Capturing multiple benefits from agroforestry

Introduction

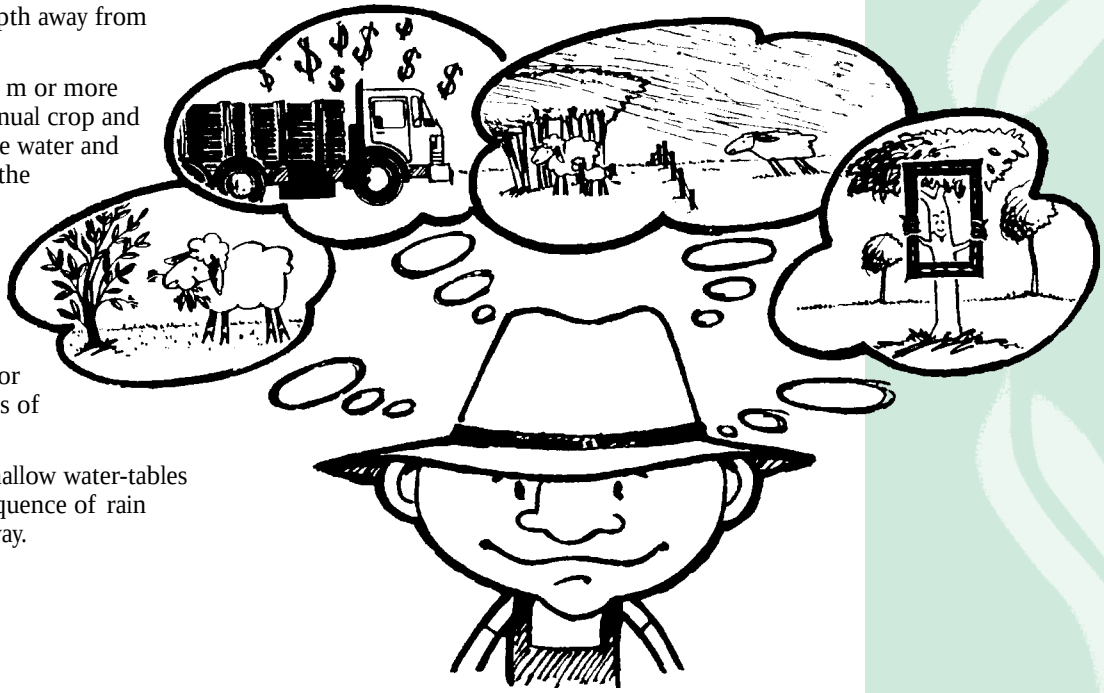
Trees have been cleared from the Australian landscape in the past because they competed with crops and pastures for light, water and nutrients. Will the same happen again if we put the trees back? Agroforestry design is about getting the right number of trees, of the right species, into the right parts of a catchment. It is about maximising all the benefits of trees and minimising the disadvantages. Careful design is paramount.

Growing trees is different from other farm enterprises because a tree exerts an influence for a considerable distance and/or depth away from where it is planted. For example:

- trees explore layers of soil 1–5 m or more below the rooting depth of annual crop and pasture species and thus recycle water and nutrients that were 'lost' from the traditional agricultural system;
- tall trees may shade or compete for water with crops growing tens of metres away;
- trees can reduce wind erosion or modify microclimates hundreds of metres away; and
- trees can extract water from shallow water-tables that may have risen as a consequence of rain falling thousands of metres away.

Reasons for planting trees

The preceding chapters have covered the major reasons why a farmer may start to plant trees. We recognise that a farmer will have some main purpose (trigger) in mind for planting trees but there will often be secondary benefits that can be obtained. We call this 'capturing multiple benefits' and it is important to the success of any agroforestry venture.



Broadly speaking, the four main reasons for planting trees are as follows:

- **new product diversification:** tree products such as wood, pulp or oils provide new income streams to buffer against the cyclical downturns in the profitability of other farm enterprises. In this case the trees are planted for their direct cash value;
- **enhancement of existing enterprises:** agroforestry can increase the productivity of a traditional pasture-based enterprise through, for example, the provision of shelter for animals or fodder shrubs to fill a seasonal feed gap. Other examples include windbreaks to protect crops or tree planting to alleviate waterlogging in low-lying paddocks. In this case, the primary value of the tree is in adding value to some other enterprise rather than the direct value of the tree itself;
- **resource protection:** the resource base (quality of the soil and water resources) of the farm must be protected and enhanced so that traditional farming enterprises can survive long-term. Trees may be planted to address wind and water erosion or salinity. In this case, the primary purpose of planting trees is to ensure the long-term viability of some other enterprise; and
- **conservation and beauty:** trees add horizontal and vertical structure to the landscape and provide new niches for other plants and animals. Trees can be planted to buffer remnant vegetation, to provide wildlife corridors, and to make the landscape more pleasing for human habitation.

Designs to capture multiple benefits

The skill of agroforestry design is to identify the main reason for planting trees and then to capture as many other benefits as possible. For example, the trigger for planting trees may be the need to diversify into a new product and hence the establishment of a plantation of sawlog trees. This plantation could also use up excess water and therefore give a salinity benefit (resource management) as well as provide shelter to an adjacent wheat paddock from damaging winds (enhancement of existing enterprise). Tree planting for sawlogs may be only marginally profitable, but the extra benefits of resource management and enhancement of crop growth could make the enterprise well worth the investment.

The location, size, shape and orientation of the sawlog plantation will determine how much of these 'extra' benefits are achieved. For example, it may be possible to change the layout of a plantation to get a greater windbreak benefit. But there are always limits. A long, thin plantation may incur management costs such as pruning which will outweigh the benefit of more wind protection.

Once the trigger for planting trees has been identified, two questions arise:

- how flexible are the design criteria to achieve my primary objective? and
- how can I modify the planting design to capture other benefits but still achieve my primary objective?

In general, the design becomes more flexible when you are planting large areas of trees. If, for example, you have a market for wood products and 20% of the farm will eventually be planted to trees, there is ample scope for capturing benefits of resource protection, enhancement of existing enterprises and nature conservation. Conversely, it is possible to get adequate shelter protection on the farm with as little as 5% of the land area planted to trees. In this case it would be difficult to capture many other benefits with such a small planting.

Competition and complementarity

Trees are in competition with crops when both species are struggling to get as much as they can of a limited resource. An example is the poorer growth of a crop near a tree during a hot dry spring or summer. Although trees do have access to water much deeper in the soil than crops, the water held in the topsoil is used first. In this case, trees and crops are in direct competition for surface water, and the tree generally comes off best. In addition, trees that use water during the fallow period between successive crops will reduce the amount of water stored in the soil for the crop at planting. Competition can be above ground too. Shade can be beneficial during summer but is likely to be a problem with winter crops, particularly in higher latitudes.

But competition is only half the story. Trees, crops and pastures are often complementary to each other and that is what most of this book is about. Complementarity occurs when a mixture of trees and crops or pastures on a farm is more productive than either trees or crops alone. Trees and crops are complementary when:

- there is greater capture of a limiting resource – for example, trees can use more water than crops by virtue of spatial (deeper rooting habit) or temporal (using rain that falls in summer in a paddock growing winter crops) complementarity. There may also be a functional complementarity – for example, some trees can extract phosphorus from low P soils or fix atmospheric nitrogen and make these nutrients available to crops through the litter;
- the limiting resource is used more efficiently – for example, in the lee of a windbreak, crop productivity per unit water used can be higher. Similarly, the productivity of animals per unit

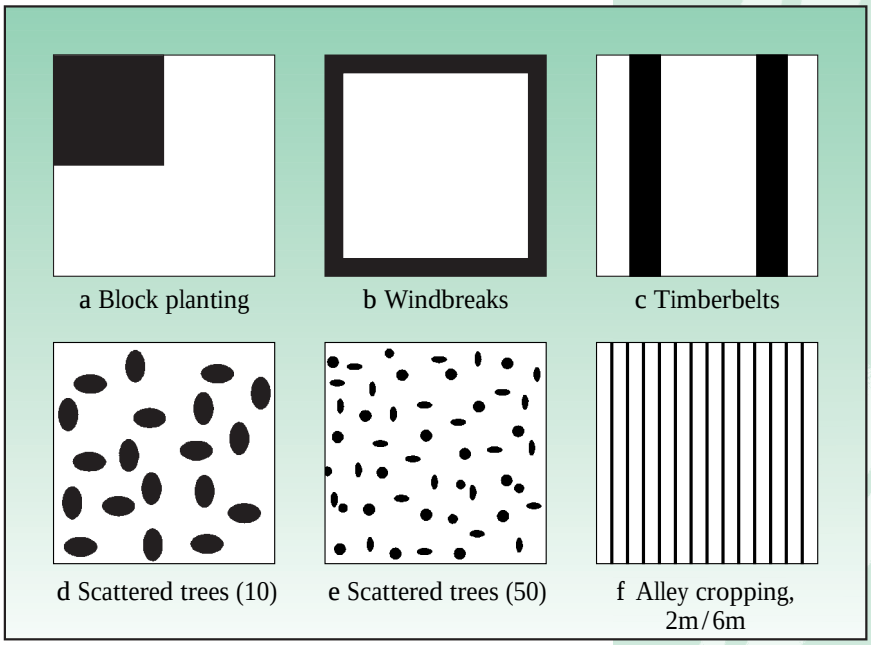


Figure 30: There are a number of different ways to put one quarter of a paddock (or farm) under trees. Above are six examples, from block plantings to belts to scattered trees (redrawn from Young 1987).

Agroforestry practice	Design	Tree/crop interface (m per hectare)
Block planting	block 50 x 50 m	200
Windbreaks	Belts, 6.25 m wide	750
Timberbelts	2 belts, 12.5 m wide	450
Trees in field	10 trees, radius 8.9 m	560
Trees in field	100 trees, radius 2.8 m	1770
Alley cropping	Rows: 2 m tree, 6 m crop	2500

Table 8: The length of the tree/crop interface for six arrangements of planting 25% of land to trees

feed consumed can be higher if the animals have protection from adverse weather; and

- the trees protect a crop or livestock from an extreme event – such as a wild storm.

How to quantify competition and complementarity

Complementarity between trees and crops is a subtle but positive effect that occurs widely over the farm but it is often hard to measure because the benefits accrue continuously at a low level. Competition, on the other hand, is restricted to the immediate vicinity of the trees and is easier to recognise. That is why trees sometimes get bad press: it is easier to see the small area where trees have competed with crops than the much larger area where growth may have been enhanced.

Because competition is restricted to the immediate vicinity of the trees, the degree of tree/crop competition depends largely on the length of contact between the trees and the crop. If we consider each diagram in Figure 30 to be a field of 1 hectare (100 m x 100 m), the length of the tree/crop interface (the distance along which trees and crops meet) can vary from 200 m to 2 500 m (Table 8), for the same area of land occupied by trees. Thus our first guess would be that competition is minimised by having a short tree/crop interface length – that is, block planting would be less competitive than scattered trees.

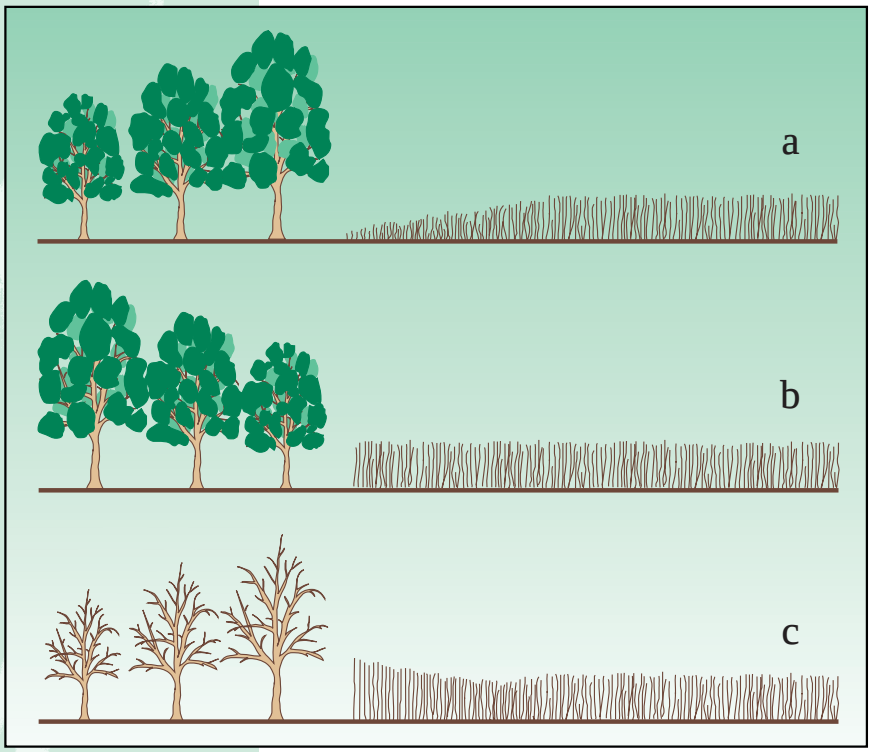


Figure 31: Three scenarios showing the productivity of trees and crops along a tree/crop interface: (a) trees growing adjacent to a cereal crop; (b) trees growing adjacent to a perennial pasture; (c) deciduous trees growing adjacent to a winter crop (redrawn from Young 1987)

What happens when trees and crops meet?

The length of the tree/crop interface is not the end of the competition story. Just as important is the productivity of both the trees and crops at the interface, as shown in Figure 31. Case (a) shows an annual cereal crop adjacent to a timber belt. In this example, crop yield is reduced at the interface because of competition for water, nutrients or light by the tree. Tree growth is enhanced because of access to these extra resources. At a distance of 2 to 10 times the height of the trees away from the treeline, yield may be higher than in an open paddock because of positive shelter effects.

Case (b) shows perennial pasture adjacent to a timber belt. In this case the deep-rooted pasture is little affected by the trees, but the economic value of the trees may be lower at the edge because of increased branching.

In Case (c), both tree and crop growth are enhanced at the interface. This is a rarer event but can occur where the tree and crop growth cycles and hence demand for resources are out of phase (eg deciduous trees growing adjacent to a winter crop) so that only the beneficial interactions are expressed in each season.

Case (a), yield reduction close to trees and yield enhancement further away, is the most commonly observed scenario to date, but as we gain more understanding of tree/crop interactions it is likely that we will uncover more situations similar to Case (c).

The principle for maximising productivity is as follows: if the interaction at the tree/crop interface is negative, then we should minimise the length of the interface. However, we often plant trees to enhance existing enterprises (eg windbreaks), resource management (eg control of water-tables) or nature conservation (eg wildlife corridors). In these cases we may need to spread the trees out.

Thus there is a fundamental tension between tree and crop monocultures – which make management easier – and the need to spread trees out to capture other benefits. Once we have a feel for what happens at the tree/crop interface we can find compromises between keeping the trees in blocks and spreading them out.

Balancing productivity and resource management

Balancing the need to be productive with the need to maintain the quality of soil and water resources is the greatest challenge facing farmers in Australia. We can try to reach this balance in two steps. First, we concentrate on issues that affect productivity and, second, we look at issues of resource management or sustainability.

Step 1: Productivity

We can explore the productivity of an agroforestry system by looking at an example of wheat growing in alleys between rows of tagasaste (Figure 32). The tagasaste displaces wheat from part of the field and this represents a loss of income to the farmer. The tagasaste may also decrease the yield of the wheat growing close to the tree line.

On the positive side the tagasaste may increase the growth of the crop further away because of a

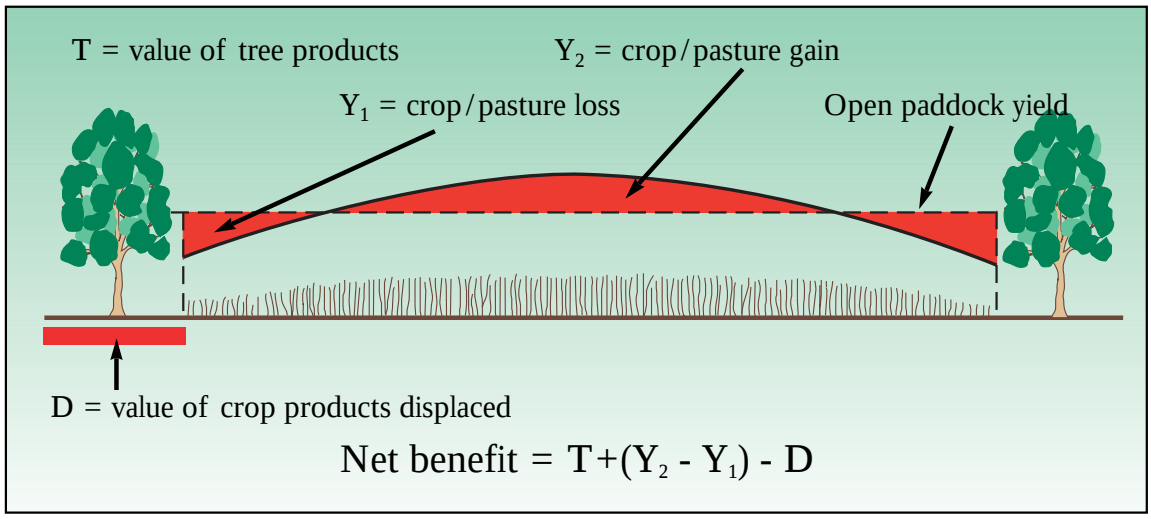


Figure 32: Tagasaste displaces wheat from part of the paddock, and may decrease wheat yield close in and increase it further out. It also provides fodder during the autumn feed gap. The net benefit of the agroforestry system depends on the balance between the above factors (redrawn from Lefroy and Scott 1994)

reduction in wind speed. The tagasaste also has a value of its own as a feed source during the autumn feed gap. If the value of the fodder plus the enhanced microclimate effect exceeds the costs of establishment, crop displacement and competition, then alley cropping wheat plus pasture will be a more productive wheat/sheep farming system than monocultures of wheat and annual pastures alone.

Step 2: Resource management

There will be times when the net short-term benefit (productivity) of the agroforestry system is the same as or even less than that of the conventional system. Then we have to decide on the value of the trees (or the tagasaste in the above example) as a means of resource management. The trees may be helping to keep a water-table down. This will not give a productivity increase in the short term but over the long haul may ensure that cropping can continue. Similarly, the trees may be stopping erosion or providing habitats for other plants and animals. These benefits are much more difficult to put a dollar value on, but will often tip the scales in favour of agroforestry.

Case studies

Following are examples where agroforestry has made a difference in both productivity and resource management. The examples highlight how agroforestry can capture multiple benefits when carefully designed for particular problems and locations. These case studies are not exact representations of particular farms but are drawn from experiences that are showing promise around the country.

Case Study 1

Location:
southwest Western Australia

First trigger for planting trees:
reclamation of waterlogged paddocks

Additional benefits captured:
timber, nature conservation, windbreaks

In southwest Western Australia, wheat and lupins are grown in rotation with annual pastures. The climate is strongly Mediterranean, with almost all the annual rainfall occurring within the six winter months. Early in the rainy season, when the leaf area of annual crops is low, rainfall generally exceeds crop water use. Soil becomes waterlogged when water piles up above a soil layer (usually clay) which has a very low permeability. This is called a perched water-table. Often the water-table of a whole region rises. This is a more serious problem than a perched water-table, because water-tables that were deep but have become shallow after tree clearing are often salty.

Waterlogging is usually first seen in low areas on the farm, although certain landscape features can make 'wet spots' show up in unexpected places. In this example, the farmer noticed that two low-lying paddocks were becoming severely waterlogged in winter and remained boggy right through the summer months as well. The farmer knew that water was moving down the slope to the waterlogged area, so he set about planting trees upslope.

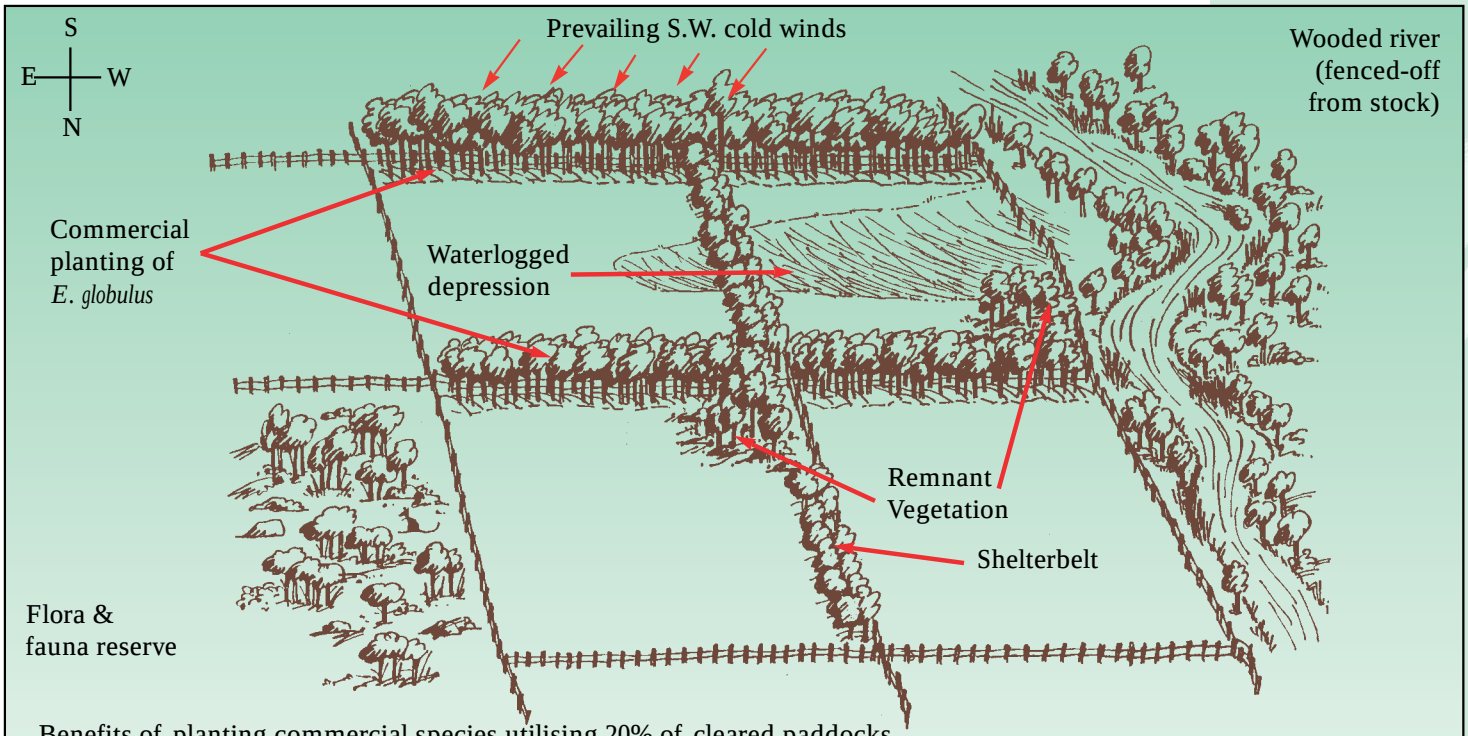
Waterlogged pasture is unproductive, so the trigger for planting trees was to reclaim the affected paddocks. Intuitively the farmer knew that quite a large area of trees would be needed to control the problem. He didn't know how many, but reasoned that if he was going to plant a number of trees he should manage them for timber. There was a blue gum industry close by, so that made the choice easy.

The farmer planted the trees upslope and parallel to the depression of waterlogged land. The exact location of the planting was dictated by the existing fencelines. Another factor for the location of the timber belts was the presence of remnant native bush. There were three pockets of remnant

vegetation in the area, each 1–2 hectares in size. The farmer knew that the best way to protect remnant vegetation was to plant trees around them as a buffer. Also, by connecting remnants with timber trees, he made corridors between the remnants so birds and animals could move from one remnant to the other.

The final tree planting design (shown in Figure 33) produced two belts of trees about 1 400 m long and 140 m wide on both sides of the depression. But one problem remained. The timberbelts were orientated east–west (because of the lie of the land and existing fences), but the prevailing winds came from the southwest. The farmer decided to plant

Figure 33: A schematic representation of case study 1 – a farmer's solution to waterlogging, with several added benefits



Benefits of planting commercial species utilising 20% of cleared paddocks.

1. The E–W plantings are in the recharge areas of the waterlogged depression and have lowered the water-table, allowing improved grazing.
2. The E–W and N–S plantings provide shelter to stock from prevailing cold SW winds in winter (and shade in summer).
3. The northern-most E–W planting forms a corridor between a reserve and wooded, fenced-off river.
4. There has been an improved amenity on aesthetic value to the farm.
5. This section of the farm continues to carry as many grazing animals as before the planting. The economic benefits of planting are twofold:
   - diversified income from a new commodity (as a 'bonus' above grazing income)
   - the harvest can be fitted in with other cash requirements ie education and is a form of 'risk management'.

narrower timberbelts in the north–south direction to give better protection to stock. The shelterbelts were much narrower than the timberbelts. They required more management because trees at the edges required more pruning but could be managed and marketed together with the main timberbelts.

The waterlogged area is now disappearing. The farmer ended up putting 20% of his land to trees. He may have been able to do the job with fewer trees but he is unconcerned because he may well make more money from the trees than from the reclaimed paddocks. His carrying capacity on 80% of the land is the same as it was when he could graze the whole farm because the waterlogged areas have been reclaimed and the stock are more sheltered. In addition, remnant vegetation has been protected and nature conservation value enhanced. Some uncertainties remain; if the water-tables are salty, the salt might concentrate under the trees because trees only use fresh water and leave the salt behind. But for now the tree planting strategy is working extremely well.

Case Study 2

Location:
central Queensland

First trigger for planting trees:
fodder for cattle during dry periods

Additional benefits captured:
soil fertility, soil conservation

In parts of central Queensland there is no reliable annual forage legume, particularly on the heavier clay soils. *Leucaena leucocephala* is a shrub legume that produces both high biomass and high quality forage. It has also proved itself to be drought tolerant during years of below average rainfall.

The farmer's trigger for planting leucaena was to provide fodder for cattle, especially in periods of drought. Opportunity cropping was also carried out on the farm; sorghum in summer and wheat in winter, depending on the availability of stored water. The farmer had heard about alley farming from the southern states and Western Australia where crops are grown between rows of shrubs such as tagasaste or saltbush, and wanted to try cropping between strips of leucaena.

Leucaena could also play the role that annual legumes play in a conventional rotation. The idea was that nitrogen from the leucaena would be distributed over the whole field by grazing cattle when no crops were being grown.

Leucaena is usually planted in rows 5 m apart when grown for cattle fodder. The farmer increased this width to 30 m so that there would be enough space to get the agricultural equipment between the tree rows. A leucaena paddock must be locked up for up to 12 months after sowing. This is usually a considerable disincentive, but as it was possible to crop between the rows this was no longer an issue.

The paddock chosen for the leucaena alley cropping was on a slight slope which eroded during heavy rain. Thus the farmer planted in strips along the contours. The leaf fall from the leucaena and weed growth under the shrubs formed an effective barrier against overland flow of water and hence helped limit erosion.

The farmer chose the site for planting leucaena carefully. The prime cropping soils on the farm were too valuable to be taken up by leucaena – fertilising soils was a better option for nitrogen management. However, on the less fertile sloping soils the leucaena played multiple roles. It provided a high quality fodder bank, allowed the option of cropping when water was available, provided some nitrogen input to the crops and gave some control over erosion. This multiple role was important, as planting leucaena for any one of the above reasons alone would not have been economic.

The farmer is aware that there will be some competition between the leucaena and the crops for

water and other resources and that no one is quite sure how serious the competition will turn out to be. However, the relative importance of drought fodder compared to the amount of grain that could be grown on these poorer soils means that it was worth taking the risk. If necessary, the farmer will use the management option of ripping the tree roots at the edge of the treeline before sowing crops.

Nearby graziers have tried a completely different approach to improving the profitability of their enterprise. Instead of planting trees they have found benefits in conserving existing natural vegetation. The family were busy with the expensive business of clearing brigalow country. To cut down on expenses, they decided to clear strips 50 m wide and to leave 50 m strips of brigalow standing. They were amazed to find that the productivity of paddocks that were half-cleared was similar to fully cleared paddocks. This example shows that you do not have to plant trees to be successful in agroforestry. Encouraging natural regrowth or partial clearing of timbered country are important options.

Case study 3

Location:
southern Victoria

First trigger for planting trees:
management of an eroded creek

Additional benefits captured:
timber, shelter, nature conservation

The family farming this sheep and cattle property in Victoria had decided to embark on a new whole farm plan. This involved re-fencing land classes and management of the eroded creek which had become an unsightly gully right through the middle of the farm. There were several soil types along the creek, from areas of heavy clay which became waterlogged and were prone to slumping to sandy banks which were eroded by cattle where they gained access to the creek for water. The local landcare group, of which the family was an active member, decided something needed to be done about the eroded creek because of its importance to the catchment as a whole.

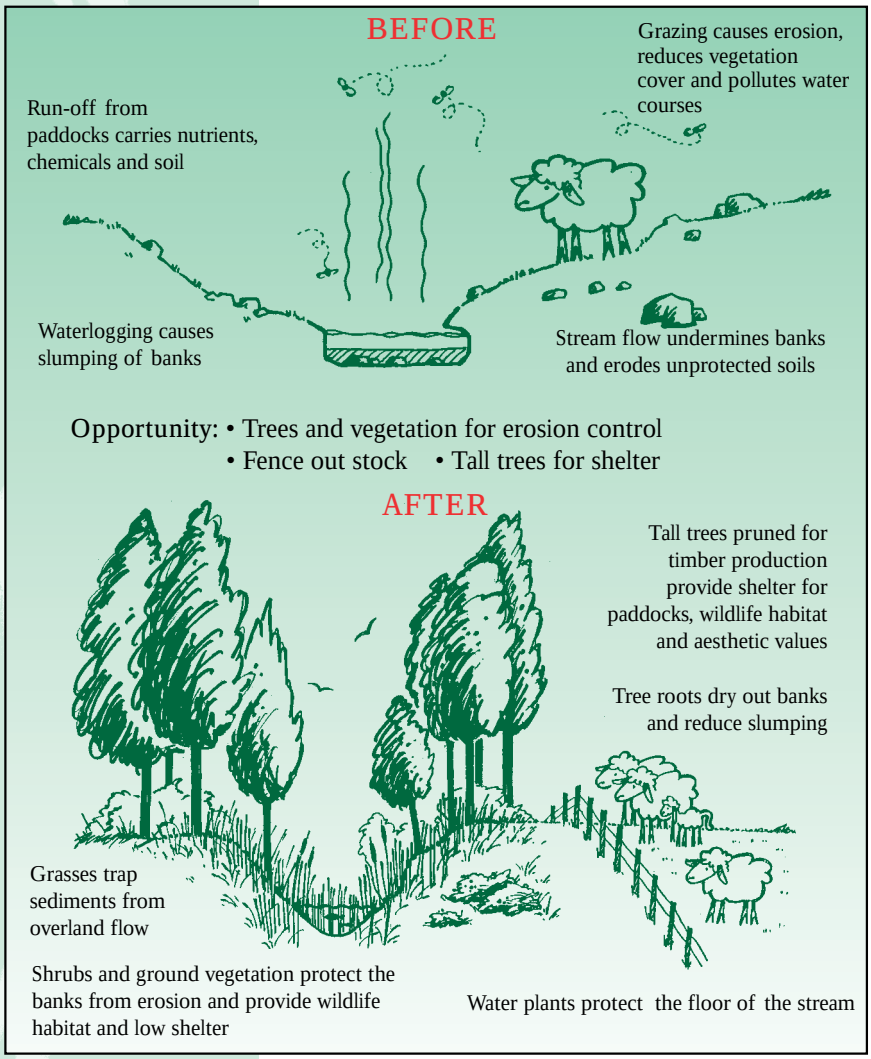
A grant was obtained that would pay for the creek to be fenced off. This was the impetus that opened up a whole range of possibilities. The first objective of preventing cattle access to the creek was easily reached, especially as there were alternative watering points. The next objective was to address the 'wet spots' along the creek bank. In these areas the fence was moved much further back from the creek so that trees could be planted in the hope that they would use the extra water.

Fencing took care of the underlying problem, but the now-vulnerable creek banks required stabilisation. The choice of species was important. The family needed something that would quickly cover the eroded banks but would not grow in the water itself and choke the flow of the creek. They chose an indigenous multi-stemmed shrub for the steep banks because this shrub had the ability to withstand being undermined and rapidly re-suckered from its roots. Other indigenous tree and shrub species were also used along the bank. A particular favourite was *Bursaria*, which is an importance source of nectar for the parasitic wasps that feed on pasture grubs. Grass was used on gentle slopes and rushes and water plants in the creek bed itself (Figure 34).

Once the bank had been stabilised there was the option of using the fenced-off land on either side of the creek more creatively. Shelter and shade were obvious needs, particularly from cold winter winds for the shorn sheep and for cattle from the summer heat. Trees planted along the bank would provide shelter and had the advantage of not concentrating cattle in just a few areas of the paddock during harsh weather. The pasture too could benefit from the protection that trees

provided from drying winds in spring and early summer. Because the paddock was large, the windbreak trees needed to be very tall to give protection to pasture 200 m or more from the windbreak.

Figure 34: Stabilising the creek has a number of benefits



The family was keen to diversify farm income and evaluated the possibilities of harvesting the tall windbreak trees. Their calculations showed that quality sawlogs should be viable. This option presented a few challenges. Trees in a thin strip would not self-prune as in a plantation, so manual pruning to 6 m was required. Pruning let the wind through and reduced the shelter benefit, but this was compensated by the thick bush planted adjacent to the creek. Of course, a continuous harvesting and replanting schedule would be needed to combine windbreaks and timber. The family intends to alternate the timber harvest from one side of the creek to the other to ensure that there is a continuous standing windbreak.

The family hope to recoup much of their investment from better pasture and animal production through shelter. They are well aware that the diversification into trees presents new challenges. The strip of native vegetation and trees along the creek could become a refuge for feral animals and weeds. Fire will be difficult to control in the area. Management and harvesting of trees close to a river will not be easy when the goal is to protect banks and improve water quality. However, these are challenges the family is willing to meet in the knowledge that they are protecting the creek, enhancing the biodiversity of the farm and have healed what was once an ugly scar on the landscape.

References / Further reading

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