

Australian acacias as multi-purpose agro-forestry species for semi-arid regions of Africa

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Introduction

Human populations living in semi-arid regions of the developing, tropical world who are reliant on annual crops and/or pastures (for livestock) for food are particularly vulnerable to hunger and periodic famine. Certain Australian *Acacia* species have great, untapped potential as multi-purpose tree species in agro-forestry systems in these regions. A number of species thrive under conditions which annual plants struggle to survive in. Uses include planting for windbreaks, reclamation of degraded land, biomass production for mulch and organic matter, firewood, feed for honey bees, and food for humans and livestock.

The real problem of rain-fed agriculture: drought or farming practices?

News headlines announcing famine in Africa are tragically all too common. Though the exact country or region impacted by famine may vary from year to year, more often than not, crop failure and subsequent famine are related to drought. Media releases and reports from aid and government agencies often express surprise that drought has occurred again even in climatic zones where one should expect drought to be a regular feature of the climate. Thus, even in semi-arid zones, analysts have tended to treat drought as an anomaly and people relying on annual crops in these regions regularly experience drought-induced crop failure. While the significant impact drought has on crop yield and subsequent famine cannot be ignored, drought itself is not as big a contributor to famine as the actual farming practices of people living in arid and semi-arid regions.

Two features of many African farming systems in particular increase vulnerability to crop failure:

- lack of biodiversity. Farming systems are dominated by a narrow range of annual crop species. Often farmers rely primarily on a single annual crop such as maize, millet or sorghum in a highly risky environment. If this crop is damaged through drought, pests or other adverse factors, subsistence farmers have little else to fall back on and famine can ensue.

Abstract

The seeds of certain Australian *Acacia* species are tasty, safe to consume and nutritious. Being perennial, mature acacias can take advantage of rains that would be ineffective for annual crops, such as out of season or poorly distributed rains. *Acacia* seeds are easily harvested and processed into flour using simple technologies which already exist in typical African villages. The flour can be incorporated into local dishes and "non-traditional" foods such as spaghetti, bread and biscuits. The seed also has great potential as livestock feed. Alternatively, the hard-coated seeds can be easily stored for many years and act as a famine reserve food.

Much effort has gone into safety testing and promoting edible seeded Australian acacias for direct human consumption, but the rate of adoption has been slow. However, other characteristics of these same species may have an even greater impact on food security than actual consumption of the seed. The Farmer Managed Agro-forestry Farming System (FMAFS) that incorporates a range of annual and perennial crops is being promoted as a sustainable rainfed farming alternative to traditional and destructive slash-and-burn monocultures.

Muelleria 26(1): 79-85 (2008)



- absence of ground cover and low soil organic matter content. Farming methods commonly practiced involve the complete removal or destruction of crop residue through burning. Regular turning of the soil under hot tropical conditions hastens the rate of loss of organic matter. In highly degraded environments, where there is a shortage of fire wood and fodder, crop residues are removed from fields for use as cooking fuel or for animal fodder. With no mulch covering the soil, heavy downpours result in high levels of water runoff and soil erosion, high evaporation rates and low water infiltration rates. Bare soils are also exposed to higher temperatures than covered soils which adversely effects germination and the growth of juvenile plants (Ashraf *et al.* 2004). Bare soil surface temperatures measured at the start of the rainy season in fields near Maradi, Niger Republic, reached 50°C, whereas number of days to 50% germination of millet decreases due to high temperatures (45 °C) (measured by author). Soil organic matter also helps improve soil structure and increases water and nutrient holding capacity.

Conversely, unpublished field measurements undertaken by the Maradi Integrated Development Project (MIDP) in Niger Republic showed at least a doubling of crop yield and significant increases in income, and ensured annual minimum production levels despite variable conditions, have been attained through increasing biodiversity and returning organic matter to the soil (Pasternak *et al.* 2003).

Promotion and use of Australian acacias for human nutrition

Australian edible seeded acacias have great potential for combating hunger in semi-arid lands (Rinaudo *et al.* 2002). A number of species thrive under conditions which are adverse for common annual crops such as millet and sorghum. Growth and yield performance of such annuals can be compromised by high soil temperatures at planting time, strong winds causing abrasion of leaf surfaces and desiccation, inadequate or untimely rains, or outright burial by sand. Whereas annual crops must be planted each year and so face these risks annually,

acacia trees live for many years after establishment and are resilient to high temperatures and strong winds. *Acacia* species trialled in Niger have extensive root systems and other drought coping strategies and being perennial, they are able to take advantage of untimely rains. These include species such as *A. colei* Maslin & L. A. J. Thomson var. *ileocarpa* M.W. McDonald & Maslin, *A. coriacea* DC. *sens lat.* (including *A. sericophylla* F. Muell.), *A. elachantha* Maslin & M. W. McDonald, *A. torulosa* Benth., *A. tumida* F. Muell. ex Benth. var. *tumida*, *A. tumida* var. *kulparn* M. W. McDonald, and *A. victoriae* Benth. *sens lat.* (subspecies unknown). The seeds of these species are tasty, safe to consume and nutritious, having a protein, carbohydrate and fat content of 17-25%, 30-40% and 14-16% respectively (Brand and Cherikoff 1985). In many regions, such as West Africa, the seeds ripen at a time of low labour demand when non-irrigated crops are not being cultivated. Being perennial and thus having established root systems, mature acacias can take advantage of rains that would be ineffective for annual crops (e.g. out of season or poorly distributed rains). *Acacia* seeds are easily harvested and processed into flour using simple and existing local technologies. The flour can be incorporated into local dishes and in "non-traditional" foods such as spaghetti, bread and biscuits. The seed also has great potential as a food supplement for livestock. Alternatively, the hard-coated seeds can easily be stored for many years so give flexibility with timing of use and can act as a famine reserve food. *Acacia* species can also supply various other products, especially fuel wood, and services such as improvement of soil fertility through fixation of atmospheric nitrogen.

With the technical assistance of the Australian Tree Seed Centre, *Acacia* species trials were commenced in the Maradi region of Niger in 1992 by the Maradi Integrated Development Project (MIDP). During the famine of 1994, MIDP facilitated the planting of over 100,000 *Acacia* trees and promoted the utilization of the seeds for food. Since 1994, MIDP staff have continued to promote *Acacia* planting and use in the Maradi Department. Despite these concerted efforts, adoption of *Acacia* seed into human diets in Niger has been slow, although a number of individuals and in some cases, whole villages in the Maradi area are consuming *Acacia* seed regularly (Abasse & Yahaya, pers. comm.).

In light of Niger's chronic food shortages and recurrent famines, the slow adoption rates have been both surprising and disappointing. The lack of market demand for seed for consumption both locally and abroad has also resulted in a general lack of interest in planting and cultivating acacias. It is now felt that in order for the farmers to become interested in planting acacias, and in the absence of a significant market for seed, focus has now moved from promotion for direct human consumption alone to promotion of the multiple benefits acacias offer.

Farmer managed agro-forestry farming system

In continuing to explore how acacias can be best promoted and utilised, MIDP staff are developing the

Farmer Managed Agroforestry Farming System (FMAFS). FMAFS is an alley-cropping, agro-pastoral forestry system which incorporates a wide range of annual and perennial, and indigenous and exotic plant species and livestock. While the FMAFS is being introduced as a model, actual layout and choice of tree numbers and types of indigenous and exotic trees and annual crops is determined by farmers themselves. However, a major recommendation to FMAFS implementers is that acacias be widely spaced on the boundary and within the farm. FMAFS introduces a range of high yielding seed and wood producing Australian acacias (*A. colei*, *A. torulosa*, *A. tumida*, *A. elachantha*) which are planted along farm borders and in rows within the farm and provide human and animal food, services of environmental restoration and crop protection, firewood, timber and mulch.

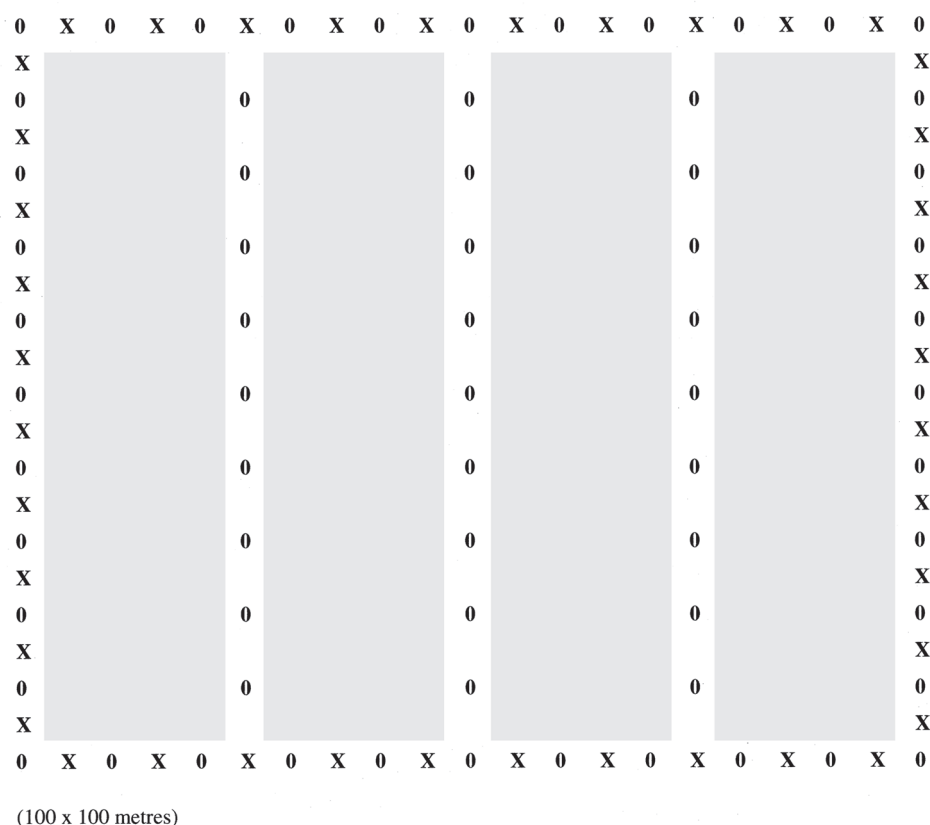


Figure 1. The Farmer Managed Agroforestry Farming System, one hectare model. 0= *Acacia colei* (68), X= *Acacia torulosa* (40): Total acacia trees 107 per ha. Trees on boundary are 5m apart. Trees within the farm are 10m apart. Rows of trees are 25m apart. Rows of trees are planted across the prevailing wind direction. Shaded area: FMAFS with 40 to 120 trees per ha and annual/perennial crops in rotation.

Including more than one species of *Acacia* increases the likelihood of realising a seed harvest each year. Other valuable agroforestry trees such as *Pomme du Sahel* (*Ziziphus mauritiana* Lam.), Tamarind (*Tamarindus indica* L.), Baobab (*Adansonia digitata* L.) and Moringa (*Moringa oleifera* Lam.) complement regenerated indigenous trees and acacias. Annual cash crops such as millet, sorghum, cowpeas, peanuts, hibiscus, sesame and cassava can then be planted in rotation between the tree rows, providing food and fodder and income while crop residues are used as mulch for soil improvement and protection. FMAFS provides a diversity of income sources, and enables a better distribution of farm labour and income throughout the year. With FMAFS, farm income is increased significantly compared to traditional millet farming.

The *Acacia* trees are planted on the farm borders at five metre intervals and in rows 25 metres apart with trees within the row 10 metres apart. Rows of trees are planted across the prevailing wind direction. Various models have been designed to suit varying sites. The one hectare model (Figure 1) has 107 acacia trees per hectare and half hectare models have between 69 – 72 trees. The *Acacia* trees are pruned every second year and produce edible seed every year from the second year after planting. As seed yields vary considerably between trees and from year to year (Table 1), cultivar selection trials are being conducted by MIDP to identify

superior trees and to generate stable high-performing cultivars.

Acacia trees are planted at wide spacing on farm borders to allow high seed and wood yields and in order to minimise competition with crops. Pruning is undertaken every second year in order to maximise seed production. While branches and phyllodes pruned from acacias provide mulch, the bulk of the mulch in FMAFS comes from crop residues and pruning of indigenous species.

FMAFS addresses the principal contributors of vulnerability to food insecurity, namely lack of biodiversity, absence of ground cover and low soil organic matter content. Thus implementation of FMAFS results in shifting from reliance on an annual species monoculture to spreading risks through maximising biodiversity and incorporation of perennial indigenous and exotic species into the cropping equation. This shift provides alternate income sources and greater insurance against total crop loss during adverse events such as drought or insect attack. Not all species will be equally disadvantaged by the same adverse event in a particular year. In a biologically diverse farming system, there will be an assured minimum income in any year. The Australian acacias' high tolerance to drought (Cossalter 1987) and lack of susceptibility to most African crop pests and diseases make them an excellent backstop for seasons when annual crops fail. The *Acacia* species planted in Niger come from Australia's subtropical dry zone which receives less than 500 mm of rainfall per

Table 1. Seed and wood production from four year old *A. torulosa* trees grown on field borders. Danja, Niger Republic (Cunningham & Abasse 2004).

Tree type/ Number	Mean weight of pods and seed (kg)	Mean weight of pods (kg)	Mean weight of seed (kg)	Dry weight of wood (kg)
Branching types (39)	9.7	5.4	4.0	
Branching types (25)	12.5	7.0	5.2	
Tall types (19)	4.9	2.4	1.7	
Branching tree No. 222	27.0	14.0	12.0	117.0
Branching tree No. 241	21.0	13.0	7.5	30.0
Branching tree No. 62	18.0	9.0	7.7	14.0
Tall tree No. 313	12.0	5.0	3.5	49.0
Tall tree No. 300	8.0	4.0	3.5	25.0
Tall tree No. 305	8.0	4.0	3.0	38.0

Column one: (Tree type / number) is the category of trees or tree. The number in brackets is the number of trees. For example, branching types (39), means that 39 branching trees were selected and the data in other columns is the mean of these 39 trees. All the other categories are the data for individual trees (i.e. Branching tree no 222 gave 14 kg pods, etc.)

annum. Acacias are growing under harsh conditions in Niger, in areas receiving as little as 200 mm of rainfall, with the dry season lasting at least eight months and temperatures often exceeding 40°C. In the 20 years that Australian acacias have been grown in Maradi, no serious or sustained insect attack or diseases have been reported. In 2007, hairy caterpillars (species unknown) caused some damage on newly planted trees and required spraying. These caterpillars do not appear in plague proportions every year. Die-back, perhaps caused by a fungus, has been noted to affect *A. colei* in some years but this has not posed major problems. Even in high rainfall years, crop yields and incomes are increased by intercropping with acacias for a number of reasons. Few farmers in Niger can afford to buy pesticides or artificial fertiliser, and organic matter is in short supply. Pests can reach plague proportions quickly in the absence of artificial or natural controls and soils are very infertile. Having trees in fields provides food, shelter, habitat and vantage points for natural pest predators. Over time, acacias contribute nitrogen and organic matter to soils, positively impacting millet yields. Even in good years, wind speeds at planting time can reach up to 70 km per hour, devastating emerging crops in the absence of wind breaks.

Implementation of FMAFS also results in the production of biomass by both acacias and indigenous species, providing mulch, organic matter, a wind-break effect and fuel for firewood and income generation. Soils in Niger are extremely infertile and average per hectare fertiliser use is only 5 kilograms. Consequently, average millet yields under traditional cultivation techniques are only in the order of 300 kg per hectare. Mulching increases soil fertility, enhances moisture infiltration and retention significantly and reduces soil temperatures. The large quantity of biomass laid down as mulch results in millet yield increases of 100% or more over untreated plots (unpublished MIDP data). The rainy season in Niger only lasts for four months and is very variable and erratic. Under traditional farming systems, millet is grown during the rainy season in fields completely cleared of trees. Millet stalks constitute low quality fodder and very few grasses or edible weeds grow in the fields during the eight-month dry season. Under FMAFS, many indigenous trees left in fields produce edible pods and leaves which attract livestock. In addition to leaf litter fall contributing to soil organic

matter, livestock spend more time seeking pods and leaves from trees and therefore deposit more manure in treed fields than in non-treed fields.

FMAFS is flexible enough to meet farmers varying needs and priorities as it is not prescriptive. FMAFS builds on the strengths of two existing agroforestry systems, the Sahel Eco Farm model (Pasternak *et al.* 2005) and Farmer Managed Natural Regeneration (FMNR) (Rinaudo 2001), which have also been developed in Niger Republic (Appendix I).

Adoption of innovation can be very slow. Building on the success of FMNR and on farmers' existing knowledge is important. Though now widely practiced, FMNR initially met with strong resistance from communities in which it was a tradition to clear all trees from cropland. Nigerien farmers have now had up to 20 years of experience growing indigenous trees on cropland and are familiar with the benefits and the various management options open to them. Introducing FMAFS to farmers already practicing FMNR requires only a relatively small adjustment in thinking and involves a slight increase in complexity. Farmers practicing FMNR have already made a significant paradigm shift in moving from mono-cropping of annuals to agroforestry. Good reasons for building on FMNR include:

- FMAFS represents an incremental graduation into a slightly more complex farming system, but one which offers increased benefits and a reduction in vulnerability to famine. Through FMNR, farmers' deep prejudice against having trees on fields has already been overcome and this knowledge base can be built on.
- Through FMNR, most farmers' fields in Southern Niger are already covered with a diversity of trees which contribute to land restoration and provide food, medicines, firewood, timber and rope and enhanced crop and livestock production.
- FMNR has a low labour requirement, is cheap and easy to implement, and gives multiple benefits quickly. These characteristics have resulted in FMNR spreading across Niger largely by word of mouth, from farmer to farmer in contrast to high external input initiatives which are entirely dependant on the presence of a project manager and external funding.

Progress to date

MIDP has been promoting edible-seeded acacias since 1994 and World Vision, with technical assistance from MIDP has been involved since 2004. In 2006, following formation of ten village farmers groups, 15 to 25 selected farmers per village established 125 FMAFS plots. In 2007 there have been 253 new FMAFS established in 33 villages in the Maradi area. As interest grows, ongoing discussions and evaluation of the work to date will further inform how FMAFS will be tailored to meet farmers changing needs.

Conclusion

Multi-purpose Australian acacias are poised to make a significant contribution to food security in semi-arid regions of Africa; regions with a history of recurring food shortages. The Farmer Managed Agroforestry Farming System provides a good vehicle for the rapid spread and adoption of this model because of its flexibility, simplicity, low dependence on external inputs, low cost and ease of replication by farmers themselves.

Cautionary note

The Australian species mentioned in this article have not become weeds under the high livestock pressure, high wood demand and harsh environment of West Africa. However, being pioneering species, caution needs to be exercised when introducing acacias into new regions. National regulations for introducing exotic species should be obeyed. Project managers should consult Departments of Agriculture and Forestry and other historical records on plant introductions before proceeding. Once authorisation has been obtained, testing should be undertaken in collaboration with the appropriate government department only on well controlled and managed sites. Contingency and eradication plans should be in place from the outset if weediness tendencies are noted.

Acknowledgments

To the Australian Aboriginal people without whose traditional knowledge this work would not have been commenced. To Dr Steve Adewusi, Dr Chris Harwood and Dr Lex Thomson for their inspiration, hard work, encouragement, advice and follow up of the various *Acacia* trials and implementation work.

For the pioneering work of the organisation 'Serving Mission' which operates the Maradi Integrated Development Project, and has supported the introduction, testing and promotion of Australian Acacias and food products since 1986.

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Appendix I

Sahelian Eco-farm

The Sahelian Eco-farm (SEF) is an alley cropping system under development at ICRISAT Sahelian Centre (Niger), in which trees and/or shrubs are intercropped with annual crops. The first SEF model under development is composed of *Acacia colei*, *Ziziphus mauritiana* and three annual crops (millet, cowpeas and Roselle). Erosion by wind is prevented by the wind breaking effect of the *A. colei* trees and by mulch produced from the *Acacia* branches and phyllodes. *Acacia colei* trees play a major role in soil fertility enhancement. The trees are pruned once a year and their branches are spread over the field adding organic matter to the soil. Tree roots add organic matter and fix atmospheric nitrogen. Soil fertility is also enhanced by crop rotation. *Acacia* seeds are used in poultry feed. It is estimated that the combined profit per ha from all the SEF components is ten times higher than the profit derived from a millet field. SEF addresses the main constraints of Africa's rain fed agriculture, namely soil erosion, low soil fertility, low water use efficiency, drought, shortages of animal fodder, low income and an inefficient distribution of the labour force throughout the year.

Farmer-Managed Natural Regeneration

Farmer-managed Natural Regeneration (FMNR) is a rapid, cost effective method of re-establishing tree and woody shrub cover in forestry and agro-forestry production systems. It involves farmers managing coppice shoots from pre-existing stumps and natural seedling regeneration, especially of useful woody species. In most cases neither guarding nor fencing are employed to protect new growth. Shoots pruned at the start of the rainy season when crops are growing in the fields have five months to grow without interference from livestock. After this time some damage may be incurred but trees generally are able to grow large enough to not be destroyed by livestock. Of greater importance for the survival of the trees is agreement by all stakeholders to respect each others property.

Its direct benefits include:

- increased availability and use of firewood and building timber;
- increased incomes from sale of wood and tree products; and
- improved human nutrition associated with a more diverse and healthy diet (incorporating edible leaves, seeds, nuts and fruits).
- higher annual crop yields grown in FMNR treated fields through environmental protection (reduced wind and soil erosion), improved soil fertility and water-holding capacity,
- improved livestock productivity through better nutrition (as a result of increased availability of tree fodder in the dry season).

Since FMNR was introduced into Niger in 1983, the practice has spread to at least 3 million hectares of previously denuded farmers land (Larwanou *et al.* 2006) in Niger Republic.