A VISION FOR THE FUTURE OF AGROFORESTRY

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WHY AGROFORESTRY?

The evolution of agriculture has incorporated two practices, based on the systematic use of mixtures of plants, that are fundamental to productivity. They are:

- rotations: alternating crop and pasture species over time.
- mixtures: growing different species together at the same time, most notably legume and non-legume species.

In Australian agriculture these two plant mixture practices have combined to give the ley farming system, where a legume dominated pasture phase is alternated with a cereal crop phase. This system suits the infertile, poorly structured soils of southern Australia. Soil fertility is maintained by organic matter and nitrogen input during the pasture phase. In addition the alternating regime limits the build up of weeds, pests and disease.

However, there is plenty of scope for further improvement. The ley system relies heavily on winter growing annual species. These species are not deep rooted enough to prevent leakage of surplus winter rainfall into deep subsoils. This unused water is the driving force of salinity. Also the annual species are not tall or robust enough to protect the land, plants and animals from severe weather. These two deficiencies are the cause of chronic land degradation and a loss of potential production widely across southern Australia.

The ley system needs to have some deep rooted, woody perennial shrubs or trees added to the plant mix to overcome these deficiencies. The addition of such plants would create a system that could be described as 'agroforestry'. In agroforestry the woody plant component is generally considered to include species able to produce timber or other products, but excluding horticultural and grazing plants.

The vision for agroforestry is that it will converge with the ley system to achieve control of land degradation and deliver a quantum gain in productivity for Australian agriculture. This paper presents some views on what needs to be done to realise this vision.

THE MOTIVATION TO IMPROVE CONVENTIONAL AGRICULTURE

Reeves and Ewing (1993) describe the ley farming system as dynamic and adaptable. This is well demonstrated by the continuing evolution of practices to manage soil organic matter and nitrogen content to achieve a long term balance in soil fertility. Legumes are a key component of fertility management. Reeves (1993) calls legumes 'the engine room of agriculture in Australia'. The success of ley farming in these and several other aspects is renowned.

Unfortunately there are other aspects of the ley farming system where a balance has not yet been achieved and where severe decline is evident. A summary of the findings of the Select Committee in Land Conservation (1991) indicates the extent of these problems in WA. Such problems are evident to varying degrees throughout southern Australia.

Table 1: A SUMMARY OF LAND DEGRADATION PROBLEMS IN WA

PROBLEM	EXTENT OF DAMAGE
1. Dryland salinity	3% now - 15% projected
2. Stream salinity	all streams/rivers degraded
3. Water logging	variable up to 3 million ha
4. Water erosion	2 million ha vulnerable
5. Wind erosion	intermittent/universal
6. Soil acidification	10.5 million ha vulnerable
7. Soil structure decline	3.5 million ha affected
8. Subsoil compaction	8.5 million ha affected
9. Remnant vegetation decline	extensive, some severe
10. Nature conservation	all wetlands, rivers, estuaries degraded, 260 rare and endangered species

Source: Select Committee into Land Conservation (1991)

It is very striking that many of these problems could be ameliorated by the incorporation of a woody perennial plant component into the ley system. Reeves (1993) acknowledges the deficiency of current agricultural species in water use potential. However, the dynamic and adaptive ability of the ley farming system has not yet been triggered by these problems! The problems appear to be regarded as external to the ley system and to warrant no particular priority for attention within the evolution of the system.

This apparent neglect is even more difficult to understand given the emerging evidence from agroforestry research that mixtures of trees and annual plants can be complementary. Hence the losses of land degradation might not only be eliminated by trees but actually converted into additional production.

This potential is demonstrated by Moore et al (1991). Using wide-spaced pine trees in pasture in an 800 to 900 mm rainfall area in the south west of WA, they observed a productivity increase of 40% (Fig 1).

Fig 1: ENHANCED PRODUCTIVITY FROM AGROFORESTRY

Production from **10 ha** mixed trees and pasture	=	Production from **8 ha** pure plantation	+	Production from **6 ha** pure pasture

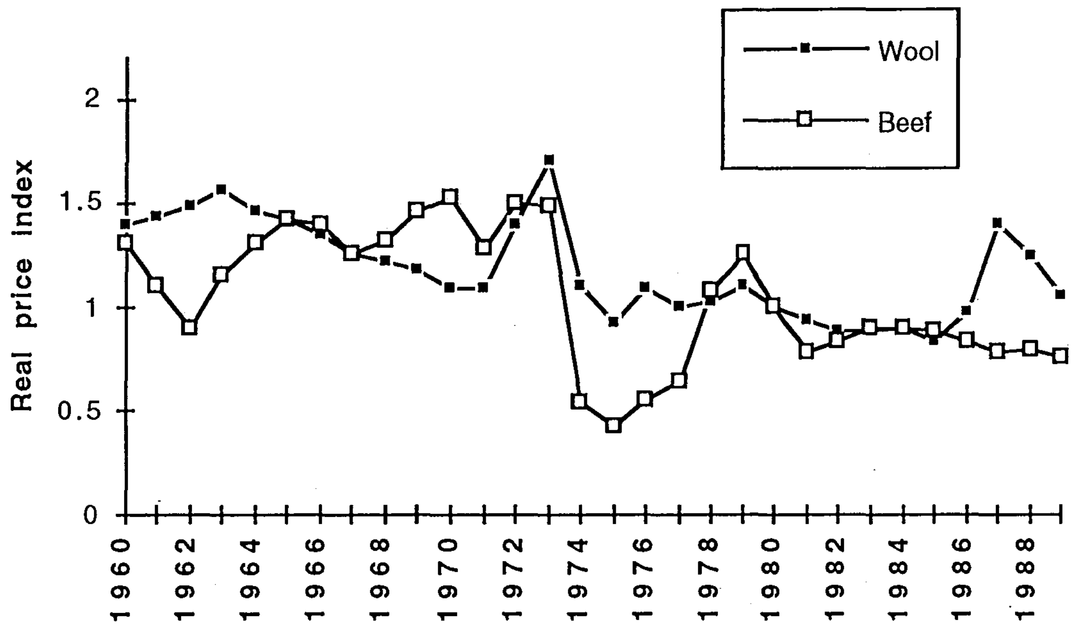
The relationship between the productivity of crop mixtures and the productivity of monocultures of the components is called the land equivalent ratio (Vandermeer, 1989). In the above example the land equivalent ratio is 1.4, i.e. 1.4 ha of monocultures was required to produce the same as 1 ha of mixture. The explanation for this effect is simple in concept: the mixture of tall, perennial, deep rooted trees and shallow rooted, annual legume based pasture makes better use of resources (water, nutrients, sunlight and carbon dioxide), and generates a more favourable local climate for plant production within the tree sheltered area. Clearly the components of the mixture are not fully in competition with each other and can also complement each others performance.

Although the results of Moore et al (1991) relate to wide spaced pine trees the principle will apply to any mixture of diverse plants that achieves complementary, integrated use of the resources of the land (Bird 1992, Knowles 1993, Lefroy and Scott, 1994). The best potential mixtures will incorporate tall species where greater water use capacity and shelter benefits will be provided.

For decades the average real prices of traditional agricultural products have been declining (Fig 2). Over the past 4 decades the gross real value of farm production has not increased despite production increasing two and half times (Chisholm 1992). This appears to be a deep structural characteristic of international agricultural commodity markets and one that calls for serious national policy and individual grower review . There are two responses that can be made to chronically weak markets:

- become more efficient and tolerate the decline.
- diversify into crops not so adversely affected by weak prices.

Fig 2: REAL PRICES FOR WOOL AND BEEF 1960 TO 1989



Historically, improvements in the ley system have achieved productivity advances of about 2.5% per year off-setting much of the pain of contracting prices (Chisholm 1992). Unfortunately there has been little serious attempt at diversification of Australian agriculture. To qualify as 'serious' a new crop or product would have to be a major commodity that sells into markets that are not so prone to the structural weakness of agricultural markets e.g. industrial markets which do not attract agricultural subsidies in the developed nations. Since there are other compelling reasons to incorporate trees and woody plants into agriculture, why not also seek species able achieve the objective of diversification?

There is vast opportunity to diversify into woody plants. Diminishing areas and access to native forests around the world has highlighted the opportunity to grow timber on farmland. In contrast to agricultural commodities timber prices have been very firm over the last couple of decades (Shea and Hewitt 1990). There are many other non-wood and industrial product prospects that warrant investigation (Bartle and Reeves, 1993).

Table 2 gives the scale and cost of treatment of land degradation by tree planting for WA (Bartle, 1992). Some 3 million ha of planting and $2 billion of investment are required to make substantial impact on land degradation.

Table 2: COST OF TREE PLANTING FOR TREATMENT OF LAND DEGRADATION

	RANGE	MEAN
Required cover (%)	10 to 30	20
Area to plant (million ha)	1.6 to 4.8	3.2
Tree cover (stems/ha)	400 to 1 000	700
Unit Cost ($/ha)	400 to 1 000	700
State Cost ($billion)	0.64 to 4.8	2.24
Average Farm Cost ($thousand)	44 to 330	154
Annual State Cost ($million/yr)	32 to 240	112
Annual Cost/Farm ($thousand/yr)	2.2 to 16.5	7.7
State Maintenance ($million/yr)	20 to 140	67
Average Farm Maint ($thousand/yr)	1.3 to 10	4.6

Note:
1. Total W.A. farmland area of 16 million ha.
2. Average farm 1 100 ha.
3. Annual costs over 20 year term.
4. Maintenance costs 3%/yr of initial planting cost.

The percentage tree cover suggested in Table 2 is deliberately vague. The reluctance to sharply specify percentage cover is appropriate since the trees need to be widely dispersed (in belts and small blocks) to be effective in meeting their landcare objective. The tree planting target is most appropriately considered in terms of degree of dispersal not area.

Nevertheless the amount of planting required is large and it will be difficult to finance the investment solely from the benefits within agriculture under present economic circumstances. Furthermore, a rigorous accounting of tree planting will include an opportunity cost for the crop or pasture land converted to trees.

If commercial return can be gained from the trees the opportunity cost is reduced (or eliminated) and the potential to finance planting based on the expected revenue of the crop can be pursued. Many arrangements to finance bluegum pulpwood planting have been developed in the high rainfall areas of south west WA (Eckersley et al 1994).

To remedy land degradation on a national scale within the 20 year period suggested in Table 2 it will be imperative to develop several commercially attractive woody plant species, products and industries and for these crops to be adopted as a mainstream component of ley farming. The present approach to landcare tree planting, motivated by the landcare benefit alone and subordinate to the income earning activities on the farm, needs urgent review.

It is important to note that tree crops need not give returns that are fully competitive with conventional crops. It is the aggregate costs and benefits that determine whether the tree crop will be competitive. In this respect tree crops may be analogous to the ley phase in the present system, where the direct return from pastures and wool may not be comparable with wheat but other long term benefits, such as the rejuvenation of soil organic matter and the nitrogen pool, makes it attractive.

AGROFORESTRY DESIGN

The aim of integrating tree or woody plant crops into ley farming is to achieve an optimum of the several potential benefits while also ensuring that the total benefit exceeds the cost and inconvenience. The different benefits may call for quite divergent planting distributions. For example, the ideal layout for shelter is not likely to be the same as that required for maximum water use. Shea et al (1993) illustrate tree crop placement to achieve an optimum of tree products, shelter and salinity control.

Strategic placement of trees for maximum water use will often be a major objective. Skilful placement for water use will grow more tree products as well as give better control of ground water and salinity. New techniques using geology, geophysics and hydrogeology are emerging which should greatly improve the accuracy with which trees can be placed to achieve maximum water use (Engel et al, 1987; George et al, 1994).

The costs and inconvenience of trees to other farm activities will also be a major factor influencing planting distribution. The tree crop must not compromise the large scale mechanisation of conventional cropping or the low management input of extensive grazing.

Two typical tree layouts are likely to emerge:

- concentrated block planting at strategic landscape positions where particular advantage can be gained, for example, where water can be efficiently exploited such as sand plain seeps, valley bottoms or break of slope;

• dispersed belt or 'alley farming' patterns suited to mopping up surplus water across recharge areas, providing extensive shelter and for compatibility with cropping. This option is only likely to be successful where fencing of the belts is not necessary.

Alley farming practice is rapidly developing in WA and alley layouts appear likely to become the most popular tree crop planting distribution. Lefroy and Scott (1994) review this development. The major design variables of alley systems are tree species, tree belt width, alley width and belt orientation. These features must be investigated to determine the finer points of the 'agronomy' of alley systems. Eckersley (1994) presents some economic analysis of bluegum alley systems that indicate the importance of correct design.

AGROFORESTRY SPECIES

Conventional timber producing species provide some ready options for incorporation into ley farming in the higher rainfall (greater than 600 mm rainfall) areas of southern Australia. In particular, fast grown, short rotation eucalypts for pulpwood (mainly *Eucalyptus globulus*) and pine (mainly *Pinus radiata*) are recognised commercial species with expanding markets, strong price projections and existing agroforestry techniques.

From the farmers' perspective the impediments to planting are the long rotations (greater than 10 years), difficulty in financing such a long term investment and the need for firm arrangements to consolidate individual agroforestry plantings into big enough blocks of timber resource to attract investment in infrastructure and marketing. However, these problems could be readily solved by careful planning.

A concerted effort to develop the agroforestry potential of the traditional timber species could revitalise Australian forestry and arrest much of the land degradation in the higher rainfall zone of southern Australia (Bartle 1991; Eckersley, 1994; Shea et al, 1994).

However, the bulk of Australian farmland is too dry for conventional timber species and no other tree crop option of any significance exists. The low rainfall wheat and sheep zone has an area of some 100 million hectares, large property sizes, low management inputs, low profitability and long transport distances. Development of tree crops for this area should therefore focus on species which:

• are amenable to large scale, extensive management;
• have products with an economic transport horizon up to 400 km or else be amenable to local processing to add value;
• have products that will sell into large volume markets;

- produce over short rotations to improve the ease of financing;
- have potential uses for any wastes or residues;
- have desirable agroforestry attributes.

Ideally many tree crop species and products should be developed to provide a range of options for all soils, climates, forms of degraded land and to give economic diversity. To achieve the vision of merging agroforestry into ley farming the focus for tree crop development has to be on scale. While there may be many options for production for local use (farm timber, fence posts) or for specialty markets (flowers, craftwood, furniture), these options are likely to remain modest in scale and are not seen to justify major agroforestry development effort.

Bartle and Reeves (1992) outline a systematic process by which the search for and evaluation of potential major tree crop products could proceed. They identified several large scale prospects for wheatbelt areas including plant extracts, especially eucalyptus oil and biomass fuels, especially ethanol.

A project to investigate the feasibility of eucalyptus oil production from mallee species of *Eucalyptus* commenced in WA in 1994.

THE EUCALYPTUS OIL PROJECT

The market potential of eucalyptus oil is based on its excellent solvent properties. The attraction of solvent markets is that they are large, diverse and mainly supplied with a product (trichloroethane) which is being withdrawn from use under international conventions to control ozone depletion. There is a strong preference in these markets for 'natural' replacement products. Even a modest 10% penetration of world solvent markets by eucalyptus oil would require at least 0.5 million ha of oil mallee planting. The current pharmaceutical market for eucalyptus oil is less than 3000 tonnes and too small to yield any significant landcare benefit.

The major challenge of solvent markets is price. Historically trichloroethane and the major natural product competitors, limonene (from citrus peel) and pinene (from Pinus species) have sold for around $2/kg. Synthetic competitors are likely to be preferred if natural product prices climb too far above this level. The WA project aims to be viable at this price.

Prefeasibility investigation indicates that $2/kg is an achievable target. There are several avenues by which development of oil mallees can proceed to achieve this target.

Firstly, there are many mallees with potential for development as crop plants. Great diversity and scope for selection exists between and within these species. The early indications are that superior oil characteristics are strongly heritable. and that considerable in-breeding depression is present in native populations. Also flowering occurs at age 3 to 4 years. Hence selection, breeding and seed production programs should be able to make rapid advance in leaf oil content and leaf production.

Secondly, the leaf oil contents and yields reported from trial plots in farmland range from modest (3.5% and 40kg/ha/year from Eastham et al 1993) in biennial harvests at Wongan Hills in WA to very encouraging (4.0% and 200kg/ha/year from Milthorpe et al, 1994) in annual harvests at Condobolin in NSW. Both results are from 'plantations' and do not indicate the potential for enhanced production from agroforestry layouts designed to exploit surplus water and nutrients by wide dispersal across agricultural land.

Thirdly, wheatbelt farmers have been toughened by surviving in an industry with long term declining terms of trade. They operate highly efficient, highly mechanised production systems. Mallees for oil production could be readily adapted to such systems. The likely most common planting configuration will be in 'alley farming' distribution i.e. long belts along the contour (often in conjunction with a grade bank or drain) and repeated at a horizontal spacing of 100 to 200m such that the scale and efficiency of the conventional cropping in the alley (the space between belts) is not compromised. Many farmers in WA are establishing such tree planting patterns motivated solely by the landcare and agricultural production benefits. There is scope to reduce the cost of planting (currently some $500/km of belt) as knowledge, experience and skills develop and to refine farm and catchment planning practices to increase the benefits.

Fourthly, the cost of harvest and oil extraction will be a sensitive determinant of success. A cost of $60/tonne is quoted by Abbott (1989) using heavy rotary slashing equipment and steam extraction in operations near Bendigo. Slashing does not separate the 66% of wood from the 33% of leaf and hence the effective cost of processing each tonne of leaf is $180. With only some 35kg of oil/tonne of leaf there would be no incentive to harvest at an oil price of only $2/kg. However, under an annual harvest regime or with altered harvest technique the wood proportion could be reduced. Also the extraction step using steam could be reduced in cost with the substantial economies of scale likely to available. The scale being aimed for could also justify a systematic investigation of alternative extraction technologies including solar, microwave, chemical and mechanical. Clearly the whole process of harvest and extraction must be subject to detailed investigation and redesign to reduce cost.

As part of the development program WA has embarked on large scale pre-commercial planting. The logic of this is that without development and demonstration on the ground the real costs and pitfalls will not be detected; the practical innovation input from farmers will not be forthcoming; the sizeable batches of product and signals of 'serious intent' required for market development will not be available.

Six centres of production have been initiated to encompass the full range of wheatbelt environments in WA. They are Esperance, Woodanilling, Lake Toolibin, Narembeen, Kalannie and Canna. At each centre a five year program of planting was initiated in 1994 to establish 5000 ha over 5 years. A total of 2000 ha (or 2.4 million seedlings) was planted this winter. The WA Department of Conservation and Land Management operates this program with support from the Commonwealth Farm Forestry and National Landcare Programs. All planting is with selected stock. Plantings are designed for maximum landcare benefit and farmers enter the program in the full knowledge that successful commercial development is not assured. Farmers meet the cost of establishment and management (with a small input to seedling cost from the State). This State input is on a sharefarm basis and the cost plus interest is repayable from future oil revenue should the project be successful. The sharefarm contract also specifies that the farmer will participate in orderly industry development arrangements, including harvest, processing and marketing.

CONCLUSION

There is a perception that the range of plants suitable for extensive, economic use in wheatbelt agriculture is confined to annual species and that consequently the concept of agroforestry is misguided. I would contend that the availability of economically attractive perennial species and associated industries is limited only by the level of R&D investment that we are prepared to commit to their development. Historically, the lions share of R&D expenditure has gone into improving the present species within the present system. This fails to recognise the clear signs of fundamental deficiencies in our current system of agriculture. This paper presents a vision for the merging of agroforestry into ley farming to face these deficiencies.

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