Conservation farming - a crop establishment alternative or a whole-farm system?

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Introduction

Wind erosion devastated much of southern Australia in February, 1983 and the drought-breaking rains which followed in March also led to widespread soil loss. More severe water erosion occurred in northern NSW and Queensland in the autumn of 1984. Over this period the National Soil Conservation Programme was launched; with fortuitous timing and much publicity. The result of these events was a much better appreciation of the magnitude of the problem of soil degradation in Australia and, we perceive, an unprecedented commitment from Government and the farming community to do something about it. It is our belief that a change to more appropriate tillage practices offers the best prospects for maintaining a productive agriculture.

In this paper we develop the argument that the scientific and technological data base is largely adequate for us to move immediately to replace conventional, multi-pass tillage with practices which ensure soil stability.

The problem is that these data are all derived from classical experimentation in which one or at most a few factors are considered in isolation from the far more complex environment of the farm and the economic implications. Because research data are obtained in relatively simple experiments they tend to be presented to farmers in that way, often in isolation from the whole farm. Reports of, for example, simple comparisons between crop establishment methods, weed control options, stubble treatments and an infinite variety of other treatments or techniques are provided to farmers who are left to integrate the data and apply it to their own farm. Most farmers appreciate the need to integrate and adapt research data, but it is no surprise that many of them prefer instead to think in simpler terms: if a new technique does not fit the existing system it is rejected in preference to changing the system or modifying the technique.

Our review leads to the conclusion that a whole-farm approach to conservation farming, embracing many interacting factors, is necessary for economic success and to achieve the primary objective: more stable soil. The components of a whole-farm approach are discussed and areas requiring further work identified.

Reduced cultivation techniques for crop establishment

It has long been established that it is technically feasible to replace cultivation by herbicides (e.g. ICI Sprayseed Conferences in the late 1970s and early 1980s). Considerable literature has been published indicating that in many situations equal or higher yields are achievable by direct drilling when compared with conventional cultivation. Some of this literature is surveyed in Appendices I and II. The exceptions appear to be in South Australia and perhaps in north western Victoria and central western NSW where yields have generally been lower, presumably because of hard setting soils and in some cases weed, disease and pest problems.

No-till or direct drilling and minimum tillage therefore are crop establishment alternatives to conventional multi-pass tillage. Farmers have seen them as viable alternatives and have increasingly adopted them since the mid 1970s (Table 1).

It is clear that these techniques are ecologically desirable because the destructive nature of traditional cultivation practices can result in soil structure degradation with consequent soil erosion and surface crusting. This can have substantial effects on farm productivity and at the same time cause siltation of waterways and water storages. In the past such erosion has blocked roads and railways and buried fences. The Standing Committee on Soil Conservation (33) indicated that 61% or 3 x 10^6 km^2 of land used for agriculture was in degraded condition or required treatment. It was estimated that about two-thirds of this could be treated by changed management practices such as minimum tillage, direct drilling and stubble retention.

Table 1. The estimated area of cereal crops established by direct drilling and minimum tillage in winter rainfall areas of southern Australia, 1971-1983 (Pratley and Rowell, unpublished).

YEAR	AREA ('000 ha)				
	WA	SA	VIC	NSW*	TOTAL
1971	21	-	-	-	21
1972	24	-	-	-	24
1973	57	-	-	-	57
1974	140	2	-	-	142
1975	46	1	-	-	47
1976	45	2	<1	-	47
1977	51	5	<1	<1	57
1978	80	n.a.	n.a.	4	84 approx.
1979	160	55	25	20	260
1980	250	88	24	50	412
1981	1000	125	125	100	1350
1982	1680	125	86	280	2171
1983	2340	168	171	400	3079

* tabulated figures in NSW related only to southern NSW with winter-dominant rainfall.

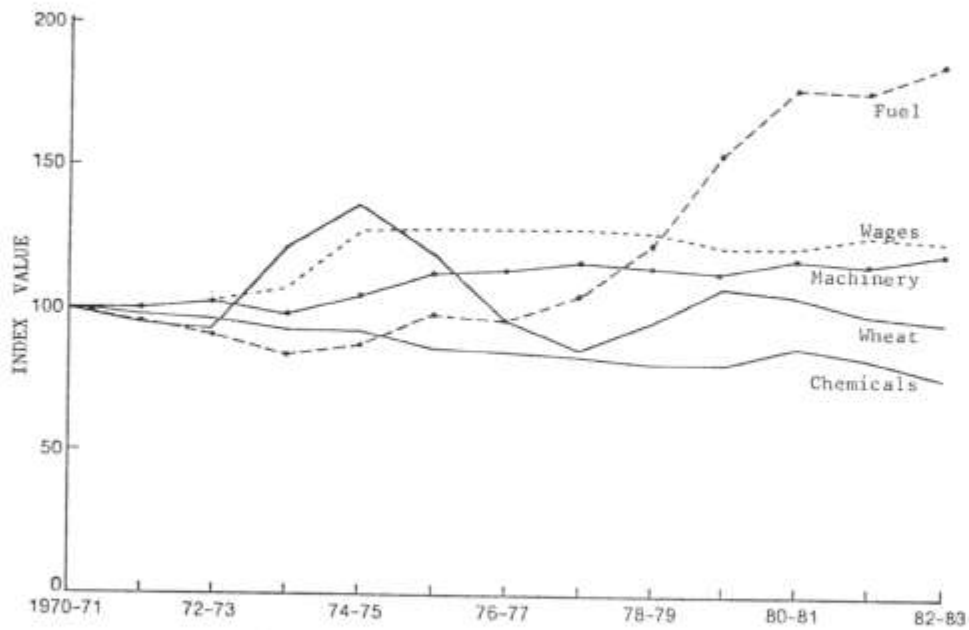
It is also apparent that these techniques can be either commercially successful or commercially disastrous depending upon the pre-disposing seasonal, soil and weed conditions and the level of management expertise involved. The popular farming press regularly reports on both success and failure thereby adding to farmer confusion as to the value of the techniques.

Rates of Adoption

The date in Table 1 provide sufficient evidence of the adoption of the techniques. While the figures at first reading indicate ready acceptance by farmers of reduced cultivation techniques, observations by the authors in the autumn of 1983 and 1984, especially in southern NSW, question whether farmers have had a real commitment to, and an understanding of soil management. The early autumn break in 1983 and the wet summer of 1983-84 saw the re-emergence, quite unnecessarily, of disc ploughs on land that had previously been direct drilled. Although cash flow problems in the aftermath of the drought together with low stock numbers may have been partially responsible in 1983 and the inflexibility of the Pesticides Act in NSW in not allowing the use of 2,4-D on cereal stubbles and fallow in the wet summer of 1983-84 also contributed, there may be some merit in evaluating the likely reasons for adoption during the last decade of reduced tillage techniques.

Instrumental in the rate of adoption has been the cost/price squeeze where the price for crop products has not kept parity with the costs of fuel, labour and machinery. In 1984, for example, one tonne of wheat purchased only 30% the amount of fuel, 70% the amount of labour and 60% the machinery than was the case in 1974. The cost of herbicides relative to wheat prices has, however, decreased during that period (Figure 1). The emphasis, therefore, in the eyes of practitioners and others has been a financial one although concerns about soil structure resulting from a decade of use of soil- incorporated pre emergent herbicides also existed.

<u>Figure 1.</u> The indexes of farm input and wheat prices, 1970-71 base (Godyn and Brennan, 1984).



The direct drill technique of crop establishment fitted neatly into the defined seasonal pattern in the West and was also appropriate in the southeast in the late 1970s - early 1980s when relatively dry autumns provided little weed growth to be controlled and little moisture on which to cultivate seedbeds. Because farmers had little option in these circumstances, we suggest therefore that direct drilling and minimum tillage was adopted often by default or for expediency.

Direct drilling has been seen by farmers only as a crop establishment technique, in which herbicides are substituted for cultivation, in isolation from the operations of the whole farm. This belief was encouraged by some commercial advertising ("the plough in the drum" concept) while advisory services also contributed by advising on the technique rather than on the system - understandably because it was simpler and easier to explain and have understood. This approach, however, tended to be interpreted by farmers as "all or nothing" with little flexibility for adaptation to particular conditions. In 1984, for example, many farmers in southern NSW endeavoured to direct drill into seedbeds compacted on the surface following grazing by livestock on the wet soils in autumn. The poor crop results obtained may have been avoided by using minimum tillage in these circumstances.

Researchers also have to share the blame. Most of the tillage research published in Australia (see the 2nd Australian Agronomy Conference Proceedings) is short-term and isolated from a farming <u>system.</u> Rarely is the non-crop period (from harvest to sowing) taken into account (except for fallow weed control) or the relationship of the crop to the remainder of the farm activities, in particular the livestock enterprises. It is pleasing to note that some papers relevant to this topic in the current Proceedings relate to long term effects and studies of systems.

It is clear, however, that there needs to be further research undertaken to fully understand the reasons for adoption, or non-adoption of reduced cultivation techniques. This work is necessary in order to identify the important extension and research needed to improve adoption rates.

Recent Trends

It is worth noting that there is a change taking place in the definition of various practices. Traditional or conventional seedbed preparation has, in the past, generally inferred at least three workings prior to sowing. Minimum tillage has generally been considered to mean one working prior to sowing. In the popular press minimum tillage is now being regarded as traditional practice (24) - farmers disenchanted with direct drilling are "reverting" to the "traditional" practice of minimum tillage. In effect, therefore, the objective of reducing cultivation has been achieved to some extent.

Since the 1982 Australian Agronomy Conference there has been great interest by farmers and scientists in combining the advantages of direct drilling and minimum tillage with those of stubble retention. In the winter rainfall areas of the Australian wheat belt this has involved superimposing stubble retention techniques on direct drilled crops whereas in the summer rainfall areas the combination has required the replacement of stubble retention methods, which previously had relied upon blade ploughs and rodweeders for fallow weed control, by no-till fallow.

Winter-rainfall zone - the major difficulty in adopting stubble retention in this zone relates to the inability of sowing implements to proceed through the stubble without regular, time-consuming blockages, Dnlike the summer rainfall areas where stubble deterioration is at an advanced stage by sowing time and therefore brittle, the stubble in the south remains tough and resilient having experienced mainly hot dry conditions prior to sowing, with little deterioration. To date, no commercial machinery is available which can handle the stubble burdens from high yielding crops. Consequently, some farmers have tried to incorporate their stubbles, opting away from minimum tillage in favour of maximum stubble retention using disc implements. Curiously, this is a repetition of thinking in the 1960s when stubble retention was tried experimentally in southern NSW and found wanting (19). There is growing evidence that changes in soil organic matter and structural stability are most closely related to the amount of cultivation used (23). Stubble incorporation therefore may not be particularly useful due to the cultivation necessary to provide effective incorporation. Further research is needed to clarify this. Options for stubble management are considered later in this paper.

Summer-rainfall zone the development of no-till fallows in the northern cropping areas continues to depend on the development of short-term residual chemicals for fallow weed control. The use of non-residual herbicides like Roundup? and Sprayseed? necessitate repeated applications and may be precluded on the basis of cost. Residual herbicides under test include Gleans?, Bladex? and Atrazine?, the major concerns being the length of residual activity, the weed spectrum affected and the susceptibility of the crop species to be sown.

3. Conservation farming - a whole farm system

The substitution of herbicides for cultivation on an *ad hoc* basis does not take account of the dynamics of farm operations and resources management. Such a change in crop establishment methods has management and economic implications with respect to other factors such as feed availability for livestock, machinery depreciation, cash flow, rotations, stubble management. Some of these implications are considered in later sections of this paper.

The term 'conservation farming' is a new term coined to emphasise the whole-farm approach not generally inferred by the terms direct drilling and minimum tillage. It also allows for a flexibility of approach which has hitherto not been the case with the promotion of direct drilling. Such a systems approach is not only desirable from a management viewpoint, but also economically necessary, It is clear that the substitution of one herbicide for one cultivation is not an economic proposition. However, if this substitution also results in savings in labour, fuel and machinery costs, better weed control, improved animal production, long term soil stability and yield benefits from timeliness of operations - to name a few - the farmer then has a recipe for improved economic performance.

While the need for considering conservation farming as a whole farm system is emphasised in this paper, various aspects, or subsystems, need further comment and are treated separately for simplicity. Where appropriate, research needs are identified though clearly the treatment is not comprehensive. The primary technical objective of conservation farming is the development of soil stability - to enable this objective to be achieved by farmers ECONOMICALLY requires much broader considerations than simply a reduction in tillage.

Soil Management - With national concern on the degradation of soil structure in Australia, it is clear that one of the major thrusts of conservation farming is the reduction in the amount of cultivation undertaken in order to establish crops and pastures. The ultimate goal perhaps is that of direct drilling. However promotion of direct drilling *per se* has unwittingly led to disaster on many occasions where the technique was applied under conditions where it was inappropriate. The inflexibility interpreted by farmers (the "whole or nothing" approach) has clearly resulted in disenchantment by the practitioners who have endeavoured to direct drill into surface compacted soils, heavy stubble burdens, weedy conditions or into sodbound perennial pastures, culminating in disaster. A more flexible approach is therefore needed to adapt these techniques according to the conditions. For example, in areas where hard setting soils occur, such as in South Australia and in the western portion of the NSW wheatbelt, minimum tillage is likely to be more successful than direct drilling (S). This would apply also where surface soils have been compacted by livestock during the pasture phase or where stubbles have been grazed when the soil is wet. In the latter case, the compaction may be minimised by allowing grazing of stubbles when the soils are dry (13) although this may be impractical in some seasons. The factors leading to soil degradation (excess cultivation, burning of stubbles, grazing wet soils, etc) need to be ranked in terms of importance so that farmers can make informed decisions about which operations can be safely changed in a flexible conservation farming system. The need to direct drill will also depend on the intensity of the cropping activity and on the stability and hence erodibility of the soil type being cropped.

Weed Management - The use of knockdown chemicals such as Sprayseed[?]and Roundup[?] have in the past been expected by some farmers to provide a complete weed control programme. Early planning of weed control strategies during the pasture phase in a rotation system allows techniques such as spray-graze and spray topping to be employed which are inexpensive and highly effective. Weeds which are difficult or costly to control in crop can therefore be controlled by low rate of chemicals in the seasons preceding cropping activity. This is environmentally and financially more desirable. In the case of annual grasses which are alternate hosts to several cereal diseases, control at this stage provides a break in disease build-up with reduced incidence in the cropping phase. In all cases the production of desirable species in the pasture phase is enhanced as is the associated animal production. Although the techniques have been available since the early 1970s (25, 26) and practised in the west for many years, their incorporation into farming programmes on a regular basis in the east is relatively recent, Details of these techniques have been expertly reviewed in the special weed management issue of "The Direct Drill Farmer and Grazier" in 1983 together with other weed management options.

Where weeds such as silver grass *(Vulpia* spp) which are difficult to kill using the knockdown chemicals and for which chemicals are not available for in-crop control, strategies such as the use of a full combine, in preference to a modified combine or disc drill need to be implemented if the weeds are present at sowing (28).

Clearly there is a need for more information and guidance for farmers on suitable chemicals, rates, mixtures, water volumes and spray technology. Currently in NSW there are approximately 50 chemicals registered for use on winter crops. In other States there is a larger number with mixtures being used which are illegal in NSW. NSW farmers are using some of these with great effect. As a consequence the inability of district agronomists in this State to recommend such mixtures puts their credibility at stake and therefore lessens their impact on farmers to adopt other practices such as direct drilling. While appreciating the intention of the Pesticides Act of NSW it is our view that a national approach to pesticide use is necessary to overcome these current difficulties. This would be appreciated by farmers, extension officers and chemical companies. It should be noted that some chemicals are not available in NSW simply because companies have not proceeded with registration because of the difficulties involved, It must be noted that weed management in both pastures and crops is of paramount importance in the efficiency of plant production. A combination of methods and chemicals has the advantages in the long term of lower risks of residue buildup and herbicide resistance. It must be noted, however, that good weed control in crops, while contributing to higher crop yields and harvest efficiency, reduces the value of stubbles for livestock and reinforces the need to look more closely at stubble management. This is considered in part (d).

The extra grazing provided in autumn by direct drilled crops can have a significant effect on animal production (11). Conversely the animals are also important in managing the amount of vegetation so that an effective kill can be achieved by the knockdown herbicides prior to sowing. Where the cropping area on individual properties has increased because of financial needs, the number of stock available for grazing is necessarily reduced as is the ability therefore to have animal-organised weed management. In southern NSW, for example, it is not uncommon for a third of the farm to be cropped. As described by Patterson (24) this proportion allows for double stocking rates on cropped areas if necessary, However, where farmers have increased their cropping area to two-thirds of the property, as has happened since the 1982 drought, they can only achieve half the normal stocking rate on the cropped area. This has been inadequate to control the weeds which have flourished in the wet autumns and reduced and in some cases negated the effect of the presowing herbicides. Consideration of the whole farm implications before the event would have allowed remedial measures to be taken.

(c) Stubble Management - While crop stubbles are an integral part of the whole farm system they have been a much neglected resource. Ignored in much of the tillage research they have also been dispensed with by farmers as soon as conditions for burning allow. While they have been retained in the summer rainfall areas and on the sandy mallee soils as an erosion control measure, potential benefits have only recently been acknowledged in the winter rainfall areas, These benefits includes

- an improvement in soil structure by contributing to soil organic matter levels and reducing raindrop impact and its effect on surface crusting;
- a reduction in soil erosion; and
- improved soil moisture storage by the reduced evaporation and improved infiltration (18).

For these benefits to be realised, however, stubble management practices must be developed, particularly in these winter rainfall areas, whereby the sowing operation can be facilitated, Current commercial seeding equipment can cope with up to 3t hr^{-1} stubbles, a performance which precludes their use in 3 to 4 t ha-1 cereal crops having 'on average' a stubble burden of 4 to 6 t hr^{-1}.

Further work is necessary in winter rainfall areas to determine whether stubbles are best retained on the surface, partially or fully incorporated. Such information has implications for machinery, for weed control and for plant disease. Unless stubble breakdown has occurred between incorporation and sowing the physical problem of combine blockages still remains. Burning of residues just prior to sowing remains a management option which might be a useful compromise given that by this time the stubble will have made a significant contribution while the roots and any decayed material will add to soil organic matter levels providing it is not lost through subsequent cultivation. Assuming that the stubble is to be retained on the soil surface, two questions in particular remain to be answered:

- how much stubble is it necessary to retain in order to maximise the benefits in its retention in terms of soil moisture and soil organic matter?
- how best is the stubble managed to achieve the level identified in (i)?

While no answers are offered as to the levels needed for maximum benefit several options are available at harvest time for reducing the problems associated with stubble at sowing time. Cutting the crop low to the ground at harvest will reduce the level of standing straw but increases the amount of threshed residue. The more straw pushed through the header the slower and therefore more expensive the harvesting operation although the axial flow headers allow more straw throughput without substantial reduction in harvesting speeds but have not been readily available in the small range of equipment. Having harvested the straw, Hill and Butt (14) identify three options: spread the straw; chop and spread the straw; or chop and spread the chaff and straw. Straw spreaders are now fitted to most modern headers but usually only spread the straw over half to two-thirds of the machine, often in lumps. The straw is not reduced in length or pulverised and therefore straw breakdown is not assisted. Chaff however is not spread.

Straw choppers are available for some makes of large capacity and axial flow harvesters - straw is chopped and pulverised into 100-150 mm lengths and then spread over about two-thirds of the machine width. Straw stems are cracked thereby aiding stubble breakdown. The use of a "straw storm" attachment allows for better spread of both straw and chaff. This attachment consists of counter-rotating steel blades which cut and propel the strew onto spinning discs which spread the material. The major drawback with choppers and straw storms, apart from their limited range of machines, is the horsepower required and the consequent reduction in the capacity of the harvester. Hill and Butt (14) report capacity reductions may be as high as 5 t ha^{-1} on the large machines.

Also recently available are stubble mulchers or "busters" which consist of a rotating drum with a series of attached flails that smash the stubble into short lengths from 20-120 mm. The outer waxy layer of the stem is cracked allowing for improved breakdown of the stubble. A major problem with these machines is the high horsepower requirement and slow speed of operation with a cost of up to \$12 hr^{-1}. Farmer experience in southern NSW has been disappointing because of the cost, the incomplete coverage due to wheel tracks and the poor rate of breakdown by sowing time not alleviating the blockage problem at sowing. The presence of the straw at sowing also produced poor soil-seed contact and the partial incorporation caused nitrogen tie-up in proximity to the seed.

Improved utilisation of stubbles by livestock also offer a valuable and realistic option to reduce the amount of stubble (21, 22). It also provides a feed supply during a period of the year when feed is lacking. The significance of this feed source is indicated by calculation that NSW wheat stubbles potentially contain sufficient energy to maintain the State's sheep flock for more than 4 months (27), The Western Australian cereal stubbles have been calculated to have the potential to run that State's sheep population for half the year (32), To realise this potential, however, will require further research into feed supplements for livestock and appropriate management techniques.

The role of stubble in the efficiency of herbicide application needs further elucidation. Adsorption of chemicals by stubble and its retention of activity as well as the problem of targeting require further research. The commercial development of the electrodyn and weed sensing devices and the use of header-mounted boom sprayers may make major contributions in this respect.

(d) Water Management - It has long been appreciated that productivity of dryland agriculture in Australia depends on efficient water use. With wheat, for example, there is a linear relationship between yield and the water consumed by the crop, As a rule of thumb, 10 kg grain ha mm^{-1} of evapo- transpiration is a reasonable expectation in southern Australia. The actual figure on farms is frequently half of this or less (6, 10). Hence water management has always been a high priority although, in practical terms, it has not extended much beyond fallow management and choice of sowing rates and fertilisers.

Technological advances in recent years offer a wider range of possibilities for improving water management, These advances include a better understanding of plant physiology (especially water relations and growth), better techniques for measuring soil water (the neutron probe), a wider range of crop and pasture genotypes, better herbicides and the application of computer models to management decision-making. Armed with these tools it is likely that conservation farming will lead to more efficient water-use.

In this section we briefly review the options for improving water management, with particular reference to conservation farming.

Efficient water use depends on;

- harnessing and storing all of the available water (minimising through- drainage and runoff);
- minimising unproductive losses such as evaporation from the soil surface; and
- directing water through the chosen plant (not weeds) at a rate and time of year that maximises yield of product per unit of water transpired.

All of these are within economic and, hopefully, environmental constraints. Conservation farming practices have the potential to improve water-use efficiency through a number of small, additive effects. To realise the potential increases in productivity requires attention to the package of practices. Reduced soil disturbance and the improved structural stability that usually follows will improve infiltration and, on occasions, increase crop-available water, Crop residue retention can also improve infiltration (via channelling) but the main benefit of stubble is reduced evaporation from the soil surface, This applies to both between crop (fallow) and in- crop soil evaporation, Responses are variable. Subsoil loosening may also improve waterless efficiency by removing any "throttle" to infiltration, increasing the depth of freely drained soil, in which roots can grow, and increasing rooting depth in mechanically strong soils. How widespread the response to subsoiling will be remains to be seen. The principles involved are reviewed in the Proceedings 13th Riverina Outlook Conference.

Timely sowing improves water use efficiency, Hence direct drilling can increase water use efficiency by allowing more timely sowing in wet seasons. This applies particularly in Western Australia where sowing traditionally has been delayed by ground preparation after the autumn break, Because wheat cultivars have been selected for this agro-climatic environment based on traditional practices, it is likely that longer season types will need to be selected to take advantage of the earlier sowing times.

No-till of summer crops has also led to improved water use through better water conservation and reduced soil temperatures C16). Double cropping and opportunity cropping are now likely to be more economic than in the past. It is important to note, however, that a change to the crop rotations used may be <u>necessary</u> in order to <u>economically</u> change to a conservation farming system.

Direct drilling has also brought an unexpected benefit in some dry seasons. Slow early crop growth following direct drilling leads to water-rationing which, in the event of a dry spring, has increased grain yields. On the other hand, direct drilling (graze-spray-sow) can forego some water conservation in a wet autumn, compared with a short cultivated (or chemical) fallow. Yield is a trade-off between these two effects. Cornish and Murray (unpublished) used a water balance model to find the frequency of autumn-fallow responses in the Wagga district. Their results indicate that a short fallow would increase water storage at sowing by 20 mm in about 40% of years.

Thoughts of autumn fallowing in a direct drill system emphasise the need for a systems approach to conservation farming. The weeds and volunteer crop or pasture controlled by herbicides would otherwise provide grazing for livestock. There is clearly a choice between autumn grazing and better crop yields although the value of autumn grazing can be small (5). The choice is the same, in principle, as that between long fallowing or stubble cropping in the southern (low rainfall) wheat belts, long fallowing or double cropping in the north, and the choice between opportunity cropping or a rigid rotation in areas as diverse as the Wimmera (P.E. Ridge, pers. comm.), northern NSW (15) and the eastern grain belt of Queensland (2). Some management decisions involve long-term or regional strategies (e.g. what are the long-term economics of opportunity cropping) and others are tactical in nature (following a given rainfall, should a farmer spray weeds to save water for the next crop?). Management decisions of this kind are particularly amenable to computer simulation. Soil water balance and numerous plant growth models are available, but they need to be applied to the management problems and interfaced with economic models. The approach is not new, but needs to be applied much more widely.

(e) <u>Disease and Pest Management</u> - Little is understood of the microbial activity associated with different farming systems. Some research has shown the increase in yellow leaf spot with wheat-stubble retention in the summer rainfall areas of north-eastern Australia (29). Whether similar increases occur in winter rainfall areas of southern Australia remains to be determined. Increases in Rhizoctonia bare patch with direct drilling have been reported in Victoria (17), South Australia (30) and Western Australia (20), although other reports suggest the opposite in Victoria (9). Rovira (30) reports an increase in take-all in direct drilled wheat in South Australia but whether this is due to the tillage treatment *per se* is questioned by work elsewhere (17, J,E. Pratley, unpubl.). Pratley (unpubl.) has shown lower incidence in eyspot lodging in direct drilled wheat than in conventionally cultivated wheat in a long-term tillage experiment in southern NSW. Clearly, changes in the cultural methods will have dramatic effects on the ecosystem. These changes will not occur instantaneously but evolve over time. *Ad hoc* short-term experiments therefore contribute little to our knowledge in this regard. There is, therefore, enough confusion in this area to suggest that there needs to be undertaken the important basic research in order to understand the ecological requirements of these diseases and to develop <u>systems</u> of weed, soil and stubble management which minimise the destructiveness of these diseases. Rotations involving break crops or pastures provide one simple and effective answer but are they really necessary to control diseases if we understand the microbiological subsystem? If the grass weeds, which are alternate hosts to the root rot diseases of wheat, are controlled in the pasture phase, for example, it may be unnecessary to grow a break crop to control these diseases, In any case the farmer may not wish to grow alternative crops to wheat if they are less attractive financially or otherwise.

Some reports indicate difficulties with pasture pests in the first year of direct drilling, These pests include red legged earthmite, lucerne flea, blackheaded pasture cockchafer and the pasture webworm (1) and require the application of insecticide with the pre-soaking herbicide spray. In South Australia the cereal curculio has also caused severe damage to direct drilled crops (12) although this can be minimised by barley grass removal during the pasture phase (D/L, Rowell, pers.comm.).

In 1984 in the central and southern wheatbelt of NSW farmers had to contend with a severe mice plague which devastated crops in some areas. Experience from this season has indicated that crops established by minimal disturbance techniques such as modified combines and disc drills are more prone to seed harvesting by rodents than if the crops are sown by full soil disturbance

methods such as a full combine or by minimum and conventional tillage. Mice damage was more severe where stubbles were retained. In spring, damage to crops at flowering was more severe in some crop species such as lupins and wheat than in triticale and in some varieties (N.A. Fettell, pers.comm.). Mice damage was also more severe where stubbles were retained. The lessons therefore for predicted plague conditions include full soil disturbance at sowing, stubble removal and, if appropriate information is available, judicious choice of crops and cultivars.

(f) Animal Management - Great significance has been made of the benefits to animal production from a swing to direct drilling in southern Australia. Indeed, increased animal production may be necessary for the change to be economic (11). In practice, however, there is evidence that these advantages are not being realised, In the higher rainfall wheat-sheep zone of NSW, Simpson (31) claims that, after five years of promotion, conservation farming has failed to integrate the farming system with livestock enterprises. Since the concept of 'direct drilling' was introduced to farmers in the late 1970s, no real attempt has been made to demonstrate the advantages that a conservation farming system can offer to livestock production. Consequently, the majority of landholders have continued with the same livestock management pattern that existed with a conventional farming system.

The failure to understand how a conservation farming system can be integrated with or affect livestock management and production is a major obstacle to the adoption of conservation farming practice. If returns from cropping relative to livestock continue to decline, then this obstacle will grow in importance.

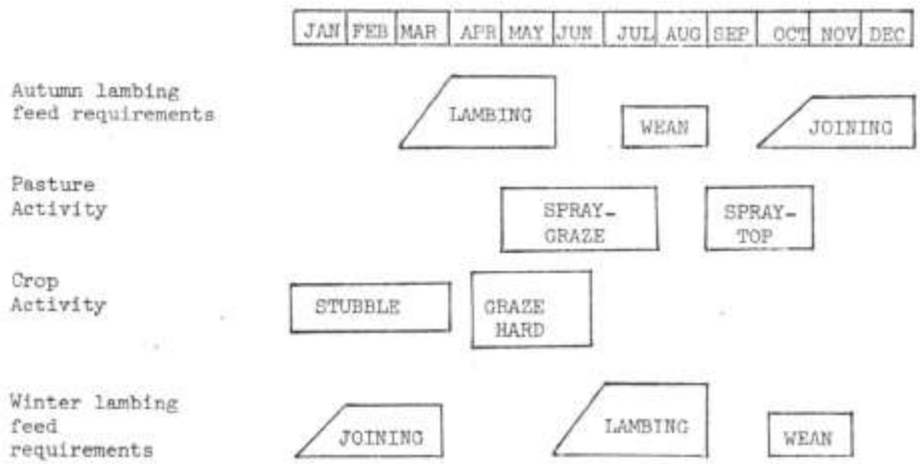
On most properties where direct drilling or a similar practice has been adopted the only major difference in the livestock grazing pattern is that sheep are no longer grazed on fallow paddocks during autumn. Instead they are run, at various stocking intensities on proposed cropping paddocks, according to the pre-spraying grazing recommendations for the particular herbicide to be applied prior to sowing.

Crazing prior to herbicide application is acknowledged to be a vital part of the conservation farming system, Sheep are preferred to cattle and dry sheep are more effective than ewes and lambs. Where cattle are the only animals available, high stocking rates may be needed to control growth. This aspect is unlikely to appeal to the average beef producer who likes his cattle to be in good condition at all times.

These recommendations automatically place limitations on the type of sheep to be used for grazing prior to herbicide application. For example, a sheep reproduction cycle involving a spring joining for an autumn lambing is unlikely to fit in with a conservation farming programme. Winter lambing and conservation farming are the most successful combination (Figure 2). Joining is in February/March when the bodyweight of ewes is high and often gaining bodyweight grazing freshly harvested stubble, The post-joining period, when nutrition is not as critical, coincides with the need for autumn grazing in preparation for herbicide application and sowing. The prelamb buildup and lambing can be undertaken on a range of grazing crops and pastures, Finally, the natural spring flush ensures ewes have an abundant milk supply for their lambs. Weaning can be carried out at the end of spring with weaners having sufficient wool to be shorn so as to prevent losses caused by grass seed (Figure 2), In any case the grass seed risk should already have been reduced by spraytopping activities.

In livestock production, the advantages that a winter lambing-conservation farming combination offers to producers, may require a change in the lambing time, Although sheep producers are often reluctant to alter time of lambing, those who wish to adopt successfully a whole, farm approach to conservation farming will need to consider the complementary nature of this combination.

<u>Figure 2.</u> **The relationship between the feed demands of sheep reproduction cycles and the grazing demands of a conservation farming system (adapted from Simpson, 1984).**



In this context, the development of winter wheats for southern Australia also provides great prospects for augmenting pasture feed supplies, Their grazing contribution occurs at a time when pastures could be carried over into the winter feed trough but negating, at least partially, the need for extra land being devoted solely to forage crops.

(g) <u>Pasture Management</u> - Because of the emphasis of research on the cropping aspects of conservation farming little attention has been paid to the contribution of the pasture phase. In particular, the establishment of pasture species and the regeneration of annual legumes following a direct drilled cropping phase need to be clarified. It can be argued that the improvement in soil structure may facilitate the process of burr burial and radical penetration it may conversely be argued that the firmer, relatively undisturbed soils may prove inhibiting to these processes. If the latter is the case, not only will seed ecology and seedling re-establishment be influenced, but a high proportion of seed is at risk of being consumed by animals during summer, More research attention must also be given to pasture establishment by direct drilled methods involving stubble retention and the role of cover crops in these conditions, Direct drilled crops, with their slower early growth(7) may be less competitive to establishing pasture seedlings and therefore more effective for cover cropping.

The trend towards increased intensity of cropping has implications for the bank of hard seed on which many farmers depend for pasture regeneration (3). In addition, Taylor (35), has shown that cultivation buries seed thereby reducing the breakdown of hard seed and improving pasture regeneration after extended cropping periods.

Perhaps consideration needs to be given to appropriate species and cultivars which are more suitable to the requirements of conservation farming in particular districts. More attention must also be paid to grazing management in the spring to enable large quantities of annual legume seed to be set. While weed management of pastures by herbicides can control both broadleaf and grass weeds, caution is needed to prevent a reduction in seed set by subterranean clover, This especially applies where spraytopping is carried out using Roundup[?].

It should be noted that improved utilisation of stubble by livestock as previously described has substantial potential benefits in pasture production - it occurs at a time in southern Australia when feed supply is short, where lucerne pastures are struggling and often when annual pastures are regenerating. It therefore provides some respite to these pastures, in some years enabling them to regenerate more quickly with consequent benefits to animal production.

4. The potential role of simulation in research and extension of soil- conserving agricultural systems

We began by pointing to the gap between the relative simplicity of experiments and the complexity of the farm. At present, the farmer is left to integrate the research data and incorporate it into his own farm. Since the concepts of systems analysis and simulation modelling were first conceived in the 1960s they have been used widely to integrate the interacting components of complex systems. What application do they have in agriculture, and particularly to conservation farming systems?

With soil conservation as the major aim of a new agricultural system, we can define the components for inclusion in the systems (crop species, pasture species, weed control methods, cultivation options, stubble options, disease control options, stocking rate, etc). Clearly, with the combinations and permutations of the options of these components, there are hundreds of options or tactical day-to-day decisions to be made in order to successfully manage such a system. These decisions are further complicated by the uncertainty of climate and of commodity prices.

Classical agricultural experimentation techniques can only be used to investigate a small number of options in a few locations over a relatively short period of time. Even experiments with agricultural systems (e.g. (34)) suffer from too few treatments, inflexibility with respect to management and change of treatments, and from results which are valid strictly for the sites and seasons tested. Such experiments frequently give no insight to the mechanisms involved.

There is clearly a need to synthesise the information from many such experiments into a framework which will:

- adequately represent the system; and
- define the relevant management options.

This can be achieved by the development of simulation models. Such models can then be used to analyse the performance of the system under different management and environment conditions.

Economic analysis can then be applied to any combination of options and exogenous variables. Thus many criteria can be applied to decide what is a successful strategy for management of the system. Economic objectives such as profit, stability of income and cash flow can be considered together with other imperatives such as erosion, soil organic matter, fuel conservation.

Each objective can be assigned limits of acceptable results.

The development of such a model would in the first instance be a conceptual framework into which existing models which simulate parts of the overall system could be incorporated, Many such models now exist (water balance, erosion, crop and pasture growth, etc), The model can then be expanded in detail by successive identification of:

- major subsystems (e.g. wheat growth, lupin growth, fallow water);
- important components and relationships within each subsystem;
- links between subsystems;
- important environmental variables;
- important management variables.

The process of modelling invariably identifies the gaps in our knowledge and results in a list of areas of research which are relevant to a full definition of the system. Once a model has been developed, sensitivity analysis can be used to allocate priorities for further research since parameters which have greater impact on the final output of the model must be more accurately defined, Sensitivity analysis would also alert advisory workers to the factors most affecting productivity or parameters of concern to soil stability.

Up to this stage the main benefits of the modelling exercises would accrue through improved appreciation of the system by research and advisory workers.

However, once a model has been validated it is reasonable to expect that farmers working together with advisers could use the model for day-to-day decisions on the farm.

To date in Australia no comprehensive model of an agricultural system has been developed or used to aid farm management. "SiragCrop" a joint venture

by CSIRO and the NSW Department of Agriculture, aims to do this for irrigated wheat.

The project is ambitious and will take some years to come to fruition. It would be naive to expect useful management-models of more complex dryland farming systems to be developed in the foreseeable future. Yet such models offer one of the best long-term prospects of raising productivity through research.

Successful management models <u>have</u> been developed for major <u>subsystems</u> or sets of interacting subsystems. Management models to aid fertiliser decisions (in the context of the whole-farm operation) have been used, as have pests and disease management models (e.g. Siratac) and water management models

in both irrigated and dryland crops. The application of modelling to water management has been considered already. These models do not represent the whole system (in detail), and they are often imperfect, but they have proven useful in aiding management.

5. A new approach to extension

There is an urgent need for farmers to adopt the conservation farming ethic. For this to happen extension services, educational institutions and commercial companies must become more professional in de-emphasising reduced tillage as a technique and increasingly emphasise it as part of a whole-farm system. A significant proportion of the farming population has tried or is using direct drilling, minimum tillage or no-till fallow and these techniques now have credibility. The next stage therefore is to develop these techniques into whole-farm systems. Vance and Chamala (36) describe an extension programme which complements the cropping systems approach now being developed by researchers in Queensland, Vance and Chamala indicate that whole conservation cropping systems require a high degree of management skill, and that this skill can be developed with an appropriate extension programme.

Central to the Vance and Chamala approach is the view that extension programmes are best planned when the specific needs of the target group have been identified. The idea is not new, as market surveys have been conducted by industry for many years. Yet it is very encouraging to see "public sector" extension specialists adopting this approach. The University of Queensland and the Queensland Department of Primary Industries have jointly studied farmers and the decision-making processes in relation to conservation farming. The practical result was an "information package" involving both written material and videotapes (4) which serves as a model for others. ICI adopted a similar approach when first promoting direct drilling.

B. Conclusion

Systems of farming will only be attractive to farmers where clear economic benefits are to be realised. Where herbicides are able to replace cultivation more cheaply, or in seasons where herbicides are not required, direct drilling will therefore be attractive. at other times farmers will revert to farming methods which are more cost effective. This situation, while meeting the economic constraints faced by farmers, is not consistent with the objective of soil conservation. It is our hope that soil conserving practices be consistently and universally adopted throughout Australia in order to maintain the productive capacity of our soils.

It is therefore imperative that farming systems for the different environments be developed and promoted which are consistent with the conservation ethic but which necessarily provide ECONOMIC incentives for their adoption. These economic incentives must be available in BOTH the short and long term. Simply promoting the technique of direct drilling or equivalent will not provide these incentives consistently and they will continue to be adopted on an *ad hoc* basis.

We therefore encourage researchers and research administrators to take account of the need to design and conduct experiments in the context of whole-farm systems. This is not to suggest that all researchers become systems analysts but rather that the data generated from their experiments be readily suitable for use in models and in systems analysis. A summary of those areas identified in this paper as requiring further research in order to encourage adoption of conservation farming is shown below:

(a) Technical

- stubble management
- incorporation and retention
- handling at sowing
- supplements for improved livestock utilisation
- pests and diseases
- ecological understanding for development of management systems
- pastures
- establishment by direct drilling including role of stubble retention and cover crops
- adaptability of species and cultivars
- herbicides
- more information on rates, water volumes, mixtures, spray technology, stubble

(b) Regulatory

- national approach to pesticide usage

(c) Economic

- integration of reduced cultivation techniques into whole farm systems

(d) Extension

- understanding of reasons for adoption and non-adoption
- methodology of promotion of conservation farming
- ranking of importance of factors influencing soil degradation

(e) Modelling

- development of whole farm models involving economics

We urge extension officers to promote these soil conservation methods in the context of the whole farm. Their consistent adoption will only take place if the economic benefits can be demonstrated. This is unlikely by promotion of the techniques in isolation from the whole farm.

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References

82. Allen, P.G. 1982. Proc. 2nd Aust. Agron. Conf. Wagga Wagga : 323.

83. Berndt, R.D. and White, 6.J. 197b. Agric. Met. lb: 221-9.

84. Carter, S.D., Wolfe, E.C. and Francis, G.M. 1982. Proc. Aust. Agron. Cont., Wagga Wagga: 1b8-82.

85. Criamala, S., Graham, D., Hepworth, L., Pitkeathly, A., Bateman, R. and Keith, K.J. 1964. Developing and Testing of a Conservation Cropping Information Package. Unit. Old. and Qld. Dept. Prim. Ind. 44 pp.

86. 5. Cooke, J.W., Willatt, S.T. and Ford, 6.W. 1985. Proc. 3rd Aust. Agron. Conf., Hobart.

87. b. Cornish, P.S. 1983. Proc. District Agron. Conf. NSW Dept. Agric. Orange.

88. Cornish, P.S. 1985. Proc. 3rd Aust. Agron. Conf., Hobart.

89. Dillon, T. 19o3. Proc. Nat. Workshop on Weeds in Reduced Tillage Cropping Systems, Horsham: 19-21.

90. 9. Ellington, A. 1984. Direct Drill Farmer and Grazier, July: 14.

91. 1U.. French, i.J. and Schultz, J.E. 1984. Aust. J. Agric. Res. 35: 765-75.

92. Goody, D. and Brennan, J.P. 1984. NSW Department of Agriculture Eco. bull. No. 4.

93. Grierson, I.T. and Allen, P&G. 1977. Aust. J. Exp. Agric. Anim. Husb. 17: 406-8.

94. Hamilton, 6.J.,Packer, I.J. and Lynch, L.6. 1983. Proc. Conf. on Conservation Tillage, Wagga Wa6ga: 12.

95. Hill, J. and Butt, S. 1984. Proc. "Pros and Cons of Stubble Retention" conference, Ryden, WA: 47-51.

96. O. Holland, J.F. and Felton, W.L. 1983. Proc. "No-Tillage Crop Production in Northern NSW" Conf, Tamworth: 81-9.

97. Holland, J.F. and Kidge, P.S. 1964. Proc. 3rd Aust. Agron. Conf., Hobart.

98. Kollmorgen, J.F. and Ridge, P.S. 1964. Proc. Workshop on root and crown rots of wheat. Adelaide: 24-9.

99. Lovett, J.V., Moult, E.H., Jessop, R.S. and Purvis, CAE. 1982. Proc. 2nd Aust. Agron. Conf., Wagga Wagga: 101-15.

100. Macadam, RED. and Southwood, O.K. 1968. Agric.Gaz. NSW 79(8): 490-2. 2U.

101. MacNish. 1983. Australasian Plant Path. 12:49.

102. Mulholland, J.6., Coombe, JAB., Freer, M. and McManus, W.R. 1976. Aust. J. Agric. Res. 27: 881-93.

103. Mulholland, J.6. and Coombe, J.B. 1979. Aust. J. Exp. Agric. Anim. Husb. 19: 23-31.

104. Packer, 1.J., Hamilton, 6.J., Craze, B. and Doust, R. 1985. Proc. 3rd Aust. Agron. Conf., Hobart.

105. Patterson, K. 1984. Farm 5 (ii): 32-3b.

106. Pearce, 6.A. 1972. J. Agric. WA 13: 16-19.

107. Pearce, 6.A. and Holmes, J.E. 1976. J. Agric. WA. 17: 77-80. 27.

108. Pratley, J.E. 1983. Proceedings 12th Riverina Outlook Conf., Wagga Wagga: 9-20.

109. Pratley, J.E. 1965. Proc. 3rd Aust. Agron. Conf., Hobart.

110. Rees, K.C. and Plat, W.J. 1979. Aust. J. Exp. Agric. Anima. Husb. 19: 3b9-72.

111. 3U. Rovira, A.D. 1984. Proc. Workshop on root and crown rots of wheat. Adelaide: 0-14.

112. Simpson, I. 1984. Proc. Southern Conserv. Workshop: Yanco.

113. Stallwood, P. 1983. Proc. "Potential for Chemical Treatment of Stubble in Western Australia" Seminar, Beverley, WA: 1-b.

114. Standing Committee on Soil Conservation. 1983. Review of Activities 1962-63, 48th Meeting, Tasmania.

115. Taylor, A.. and Lill, W.J. 1982. Proc. 2nd Aust. Agron. Conf., Wagga Wagga: 190.

116. Taylor, G.B. 1980. Proc. Aust. Agron. Conf., Lawes: 193.

117. Jo. Vance, P.N. and Chamala, S. 1985. Proc. 3rd Aust. Agron. Conf., Hobart.

Further Reading

The Direct Drill Farmer and Crazier, Special Edition "Weed Management" 1983. Published by F.8. Moroney and Co. Perth. Proceedings of 13th Revering Outlook Conference, "Ripping Yarns - the story of soil compaction" held at Riverina College, Wagga Wagga, July, 1984.

APPENDIX 1. Yield of direct drilled wheat relative to that from conventional cultivation.

conventional cultivation.

LOCATION		YIELD relative to conventional	REFERENCE*
NSW	Murrumbateman	lower	Fischer *et al.* (1981)
	Jugiong	lower	Fischer *et al.* (1981)
	Wagga	higher	Fischer *et al.* (1981)
		higher	Cornish and McNeill (1981)
		higher	Taylor and Lill (1981)
		higher	Pratley and McNeill (1982)
	Yanco	higher	Bacon (1982)
VIC	Rutherglen (many experiments)	equal	Ridge (1981)
	Bendigo (incl.fallow)	lower	Cooke and Willatt (1982)
	Mallee/Wimmera (inc.fallow)	lower	Ridge (1983)
SA	Avon	lower	Rovira (1981)
	Field & Chapman bore	lower	King (1981)
	Lameroo	lower	Maynard (1981)
	Roseworthy	equal	Hodgkins *et al.* (1981)
		lower, equal	Hodgkins *et al.* (1982)
		lower	McCord *et al.* (1981)
WA	Avondale	higher)	Jarvis (1981)
	Badgingarra	lower)	
	Esperance	higher)	
	Merredin	lower)	
	Mt.Barker	lower)	
	Wongan Hills	lower)	

* see footnote to Appendix II

<u>APPENDIX II.</u> Yield from no-till fallow relative to that from conventional fallow.

LOCATION	YIELD relative to conventional	REFERENCE*
QLD		
Southern Queensland	higher	Ward and Bateman (1982)
Darling Downs	higher	Ward (1983)
East Darling Downs	lower	Freebairn (1984)
Central Queensland	higher, equal	Sallaway *et al.* (1984)
Central Queensland	higher	Spackman *et al.* (1984)
NSW		
Gurley	higher	Holland *et al.* (1982)
Warialda, Breeza	equal	Felton (1984)
Winton	lower	Felton (1984)
Tamworth (several sites)	higher	Holland and Doyle (1981)
	higher	Felton (1983)
	higher	Felton *et al.* (1983)
	lower/higher	Martin and Felton (1984) Ford (1984)
Duri	higher	Felton *et al.* (1983)
North Star	lower	Harte and Armstrong (1984)
Gunnedah	lower	Hayes and Campbell (1981)
	lower	Holland and Doyle (1981)
	lower	Lloyd (1981)
	equal	Thompson and Marschke (1984)
Moree	higher	Hayes and Campbell (1981)
Bellata	equal)	Colless (1984)
Bugalde	higher)	
Werris Creek	higher	Colless and Popovic (1984)
Condobolin	higher	Fettell (1984)

* References are to the following publications:

1901 - Proceedings of National Workshop on Tillage Systems for Crop Production, Roseworthy Agricultural College, August-September 1981.

1982 - Proceedings of Australian Agronomy Conference, Riverina College of Advanced Education, Wagga Wagga, July 1982.

1983 - Proceedings of National Workshop on Weeds in Reduced Tillage Cropping Systems, Horsham, March 1983.

1984 - Proceedings of Meeting on No-Tillage Crop Production in Northern NSW, Tamworth, April 1984.