Wattle Seed Production

in Low Rainfall Areas

A report for the RIRDC/Land & Water Australia/FWPRDC Joint Venture Agroforestry Program

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Foreword

Wattle seed (*Acacia* spp.) has been used as a food source by Australian Aboriginal people for thousands of years. More recently, there has been a small but increasing demand for wattle seed as part of the commercial bush food market. *Acacia* spp. are often used in planting programs aimed at ameliorating land degradation. It has been suggested that the opportunity for broadscale wattle seed production and use of wattle seed in mainstream food production industries such as bread and biscuit making be investigated as a commercial output of future plantings of perennial species to combat rising water tables and dryland salinity.

The aim of this project is to investigate the potential for broadacre wattle seed production in the medium to low rainfall areas of southern Australia.

The report covers the current and potential markets for wattle seed, including a discussion of the nutritional aspects. The report also considers the type of production systems that would be required for servicing a large scale wattle seed market and presents a discussion of the economic feasibility of such extensive production systems. Also, the implications of such production systems for resource sustainability are briefly discussed. The report concludes by identifying future research and development needs and makes recommendations for future activity by JVAP.

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This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our Joint Venture Agroforestry Program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Abbreviations

BCA	Benefit-Cost Analysis
B/C ratio	Benefit to Cost ratio
GI	Glycaemic Index
IRR	Internal Rate of Return
JVAP	Joint Venture Agroforestry Program
MDB	Murray Darling Basin
NPV	Net Present Value
QDPI	Queensland Department of Primary Industries
RIRDC	Rural Industries Research and Development Corporation
WA	Western Australia

Executive Summary

Wattle seed (*Acacia* spp.) has been used as a food source by Australian Aboriginal people for thousands of years. More recently, there has been a small but increasing demand for wattle seed as part of the commercial bush food market. *Acacia* spp. are often used in planting programs aimed at ameliorating land degradation. It has been suggested that the opportunity for broadscale wattle seed production and use of wattle seed in mainstream food production industries such as bread and biscuit making be investigated as a commercial output of future plantings of perennial species to combat rising watertables and dryland salinity.

Currently, the market for wattle seed is almost solely as a bushfood. Wattle seed has been identified as one of the ten most commercially acceptable species of the bushfood industry (Graham and Hart 1998). Total product used by processors in 1995/96 was 6.0 tonnes at a wholesale price of approximately $30 to $35 a kilogram for clean, roasted seed, and $53 to $59 a kilogram for ground clean roasted seed (Graham and Hart 1998). A separate, more recent estimate is that the current demand for wattle seed is between 12 and 20 tonnes, with a farm-gate price of between $12 and $25 per kg of clean seed (Beal, pers comm, 2000). Variables that affect the price include the size of the consignment and the size and quality of the seed.

The existing bush food market is expected to grow modestly over the next decade, particularly if export markets are developed. However, this specialty and novel food market will most probably never reach a scale where broadacre dryland production would be required.

It may be possible to develop other markets for wattle seed, for example low glycaemic foods and in specialty flour markets for bread, biscuits, cakes and pastas. It is possible that only low proportions of wattle seed could be used in breads due to the absence of gluten. Further research is required into the baking characteristics of wattle seed in order to determine the maximum proportion of wattle seed that can be incorporated into breads.

High usage markets such as starches, vegetable proteins or vegetable oils are possible, but would depend on the nutritional characteristics and food processing qualities of the seed, and on being able to be produced at very low cost in order to penetrate and compete in these markets.

Four separate options for production systems for wattle seed have been identified

- plantation
- rotation (phase) cropping
- alley planting
- companion planting

Currently, wattle seed supplying the bush foods market is harvested from natural stands. This wild harvesting is generally effected by hand and is very labour intensive. The development of an efficient and economic harvester for extensive wattle seed production is one of the key constraints to achieving a low production cost of seed and a large portion of the R&D required in regards to wattle seed production will need to be aimed at reducing the cost of harvesting.

Three possible harvesting options have been identified:

1. 'Butt-shaking': An arm grabs the main stem (butt) of the tree and shakes, causing the seeds and pods to fall off. The Acacia seeds and pods are then collected in a metal tray that surrounds the tree.

2. 'Fingers': A mechanical shaker which works by brushing plastic fingers through the outer foliage. This would be in the form of a stripper harvester that would have brushing fingers with keyholes to strip the pods. For this type of system to be successful however, the seed pods would need to be at the extremities of the bush and the bush would need to contain little heavy wood (maximum 15mm diameter).

3. Biomass harvest: Refers to harvesting by removing the entire above-ground biomass and then allowing coppicing. This would involve harvesting both seed and biomass once every four years or so by cutting back the tree to a stump and then allowing it to regenerate

The major factors regarding the success and economic feasibility of harvesting Acacia seed relate to:

- the shape and silviculture properties of the species chosen
- the length of the available harvest window
- the harvesting method and its interaction within the production system with average yield per annum
- the potential for harvesting and utilising co-products

There are over 1000 species of *Acacia* found in Australia, and caution must be exercised in selecting species suitable for cultivation for human consumption, and land restoration. One of the most important factors to consider is the toxicity of the seed of many species. Other important factors to consider in the selection of *Acacia* species suitable for broadscale production for human consumption include:

- Nutritional characteristics
- Adaptability of species to various climates and landscapes
- Growth characteristics (speed)
- Seed characteristics (size of seed crop, reliability and harvest window of the seed crop)
- Ease of propagation

There is evidence to suggest that many species of *Acacia* are suitable for agroforestry systems for environmental purposes, and in fact there are many reported examples of Acacia being used for mine site rehabilitation and other land regeneration plantings. Little or no research has been done at this stage into the rate of water use of *Acacia* species, and their likely success in reducing the level of the water table.

Olsen (pers comm, 2000) states that the level of water use of Acacias will be dependent on many factors, including the growth rate of the plant, the plant spacing, frequency of harvest, amount of foliage growth between harvests, and a range of environmental factors (eg. rainfall, soil type, depth of unsaturated zone, availability of fresh groundwater).

Investment analyses were carried out for each of the three separate harvesting scenarios identified. Specific assumptions used are associated with a high degree of uncertainty. Results are presented below.

Base Results for Benefit-Cost Analysis
(for 1 hectare, over 12 years, at a 10% discount rate)

Investment Criteria	Scenario 1: Shaking	Scenario 2: Fingers	Scenario 3: Biomass harvest
NPV ($)	-11,481	1,785	851
B/C ratio	0.4 to 1	1.4 to 1	2 to 1
IRR (%)	no solution	45	39

The results show that production under Scenario 1 (harvest by 'butt-shaking'), is not economically viable unless the cost of harvesting can be reduced to $1070 per hectare, or if the yield and/or farm-gate price can be significantly increased. It may only be appropriate for this harvesting method to be used to service the bushfood or other niche industries, where a premium price for wattle seed can be attained and where other harvesting methods have not been developed.

Scenarios 2 (harvest by 'fingers') and 3 (biomass harvest) both show promise of being economically viable, and at appropriate yields, able to be remain economically viable at a farm-gate price of less than $1/kg. Other analyses in the report suggest that wattle seed production could compete with wheat financially, given the assumptions made.

From sensitivity analyses conducted it is evident that there are three key drivers of the economic viability of wattle seed production.

- harvesting method and cost
- yield, and
- farm-gate price

Potential sustainability benefits were not quantified in the analysis.

This preliminary feasibility study suggests that the idea is worth pursuing further. However, it is apparent that before any position on the viability of wattle seed production is adopted, a significant amount of further information needs to be assembled. Information needs are divided into four separate categories:

- Food production and nutritional characteristics
- Market research
- Economic analyses
- Seed production, harvesting and sustainability

1. Introduction

1.1 Background

Wattle seed (*Acacia* spp.) has been used as a food source by Australian Aboriginal people for thousands of years. More recently, there has been a small but increasing demand for wattle seed as part of the commercial bush food market. *Acacia* spp. are often used in planting programs aimed at ameliorating land degradation. It has been suggested that the opportunity for broadscale wattle seed production and use of wattle seed in mainstream food production industries such as bread and biscuit making be investigated as a commercial output of future plantings of perennial species to combat rising water tables and dryland salinity.

The aims of this report are:

1. to investigate the potential for broadacre wattle seed production in the medium to low rainfall areas of southern Australia,

2. to assess the implications for resource sustainability, and

3. to determine the potential for use of wattle seed as a substitute for wheat in bread making.

1.2 Terms of Reference

The terms of reference of this consultancy are to carry out investigations to:

(i) Determine the potential for the production of broadacre wattle seed in the medium to low rainfall areas of southern Australia.

(ii) Assess the implications for resource sustainability, particularly in saline areas of Western Australia (WA) and the Murray Darling Basin (MDB).

(iii) Determine the potential for use of wattle seed as a substitute for wheat in breadmaking and any other large scale uses.

(iv) Assess the market size for wattle seed, both domestically and for export.

(v) Assess the overall economics and technical feasibility of harvesting within a wattle seed production system.

(vi) Make recommendations as appropriate for further steps that might be undertaken by the Joint Venture Agroforestry Program (JVAP) of the Rural Industries Research and Development Corporation (RIRDC) to further a potential industry based on wattle seed production.

1.3 Overview of Report

Section 2 of this report discusses the current and potential markets for wattle seed. This includes a discussion of the nutritional aspects of wattle seed, its current 'bush food' niche, and its potential as a carbohydrate and protein source. Section 3 details the wattle seed production systems currently used in targeting the existing bush food market (gathering and farming), and considers the type of production systems that would be required for servicing a larger scale market. Included in this section is the identification of those *Acacia* spp. likely to be suitable for broadacre production systems in the medium to low rainfall areas of Southern Australia. Next, Section 4 assesses the implications of such production systems for resource sustainability. Section 5 presents a discussion of the economic feasibility of such extensive production systems. Future research and development needs are presented in Section 6.

2. The Market for Wattle Seed

2.1 Nutrition and Other Functional Characteristics of Wattle Seed

Known nutritional details of the seeds from two *Acacia* spp. identified by Maslin et al (1998) as having potential for broadscale production for human consumption are presented below in Table 2.1.

Table 2.1: Known Nutrition Details of the Seeds From Two *Acacia* Species (per 100g raw, whole seed analysed on a wet weight basis)

Species	A.murrayana	*A.victoriae*
Energy (kJ)	1435	1384
Water (g)	8.1	6.9
Protein (g)	20.1	17.5
Fat (g)	5.2	3.2
Total Carbohydrate (g)	63.7	67.5
Available Carbohydrate (g)	37.6	40.8
Dietary Fibre (g)	28.9	29.4
Ash (g)	3.9	3.5
Inorganic Constituents (mg per 100 g acacia seeds)		
Na (Sodium)	37	33
K (Potassium)	705	601
Mg (Magnesium)	218	173
Ca (Calcium)	141	243
Fe (Iron)	4.8	10.4
Zn (Zinc)	5.9	2.2
Cu (Copper)	2.3	1.1

Source: Brand, J. and Maggiore, P. (1992)

The authors' note that the analysis above was based on the whole seed, including the seed coat. Therefore the results for protein, fat and carbohydrate content are probably underestimates compared with analyses after removal of the seed coat. The seed coat can be included in Acacia seed products as it contributes roughage to fibre-depleted diets.

The average protein of the dried seed of the two *Acacia* species above is slightly lower than the average protein level of 22.8g (22%) calculated based on the 26 separate species analysed as part of Brand and Maggiore's study (1992). At this level of protein, 100g of Acacia seed could provide about 40-50% of the Australian recommended daily dietary intake for protein (Brand and Maggiore, 1992). The protein level of wattle seed is comparable to most other legumes; however some, such as soybeans, do have higher levels.

The protein content was calculated by multiplying the nitrogen content by the factor 6.25. The use of this factor (6.25) may result in an over estimate of the protein levels. This is because some of the nitrogen in Acacia seed may be non-protein nitrogen. The amino acid proportions of Acacia seeds have not been studied in detail, and these will need to be analysed before the exact levels of protein can be determined. The authors suggest that if people have access to a mixture of protein sources, then the absence of a particular amino acid in Acacia seed may not be a problem. The authors recommend that if Acacia seed were to become the sole source of amino acids, it may be appropriate to ensure that two complementary proteins are consumed simultaneously. This is generally more relevant to the use of Acacia seed in indigenous diets, however it may also have implications for the development of new Acacia seed products and markets.

The fat content of Acacia seed is higher than that of most legumes, however the oil is largely unsaturated, making it desirable from a health point of view (Brand and Maggiore, 1992). The authors also comment that the ease of oxidation of unsaturated oils may present problems when storing the seed. However, Andrew Beal of Australian Native Produce Industries Pty Ltd has stored seed for long periods with no oxidation or deterioration problems (pers comm, 2000). Storage may be an issue to be given further consideration. The energy content is also high in Acacia seed, compared to other legumes, due to the high level of fat.

The mean fibre content for all species analysed of 32.3% reported by Brand and Maggiore (1992) is very high compared to most legumes. However, the analysis on which this figure is based could be considered inconsistent and unreliable. The analysis techniques used may have resulted in the values being overestimates as some of the starch may have been analysed as fibre.

The reported mean total carbohydrate content for all species analysed of 55.8% is lower than that of lentils but higher than that of soybeans (Brand and Maggiore, 1992). However, as fibre was not always determined, and the Acacia seeds have a substantial seed coat, the estimated carbohydrate figure (estimated by subtraction) is likely to be a gross overestimate (Brand and Maggiore, 1992). The authors report a more reliable estimate that analysed the starch and sugars directly in the wet pastes made from three *Acacia* species (seed coats removed). This found that starch content varied from 30.5% to 37.2%, and that there were little sugars present (0.1% to 2.1%) (Thorburn et al 1987). The low level of sugars may mean Acacia seed could be appropriate for inclusion in low-glycaemic foods for consumption by diabetics.

In regards to inorganic constituents, the values estimated for Acacia seed are not very different to those estimated for other legumes (Brand and Maggiore, 1992). However, mineral availability is often reduced in some legumes, as they contain fibre and associated factors such as phytate. These bind calcium, iron and zinc and make them unavailable for absorption. Further research in this area needs to be effected to examine the extent of this problem in Acacia seed (Brand and Maggiore, 1992).

While there is no information available about vitamin content of Acacia seeds it is likely they would be a rich source of all except vitamin C, riboflavin and vitamin B12 (Brand and Maggiore 1992).

Acacia seeds, like many legumes, may contain toxic compounds and anti-nutritional factors. Generally, the anti-nutrients are denatured by heat, and are therefore destroyed by cooking. Those that can be destroyed by heat include protease inhibitors, amylase inhibitors and haemagglutinins. Those that can not be destroyed by heating include tannins, toxic amino acids, cyano-genetic glycosides, and alkaloids. Toxic amino acids that may be contained in Acacia seeds include djekolic acid derivatives and lathyrogens. Studies to date indicate that any presence of these factors is in the lower range, and is comparable to the presence of these factors in other common legumes. The authors recommend that heat treatment of Acacia seeds is a safeguard that needs to be emphasised, and that long-term studies should be carried out before Acacia seeds can be safely integrated as a mainstream part of any diet. However, they acknowledge that evidence to date would suggest there are not likely to be significant problems resulting from the presence of toxic compounds or anti-nutritional factors.

It should be noted that the above information on nutrition is almost 10 years old, and therefore quite dated. However, no more recent sources of information on this topic were found. It is unlikely any more substantial work on the nutrition or toxicity of Acacia seed has been undertaken.

2.2 The Existing Market for Wattle Seed

Currently, the market for wattle seed is almost solely as a bushfood. Wattle seed has been identified as one of the ten most commercially acceptable species of the bushfood industry (Graham and Hart 1998). Total product used by processors in 1995/96 was 6.0 tonnes at a wholesale price of approximately $30 to $35 a kilogram for clean, roasted seed, and $53 to $59 a kilogram for ground clean roasted seed (Graham and Hart 1998).

A separate, more recent estimate is that the current demand for wattle seed is between 12 and 20 tonnes, with a farm-gate price of between $12 and $25 per kg of clean seed (Beal, pers comm, 2000). Variables that affect the price include the size of the consignment and the size and quality of the seed.

Clean seed is defined as containing no twigs, leaves or shell.

Currently, the supply of wattle seed for the bushfood industry is almost entirely reliant on seeds hand picked from natural stands of acacias by Aboriginal communities, land holders and commercial seed collectors. The current level of commercial cultivated plantings is unknown.

Current uses of wattle seed include:

- Flavouring agents in confectionery, sauces and ice cream
- Coffee substitute
- Edible oils
- Flour used in biscuits, breads and pasta
- Cosmetics including soaps and facial scrubs
- Animal and fish feeds.

Graham and Hart (1998) provide some approximate wholesale prices for value-added products. These include $16-$20 per kg for wattle seed pastas; $27-$30 per kg for wattle seed coffee mix; and $20-$22 per litre for wattle seed syrup.

Table 2.2 presents the results of a search of the Internet, which found the following bushfood products containing wattle seed were available for purchase:

Table 2.2: Bushfood Products Containing Wattle Seed Available for Purchase on the Internet

Product	**Price**
Youngberry and wattle seed jam	$3.90/100g
Wattle seed mustard	$5.10/190g
Wattle seed ANZAC biscuits from Emu Bottom Homestead	$3.55/200g
Dinkum damper mix, plain or wholemeal (includes wattle seed)	$3.60/350g
Wattle seed herb shaker	$6.10/25g
Roasted and ground wattle seed (Blue Gum Fine Foods)	$13.00/100g $93.00/kg
Roasted and ground wattle seed (Australia's Own Bushfood ®)	$US109/carton (12 jars, no weight provided)
Witjuti Bush Chocolates (includes other bushfoods)	$24.95/200g

2.3 Potential Markets for Wattle Seed

The bushfoods market

As discussed in Section 2.2 above, the current market for wattle seed is primarily for inclusion in bush food products, marketed on a novelty basis. The wattle seed market is currently small, however there is potential for some growth within this bush foods industry.

It was also stated above in Section 2.2 that the current demand for wattle seed from the bushfood market was estimated at between 12 to 20 tonnes per annum. There is considerable interest from overseas (especially UK) in wattle seed (Beal, pers comm, 2000) and demand, and therefore supply, is likely to increase in the future. However, even if the demand for wattle seed from the bush food industry was to grow to 1000 tonnes per annum, this would still only require 800 hectares of Acacias to be planted, assuming an average yield of 1.25t per hectare.

In order for extensive plantings of Acacia to be feasibly undertaken, more mainstream markets for Acacia seed would need to develop. Several potential products and markets are identified and discussed below.

Flour and bread making

As discussed above, wattle seed is currently roasted and ground to produce flour, which has already been incorporated into commercial bread, biscuit and pasta products.

For example, the inclusion of wattle seed flour for baking was found on the Blue Gum Fine Foods Website, which advertises roasted and ground wattle seed for sale. It makes the note that "It (wattle seed) will also add flavour to baked goods such as biscuits, butter cakes, breads etc. If using in flour based products add the wattle seed at the end of the mixing process as it can toughen the gluten content of the flour."

One concern raised is that it is often difficult to remove the seed coat of wattle seed, which can cause problems when grinding for flour (Harwood, pers comm, 2000). Ease of removing the seed coat is one aspect that should be considered when selecting species whose seeds are considered appropriate for flour making.

Another concern relates to the lack of gluten present in wattle seed flour. Michael Southen from BRI Australia Ltd (pers comm, 2000) indicated that it is the gluten level which makes wheat so attractive for breadmaking, and therefore the potential for inclusion of wattle seed flour in bread products would most likely still be limited to novelty and smaller markets such as the gluten free food market. Also, the darker colour of the wattle seed flour may work against it in terms of blending with wheat flour to produce white bread.

One suggestion could be for wattle seed to be included in breadmaking in the form of whole or ground seed in specialty seeded breads, rather than as a flour. Often smaller bakers develop these seeded breads in order to obtain a premium price over plain white bread.

It was reported in Brand and Maggiore (1992) that Maggiore experimented with incorporating flour from the seeds of *A.ancistrocarpa* into a sweet biscuit recipe. The flour produced contained no gluten. Sensory evaluations were carried out using 86 subjects and three biscuit products, one with 100% wheat flour, one with 100% wattle seed flour and one with 50% of each. The biscuit containing 100% wheat rated most acceptable, but the biscuit containing 50% of each also scored well. The 100% Acacia flour biscuits were not acceptable because of the strong flavour, oily consistency and pronounced gritty texture. It has been suggested that the characteristics contributing to these problems (such as fat content and flavour) could differ between *Acacia* spp. and that more research is needed to further determine the most appropriate species for inclusion in such recipes. It was further suggested that a blend of seeds from two separate *Acacia* spp. could be more acceptable.

Nevertheless, even if up to 10-20% of wattle seed could be used in biscuits in a technical product “acceptability” sense, this may increase the price to unacceptable levels based on existing production systems. The challenge would be to produce wattle seed at very low costs so that the premium over wheat on a raw ingredient basis was not too high.

There is extensive R&D required before wattle seed (whole or flour) could be incorporated into flour, pasta and bread markets to provide a wider positioning than the bushfoods market. Substantial milling and baking R&D would be required which investigates nutrition and other functional characteristics such as texture and taste. Both Food Science Australia (CSIRO) and BRI Australia indicated they could be interested in pursuing research into the milling and baking properties of wattle seed (Sleigh, R. and Southen, M., pers comm, 2000).

Any research program should be planned as a step-wise process, the first step of which may include the identification of characteristics such as:

- amino acid composition
- protein inhibitors
- other nutritional qualities
- isoflavins
- flavour characteristics
- oil and fat composition
- carbohydrates
- soluble fibre
- characteristics of seed coat
- removal of seed coat
- mineral composition

Dependent on the results of the initial research, more detailed research could be undertaken including:

- extrusion runs,
- potential for blending with other flours, and
- processing and baking characteristics including texture and taste

It can be tentatively concluded that there may be growth potential in the existing market for wattle seed cakes, biscuits and some specialty breads and pastas given existing technology. However, the potential may not be able to be fully exploited unless the price of seed is substantially reduced.

Further, as only limited information on nutritional and food processing characteristics is available, it could be worthwhile funding preliminary research to assess such characteristics. This may not be expensive.

Low-glycaemic foods

It was mentioned above in Section 2.2, that due to its low sugar content, wattle seed might be appropriate for inclusion in “low glycaemic” foods, for consumption as part of diabetic, and other specialty diets. Low-glycaemic refers to foods that are low on the Glycaemic Index (GI). The Glycaemic Index is a numerical system of measuring how fast a carbohydrate triggers a rise in circulating blood sugar. A low GI food will cause a small rise in the blood sugar response, while a high GI food will trigger a dramatic spike. The GI value of a particular food is meaningful only in relation to a previously established base number. The base against which the GI is measured is based on the average blood sugar response to 50g of white bread. This response is given a value of 100, and responses to 50g of other foods are measured in relation to this. For example, *Acacia aneura* seed has a GI value of 11. This means that the seed raises blood glucose levels 11% as much (on average) as white bread does. This compares to soya beans, which have a GI of 25, and lentils, which have a GI of 42 (Mendosa 2000). Further research is required to evaluate the size and potential of this low-glycaemic market and how wattle seed products may best penetrate this market.

Starch

Competing in the generic starch market would be difficult as starch can be imported into Australia for $300 to $700 per tonne depending on package form and other factors. Supply of wattle seed would have to be significantly below these prices to allow for processing and the percentage of the non-starch components (McNaught, pers comm, 2000).

On the other hand, if the starch contained in wattle seed contained any unique properties then it may be possible to extract a further premium, but again this would depend on the end use. However, in the main, the higher the price the lower would be the total market size and the market may be constrained to a niche or intermediate sized market.

The next step would be to have the seed analysed for its starch properties. Starch Australasia could be interested in pursuing this if a sample was made available to them (McNaught, pers comm, 2000).

Oil

The oil seed content of most *Acacia* species is high, and in some cases, the oil extracts are extremely palatable. Brand and Maggiore (1992) report that the seed oils generally exhibit a high proportion of linoleic acid (40-70%), oleic acid (13-14%), and palmitic acid (7-16%). Some species contain higher proportions of oleic acid (38-56%) which is similar to olive oil. These monounsaturated seeds are desirable from a health point of view.

It has been found that the major proportion of the total seed oil is found in the arils attached to the majority of seeds. Because of this, it may be possible for the seed oil to be extracted for commercial use, while still using the remainder of the seed for other commercial purposes, such as textured vegetable protein.

Janette MacDonald from DPI Food Technology Institute (pers comm, 2000) indicated the vegetable oil market was a very high volume, low margin and crowded market. The oil content of 3-5% could be seen as fairly low for wattle seed to compete successfully in this oil market. Again, if there were special properties of the oil that could be exploited, it may be possible to compete with other high profile oils that sell for $8-10 per kg. Even if this were the case, it would be unlikely that a higher price than $400 per tonne could be paid for the seed based on its oil content, unless the oil content could be increased via selection and breeding. However, if both the seed and the oil could be utilised as separate products, it would increase the total value of production.

Textured vegetable protein

As discussed in Section 2.2 above, Acacia seed has the potential to be a rich source of protein, however a significant amount of further research is required before this potential can be realistically assessed. Research is required in relation to the presence of specific amino acids and their proportions in Acacia seeds, in order to determine the total level of protein available. If the protein levels do prove to be higher than or comparable to that of other legumes, then there may be the potential for use in the protein vegetable market. Also, if certain amino acids are unavailable in Acacia seed, then it may be appropriate for protein extract from Acacias to be blended with other vegetable proteins in order to give a favourable combination of amino acids.

Chris Harwood (CSIRO Forestry, pers comm, 2000) doubts the potential for Acacia seed as a vegetable protein filler as there is still so much uncertainty regarding the actual protein level until the amino acid proportions have been studied in detail. Also, he suspects the protein levels would be comparable to or less than other legumes such as beans and peas, and that the economics of growing and particularly harvesting wattle seed will mean it is unlikely to succeed as a high protein vegetable filler. Michael Southen from BRI Australia Ltd (pers comm, 2000) also expressed a similar opinion that wattle seed would be unlikely to complete with soybeans and lentils in the textured vegetable protein market.

Also, Keith Richardson of Food Science Australia (pers comm, 2000) indicated penetration into the vegetable protein market would be difficult, unless the wattle seed is found to possess some unique protein characteristics, when compared with current protein sources such as soybeans and lentils.

Janette MacDonald from DPI Food Tech (pers comm, 2000) also expressed little confidence in the ability of wattle seed to penetrate the textured vegetable protein market. She indicated all processing of vegetable proteins took place overseas (USA) and was carried out by large multi-national companies. She also indicated it was a very expensive process.

However, Janette Brand-Miller of the University of Sydney's Human Nutrition Unit (pers comm, 2000) indicated there may be a potential for wattle seed to be used in this way if blended with protein from another source (see limiting amino acids discussion above).

As future markets envisaged could depend on the amino acid composition of the seeds, research is needed into the amino acid proportions of Acacia seeds. The results of this research may have implications not only for assessing potential markets but also for choosing species and provenances most appropriate for planting. Such research therefore would best be conducted across a range of *Acacia* species.

2.4 Other Acacia Products and Markets

In their report on commercial prospects for low rainfall agroforestry, Zorzetto and Chudleigh (1999) make the point that agroforestry products that can produce more than one product are more likely to be commercial than those where a co-product is not a possibility. It may important therefore to ensure that the *Acacia* species planted have the potential for commercial uses other than seed production.

Such commercial uses of *Acacia* species include:

- Stock fodder
- Biomass for fuel

- Firewood
- Specialty timbers (for furniture, handicrafts/turnery and musical instruments such as bagpipes, flute heads and guitar fret boards.
- Fence posts and other timber products
- Combating land degradation, including shelter belts, windbreaks and water use in areas susceptible to salinity.
- Tannin
- Gum arabic
- Flowers

There is currently a project being undertaken by Western Australia's Department of Conservation and Land Management and Department of Agriculture which aims to screen woody perennial native species for their potential to be developed as large-scale commercial crop plants for agricultural land in southern Australia. Several *Acacia* species are being considered for inclusion in trials. However, at this stage, the harvesting of wattle seed is not seen as a high priority commercial activity. Rather, several other commercial activities have been identified as having higher commercial prospects for *Acacia* species, and seed for human consumption would only be considered a secondary product. As a result seed production potential was not a primary criterion for selection of species to be trialed. Rather, the project aimed to select species likely to produce products with large potential volume markets such as biomass for energy, as achieving salinity control is the major motivation for the project, and this will require very large scale planting.

Researchers involved with the project (Olsen, pers comm, 2000) subjectively suggest that the following order of importance for Acacia uses under large scale planting may be:

- Woodchips for panel board manufacture
- Stock fodder (modified feed pellets for feed lots)
- Bio-energy
- Stock fodder (grazed in the paddock)
- Tannins
- Edible seeds

If wattle seed is considered the principal product, many of the above co-products may not be compatible. For example, the tree form for seed production may not be consistent with that required for specialty timber production. On the other hand seed production may be more of a complementary product to other production systems being developed that are based on biomass utilisation.

2.5 Summary

The existing bush food market is expected to grow modestly over the next decade, particularly if export markets are developed. However, this specialty and novel food market will most probably never reach a scale where broadacre dryland production would be required.

It may be possible to develop other markets for wattle seed, for example low glycaemic foods and in specialty flour markets for bread, biscuits, cakes and pastas. It is possible that only low proportions of wattle seed could be used in breads due to the absence of gluten. Further research is required into the baking characteristics of wattle seed in order to determine the maximum proportion of wattle seed that can be incorporated into breads.

Domestic wheat consumption for human food in Australia is around 2,000kt per annum. If wattle seed, for example, could gain 30% of this market, this would give a total market of 600,000 tonnes and perhaps a harvestable area of nearly 0.5 million hectares, assuming a yield of 1.25 tonnes of seed per hectare. Export markets would provide further potential.

High usage markets such as starches, vegetable proteins or vegetable oils are possible, but would depend on the nutritional characteristics and food processing qualities of the seed, and on being able to be produced at very low cost in order to penetrate and compete in these markets.

While the nutritional analyses to date have produced some promising results, it is recommended that a step-wise research and development plan be developed and undertaken to help assess the markets that might be technically feasible to address, the food development prospects and strategies that could be employed, and the potential sizes of different target markets.

3. Production Systems

3.1 Layout

Most of the currently developing systems for wattle seed production are being planned in order to meet the quality and continuity of demand characteristics of the existing bush food market. Hence they are likely to develop as intensive systems using inputs such as irrigation and may be associated with high labour and management inputs. As such production systems are unlikely to deliver extensive sustainability benefits, they are not given prominence in the current study.

Identified and described below are four separate options for production systems for wattle seed.

Plantation

Acacia spp. can be grown in rows, as for other agroforestry enterprises. Under intensive conditions (irrigated cropping) it is recommended Acacias be planted to a density of 675 trees per hectare (Beal, pers comm, 2000).

Rotation (phase) cropping

Rotation cropping is very similar to the plantation system described above. The key difference however is the time that the plants remain in the ground. One suggestion is that Acacias could be used as a 3 to 5 year perennial phase in a 10 year cropping cycle (Bartle, pers comm, 2000). Harvest of the wattle seed would only occur once, in conjunction with tree removal. The seed could be separated from the biomass after the entire tree has been harvested. The biomass could be used for wood chips and the leaves may have potential for stock feed.

Alley planting

Alley planting involves retaining the existing land use, while planting strips of trees through the landscape so that the existing land use (pasture or cropping) can continue. Rows could be 50m to 100m apart, with alleys being only one or two trees wide and existing cropping or pastures between rows.

This method could be used on land which is still relatively productive for traditional cropping practices, but which is threatened by a rising water table and salinity. Use of this method would result in reduced yield of wattle seed per hectare of land, however income would still be being derived from the other crops.

Companion planting

Some other agroforestry species require host plants, for example quandongs or sandalwood. *Acacia* is often an appropriate species to fulfil this companion role. In this situation, Acacia seed would be a secondary product, and therefore the layout and management of the Acacia is dependent on the layout and management requirements of the plant it is hosting.

This type of production is normally intensive, and therefore would most likely require irrigation. For this reason, we will assume this type of production would not be suitable for containing rising groundwater tables on a landscape basis.

3.2 Establishment and Management

Establishment

Acacia can be established by either direct seeding or bare rooted seedlings. Direct seeding would be the preferred and lower cost method of establishment (Bartle, pers comm, 2000). However, if bare-rooted seedlings could give an economically justifiable boost to early growth, there may be an argument for using this method of establishment. For example, if using the rotation system, one year less may be needed to achieve the desired water use before returning to the annual cropping phase of the rotation (Olsen, pers comm, 2000).

Pruning, shaping and coppicing

Depending on the species and harvesting system chosen for wattle seed production, pruning and shaping may be a time consuming and expensive input. It would be best to assess and develop the shape and silviculture of different species before selecting species for use in plantations. As discussed further in Section 3.4 below, the successful development of an economically efficient harvesting system could rely on the form and shape of a species.

Coppicing is possible as some Acacia varieties do coppice well. This may allow seed and wood (biomass) to be harvested together after 3 or 4 years with the tree then sprouting again for another harvest in a further 3 or 4 years. It is likely that 3 or 4 years would be adequate for the tree to commence seeding again. The advantage of this would be to lower the harvesting cost, although sacrificing average annual yield.

It should be recognised that coppicing and seeding are competitive tree strategies for survival and to some extent may be contradictory (Bartle, pers comm, 2000). However, it is quite possible that some species will be suitable for such a production system. Further information is required.

Pests, weeds, diseases and fertilisers

Acacias may experience pest, weed and disease problems under extensive growing conditions. The occurrence of these is most likely comparable to that of other woody native species. It is not anticipated that pest, weed and disease control, or fertiliser cost will present any significant barriers to the economic production of wattle seed, however this is an area where further research could be required.

Under a rotation cropping system, Acacias may provide significant benefits to subsequent crops in relation to the control of pests, weeds, diseases and fertilisers. For example, growing Acacias during the ‘fallow’ period can help to overcome herbicide resistance in weeds of annual cropping, and lower populations of pest and disease organisms. Other potential benefits include the nitrogen fixing capacity of Acacias; additions of organic matter to the soil; and development of new root channels through the soil (Bartle, pers comm, 2000).

3.3 Harvesting

Currently, wattle seed supplying the bush foods market is harvested from natural stands. This wild harvesting is generally effected by hand and is very labour intensive. One method is to thresh the branches of the tree or shrub with poles and collect the seed and pods which fall off on to a mat placed below the tree.

The development of an efficient and economic harvester for extensive wattle seed production is one of the key constraints to achieving a low production cost of seed and a large portion of the R&D required in regards to wattle seed production will need to be aimed at reducing the cost of harvesting.

Anecdotal evidence from several sources suggests there is a mechanical harvester for plantations called a “butt-shaker” being used or developed for use for the harvesting of wattle seed. An arm grabs the main stem (butt) of the tree and shakes, causing the seeds and pods to fall off. The Acacia seeds and pods are then collected in a metal tray that surrounds the tree.

However, Chris Norris from BSES, Bundaberg (pers comm, 2000) was reluctant to recommend ‘shaking’ as an appropriate harvesting method for wattle seed. This is because shaking is generally a method used for a species with a solid tree structure, with the product being harvested being quite heavy, for eg apples or plums. A butt-shaking system is being used for the harvesting of olives, but its success has not been great, as a lot of vibration is needed to shake off something that weighs so little. It is expected similar problems may occur with wattle seed.

One suggested alternative, if pods grow at the tips of the branches, not deep in the tree, and if the shrubs could be shaped into hedgerows, is for Acacia seed to be harvested by a mechanical shaker which works by brushing plastic fingers through the outer foliage.

Jeff Tullberg of the Farm Mechanisation Centre UQ Gatton agreed that shaking might not be the best method of harvesting wattle seed, and he also suggested a similar harvesting method as that described above. This would be in the form of a stripper harvester that would have brushing fingers with keyholes to strip the pods. For this type of system to be successful however, the seed pods would need to be at the extremities of the bush and the bush would need to contain little heavy wood (maximum 15mm diameter).

The machine could consist of a tractor with a front-end loader, a hydraulic motor and build on a rotor with plastic fingers. This type of machine is usually intended for grain. A rotor would run up and down the side of each shrub, or if the woody part is kept low it could run right over the top of the hedge.

To develop a prototype harvester, including R&D may be expensive, however the actual machine once developed need not be expensive or complex. The main R&D required is not mechanical, but agronomic and silvicultural in order that plants are appropriate to harvest.

The cost of harvesting may be largely dependent on the period of time over which seed matures. This could be a major constraint to low cost and efficient harvesting as many Acacia species only have a fairly narrow window for harvesting. It would be necessary to select species with as wide a window as possible in order to reduce harvesting costs (Bartle, pers comm, 2000).

Plantation layouts could be preferred for lowering harvesting costs compared with alley plantings where harvesters may have to cover more ground to achieve a given tonnage. However, alley plantings may be preferable from a hydrological viewpoint. The question of landscape coverage and hydrological impact are critical from a sustainability impact point of view.

At this stage it appears there are two options for seed harvesters, the ‘butt-shaker’ harvester and the “stripping fingers” type harvester. The use of each of these is almost primarily dependent on the species used, ie. some species such as *A.victoriae* are multi-stemmed and shrub like and therefore the finger type harvester would be appropriate for these species. In fact it would be very difficult to train this species to a single stem for a butt-shaker. However, there are some species that do grow with a single stem. As earlier stated, silviculture of species will be a major R&D point relating to the development of a harvester.

A third harvesting option applies if using the rotation cropping method, where seeds are only harvested once, on removal of the tree. Trees would need to have diameters less than 10-12 cm at harvest time if low cost row harvesting of total biomass is to be used. Hence both single and multiple stemmed trees could be suitable. Harvesters involving complete tree removal have already been developed, however research may be required into the most appropriate tree shape at time of harvest, as well as suitable and efficient methods for separating seeds for human consumption from the rest of the biomass which may be used for other commercial purposes.

A fourth system, which is very similar to the third, is harvesting by removing the entire above-ground biomass. This would involve harvesting both seed and biomass once every four years or so by cutting back the tree to a stump and then allowing it to regenerate. While the total seed yield of the tree over its life would be greatly reduced, this is likely to be a much lower-cost method of harvesting.

In summary, the major factors regarding the success and economic feasibility of harvesting Acacia seed relate to:

- the shape and silviculture properties of the species chosen
- the length of the available harvest window
- the harvesting method and its interaction within the production system with average yield per annum
- the potential for harvesting and utilising co-products

3.4 Suitable Species

There are over 1000 species of *Acacia* found in Australia, and caution must be exercised in selecting species suitable for cultivation for human consumption, and land restoration. One of the most important factors to consider is the toxicity of the seed of many species. Historical information is available regarding the species of *Acacia* that were consumed by Aboriginal communities. However there has been limited scientific analysis regarding the toxicity of most species. Other important factors to consider in the selection of *Acacia* species suitable for broadscale production for human consumption include:

- Nutritional characteristics
- Adaptability of species to various climates and landscapes
- Growth characteristics (speed)
- Seed characteristics (size of seed crop, reliability and harvest window of the seed crop)
- Ease of propagation

It appears there has been comparatively little work done on identifying the suitability of various species for inclusion in intensive or extensive production systems aimed at producing commercial seed crops for human consumption, as well as sustainability purposes. However, a substantial amount of work has been undertaken relating to desert species appropriate for Northern and Central Australia, and in desert regions of Africa. Much of this work relates to the potential for use of wattle seed as a drought tolerant food source.

Maslin *et al* (1998) identify 47 *Acacia* spp. with the potential for production for human consumption. They identify two species as particularly promising for production of human food in southern Australia based on the above characteristics. These two species are *Acacia victoriae* and *A.murrayana*. *A.victoriae* is currently the most important species producing seed for the bushfood industry, and its seeds are harvested from natural stands.

The characteristics used by Brand and Maslin (1998) when considering appropriate species of *Acacia* were as follows:

- Recorded as having been utilised for human food by Aborigines
- Regular, heavy, synchronously-ripening seed crops starting from a young age (2-3 years)
- Moderately large to large seed size
- Appropriate plant growth form and pod arrangement for ease of harvesting (e.g. compact, multi-stemmed shrubs with terminal/exterior-arranged pod crops, or trees with well-defined trunks suitable for harvesting by mechanical shaking technology
- Ease of establishment (especially by direct seeding), adaptability, longevity, and capacity to regenerate by coppicing.

The following table describes key characteristics of some *Acacia* species that were identified by Maslin et al (1998) as promising for seed production for human consumption.

Table 3.1: Key Characteristics of *Acacia* Species Identified as Promising for Seed Production for Human Consumption

Species	Seed collection/harvesting	Silvicultural and other features
A. jennerae	- larger seeds (9000 viable seeds per kg) - Seeds mature Nov-Jan in southern Australia. - pods produced in large pendulous bunches - consumed by central Australian Aborigines - if pods are mature, seeds can be difficult to extract	- adaptable - fast-growing - strong coppicing and suckering ability - drought tolerant - often multiple stems - potential source of fuelwood - grows in acid to neutral sands and loams - salt tolerant
A. microbotrya	- large seeds(14,000 viable seeds per kg) - heavy pod crops - used by Australian Aborigines - seeds easily extracted from pods	- drought and frost tolerant - hardy and fast-growing - used in direct seeding programs for regneration in WA - grows in a variety of soil types - large species variation between regions - can be both multi-stemmed and single stemmed (varies)
A. murrayana	- seeds at an early age (17 months) - seeds between Nov and Jan - moderately large seeds (18,000 – 27,000 viable seeds per kg) - seeds separate from pods easily - used for food by central Australian Aborigines	- provenance variation is great - grows in a variety of soil types - generally multi-stemmed, but can be pruned to one main stem to facilitate shaking harvesting - rapid growth - coppices well - potential to be weedy - relatively salt sensitive - not especially drought tolerant

Species	Seed collection/harvesting	Silvicultural and other features
		- can be short-lived
A. pycnantha	- pods mature between Dec and Jan - 33,000 viable seeds per kg - seeds easily extracted from pods - eaten by Australian Aborigines - small plantings established for agronomic assessment for bushfood potential	- grows on a variety of soil types - readily propagated from seed - moderately fast growth rate - 15-30 year life-span - survival under cultivation can be erratic - single-stemmed - used for mine-site rehabilitation - tannin potential, seed may be a secondary commodity. - plants need to be spaced widely for seed production may be affected by a wide range of insect pests and diseases
A. retinodes	- fruits irregularly throughout the year, but mature fruits often collected in Dec to Jan - ripening of fruit crops over an extended period may necessitate more than one harvest - does not produce seed in large quantities, however seeds have a very good flavour	- grows in a range of soil types - single stemmed - rapid growth - life span of 12 –20 years - drought-tolerant but would benefit from irrigation in dry periods - tolerates slightly saline soils
A. rivalis	- seeds easily separated from pods - pods ripen over a year, maturing between mid-Sep and Nov. - pods and flowers often found together on the same plant which may cause harvesting problems	- multi-stemmed - careful early pruning may allow plant to be amenable to shaking harvesting - moderate to fast growth rate
A. saligna	- seeds mature between Dec and Jan - set profuse seed crops from about 6 years of age - typically 30,000-60,000 viable seeds per kg - seeds readily detach from pods - consumed by Australian Aborigines - valued as a stock fodder overseas	- either single or multi-stemmed - tolerates alkaline and moderately saline soils - short-lived - coppice strongly - susceptible to insect pests and diseases - has the potential to become a weed - currently being used in direct seeding programs for regeneration and salinity control in WA
A. victoriae	- seeds mainly between Nov and Jan - pods held on the extremities of	- suitable for a variety of soil types - highly variable species

Species	Seed collection/harvesting	Silvicultural and other features
	the plant - produces uniformly heavy seed crops, even during drought - 24,000 viable seeds per kg - currently most important bush food species	- short-lived - coppices well - multi-stemmed - useful species for land reclamation

Source: Maslin et al, *Edible Wattle Seeds of Southern Australia*, 1998.

It is evident from the brief information presented in Table 3.1 that there is considerable variation both within and between *Acacia* spp. While a large amount of research has already been undertaken in regards to the taxonomy and silviculture of *Acacia* species, there is still a lot that is not known, especially due to the large variation within species. Much of the variation observed within species appears to be due to the conditions under which the Acacia is growing (eg. soil, climate and rainfall).

It should be recognised that any future R&D requirements could be substantially increased due to the variation within species. At a later stage, it may be appropriate to establish a small selection program for Acacia species in order to assess the likely success of any large scale plantings of Acacia, if market characteristics and production cost levels appear promising. This could be followed by a more rigorous selection or breeding program as confidence grows.

4. Implications for Resource Sustainability

4.1 Water Use and Salinity

At the current demand level for wattle seed, the establishment of plantations remains costly and risky. However, plantations of suitable species may be incorporated into land rehabilitation projects in order to improve the economics of planting wattle seed for food (Maslin *et al*, 1998).

As is well documented, the removal of native perennial vegetation, and its subsequent replacement with shallow rooted annual cropping systems, has led to a significant increase in the height of the water table in many agricultural areas. This rise in the water table can then result in significant land degradation due to salinity.

A possible solution to help alleviate this problem is to return annual cropping areas to native perennial vegetation, through agroforestry systems as described above in Section 3.1. There is evidence to suggest that many species of *Acacia* are suitable for agroforestry systems for environmental purposes, and in fact there are many reported examples of Acacia being used for mine site rehabilitation and other land regeneration plantings.

As highlighted in Table 3.1, many *Acacia* species are moderately saline tolerant, as well as hardy, adaptable and drought tolerant. However, as noted in Section 3.4, there is great variation within and between species relating to these factors, and further research would be required in order to identify the most appropriate species for ameliorating rising water tables and salinity.

Little or no research has been done at this stage into the rate of water use of *Acacia* species, and their likely success in reducing the level of the water table. For example, *Acacia* species may be inferior to eucalyptus species in this area, but still would have significant water use characteristics and far greater water use than annual crops (Bartle, pers comm, 2000). Tom Hatton of CSIRO (pers comm, 2000) has commented that there is currently no research to indicate annual water balance of Acacias would be distinctly different from any other farm forest species grown under similar conditions.

Olsen (pers comm, 2000) states that the level of water use of Acacias will be dependent on many factors, including the growth rate of the plant, the plant spacing, frequency of harvest, amount of foliage growth between harvests, and a range of environmental factors (eg. rainfall, soil type, depth of unsaturated zone, availability of fresh groundwater).

The uncertainty regarding water use will remain until a number of properly designed and monitored trials have been completed. However, as stated above, researchers are certain that *Acacia* species will use more water than existing farming systems, and are confident that layouts and rotation lengths can be designed to achieve a range of different water usage targets (Olsen, pers comm, 2000).

Planting design will be important in terms of the percent of the landscape that has to be covered in order for any significant impact on the water table to be achieved. Although predictions on this are becoming more accurate, it is still unclear whether alley plantings may be preferable to plantations from a hydrological viewpoint as they could impact on larger areas. The nature of groundwater recharge and hydrology differs between the various farming regions of Southern Australia, and any research into planting design and impact on local and regional watertables will need to be designed with this in mind.

4.2 Other Resource Sustainability Issues

To continue harvesting from the wild (particularly *Acacia victoriae*) would be unlikely to have any negative impact in terms of biodiversity etc. at current demand levels, and even significantly higher demand levels. It is possible up to ten times the current demand level could be maintained. This is because there are widespread stands of most species, and the sustainable off take of seed is likely to be very high. However, the sustainable seed off take level will vary according to species and geographic location. Protocols regarding the maximum level of seed that can be harvested from specific species in specific regions may need to be established, if not already in place. For example, a maximum of say 10% of seed from a particular species in a particular stand may be harvested. Based on this, there is no strong argument currently that can be made here for establishing plantations, due to harvesting from wild stands having a negative impact on the environment.

As mentioned above in Section 3.3, using *Acacia* species as part of a rotation cropping system may provide potential benefits from the nitrogen fixing capacity of Acacias; addition of organic matter to the soil; and development of new root channels through the soil (Bartle, pers comm, 2000).

5. Economic Feasibility and Benefit-Cost Analysis

5.1 Introduction

From the information presented in Sections 1 to 4 it is evident that many uncertainties remain regarding the commercial prospects of growing wattle seed for large human food markets. It is evident from the foregoing that production costs for wattle seed will need to be low if significant quantities of seed are to be grown and marketed. An attempt is made here to conduct an economic analysis on the production of wattle seed under an extensive production system. Firstly, assumptions are made for a basic benefit-cost analysis (BCA) for three different harvest methods. The assumptions used are presented and explained in Section 5.2. Secondly, the results of this BCA are presented in Section 5.3.

As there is so much uncertainty regarding the assumptions used in the BCA, extensive sensitivity and break-even analyses are conducted on key variables and reported in Section 5.4. Also, as there are many alternative methods of production, expected differences in the results are discussed qualitatively for other alternatives that have not been quantified (Section 5.5).

A qualitative assessment of the feasibility of commercial wattle seed production is presented in Appendix 1. This is based on a series of assessment criteria established in Zorzetto and Chudleigh (1999). The criteria were intended for use in assessing prospective agroforestry enterprises in low rainfall areas of Australia where sustainability was a key consideration.

5.2 Assumptions Used in Benefit-Cost Analysis

Benefit-cost analyses have been conducted for three harvest method scenarios. Assumptions relating to all scenarios are presented in Table 5.1.

The first scenario assumes annual harvesting of the wattle seed by a mechanical “butt-shaker” harvesting method. The second scenario assumes harvesting of wattle seed by the “fingers” type harvester, which is assumed to be a lower-cost harvesting method. The third scenario assumes harvesting only occurs every four years, and that the seed is harvested by harvesting the entire tree, with the tree then allowed to coppice. In this scenario, biomass is also produced and used every four years.

The economics of other options including alley farming and rotation cropping are discussed qualitatively in Section 5.5.

For the purposes of this analysis, no pruning and training, or fertiliser and pesticide application costs have been included. It should be noted that these inputs may be necessary, and this should be kept in mind when considering the results of the analyses. Further investigation of the need for these inputs is required.

Table 5.1: Summary of Assumptions Used in Benefit-Cost Analysis

Item	Harvesting method		
	Scenario 1: Shaking	**Scenario 2: Fingers**	**Scenario 3: Biomass harvest**
Discount Rate	10%	10%	10%
Longevity of trees	12 years	12 years	12 years
Density under plantation conditions (a)	625 trees/ha	625 trees/ha	625 trees/ha
Cost of plant material (b)	\$300/ha	\$300/ha	\$300/ha
Ground preparation and direct seeding (c)	\$80/ha	\$80/ha	\$80/ha
Pruning and training (d)	\$0/ha	\$0/ha	\$0/ha
Pesticide and fertiliser application (d)	\$0/ha	\$0/ha	\$0/ha
Harvesting cost (e)	\$3125/ha	\$750/ha	\$500/ha
Farm-gate price for wattle seed	\$1/kg	\$1/kg	\$1/kg
Marketable yield per plant at full production (f)	2kg per tree	2kg per tree	2kg per tree
Year of first harvest (g)	Year 3	Year 3	Year 4
Yield per plant (% of full production)			
Year 1	0%	0%	0%
Year 2	0%	0%	0%
Year 3	50%	50%	0%
Year 4	85%	85%	85%
Year 5	95%	95%	0%
Year 6	100%	100%	0%
Year 7	100%	100%	0%
Year 8	100%	100%	85%
Year 9	100%	100%	0%
Year 10	100%	100%	0%
Year 11	85%	85%	0%
Year 12	85%	85%	85%
Growth rate of biomass (h)	$5m^3$/ha/year	$5m^3$/ha/year	$5m^3$/ha/year
Value of biomass (h)	\$10 / m^3	\$10 / m^3	\$10 / m^3

Explanatory notes for Table 5.1:

(a) It is reported in Graham and Hart (1998) that the plant density for wattle seed is 625 plants per hectare. It is not specified whether this density relates to dryland or irrigated systems. Beal (pers comm, 2000) indicates the plant density under irrigated conditions is 667 plants per hectare.

(b) The cost of seed for one hectare was calculated by making assumptions about the survival rate, quantity of seed per kg, and the price per kg of seed. It is assumed there are approximately 20,000 seeds per kg, that the average survival rate is 0.1%, and that the cost of seed is \$10/kg.

(c) Ground preparation and direct seeding cost were estimated at approximately \$80/ha, based on 2 hours/ha operating time for ground preparation and 2 hours/ha for direct seeding, with each activity requiring one labour unit at \$10/hour (\$40) plus an equivalent amount (\$40) for fuel and maintenance.

(d) These two variables are assumed at zero cost for the purposes of the basic analysis. It should be noted however that these inputs may be necessary.

(e) The harvesting cost for Scenario 1 (Shaking) is based on the following assumptions. Assuming the machine can be adequately utilised throughout the year in different regions, then the hourly cost of using the harvester can be assumed to be $100/hour. This is inclusive of labour, fuel, maintenance, capital depreciation etc. It is further assumed that the harvester can harvest 20 trees per hour. Therefore, the harvester would take 31.25 hours to harvest one hectare containing 625 trees, at a cost of $3125 per hectare. At full yield production of 2 kg per tree, this equates to harvesting 40 kg per hour, at a cost of $2.50 per kg.
The harvesting cost for Scenario 2 (fingers) is based on the assumption that as this is a similar harvesting method to coffee harvesting, the harvesting cost can be assumed to be roughly similar, at $750 per hectare.
The harvesting cost for Scenario 3 (biomass harvest) is based on that for tea tree oil, but allowing for the reduced amount of biomass for Acacias. However, Acacia harvesting will incur the additional cost of separating the wattle seed from the biomass.

(f) Graham and Hart (1998) state that the average yield is 1.5 kg per plant. Maslin et al (1998) quote slightly higher potential yield figures of 2 kg of seed per plant. It is assumed that both of these figures relate to yields being observed on natural stands of Acacias. Therefore, it is assumed that with appropriate selection of seeds from plants and varieties known to be high yielding, a marketable yield of 2kg per tree with 625 trees per hectare, in a year of average rainfall could be expected.

(g) The year of first harvest could vary depending on the economics of the level of yield, price and harvest cost in a given year. Yield distribution by year will depend on species type, as well as other variables (e.g. rainfall, soil type)

(h) The growth rate of biomass is based on that reported for Eucalyptus species in Zorzetto and Chudleigh (1999). Also adapted from this publication, is an approximate price per wet tonne of biomass (one wet tonne is assumed to be equivalent to $1m^3$) for Acacia species.

5.3 Base Results

The investment criteria for both base scenarios are presented below in Table 5.2.

Table 5.2: Base Results for Benefit-Cost Analysis (for 1 hectare)

Investment Criteria	Scenario 1: Shaking	Scenario 2: Fingers	Scenario 3: Biomass harvest
NPV ($)	-11,481	1,785	851
B/C ratio	0.4 to 1	1.4 to 1	2 to 1
IRR (%)	no solution	45	39

The results show that production under Scenario 1 (shaking) is not profitable, due to the high cost of this harvesting method.

The NPV for Scenario 2 ($1,785) is higher than that for Scenario 3 ($851), however, the B/C ratio for Scenario 3 (2 to 1) is greater than that for Scenario 2 (1.4 to 1). This result is a reflection of the lowered harvesting cost, as well as the reduced yield through coppicing for Scenario 3 when compared to Scenario 2.

5.4 Sensitivity and Break-even Analyses

As there is considerable uncertainty regarding many of the assumptions on which this analysis is based, sensitivity analyses have been carried out on many of the key variables. These variables and the ranges used are presented below in Table 5.3.

Table 5.3 Expected Minimum and Maximum Values for Each Variable

Variables subject to sensitivity analysis	Worst case	Base case	Best case
Yield per tree	1kg	2kg	5kg
Farm-gate price per kg	$0.20	$1	$5
Harvesting cost (scenario 1 - shaking)	$6,250/ha	$3125/ha	$1,563/ha
Harvesting cost (scenario 2 - fingers)	$1,500/ha	$750/ha	$375/ha
Harvesting cost (scenario 3 - biomass harvest)	$1,000/ha	$500/ha	$250/ha

The results of the sensitivity analyses on the harvesting costs are presented below in Table 5.4.

Table 5.4: Results of Sensitivity Analyses on Harvesting Costs

Harvesting Method	Investment Criteria	Worst case	Base case	Best case
Scenario 1: Shaking	NPV ($)	-28,938	-11,481	-2,756
	B/C ratio	0.2 to 1	0.4 to 1	0.7 to 1
	IRR (%)	no solution	no solution	no solution
Scenario 2: Fingers	NPV ($)	-2,404	1,785	3,880
	B/C ratio	0.7 to 1	1.4 to 1	3 to 1
	IRR (%)	no solution	45	79
Scenario 3: Biomass harvest	NPV ($)	44	851	1,225
	B/C ratio	1 to 1	2 to 1	3 to 1
	IRR (%)	12	39	49

The results in Table 5.4 show that if the harvesting cost for Scenario 1 is halved production is still not economic, given all other assumptions. In fact the break-even harvesting cost for Scenarios 1 and 2 is equal to $1,070 per hectare. Production under Scenario 3 is only just economically viable at a 10% discount rate when the harvesting cost is doubled to $1000 per hectare. The break-even harvesting cost for Scenario 3 is $1027 per hectare.

The results of the sensitivity analyses on the yield per tree are presented in Table 5.5.

Table 5.5: Results of Sensitivity Analysis on Seed Yield per Tree

Harvesting Method	Investment Criteria	Worst case (1 kg per tree)	Base case (2kg per tree)	Best case (5kg per tree)
Scenario 1: Shaking	NPV ($)	-14,554	-11,481	-2,265
	B/C ratio	0.2 to 1	0.4 to 1	0.9 to 1
	IRR (%)	no solution	no solution	no solution
Scenario 2: Fingers	NPV ($)	-1,287	1,785	11,002
	B/C ratio	0.7 to 1	1.4 to 1	3 to 1
	IRR (%)	no solution	45	143
Scenario 3: Biomass harvest	NPV ($)	-7	851	3,425
	B/C ratio	1 to 1	2 to 1	4 to 1
	IRR (%)	10	39	89

The results in Table 5.5 show that Scenarios 1 and 2 are not economically viable if yield per tree is reduced to 1 kg per tree, however Scenario 3 almost breaks even. If the yield is increased to 5 kg per tree, Scenario 1 still remains uneconomic, as the break-even yield for Scenario 1 is 5.7 kg per tree. The break-even yield for Scenario 2 is 1.4kg per tree, while for Scenario 3 it is 1kg per tree.

The results of the sensitivity analyses on the farm-gate price for wattle seed are presented below in Table 5.6.

Table 5.6: Results of Sensitivity Analysis on Farm-gate Price for Wattle Seed

Scenario	Investment Criteria	Worst case ($0.2 per kg)	Base case ($1 per kg)	Best case ($5 per kg)
Scenario 1: Shaking	NPV ($)	-16,397	-11,481	13,096
	B/C ratio	0.1 to 1	0.4 to 1	2 to 1
	IRR (%)	no solution	no solution	128
Scenario 2: Fingers	NPV ($)	-3,130	1,785	26,363
	B/C ratio	0.3 to 1	1.4 to 1	7 to 1
	IRR (%)	no solution	45	239
Scenario 3: Biomass harvest	NPV ($)	-521	851	7,715
	B/C ratio	0.6 to 1	2 to 1	7 to 1
	IRR (%)	no solution	39	139

The results presented in Table 5.6 show that at a farm-gate price of $0.20/kg, production under all Scenarios is not economically viable. The break-even farm-gate price under Scenario 1 is $2.87/kg, for Scenario 2 it is $0.71/kg, and for Scenario 3 it is $0.50/kg.

5.5 Comparison with Wheat

In order to compare the NPV for wattle seed production with that of wheat production, several assumptions have been made. It is assumed that the budget for wattle seed developed above refers to an operation which is currently farming wheat, and wishes to move part of the farm from wheat production into wattle seed production. Therefore, all fixed costs are not relevant in the comparison, and the comparison is made on the basis of annual cash flows. It is further assumed that all ground preparation, planting, and harvesting is undertaken through contracting, for both operations.

Three separate gross margins for wheat production were assumed, and NPVs were calculated for these cash flows. Table 5.7 presents the results of analysis.

Table 5.7: Comparison of NPVs for Wheat Production and Wattle Seed Production (over 12 years at a 10% discount rate)

	Wheat Gross Margin ($/ha)			Wattle Scenario (Base cases)		
	100	140	180	Scenario 1	Scenario 2	Scenario 3
NPV ($)	750	1049	1349	-11,481	1,785	851

The results above suggest that wattle seed production could compete with wheat financially, given the assumptions made.

5.6 Costs and Benefits Not Quantified

Alley farming

Any economic analysis of this system would need to include assumptions about the costs and benefits of the existing land use (e.g. crops or pastures). Any of the three base harvesting scenarios described above could be applied to an alley farming system. However, the harvesting cost could increase, due to the time needed to travel between rows of Acacia. Yields per tree could increase.

Rotation cropping

An economic analysis of a rotation cropping system would have similarities to Scenario 3 (harvest by coppicing) described above. However, after the first four to five years, the entire tree, not just the above-ground biomass, would be removed and replaced with an annual crop such as wheat. After six years of wheat production, the Acacias would be re-established, and once again, the entire plant would be harvested and removed after four to five years growth. The costs and benefits of the wheat production would also need to be included in any analysis of this scenario.

As mentioned in Section 3, under a rotation cropping system, Acacias may provide significant benefits to subsequent crops in relation to the control of pests, weeds, diseases and fertilisers. For example, growing Acacias during the ‘fallow’ period can help to overcome herbicide resistance in weeds of annual cropping, and lower populations of pest and disease organisms. Other potential benefits include the nitrogen fixing capacity of Acacias; additions of organic matter to the soil; and development of new root channels through the soil (Bartle, pers comm, 2000). These benefits should also be considered in any analysis of this scenario.

Sustainability benefits

As described in Section 4, sustainability benefits from Acacia plantings are likely to be increased groundwater use over annual crops and pastures in particular locations, which will result in a lowering of the water table and hence avoided or ameliorated salinity.

This sustainability benefit may be estimated by making assumptions about the ‘without’ agroforestry situation. That is, how degraded would the land have become, and what cropping or pasture revenue would have been lost by not being able to use the land for those, or any other purposes in the future. Methods for taking these factors into account are provided in Zorzetto and Chudleigh (1999).

5.7 Conclusions

From the analyses conducted above, it is evident that there are three key drivers of the economic viability of wattle seed production.

- harvesting method and cost
- yield, and
- farm-gate price

The results show that production under Scenario 1 (harvest by shaking), is not economically viable unless the cost of harvesting can be reduced to $1070 per hectare, or if the yield and/or farm-gate price can be significantly increased. It may only be appropriate for this harvesting method to be used to service the bushfood or other niche industries, where a premium price for wattle seed can be attained and where other harvesting methods have not been developed.

Scenarios 2 and 3 both show promise of being economically viable, and at appropriate yields, able to be remain economically viable at a farm-gate price of less than $1/kg

It should be stressed that the assumptions used in this analysis should be considered indicative only, and that further work is required in order to confirm or identify more accurate parameters. One way of developing greater confidence in the economic analysis could be for JVAP to conduct a small workshop of Acacia and other specialists in order to gain expert opinions on the parameters used in the analysis.

6. Research and Development Needs

It is apparent that before any position on the viability of wattle seed production is adopted, a significant amount of further information needs to be assembled. Information needs are divided into four separate categories for the purposes of this discussion.

6.1 Food production and nutritional characteristics

While the information from nutritional analyses carried out in the past is promising, it is recommended that a step-wise investigation program be considered to assess whether wattle seed is likely to be able to successfully penetrate the large-scale markets identified in Section 2.

A first step may include producing further information on:

- amino acid composition
- protein inhibitors
- other nutritional qualities
- isoflavins
- flavour characteristics
- oil and fat composition
- carbohydrates
- soluble fibre
- characteristics of seed coat
- removal of seed coat
- mineral composition

Dependent on the results of the initial research, more detailed research could be undertaken including:

- extrusion runs,
- potential for blending with other flours, and
- processing and baking characteristics including texture and taste

6.2 Market research

Once the nutritional and food processing characteristics are better known, it would be necessary to carry out market research to ascertain the potential size of any intermediate and large scale markets that appear promising, and the range of prices of seed that would allow wattle seed to penetrate such markets. This would not only be required to assess the overall economic viability of broadacre production but also to give guidance to selection of those species, and possibly production systems, that are likely to produce the desirable end products.

It may also be advisable for some preliminary market research to be undertaken in order to identify the characteristics of those commodities with which wattle seed would be competing in large scale markets, for example, soybeans and lupins.

The size of the low-glycaemic food market could be established, together with the likely penetration rate for wattle seed.

6.3 Economic analyses

While the results of the benefit-cost analyses contained in this report are promising, they are based on a range of assumptions, many of which could not be checked thoroughly given the resources available. It is likely these assumptions could be improved and refined to a degree if all knowledge and expertise available in Australia could be assembled. Such knowledge is not likely to be published, and much of it would still be informed estimates by knowledgable individuals.

It is therefore recommended that a small workshop made up of those working with *Acacia* spp., bushfood industry producers, and engineers with experience in harvesting systems be held to refine and improve the assumptions.

Economic analyses could also be extended to other production systems (eg. rotational cropping) not covered in this initial analysis.

6.4 Seed production, harvesting and sustainability

As stated in Section 3, it is evident that there is considerable variation both within and between *Acacia* spp. While a large amount of research has already been undertaken in regards to the taxonomy and silviculture of *Acacia* spp., there is still a lot that is not known, especially due to the large variation within species.

Significant R&D may have to be targeted at this variation within species. It may be appropriate to establish a small selection program for Acacia species in the short-term.

This R&D would seek to identify factors relating to such aspects as:

- pests, weeds and diseases affecting different species of Acacia,
- flowering and seeding patterns and associated harvesting windows,
- yield under different spacings,
- tree form and silviculture, and
- the ease of seed harvesting.

Much of this research could link closely to R&D on the most appropriate harvesting system for Acacia seed. As the economic analysis in Section 5 shows, the appropriateness of the harvesting system, and the subsequent cost, will be the key driver of the economic viability of any Acacia seed enterprise.

R&D is also required on the rate of water uptake of *Acacia* spp., and the effect this and planting design may have on the hydrology of the landscape in which the plantings are undertaken. As stated in Section 4, planting design will be important in terms of the percent of the landscape that has to be covered in order for any significant impact on the water table to be achieved.

Conclusions and Recommendations

1. The existing bush food market is expected to grow modestly over the next decade, particularly if export markets are developed. However the size of this market will probably be insufficient to support a broadacre industry that will have a significant land sustainability impact.

2. It may be possible to develop other markets for wattle seed, for example low glycaemic foods and specialty flour markets for bread, biscuits, cakes and pastas. However, such markets may be difficult to develop on a large scale due to the current cost structure of producing wattle seed which is heavily influenced by the harvesting cost.

3. High volume markets such as starches, vegetable proteins or vegetable oils are possible, but would depend on seed being able to be produced at very low cost, for example, significantly less than $1 per kg.

4. A key to the success of commercial wattle seed production will be the development of an appropriate and cost-effective harvesting system. There are several options already identified that can be further explored.

5. The harvesting systems most likely to be developed to low cost levels would be “finger” type harvesters applied annually, or above-ground biomass harvesting with later separation of seed from the biomass, and allowing the tree to coppice.

6. Wattle seed production could contribute to increased water use over annual crops and pastures. However, the extent of such contribution to lowering groundwater tables and reducing the impact of salinity has not been quantified.

7. From the basic benefit-cost and sensitivity analyses conducted, it is evident that there are three key drivers of the economic viability of wattle seed production.

    - harvesting method and cost
    - yield, and
    - farm-gate price

8. It is likely that to compete in large scale markets, the cost of wattle seed will need to be considerably less than $1/kg, possibly as low as $0.20/kg. The current cost estimates suggest that these levels may be achievable at yields of 2 kg per tree per annum and tree density of 625 trees per hectare, provided low cost harvesting systems can be developed. R&D would be required to achieve the assumed yield.

9. It should be stressed that all assumptions used in this analysis should be considered indicative only, and that further work is required in order to confirm or identify more accurate estimates.

10. The following four areas of further information needs have been identified:

    - food production and nutritional characteristics of wattle seed,
    - market research,
    - economic analyses, and
    - seed production, harvesting and sustainability.

11. It is recommended that further information in these four areas be sought by the JVAP. This could be achieved in a staged process to make best use of financial resources.

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Appendix 1: Assessment Criteria

In their report on the commercial prospects for low rainfall agroforestry, Zorzetto and Chudleigh (1999) identify thirteen assessment criteria, which may be used in assessing priority commercial prospects warranting further investigation. Each of the criteria is scored in order to facilitate comparison with other commercial agroforestry enterprises assessed in Zorzetto and Chudleigh (1999).

An assessment of wattle seed against these criteria follows:

1. **Technical feasibility (Score of 4)**

   While the technical feasibility of producing wattle seed appears promising, further information is required before this can be confirmed. Technical feasibility issues relate to the development of a mechanical harvester that is appropriate to the shape and silviculture of *Acacia* spp., as well as yield, harvest window, and species and variety selection.

   Other technical issues do not relate to the growing of Acacias, but rather the processing of the wattle seed into an end product for human consumption. Roasting and grinding technology is developed and adequate, however depending on the products envisaged, further technology for removing the seed coat, isolating flavour, carbohydrates, protein etc. may need to be developed.

2. **Climatic zone suitability (Score of 5)**

   At this stage, it appears there should be no problems with climatic zone suitability. There is a large range of *Acacia* spp., and many of them are suitable to most climatic zones of Australia, particularly low to medium rainfall areas of Southern Australia.

3. **Robustness to land and soil types (Score of 4)**

   While further work is required to determine the most appropriate *Acacia* spp. for particular land and soil types, generally Acacia are extremely robust to various land and soil types. Many *Acacia* species are capable of tolerating saline soil.

4. **Integration with existing farming systems and culture (Score of 4)**

   This criterion was developed as it may have an influence on adoption rates of agroforestry enterprises. At this stage the feasibility/suitability of integrating Acacias as a row crop between wheat etc. is still unclear, but it is not expected this would be any different than for other agroforestry enterprises. Acacias could be expected to experience similar integration and adoption problems as other forms of agroforestry.

5. **Size of market (Score of 3)**

   At present, the size of the market is a major stumbling block. The bushfoods market is solid and does have the potential to grow, however there is still uncertainty regarding the size of the market for use of wattle seed in more mainstream products such as breads, pastas, biscuits, oils, starches, or as a textured vegetable protein. This uncertainty stems from the lack of conclusive research conducted to date on the nutritional and functional aspects of wattle seed, its processing characteristics, as well as the current high cost of production of wattle seed.

6. **Likelihood of market penetration (Score of 2)**

   Subjectively, it is estimated market penetration will be difficult and slow, especially if the cost of production can not be reduced to a competitive level. (Mainstream markets not bushfood markets)

7. **Commercial profitability (Score of 1)**
   With current technology, the production of wattle seed in plantations on a broadacre scale would not be commercially profitable. However, as the basic economic analysis conducted in Section 5 of this report shows, with appropriate yields and lower (but possibly achievable) harvesting costs, production of wattle seed could be commercially profitable.

8. **Commercial profitability including capturable long-term sustainability benefits (Score of 3)**
   The exact nature and degree of the long-term sustainability benefits are still a little unclear. However benefits will include increased water use, which lowers the groundwater table and reduces the likelihood of salinity. The uncertainty comes from the degree to which certain species impact on the groundwater level.

9. **Social profitability including both capturable internal benefits and external benefits (Score of 3)**
   Similar to criterion 8, however it is possible some of these sustainability benefits may be experienced off-site.

10. **Riskiness (Score of 2)**
    If the appropriate research and development is carried out, on both the nutrition and market factors, as well as varieties, production and harvesting, the risks of wattle seed production should remain relatively low. As most *Acacia* species are drought tolerant, there is not a lot of risk in terms of plants dying from several dry seasons. A major risk could relate to acceptance by the market.

11. **Flexible product potential (Score of 3)**
    Acacia species can be used for many other products if the mainstream market for wattle seed does not grow sufficiently. The seed produced may still be used to service a portion of the bushfood industry. Other Acacia products include fodder, biomass, timber for many uses, and tannins, which may yield some return on the investment. Alternatively the plantings could remain purely for their sustainability benefits.

12. **Multiple product potential (Score of 4)**
    It is possible the alternative products identified for Criterion 11 may also be appropriate here. The area needs further investigation. However at the end of the seeding life of the tree (10 to 20 years) it may be possible for the trees to be used for those markets identified above. These products could be produced while the tree is still being used for seed production if the seed is harvested in conjunction with the above-ground biomass, with the plant then regenerating through coppicing.

13. **Likely extent of enterprise (Score of 3)**
    A major limiting factor will be the size of the market as at this stage the market would be easily flooded if another 20 to 30 hectares were planted. The only other limiting factor is the area of land over which farmers are able or willing to adopt this practice. They may wish to only plant on degraded land, and not replace other profitable crops with Acacia plantations etc.

Table 1 below presents the overall scores of those agroforestry enterprises assessed in Zorzetto and Chudleigh (1999), as well as the overall score for wattle seed production.

Table 1: Agroforestry Enterprises in Low Rainfall Areas Ranked According to Assessment Criteria

Agroforestry Enterprise	Overall Score
Fodder	50
Eucalyptus oil	47
Wattle seed for human consumption	41
Biomass for electricity	41
Domestic firewood	41
Sawntimber	38
Posts	38
Biomass for ethanol	38
Wood panel products	37
Charcoal and activated carbon	37
Specialty wood uses	32
Poles	19