PROCEEDINGS

of

THE WEED SOCIETY OF NEW SOUTH WALES

VOLUME II

1969

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Collated by J.M. Swain
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THE WEED SOCIETY OF NEW SOUTH WALES

FORMATION AND OBJECTS

The Society was formed at an inaugural meeting in Sydney on 17th February, 1966, and as part of its constitution established its objects to be:-

(a) To promote wider interest in weeds and their control.

(b) To provide opportunities for those interested in weeds and their control, to exchange information and ideas based on research and practice.

(c) To encourage the investigation of all aspects of weeds and weed control.

(d) To co-operate and, where appropriate, affiliate with other organisations engaged in related activities in Australia and overseas.

(e) To encourage the study of weed science and the dissemination of its findings.

(f) To produce and publish such material as may be considered desirable.

(g) To foster the development of an Australian-wide Weeds Organisation.

MEMBERSHIP:

(a) Membership is of three classes, "ordinary", "honorary" and "corporate body", and is open to all those individuals and corporate bodies respectively who are interested in weeds.

(b) Honorary members are elected from persons who, in the opinion of the Executive Committee, have made major contributions to the objects of the Society and have the same rights as ordinary members.

(c) Corporate body members may nominate one representative to the Society who has the same rights as an ordinary member.

Membership fees are: private members $4.00 annual subscription, corporate body members, $10.00 joining fee and $10.00 annual subscription. Fees are payable on the first day of March in each year.

PROCEEDINGS:

Papers presented at the Symposium "Impact of Weeds on the Community" held on 10th November, 1967 constitute the first volume of proceedings.

This second volume publishes papers presented at the Symposium : "Problem of Woody Weed Control", held on 27th May 1969.

Members are entitled to receive one copy of the Proceedings free; non-members may purchase copies for two dollars.

Applications for membership, payment of subscription and orders for copies of the Proceedings should be sent to the Treasurer, Weed Society of N.S.W., c/- Dept. of Agriculture, State Office Block, Sydney, N.S.W. 2000.

"WOODY WEEDS OF THE SOUTHERN TABLELANDS"

By B.G. Long, Weeds Officer, Berrima County Council.

The main species which would come under the category of Woody Weeds in this district are as follows -

1. Blackberries 2. Sweet Briar 3. Gorse 4. African Boxthorn Scrub Kurrajong and on the Coastal areas, Lantana.

Control measures as adopted here have shown marked success and are listed in order.

1. Blackberry. (Rubus fruticosus). This persistent perennial had obtained many years start before any real control was attempted. In early days arsenic was used with disastrous results to stock. The berry picking for jam manufacturers became quite an industry, and provided seasonable work for many persons. With the introduction of 2-4-5-T Hormone, the whole situation was changed and a very definite attack was commenced to eradicate the blackberry, firstly from roadsides and secondly from private lands.

Spraying is commenced in December using 2-4-5-T strictly to manufacturers recommendation and this has now reduced roadside blackberries to purely a maintenance problem. Spraying must be carried out over at least three (3) consecutive years, and maintenance continued to control seedlings, which will germinate later. Thorough overall coverage is necessary and the bushes must be wet to the point of run-off.

There are several resistant varieties of blackberry in the District, and these pose a very difficult problem. However, it has been found that using a 20% increase in chemical, plus use of a surfactant, the plant can be brought under control over a four (4) year period. Burning should not be carried out of sprayed plants, the old dead canes soon rot away.

2. Sweet Briar. (Rosa rubiginosa). Here we have a plant which has proved very resistant to 2-4-5-T and 2-4D Hormones, and although the top growth may be killed, re-growth will occur from the base.

Many chemicals have been tried, and it now appears that Pichloram is proving to give best results, using an overall spray in January at the rate of 1 to 100 has given best results to date. However, it must be stressed that application is most important. No chemical can be expected to work if not correctly applied.

3. Gorse. (Ulex europaeus). A dense prickly plant, which will successfully compete with any pasture, and owing to its heavy seeding habit, will rapidly take over good grazing land, and provides perfect cover for rabbits.

Early work on Gorse proved of very doubtful value, and slashing and burning appeared the order of the day, with disastrous results. However, 2-4-5-T has proved the answer and Gorse can now be completely eradicated over a few years.

Spraying with 2-4-5-T should be carried out in November, or as soon as the flower has finished, and new young shoots commence to appear through the old seed head. Spraying should be at the rate of 1 in 300, using a 40% 5-T Hormone, plus 1 pint of surfactant for 100 gallons. Chemical should be sprayed with high pressure and the plant thoroughly soaked, fine nozzles Rosebery Mist 32 are found to be ideal as the material is then applied in a fine mist and overall coverage is good.

Gorse should be left to die off and break down without interference, particularly by burning, which only results in a new crop of seedlings. After Gorse has been eliminated, sowing of pasture species should be carried out to ensure adequate coverage and so prevent the germination of seed, which must remain in the soil.

In New Zealand good results have been obtained using 2 pints "Diquat", plus 2 pints 2-4-5-T, 80% per 250 gallons water per acre. This results in a quick brown-off and less 5-T Hormone.

4. Lantana. (Lantana camara). A very dense growing prickly plant which is mainly confined to the coastal trees. Much control work is carried out, using bulldozers, or tractors equipped with rippers. However, spraying with Amine 2-4-D in autumn at the rate of 1 in 100 gallons has proved very effective, and providing the coverage is complete, little regrowth occurs. Once Lantana is eradicated, improved species of grasses etc. must be sown to maintain control.

5. Scrub Kurrajong. (Pimelea pauciflora). A dense shrubby plant which has become a great pest in the Snowy Mountains area. It has been found that the Shrub will not stand mechanical injury, and where possible this type of control appears satisfactory. Again Picloram 500 at the 1 in 100 rate in November and applied in overall spray has proved most effective.

6. African Boxthorn. (Lyeium ferocissimum). Very little of this plant is found in this district, so therefore, experience in control is limited. However, it has been found that Amine 2-4-D does achieve some results, but with the advent of Picloram overall spraying in summer months is very effective.

Pelletts of Fenuron have also been used with good results, but the cost is a governing factor.

In conclusion, these control measures have been presented from a Weeds Officer's viewpoint, and rates of application are as recommended to landholders who will carry out noxious weed control work, thus the chemical rates and application are given to them as simply as possible.

LAND CLEARING ON THE TABLELANDS

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Over recent years there has been a considerable increase in the amount of timbered country on the tablelands which has been brought into pasture production. This trend will continue during the coming years and may increase considerably.

The reasons for this development are:

*1 City business and professional men looking for suitable investments for money which would otherwise be taxable.

2 Graziers undertaking development to keep pace with economic situations.

The choice of technique used in development of timbered country depends largely on the amount of capital available for investment and on the rate at which some return must be obtained.

It is not intended to discuss in this paper, the processes by which a decision is reached regarding the technique to use - rather it is intended to discuss the various methods, their limitations, dangers and advantages. Where possible it is intended to suggest avenues for improvement of the methods and equipment available.

In most cases, the methods have "just growed", like Topsy, and most of the equipment used in this work has been used because it was available from some other job, and has not been designed for the job it is asked to do.

I would like to see some thought given to the whole aspect of land clearing, what is involved and what is the object when clearing and as well to see if some more suitable equipment and technique can be evolved.

AIMS OF LAND CLEARING.

I consider there are four main aims in clearing land.

1. To Bring new land into production.

This is basically the case with virgin timber areas which have not been previously developed. Utilisation of this class of country has up to now been with dry stock - generally cattle during the early winter plus some early summer feed. Traditionally fires are put through the areas each spring to encourage a green flush and remove rubbish left from the winter. This technique has encouraged coarser grass species and also undergrowth - dogwood, native wattles, black and boxthorn, and Ti-tree.

As a result there is relatively poor grazing obtained varying from one dry sheep to twenty acres up to 2/3 of a dry sheep per acre, or their equivalent.

2. Reclamation of previously clean areas.

A surprisingly large area of the Tablelands now shows dense timber when it used to be open grazing country. This reversion can be traced back to the war years when labour was not available to keep up the consistent grubbing that was necessary under the management systems adopted in those times. As a result regrowth became established over large areas. This was followed by the wool boom and many people found they could make all the money they wanted without doing much to their properties. By then the regrowth had reached a reasonable size and involved almost a full clearing job to remove.

This class of country presents a different problem to the virgin country as it still has a reasonable production - $\frac{1}{2}$-$\frac{3}{4}$ d.s.e. per acre, and can be brought back into production relatively quickly.

3. Removal of Weed and Rabbit Harbour.

This is a later aspect of land clearing. Here large areas have been and are being timber treated and in this case trees are killed and left standing. These trees remain standing for some years and present no cause for concern while they do. But once the root system begins to rot away the trees fall, due to winds and then become a serious problem, by providing harbour for rabbits, a place where weeds can get a foothold, an obstruction to easy movement around the property and eventually a definite restriction of the amount of ground available to grow feed.

Therefore it becomes necessary to remove these trees. The actual knocking down is no real problem apart from danger to operators, and generally can be done far more cheaply than when trees are green. However, raking up is more costly because the dead trees break up as they fall and the same sweeping action as obtained when raking green timber does not occur.

If timber is thick enough it is possible to get a burn to run through the pulled down dead trees without raking.

4. Improvement in Appearance.

This aim applies basically to the removal of standing and fallen dead timber, but does play some part in the decision on how to handle green timber. The importance of this aim must not be overlooked in many cases, particularly when a property is being developed with resale in mind.

Methods Available for Land Clearing.

Firstly the methods of killing timber will be discussed. These are not land clearing methods truly speaking, but do come within the scope of this paper.

Conventional Ringbarking.

This method is still used widely throughout the tablelands. Timing of the treatment and the species concerned will govern the amount of suckering that will occur, but generally suckering is severe and persists for several seasons. This means that there is the additional cost and labour problem associated with getting 'sucker bashing' to be considered, plus the problem associated with procurement of suitable labour.

Another drawback to ringbarking is the time it takes for the trees to die and the variation that will occur within any one area. This is particularly important if seeding of pastures is to be carried out from the air, which must coincide with the leaf fall and the most suitable time for pasture establishment.

Ringbarking Plus Herbicide Application

The introduction of a herbicide to the tree after ringing or frilling has improved results from the point of view of producing an even leaf fall in an area. As leaf fall occurs more quickly planning of follow up operations can be done with more certainty.

The chemicals used in this method range from Arsenic compounds to the hormone 2.4.5-T.

Suckering does occur and some treatment for suckers is still necessary, but generally one or at the most two treatments should be sufficient.

The basic problem with this method, is the volume of diluted chemical which has to be handled - generally over steep and rough country.

Partial Ringing Plus Chemical Treatment

With the introduction of the Chemical known as Picloram ("Tordon"R) it was generally felt that the complete answer to timber killing had been found. This chemical could be used by making a few cuts per tree; a small dose of the chemical per cut would kill the tree and there would be no suckering. Unfortunately there were many failures not due entirely to the chemical, but rather to poor application and lack of knowledge and misinterpretation of the recommendation.

This has led to some reaction against the chemical which is unfortunate, because I feel that there is a very sound future for this particular material. Over the last few years there has been considerable trial work done, both by the Company concerned and by Landholders, which has given a lot of information on how this material can be used.

It appears that there are certain points which must be carefully adhered to if sound results are to be obtained.

1. Placement of the cuts is very important - both spacings around the tree and also angle of cut (shallow) to give as large an area for absorption of the chemical as possible.

2. Placement of the chemical into the sap wood area - not the bark -

3. Treat when tree actively growing - bark splits off freely.

This will depend on seasonal conditions, rather than month of year.

4. Treat preferably when soil moisture is not limiting.

5. Concentration of chemical will depend on type of cut being made e.g. with a narrow bladed axe - the concentration is: 1-1½ in water; Broad blade axe - a concentration of 1-4 in water should be used.

All of the above points indicate that the actual method of doing the job is critical and so the standard of the labour being used or the amount of supervision given, will have a big bearing on the result. Where only small areas are being done, this is not so difficult to overcome, but when large areas are being handled it becomes essential to have reliable contractors. These are hard to come by in this field. Because of this I tend towards using the broad blade and joining up the cuts and using the lower concentration of chemical. As the complete frill has a reasonable effect on its own, this method can therefore allow some inefficiency in the application of the chemical.

Results where this technique has been used correctly, have been satisfactory, with a brown-out occurring three weeks after treatment, and no apparent regrowth after twelve months. Suckering has occurred consistently, both below the cuts and throughout the whole length of the tree but suckers have generally been weak and have not survived.

Some recovery of the trees does appear to take place, but after a further 6-12 months these will die. Results generally in the order of 80-90% should be possible.

One aspect which concerns me is the slow rate of breakdown of Picloram in the soil and the possible residual affect on establishment of clover species. There has been one reported case of this at Bathurst and I have observed the disappearance of an exceptionally good germination of white clover when seasonal conditions would not have suggested that this would occur.

Because of this concern, I feel that it is not wise to undertake clover seeding in the initial year of Picloram treating an area. A strong natural grass growth will occur with the death of the trees and a management system can be evolved to suit. This will be discussed in more detail later.

<u>Mechanical Land Clearing</u>.

The basic difference between clearing country on the Tablelands and that on the slopes and plains is one of scale and topography. Also there is usually a difference in timber density and size. These factors control and limit the size of equipment that can be worked economically and the method of clearing that is adopted.

As most of the land that is cleared on the tablelands is intended for grazing use i.e., pastures - the thoroughness with which the clearing has to be done is controlled by the need or otherwise to use specialised equipment in sowing and establishing the pastures, or for controlling regrowth.

Roots left in the ground and sticks left on the top will eventually rot away, so if their removal serves no other purpose than appearance, then this is money which need not be spent.

Generally on the tablelands it is necessary to take care with inoculation and with placement of seed in relation to fertilizer to get sound pasture results. Therefore it becomes necessary for the clearing job to be thorough enough to allow the necessary equipment to get over the country with minimum breakdown and damage. In addition there is the regrowth problem - this will be discussed more fully later.

Because areas treated on the tablelands are not very extensive 200-300 acres at a time - the heavy equipment used is normally of the D7-8 class. The use of larger units does not appear to be economical. Also topography often limits the rope or chain technique as does tree size and density, making it necessary for the trees to be pushed individually. These factors tend to make tableland clearing more expensive relative to clearing on the slopes and plains.

Generally a crawler trailer with the blade and tree pusher are used, but recently the front end loader type of track equipment have been introduced and appear to be doing a very good job. This is particularly so in areas with smaller diameter trees. The bucket on the loaders, fitted with teeth, can grip the trees well and with the lift and tilt action of the bucket are able to lift the trees out by the roots very efficiently. This is particularly important where later cultivations are planned.

Soil moisture varies considerably on tablelands soils and can greatly alter the efficiency of roping or chaining. When dry conditions prevail severe snapping and breaking of trees occurs with the rope or chain and this can introduce later problems with cultivation and re-growth. Pushing will generally remove the trees more efficiently but will cost more depending on skill of the operator.

There can be little variation in the removal of the trees, apart from the size of the stacks or windrows that are made. The direction of the windrows will of course depend on the intended direction of cultivation. Where cultivation is planned then wide spacing between rows is the most practical. This will also ensure that the stacks are large which enables efficient burning to be carried out.

It is during the stacking operation and thereafter that most of the possible variations have to be considered. While stacking, the machinery can carry out a raking operation at the same time. Provided no cultivation is planned immediately after the clearing it is possible at this stage to speed up the operation and so reduce costs, by not being as particular in the raking. Apart from the appearance of things it is possible to leave a reasonable amount of sticks and roots about and these will eventually rot away. Up to 25% of the final costs can be saved at this stage.

There are two aspects to be considered here; the establishment of the pastures without cultivation, and the treatment of the regrowth in later years. Therefore, provided it is not necessary to cultivate to establish the pastures, the ground has only to be cleaned sufficient to allow movement over the country for stock management and treatment of regrowth.

If however it is considered that cultivation is necessary for the establishment of the pastures, then more time must be spent raking. It is in this regard that I feel a major improvement can be made in the type of machinery available. Most raking operations on the Northern Tablelands are done with the bulldozer blade or a crawler fitted with a front end rake.

Because of slope the rake is usually restricted to around 10 feet. With wider rakes, difficulty is encountered in keeping at least one end out of the ground and also considerable dirt can be put into the windrow, which causes concern when burning.

After stacking the timber into windrows a decision has to be made on when to burn - immediately or delay until timber is dried out. Green burning is possible provided it is done correctly. The following points are important;

1. Commence burning 2-3 weeks after stacking - just as the leaves are dried out but still hanging on the trees.

2. Stacks must be large and packed as tightly as possible.

3. Once set alight the heaps must be stoked with large machines and kept stoked.

4. Do not undertake if there is a chance of rain before burning complete. If rain puts out the fire before it gets really under-way, subsequent burning of the heap will be difficult.

5. Do not light too many fires for the stoking units to get around conveniently.

The dangers of green burning are mainly associated with the above points. If not adhered to then the heaps will not really get burning and then just charred logs will be left and these are very difficult to get burning again and require stoking with a lot of smaller timber to have any success.

The advantages of green burning are:

1. Job completed in one go.

2. If pastures to be sown initially, then there are no areas which have to be left unsown.

3. There is no harbour left for rabbits to build up in and cause trouble with establishing pastures.

4. No windrows to interfere with ease of working ground.

5. No heaps to burn later and so scorch the established pastures adjacent to the windrows,

6. The whole problem of burning needs closer study both from the physical aspects and from the aspect of development of chemical or other treatments which will improve results and reduce costs.

Cultivation.

Problems associated with cultivation after clearing are many, but mainly revolve around the thoroughness of the initial raking operation and the presence of stumps and roots left in the ground.

1. Considerable amount of roots and sticks are brought to the surface - particularly with tyne type implements.

2. Sticks and stumps cause considerable damage to machinery.

3. Injury to operators from flying sticks and sudden stops of machines.

4. Blocking of equipment.

5. Working around windrows.

6. Uneven surface where big stump holes left, causes damage to machines.

To overcome all these problems it is necessary to produce a clearer job in the initial raking and/or design equipment more suitable to work through dirtier country. The degree of thoroughness of the raking operation will depend on the machine that is to be used that will handle the least amount of rubbish. With the present range of equipment it is felt that it is wiser to do a better job initially than to spend more time and money on repairs and breakdown time during the cultivation period, when timing of operations can be more critical.

It is possible to argue that disc implements remove a lot of the problems, but not all soil types lend themselves to the use of discs, and unless reasonably clean ground is provided for the disc, a poor job results. In addition breakages will be high, which with disc implements can be very costly.

The use of track type equipment is not really feasible as wide implements have to be used to make costs acceptable.

The availability of three point linkage harrows has made a great contribution to the operation of cleaning up the smaller roots and sticks prior to sowing. However the construction of this class of implement could be more substantial as it is impossible to avoid hooking the implement on stumps etc. The skill of the operator will contribute greatly to reducing damage but will not eliminate it.

Until some other sowing implement is designed, we are left with the combine or disc drill for sowing into this cleared country. This is the limitation we work with at the moment and gives us an idea of how clean the country has to be, before sowing can be carried out with these pieces of equipment.

REGROWTH

The major problem with land clearing, be it full scale removal of trees or the killing of trees alone, is that of regrowth.

This takes the form of suckers coming from roots and stumps left in the ground or from below the level of ringing. Seedlings germinating after the killing and removal of older trees is also a problem. Both these forms of regrowth occur consistently on the Tablelands.

SUCKERS

The critical factors here are;

1. The use of chemicals to kill existing trees will weaken sucker growth both in number and vigour. Picloram has apparently reduced this problem considerably when applied correctly.

2. When removing timber as much of the root system as possible within the realms of economics should be taken. This means that if the ground is too dry to allow the trees to come out freely then serious consideration should be given to delaying the clearing operation. Some stumps can be accepted as the treatment of a few stumps in subsequent years presents no major problem. However, if every second tree snaps it will become physically and economically impossible to control the sucker problem.

Treatment is basically manual removal of the suckers from trees still standing and from stumps, but in the case of stumps it is usual to lacerate the top and treat with 2.4.5.T.

SEEDLINGS

Almost invariably when timber is killed or cleared a strong germination of seedlings trees occurs. This will depend to some extent on the dominant timber species present, but most Tablelands timbers do produce considerable seedlings.

With ringing and chemical methods it is not possible to handle this problem with machinery, and so we have to choose between the following:

1. Manual removal - grubbing

2. Chemical spraying - overall Spraying of 2.4.5.T or Picloram mixed in water.

3. Management of stock to get them to constantly eat seedlings.

It is becoming increasingly difficult to find labour willing to do a thorough job with the first method so the last two alternatives are left. Chemical treatment of a moderate density of seedling regrowth can exceed \$6.00 per acre, therefore I feel that where possible every endeavour be made to control seedlings through stock management.

Once timber has been killed a definite flush of natural grass growth occurs. This is increased if super is applied to the country. When improved pasture species are sown at the time of the leaf fall, it becomes necessary to reduce stocking on the seeded area during the establishment period and to continue to treat it leniently till the pasture species are well established and possibly seeded. This means there is a considerable period in which the seedling tree can become well established and get beyond the point where stock can be encouraged to graze them.

The idea in seeding at this stage has been to get the improved species established before the flush of natural grass takes place. This is sound reasoning apart from the problem of the seedling, and also as mentioned earlier, the possible residual effect of Picloram on the clover seedlings.

Therefore I feel it is more advantageous to delay the seeding operation - to fence the treated area so that high density grazing can be carried out with dry sheep and the sheep more or less forced to graze the seedlings. This can be achieved during the winter months - especially if super is applied. The natural grass flush will give a considerable lift in the production from this area and will last for at least two years. Once the natural grass does not show the same vigour the introduction of improved species can be undertaken. By this time the seedling problem should be considerably reduced or eliminated and the possible residue of Picloram be reduced.

Under this system it will be possible to get a more immediate return on the capital invested. If an area is treated each year the reduction in grazing on the area to be seeded can be taken up by the increase in production from the area that has just been killed.

On country which has been cleared of timber, the seedling problem is not as acute, unless pastures are sown as the initial crop. Under these circumstances the management of the pastures will favour the establishment of the seedlings once again. Manual grubbing or overall chemical spray will be required to control these. One other alternative is the use of a slasher or the tritter type of machine. This can be done provided the seedlings don't get too big.

The alternative is to sow a grazing crops or cash crops, prior to sowing the permanent pasture down. This means that stock will be able to control the first crop of seedlings and the follow up cultivations will control the subsequent crop of seedlings. When the pasture is sown the number of tree seedlings that establish themselves will be greatly reduced and will present no major problem.

The subject of the economics of use of fodder crops is a rather complicated one and too large to bring into this paper. It is sufficient to say that sound use can be made of them within a developmental programme and by so doing a great reduction in the regrowth problem can be achieved.

CONCLUSION

Land clearing on the tablelands does present problems - some of which can be handled.

However the problem causing the most concern is that of arriving at the technique and selecting equipment which will give the most economical finished product.

The overall problems can be summarised as follows:

1. We have virgin timber which has to be removed

2. We have to establish pastures on the country left after the timber is removed

3. We have to control or remove the regrowth - sucker and seedling - from the country before or after establishing the pasture.

The problem must be examined as a whole and I strongly recommend that this be undertaken because of the increasing importance of this aspect of land development to the country as a whole.

There may be other avenues of investigation worthy of thought -

a. the possibility of preventing seedlings from coming by treatment of the trees some years before clearing or poisoning, so that only non viable seeds are set.

b. Can the ground or trees be treated to induce all seed present, to germinate just prior to clearing or killing.

c. If the above are not feasible then we are left with the need to develop equipment that will clean up roots and sticks and cultivate at the same time with a minimum risk of damage to machine or operator.

PRINCIPLES AND PROBLEMS IN THE CONTROL OF WOODY WEEDS

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In general, the principles and problems associated with controlling woody weeds are fundamentally the same as for other weeds, the basic factors being the toxicity and selectivity of the herbicide used.

Although the effects of herbicides on woody plants are well documented numerous trials continue to be set up to determine the most effective herbicide treatment for a particular problem and situation. Unfortunately, it seems that research results on herbicide effectiveness in one area are not necessarily applicable even for areas relatively nearby, and there is no guarantee that particular treatments will give reproducible results. Apparently valid results from research trials frequently fail when applied on a large-scale operational basis. Clearly, we need more knowledge of the basic requirements for effective herbicide action.

Wort (1964) discussed some of the variables involved. These include the general nature of the herbicides, the chemical formulation of the herbicide, e.g. acid, amine, ester, the concentration used, pH, carrier and surfactant, method of application, the size of droplet or dust particle applied. Plant variables include the species, the part of the plant to which the herbicide is applied, the age, vigour, growth rate and past history of the plant. Environmental conditions such as temperature, light intensity, humidity, when the chemical is applied, when the herbicide is active within the plant, and soil properties both chemical and physical are also involved in determining the effectiveness of a herbicide treatment. Consequently variable results can be expected from field applications of herbicide when few of these factors are controlled or even noted, and the herbicides now available must be remarkably effective to give the good results frequently obtained.

To kill a plant, a herbicide must be taken up by the plant, be moved to the site or sites of action, and be toxic to the plant.

Uptake of herbicide

Usually, in controlling woody weeds, the herbicide is injected into the stem of the plant or applied as a foliar spray. With stem injection, the herbicide gains ready access to at least some of the plant's tissues whereas with foliar sprays the herbicide must be taken in by the plant.

There are three barriers to the foliar uptake of herbicides: the cuticle, the cell wall, the cell membrane. The cuticle is a complex structure (Crafts 1964, Franke 1967) consisting of fatty (cutin, cuticular waxes) and non-fatty (hemicelluloses, cellulose, pectins) substances. It plays a major role in determining the behaviour of droplets on the leaf surface, and it may vary both between species and within a species at different developmental stages and under different environmental conditions (Currier and Dybing 1959, Sargent 1965, Silva Fernandes 1965a,b).

Probably there are both fatty and aqueous routes through the cuticle allowing penetration of fat-soluble and water-soluble substances respectively but the actual mechanisms and paths of penetration are little understood.

Once through the cuticle the herbicide must penetrate the wall of the outermost cells and the underlying cell membrane. The cell walls, which are composed primarily of non-fatty materials, are penetrated most readily by water soluble herbicides. However, the cell wall is traversed by extremely small pores or channels called ectodesmata, through which both fat-and water-soluble substances may pass (Franke 1967), and greatest absorption of herbicide seems to be where ectodesmata are concentrated in the cell wall.

Finally, the herbicide must penetrate the cell membrane and enter the living tissue of the plant. The mechanism of this penetration appears to be on "active" process requiring the production of energy by the plant.

There has been considerable discussion concerning the role of stomata in foliar uptake of chemicals (Crafts 1964, David et al 1968, Franke 1967, Silva Fernandes 1965b) and it seems that although stomata sometimes may aid penetration, they are not essential for it.

Penetration of the outer surface of the leaf is greatly increased by the use of surfactants. These substances play a major role by increasing the wetting, spreading and sticking of the herbicide spray but they have a greater effect than can be attributed solely to these functions (Jansen 1964). Suggested additional roles of surfactants are:

1. that they increase the humidity of the leaf surface so preventing rapid drying of the herbicide solution;

2. increase the area of the channels through the cuticle;

3. they physically break down some of the barriers to leaf penetration.

The entry of herbicides into the leaf is a complex process involving a system consisting at a minimum of, the herbicide, the carrier or formulation, the surfactant, and the leaf surface (Jansen 1964). Modifications of any of these can affect herbicide effectiveness and all must be evaluated for a better understanding of the entry process.

The environmental conditions at the time of spraying may also affect the uptake of foliar sprays and in particular, high atmospheric humidity and warm temperatures favour uptake (Brian 1966, Chlor et al 1963, Currier and Dybing 1959, Pallas 1960). Light intensity also affects uptake but all possible effects, from favourable to detrimental, have been reported (Brian 1966, Currier and Dybing 1959, Davis et al 1968, Sargent and Blackman 1965) indicating that light is not acting independent of other factors.

Thus, although the mechanisms of foliar uptake are incompletely understood many variables are clearly involved.

Uptake is the first, and possibly the greatest problem involved in effective herbicide treatment.

Translocation of herbicides

After penetrating the outer surface of the plant the herbicide must move to the site or sites of action in sufficient quantities to kill the plant. Different herbicides differ in their sites and mechanisms of action and one of the most important reasons for knowing these sites and mechanisms is to know to where, and in what quantities, the herbicide must be distributed throughout the plant. Some herbicides e.g. the substituted ureas, the triazines, and diquat and paraquat, act on photosynthetic mechanisms (Van Overbeek 1964) and, in plants with little regenerative capacity it may be sufficient to kill the existing foliage. However, in most woody species which possess some degree of regenerative power from dormant or axillary buds, greater distribution of herbicide is necessary to kill or suppress all buds, or even to kill the roots directly.

Frequently only a very small proportion of the herbicides most commonly used in killing woody plants (2,4-D; 2,4,5-T; Picloram) is transported from the leaves to stems and roots (Bovey et al 1967, Crafts 1964, Pallas 1960). The major movement of herbicides in plants is associated with the movement of plant foods and this depends on the activity of sites of production (sources) and sites of utilization (sinks) of food. The herbicide itself can inhibit movement of food from leaves to root further inhibiting the movement of herbicide (Leonard et al 1966).

Movement of foods from leaves strongly depends on the physiological condition of the leaf. Young actively growing leaves tend to import foods (i.e. they are active sinks) but this tendency decreases with age until the leaves reach a stage where they are exporting foods to other more active parts of the plant. Hence, the proportion of young expanding leaves to mature and over-mature leaves may have an important bearing on the patterns of distribution of herbicides. Root activity also influences herbicide movement and the finding that translocation and herbicide effectiveness are greatest when soil moisture is high (Johnson 1964, Merkle and Davis 1967, Pallas and Williams 1962) can probably be explained in terms of increased root activity. Crafts (1964) suggests that the optimal time for herbicide treatment is when the foliage is mature and exporting foods, and root growth is active.

Translocation in both phloem and xylem is increased under conditions of high atmospheric humidity (Brian 1966, Chlor et al 1962, 1963, Currier and Dybing 1959, Pallas 1960) and while increased phloem transport is probably of greatest importance following foliar treatments, increase in xylem transport could be important when herbicides are injected into living stems.

Selectivity and Metabolism of Herbicides

The selectivity of herbicides is vital for weed control both from the viewpoint of selectivity between crop and weed, and of differences in susceptibility between different weed species. In Australian forestry one of the most important potential uses of herbicides is to free man-made coniferous plantations from competition by native woody weeds. This can be done most readily (for management reasons) after the crop has been established but the herbicide must kill or control the weed without unduly harming the crop. Selectivity may occur in one or more of several ways (Holly 1964).

1. <u>After exposure to foliar spray</u>

   a. By differences in retention of herbicide by the shoot

   b. By differences in penetration into the shoot

2. <u>After uptake of herbicide</u>

   a. By differential translocation within the plant

   b. By differential absorption or detoxication

   c. By differential metabolism of inactive to active compounds

   d. By selectivity in effect on metabolic systems at the site of action.

As discussed, differences in morphological and physiological foliar characteristics both between and within species can affect retention and penetration of herbicides. This can be a major cause of selectivity. Differential translocation within plants may be caused by differences in their growth characteristics at the time of treatment whilst their requirements for translocation may also differ. Plants with little regenerative capacity may be killed by a poorly translocated herbicide particularly if treated at a susceptible time, e.g. when stored food reserves are low, whereas other plants may be little damaged by the same treatment.

Frequently, selectivity to herbicide treatment cannot be explained solely in terms of differences in uptake and translocation (Davis et al 1968, Holly 1964, Pallas 1963, Slife et al 1962). Some species absorb or bind the active herbicide molecule at non-reactive sites (Wain 1964) whilst others break down the active molecule into inactive substances (Slife et al 1962). A subtle variation of detoxification is the ability of some species to convert an inactive molecule into an active one (Wain 1964) rendering such plants susceptible to a chemical which is harmless to other plants.

In addition to variation in morphological and growth characteristics, plants differ greatly in their biochemical constitution and are likely to respond in different ways to foreign substances introduced into their systems. A great difficulty in distinguishing between primary and secondary effects of herbicides in plant systems is the number of effects induced (Brian 1964, Moreland 1967, Wort 1964). Precise knowledge of the mechanism of action of any herbicide is rare indeed and, in its absence, biochemical causes of resistance cannot be determined. A number of workers have reported the effects of hormone herbicides in inducing increased production of nucleic acids and proteins which could lead to uncontrolled growth (Shannon et al 1964, Van Overbeek 1964), and Malhotra and Hanson (1966) suggested resistant plants may be characterized by high levels of nuclease enzymes.

Seasonal variation in herbicide effectiveness has been observed frequently (Arend 1955, Bachelard and Boughton 1967, Baron et al 1964) and many of the factors already discussed could be involved. Carns and Addicott '1964), however, have described the variety of effects herbicides can have on the natural growth regulator systems in plants. Since the concentration, distribution and relative proportions of plant growth regulators within the plant vary markedly with season, herbicide effectiveness might be determined, at least in part, by the levels of naturally occurring growth substances.

Where selectivity between crop and weed is one of the requirements of a particular herbicide treatment it seems essential to determine, at least in broad terms, the cause of the selectivity. If it is based primarily on physical factors such as differences in retention and penetration of herbicide any modification in herbicide formulation, surfactant, or method of application aimed at increasing herbicide effectiveness may also reduce selectivity. If selectivity is caused primarily by differences in the growth stage of weed and crop, treatment must be at the right time. Inherent differences in the metabolism of weed and crop appear the safest basis of selectivity but these differences could vary with physiological variations within the plant and at different times of the year. Ideally, we need to know just what each herbicide does within a plant and all the factors, internal and external, which modify these reactions.

All these considerations with respect to selectivity between crop and weed are just as important in situations where more than one weed species is required to be controlled preferably with one herbicide treatment. Obviously more fundamental knowledge is required before we can use this very powerful method of chemical weed control with greatest efficiency.

Practical Lines of Approach

Many of the problems described here can only be investigated by intensive research and sophisticated techniques, and this should be encouraged by all those with an interest in weed control. However, much more information can also be obtained from applied field trials. Observations and recording of plant size, of variations in leaf type - old or young, the proportions of each, thin, leathery, glaucous, hairy etc., the general health of the plant and its past history, the actual environmental conditions (humidity, light, temperature) at the time of treatment and immediately thereafter, soil moisture and fertility status, precise methods of application, formulation of herbicide and surfactant used, may all aid in the evaluation of effects of treatment. With the aid of computers the relevance of each variable can be readily assessed and, if they could not tell us much directly about mechanisms of action, they could aid considerably in practical applications. Knowledge of the most important factors involved could also indicate the basic mechanisms.

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THE ECONOMICS OF LAND DEVELOPMENT IN AUSTRALIA

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Land is only one of the resources used in agricultural development. Before land can be used to produce plant and animal products it must be combined with labour and capital. Any study of economics of land development is thus merely part of the wider subject of agricultural development.

In an economic sense agricultural development can be regarded as the use of resources or the better combination of existing resources in the form of management, land, labour and capital either to increase agricultural output or to maintain existing output with fewer resources. If this definition is accepted, possible forms of development may be classified as follows:

1. Creating new farms on unused land.

2. Using larger amounts of management, capital and labour in areas that are already farmed to produce a larger total output.

3. Reallocating resources in such a way that the total value of resources used per unit value of output decreases. In other words producing at a lower cost.

In Australia all of these types of development are possible, but because of labour, capital and management are limited it is necessary to decide which class of development will be undertaken first and in which particular regions. This problem can be solved on a national level in the same way as a farmer solves it on his farm. A farmer attempts to invest any additional capital or labour in such a way that he obtains a maximum return per unit of capital invested. A farmer may have $2,000 to invest. He could clear, fence and sow to pasture and stock 50 acres of land and receive a net return of $200 per annum or 10% on the capital he has invested. He could Alternatively increase the stocking rate on land already developed by investing the $2,000 in sheep and increase his profit by $300 per annum, a return of 15 per cent on the additional capital invested. The farmer in this instance will naturally choose to stock more heavily. In economic jargon he will maximize his profits by farming more intensively rather than by increasing the area of land he uses. A nation should decide on its priorities of development in exactly the same way. It should increase the amount of capital and labour used in that section of agriculture which gives the highest return per unit of capital and labour used.

If a nation is to make a rational decision, it must know the additional return which will be obtained by intensifying the use of a resource in an existing type of farming in any area. It must also know the returns on capital which might be expected if new farms are established, settled in undeveloped farming areas. No country has such information for all its farming areas or for all its unsettled land, but some information is available in Australia from which some order of priorities might be suggested. Even so the information is limited to production based on existing techniques and assumes that resources and commodities are purchased and sold at existing prices. Changes in techniques could alter the order of priorities, but there is no reason for assuming that technical advance will be more rapid in one field than another. There is little point in rejecting a profitable form of development using existing techniques because some change in techniques might make some other form of development possible in the future. On the other hand the order or priorities suggested by the present cost of resources and price of products might have to be modified because of predicted changes in costs and prices.

Some of our agricultural industries are only profitable to the farmer because they are heavily subsidized by the taxpayer or consumer either by means of a tariff, a direct government grant, a home support price or a combination of these measures. Butterfat, sugar, cotton and tobacco are heavily subsidized. Cheese, dried fruits, eggs, oil seeds and rice receive a smaller subsidy (See Table 1). In these circumstances some or all of the resources used in producing these commodities are being wasted and the nation has nothing to gain by producing more of a commodity if this expansion has to be supported by additional subsidies. The payment of the subsidy indicates that some resources could be used more profitably by other sections of the agricultural industry. It would be wise to decrease the production of subsidized products on the less profitable farms and in the areas where costs are highest. This would lead to a radical reduction in sugar and butter fat production.

A large proportion of the exports of butter fat, sugar and dried fruits are sold in the United Kingdom and would face heavy tariffs if Britain enters the Common Market. In these circumstances even heavier subsidies would be required to maintain the standard of living of farmers producing these products.

It is estimated that there are 71 million acres of uncleared land in Australia with a growing season of more than five months. Approximately half of this land is situated south of the tropic of Capricorn and could be used for wool and meat and wheat production, even if the subsidy paid to wheat producers were abolished. Techniques for developing land north of the tropics are less certain and in the Northern Territory and some parts of North Western Australia profitable methods of intensively farming the land have not been developed. There are also 2 million acres of land in temperate and tropical Australia which could be irrigated.

Some idea of the national benefits which might be obtained from developing new land can be estimated by finding the return to capital which is obtained from agriculture in different parts of Australia. The total capital invested from the nation's point of view is equal to the total state capital invested, plus the total capital invested by the farmer, minus the unimproved value of land. The efficiency with which capital is being used to create new capital can be measured by finding the ratio between net output and the total capital used in creating it. This is represented by the following formula:

$$\frac{\text{Unsubsidized total revenue - Unsubsidized annual costs}}{\text{Total state capital + (Total farmers' capital - Unimproved value of land)}} \times \frac{100}{1}$$

Alternatively the efficiency with which capital is used to create revenue can be measured by finding the ratio between output and total annual capital. This is represented by the following formula:

$$\frac{\text{Total unsubsidized revenue}}{\text{(Total state capital + Farmers' capital - Unimproved value of land)} \times 7/100 + \text{Unsubsidized annual costs}} \; *$$

Some state services such as roads, railways and research facilities are common to all types of farming and can be excluded from the equation, but others such as irrigation works and drainage schemes are peculiar to a particular type of farming and must be included in the above equations.

The efficiency of different types of farming in the various Australian farming regions calculated on these two bases is shown in Table 2.

Large scale dry land farming employing large amounts of capital and using large areas of land is a more efficient user of capital to create more capital or to create additional output than small scale farming. Irrigation farming is only efficient if highly priced products such as citrus fruits are produced on a large scale. Irrigation is an inefficient means of producing cereals and livestock products. As the market for fresh fruit is limited these results suggest that further irrigation schemes are unlikely to be as profitable. On the other hand large scale dry land farming should give satisfactory returns.

A detailed examination of several suggested settlement projects supports this conclusion. (See Table 3). Satisfactory returns can be obtained from developing new land for large scale wheat farming in Western Australia and from the Spear Grass and Brigalow in Queensland for cattle grazing. The schemes giving the highest returns are those which should be undertaken first.

The cost of increasing production on existing farms is far more difficult to calculate as complex mathematical techniques are required to estimate the additional return which would be obtained from investing more capital in any particular resource in a certain region. Even where these calculations have been carried out they simply indicate additional production which would be obtained by increasing the investment in a particular resource above the average level used in the region, thus they cannot be taken as a recommendation for any particular farm. The average results which might be expected from additional investment in particular resources for different farming are shown in Table 4. It is obvious that the efficiency of farming in all regions could be improved by spending more on some resources and less on others. Resources which at present show the

* Assuming 7 per cent equals the opportunity cost of capital.

highest additional returns per unit of capital should be invested in first. It is also obvious that in all areas capital has been invested in some resources beyond the point where returns justify any additional expenditure. Under these circumstances output could be increased with current costs or the same output produced with lower costs in all of the regions studied by a more intensive use of some resources and a less intensive use of other resources. Similarly some resources could be used more profitably if they were transferred to other areas.

Care must be taken however in placing too much faith in figures shown in Table 3. The mathematical method used to obtain the figure shown in Table 3 can often give misleading results.

Even when accurate marginal returns are available they give no indication of how much capital could be invested before returns fall to a much lower level. Additional fencing and watering points in the pastoral zone would probably absorb little capital before marginal returns disappeared entirely. On the other hand large amounts of capital could be absorbed in improving pasture in the southern wheat and sheep zone and in increasing the wheat acreage.

A comparison of Table 2 and Table 3 indicates that higher returns could be obtained from further investment in some resources in existing farming areas than by developing new land. It is possible that even after capital has been re-allocated between resources and between farming regions to obtain optimum returns, further capital investment in intensifying farming in settled areas might yield better returns than establishing new farms in unsettled lands.

On the basis of this evidence, priorities for agricultural development in Australia might be summarised as follows:

1. Checking the expansion of the production of subsidized commodities.

2. Re-allocating the capital invested in regions already farmed and between regions to obtain the optimum level of investment as indicated in Table 3.

3. Further investment in resources in settled areas after optimum allocation of capital between resources has been obtained if the additional returns obtained are greater than those obtained by developing new land. This decision could only be made by finding the additional returns after the re-allocation of capital had taken place.

4. Establishing new farms on unsettled land where this can be done without subsidies.

TABLE 1

Total Subsidies Paid on Agricultural Commodities

Commodity	Subsidy as a Proportion of Sale Value	Subsidy as a Proportion of Actual Value of Product	National Cost of Subsidy
	Per Cent	Per Cent	$m
(i) Exported Commodities			
Butter	28	39	50.2
Cheese	10	11	2.8
Wheat	2	2	8.0
Sugar	21	26	27.6
Eggs	16	19	7.8
Currants, sultanas, and raisins	12	13	2.0
Rice	8	9	1.0
(ii) Imported Commodities			
Cotton	44	77	0.6
Linseed	8	9	0.2
Tobacco	33	49	9.0

Source: Harris, S. "Some Measures of Levels of Protection in Australia's Rural Industries Australian Journal of Agricultural Economics. V.8, No. 2, December, 1964.

TABLE 2

Capital required for and returns from development schemes at unsubsidized prices

Scheme	Area	Including public capital		Excluding public capital	
		Total capital	Return as percentage of capital	Total capital	Return as percentage of capital
	Million Acres	$m	percent	$m	percent
Clearing land on farms in the 15 to 25 inch rainfall areas in W.A.	2.7	108.0	13.8	108.0	13.8
Establishing new farms in the 15 to 25 inch rainfall areas in W.A.	2.6	102.0	12.2	94.0	13.2
Completing the Ord River Scheme for cotton production	0.12	68.8	negative	8.8	negative
Wallum Lands	3.5	n.a.	n.a.	365.4	5.3
Brigalow land clearing	9.5	120.0	12.5	101.2	15.3
Coleambally Irrigation Scheme	0.46	100.2	5.1	42.2	12.1
Irrigation at Humpty Doo, N.T. for rice production	0.5	n.a.	n.a.	175.0	negative
Tipperary land system (peanut production)	0.5	n.a.	n.a.	75.0	negative

Source: Prunster, R.M. "Alternatives in land development. A symposium on 'The Value and Desirability of Irrigation Development in Australia'. July, 1964.

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TABLE 3

The national efficiency of Australian farming zones

Region	Net return to total capital	Cost benefit ratio
	percent	
Pastoral	5.9	100
Wheat and sheep	8.7	105
High rainfall sheep	4.6	90
Dairying	0.7	86
Irrigation, rice and sheep	2.6	64
Sheep	2.3	59
Large scale citrus	4.2	80

Additional output per $1 invested in different resources in various farming types and regions in Australia

Sheep Farming

Resource	Pastoral Zone N.S.W.		Pastoral Zone Q'ld.		Pastoral Zone S.A.		High Rainfall Zone N.S.W.		High Rainfall Zone Western Vic.		High Rainfall Zone Eastern Vic.		High Rainfall Zone Tasmania	
	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %
Watering points	4.6	55	5.6	69	5.7	70	n.a.		n.a.		n.a.		n.a.	
Fencing	4.0	33	6.6	57	6.2	53	2.3	18	4.0	33	1.6	11	3.5	29
Labour	2.5		2.1		1.3		1.0		1.4		1.2		1.4	
Fuel	1.6		4.0		n.a.		n.a.		n..a		n.a.		n.a.	
Land	2.1	12	0.3	2	2.5	15	1.4	n.a.	1.2	7	1.7	11	1.7	n.a.
Fertilizer	"		"		"		n.a.		n.a.		n.a.		n.a.	
Improved pasture							2.5	40	2.1	32	2.2	35	2.4	57

Wheat and Sheep Farming

Resource	Wheat								Sheep							
	Northern N.S.W.		Southern N.S.W.		Vic.		S.A.		Northern N.S.W.		Southern N.S.W.		Vic.		S.A.	
	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %	a $	b %.	a $	b %
Land	2.9	17	3.6	22	2.0	12	8.1	49	3.6	22	3.6	22	0.6	4	3.1	19
Machinery	0.5		0.5		1.5		0.5		x		x		x		x	
Crop expenses	3.8		n.a.		1.2		1.3		x		x		x		x	
Improved pasture	n.a.		0.2	n.a.	7.7	716	2.1	123	n.a.		2.6		3.5	271	3.8	303
Labour	n.a.		n.a.		n.a.		n.a.		0.5		0.4		negative		0.5	
Fencing	x		x		x		x		4.3	36	4.2	35	2.7	21	4.3	36

Dairying (Including subsidies)

Resources	N.S.W. South Western Slopes	Western Australia Bunbury	South Australia Irrigation on Lower Murray
	a $	a $	a $
Land	1.26	n.a.	2.1
Labour	0.5	0.9	0.6
Operating expenses	1.4	2.5	1.3
Agistment	n.a.	n.a.	4.9
Fertilizer	n.a.	1.5	n.a.
Purchased feed	n.a.	0.7	1.7

a = Return per $1 annual cost of capital   b=Return as % of capital invested at the margin
n.a. = not available   x = not applicable.

Source: Duloy, J.H. "Allocation of resources in the Australian sheep industry" Unpublished thesis, University of Sydney, 1963; and

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ECOLOGICAL ASPECTS OF TREE AND SHRUB CONTROL ON GRAZING LAND

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The tendency to revert to an original steady state following the cessation of disturbance is an intrinsic characteristic of vegetation. In the sense of use of land for agricultural purposes, disturbance means a permanent or near-permanent modification of the environment and the steady state in this new environment is different to the original or climax state and is intended to be so. Indeed, in the higher rainfall parts of Australia, agriculture involves destruction of the original plant communities and their replacement by others composed almost invariably, of introduced species. The stability of these communities (of pastures for example) depends, among other factors, on maintenance of high levers of soil fertility.

In areas too dry for other than term survival of introduced species, use of land for agriculture depends on native species and usually on the climax dominants. In effect this means that disturbance (in most cases the frequency and intensity of grazing) has to be controlled and limited to ensure that succession is always towards the climax and not as in higher rainfall areas away from the climax.

Between the high rainfall areas where replacement of native by introduced species is possible and the arid areas where it is not, there are large areas of woodlands and shrublands the agricultural use of which depends on partial destruction of the original community - usually a reduction in tree density to stimulate production of grass for sheep and cattle. Most of these communities are sclerophyllous and grow on soils of low fertility.

There is evidence that the less fertile the soil and the drier the environment, the higher the proportion of ligno tuberous stem and root sprouting species in the community. Species of the relatively poor soils of dry sclerophyll forests and of the dry mallee are strongly ligno tuberous as are practically all species of tropical sclerophyll forests and woodlands. There are experimental data too, that relate high underground to top ratios to low levels of nutrients.

This, then, is my first hypothesis: the lower the fertility and the drier the environment of a forest, woodland or shrubland, the greater the likelihood of regeneration from root and stem tissues following injury. It follows from this that mechanical methods of clearing involve risks of regrowth. In the case of ringbarking the original tree may produce two or more stems and may subsequently be more difficult to kill than before ringbarking. Regeneration following clear felling by bull-dozing or pulling by chain or cable involves most of the woody species of the community and the densities of such species may be much greater in the regenerated than in the original community. In addition clear felling, particularly if followed by windrowing, destroys a high proportion of the native grasses present and the soil is disturbed sufficiently to initiate secondary succession at an early pioneer stage. The plants of these stages are usually low in grazing value. There are thus two problems in a grazing enterprise - one, the relatively high degree of regeneration from roots, stems and ligno tubers and secondly, the low feeding value of the resultant herbage. Such a situation calls for (a) a method of thinning trees without destruction of the native grasses and of the environment suited to their regeneration from seed, or (b) in the case of clear felling, the sowing of adapted pasture species. Unfortunately the chances of finding such species diminish with the dryness of the environment.

For those species - and there are many in semi-arid environments - not easily killed by ringbarking, injection with chemicals offers a practical method of reducing tree densities on grazing lands. The results of our experiments with chemicals will be given by Mr. J.A. Robertson in the next paper. Using the information from these experiments, immediate and substantial increases in native grass production have been obtained in poplar box (Eucalyptus populnea) woodlands in southern Queensland following injection of box trees with chemicals. The effect of thinning trees on subsequent densities of trees and shrubs, that is, on germination and establishment of the woody species of the community, is as yet uncertain. We are seeking information on this point in current experiments. In effect, we are trying to ascertain if there is a critical tree density that will enhance grass production without stimulating germination and establishment of trees and shrubs.

Preliminary results indicate that reduction of the density of living trees is accompanied by a rise in nitrate and ammonia nitrogen levels in surface soils. Moisture levels in surface soils are also higher at low tree densities. If the additional nitrogen and water enhance competition of grasses and herbs with tree and shrub seedlings, it may be possible to establish a relatively stable community at a new and lower density of trees. The densities at which stability is achieved may vary with species, soils and climates. Unless clear felling can be followed by a permanent crop-pasture system it could be undesirable for both aesthetic and economic reasons.

In higher rainfall environments the closer a forest or woodland is to its climax state the more likely are the original trees and shrubs to regenerate from seeds and in fact, seedling regeneration is frequently a problem in such circumstances. We may infer from this that the killing of adult trees is mesophytic forests by methods that do not involve marked soil disturbance may be followed by regeneration of the same species from seed.

To prevent this happening a more drastic change in the environment seems necessary. Fortunately the possibilities of effecting such changes are greater in the forests of high than of low rainfall areas. The question is: in what direction should the modification be made?

This brings me to my second hypothesis: the closer the soil environment is to the climax state, the lower the levels of freely available nutrients e.g. nitrogen. From this we may infer that the desired direction of change in high rainfall forests and woodlands is to higher levels of available soil nutrients such as nitrogen. The most permanent way of accomplishing this is to sow introduced legumes and apply the fertilisers necessary for their growth and survival. Where the establishment of a pastoral enterprise if the objective it is common practice in mesophytic forests to pull or bulldoze the trees, windrow, stick rake, plough and sow pastures. As a result the soil environment is greatly altered and if the legumes grow well there is a continuing trend to higher levels of nitrogen and the regeneration of woody species from seed is less likely. A possible exception is Acacia where the fallen timber has been burnt. To summarise:

In dry environments the objective in a pastoral system is to reduce densities of trees and shrubs without making the environment unfavourable for native grasses and herbs. This can be accomplished by chemical treatment of individual trees; injection, or basal stem treatment.

In humid environments complete destruction of the community and its permanent modification by sowing pasture legumes is the most effective method. In environments between dry and wet, a combination of the two methods may be the most effective. In some tropical woodlands for example, it may be desirable to thin the trees by chemical methods and to establish legumes by sowing on the soil surface. In others, it may be more economical in the long term to chemically treat trees and shrubs individually before pulling the woodland and sowing pastures.