. The need for food security in Africa, however, is widely regarded to precede the importance of biofuel production.

While nearly 250 plant species in tropical Africa are known to yield oils and fats, relatively few are used on a wide scale in Africa. Important cultivated oil-producing plants include oil palm (*Elaeis guineensis*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), coconut (*Cocos nucifera*), sunflower (*Helianthus annuus*), soya bean (*Glycine max*) and safflower (*Carthamus tinctorius*). Others, such as the shea butter tree (*Vitellaria paradoxa*) are wild harvested from managed or entirely natural populations. PROTA 14: *Vegetable oils,* provides a detailed synthesis of information from thousands of scattered publications about these species, among which 48 species are considered the most important.

To make the information accessible to as wide an audience as possible, this booklet, an addition to the PROTA Recommends Series, has condensed the key findings from PROTA 14: *Vegetable oils.* The conclusions and recommendations presented here were developed by a stakeholders' consultation, to reflect opportunities and needs for sustainable vegetable oil production in Africa. The findings are aimed at target groups, whose work impacts on the end-users of PROTA's information: people whose livelihoods depend on plants (farmers, forest communities and entrepreneurs in Africa).

PROTA's outreach to target groups:

- Rural development agencies, including extension services, must be made aware of appropriate **Candidate technologies** that are ready to be tested or applied in farmers' fields.

- Vocational training centres need to incorporate these appropriate **Candidate technologies** in their training programmes.
- Private enterprises have an important role to play in overcoming numerous **Development gaps** for locally-produced oil products.
- Researchers are given a concise overview of **Research gaps** requiring their action, and highlights on threatened or endangered biodiversity and **Conservation needs**.
- Students in higher education can make a meaningful contribution to research and development of vegetable oils through their **Thesis subjects**.
- Policy makers are asked to address the **Policy issues** identified to enable the above topics to be implemented optimally.

1.2 Methods

The botany, geography, ecology, cultivation and use of species in PROTA 14: *Vegetable oils* are summarised in Chapter 2. Detailed species data are presented in Appendix 1.

About 40 stakeholders (people with active interests in vegetable oil production in Africa) were asked to identify six key issues about the 48 most important oil-producing plants in PROTA 14: *Vegetable oils*. For each species, they generously gave their ideas and suggestions for addressing candidate technologies, development gaps, research gaps and thesis subjects, conservation needs and policy issues.

In March 2008, 24 of the stakeholders participated in a Brainstorm Workshop held in Entebbe, Uganda to finalise the conclusions and recommendations to be published in this booklet. These are highlighted in Chapters 3–8, profiling key interventions that require swift attention from various target groups, on oil-producing plants and general topics relevant to the vegetable oil sector. The complete matrix of stakeholder responses and workshop outcomes for each species is presented in Appendix 2.

This PROTA Recommends Series booklet will follow the approach PROTA has successfully used for cereal and pulse crops (PROTA 1: *Cereals and pulses*), for vegetables (PROTA 2: *Vegetables*) and for plants used for dyes and tannins (PROTA 3: *Dyes and tannins*). Based on the findings in this booklet, pilot projects will be established with the aim of raising incomes, improving food security and nutrition. Overall, the aims are to improve the livelihoods of the end-users of PROTA's information in Africa, who directly depend on vegetable oils.

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1.4 Literature

Van der Vossen H.A.M. & Mkamilo, G.S. (Editors), 2007. Plant Resources of Tropical Africa 14. Vegetable oils. PROTA Foundation, Wageningen, Netherlands; Backhuys Publishers, Leiden, Netherlands; CTA, Wageningen, Netherlands. 237 pp.

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2. Vegetable oils: an overview

This chapter presents a general overview of oil species in Africa, including aspects of their botany, geography, ecology, cultivation and use. Data presented in Appendix 1 are intended as a quick reference guide.

2.1 Primary Use vegetable oils

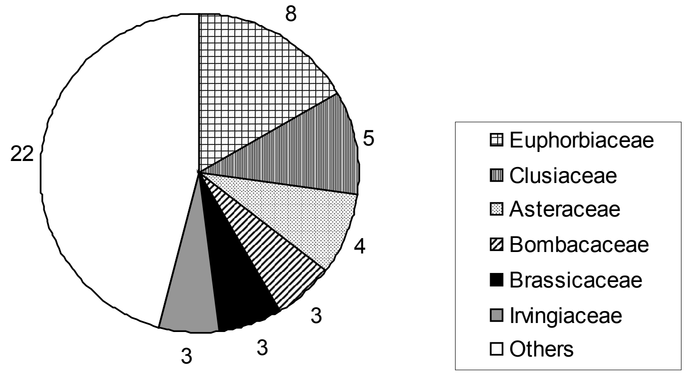
While more than 250 plant species are used for their oils in tropical Africa, only 65 of them are known to be used principally for their vegetable oils. These species were described in PROTA 14: *Vegetable oils* as Primary Use vegetable oils; here, we deal with the 48 Primary Use species for which considerable information is available in the literature.

The 181 Secondary Use vegetable oils listed in PROTA 14: *Vegetable oils* handbook will be discussed in other PROTA publications dealing with other Commodity groups, in order to avoid duplication.

2.2 Plant families

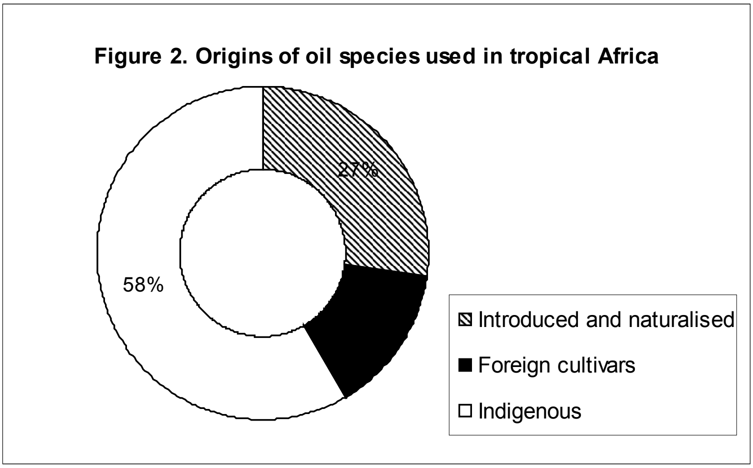
The 48 most important oil species in tropical Africa belong to 23 plant families (Figure 1). *Euphorbiaceae* is the family with, by far, the largest number of oil species used in tropical Africa (8 species), followed by Clusiaceae (5 species), Asteraceae (4 species) and Bombacaceae, Brassicaceae and Irvingiaceae (3 species each). The remaining 22 species are spread over 17 families, with 12 of these families having only a single species, while the remaining five families, Arecaceae, Meliaceae, Mimosaceae, Moringaceae and Papilionaceae are represented by two oil species.

Figure 1. Oil species in plant families



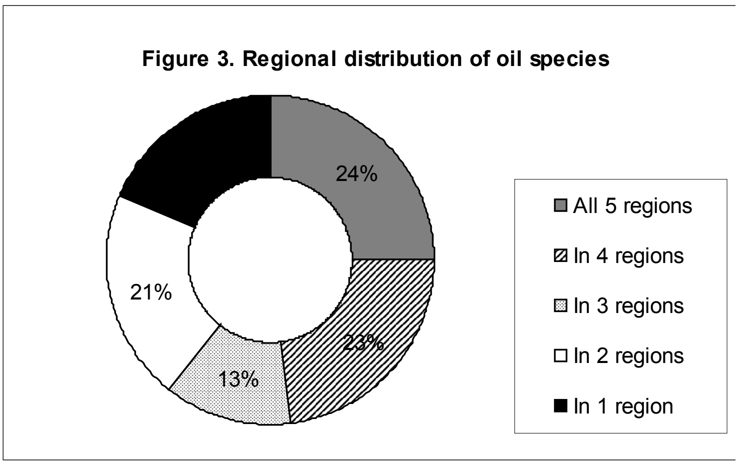
2.3 Origins of vegetable oils

Over half of the important vegetable oils are extracted from species indigenous to Africa. Of the 13 introduced species, the majority (7 species) were introduced long ago , have become locally naturalised and are represented by landraces, adapted to conditions in tropical Africa (Figure 2). The cultivation of the other introduced species depends on foreign cultivars.



2.4 Distribution in tropical Africa

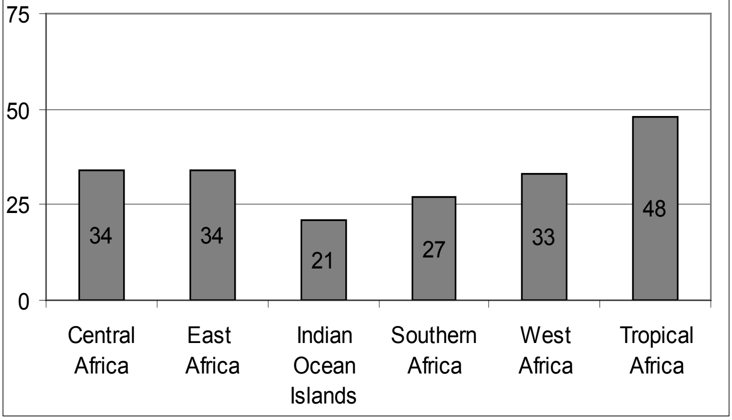
The regional occurrence of oil species in tropical Africa (Figure 3) is important in formulating recommendations for their use and management on national, regional or continental levels. It appears that nearly half of the 48 important oil species are more or less pan-African, occurring in all five (12 species) or in four (11) of the regions (Central, East, Indian Ocean Islands, Southern, West Africa). Some 18 species are less widespread, and occur in one (9 species) or two (10) regions.



Not surprisingly, endemism among important oil species is highest in the Indian Ocean Islands, where unique levels of biodiversity are found; three Madagascan species of baobab *(Adansonia* spp.*)* are used for their vegetable oils there. In contrast, no oil species used in southern Africa are endemic there.

The number of oil species used in West, Central and East Africa is very similar (34 species, figure 4). Of the 48 important oil species, 27 occur in East Africa and 21 in the Indian Ocean Islands.

Figure 4. Regional diversity of oil species



2.5 Cultivation status

Of the 48 most important oil species in tropical Africa, nearly half are harvested only from the wild, eight species are collected from the wild but are also cultivated, and 17 are only cultivated. Among the species that are both cultivated and wild-harvested, castor (*Ricinus communis*) is the only one that has been domesticated and may now be considered a crop. The other seven species in this group are in the early stages of domestication.

2.6 Secondary uses

Primary Use oil species (that is, species from which vegetable oils are the most important commodity) are often multipurpose and have at least five Secondary Uses. The most important of these is their use for medicine (40 species).

2.7 Growth form

The majority of the 48 oil species are shrubs and trees (35 species), while less than a quarter are annual herbs. As a wild plant, castor (*Ricinus communis*) is a perennial shrub or even tree but in cultivation it is often managed as an annual, and breeding has resulted in short-lived dwarf cultivars.

2.8 Altitude

The information on altitudinal range is incomplete for some 38% of the oil species in tropical Africa. The majority of these data are available for species occurring from sea level upwards; high-altitude species are poorly documented.

Altitudinal ranges are important, since highland species such as Ethiopian kale (*Brassica carinata*), safflower (*Carthamus tinctorius*), cram-cram (*Crambe hispanica*) and niger seed (*Guizotia abyssinica*) in the Ethiopian highlands and mkange (*Allanblackia stuhlmannii*) in the Eastern Arc Mountains of Tanzania have no tolerance for the high temperatures in the tropical lowlands.

2.9 Propagation

Only the olive (*Olea europaea*) is propagated by vegetative means for oil production, usually by cuttings, because seedlings are very unpredictable in yield. Propagation by cuttings is commonly practiced for jojoba (*Simmondsia chinensis*), although some producers use seeds from selected mother plants. Most other species are solely propagated by seeds (32 species). The remainder is largely propagated by seed, but have been propagated generatively (6 species) while seven woody species may be propagated by either method. No information is available on propagation of mogongo (*Schinziophyton rautanenii*).

2.10 Production and trade

Comparative statistics on vegetable oil yields are difficult to compile (Table 1). In many cases it is not clear if production data refer to oil or to the seeds from which vegetable oil is extracted. Vegetable oil consumed locally is often excluded from the statistics, while cultivars of species such as linseed (*Linum usitatissimum*) are grown for different products, such as fibre or for vegetable oil. Similarly, oil seed and vegetable cultivars exist for different species of rape, the source of canola oil. Whereas Ethiopian kale (*Brassica carinata*) and to some extent *Brassica juncea*, are important oil species in tropical Africa, *Brassica napus* and *Brassica nigra* are important vegetable crops in the region.

The demand for edible vegetable oils is expected to rise by 50% in 15 years. While the demand for biofuel from vegetable oils is difficult to predict, this market is expected to continue effecting price increases in the global vegetable oil industry. Farmers in tropical Africa could benefit from these trends. For instance, there is much scope for oil palm yields in tropical Africa (which are presently low) to be drastically increased while tropical Africa imports a million metric tons of palm oil every year. Apart from already well-established oil crops, there are opportunities for new crops in tropical Africa, such as olive (*Olea europaea*) in Ethiopia, and for speciality products like solid fats from the vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*) and mkange (*Allanblackia stuhlmannii*) and shea butter from the shea butter tree

(*Vitellaria paradoxa*). The use of fats and oils for lubrication, pharmaceuticals, cosmetics and health benefits offers numerous opportunities for high value products.

Table 1. Global vegetable oil production from selected species during 2000

Vegetable oil	Oil species	Production (1000 t)
Soya bean	*Glycine max*	26,000
Palm oil	*Elaeis guineensis*	23,300
Palm kernel oil	*Elaeis guineensis*	2,700
Rape seed (canola)	*Brassica* spp.	13,100
Sunflower	*Helianthus annuus*	8,600
Groundnut	*Arachis hypogaea*	4,200
Coconut	*Cocos nucifera*	3,300
Olive	*Olea europaea*	2,500

3. Candidate technologies

This chapter outlines crucial interventions recommended by stakeholders for the development of oil crops in Africa. The interventions, referred to here as 'candidate technologies', relate to the work of various extension service providers and other stakeholders involved in the production of vegetable oils. The purpose of candidate technologies is to improve the productivity and profitability of oil species, for poverty reduction and improved rural livelihoods.

In this context, candidate technologies refer to best practices, skills, innovations and knowledge for each species that are ready to be disseminated or introduced to oil crop farmers and vegetable oil processors. Candidate technologies are, therefore, ready to be applied and tested by farmers (for instance, in demonstration plots and on-farm adaptation trials) or included in training programmes at vocational training centres, where they can be taken up by farmers and processors. Candidate technologies identified for each species (Appendix 2) are discussed here in technology themes (Table 2).

3.1 Improved cultivars, best practices and innovations

Much research attention has been devoted to the development and marketing of appropriate technologies, innovations and best practises for oil species in sub-Saharan Africa by the National Agricultural Research Systems (NARS) and with support of institutes belonging to the Consultative Group on International Agricultural Research (CGIAR).

A wide range of technologies are available for many important oil species. Technologies include optimal agronomic practices, high oil-content cultivars, disease and pest resistant cultivars, improved seed and planting materials adapted to various agro-ecological zones, rapid multiplication techniques, on-farm grafting techniques, Integrated Pest Management (IPM) and recommendations for mechanised farm operations. Also available are modern oil extraction protocols, oil processing and preservation methods, established oil uses and value addition methods.

While technologies may be available for many oil species, stakeholders noted that farmers in most African countries have limited awareness and access to appropriate technologies. There is therefore a pronounced need to source, exchange and promote the adoption and use of these technologies using participatory extension approaches, such as establishment of demonstration plots, on-farm adaptation trials and farmer field schools.

In particular, on-farm adaptation trials which allow farmers to verify the performance of new cultivars have proved an effective participatory method for technology transfer and to promote cultivation of improved cultivars. Similarly, farmer field schools offer a group-based learning process pioneered by the Food and Agriculture Organization of the United Nations (FAO) in Indonesia; they have proved a successful method for empowering communities. Beside the good possibility of farmers adopting new technologies, these approaches are equally effective in ensuring that farmers' feedback about perceived shortfalls and desired characteristics of new technologies, reaches the source of new technologies, such as plant breeders or machinery manufacturers.

Improved cultivars developed by NARS and CGIAR are available for several important oil species, such as groundnut (*Arachis hypogaea*), Ethiopian kale (*Brassica carinata*), brown mustard (*Brassica juncea*), safflower (*Carthamus tinctorius*), coconut and oil palms (*Cocos nucifera* and *Elaeis guineensis*), soya bean (*Glycine max*), niger seed (*Guizotia abyssinica*), sunflower (*Helianthus annuus*), linseed (*Linum usitatissimum*) and sesame (*Sesamum indicum*).

Whereas agronomic practices typically require adjustment for domesticated crops to be viable for small-scale production and home consumption, the opposite is true of species like mogongo (*Schinziophyton rautanenii*), and oyster nut (*Telfairia pedata*), for which agronomic practices for profitable large-scale production have yet to be identified.

Using modern technologies enhances farm competitiveness and growth because they allow product development, facilitate business opportunities and enable farmers to create niche markets for their new products.

3.2 Current extension materials

There is need to develop and disseminate extension materials in printed and audio-visual forms, e.g. leaflets, posters, fact sheets, cultivation and identification guides, slides and videos.

To be effective, extension materials must provide a clear means of communication to farmers and oil processors, preferably in their local language. Extension materials must convey the benefits to the farmer of adopting new technologies for cultivation and processing of oil species; these may include increased yields, fewer inputs and higher gross margins. Extension materials must also demonstrate how to correctly apply new technologies, which may differ in different countries or regions. Stakeholders identified a particular need in several regions of tropical Africa for extension materials to promote emerging oil crops such as jatropha (*Jatropha curcas*), the vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*) and the related mkange (*Allanblackia stuhlmannii*). The Centre for Jatropha Promotion and Biodiesel in India (www.jatrophaworld.org) provides information on technologies available for the former.

Well known domesticated oil species are comprehensively documented and information is widely available on appropriate technologies for their cultivation and oil processing. There is, however, a need for extension materials communicating current information for indigenous oil species such as Ethiopian kale (*Brassica* *carinata*) and niger seed (*Guizotia abyssinica*), as well as exotic crops like groundnut (*Arachis hypogaea*), brown mustard (*Brassica juncea*), safflower (*Carthamus tinctorius*) and coconut palm (*Cocos nucifera*).

For wild harvested oil species, management guides for sustainable management, assisted natural regeneration methods and optimal use are required. In particular, such information is needed to manage popular species such as the vegetable tallow tree (*Allanblackia floribunda* and *Allanblackia parviflora*), dwarf red ironwood (*Lophira lanceolata*) and shea butter tree (*Vitellaria paradoxa*). Information relevant to local situations where these species are used may be obtained from review articles in PROTA 14: *Vegetable oils* handbook, also freely available at (www.prota.org) and additional information to produce extension materials.

3.3 Expansion

The increasing demand for vegetable oils to be used in food, livestock feed and non-edible industrial application signals an opportunity for African producers. According to FAO, the global demand for vegetable oils will increase by nearly 400% from 1990–2010. Per capita consumption of vegetable oils in developed nations is double that of developing nations where vegetable oils are mostly produced. Despite this opportunity, vegetable oil production is increasing slowly in Africa, by 2.1% annually from 2000–2003 compared to 10.7% in Latin America, 4.5% in Asia and 4.2% in Europe for the same period.

Whereas vegetable oils, notably palm oil (from *Elaeis guineensis*), are an export commodity in some African countries, most are net importers of either oilseeds, crude or refined vegetable oils or protein meals. To address this shortfall, the area under oil crops in both traditional and non-traditional areas needs to be expanded.

Despite the scarcity of quality agricultural land in Africa, expansion of oil cropping may yet be achieved by irrigation, (re-)forestation, establishing new plantations of perennial tree oil species or cultivating species adapted to marginal areas which do not compete with food crops. For example, vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*) and jojoba (*Simmondsia chinensis*) may be promoted in dry areas while brown mustard (*Brassica juncea*) has a wide adaptive suitability. Safflower (*Carthamus tinctorius*) can thrive both on saline soils and in drylands. Jatropha (*Jatropha curcas*) and castor (*Ricinus communis*) can be established on disturbed, marginal or wasteland land. Species suitable for (re-)forestation include the sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively).

Several species have potential for market expansion. An existing local market niche, either as substitutes for imported products or to satisfy local demand, is essential. The most promising candidates for expansion for local consumption with possibilities for export include Ethiopian kale (*Brassica carinata*), sesame (*Sesamum indicum*), niger seed (*Guizotia abyssinica*), and brown mustard (*Brassica juncea*), linseed (*Linum usitatissimum*), sunflower (*Helianthus annuus*), safflower and jatropha.

3.4 Appropriate extraction and processing technologies

In the face of increased demand for quality vegetable oils and maximum profitability, the use of modern high-output manual or motorised equipment should be promoted among oil processors in tropical Africa. Traditional processing methods in most cases are slow, inefficient, labour-intensive and use large quantities of energy, mostly obtained from fuel wood.

A wide range of extraction equipment and machinery for coconut palm (*Cocos nucifera*), oil palm (*Elaeis guineensis*), and other oil species are available in Ghana, Nigeria, Burkina Faso, and Mali. Appropriate technologies have been developed in India, where all oil extraction and processing machinery, ranging from dehuskers, cleaners, expellers, pressers, filters, dryers, and packaging machines is available for several oil crops, particularly jatropha (*Jatropha curcas*) and coconut.

Technologies for oil extraction, processing and local value addition for shea butter, the high quality vegetable fat extracted from the nut of the shea butter tree (*Vitellaria paradoxa*) are quite advanced in West African countries including: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali and Nigeria. In Ethiopia, the centre of origin for oil crops such as Ethiopian kale (*Brassica carinata*) small-scale oil extraction technology has been developed for several important oil species. Besides globally cultivated oil species, modern extraction and processing equipment is also available for locally important species.

3.5 Mechanisation

Mechanisation possibilities exist for most farm operations, from land preparation, sowing, weeding, harvesting and processing, for oil species grown on small- and large-scale farms in tropical Africa. While energy costs may limit the extent of mechanised farming, especially for smallholders, the advantages of mechanisation technologies outweigh the related cost.

Mechanisation facilitates timely land preparation at the start of rains and provides a longer planting period, consequently maximising yields and profits. Using mechanisation, farmers can prepare large surfaces of land within a short time even on difficult soil; they are able to improve weeding, disease and pest control, and minimise harvest time and reduce post-harvest losses. Importantly, mechanisation overcomes poor labour efficiency, one of the biggest problems in African agriculture. Indeed, labour-intensive farm activities such as planting very small seeds (e.g. niger seed, *Guizotia abyssinica*; Ethiopian kale, *Brassica carinata*; and sesame, *Sesamum indicum*), dehusking the stones of coconut and oil palm (*Cocos nucifera* and *Elaeis guineensis*, respectively) and shelling groundnut fruits (*Arachis hypogaea*) may be more efficiently achieved using machines.

The traditional method of making shea butter from the shea butter tree (*Vitellaria paradoxa*), usually by women, has drawbacks as it may be inefficient, labour-intensive and time consuming. Mechanisation of these operations, in particular the use of hydraulic or continuous screw expellers or applications of solvent extraction, could significantly improve the efficiency of oil extraction.

The economy of scale gives larger production units an advantage over the more common small-scale farms in tropical Africa. For smallholders, common-interest groups and cooperatives are likely to benefit a greater number of farmers with the profits of large-scale production by combining production efforts such as the use of machinery and marketing.

3.6 Product diversification and value addition

The profitability of oil species not only depends on efficient oil extraction and processing, but also on income from diversified oil products and by-products. On-farm processing of vegetable oils should be encouraged for farmers in tropical Africa to obtain maximum returns from sale or household use of oil products, including edible protein meal as well high quality edible oil, and inedible products such as biodiesel, soap, cosmetics, candles and lamp fuel for illumination, paint, industrial lubricants and organic fertilisers. For instance, several products can be produced from coconut palm (*Cocos nucifera*): edible coconut milk, as well as soap, detergent, pharmaceuticals, cosmetics and shampoo, paint, varnishes, shell- and coir products, coco peat and coco charcoal. Wine can be made from the fruit pulp of baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa*, *Adansonia za*). Numerous other important oil species offer opportunities to diversify the products used.

3.7 Sustainable harvesting from the wild

Among the important wild harvested oil species in tropical Africa, demand is greatest for the shea butter tree (*Vitellaria paradoxa*), the source of sought-after shea butter. However, there are concerns that demand will result in non-sustainable harvesting of shea fruits, and jeopardise the productivity of this micro-industry. To ensure sustainability, communities should be encouraged to allow natural regeneration of existing populations, rejuvenate old trees by pruning, and establish more trees. Domestication and on-farm grafting are key interventions that may be used to increase fruit production to meet demand. Shortening the juvenile stage by on-farm grafting of existing shea butter trees has been very successful in Burkina Faso and other West African countries.

3.8 Biofuel

The use of vegetable oils to produce biodiesel has the potential to enhance both national and household energy security, while raising farm incomes at the local level in tropical Africa. Compared to oil from fossil fuels, biofuels are generally non-toxic, biodegradable and renewable sources of energy, with lower environmental impact due to potentially lower carbon emissions during their production and when they are burned.

Biofuel programmes based on agricultural feedstock (the raw material) have been developed around the world in response to recent increase in prices for fossil-based oils and growing global demand for energy. Demands for ethanol and biodiesel from grains, vegetable oils and other crops such as sugarcane, have grown considerably. Numerous oil species cultivated in tropical Africa have potential as feedstock for biodiesel, including species that are readily cultivated on marginal land, such as cram-cram (*Crambe hispanica*), a species from the Mediterranean and African highlands that is presently being developed as a temperate crop.

Taking into consideration the grave need for food security in Africa, biodiesel production should focus on non-edible oil species. It is necessary for governments to develop stringent policies to allow the biofuel sector to grow without compromising efforts to achieve food security in Africa, where the production and distribution of food crops is quite fragile.

Against this background, stakeholders identified jatropha (*Jatropha curcas*) and castor (*Ricinus communis*) oils as the best candidates for biodiesel feedstock, since both species produce non-edible oil and are suitable for cultivation on disturbed or marginal land. Countries in tropical Africa with major development projects on jatropha biodiesel production include Burkina Faso, Ghana, Madagascar, Malawi, Mali, South Africa, Tanzania and Zambia. Other African countries have started developing jatropha biodiesel projects in an effort to reduce energy deficiency.

Through Public-Private Partnerships (PPPs), India has established large scale plantations of jatropha for biodiesel production. Other countries outside Africa which have registered an increasing trend on jatropha production include Malaysia, Cambodia, Indonesia and Brazil.

3.9 Quality control and safety standards

Regardless of the use of vegetable oils, for edible or non-edible purposes in export or domestic markets, production and processing must meet quality control and safety standards. While regulations and certification procedures vary depending on the products, regions and countries, Good Agricultural Practices (GAP), biological contaminants, product traceability, environmental and phytosanitary safety, are universal. Global quality control systems include the International Organization for Standardization (ISO), Global Good Agricultural Practices (GLOBALGAP) and Hazard Analysis and Critical Control Points (HACCP). Regional and national quality control systems are usually determined according to these international standards.

Compliance of vegetable oils and products for export with food safety and quality standards will protect the consumer and the producer. All stakeholders in the vegetable oil sector in tropical Africa (farmers, oil processors, distributors, importers and exporters) should assume responsibility for food safety and quality standards and ensure that their products comply. There is a need, therefore, to develop national quality control systems for vegetable oils where they are absent, and create awareness of the need for compliance.

Proper drying, cleaning and storage of oilseeds, extraction, processing and packaging of the extracted oil are important issues for quality oil production. Most importantly, preservation and storage of oil require care to avoid chemical deterioration (rancidity). For example, sunflower (*Helianthus annuus*) oil has a short storage life, but heating and storing in airtight containers can extend the shelf life. For groundnut (*Arachis hypogaea*) seed and oil, ventilation during storage is crucial to prevent moisture build-up which can promote fungal contamination and aflatoxin production. Similarly, aflatoxins are likely to contaminate copra, the raw material from which coconut (*Cocos nucifera*) oil is extracted, if the moisture content of copra exceeds 12%. Awareness among producers and consumers of the causes and symptoms of fungal infection in oil crops is necessary, so that contaminated products are rejected for consumption.

Due to the demand of quality products the following species were prioritised: shea butter tree (*Vitellaria paradoxa*), groundnut (*Arachis hypogaea*), coconut and oil palms (*Cocos nucifera* and *Elaeis guineensis*), soya bean (*Glycine max*) and castor (*Ricinus communis*).

3.10 Introduction of new species

Introducing species from other growing regions in tropical Africa is likely to benefit expanding vegetable oil production systems. For instance, Ethiopian kale (*Brassica carinata*) is important in Ethiopia as an oil crop and is used as a leafy vegetable elsewhere in tropical Africa in countries like Tanzania, Malawi, Zambia and Zimbabwe. The species is a likely candidate for use in these and other countries both for oil and as a vegetable. Similarly, both niger seed (*Guizotia abyssinica*) and linseed (*Linum usitatissimum*) are recognised for their export potential and continued introduction outside Ethiopia.

3.11 Nutritional value

Edible oils constitute an important part of our daily dietary requirements. They provide energy, essential fatty acids and vitamins, and are highly nutritious. For example, soya bean (*Glycine max*) and linseed (*Linum usitatissimum*) should be promoted among vulnerable social groups as they have high nutritional value. Where such species are new to consumers, recipes for preparation should be provided.

3.12 Multipurpose species

Most oil species have secondary uses, with regional differences in importance. The product of highest local priority determines how a species is used, but information about all these uses should be given to farmers to allow them to make informed decisions.

The wood of perennial species such as vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*), mkange (*Allanblackia stuhlmannii*), bush mangoes (*Irvingia gabonensis*, *Irvingia wombolu*), African nutmeg (*Pycnanthus angolensis*), *Pentaclethra eetveldeana*, *Pentaclethra macrophylla*, forest mahogany (*Trichilia dregeana*) and mafura (*Trichilia emetica*) is either used for fuel or timber. Sometimes the wood is the most valued product. Besides vegetable oils with medicinal purposes, other plant parts of jatropha (*Jatropha curcas*), bush mangoes, dwarf red ironwood (*Lophira lanceolata*), *Pentaclethra eetveldeana* and *Pentaclethra macrophylla*. are used medicinally. Establishing these species in agroforestry systems should be encouraged to increase their productivity. Likewise, leguminous crops such as soya bean (*Glycine max*) are important for diversifying cereal-based farming systems. The International Institute of Tropical Agriculture (IITA) has developed multipurpose soya bean cultivars suitable for promotion in tropical Africa.

Oil species may have various other beneficial purposes, such as ornamental uses (baobab, *Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*), apiculture for premium quality honey (sunflower, *Helianthus annuus*) or as a cover crop and green manure (niger seed, *Guizotia abyssinica*). Castor (*Ricinus communis*), jatropha (*Jatropha curcas*) and jojoba (*Simmondsia chinensis*) may play a role in soil rehabilitation.

Table 2. Technologies required for development of vegetable oils in tropical Africa

Candidate technologies	Interventions	Species
Improved cultivars, best practices and innovations	Seed scarification for improved germination	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab)
	Promote improved varieties	*Arachis hypogaea* (groundnut) *Brassica carinata* (brown mustard) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Helianthus annuus* (sunflower) *Linum usitatissimum* (linseed)
	Integrated Pest Management	*Arachis hypogaea* (groundnut) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm)
	Use in inter-cropping, crop rotation and agroforestry systems	*Brassica carinata* (brown mustard) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Guizotia abyssinica* (niger seed) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Lophira lanceolata* (dwarf red ironwood) *Pentaclethra eetveldeana* *Pentaclethra macrophylla* (African oil bean) *Pycnanthus angolensis* (African nutmeg) *Sesamum indicum* (sesame) *Telfairia pedata* (oyster nut) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)
	On-farm grafting of improved varieties	*Vitellaria paradoxa* (shea butter tree)
	Marketing	*Guizotia abyssinica* (niger seed) *Vernicia montana* (wood-oil tree)

Table 2. Technologies required for development of vegetable oils in tropical Africa (Continued)

Candidate technologies	Interventions	Species
Current extension materials	Improve producers' network	*Vitellaria paradoxa* (shea butter tree)
	Managing wild populations	*Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Lophira lanceolata* (dwarf red ironwood) *Vitellaria paradoxa* (shea butter tree)
	Recommended agronomic practices for cultivated plantations	*Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Guizotia abyssinica* (niger seed)
Expanded cultivation of oil species	Promote planting for specific conditions	*Allanblackia floribunda* (vegetable tallow tree) (drylands) *Allanblackia parviflora* (vegetable tallow tree) (drylands) *Allanblackia stuhlmannii* (mkange) (drylands) *Carthamus tinctorius* (safflower) (saline soils, drylands) *Jatropha curcas* (jatropha)(disturbed land) *Linum usitatissimum* (linseed) (highlands) *Simmondsia chinensis* (jojoba) (drylands)
	Promote planting	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Elaeis guineensis* (oil palm) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Jatropha curcas* (jatropha) *Pentaclethra eetveldeana*

Table 2. Technologies required for development of vegetable oils in tropical Africa (Continued)

Candidate technologies	Interventions	Species
Expanded cultivation of oil species	Promote planting	*Pentaclethra macrophylla* (African oil bean) *Ricinus communis* (castor) *Simmondsia chinensis* (jojoba) *Sesamum indicum* (sesame) *Telfairia pedata* (oyster nut)
Mechanisation		*Arachis hypogaea* (groundnut) *Brassica carinata* (brown mustard) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Ricinus communis* (castor) *Sesamum indicum* (sesame) *Simmondsia chinensis* (jojoba) *Vitellaria paradoxa* (shea butter tree)
Appropriate extraction and processing technologies	Post-harvest technology	*Arachis hypogaea* (groundnut) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Helianthus annuus* (sunflower) *Sesamum indicum* (sesame) *Vitellaria paradoxa* (shea butter tree)
	Appropriate oil extraction technologies	*Arachis hypogaea* (groundnut) *Brassica carinata* (brown mustard) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Sesamum indicum* (sesame)
Biofuel		*Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Jatropha curcas* (jatropha) *Simmondsia chinensis* (jojoba)
Quality control and safety standards	Correct storage conditions	*Arachis hypogaea* (groundnut) *Cocos nucifera* (coconut palm) *Helianthus annuus* (sunflower)
	Demand for high quality oil	*Arachis hypogaea* (groundnut) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Ricinus communis* (castor) *Vitellaria paradoxa* (shea butter tree)

Table 2. Technologies required for development of vegetable oils in tropical Africa (Continued)

Candidate technologies	Interventions	Species
Introduction of new species	Promote in new growing region	*Brassica carinata* (Ethiopian kale) *Guizotia abyssinica* (niger seed) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed)
Sustainable wild harvesting		*Vitellaria paradoxa* (shea butter tree)
Nutrition	Promote for nutritional value	*Carthamus tinctorius* (safflower) *Glycine max* (soya bean) *Linum usitatissimum* (linseed)
Multipurpose species	Promote secondary uses for medicinal, ornamental, timber, green manure, apiculture and soil rehabilitation	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Balanites maughamii* (Y-thorned torchwood) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Jatropha curcas* (jatropha) *Lophira lanceolata* (dwarf red ironwood) *Pentaclethra eetveldeana* *Pentaclethra macrophylla* (African oil bean) *Pycnanthus angolensis* (African nutmeg) *Ricinus communis* (castor) *Simmondsia chinensis* (jojoba) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)

4. Development gaps

Research and development to establish a thriving vegetable oils industry in tropical Africa depend on the work of varied sectors, including research institutions, policy makers and non-governmental organisations (NGOs). Investment from the private sector (entrepreneurs operating on local, national and multinational scales) is critical for the development of oil crops and new vegetable oil products. This chapter highlights opportunities for intervention from the private sector, termed as development gaps, identified by stakeholders in Africa's vegetable oil industry. Development gaps generally represent discrete, marketable innovations and the final stages of research attractive to the private sector. Such opportunities were identified for 65% of the 48 important oil species in tropical Africa (Appendix 2) and are discussed here in three broad categories (Table 3).

4.1 Breeding and selection

Breeding and selection are the first steps towards improving oil yields from oil species in tropical Africa. Selection is best suited to improvement in perennial oil species, while breeding may allow for quick improvements in annual or short-lived perennial species. In many tropical African countries, breeding and selection of valuable utility species are the mandate of the National Agricultural Research Systems (NARS). However, the public sector benefits from valuable support of independent research institutes such as those of the Consultative Group on International Agricultural Research (CGIAR), which facilitates access to resources and capacity building among scientists in the public sector. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) breeding programme on groundnut (*Arachis hypogaea*), for example, has created a secure source of germplasm and breeding materials for NARS in the region.

Taking into account the increasing demand for vegetable oils in tropical Africa for local and export markets, the private sector will be essential to breeding and selection programmes to develop profitable oil species. NARS are burdened by limited resources and demands for diverse cultivars for the varied ecological zones typical of the African landscape. Public-Private Partnerships (PPPs) are proven to be effective in addressing development gaps throughout ecological zones, which usually extend across political boundaries, without challenging national research agendas.

Private seed companies that have successfully ventured into development of improved cultivars for oil crops include the East-West Seed Company in Thailand which developed cultivars of brown mustard (*Brassica juncea*) suitable for tropical conditions, and several private companies breeding soya bean (*Glycine max*) for mechanised farming in southern Africa. A partnership between the International Union for Conservation of Nature (IUCN), Netherlands Development Organisation (SNV), World Agroforestry Centre (ICRAF), Unilever and public sector institutes in Africa has resulted in an extensive domestication programme for vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*). The initiative, known as

Project Novella (www.allanblackia.info), exemplifies the benefits of public-private partnerships for vegetable oil development. ICRAF has also started domestication programmes for sweet- and bitter bush mangoes, respectively (*Irvingia gabonensis* and *Irvingia wombolu*, respectively), African nutmeg (*Pycnanthus angolensis*) and the groundnut tree (*Ricinodendron heudelotii*).

The principal selection criteria for oil species include fatty acid content and oil quality , harvest index, early production, uniform ripening, resistance to diseases and pests, pod shattering and plant architecture suitable for mechanisation. In the case of perennial species, large fruits and kernels, ease of cracking and oil extraction, earliness, long fruiting season and tree size are important criteria. In tropical Africa, tolerance to adverse conditions and quality (i.e. low toxicity, high quality oil) is necessary for the success of cultivars.

4.2 Supply systems for seed, seedlings and farm inputs

Access to quality seeds, planting materials (e.g. seedlings), fertilisers, pesticides and farm equipment is the principal, long-standing impediment to agriculture, and vegetable oil production, in tropical Africa. Importantly, access to credit facilities is inadequate or absent, especially for women who represent a significant community of vegetable oil producers and small-scale processors in tropical Africa. For instance, production and local processing of groundnut (*Arachis hypogaea*) and shea butter tree (*Vitellaria paradoxa*) are dominated by women.

Farmers in Africa historically relied on publicly owned institutions for seed and other farm inputs such as fertiliser and pesticides. The decline in public sector capacity, due to limited resources, led to the entry of NGOs, farmer cooperatives and private companies to the seed sector. As a result, the distribution of quality seeds, planting materials and other farm inputs has improved in recent years. Despite this development, quality seeds remain unavailable to the majority of smallholders in many African countries. According to the Food and Agriculture Organization of the United Nations (FAO), less than 10% of the small-scale farms in sub-Saharan Africa are planted with improved seeds: much of the seeds used come from seed saved by the farmer, or via farmer seed exchange. Improved cultivars and good agronomic practices are the principal factors influencing increased crop productivity and oil yields from oil species. While farmers may readily produce their own seed of crops such as Ethiopian kale (*Brassica carinata*), reliable sources of modern cultivars would increase their profitability. Likewise, improved cultivars of niger seed (*Guizotia abyssinica*) have been shown to double the yields usually harvested from local landraces by farmers in Ethiopia. Similarly, hybrid cultivars of coconut palm (*Cocos nucifera*) can yield up to 6 t/ha of copra (the raw material for oil extraction) compared to about 4 t/ha from well-managed plantations of selected local tall cultivars and less than 1 t/ha of copra from smallholder plantations.

The scenario is similar for numerous other oil species grown as crops, presenting numerous opportunities for investment from the private sector. Indeed, the combined crop improvement, seed production and distribution channels provided by private seed companies, NARS and other organisations could feasibly provide the planting materials required for African farmers to build the vegetable oils industry in Africa. Demands for seed are particularly high for groundnut, niger seed, Ethiopian kale, brown mustard (*Brassica juncea*), safflower (*Carthamus tinctorius*), soya bean (*Glycine max*), sunflower (*Helianthus annuus*), linseed (*Linum usitatissimum*) and sesame (*Sesamum indicum*). For perennial oil species such as baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa*, *Adansonia za*), jatropha (*Jatropha curcas*), the vegetable tallow tree (*Allanblackia floribunda* and *Allanblackia parviflora*), *Allanblackia stuhlmannii*, oil palm (*Elaeis guineensis*) and coconut palm, quality planting materials are in high demand. The role of the private sector in facilitating farmers' access to seed, seedling and farm inputs in tropical Africa is expected to increase as a consequence of improved yields and commercialisation in the vegetable oil industry.

4.3 Oil extraction, value addition and marketing

Local or on-farm processing of vegetable oils enhances the efficiency and profitability of the oil production enterprise. It raises the quality and shelf life of oil extracted, lowers transport costs, and reduces waste since by-products can be used, which in turn increases market opportunities and the competiveness of the enterprise. Importantly, local processing generates employment and stimulates rural development. However, the substantial gains from local vegetable oil processing and value addition are poorly exploited in tropical Africa.

Access to appropriate and affordable processing equipment, microfinance and information are the principal constraints preventing African farmers from diversifying their oil production systems. Consequently, markets for refined vegetable oil, protein cake and products are undeveloped throughout Africa. For instance, the principal product from groundnut (*Arachis hypogaea*) is the edible seed rather than oil, while in sub-Saharan Africa, export of soya oil from *Glycine max* is negligible compared to export of soya bean seeds.

Traditional methods of extraction are presently used by small-scale entrepreneurs in tropical Africa for oil species used locally (e.g. forest mahogany, *Trichilia dregeana* and mafura, *Trichilia emetica*) as well as oil crop species such as oil palm (*Elaeis guineensis*), oil from which is the second-most widely traded (45%) on global markets. However, the oil extraction efficiency of traditional methods is low (less than 50%), as well as labour intensive, time consuming and possibly compromising quality and safety standards.

Opportunities exist throughout tropical Africa for local entrepreneurs to produce machinery to meet the needs of farmers wishing to diversify farm activity by extracting and processing oil from their crops. Accordingly, there are prospects for inventors and innovation research institutes to develop appropriate oil extraction and processing equipment. Further along the supply chain, capacity building and technology transfer (via training programmes and extension services) are necessary among farmers, oil processors, manufacturers and distributors. Models of successful micro-enterprise for oil producers are those of Practical Action (formerly ITDG, the Intermediate Technology Development Group) for processing groundnut in Zimbabwe and cashew (*Anacardium occidentale*) in Sri Lanka. In tropical Africa, cultivated oil species for which extraction technology is especially needed include sesame (*Sesamum indicum*), linseed (*Linum usitatissimum*) and niger seed (*Guizotia abyssinica*), as well as non-cultivated species such as baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa*, *Adansonia za*), vegetable tallow tree (*Allanblackia floribunda* and *Allanblackia parviflora*) and *Allanblackia stuhlmannii*. Machinery modified to run on biofuel from *Jatropha curcas* and other vegetable oils is needed as cultivation of these species continues to attract interest.

Table 3. Opportunities for the private sector to develop oil species in tropical Africa

Development gaps	Development need	Species
Breeding and selection	Selection and breeding for improved adaptation, pest resistance, yield, properties, harvesting and storage Adaptation trials for *Simmondsia chinensis*	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Crambe hispanica* (cram-cram) *Glycine max* (soya bean) *Helianthus annuus* (sunflower) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Pentaclethra macrophylla* (African oil bean) *Simmondsia chinensis* (jojoba) *Sesamum indicum* (sesame) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura) *Vitellaria paradoxa* (shea butter tree)
Supply systems for seed, seedlings and farm inputs	Commercial seed production, marketing and distribution Seedlings Clonal planting Hybrid seed Agronomy Germplasm exchange	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Arachis hypogaea* (groundnut) *Balanites maughamii* (Y-thorned torchwood) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm)

Table 3. Opportunities for the private sector to develop oil species in tropical Africa (Continued)

Development gaps	Development need	Species
Supply systems for seed, seedlings and farm inputs	Commercial seed production, marketing and distribution Seedlings Clonal planting Hybrid seed Agronomy Germplasm exchange	*Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Linum usitatissimum* (linseed) *Olea europaea* (olive) *Ricinus communis* (castor) *Sesamum indicum* (sesame) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)
Oil extraction, value addition and marketing	Mechanised post-harvest handling Appropriate oil extraction technologies Motorised oil presses (*Helianthus annuus*) Local value addition (e.g. *Adansonia* wine) Use of by-products (e.g. *Jatropha curcas* for biopesticide) Create market opportunities (e.g. market for ricinoleic acid from *Ricinus communis*) Establish microfinance facilities for smallholders (e.g. savings and credit models for *Elaeis guineensis* farmers) Develop opportunities for oil use (e.g. engines modified to run on biofuel)	*Adansonia za* (Za baobab) *Allanblackia floribunda* (vegetable tallow tree) *Arachis hypogaea* (groundnut) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Pentadesma butyracea* (kanya) *Ricinus communis* (castor) *Sesamum indicum* (sesame) *Vernonia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)

5. Research gaps

The research sector has a crucial role to play in developing a sustainable vegetable oil industry in Africa. Stakeholders identified research needs for all but four of the 48 major oil plant species in tropical Africa: olive (*Olea europaea*), sesame (*Sesamum indicum*), Chinese tallow tree (*Triadica sebifera*) and *Irvingia grandifolia* (Appendix 2).The most common research needs (Table 4) lie within the research themes of domestication, agronomy and genetic improvement of cultivated species (Appendix 2). Fewer oil species warrant research into the sustainable management of wild resources, but these species, instead, require conservation and policy interventions (see Chapters 7 and 8).

A small number of species are likely candidates for cultivation on an increased, more intensive scale in tropical Africa, such as oil palm (*Elaeis guineensis*) and sunflower (*Helianthus annuus*). Specialist studies are required to identify optimal conditions for their cultivation, post-harvest technology and oil processing. In contrast, locally important crops such as sesame (*Sesamum indicum*) do not require intensive optimisation throughout the region and are a research priority only for institutions in areas where they are cultivated. Indigenous oil plants such as *Moringa drouhardii*, *Irvingia grandifolia*, ben tree (*Moringa peregrina*), sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively) are recognised for their potential for scaled-up production and require broad investigation to assess market opportunities and their suitability for intensive production.

It is advisable that valuable resources of national research institutes are pooled to address regional research gaps in tropical Africa. Collaborative programmes between regional governments, academic (Chapter 6) and specialist research institutions are recommended, to meet research objectives on broad geographical scales while allowing local conditions to be incorporated into experimental design. This approach is particularly appropriate to commodity oils in high demand that are suited to cultivation throughout the continent, notably jatropha (*Jatropha curcas*), oil palm, groundnut (*Arachis hypogaea*) and, in coastal regions, coconut (*Cocos nucifera*).

5.1 Domestication and agronomy

More than two thirds of important oil species used in tropical Africa are wild harvested, with prospects to be domesticated, mitigating increasing harvesting rates should demands increase. Provided natural populations of such species are protected as the source of wild germplasm, the domestication process may hold promise for species to be adapted for cultivation under local conditions. Not surprisingly, species for which domestication is most relevant are predominantly perennial tree species that are traditionally managed *in situ* rather than propagated. Oil-yielding trees in which the domestication process requires priority in tropical Africa include the vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*) and mkange (*Allanblackia stuhlmannii*), among which high oil and fat-yielding plants must be selected for domestication. The African oil bean (*Pentaclethra macrophylla*) and kanya (*Pentadesma butyracea*) are well suited for use in agroforestry systems and, in the case of the latter, for reforestation, but research is necessary for domestication programmes.

Nearly half the important oil plant species in tropical Africa are cultivated at least in mixed cropping systems or at the subsistence levels; such species are in the early stages of domestication. Little is known of species cultivated in localised regions; research is needed to document present agronomic practices for them, as well as domestication trials.

Relatively few oil species are cultivated in monoculture systems, and most of these are domesticated oil crops introduced from around the globe, such as sunflower (*Helianthus annuus*) and brown mustard (*Brassica juncea*). Agronomic practice for many species is troubled by problems specific to local conditions. Constraints affecting farmers at all scales include seed distribution channels, availability of planting materials for locally-adapted cultivars, and on-farm production methods. For instance, optimal agronomic practice needs to be identified for the cultivation of soya bean (*Glycine max*) in mixed farming systems, and for niger seed (*Guizotia abyssinica*) for mixed and large scale production.

Further along the development chain, researchers should be influential in developing novel, appropriate methods for harvesting and post-harvest processing of oil species in tropical Africa. Optimal species-specific technologies for African vegetable oil processing are poorly understood. There is scope for innovative solutions to these constraints. Research into entry-level technologies for small-scale farmers and processors, in particular, is called for since many important oil species in tropical Africa have yet to be fully domesticated. For example, oil extraction from the seed of *Panda oleosa* cannot be optimised until mechanised methods for opening the hard fruit are developed.

5.2 Local value addition

There is a need for research to address opportunities to improve the standard and competitive value of local vegetable oil products, especially those from major oil crops such as coconut (*Cocos nucifera*) and soya bean (*Glycine max*). For instance, processing methods are required in tandem with post-harvest technology to prevent aflatoxin-contaminated harvests of groundnut (*Arachis hypogaea*). Research is also required to identify ways in which value may be added to oil products through additional processing and packaging. Opportunities have been identified for local women's networks to produce novel shea butter products for high-end consumer markets from the shea butter tree (*Vitellaria paradoxa*) in regions where the species occurs, to boost local economies.

Studies are most urgent, however, to identify effective and appropriate technologies for oil extraction. In some cases, research is necessary to modify existing technology used elsewhere in the world, such as oil extraction units from Asia for jatropha

(*Jatropha curcas*) and engines run on jatropha oil. For less widely cultivated species, however, primary research is required into oil extraction from species such as kanya (*Pentadesma butyracea*), the hard-stoned *Panda oleosa* and the thick-shelled Y-thorned torchwood (*Balanites maughamii*).

5.3 Oil research

Baseline data are required to characterise the oils afforded by species with recognised market potential in tropical Africa. Oil composition and fatty acid analyses are required for mkange (*Allanblackia stuhlmanii*), Y-thorned torchwood (*Balanites maughamii*), *Irvingia grandifolia* and *Pentaclethra eetveldeana*. Regional variation in the composition of oil from brown mustard (*Brassica juncea*) requires investigation for improved landraces to be identified. Similarly, oil composition from the coconut palm (*Cocos nucifera*) from different regions requires assessment for quality control purposes. There is a need to explore the manipulation of fatty acid content in species such as Ethiopian kale (*Brassica carinata*), in which the presence of erucic acid and glucosinolates are undesirable. The transformation and preservation of oil from the sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively) require investigation to expand the potential utility of oil from them.

5.4 Genetic improvement

Research in the rapidly advancing disciplines of molecular biology and genetics could offer solutions to constraints affecting the development of oil plant species as crops in tropical Africa. Notable research targets identified by stakeholders included phytogenetic study and sex determination in the dioecious oyster nut (*Telfairia pedata*), a species with widely recognised potential for increased production. Genetic studies are particularly important for high-potential native African oil species such as castor (*Ricinus communis*), niger seed (*Guizotia abyssinica*) and oil palm (*Elaeis guineensis*).

Domesticated oil crops are high on international research agendas, and the need for new African research agendas should be carefully considered in this context. However, there are needs for genetic research to optimise the cultivation of oil crops in Africa. For instance, gene tilling and gene introgression from wild relatives of sunflower into the domesticated species (*Helianthus annuus*) holds promise for improved suitability to African growing conditions. There are similar opportunities to improve stress tolerance in brown mustard (*Brassica juncea*) using gene introgression.

5.5 Integrated Pest Management

Integrated Pest Management (IPM), using complementary interventions to manage pests, diseases and weeds, is lacking among widely cultivated oil crops in tropical Africa. There is a need for locally appropriate IPM systems that will allow yields to be optimised. Research is particularly urgent to identify effective IPM for important oil crops that include groundnut (*Arachis hypogaea*), coconut palm (*Cocos nucifera*) and sesame (*Sesamum indicum*) as well as the indigenous oil species jatropha (*Jatropha curcas*) and dwarf red ironwood (*Lophira lanceolata*).

5.6 Diversified uses

Stakeholders identified the need for multidisciplinary research to explore the possibility of diversifying the uses of some oil species, thereby highlighting their economic potential. Angueuk (*Ongokea gore*), African nutmeg (*Pycnanthus angolensis*), *Symphonia louvelii* and the sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively), require such general investigation. The nutritional value of edible seedling roots of the Za baobab (*Adansonia za*) requires study as a food source and the implication this may have on nursery propagation.

Oils from several species may be suited to applications for which they are not widely used. For example, the edible oil of *Cephalocroton cordofanus* may be suitable for industrial applications, and that of soya bean (*Glycine max*) could be used more widely in food preparation. Castor oil from *Ricinus communis* and oils from forest mahogany (*Trichilia dregeana*) and mafura (*Trichilia emetica*) are recognised for their potential as ingredients in cosmetics and pharmaceuticals.

Several oil species are valued locally for their medicinal properties that require research, namely Y-thorned torchwood (*Balanites maughamii*), Ethiopian kale (*Brassica carinata*), *Pentaclethra eetveldeana,* African oil bean (*Pentaclethra macrophylla*), African nutmeg (*Pycnanthus angolensis*), mafura (*Trichilia emetica*) and the domesticated safflower (*Carthamus tinctorius*). There is also potential to harness the bioactivity of toxic principles from jatropha *(Jatropha curcas*).

5.7 Conservation and ecology

Of the 48 important oil-yielding species discussed in this booklet, half are gathered exclusively from natural populations. Little is known of the management interventions required for the sustainable use of these species should demand increase, and the needs for their conservation have been noted. Three wild harvested species were identified for research attention to facilitate their development: a study of the groundnut tree (*Ricinodendron heudelotii*) to identify appropriate management of natural populations, and studies of forest mahogany (*Trichilia dregeana*) and mafura (*Trichilia emetica*) to identify germplasm conservation methods that overcome the problem of storing their recalcitrant seeds in seed banks.

The ecological consequences of potentially weedy species escaping from cultivation are a risk often associated with the introduction of new crop species. Among the potential new oil crops for Africa, *Jatropha curcas* was highlighted for research attention to mitigate possible negative impacts on natural vegetation should the species escape from cultivation.

Table 4. Research gaps on oil species in tropical Africa

Research theme	Research gaps	Species
Domestication and agronomy	Selection/ breeding/yields Cultivation in small-scale, mixed or large-scale systems Post-harvest technology Seed harvesting Germination Tissue culture Adaptation trials for expanded regional cultivation	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Afrolicania elaeosperma* (po-yok) *Aleurites moluccana* (candlenut tree) *Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Cephalocroton cordofanus* *Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Lophira lanceolata* (dwarf red ironwood) *Moringa drouhardii* *Moringa peregrina* (ben tree) *Ongokea gore* (angueuk) *Panda oleosa* *Pentaclethra macrophylla* (African oil bean) *Pentadesma butyracea* (kanya) *Pycnanthus angolensis* (African nutmeg) *Ricinus communis* (castor) *Schinziophyton rautanenii* (mogongo) *Sesamum indicum* (sesame) *Simmondsia chinensis* (jojoba) *Symphonia louvelii* *Telfairia pedata* (oyster nut) *Vitellaria paradoxa* (shea butter tree)

Table 4. Research gaps on oil species in tropical Africa (Continued)

Research theme	Research gaps	Species
Local value addition	Appropriate oil extraction technology Processing	*Aleurites moluccana* (candlenut tree) *Arachis hypogaea* (groundnut) *Balanites maughamii* (Y-thorned torchwood) *Cocos nucifera* (coconut palm) *Glycine max* (soya bean) *Panda oleosa* *Pentadesma butyracea* (kanya) *Vitellaria paradoxa* (shea butter tree)
Oil research	Fatty acid profile Oil analysis Oil preservation	*Allanblackia stuhlmanii* *Balanites maughamii* (Y-thorned torchwood) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Cocos nucifera* (coconut palm) *Irvingia gabonensis* (sweet bush mango) *Irvingia wombolu* (bitter bush mango) *Pentaclethra eetveldeana*
Genetic improvement	Adjusted fatty acid composition Stress tolerance Improved yields Pest and disease resistance Allergen regulation	*Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Linum usitatissimum* (linseed) *Ricinus communis* (castor) *Telfairia pedata* (oyster nut) *Vernonia galamensis* (ironweed)
Integrated Pest Management		*Arachis hypogaea* (groundnut) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Glycine max* (soya bean) *Helianthus annuus* (sunflower) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Lophira lanceolata* (dwarf red ironwood) *Sesamum indicum* (sesame)
Diversified uses	Potential as industrial oil Novel oil products (food, cosmetic and/or pharmaceutical applications) Medicinal uses Toxicity	*Adansonia za* (Za baobab) *Balanites maughamii* (Y-thorned torchwood) *Brassica carinata* (Ethiopian kale) *Carthamus tinctorius* (safflower) *Cephalocroton cordofanus* *Glycine max* (soya bean) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango)

Table 4. Research gaps on oil species in tropical Africa (Continued)

Research theme	Research gaps	Species
Diversified uses	Potential as industrial oil Novel oil products (food, cosmetic and/or pharmaceutical applications) Medicinal uses Toxicity	*Jatropha curcas* (jatropha) *Ongokea gore* (angueuk) *Pentaclethra eetveldeana* *Pentaclethra macrophylla* (African oil bean) *Pycnanthus angolensis* (African nutmeg) *Ricinus communis* (castor) *Symphonia louvelii* *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura) *Vitellaria paradoxa* (shea butter tree)
Conservation and ecology	Management for sustainable wild harvesting Germplasm conservation Invasiveness	*Jatropha curcas* (jatropha) *Ricinodendron heudelotii* (groundnut tree) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)

6. Thesis subjects

African-led academic research programmes should be pivotal in the development of oil crops for the continent. During their training, postgraduate students, in particular, may offer meaningful contributions to the research needs discussed in Chapter 5. Theses and dissertations written by students undertaking their Doctoral, Masters and even Honours research projects represent a substantial but underutilised resource, since few will be published after peer review and as such will remain in the so-called grey literature. Initiatives to champion African academia and promote access to African scholarly material such as Aluka (www.aluka.org) and the Association of African Universities (www.aau.org) are changing that pattern.

Stakeholders identified research gaps in seven research themes (Chapter 5) and topics suitable for postgraduate research. Whereas local value addition is a research theme appropriate for regional research agendas (Chapter 5), thesis subjects in this theme were not identified, while taxonomy is a research theme well suited to postgraduate research (this chapter). Topics and species requiring investigation in each research theme are listed in Table 5.

6.1 Domestication and agronomy

Baseline research into the economics and production of vegetable oils is required to harness the potential of African biodiversity. Postgraduate research could contribute to various aspects, from market surveys and testing the economic returns of present supply chains, optimising production, or determining whether a particular vegetable oil has commercial potential at all, and identifying the socioeconomic factors to be considered when promoting the oil crop cultivation. Studies to address such questions are necessary not only for wild harvested species whose agronomy is poorly understood (e.g. the baobabs, *Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*) but also species that are already domesticated (e.g. sunflower, *Helianthus annuus*).

The principal aim of research into oil species presently in cultivation is optimised oil production. To achieve this, all steps of the cultivation or management system, harvest and post-harvest phases require research. For lesser known species that are not yet cultivated, research into the reproductive biology (notably the puzzling oyster nut, *Telfairia pedata*), seed physiology and cultivation systems is required. For oil species already in cultivation, research to identify opportunities to raise yields is necessary, including breeding, exploring landraces to find adaptive traits, and testing the suitability of species to various cropping systems. Evaluation of post-harvest technology for oil palm (*Elaeis guineensis*) and rhizobia on soya bean (*Glycine max*) were among the student project opportunities identified.

6.2 Oil research

The properties of oils determine how they are used and stored. Characterising the fatty acid composition and properties of oils from plants is, therefore, the first requirement for oil to be used commercially. It is not surprising that analyses are needed for oil species used on local scales, such as the baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa*, *Adansonia za*) and *Moringa drouhardii* in Madagascar. However, research into oil properties is also needed for more widely-traded oil species, for example the sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively), groundnut tree (*Ricinodendron heudelotii*) and even the oil crops sunflower and soya bean. For instance, saponification and quality control of oil from the shea butter tree (*Vitellaria paradoxa*) is needed to optimise shea butter production. The physiology of fatty acid synthesis in *Cephalocroton cordofanus*, which contains high concentrations of epoxy and hydroxy fatty acids, also warrants research.

6.3 Taxonomy

Taxonomy is fundamental for research and development of valuable plants, including those used for oil, so that accurate study and communication about a plant species is possible. This is a very important research theme where postgraduate students may have an important impact on science. Taxonomic uncertainties at the genus rank could affect the future exploitation of African oil species like the vegetable tallow tree (*Allanblackia floribunda, Allanblackia parviflora*), mkange (*Allanblackia stuhlmannii*), sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively), forest mahogany (*Trichilia dregeana*), mafura (*Trichilia emetica*) and jatropha (*Jatropha curcas*). A taxonomic evaluation of infraspecific classification of the coconut palm, *Cocos nucifera*, is necessary to document the variation in the pantropical species. Taxonomic investigation is required to identify the extent to which *Brassica juncea*, *Brassica napus*, *Brassica nigra* and *Brassica carinata* are grown in Africa, to highlight demands for these species.

6.4 Genetic improvement

Genetic techniques for plant breeding, manipulation and conservation are increasingly accessible to students of African universities. Baseline genetic characterisation and selection of superior germplasm are required for the heterogeneous niger seed (*Guizotia abyssinica*), sweet bush mango (*Irvingia gabonensis*) and linseed (*Linum usitatissimum*). Genetic techniques may be used to overcome the challenge of germplasm conservation and storage of the recalcitrant seeds of forest mahogany (*Trichilia dregeana*) and mafura (*Trichilia emetica*). There is scope to apply biotechnology to improve the vigour and yields of indigenous oil species such as Ethiopian kale (*Brassica carinata*), niger seed, castor (*Ricinus communis*), the shea butter tree (*Vitellaria paradoxa*), and the groundnut (*Arachis hypogaea*).

6.5 Integrated Pest Management

Several species were identified as subjects for possible postgraduate research on Integrated Pest Management (IPM). Controls for pests such as safflower fly on safflower (*Carthamus tinctorius*), and bird and rodent control in sunflower (*Helianthus annuus*), were among the topics identified by stakeholders. The management of fungal contamination is an ongoing problem for groundnut (*Arachis hypogaea*) farmers. Aflatoxins result in an inferior product, and are responsible for illness and death among people who eat contaminated products. Postgraduate research on this topic may highlight localised problems affecting farmers in different regions, and identify appropriate management interventions on the same local scale.

Studies of the useful qualities of oil species in IPM systems are needed. The suppressive effects of niger seed (*Guizotia abyssinica*) on weeds, and the effectiveness of soya bean (*Glycine max*) as a trap crop for the parasitic plant pest *Striga* spp., require investigation. The efficacy of seedcake from jatropha (*Jatropha curcas*) to control nematodes and the snail vector of bilharzia (schistosomiasis) also warrants research.

6.6 Diversified uses

Several important oil species used in Africa are valued for properties beside their oil content; research to optimise multipurpose value is well-suited to postgraduate research. Ethnobotanical studies and documentation of uses are required for several species (e.g. oyster nut, *Telfairia pedata*; dwarf red ironwood, *Lophira lanceolata*; kanya, *Pentadesma butyracea* and the baobabs, *Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*) to determine their biocultural value and highlight opportunities as multipurpose species.

The medicinal value and bioactivity of Y-thorned torchwood (*Balanites maughamii*), forest mahogany (*Trichilia dregeana*), mafura (*Trichilia emetica*) and the potential of po-yok (*Afrolicania elaeosperma*) for fertiliser, are likely research topics. In cultivation, prospects for the medicinal use of jatropha, apiculture in association with sunflower crops and dwarf red ironwood (*Lophira lanceolata*), and the role of jatropha (*Jatropha curcas*), *Moringa peregrina* (ben tree) and *Moringa drouhardii* in water purification, should be studied.

Opportunities to diversify the use of certain oils present suitable topics for postgraduate research, and include the potential of oil from the groundnut tree (*Ricinodendron heudelotii*) for industrial applications, the oil from the candlenut tree (*Aleurites moluccana*) in paint, and a detoxification process for the seedcake from jatropha and castor (*Ricinus communis*).

6.7 Conservation and ecology

Conservation concerns associated with vegetable oil production need to be identified and addressed in Africa. Topics of interest to students of ecology and conservation sciences may include the impacts of oil crops on the environment, such as the biodiversity supported by sunflower (*Helianthus annuus*) fields and the impacts of sunflower cropping on soil quality.

Oil species that are presently harvested from the wild attract the greatest concern for their conservation. The population dynamics and essential baseline distribution data for the baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa*, *Adansonia* za) and *Symphonia louvelii* are required for basic conservation need assessment. Sustainable rates of wild harvesting for mogongo (*Schinziophyton rautanenii*) and the effectiveness of on-farm protection for the shea butter tree (*Vitellaria paradoxa*), require assessment.

Table 5. Subjects for postgraduate research on oil species in tropical Africa

Research theme	Thesis subjects	Species
Domestication and agronomy	Cost-benefit analysis	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Balanites maughamii* (Y-thorned torchwood) *Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Jatropha curcas* (jatropha) *Lophira lanceolata* (dwarf red ironwood) *Ricinodendron heudelotii* (groundnut tree) *Ricinus communis* (castor) *Schinziophyton rautanenii* (mogongo)
	Market survey and current production figures	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Afrolicania elaeosperma* (po-yok) *Guizotia abyssinica* (niger seed) *Ongokea gore* (angueuk) *Pentadesma butyracea* (kanya) *Ricinus communis* (castor) *Schinziophyton rautanenii* (mogongo) *Telfairia pedata* (oyster nut) *Vernonia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)
	Germination studies	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Aleurites moluccana* (candlenut tree) *Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Panda oleosa*
	Commercial potential of oil	*Cephalocroton cordofanus* *Pycnanthus angolensis* (African nutmeg) *Telfairia pedata* (oyster nut) *Vernicia montana* (wood-oil tree)
	Adaptations	*Ricinus communis* (castor) *Simmondsia chinensis* (jojoba) *Verononia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)

Table 5. Subjects for postgraduate research on oil species in tropical Africa (Continued)

Research theme	Thesis subjects	Species
Domestication and agronomy	Breeding barriers	*Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange)
	Seed quality	*Arachis hypogaea* (groundnut) *Glycine max* (soya bean)
	Socioeconomic impact of cropping and oil extraction industry	*Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Vitellaria paradoxa* (shea butter tree)
	Multiplication, propagation and regeneration	*Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango) *Lophira lanceolata* (dwarf red ironwood) *Panda oleosa*
	Hybridisation	*Moringa drouhardii* *Moringa peregrina* (ben tree) *Telfairia pedata* (oyster nut)
	Suitability for intercropping	*Arachis hypogaea* (groundnut)
	Post-harvest technology	*Elaeis guineensis* (oil palm)
	Investigation of rhizobia	*Glycine max* (soya bean)
	Reproductive biology	*Telfairia pedata* (oyster nut)
	Agronomy	*Moringa drouhardii* *Moringa peregrina* (ben tree)
	Suitability for timber production	*Pentaclethra eetveldeana*
Conservation and ecology	Population dynamics and distribution	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Symphonia louvelii*
	Biodiversity supported by crops	*Helianthus annuus* (sunflower) *Lophira lanceolata* (dwarf red ironwood)
	Sustainable wild harvesting	*Schinziophyton rautanenii* (mogongo)
	Impact of cropping on soil quality	*Helianthus annuus* (sunflower)
	On-farm conservation	*Vitellaria paradoxa* (shea butter tree)

Table 5. Subjects for postgraduate research on oil species in tropical Africa (Continued)

Research theme	Thesis subjects	Species
Diversified uses	Ethnobotany	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Lophira lanceolata* (dwarf red ironwood) *Moringa drouhardii* *Moringa peregrina* (ben tree) *Pentaclethra eetveldeana* *Pentaclethra macrophylla* (African oil bean) *Pentadesma butyracea* (kanya) *Telfairia pedata* (oyster nut)
	Bioactivity	*Balanites maughamii* (Y-thorned torchwood) *Trichilia dregeana* (forest mahogany)
	Biofuel potential and technology	*Brassica carinata* (Ethiopian kale) *Jatropha curcas* (jatropha)
	Apiculture	*Helianthus annuus* (sunflower) *Lophira lanceolata* (dwarf red ironwood)
	Role in water conservation	*Jatropha curcas* (jatropha)
	Role in water purification	*Moringa drouhardii* *Moringa peregrina* (ben tree)
	Detoxification of seedcake	*Jatropha curcas* (jatropha) *Ricinus communis* (castor)
	Potential as fertiliser	*Afrolicania elaeosperma* (po-yok)
	Potential as paint	*Aleurites moluccana* (candlenut tree)
Oil analysis	Physiology of fatty acid production	*Cephalocroton cordofanus*
	Saponification and quality control of oil	*Vitellaria paradoxa* (shea butter tree)
Integrated Pest Management	Management of mistletoe in production	*Vitellaria paradoxa* (shea butter tree)
	Management to prevent aflatoxin contamination	*Arachis hypogaea* (groundnut)
Genetics	Seed recalcitrance and germplasm conservation	*Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)

7. Conservation needs

Africa is celebrated for its rich biodiversity and unchanged landscapes. Natural resources from the wild are used on a daily basis by many Africans, directly for fuel, food and medicine, and livelihoods such as employment in the ecotourism industry or trading in wild harvested commodities. The value of natural resources is recognised by international agendas, including the New Partnership for Africa's Development (NEPAD) and the United Nations' Millennium Development Goals (www.un.org/millenniumgoals).

Although *in situ* conservation is the principal aim for biodiversity conservation, *ex situ* conservation is a necessary guarantee against the loss of valuable genetic diversity. Suitable facilities are available throughout tropical Africa for the *ex situ* conservation of important plant resources. Cultivated plants, including oil species, are most appropriately conserved in specialised germplasm collections or gene banks, in which viable genetic material is stored. Examples include the ICRAF gene banks in Cameroon and Nigeria where living material of sweet bush mango (*Irvingia gabonensis*) is stored, and the major Ethiopian germplasm collection for linseed (*Linum usitatissimum*). There is a need for improved germplasm exchange between Africa and the rest of the world, particularly in cases where African plant breeders have limited access to germplasm of African origin that is held in international collections.

Similar *ex situ* conservation interventions may be applied to non-cultivated plants. The principal repositories of living plant material from the flora are seed banks and botanic gardens. Local capacity, which varies throughout tropical Africa, is supported by collaborations such as Botanic Gardens Conservation International (www.bgci.org) and the Millennium Seed Bank Project at the Royal Botanic Gardens, Kew (www.kew.org/msbp). Conservation is most important for species of known conservation concern, which are likely to be protected by national law and listed on CITES appendices (www.cites.org) and the IUCN Red List of Threatened Species (www.iucnredlist.org). Among the oil species in this booklet, three baobab species (*Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*), mkange (*Allanblackia stuhlmannii*), sweet bush mango (*Irvingia gabonensis*) and the shea butter tree (*Vitellaria paradoxa*) are Red Listed.

Stakeholders identified conservation concerns for most of the 48 important oil species in tropical Africa (Appendix 2). Recommendations are discussed here according to the conservation measures required (Table 6) although interventions may be similar in practice. Wild harvested species apparently not presently threatened by exploitation include Y-thorned torchwood (*Balanites maughamii*), kanya (*Pentadesma butyracea*), *Panda oleosa* and *Pentaclethra eetveldeana.* Similarly, the widely cultivated *Moringa drouhardii* and exotic species such as the candlenut tree (*Aleurites moluccana*), olive (*Olea europaea*), Chinese tallow tree (*Triadica sebifera*) and wood-oil tree *(Vernicia montana*) were not deemed priorities for conservation.

7.1 *In situ* and *ex situ* conservation

Oil species that are wild harvested generally require both *in situ* and *ex situ* conservation to ensure that harvesting for oil extraction does not threaten existing populations, and that genetic resources are available for future use and development.

The importance of these conservation measures is clear for species such as the shea butter tree (*Vitellaria paradoxa*) which supports an expanding international market and is classified on the IUCN Red List as vulnerable to extinction. Likewise, the baobabs (*Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*), are Red Listed and require conservation intervention before exploitation for their oil might threaten their occurrence in the wild. Conservation is also required for species in growing demand, such as the groundnut tree (*Ricinodendron heudelotii*), or in decline in the wild, such as the ben tree (*Moringa peregrina*) and African oil bean (*Pentaclethra macrophylla*). Baseline conservation assessment of the Malagasy endemic *Symphonia louvelii* is recommended, since the status of the species is poorly understood.

7.2 *Ex situ* conservation priority

Domesticated species such as sunflower (*Helianthus annuus*) are no longer known in the wild, making *ex situ* conservation the only means of conserving genetic diversity in widely cultivated species. In tropical Africa, there is a need to conserve local germplasm of sunflower, groundnut (*Arachis hypogaea*) and soya bean (*Glycine max*). In the case of the coconut palm (*Cocos nucifera*), germplasm collections are needed from regions where landuse changes or climate change may threaten future cultivation. The development of cryopreservation techniques for the coconut palm, forest mahogany (*Trichilia dregeana*) and mafura (*Trichilia emetica*), which have recalcitrant seeds, is recommended. For emerging oil crops such as jatropha (*Jatropha curcas*), germplasm collections fulfill an important function in conserving genetic diversity for future crop development. The drought adaptation traits of *Cephalocroton cordofanus*, for example, could be very valuable to plant breeders in future. Of the important oil crops in Africa, Ethiopian kale (*Brassica carinata*), brown mustard (*Brassica. juncea*), sunflower, coconut and cram-cram (*Crambe hispanica*) are recognised as priorities for conservation and germplasm exchange by the International Treaty on Plant Genetic Resources for Food and Agriculture (www.planttreaty.org).

In addition to the need for access to germplasm collections outside Africa (notably those holding accessions of African origin), African plant breeders would benefit from improved germplasm exchange among African germplasm collections. Information regarding germplasm available in collections around the world is, however, problematic to scientists in Africa. Bioversity International (www.bioversityinternational.org/Information_Sources/Germplasm_Databases/index.asp) hosts links to online databases listing European germplasm collections for some oil species such as soya bean (*Glycine max*), olive (*Olea europaea*), Ethiopian kale (*Brassica carinata*) and brown mustard (*Brassica juncea*). Germplasm held in national collections in the United States may be searched via the National Plant Germplasm System (www.ars-grin.gov/npgs).

7.3 *In situ* conservation priority

In situ conservation is a priority for wild harvested oil species that are used on a local scale, with unlikely prospects for market expansion. Such species include po-yok (*Afrolicania elaeosperma*) and angueuk (*Ongokea gore*).

7.4 Conservation of landraces

Landraces are variants of a cultivated species that have developed unique adaptations to local conditions, making them well suited for cultivation in particular areas. Landraces are valuable, since they may bear significantly higher yields than other cultivars of a crop species. Conserving landraces offers opportunities for adaptive characters (e.g. tolerances to drought or soil conditions) to be used for breeding new cultivars at a later date. Hence, there is a need to conserve landraces of oil species such as groundnut (*Arachis hypogaea*), east African landraces of linseed (*Linum usitatissimum*), sesame (*Sesamum indicum*), and safflower (*Carthamus tinctorius*). The diversity of Ethiopian kale (*Brassica carinata*) and brown mustard (*Brassica juncea*) requires priority landraces for germplasm collections in the SADC region to be determined.

7.5 Conservation of ecotypes

Ecotypes are the unique, locally-adapted variants of non-cultivated plant species. Like the landraces of cultivated species, ecotypes possess valuable adaptations to local conditions and give higher yields. Ecotypes of sweet- and bitter bush mangoes (*Irvingia gabonensis* and *Irvingia wombolu*, respectively) require conservation in germplasm collections. In the case of mogongo (*Schinziophyton rautanenii*), ecotypes from throughout the species range are required to supplement the existing germplasm collection in Namibia, while African ecotypes of castor (*Ricinus communis*) are lacking from the existing germplasm collection in Ethiopia.

Table 6. Conservation measures recommended for oil species in tropical Africa

Conservation measures	Species
In situ and *ex situ* conservation	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Lophira lanceolata* (dwarf red ironwood) *Moringa peregrina* (ben tree) *Pentaclethra macrophylla* (African oil bean) *Pycnanthus angolensis* (African nutmeg) *Ricinodendron heudelotii* (groundnut tree) *Symphonia louvelii* *Telfairia pedata* (oyster nut) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura) *Vernonia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)
Ex situ conservation priority	*Allanblackia floribunda* *Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Cephalocroton cordofanus* *Cocos nucifera* (coconut palm) *Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Ricinodendron heudelotii* (groundnut tree) *Ricinus communis* (castor) *Schinziophyton rautanenii* (mogongo) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)
Conserve landraces	*Arachis hypogaea* (groundnut) *Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Carthamus tinctorius* (safflower) *Elaeis guineensis* (oil palm) *Helianthus annuus* (sunflower) *Sesamum indicum* (sesame)
Conserve ecotypes	*Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mango)
In situ conservation priority	*Afrolicania elaeosperma* (po-yok) *Ongokea gore*

8. Policy measures

Sustainable development of the vegetable oil industry in tropical Africa will rely on sound environmental policies, a clearly defined regulatory framework and robust infrastructure. The opportunities and development needs discussed in preceding chapters are all influenced by these governance structures. In this chapter, policy measures recommended by stakeholders are discussed. Policy needs were identified for most of the 48 important oil species in Africa today (Appendix 2). While the needs and opportunities for research, development and accessible technology were highlighted in preceding chapters, conservation of biodiversity was identified as an important policy issue in the development of most oil species (Table 7). With appropriate policy, the developing vegetable oil industry in tropical Africa will secure the interest of investors for the future.

8.1 Conservation

Conservation policies, at national, regional and global levels, to support the sustainable use of oil species in tropical Africa, is needed to allow legislation to be enforced, support conservation programmes and botanic gardens, and support herbaria and germplasm conservation. Non-cultivated oil species are threatened by parameters as varied as habitat loss, non-sustainable harvesting and grazing. The conservation needs of cultivated species differ considerably (see Chapter 7).

The germplasm of many oil species is conserved by member institutes of the Consultative Group on International Agricultural Research (CGIAR) such as Biodiversity International, the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), the World Agroforestry Centre (ICRAF) and International Institute of Tropical Agriculture (IITA), as well as gene banks and research institutes elsewhere in the world. Accessions of local landraces are essential for these species, as modern cultivars are slowly replacing landraces.

Whereas perennial oil species are generally widespread in tropical Africa and not endangered, germplasm collections should be initiated for localised species such as the groundnut tree (*Ricinodendron heudelotii*), oyster nut (*Telfairia pedata*) and the wood-oil tree (*Vernicia montana*). The harvesting and trade of wild harvested species, notably those with multiple uses, must be carefully monitored to protect natural populations. For instance, Grandidier's baobab (*Adansonia grandidieri*) is threatened by the loss of a significant proportion of mature trees (more than 20%), poor regeneration and recruitment, and continued harvesting pressure. Genetic diversity of the shea butter tree (*Vitellaria paradoxa*) is being eroded due to frequency of burning and overgrazing.

Conservation and policy organisations with wide geographical remits, such as the International Union for Conservation of Nature (IUCN), the Forum for Agricultural Research in Africa (FARA) and Southern African Development Community (SADC) have a role to play in coordinating efforts, improving efficiency and avoiding unnecessary duplication in conservation efforts in tropical Africa.

8.2 Market development and opportunities

Policy makers are well positioned to bring together farmers, processors, exporters, input suppliers and distributers in Africa's vegetable oil industry. The foundation of the value chain (farmers and oil processors) need to be aware of market demands to justify scaled-up production. A vibrant communication system and market research, feasibility studies and cost benefit analyses are essential for this. Poor infrastructure, in particular, affects producers' access to distant, more profitable markets. The impacts of low returns from vegetable oils and losses due to inadequate storage facilities on farmers' profit margins prevent them, in turn, from investing in quality seed and farm inputs. Improved infrastructure (e.g. telecommunications, energy, roads and clean water) would help to reduce losses and increase profitability throughout the value chain.

Regional or national branding of vegetable oils would enhance product standards and allow trade links to be established in Africa. International markets exist for several vegetable oils grown in Africa but, due to high production costs, low yields and low returns, African producers are unable to compete in these markets; they need efficient labour, farm inputs, production scales and improved infrastructure to reduce production costs and compete in global markets. Niche markets for speciality vegetable oils and products exist for vegetable tallow tree (*Allanblackia floribunda* and *Allanblackia parviflora*), shea butter tree (*Vitellaria paradoxa*), linseed (*Linum usitatissimum*), dwarf red ironwood (*Lophira lanceolata*), oyster nut (*Telfairia pedata*) and castor (*Ricinus communis*) but market links and awareness among producers are necessary to exploit them.

One market opportunity that cannot be ignored in tropical Africa is the rising demand for vegetable oils for biofuel. Jatropha (*Jatropha curcas*), castor (*Ricinus communis*), coconut and oil palms (*Cocos nucifera* and *Elaeis guineensis*), Ethiopian kale (*Brassica carinata*) and brown mustard (*Brassica juncea*) are among species with great potential for biofuel.

8.3 Quality control, safety standards and policy

Policy makers are responsible for formulating national laws and regulatory frameworks in accordance with globally acceptable quality control and safety standard concepts, such as the Hazard Analysis and Critical Control Point (HACCP) and the International Organization for Standardization (ISO). It is fundamental that legislature includes good agricultural practices (GAPs), good manufacturing practices (GMPs), food and feed quality and safety standards, product traceability, as well as environmental and phytosanitary safety regulations. Policy makers are also responsible for monitoring legislature and frameworks, and are jointly responsible with numerous other parties for enforcing legislation that influences vegetable oil production.

In tropical Africa, awareness of health hazards, food and feed quality and safety is low, and the task of governments to improve this. A major health hazard associated with vegetable oils is *Aspergillus* contamination, notably in groundnut (*Arachis hypogaea*) and coconut palm (*Cocos nucifera*) oils. Aflatoxins from *Aspergillus* fungi cause illness and death in humans and livestock, especially in areas where groundnut consumption is an important food. While imported and exported groundnut seeds, oil and protein meal are strictly regulated, there is a much greater risk of aflatoxin contamination in groundnuts destined for local consumption. African governments have a responsibility to reduce aflatoxin contamination, since sub-Saharan Africa produces nearly a quarter of the world's groundnut crop, of which 95% is consumed locally. Adherence to food and feed quality and safety standards is, similarly, critical for oils from the shea butter tree (*Vitellaria paradoxa*), oil palm *(Elaeis guineensis*), soya bean (*Glycine max*), castor (*Ricinus communis*) and coconut palm.

Quality seeds of robust and locally-adapted cultivars are a prerequisite for good yields, yet the lack of effective policies for distribution impedes their use by farmers in tropical Africa. National policies, in particular, should be formulated to promote farmers' access to seed and other farm inputs ahead of the planting season. Bearing farmers' interests in mind, policy makers must facilitate sustainable seed supply systems in the region.

Regulatory frameworks on biosafety are required to address the controversial issue of genetically modified organisms (GMOs), an alternative to improved cultivars, in tropical Africa. Policy defining regional strategies for GMOs is essential, since biotechnology tools are already, or are likely to be used in future, on crops such as soya bean, oil palm, groundnut and safflower (*Carthamus tinctorius*). Policy is also required to address the use of arable land to grow non-edible crops and raw materials for biofuel.

8.4 Support for research on vegetable oils

National research institutions and independent CGIAR institutes are likely to continue leading research and development of oil species, technology and innovations in tropical Africa. While much research has been undertaken on oil species grown as commercial crops in tropical Africa, appropriate technologies suited to African agronomic practices require attention. Governments are obliged to attract interested parties (the private sector) to address these gaps and to invest in vegetable oil research in tropical Africa.

Favourable investment conditions include political will and stability, good infrastructure, demand for novel technologies, competitiveness, access to capital investment and relatively low production costs. Furthermore, the implementation of legislation and conventions to protect biodiversity and intellectual property rights is critical for success. Vegetable tallow tree (*Allanblackia floribunda*, *Allanblackia parviflora*), jatropha (*Jatropha curcas*), linseed (*Linum usitatissimum*), dwarf red ironwood (*Lophira lanceolata*) and castor (*Ricinus communis*) are among the most promising oil species presently attracting research attention from the private sector in partnership with government, research institutions and other organisations, while opportunities for innovation also exist among widely cultivated oil species such as sunflower (*Helianthus annuus*).

8.5 Capacity building and technology transfer

The findings of African research published in scholarly literature has insufficient impact on people who depend on oil species for their livelihoods; access to current information, new technologies and innovations is similarly limited in tropical Africa. There is a need for enhanced skills and knowledge among greater numbers of extension workers and community members to ensure technical knowledge and technology transfer, and ultimately the sustainable development of the vegetable oil industry. Since policy makers may directly influence national and regional resource allocation for capacity building, they should consult key implementers including universities, research institutions, Non-Governmental Organisations (NGOs) and the private sector. Participatory and responsive training programmes for farmers, oil processors and extension workers, encompassing all aspects of vegetable oil production, require support in regional and national frameworks.

8.6 Extension and promotion

Technology in itself is not useful until the benefits are appreciated by people using it; this is the basis for efficient and effective extension methods advocated by government. Participatory extension approaches such as demonstration plots, on-farm adaptation trials and Farmer Field Schools (FFS) have proved effective methods for dissemination and adoption of extension messages.

Stakeholders identified low yields, inefficient extraction methods, and limited product diversification as the principal constraints to sustainable vegetable oil production in tropical Africa. Improved cultivars and best agronomic practices are prerequisites for overcoming these constraints. For example, best practices for cultivation and processing oil palm (*Elaeis guineensis*) can result in four to six times higher oil yields than other methods. For perennial and wild harvested oil species, interventions such as rapid multiplication techniques, on-farm grafting and assisted natural regeneration can optimise oil yields.

Promoting oil species suited to cultivation on marginal, disturbed or saline soils encourages diversification. Reasonable yields from safflower (*Carthamus tinctorius*), for instance, can be obtained from as long as 300 mm of rain is received before flowering, and salt tolerant cultivars are sown. Ironweed (*Vernonia galamensis*) and jojoba (*Simmondsia chinensis*) are suitable for cultivation in semi-arid lands while jatropha (*Jatropha curcas*) and castor (*Ricinus communis*) are appropriate in disturbed areas.

The importance of government support for the success of domestication programmes is well known. A successful domestication programme on the vegetable tallow tree, *Allanblackia parviflora*, for example, has been undertaken with government support in Ghana. Other domestication programmes that deserve government support are indicated in Table 7. Likewise, the importance of supportive policy for new export crops is crucial to their success. The shea butter tree (*Vitellaria paradoxa*) should be promoted for export market as a substitute for cocoa. There is growing demand for export market in Europe for oyster nut (*Telfairia pedata*). Kernels of bitter bush mango (*Irvingia wombolu*) are traded internationally in west and central Africa as well as exported to Europe. Creating commodity-specific extension programmes would considerably enhance promotions for novel oil products such as these to supply market niches.

Table 7. Policy measures for sustainable research and development of oil species

Policy measures	Interventions	Species
Conservation	Support conservation programmes Support sustainable wild harvesting Regulate land use and monitor environmental impacts of cultivation Protect against felling Support agroforestry Regulate trade in medicinal plants	*Adansonia grandidieri* (Grandidier's baobab) *Adansonia rubrostipa* (Fony baobab) *Adansonia za* (Za baobab) *Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Cephalocroton cordofanus* *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mangoes) *Linum usitatissimum* (linseed) *Lophira lanceolata* (dwarf red ironwood) *Moringa peregrina* (ben tree) *Olea europaea* (olive) *Ongokea gore* (angueuk) *Panda oleosa* *Pentaclethra macrophylla* (African oil bean) *Pycnanthus angolensis* (African nutmeg) *Ricinodendron heudelotii* (groundnut tree) *Ricinus communis* (castor) *Schinziophyton rautanenii* (mogongo) *Symphonia louvelii* *Telfairia pedata* (oyster nut) *Trichilia dregeana* (forest mahogany) *Trichilia emetica* (mafura)
Market development and opportunities	Support research on markets and supply chains Support local and export market opportunities Market for nutritional value Market for non-edible uses	*Aleurites moluccana* (candlenut tree) *Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Crambe hispanica* (cram-cram) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower)

Table 7. Policy measures for sustainable research and development of oil species (Continued)

Policy measures	Interventions	Species
Market development and opportunities	Support research on markets and supply chains Support local and export market opportunities Market for nutritional value Market for non-edible uses	*Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Ricinus communis* (castor) *Sesamum indicum* (sesame) *Vernonia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)
Quality control, safety standards and policy	Monitor compliance with best practices Design and implement quality assurance systems Encourage certification of planting material Encourage product certification GMO policy Biofuel policy Non-edible crop policy Carbon sequestration policy	*Arachis hypogaea* (groundnut) *Carthamus tinctorius* (safflower) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Glycine max* (soya bean) *Guizotia abyssinica* (niger seed) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Ricinodendron heudelotii* (groundnut tree) *Ricinus communis* (castor) *Simmondsia chinensis* (jojoba) *Telfairia pedata* (oyster nut) *Vitellaria paradoxa* (shea butter tree)
Research	Support oil research Support international collaboration Support national breeding programmes Facilitate reliable seed/seedling supply	*Guizotia abyssinica* (niger seed) *Helianthus annuus* (sunflower) *Irvingia gabonensis* (sweet bush mango) *Irvingia grandifolia* *Irvingia wombolu* (bitter bush mangoes) *Jatropha curcas* (jatropha) *Linum usitatissimum* (linseed) *Lophira lanceolata* (dwarf red ironwood) *Moringa peregrina* (ben tree) *Ricinus communis* (castor) *Vernonia galamensis* (ironweed) *Vitellaria paradoxa* (shea butter tree)

Table 7. Policy measures for sustainable research and development of oil species (Continued)

Policy measures	Interventions	Species
Capacity building and technology transfer	Promote for smallholder production Support technology-based enterprises Facilitate international germplasm exchange Support public-private partnerships Develop novel products	*Allanblackia floribunda* (vegetable tallow tree) *Allanblackia parviflora* (vegetable tallow tree) *Allanblackia stuhlmannii* (mkange) *Arachis hypogaea* (groundnut) *Helianthus annuus* (sunflower) *Linum usitatissimum* (linseed) *Triadica sebifera* (Chinese tallow tree) *Vernicia montana* (wood-oil tree)
Extension and promotion	Facilitate reliable seed/seedling production and distribution Support crop rehabilitation Promote for poverty alleviation Promote for multipurpose uses	*Brassica carinata* (Ethiopian kale) *Brassica juncea* (brown mustard) *Cocos nucifera* (coconut palm) *Elaeis guineensis* (oil palm) *Helianthus annuus* (sunflower) *Jatropha curcas* (jatropha)

Appendix 1. Comparative data on 48 important oil species used in Africa

Key to the table

Origin	Indigenous: of local (African) origin Introduced: introduced (to Africa) from elsewhere
Dist. (Distribution)	Distribution in tropical Africa (see map on inner back cover) C: Central Africa E: East Africa I: Indian Ocean Islands S: Southern Africa W: West Africa
Status	Cultivation status Wild: harvested from populations in the wild Cult.: cultivated
Life cycle	Annual: plant that completes its life cycle and dies within a year of germinating Perennial: plant that lives for two or more years
Growth	Growth habit Herb: plant that never produces woody growth Liane: woody, climbing plant supported by other vegetation Shrub: woody plant, branching near the ground or with several stems from the base; if single-stemmed then quite short (< 2m) Tree: perennial woody plant above 2–3 m, with a main trunk
Altitude range	Vertical range in which a plant occurs, measured in metres above sea level
Prop. (Propagation)	Principal propagation method (secondary method in parentheses) G: Generative, by seed V: Vegetative, by non-seed means B: Both generative and vegetative propagation methods possible
Oil %	Oil content, measured in percent oil in plant material
Fatty acids	Principal fatty acids present in oil
Plant part	Plant part from which oil is extracted
Oil uses	Principal applications for oil

Secondary uses Uses in other commodity groups in addition to Primary use 14, Vegetable oils.
1, Cereals and pulses; 2, Vegetables; 3, Dyes and tannins; 4, Ornamentals; 5, Forages; 6, Fruits; 7, Timbers; 8, Carbohydrates; 9, Auxiliary; 10, Fuel; 11, Medicine; 12, Spices and condiments; 13, Essential oils and exudates; 15, Stimulants; 16, Fibres

Species	Family	Vernacular name	Origin	Dist.	Status	Life cycle	Growth	Altitude range	Prop.	Oil %	Fatty acid(s)	Plant part	Oil uses	Secondary uses
Adansonia grandidieri	Bombacaceae	Grandidier's baobab	indigenous	I	wild	perennial	tree	–	G	36-39	oleic, palmitic	seed	edible	5, 6, 16
Adansonia rubrostipa	Bombacaceae	Fony baobab	indigenous	I	wild	perennial	tree	–500	G	11	linoleic, oleic, palmitic	seed	edible	6, 8, 16
Adansonia za	Bombacaceae	Za baobab	indigenous	I	wild	perennial	tree	–800	G	11	linoleic, oleic, palmitic	seed	edible	5, 6, 7, 8, 11, 16
Afrolicania elaeosperma	Chrysobalanaceae	po-yok	indigenous	C W	wild	perennial	tree	–	G	40-58	eleostearic, licanic	kernel	hair, fragrance, varnish, paint	
Aleurites moluccana	Euphorbiaceae	candlenut tree	introduced (from Asia)	C E I S	cult.	perennial	tree	–	G (V)	60-62	linoleic, linolenic, oleic	seed	cosmetics, linseed substitute	3, 4, 5, 6, 7, 9, 10, 11, 12, 16
Allanblackia floribunda	Clusiaceae	vegetable tallow tree	indigenous	C W	wild	perennial	tree	–1000	B	72	oleic, stearic	kernel	edible	6, 7, 10, 11, 16
Allanblackia parviflora	Clusiaceae	vegetable tallow tree	indigenous	W	wild	perennial	tree	–	B	64	oleic, stearic	seed	edible	7, 9, 11, 13, 16
Allanblackia stuhlmannii	Clusiaceae	mkange	indigenous	E	wild	perennial	tree	800–1200 (–1600)	B	50	oleic, stearic	seed	edible	3, 4, 5, 6, 7, 9, 10, 11
Arachis hypogaea	Papilionaceae	groundnut	introduced (from S. America)	C E I S W	cult.	annual	herb	0–1500	G (V)	42-56	linoleic, oleic	seed	edible	2, 5, 9, 10, 11, 16
Balanites maughamii	Balanitaceae	Y-thorned torchwood	indigenous	E S	wild	perennial	tree	0–1000	B	60	–	seed (mesocarp)	industrial	4, 6, 7, 10, 11
Brassica carinata	Brassicaceae	Ethiopian kale	indigenous	C E I S W	cult.	annual	herb	–2600	G (V)	25-47	erucic	seed	edible, mustard, hair, lubricant, industrial	2, 5, 11, 12
Brassica juncea	Brassicaceae	brown mustard	introduced (from Asia)	C E I S W	cult.	annual	herb	0–	G	28-45	erucic	seed	mustard, illumination, biofuel	2, 5, 11, 12
Carthamus tinctorius	Asteraceae	safflower	indigenous	E I S W	cult.	annual	herb	1000–2200	G	35-60	linoleic, oleic	seed	edible, industrial, olive oil substitute	2, 3, 4, 5, 11, 16
Cephalocroton cordofanus	Euphorbiaceae	–	indigenous	C E W	wild	perennial	shrub	0–1200	G	42	epoxyoleic	seed	edible, industrial	6

Species	Family	Vernacular name	Origin	Dist.	Status	Life cycle	Growth	Altitude range	Prop.	Oil %	Fatty acid(s)	Plant part	Oil uses	Secondary uses
Cocos nucifera	Arecaceae	coconut palm	introduced (from Asica & Pacific)	C E I S W	cult.	perennial	tree	0–500 (–1000)	G	63-68	lauric	endosperm	edible, industrial	2, 4, 5, 6, 7, 8, 10, 11, 16
Crambe hispanica	Brassicaceae	cram-cram	indigenous	C E	cult.	annual	herb	1200–2600	G	33	erucic	fruit	lubricant, industrial	2, 5, 9, 11
Elaeis guineensis	Arecaceae	oil palm	indigenous	C E I S W	cult.	perennial	tree	0–	G	20-28 (-50)	oleic, palmitic	fruit, kernel	edible, industrial	2, 4, 5, 7, 8, 9, 10, 11, 16
Glycine max	Papilionaceae	soya bean	introduced (from Asia)	C E I S W	cult.	annual	herb	0–2000	G	18	linoleic	seed	edible, industrial	1, 2, 5, 9, 15
Guizotia abyssinica	Asteraceae	niger seed	indigenous	C E S	cult.	annual	herb	500–2500	G	25-60	linoleic	seed	edible, industrial	2, 5, 8, 10, 11, 12
Helianthus annuus	Asteraceae	sunflower	introduced (from N. America)	C E I S W	cult.	annual	herb	0–1500 (–2500)	G	> 50	linoleic	seed	edible	4, 5, 6, 8, 16
Irvingia gabonensis	Irvingiaceae	sweet bush mango	indigenous	C W	wild & cult.	perennial	tree	0–1000	G	67	lauric, myristic	kernel	edible	3, 5, 6, 7, 9, 10, 11, 12
Irvingia grandifolia	Irvingiaceae	–	indigenous	C W	wild	perennial	tree	0–	G		–	kernel	edible	6, 7, 11
Irvingia wombolu	Irvingiaceae	bitter bush mango	indigenous	C E S W	wild & cult.	perennial	tree	0–	G (V)	38-75	lauric, myristic	kernel	edible	5, 7, 9, 10, 11, 12
Jatropha curcas	Euphorbiaceae	jatropha	introduced (from America)	C E I S W	cult.	perennial	shrub	0–	B	32-45	linoleic, oleic	seed	industrial, biofuel	3, 4, 5, 6, 9, 11, 12
Linum usitatissimum	Linaceae	linseed	introduced (from Asia & Europe)	E W	cult.	annual	herb	1600–2800	G	34	a-linolenic	seed	industrial	11, 13, 16
Lophira lanceolata	Ochnaceae	dwarf red ironwood	indigenous	C E W	wild	perennial	tree	0–1500	G	44	linoleic, palmitic	seed	edible	3, 5, 6, 7, 10, 11
Moringa drouhardii	Moringaceae	–	indigenous	I	wild & cult.	perennial	shrub-tree	0–	G	36-45	oleic	seed	edible, fragrance, pharmaceutical	9, 11
Moringa peregrina	Moringaceae	ben tree	indigenous	E	wild	perennial	shrub-tree	0–850	G	50	oleic	seed	edible, cosmetics, medicine	4, 5, 8, 10, 11

Species	Family	Vernacular name	Origin	Dist.	Status	Life cycle	Growth	Altitude range	Prop.	Oil %	Fatty acid(s)	Plant part	Oil uses	Secondary uses
Olea europaea	Oleaceae	olive	indigenous	C E I S W	wild	perennial	tree	1000–3150	V	15-30	oleic	mesocarp	edible	4, 5, 6, 7, 9, 10, 11, 12
Ongokea gore	Olacaceae	angueuk	indigenous	C S W	wild	perennial	tree	0–	G (V)	63	diacetylenic	seed	industrial	6, 7, 11
Panda oleosa	Pandaceae	–	indigenous	C W	wild	perennial	tree	0–	–	50	linoleic, oleic	seed	edible	7, 8, 11
Pentaclethra eetveldeana	Mimosaceae	–	indigenous	C	wild	perennial	tree	0–	G	??	–	seed	edible	6, 7, 8, 10, 11
Pentaclethra macrophylla	Mimosaceae	African oil bean	indigenous	C E I S W	wild & cult.	perennial	tree	0–500	G	35-52	linoleic	seed	edible	3, 4, 5, 6, 7, 9, 10, 11, 12
Pentadesma butyracea	Clusiaceae	kanya	indigenous	C W	wild	perennial	tree	0–	G	50	oleic , stearic	kernel	edible	2, 6, 7, 10, 11, 15, 16
Pycnanthus angolensis	Myristicaceae	African nutmeg	indigenous	C E S W	wild	perennial	tree	0–1200 (–1400)	G	45-70	myristic	seed	industrial, soap, illumination	4, 7, 9, 10, 11, 12, 16
Ricinodendron heudelotii	Euphorbiaceae	groundnut tree	indigenous	C E S W	wild	perennial	tree	200–500	G	-60	a-eleostearic, linoleic	seed	edible, industrial	2, 4, 5, 7, 9, 11, 12, 16
Ricinus communis	Euphorbiaceae	castor	introduced (from NE Africa)	C E I S W	wild & cult.	(annual-) perennial	shrub-tree	0–2000	G	43-53	ricinoleic	seed	industrial	3, 4, 5, 9, 10, 11
Schinziophyton rautanenii	Euphorbiaceae	mogongo	indigenous	C E S	wild	perennial	shrub-tree	200–1500	B	57	a-eleostearic, linolenic	kernel	edible, cosmetics	5, 6, 7, 11, 16
Sesamum indicum	Pedaliaceae	sesame	introduced (from India)	C E I S W	cult.	annual	herb	0–1500 (–1800)	G (V)	60	linoleic, oleic (glycerides)	kernel	edible	2, 5, 6, 10, 11, 12, 15
Simmondsia chinensis	Simmondsiaceae	jojoba	introduced (from America)	C E S W	cult.	perennial	shrub	0–1500	G (V)	50-54	long-chain unsaturated wax	seed	cosmetics, industrial	4, 5, 6, 11, 15
Symphonia louvelii	Clusiaceae	–	indigenous	I	wild	perennial	tree	0–2300	B	40	oleic	seed	industrial, pharmaceutical	6, 7, 10, 11, 13
Telfairia pedata	Cucurbitaceae	oyster nut	indigenous	E I S W	cult.	perennial	liane	0–2000	G	66	linoleic, palmitic	kernel	edible, cosmetics, soap, candles	5, 6, 11
Triadica sebifera	Euphorbiaceae	Chinese tallow tree	introduced (from Asia)	E S	cult.	perennial	tree	0–800	G	50-80 (50-60)	linolenic, palmitic	sarcotesta, kernel	edible but toxic	3, 4, 7, 9, 10, 11

Species	Family	Vernacular name	Origin	Dist.	Status	Life cycle	Growth	Altitude range	Prop.	Oil %	Fatty acid(s)	Plant part	Oil uses	Secondary uses
Trichilia dregeana	Meliaceae	forest mahogany	indigenous	C E S W	wild	perennial	tree	800–1600	G	55-65	oleic, palmitic	kernel	industrial, edible	2, 4, 5, 6, 7, 9, 10, 11
Trichilia emetica	Meliaceae	mafura	indigenous	C E S W	wild	perennial	shrub-tree	0–1800 (–2100)	G	c. 60	oleic, palmitic	sarcotesta, kernel	industrial, edible	3, 4, 5, 7, 9, 10, 11, 15
Vernicia montana	Euphorbiaceae	wood-oil tree	introduced (from Asia)	E I S	wild & cult.	perennial	shrub-tree	800–2000	G	42-60	a-eleostearic	seed	industrial	4, 7, 10, 11
Vernonia galamensis	Asteraceae	ironweed	indigenous	C E S W	wild & cult.	annual	herb	0–2000(–2500)	G	36-45	vernolic	seed	industrial	5, 11, 15
Vitellaria paradoxa	Sapotaceae	shea butter tree	indigenous	C E W	wild & cult.	perennial	tree	100–1600	G	31-62	oleic, stearic	kernel	edible, cosmetics, pharmaceutical	2, 3, 5, 6, 7, 8, 9, 10, 11, 13

Appendix 2. Summary of key issues for research and development of 48 oil species in Africa

Key to abbreviations in the table

COMESA	Common Market for Eastern and Southern Africa
GMO	Genetically Modified Organism
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature
PPP	Public-Private Partnership
R&D	Research and Development
SADC	Southern Africa Development Community
SME	Small and Medium Enterprises

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Adansonia grandidieri	Scarification for improved germination Promote planting and processing Commercial oil production Promote alternative use (e.g. ornamental)	Selection and breeding for yield and seed quality (soft-seeded types) Planting material, seedlings	Commercial cultivation (agronomy and socioeconomic aspects) Seed harvesting techniques	Cost-benefit analysis Production figures Phenology, growth patterns and natural regeneration Germination studies Chemical analysis of products Ethnobotany	*In situ* and *ex situ* conservation (IUCN Red List)	Support conservation and protection against felling
Adansonia rubrostipa	Scarification for improved germination Promote planting and processing Commercial oil production Promote alternative use (e.g. ornamental)	Selection and breeding for yield and seed quality (soft-seeded types) Planting material, seedlings	Commercial cultivation (agronomy and socioeconomic aspects) Seed harvesting techniques	Cost-benefit analysis Production figures Phenology, growth patterns and natural regeneration Germination studies Chemical analysis of products Ethnobotany	*In situ* and *ex situ* conservation (IUCN Red List)	Support conservation and protection against felling
Adansonia za	Scarification for improved germination Promote planting and processing Commercial oil production Promote alternative use (e.g. ornamental)	Selection and breeding for yield and seed quality (soft-seeded types) Local value addition (e.g. fruits for wine making)	Commercial cultivation (agronomy and socioeconomic aspects) Seed harvesting techniques Nutritional value of seedling roots Rapid germination techniques	Cost-benefit analysis Production figures Phenology, growth patterns and natural regeneration Germination studies Chemical analysis of products Ethnobotany	*In situ* and *ex situ* conservation (IUCN Red List)	Support conservation and protection against felling
Afrolicania elaeosperma			Selection and hybridisation to reduce non-productive juvenile period	Market surveys Explore use as organic fertiliser	*In situ* conservation	

Species	**Candidate technologies**	**Development gaps**	**Research gaps**	**Thesis subjects**	**Conservation needs**	**Policy measures**
Aleurites moluccana			Extraction technology Adaptation trials	Germination studies Suitability for paint		Support R&D
Allanblackia floribunda	Multipurpose uses Promote planting Commercial oil production Value addition through local processing	Processing and use of by-products Develop market opportunities	Domestication and selection Identify good seed sources, ecological requirements and optimum planting sites Explore potential for mixed cropping	Taxonomy of the genus Breeding barriers Germination studies for rapid germination	*Ex situ* conservation	Support domestication, assisted natural regeneration, sustainable use and market chain Support R&D for SMEs Promote PPPs
Allanblackia parviflora	Promote planting Multipurpose uses Commercial oil production Value addition through local processing	Processing and use of by-products Develop market opportunities	Domestication and selection Identify good seed sources, ecological requirements and optimum planting sites Explore potential for mixed cropping	Taxonomy of the genus Breeding barriers Germination studies for rapid germination	*Ex situ* conservation	Support domestication, assisted natural regeneration, sustainable use and market chain Support R&D for SMEs Promote PPPs
Allanblackia stuhlmannii		Processing and use of by-products Develop market opportunities	Domestication and selection for oil and fatty acid contents	Taxonomy of the genus Breeding barriers	*Ex situ* conservation (IUCN Red List)	
Arachis hypogaea	Promote improved cultivars Promote improved technologies: IPM, harvesting, shelling, drying, storing and oil extraction	Commercial seed production and distribution Develop market opportunities Breeding for oil content, adaptation, dormancy and resistance (leaf spot, rosette, bacterial wilts, rust, *Aspergillus*)	Resistance to diseases and pests Locally appropriate harvesting, post-harvest, storage and processing technologies Local value addition	Use of biotech for crop improvement Seed quality Agronomy in intercropping Models to guide aflatoxin management	Germplasm collection Conserve landraces	Facilitate export Support technology-based enterprise development Facilitate compliance with regulations on food safety and quality standards

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Balanites maughamii	Use to kill snail vectors of bilharzia	Seed processing	Oil composition Processing technology Medicinal properties	Cost-benefit analysis Bioactivity of extracts and oil		
Brassica carinata	Introduction outside Ethiopia for oil production Oil extraction technology Value addition through local processing and use of by-products	Seed production, marketing and distribution Breeding for earliness, oil content and quality	Potential for production in Sahel (including Sudan) Fatty acid characterisation Need for reduced- or zero erucic acid and glucosinolate Medicinal properties	Shifts in oil crops *B. juncea, B. napus, B. nigra* and *B. carinata* Biotech for improved oil quality and disease-resistant varieties Suitability for biodiesel	*Ex situ* conservation Conserve local landraces (risk of replacement by *B. juncea* and *B. oleracea*)	Support reliable seed sources, marketing and distribution Support national breeding programmes
Brassica juncea	Expand cultivation area due to wide adaptive suitability Promote improved cultivars Promote in cereal-based cropping systems	Seed production, marketing, distribution and certification Selection and breeding	Agronomy Gene introgression for abiotic and biotic stress tolerance Characterisation of oil from different ecological zones	Shifts in oil crops *B. juncea, B. napus, B. nigra* and *B. carinata*	*Ex situ* conservation Conserve local landraces List of priority landraces for SADC region	Support reliable seed sources, production, marketing and distribution
Carthamus tinctorius	Alternative crop for saline soils and drylands Improved varieties Mechanisation options Source of nutraceuticals Use of by-products	Selection and breeding for adaptation, low hull content, protein content, non-spiny varieties and resistance to diseases and pests Seed production, marketing and distribution Value addition through local processing	Genetic markers for valuable traits IPM Yield levels and stability Medicinal properties	Biochemical analysis of oil from different ecological zones IPM (control of safflower fly)	*Ex situ* conservation Conserve landraces	Define strategy on GMOs Facilitate marketing Promotion as nutritious food

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Cephalocroton cordofanus			Validate industrial potential Agronomy	Physiology (epoxy fatty acid production)	*Ex situ* conservation (for drought adaptation)	Support conservation and sustainable wild harvesting
Cocos nucifera	Improved varieties, intercropping and IPM Diversify products and uses through value addition (e.g. soap making) Improved product quality	Selection and breeding for earliness and short stature (ease of harvesting) and resistance to diseases and pests Hybrid seed production Value addition through local processing	Prospects for local processing Oil composition and quality	Socioeconomic impact of local cropping and oil extraction Interspecific classification	*Ex situ* conservation Conserve germplasm from threatened areas Promote cryopreservation	Facilitate marketing Support replanting and rehabilitation Monitor production for compliance with good agricultural practices
Crambe hispanica		Breeding for improved yield and erucic acid content	Production gaps in agronomy Genetic improvement for increased yield and stability	Cost-benefit analysis Industrial potential	*Ex situ* conservation Conserve germplasm from east Africa	Support uses of non-edible oils
Elaeis guineensis	Improved varieties, intercropping and IPM technologies Industrial crop for biofuel Hand-operated oil press to small-scale farmers Sanitation practices for improved product quality	Clonal planting material (e.g. through tissue culture) Oil extraction technology Establish smallholder savings and credit models	Validate best practice for intercropping, fertiliser/ manure rates and postharvest handling in smallholder production systems Genetic research Modify fatty acid composition	Cost-benefit analysis Socioeconomic impact of mixed cropping Post-harvest handling	*Ex situ* conservation Breeding to conserve local landraces Conserve germplasm from centre of origin in international collections	Biofuel policy Support replanting and rehabilitation Facilitate production for local and export markets Monitor production for compliance with good agricultural practices

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Glycine max	Improved cultivars for local and export markets Local value addition through processing Improved technology for small-scale production and mechanisation for large-scale production Diversify uses Food of high nutritive value for vulnerable groups (e.g. malnourished children)	Selection and breeding for multiple resistance (to diseases and pests, aluminium toxicity, lodging and shattering), yield, oil content, adaptation, shelf life and nodulation Seed production, marketing and distribution Mechanised post-harvest handling	Appropriate storage methods for humid tropics IPM New food products and recipes Appropriate processing and preparation methods Agronomy for mixed farming systems Seed quality studies	Trap crop for Striga Improved seed vigour Rhizobia studies (compatibility with local strains, production and storage) Biochemical analysis of oil from different ecological zones	*Ex situ* conservation Conserve wild relatives and germplasm from China	Strategy on GMOs (controversial for COMESA members) Awareness on biosafety issues Promotion as industrial crop
Guizotia abyssinica	Promote production in new areas Crop rotation systems Marketing Mechanisation options	Breeding for seed yield, oil content, adaptation and resistance (to shattering, lodging and drought) Seed production, marketing and distribution	Mechanisation options Physiology studies Agronomy for mixed farming systems and large-scale production	Cost-benefit analysis Market surveys Biotech for crop improvement Molecular characterisation Validate weed suppressing effects	*Ex situ* conservation	Support R&D Facilitate marketing Facilitate certification of planting material
Helianthus annuus	Harvesting and threshing technologies for smallholders Improved cultivars and agronomic practices	Breeding for yield, oil content, resistance to diseases and pests, stature, tolerance to abiotic factors and protein content in edible varieties	Crop management practices Genetic research (e.g. gene tilling and gene introgression from wild sunflower)	Cost-benefit analyses Bird and rodent control Biochemical analysis of oil from different ecological zones	*Ex situ* conservation Conserve African landraces (observe recommended isolation distances for parental material)	Support R&D Facilitate production and marketing for local and export markets Support international germplasm exchange

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Helianthus annuus	Small-scale processing systems for rural entrepreneurs Integrate apiculture in production systems	Seed production, marketing and distribution Motorised oil presses available in major producing areas	IPM Breeding for short stature (ease of harvesting) and local adaptation	Role in supporting insect biodiversity Effects on soil quality Apiculture	Conserve North American germplasm in African collections	Support use for poverty alleviation Promote PPPs Develop extension programmes for integrated apiculture
Irvingia gabonensis	Shade and (re-) forestation Agroforestry systems	Selection and breeding for yield, kernel size, oil content, earliness and extraction ease	Domestication Transformation and preservation of oil New products	Taxonomy of genus Multiplication and regeneration techniques Genetic diversity Oil composition	*In situ* and *ex situ* conservation of ecotypes	
Irvingia grandifolia	Shade and (re-) forestation Agroforestry systems	Selection and breeding	Domestication Transformation and preservation of oil New products		*In situ* and *ex situ* conservation of ecotypes	Support conservation (facilitate enforcement of conservation regulations) Support domestication and assisted natural regeneration Facilitate networking
Irvingia wombolu	Shade and (re-) forestation Agroforestry systems	Selection and breeding	Domestication Agronomy Transformation and preservation of oil New products	Multiplication and regeneration techniques Taxonomy of the genus Oil composition	*In situ* and *ex situ* conservation of ecotypes	Support conservation (facilitate enforcement of conservation regulations) Support domestication and assisted natural regeneration Facilitate networking

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Jatropha curcas	Small- and large-scale production to meet industrial demands Planting on degraded land for rehabilitation Local use in biodiesel Diversify use (e.g. medicine, soap manufacture, lighting products, by-products for seedcake and fertiliser)	Selection and breeding for oil and latex, ease of harvesting and earliness Appropriate post-harvest technology and oil extraction mills Use as biopesticide Engines modified to run on oil	Refine agronomic practices Record diseases and pests Rapid multiplication techniques Potential for other energy-based technology Mechanisation options Medicinal value Toxicity Invasiveness	Baseline study on the status of biofuel and biodiesel technologies Role in water conservation under rainfed conditions Taxonomy of the genus Cost-benefit analysis for biofuel production IPM (e.g. seedcake to control nematodes and snail vector of bilharzia)	*Ex situ* conservation Conserve germplasm of African landraces Exchange germplasm between Africa and growing regions in South America and Indian subcontinent	Biofuel policy Support R&D Facilitate marketing Promotion
Linum usitatissimum	Production in highlands to meet international demand for edible and industrial oils Promote as nutritious food	Breeding for oil content, fatty acid composition, low fibre content, wilt- and frost resistance Seed production, marketing and distribution Marketing and distribution of oil	Agronomy Resistance to diseases and pests Significance of linolenic acid in frost resistance Application of biotechnology (double haploid) Technology for prolonged shelf life of products	Characterisation of core germplasm	*Ex situ* conservation Conserve germplasm of east African landraces	Non-edible crop policy Support R&D Facilitate marketing Support value addition for high quality products Considerations for health and environmental impacts

Species	**Candidate technologies**	**Development gaps**	**Research gaps**	**Thesis subjects**	**Conservation needs**	**Policy measures**
Lophira lanceolata	Multipurpose use in agroforestry systems		Domestication, breeding and selection Use in agroforestry Record diseases and pests	Cost-benefit analysis Propagation methods Ethnobotany Apiculture Role in supporting insect biodiversity	*In situ* and *ex situ* conservation (high extinction risk)	Support conservation (facilitate enforcement of conservation regulations) Support domestication, assisted natural regeneration and sustainable wild harvesting
Moringa drouhardii			Domestication	Oil composition Potential for water purification Agronomy and hybridisation Ethnobotany		
Moringa peregrina			Domestication	Oil composition Potential for water purification Agronomy and hybridisation Ethnobotany	*In situ* and *ex situ* conservation	Support conservation Support R&D
Olea europaea		Dual purpose types and selection for adaptation				Support conservation in cultivated areas
Ongokea gore			Novel applications for oil Large-scale production	Survey potential international market	*In situ* conservation	Support conservation (facilitate enforcement of conservation regulations)
Panda oleosa			Mechanical opening of fruits	Germination problems and propagation		Support sustainable wild harvesting

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Pentaclethra eetveldeana	Multipurpose use in agroforestry systems Promote planting		Fatty acid composition Validate medicinal use	Potential in sustainable timber production system Ethnobotany		
Pentaclethra macrophylla	Multipurpose use in agroforestry systems Promote planting	Selection for non-shattering and simultaneous ripening	Domestication for agroforestry systems Optimal pruning Validate medicinal use	Ethnobotany	*In situ* and *ex situ* conservation	Support conservation
Pentadesma butyracea		Extraction technology	Domestication for agroforestry or reforestation Extraction technology	Market survey for cosmetic and pharmaceutical uses Ethnobotany (including related species)		
Pycnanthus angolensis	Use in agroforestry systems		Novel use for oil and medicine Domestication	Economic potential Ethnobotany	*In situ* and *ex situ* conservation	Support conservation (facilitate enforcement of conservation regulations)
Ricinodendron heudelotii			Management for sustainable wild harvesting	Cost-benefit analysis Oil composition Fatty acid characterisation Industrial potential	*In situ* and *ex situ* conservation Urgent germplasm collection throughout range	Biofuel policy Support conservation Support agroforestry
Ricinus communis	Use for rehabilitating soil and degraded land Market demands for specialist products Industrial oil crop Mechanisation options	Breeding for yield, uniform maturation, ricinoleic acid content, shattering- and disease resistance in perennials and short stature (ease of harvesting) Extraction technologies Marketing for high-value riconoleic acid	Agronomy Genetic research Energy applications of oil and seedcake Novel use (e.g. for cosmetic and pharmaceutical industries)	Cost-benefit analysis Adaptation trials Application of biotechnology (double haploids) Detoxification of seedcake Production figures and market surveys	*Ex situ* conservation Conserve germplasm of African ecotypes in existing collection in Ethiopia	Biofuel policy Support R&D Facilitate marketing Support value addition for high quality products Considerations for health and environmental impacts

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Schinziophyton rautanenii			Domestication Improved germination Propagation techniques Post harvest management Agronomy	Cost-benefit analysis Sustainable wild harvesting Production figures and market surveys	*Ex situ* conservation Conserve germplasm of all ecotypes in existing collection in Namibia	Support conservation Support agroforestry
Sesamum indicum	Planting for home consumption and local markets Improved cultivars and recommended agronomic practices Processing technologies Mechanisation options	Breeding for non-shattering, yield and resistance to diseases and pests Seed production, marketing and distribution Germplasm exchange Value addition through local processing	Breeding (biotechnology) IPM (site specific)		Conservation of landraces	Facilitate marketing
Simmondsia chinensis	Large-scale production Mechanisation options Use in drylands	Adaptation trials	Potential for production in Sahel (including Sudan)	Dryland adaptation studies		Biofuel policy Support conservation Regulate land use
Symphonia louvelii			Multi-disciplinary research on all species in the genus Domestication	Distribution and population studies	*In situ* and *ex situ* conservation Evaluate conservation status	Support conservation

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Telfairia pedata	Use in agroforestry systems Expand plantations (pending outcomes of research)		Viability of large-scale plantation and extraction Genetics and sex determination (crop is dioecious)	Survey of local and export markets Potential for large-scale production Reproductive biology Hybridisation with the West African T. occidentalis Ethnobotany	*In situ* and *ex situ* conservation	Support agroforestry and conservation Carbon sequestration policy
Triadica sebifera						Facilitate germplasm exchange Caution - highly invasive, potential weed
Trichilia dregeana	Multipurpose use in agroforestry systems Diversify use (e.g. soap making, medicinal use of bark and oil)	Breeding for resistance to diseases and pests Planting materials	Medicinal properties Limonoids for pharmaceutical industry Use in cosmetics Methods for germplasm conservation (e.g. embryos)	Taxonomy of the genus Seed recalcitrance and germplasm conservation Oil composition of seed coat and kernel Seedcake as insecticide and to control pests in storage	*In situ* and *ex situ* conservation Promote cryopreservation (recalcitrant seeds)	Support conservation Regulate trade in medicinal plants
Trichilia emetica	Multipurpose use in agroforestry systems Diversify use (e.g. soap making, medicinal use of bark and oil)	Breeding for resistance to diseases and pests Planting materials	Medicinal properties Limonoids for pharmaceutical industry Use in cosmetics Methods for germplasm conservation (e.g. embryos)	Taxonomy of the genus Seed recalcitrance and germplasm conservation Oil composition of seed coat and kernel Seedcake as insecticide and to control pests in storage	*In situ* and *ex situ* conservation Promote cryopreservation for recalcitrant seeds	Support conservation Regulate trade in medicinal plants

Species	Candidate technologies	Development gaps	Research gaps	Thesis subjects	Conservation needs	Policy measures
Vernicia montana	Poor prospects due to low prices			Verify potential for oil production		Facilitate germplasm exchange
Vernonia galamensis		Commercial production, processing and marketing	Genetic improvement	Adaptation and yield stability Survey of local and export markets	*In situ* and *ex situ* conservation	Support R&D Facilitate marketing
Vitellaria paradoxa	Rejuvenation, top-dressing and maintenance On-farm grafting of improved varieties on existing trees Support local women's' industries for karité butter production Promote appropriate post-harvest handling, processing and packaging technologies Encourage networking	Selection and breeding for yield, fatty acid composition, sweet pulp and steric acid content Technology for post-harvest handling, processing and packaging Promotion	Domestication Vegetative multiplication Extraction methods Genetic improvement On-farm methods to extend seed viability and detoxify seedcake	Management of parasites in production Adaptation and yield stability under drought conditions Reduced maturation period Socioeconomic impact of production Saponification and quality control On-farm conservation Market surveys	*In situ* and *ex situ* conservation	Support integrated international R&D and PPPs Establish value chain for local and export markets Facilitate compliance with regulations on food safety and quality standards Promote as cocoa butter substitute Develop specific extension programmes for shea butter production

PROTA
Plant Resources of Tropical Africa
Ressources Végétales de l'Afrique Tropicale

PROTA IN SHORT

The Plant Resources of Tropical Africa (PROTA) programme was initiated in 2000 and developed into an international partnership of 11 institutions in 11 countries during the Preparatory Phase 2000-2003. Since 19 February 2003, PROTA has operated as an international foundation domiciled in Wageningen, Netherlands.

PROTA is a major 'information brokerage and knowledge repatriation' programme. The objectives are to bring the 'world literature' on the useful plants of Tropical Africa, now accessible only to the resourceful happy few, into the (African) public domain, and contribute to greater awareness and sustained used of the plants, with due respect for traditional knowledge and intellectual property rights. PROTA will describe the estimated 7,000 useful plants during the Implementation Phase 2003-2015. The information carriers will be freely accessible Web databases (www.prota.org), a low-price Handbook and CD-Rom series featuring 16 Commodity groups, and PROTA Recommends Series per commodity group for rural development, education, research and policy actors (all in English and French).

PROTA 1:	Cereals and pulses (2006)	PROTA 9:	Auxiliary plants
PROTA 2:	Vegetables (2004)	PROTA 10:	Fuel plants
PROTA 3:	Dyes and tannins (2005)	PROTA 11(1):	Medicinal plants (2008)
PROTA 4:	Ornamentals	PROTA 12:	Spices and condiments
PROTA 5:	Forages	PROTA 13:	Essential oils and exudates
PROTA 6:	Fruits	PROTA 14:	Vegetable oils (2007)
PROTA 7(1):	Timbers (2008)	PROTA 15:	Stimulants
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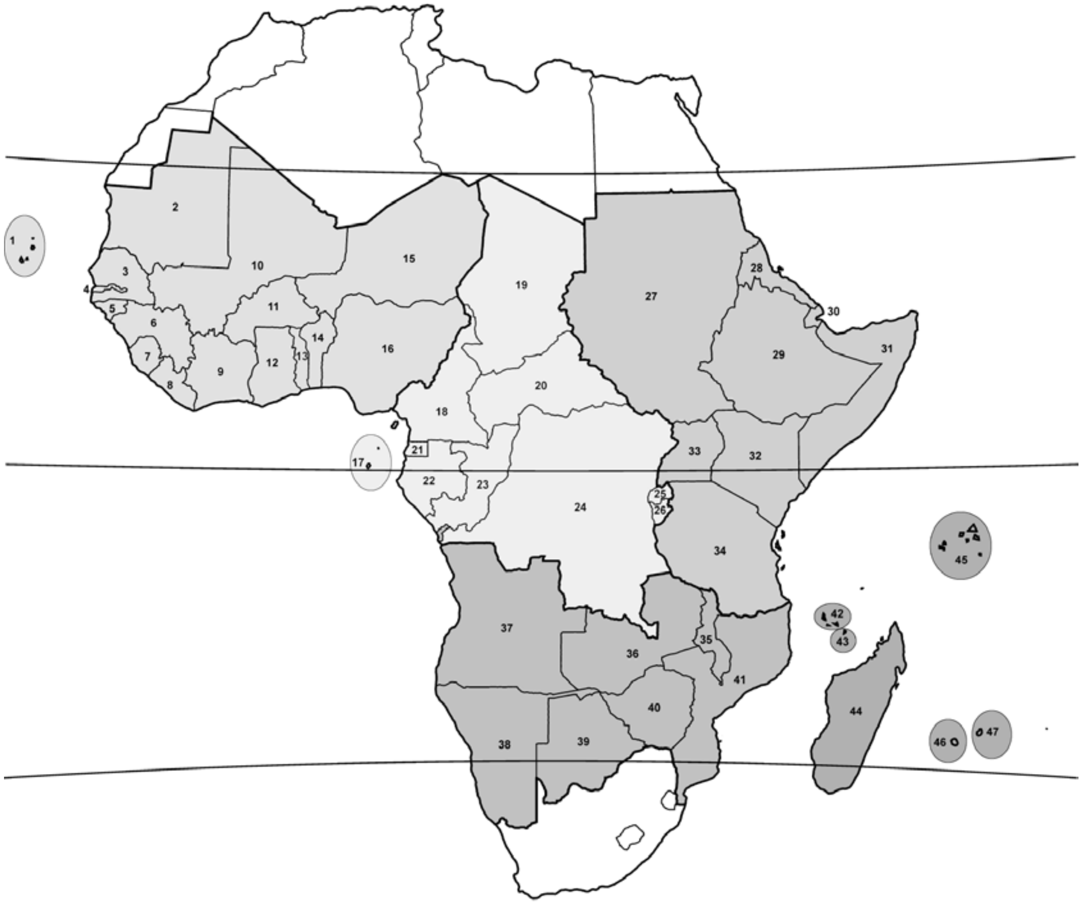

WEST AFRICA

1. Cape Verde
2. Mauritania
3. Senegal
4. Gambia
5. Guinea Bissau
6. Guinea
7. Sierra Leone
8. Liberia
9. Cote d'Ivoire
10. Mali
11. Burkina Faso
12. Ghana
13. Togo
14. Benin
15. Niger
16. Nigeria

CENTRAL AFRICA

17. São Tomé et Principe
18. Cameroon
19. Chad
20. Central African Republic
21. Equatorial Guinea
22. Gabon
23. Congo
24. Democratic Republic of Congo
25. Rwanda
26. Burundi

EAST AFRICA

27. Sudan
28. Eritrea
29. Ethiopia
30. Djibouti
31. Somalia
32. Kenya
33. Uganda
34. Tanzania

SOUTHERN AFRICA

35. Malawi
36. Zambia
37. Angola
38. Namibia
39. Botswana
40. Zimbabwe
41. Mozambique

INDIAN OCEAN ISLANDS

42. Comoros
43. Mayotte (Fr)
44. Madagascar
45. Seychelles
46. Réunion (Fr)
47. Mauritius

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