FUTURE OF AERIAL AGRICULTURE FOR GRASSLANDS

AERIAL AGRICULTURE IS ESSENTIAL FOR IMPROVEMENT OF GRASSLANDS IN NEW SOUTH WALES

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Abstract. *Aerial agriculture has contributed to the pasture improvement of large areas of non- arable land in Australia which has improved the income of landholders. In NSW alone the discounted net benefits of aerial agriculture, in 1991, from the pasture improvement of 1 million ha of non-arable land was estimated at $470 million. Additional benefits are derived from controlling weeds on non- arable land. Further improvement of non-arable land is under threat because of a demand that aerial spraying be phased out by 1994. If this occurs it will prevent full improvement (the establishment of perennial grass dominant pastures) on 2.35 million ha of non-arable NSW because it will not be possible to apply herbicides to kill resident weeds. Projected over ten years, the discounted opportunity cost of not being able to fully improve this land was estimated at $615 million. The banning of aerial spraying will also stop the application of environmental friendly bio-control agents such as mycoherbicides and result in the spread of weeds from non-arable land to arable land.*

The most important reason for using aircraft is to spread herbicides, pesticides, fertilisers and seeds to develop country too hilly or rough for ground methods of pasture improvement (Gruen and Pearse, 1959). About 25% of high rainfall areas in eastern Australia are eminently suited for pasture improvement but are inaccessible to ground machinery (Crofts, 1985). In NSW alone the potential area for aerial pasture improvement is 5.7 million ha (Gruen and Pearse, 1959). The speed, timeliness and convenience of aerial agriculture is also a major factor in the development of large blocks of land, not necessarily hilly, *eg*. large properties in the Northern Territory (Sturtz *et al.*, 1975) or in western NSW (Campbell and Bellotti, 1987). Use of aerial techniques allows wet land to be treated without compacting the soil, reduces the risk of erosion when compared to cultivation and eliminates the need to clear scattered timber or purchase ground based machinery.

DEVELOPMENT OF AERIAL AGRICULTURE IN AUSTRALIA

The first aerial sowing of pastures in Australia occurred in 1940 when A.M. Pritchard conducted trials on the Ninety Mile Beach in South Australia (Anon., 1978). The first aerial spraying occurred in 1946 when insects were sprayed in Victoria (Gruen and Pearse, 1959). The first substantial fertiliser topdressing and pasture sowing by aircraft took place in 1950 at Walcha, NSW (Gruen and Pearse, 1959) with a specially equipped Tiger Moth (Nivison, 1964). The hand-mixed superphosphate and seed was taken to the aircraft in a wheelbarrow, and physically lifted into a hopper that held 182 kg. In one day 9 t of superphosphate were distributed by 1 aircraft compared with over 60 t using today's technology.

In 1947 East West Airlines set up an agricultural division at Tamworth, NSW mainly to aerially dust linseed crops. By 1959 there were 42 licensed aerial agricultural operators in Australia: NSW 14, Victoria/Tasmania 11, Western Australia 9, Queensland 6 and South Australia 2 (Gruen and Pearse, 1959). Further industry development to 1989 resulted in the licensing of 140 operators and 280 aircraft (Civil Aviation Authority, 1989).

The development of aerial agriculture in Australia increased the area topdressed with fertiliser and/or seeded from 8 ha in 1952 to a maximum of 4.9 million ha in 1974 and the area sprayed from 100 ha in 1956 to a maximum of 3.7 million ha in 1984 (Figure 1). Of the area sprayed 10% was pasture, 45% cereal crops and 45% other crops, based on 1980 to 1985 inclusive. More fertiliser and seed was aerially distributed in NSW than any other state probably reflecting the greater amount of hill country in NSW (Figure 2). Further details of the areas treated, the inputs applied and other factors discussed in this paper are given in Campbell (1991).

BENEFITS OF AERIAL AGRICULTURE

The economic benefits from aerial pasture improvement are similar to those from using conventional cultivation as both enable substantial increases in livestock production. Greater risks are involved in using aerial techniques but if the recommended procedures (Campbell, 1985) are followed the risk is low, *eg.* three failures were recorded in 18 years (1966 to 1983) from annual surface sowing of perennial pasture species on hill country at Turondale NSW (Campbell unpublished data, 1991).

Pasture improvement is the main application of aerial agriculture in NSW and its farm investment potential has long been recognised (Gruen, 1959; Vere and Muir, 1987). It remains so even under unfavourable market developments such as the current wool market collapse. This is because the profits are sufficiently high to withstand major adverse events on the pasture improvement program.

For example, considering aerial pasture improvement in areas of medium soil fertility and moderate rainfall in the NSW central tablelands in 1990, the estimated ten-year annual average net returns from a Merino wool enterprise (at $7.50/kg greasy) were $1581/ha, equivalent to $936/ha when adjusted for inflation at a real discount rate of 8 percent (Vere and Campbell, 1990). Recalculated at a March 1991 wool price of $5/kg greasy, the estimates are $841/ha and $470/ha respectively, which remain healthy returns to investment.

These estimates also provide some indication of the broader benefits of aerial agriculture. If one million of the 5.7 million ha of the potential area for aerial pasture improvement in NSW is in the medium fertility-rainfall category and has been pasture improved, the discounted net benefits in 1991 are $470 million.

Control of weeds on non-arable land can also yield substantial economic benefits. Between 1975 and 1985, 202,000 ha of serrated tussock was controlled in NSW (Campbell, 1987) of which an estimated 130,000 ha was on non- arable land. If half this area was in the medium fertility-rainfall category and was aerially pasture improved to control this weed, the 1991 discounted annual net return was $30 million over a 15 year period (Vere *et al.*, 1991 unpublished). Large areas of other weeds (*eg.* nitrophilous weeds, poa tussock, St John's wort *Hypericum perforatum*) have been replaced on non-arable land by pastures using aerial techniques which would further increase the benefits of aerial pasture improvement to NSW.

REGIONAL USE OF AERIAL AGRICULTURE

The major contribution of aerially established pastures to Australia has been increased pasture production (Figure 3). In southern Australia the first step in increasing pasture production was the aerial distribution of subterranean clover (*Trifolium subterraneum*) seed and superphosphate into native perennial grass pastures. The second step was the aerial application of herbicides which facilitated the establishment of perennial pasture species. In temperate and sub-tropical areas with summer dominant rainfall, the aerial

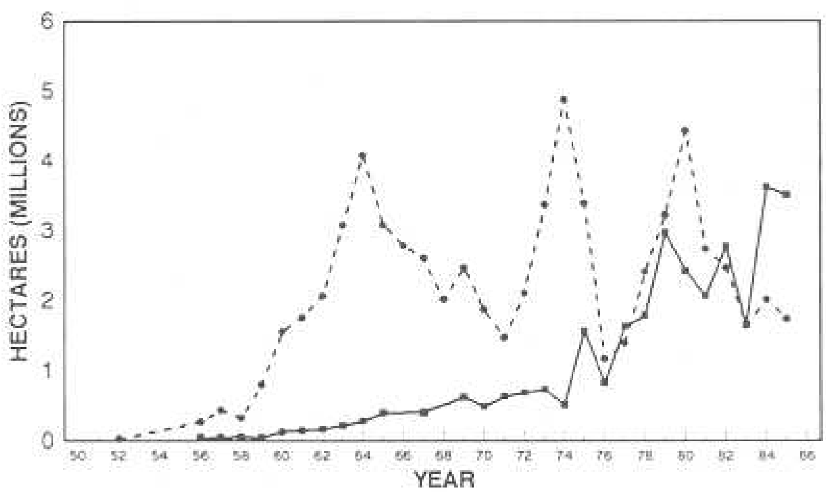

Figure 1: Areas tpodressed with fertilizer (96% superphosphate) and/or seeded (• •) and aerially sprayed (▪ ▪) (10% pastures, 90% crops) in Australia 1952 to 1985 (Source: Department of Transport and Communica-

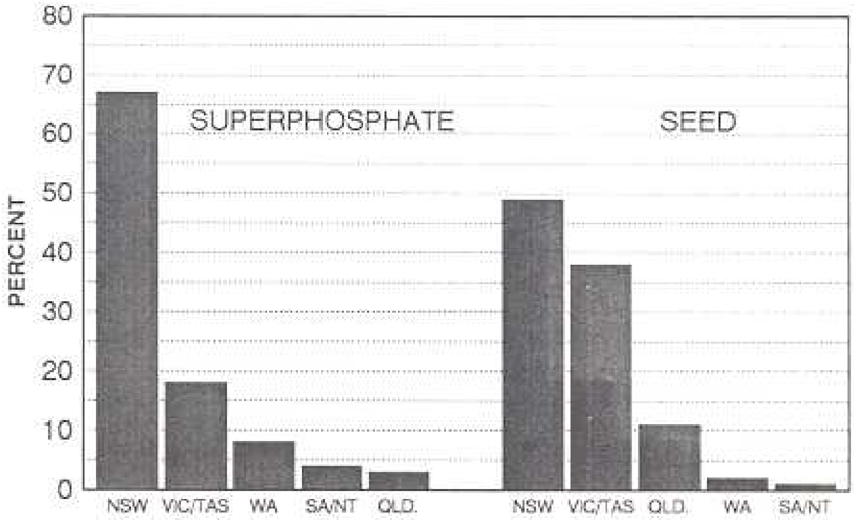

Figure 2: Total amount of superphosphate and seed aerially applied in Australia, 1980 to 1985 inclusive, apportioned on a state basis (Source: Department of Transport and Communications).

distribution of white clover (*T. repens*) seed and superphosphate increased production whilst in tropical areas the aerial distribution of Townsville stylo (*Stylosanthes humilis*) seed and fertiliser had a similar positive effect. These processes were responsible for raising the fertility of vast areas of poor soils in Australia and reversing the deterioration of the environment which had continued, with few exceptions, from the first settlement (Donald, 1965).

Aerial techniques may be applicable to flat inland Australia because large areas can be sown quickly and cheaply to take advantage of favourable environmental conditions (Campbell *et al.*, 1987), *eg*. large areas of buffel grass (*Cenchrus ciliaris*) have been established by aerial sowing in inland Queensland. Efforts to achieve similar result on degraded pastures in north-western NSW, where summer rainfall is less reliable and winters cooler than Queensland, have shown that establishment of perennial grasses may be achieved from aerial sowing provided competition is eliminated by herbicides and above average rainfall occurs after sowing (Campbell and Bellotti, 1987). Promising results have also been achieved by aerial sowing immediately prior to harvesting wheat. In both the degraded pasture and crop situations the grasses sown, curly Mitchell grass (*Astrebla lappacea*), buffel grass, bambatsi panic (*Panicum coloratum*) and purple pigeon grass (*Setaria incrassata*) are extremely sensitive to low temperatures in their first winter (Campbell *et al.*, 1990).

BOTANICAL BALANCE

By aerially applying the right proportions of subterranean clover seed and superphosphate to initially infertile soils in southern Australia it is possible to retain native grasses and prevent invasion by weeds (Crofts, 1989). However, on more fertile soils, the "sub- super- sheep" program resulted in the loss of native grasses and the consequent invasion by nitrophilous weeds (thistles, other broad leaved weeds and annual grasses) with attendant disadvantages. Similarly, in the tropics, the aerial sowing of Townsville stylo resulted in the loss of native grasses and the invasion of weeds (Gillard and Fisher, 1978). Conversely the introduction of white clover in northern NSW did not result in widespread invasion by nitrophilous weeds because summer rainfall ensured the persistence of native grasses.

To overcome most weed problems on hill country it is necessary to establish improved perennial grasses by aerial techniques, an achievement not thought possible on non-arable land in 1950-60 because of the absence of suitable herbicides, the inability to control seed-harvesting ants and a lack of understanding of time of sowing and management of the establishing pasture.

THREATS TO AERIAL AGRICULTURE

Violent fluctuations in areas treated and quantities of materials applied (Figures 1 and 4), in response to landholder income, have plagued the aerial agriculture industry and almost brought about its downfall after the 1982 drought. A more recent threat is the demand from the National Women's Consultative Council (the chief women's advisory body to the Federal Government) for the phasing out of aerial spraying by 1994 (Land Newspaper 20.7.89). This demand was at least partly responsible for the Senate Select Committee enquiry into agricultural and veterinary chemicals (Anon., 1990) which is proceeding at the moment. The aerial agricultural industry is aware of its responsibilities to protect the environment and has had an active campaign to improve the accuracy of dispersal of materials in operation since 1975. In addition, one of the objectives of the Agricultural and Veterinary Chemicals Association is to eliminate any detrimental effects of aerially applied pesticides on the environment.

There is a need to distinguish between the use of aerially applied agricultural chemicals on crops and pastures. Treatment of crops is often characterised by repeated applications, at relatively high rates, to intensive agricultural pursuits, often near towns, that occasionally result in pollution of rivers and off-target drift. Treatment of pastures more often involves a non-repetitive application of relatively low rates of inputs, *eg.* to establish a pasture, followed by intermittent well-spaced applications to maintain the pasture. These activities rarely damage the environment. However public opinion does not distinguish between the two and thus the safe use of aerially applied inputs for pasture improvement is under threat.

INPUTS USED IN ESTABLISHING AND MAINTAINING PASTURES IN HILL COUNTRY

Modern agricultural chemicals are essential for the establishment of pastures on hill country. Except for fertilisers, the inputs are generally applied once, prior to or at sowing, to establish the pasture. To maintain and develop newly-sown pastures, fertilisers are applied annually or biennially and herbicides and insecticides at well spaced intervals when pests become a problem. Off- target or environmental damage is generally minor because treated areas are remote from population and susceptible crops.

HERBICIDES

Establishment. Herbicides are not necessary for the establishment of aerially-sown legumes in native grass dominant pastures but are essential for the establishment of perennial grasses in any pasture. Herbicides cannot be replaced by increasing rates of fertiliser or seed (Dowling and Robinson, 1976) or by burning, cutting or grazing weeds prior to sowing (Cook and Ratcliff, 1984).

Because of its low cost per hectare Roundup(R) (glyphosate) has replaced almost all other herbicides for killing weeds prior to the establishment of perennial pasture species. Roundup(R) has no long term effects on the environment because of low acute toxicity (rat oral LD_{50} - 5,600 mg/kg), virtually no persistence in soils, no leaching through the soil, ready decomposition by microbes and little detrimental effect on most tree species. Short term effects on the environment can result from off-target drift onto susceptible pastures. To minimise drift in hill country, Roundup(R) is aerially applied in large droplets (250 micron) under low-wind-high-humidity conditions in early morning (Campbell, 1985).

The only other herbicide aerially applied over large areas of hill country to enable pasture establishment is Frenock(R) (flupropanate) which is used to remove serrated tussock (*Nassella trichotoma*) a weed resistant to Roundup. It has low acute toxicity (rat oral LD_{50} 10,000 mg/kg), is readily leached from the soil and has little detrimental effect on many pasture species and all tree species. To minimise drift Frenock(R) is applied under the same safe conditions as Roundup(R) and with the anti-drift adjuvant Anti-Drift(R).

Maintenance. Annual applications of herbicides for the removal of broadleaved weeds from annual pastures (*eg.* MCPA; 2,4-D) has been discouraged in recent years because of damage to trees, pasture legumes and susceptible crops. These herbicides are dangerous because of their ability to drift large distances and damage susceptible crops at extremely low rates. Where applicable, sowing perennial grass dominant pastures to replace the broadleaved weeds, has been promoted. This can eliminate the need to apply herbicides to control broadleaved weeds or reduce application to isolated years when favourable climatic conditions promote the weeds. Use of goats (Campbell and Holst, 1990) or bio-control agents (Cullen and Delfosse, 1990) to remove broadleaved weeds are other methods of reducing the use of these herbicides.

Selective removal of perennial grass weeds (serrated tussock; African lovegrass *Eragrostis curvula*; Parramatta grass *Sporobolus africanus*; poa tussock *Poa labillardieri*) from pastures with Frenock(R) (Campbell *et al.*, 1985) or Roundup(R) or spray- topping to control annual grasses with Roun-

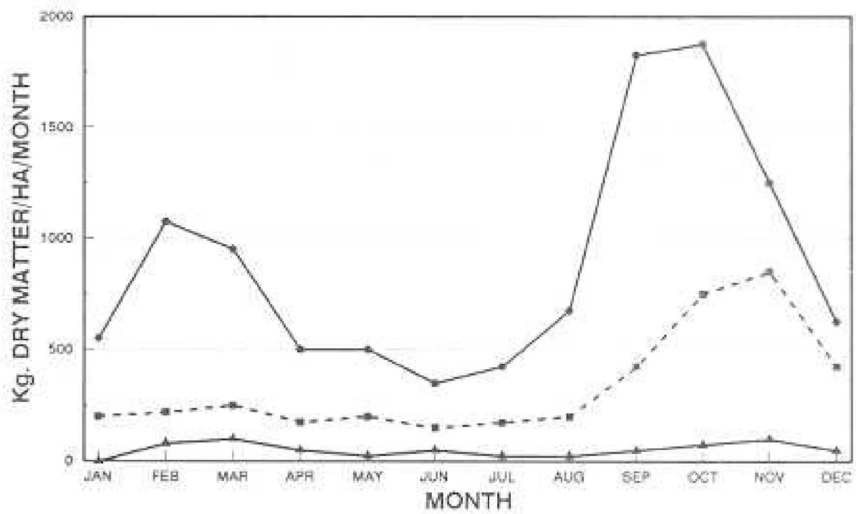

Figure 3: Average increase in pasture production over that of a native perennial pasture (▲—▲) due to aerial application of annual legume seed and superphosphate (■- -■) or aerial application of herbicide, superphosphate and seed of perennial pasture species (●—●) at Turondale NSW, 1973 to 1977 (Source: McDonald and Campbell, 1979)

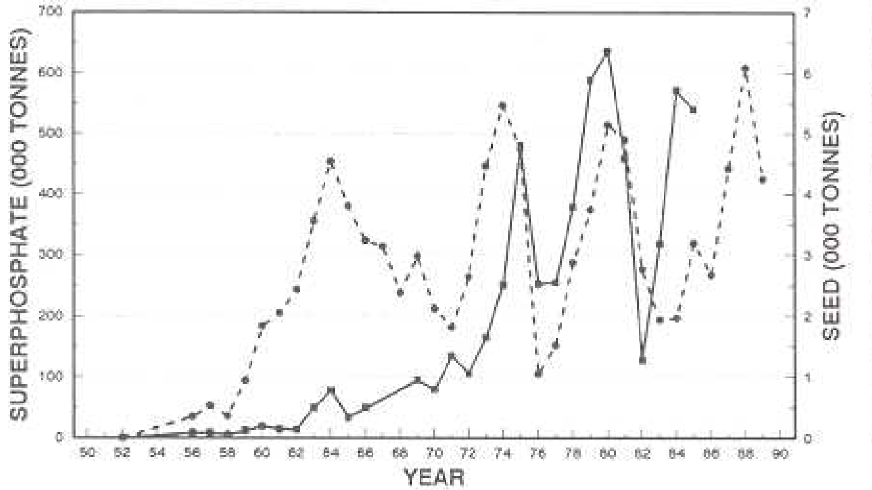

Figure 4: Quantity of superphosphate (•- - •) and seed (•—•) aerially distributed in Australia, 1949 to 1989 (Source: Department of Transport and Communications, 1949 to 1985; Incitec Pty Ltd 1986 to 1989)

dup(R) helps maintain sown pasture species and poses little threat because these herbicides are environmentally safe.

SEED TREATMENTS

Establishment. The major treatments to improve establishment of aerially-sown seeds are the addition of rhizobia for nodulation and insecticides to reduce ant theft. Of the two, the latter is the only threat to the environment. However the amount of insecticide applied (bendiocarb - 0.016 kg a.i./ha or permethrin 0.0125 kg a.i./ha; Campbell and Gilmour, 1979) and the low toxicity of the most widely used, permethrin (rat oral LD_{50} 1,479 to 20,000 mg/kg), ensure no damage to the environment. Similarly, less frequently applied seed treatments (fungicides, nutrients, water absorbing compounds) are only applied in minute quantities per hectare that pose no threat to the environment.

INSECT TREATMENTS

Establishment. Establishing pastures are susceptible to insect attack, thus treatment with insecticides becomes essential if insects reach a threshold density. The major insects that threaten establishment are mites (red-legged, *Halotydeus destructor*; blue oat, *Penthaleus major*) and the black-headed pasture cockchafer (*Aphodius tasmaniae*). These insects are treated with low rates (300 to 600 g a.i./ha) of organophosphate insecticides. Whilst the concentrates of these insecticides are dangerous to humans, once applied, they break down within days. Injury to humans handling the concentrate can be avoided by wearing protective clothing and following label instruction. Other insects attack establishing pastures intermittently and their treatment poses less threat to the environment than mites or cockchafers.

Maintenance. The use of insecticides on established pastures is restricted to isolated severe outbreaks of specific insects. The threshold density of insects has to be so high that permanent pasture damage is threatened before insecticides are applied. Again most of the insecticides used are applied at low rates and break down quickly. Marked success has been achieved in breeding pasture species resistant to some insects which lessens the amount of insecticides needed.

FERTILISERS

About 70% of the superphosphate used in NSW is applied by aircraft. The vast majority of this phosphate is retained in the top 3 cm of soil, thus pollution of the environment is minimal. Some phosphate is washed into rivers and dams by heavy storms when the country is bare. Because of harsh economic conditions and a better understanding of the response of pastures to superphosphate (*eg*. application does not give an economic response if the soil phosphate level is over 12 mg/kg, Bray No. 1) it has been used more efficiently over the last 10 years than previously, reducing the threat of phosphate enrichment in waterways. Pollution of waterways can be reduced by instructing pilots to shut off distribution when flying over them.

LOSSES CAUSED BY BANNING AERIAL SPRAYING

If aerial spraying was banned it would still be possible to aerially distribute clover seed and superphosphate. However, over time this would cause, on reasonably fertile soils, acidification, invasion by thistles, other broadleaved weeds and annual grass weeds, soil erosion on bare ground and secondary infestation by perennial weeds such as poa tussock, serrated tussock, St John's wort, African lovegrass, etc.

To develop a sustainable system relatively free of weeds on these fertile soils, perennial grasses must be established but this could not be done if aerial spraying were banned because herbicides could not be aerially applied. Under these circumstances the economic loss to NSW would be the opportunity costs of not being able to aerially pasture improve half of the 4.7 million ha of non-arable land in NSW that has yet to be pasture improved, *ie*. the half with fertile soils. This annual cost or loss results from the potential livestock production foregone by not developing country to its full production potential. It is also a measure of the potential gross benefits to the state of improving its unimproved pastures. If this area (2.35 million ha) of unimproved pastures could be made to carry an extra three dry sheep equivalents (dse) per ha, it would generate additional annual net benefits of $85 million, based on a 1991 gross margin of $12/dse for 22 micron Merino wethers. Projected over ten years, the discounted value of these annual costs-losses would be approximately $615 million. This estimate represents the long-term social costs to NSW from being denied the opportunity to aerially improve this area of country, or alternatively, the gross social benefits of being able to do so.

If weed control on non-arable land is stopped due to the banning of aerial spraying, additional costs to individual farmers and to NSW will result because weeds will spread from non-arable land onto arable land. At present there are large areas of non- arable land infested with serrated tussock, St John's wort, thistles and other broadleaved weeds, weedy annual grasses, poa tussock, African lovegrass, etc. The danger of spread will be greatest from weeds such as serrated tussock that are disseminated long distances by wind.

Research in NSW (Auld *et al.*, 1988) has developed a mycoherbicide (formulated fungal spores) that has the potential to control Bathurst burr (*Xanthium spinosum*). Mycoherbicides for other weeds, *eg.* Noogoora burr (*X. pungens*), are under investigation. These products cause no damage to the environment yet the banning of aerial spraying would preclude their distribution on non-arable land.

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