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The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Contents

1. Introduction

Tillage rearranges "The entire topsoil structure"[1]. Placing seed in the soil without disturbing the whole topsoil area is therefore sowing without tillage, known as no-tillage or zero-tillage sowing. Direct drilling is defined by the Western Australian No-Tillage Farmers Association Inc (WANTFA) as sowing in a single pass, with full cut-out tine points or discs.

Tillage reduces the infiltration of rainfall into loamy soils in Western Australia[1], thereby increasing runoff, though runoff may initially decrease following intense rainfall with tillage, because of increased surface roughness and other effects. Tillage also loosens the soil surface, increasing soil credibility. Most severe water erosion typically occurs on tilled soils.[2] Techniques of sowing without tillage using tined and disced no-till seeders were trialled on a range of soils, achieving grain yields generally comparable with direct drilling.[2,3]

Water erosion was reduced by a factor of thirty-five, on approximately 2 ha contour bays near Geraldton, Western Australia.[6] When soils become saturated, runoff occurs regardless of tillage treatment, as observed on 1 ha contour bays near Beverley, 90 km east of Perth. Earthworm numbers and size were found to increase with minimum and, particularly, no-till sowing[6], possibly indicating improved conditions for soil microorganisms. Further advantages of no-till sowing and direct drilling include the possibility of earlier sowing - because time is not lost in tillage - enabling higher potential yields of longer-growing-season crop varieties in the Mediterranean-type climate of south-western Australia.

The number of Western Australian farmers sowing without tillage has increased from a mere handful in 1990. The Australian Bureau of Statistics Agricultural Census referring to the 1993 seeding season, returned 220 (1.9%) of farmers then sowing 1.9% of the 5.6 million cropped hectares without tillage using narrow points.[7] Disced no-till seeder sales to 1993 are estimated at about 130. Therefore, some 350, (or 3.8% of an estimated 9000 commercial gram growers) are considered to have sown using narrow tine points or disced no-till seeders in 1993. Crops were direct-drilled on a further 17% of the cropped area. By 1995, on the basis of reported sales of no-till seeder openers, it is possible that some 10% of grain-growers sowed without tillage, with adoption estimated at 35% on sandy-surfaced soils in high wind-erosion-hazard, South Coastal areas. Further reported sales of no-till openers and seeders suggest a further large increase in 1996.

The Western Australian No-till Farmers Association (WANTFA) was formed in 1992 to:

(i) facilitate the exchange of ideas,

(ii) encourage no-till research, and

(iii) disseminate no-till information

WANTFA considered that it would be desirable to learn from developments in no-till in North America. In view of my 1991 Wesfarmers Churchill Fellowship study tour of

no-till seeders and their adoption in North America[8], I was requested, as Secretary, to lead a study tour.

The 1994 WANTFA No-till Study Tour of North America was arranged to follow on from a trip on leave to Ireland, and attendance at the CIGR (International Agricultural Engineering) Congress in Milan, Italy (*Appendix 1*) and International Soil Tillage Research Organisation Conference, in Aalborg, Denmark - later substituted because of scheduling clashes with a Holistic Resource Management Introductory Course and Amish Community Visit in Ohio, USA - financially supported by the Grains Research and Development Corporation. On the cancellation of the latter course and visit, GRDC kindly approved substituting an informal introduction to holistic management and a no-till study tour in Ohio and Kentucky, USA, (*Appendix 2*) The WANTFA No-till Study Tour followed immediately (itinerary shown on *Appendix 3*, and list of participants under Acknowledgements)

Salient features of no-till and relevant reduced-tillage sowing systems in the various areas visited are reported, followed by discussion of soil physical and biological aspects, together with economic and sociological issues considered relevant to Western Australia.

3. Relevance to Western Australia

Aspects of no-tillage sowing systems encountered in North America which are considered most relevant to Western Australia are considered below under holistic management, soil physical biological, economic and sociological headings

3.1 Holistic management

No-till sowing involves changes to whole farm systems, particularly for weed and disease-control purposes, such as by reducing weed seed-set in appropriate crop rotations It is therefore desirable to consider the implications of no-till practices sowing whole-systems management in Western Australia

Holistic Management is described by our Californian Work Family hosts as

" …a value-driven, goal-orientated thought process, which uses a thought model that causes decisions to be made that are ecologically sound, economically viable and socially just, and which result in an increase in biodiversity on the plant"

The Holistic Management model [18] deals with items only as wholes within wholes

Holistic Management has been developed and propagated by scientist Allan Savory, starting in Southern and Northern Rhodesia (now Zimbabwe and Zambia) and, after independence, the United States Holistic Management is currently practiced by farmers and ranchers in South Africa, Zimbabwe, Sweden, Canada, the United Sates, Mexico, Argentina and Australia

In his book "Holistic Resource Management",[18] Savory describes his initial puzzlement as to why totally de-stocked rangelands in Africa continued to degrade, when then widely-accepted scientific theory concluded that the perennial grasses should prosper After much discussion, particularly in South Africa, and after reading the French pasture ecologist, Andre Voisin, a concept which Savory describes as "brittleness" came to him Brittle-tending environments generally have too low a rainfall to support a solid woody cover, poor annual distribution of humidity and slow decay of dead plants, mainly by oxidation and weathering from the top down He believes that the concept of brittleness explains how rangeland can be simultaneously overgrazed and understocked He hypothesies that animals grazing at too low a stocking rate for too long overgraze some palatable species, allowing less palatable species to dominate the plant community - that overgrazing has to do with time1 Densely grazing herds of aminals, bunched-up by the presence of predators, have a different grazing effect than animals at low density

Savory quotes Einstein in observing how it is essential to have a goal which includes the desired quality of life and future landscape, as well as the forms of production desired Such a goal therefore articulates the deepest values people hold Technical specialties are seen from the perspective of the whole Analogously, the shaded pixels in Fig 25 do not appear as a whole until you squint your eyes As you screw up your eyes and squint, and the edges blur into each other, can you see a picture of Abraham Lincoln ?

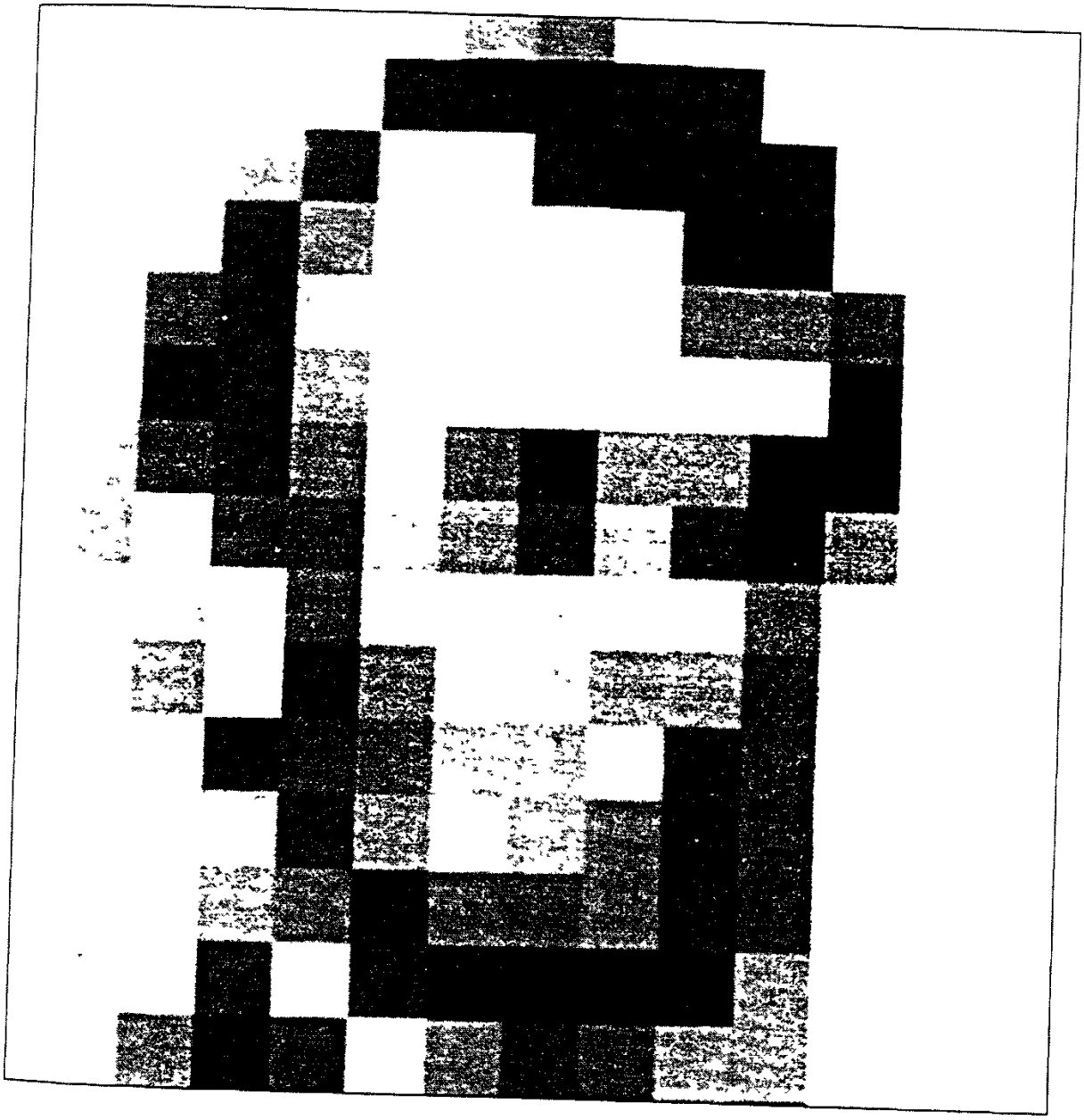

Figure 25. This picture appears as a whole only after you squint, causing the shaded pixels to blur at the edges Courtesy 'Holistic Resource Management" Allan Savory, Island Press 1991)

The Holistic Management model includes seven criteria for testing any new measure to be applied, [18] (Table 1), such as no-till sowing.

Our Work family hosts in Calformia observe that no-till sowing passes the seven testing questions better than any other crop establishment method in their farm operation "but not all that well." They look at each constituent part of a system from the point of view of the whole, always with a three-part quality of life, forms of production and desired future landscape goal in mind.

George and Elaine Work were later brought to Western Australia by the Koolanooka-Bowgada Landcare Group and the Land Management Society of Western Australia in March 1995 to speak on holistic management at meetings in Morawa, Geraldton, Frankland and Perth. George had previously made the acquaintance of Holistic Management-registered educator Bruce Ward, of the Moree District Business Centre (NSW) at the February '95 Holistic Management convention in Albuquerque.

Foundation WANTFA committee member Ian Edwards of Beverley had previously been reading of Frenchman, Andre Voisin's pasture theories, which Allan Savory incorporated into Holistic Management. Mention of Holistic Management to Ian resulted in his arranging for Bruce Ward to conduct one-day Holistic Management Introductory Courses at Morawa, Boyup Brook and Perth, in October 1995. Ten people also undertook the nine-day Holistic Management Training Course in Perth later in October and November 1995 - myself in a private capacity as a part-time farmer, while on leave. The Training Course consists of an introduction to Holistic Management (three days), biological monitoring and land/grazing planning (three days), wealth generation (two days) and one day consulting time at the farm or business of each participant.

Holistic Management offers a methodology for incorporating scientific information into whole systems, for the good of the whole, including people and our legacy to future generations. It is increasingly being observed in science that frequently, nobody currently has a brief to manage the whole (eg. Dr John Williams, Assistant-Chief of Soils Division, CSIRO, Canberra at the Western Australian State Landcare Conference, pers. comm. 1995). The Holistic Management model develops a methodology for including the management of the whole in the goal right from the start. It then utilises scientific and other available expertise, where possible, in order to achieve the desired goal.

Table 1. Holistic Management testing questions (Source: Centre for Holistic Management, 1010 Tijeras NW, Albuquerque, New Mexico 87102 - 9891, USA).

Testing Questions

1. Whole Ecosystem:

1.1 Position on a brittleness scale of one (non-brittle) to ten?

1.2 Will the proposed action move the ecosystem towards or away from the landscape part of goal?

2. Weak Link (Used in one or more of three situations):

2.1 Logjam - Is anything holding up steady progress to the goal?

2.2 Endangered or problem organisms - Are we looking first at the weakest part of the life cycle?

2.3 Solar chain - Are we addressing the weakest link this year in the chain from sun to money?

3. Cause & Effect

3.1 Are we dealing with a problem or a symptom? Could this action unleash many problems (symptoms) through defying succession?

4. Marginal Reaction (Comparing two or more actions):

4.1 Which action will give the greatest thrust towards the goal for each additional unit ($ or labour) of effort?

5. Energy/Wealth Source/Use:

5.1 What is the source of the money/energy? (External, internal, benign, interest, etc.). What is the pattern of use proposed? (Cyclical, consumptive, addictive, building infrastructure, etc.).

6. Gross Margin Analysis (To compare enterprises):

6.1 What does each enterprise, after covering added costs, contribute to covering overheads?

7. Society & Culture (Feelings more than thoughts):

7.1 Will this action really lead to the life we desire, and what will it do to others?

A creative tension appears to have developed with scientists querying particular points of fact, with both Holistic Management, and no-till sowing A common attitude among no-till farmers in Western Australia was articulated at a Crop Establishment Workshop in Jerramungup "Who cares whether every detail is correct, let's get the system correct first and then fine-tune the detail later"' (Gairdner farmer Ross Williams, Chairman of the South Coast Sustainable Agricultural Systems Panel, pers comm., 1995)

Plainly it is early days in developing the creative dimensions of the currently rapid adoption of no-till sowing, in spite of long-standing antagonism among middle and upper management of Agriculture Western Australia The main issue appears to be whole-system management contrasting with a reductionist, scientific research approach The current interest in holistic management in Western Australia would preferably, be assisted to develop in order to achieve improved land treatments on the ground Action appears particularly urgent, in view of scientific predictions of 200 ha of arable land per day being lost to salinity for the next thirty years in Western Australia

A similar " Savory" grazing system is reportedly assisted in New South Wales by the payment of federal subsidies for farmers towards Training Course fees (Greg Brennan, District Leader, Agriculture Western Australia, Derby, pers comm 1995) Subsidies of up to 50% of costs, excluding meals, for more than half-time farmers to attend Holistic Management courses are suggested in Western Australia

3.2 Soil physical aspects

3.2.1 Soil conservation

The most striking physical improvements under no-till sowing systems in North America are frequently said to be soil and water conservation By not loosening the entire topsoil, and leaving vegetative cover on the surface, both water and wind erosion are reduced under no-till sowing Surface runoff and direct soil evaporation are also usually reduced, allowing increased moisture conservation enabling potential crop yield benefits

3.2.1.1 Water erosion

Water erosion was frequently cited by North American farmers during the study tour, as the main reason that they started to apply no-till systems Minimum or conservation tillage was widely considered to have been superseded by no-till sowing on the contour, in order to achieve maximum soil conservation benefits As a consequence, farmers like Neal and Nellie Stringer of Mt Vernon. Ohio, maintain they have kept 15,000 tonnes of topsoil that would have eroded had they not used no-till sowing for the last 20 years[53] Even in cases where runoff has increased without tillage, such as on some, clayey soils in particular34, water erosion has still been reduced, as the soil has not been made more erodable by tillage

An average of 66% of the total soil loss in a 28-year period at Coshocton, Ohio occurring in only five rainfall events is mirrored at Chapman, near Geraldton in

Western Australia, where almost all of the water erosion in a nine-year period occurred in a single rainstorm6 In Queensland, also, more than 70% of the total erosion occurred as a result of only six storms in a 14-year period 36 Soil loss in two consecutive four-year periods had averaged 78 t/ha and 14 t/ha on a stubble-burnt treatment If the measurements had not started until the beginning of the second four-year period, a misleading conclusion may have been drawn about the magnitude of soil loss in the area It is therefore essential to assess average water erosion rates using **long-term** measurements

3.2.1.2 Wind erosion

Thirty percent vegetative soil cover, or 450 kg/ha - whichever is the larger - are regarded as satisfying conservation tillage criteria in the United States [3l] However, at least 40-60% vegetative soil cover is considered to be required to reduce wind erosion to acceptable levels on sandy-surfaced soils in Western Australia [37]

In the five-year period 1989-93 (inclusive) the total area of traditional tillage in the USA declined by about the same amount, as no-till sowing increased - about 10 million hectares37

In Western Australia, no-tillage sowing has increased more rapidly from a very low base estimated at 0 1% in the 1990's, particularly on sandy-surfaced soils in South-Coastal areas subject to extreme wind erosion hazard For example, while some 10% of farmers are estimated by the Western Australian No-Tillage Farmers' Association (Inc) to have sown without tillage in 1995, in South Coastal areas the estimated figure is 35%

3.2.1.3 Soil structure

Soil structural improvement is commonly acclaimed with minimum and, particularly, no-till sowing in North America - frequently after about five years of no-till Land which has been under pasture for several years - up to ten years in the US Conservation Reserve Program -frequently can be sown without tillage, with minimal erosion Near Pierre in South Dakota, for example, no-till corn had been sown on a relatively steep land (up to about 10% slope) which was formerly native prairie, without any evident sign of erosion on the 100 m-long slope.

In Western Australia also, soil structural improvements such as increasing organic carbon in the 0-25 mm-deep layer[4] is frequently evident after three or more years under minimum and no-till sowing [4]. Effects can be obvious on some soils For example, on long-term tillage trials on a sandy clay-loam soil at Merredin Research Station, a map of plot lay-out was unnecessary for inspection the treatments were obvious by eye, from the different soil tilth on each treatment ' After sowing for the fifth consecutive year in 1981, the multiple-tilled soil had many large blocks of 20-40 mm maximum dimension The minimum tillage had a well aggregated soil tilth of a few millimetres maximum crumb dimension, while the triple-disc-sown soil had a relatively smooth, minimally disturbed surface'

3.2.2 Soil moisture conservation

Increased moisture conservation in the soil profile under no-till sowing with stubble retention, typically enables more intensive crop rotations in North America[35] Even in cases where runoff increases, total plant-available water may increase by as much as 18% because of increased moisture conservation under no-till sowing, compared with a conservation tillage stubble mulch in Texas[34], for example.

Soil moisture conservation was also increased when half of a 4 6 t/ha mass of stubble was still standing 46 cm-tall after harvest, with the other half lying flat on the ground, compared to either three-quarters on the ground, or all flat on the ground[39]. In one five-week dry spell after a mid-summer rain in Colorado, only 15 1 mm was lost from the half flat - half standing treatment, and about 19 mm from the % flat - % standing and all flat treatments, and 23 1 mm from bare soil, for example.

Anecdotal evidence in Western Australia suggests that no-till sowing with full residue retention may lead to increased waterlogging of soil profiles in wetter winters, as occurred in South Coastal areas in 1993, because of reduced evaporation with the stubble cover In most seasons, however, soil water is limiting for early sowing for maximum crop yields, and full stubble residue retention is beneficial for crop establishment and growth.

3.3 Soil biological aspects

Legumes in rotation with cool and warm-season grasses are considered to increase crop yields with no-till sowing in North America It is even concluded on the Northern Great Plains, that unless rotations are intensified, there is likely to be little economic benefit from adopting no-till sowing35 Canola in particular has been observed to influence weed germination in the following crop in Western Australia, for example.

A typical minimum-tillage rotation practiced by Amish farmers in Ohio, is one or two years of lucerne-based forage crop, followed by corn, oats and winter wheat [40] Increased soil enzyme (alkaline phosphatase) activity, [16] - together with increased ponded infiltration relative to no-tillage sowing - suggest the desirability of further investigation of the effects of various crop rotations, and the different forms of the increased organic matter, on soil microorganisms under minimum and no-till sowing.

Rhizoctonia root disease was not a recognised problem in the areas visited, though reportedly present on a previous visit[8] to the Palouse Region of the Pacific Northwest (Washington, Idaho and Oregon). In Western Australia and South Australia, it has been concluded that, provided the soil is disturbed below the seed zone, point design is relatively unimportant for control of *Rhizoctonia solani* Kuhn. Limited results suggest that disturbance 25 mm below seed depth provided equivalent control as disturbance 50 mm below. [41] Trials in Western Australia in 1994 suggested no reduction from about 30% rhizoctonia bare-patch using 32 mm-wide, twelve-wave fluted coulters set to work about 40 mm below seed depth. However, some 1995 trials in the Esperance area suggest a decreased incidence of rhizoctonia after sowing with the fluted coulters (W Crabtree, pers comm 1995).

The incidence of take-all disease (caused by Gaeumannomyces gramims) was also found to be reduced with minimal-disturbance, no-till sowing in the Esperance Region

of Western Australia, compared with direct-drilled and traditionally-tilled treatments, in 11 out of 29 trials - with no difference between the sowing systems in the remaining trials. [42]

Macro-scale biological problems with no-till sowing include burrowing animals such as gophers in North America. Sheep and cattle tracks running downslope channel overland flow, leading to possible nil or gully erosion in Western Australia. Harvesting approximately on the contour can minimise the incidence of down-slope wheel-tracks, which stock tend to follow. Tracks are typically formed by grazing stock during their daily trips to the water, however. Possibly some form of soil smoothening or filling of stock tracks, may be required after several years of no-till sowing to minimise rilling in grazing situations on sloping soils.

Weed and pest problems are considered to be manageable in many, but not all, changed rotations under no-tillage sowing systems in North America. For example, a biennial barley-grass, foxtail barley (*Hordeum vubatim*) had previously been readily controlled using tillage, and is now economically controllable also using only herbicides, such as glyphosate with ammonium nitrate added in a tank mix. In drier areas, such as in south-western Saskatchewan (average annual precipitation -300 mm) water stress may frequently limit the uptake of systemic herbicides, causing farmers to resort to minimum tillage for economic control of foxtail barley.

Some perennial weeds such as green foxtail (*Setana viridis*), Canada thistle (*Cirsium arvense*) and quack grass (*Agropyron repens*) are now also chemically controllable However, others, such as wild pansy (*Viola arvensis*), may present a problem. Manitoba no-till farmer, Robert Stevenson, for example, wonders whether still other perennial weeds may make minimum tillage a preferable long-term option to no-till sowing. It remains possible that some perennial plants on road reserves in Western Australia may become problem weeds in adjacent paddocks sown without tillage, particularly in medium and high rainfall areas where the slightly longer growing season may favour over-summering perennials. Agriculture Canada weed ecologist, Doug Derksen's warning against complacency on weed control is perhaps relevant. Sound back-up strategies must be kept on hand, in case the currently preferred weed-control option fails.

One problem cited in Kentucky was that no-till fields tend to revert to the native, woody shrubs and trees, though applying available herbicides has now successfully controlled such woody weeds. The Detecta-Spray may allow economical and safe control of native perennial species by herbicides and grazing in Western Australia. An occasional tillage operation may even prove necessary in the long-term, under otherwise no-tillage systems.

A possibly gloomy spectre for both no-till and conventional tillage systems is herbicide resistance, reportedly more so in Canada than in southern Australia. Reduced weed establishment and decreased vigour with less mineralised nitrogen under no-till, indicate the complexity of the issues raised. On-going research is plainly required in order to establish the long-term viability of weed-control under no-till sowing.

3.4 Economic aspects

Reduced costs per hectare have been widely acclaimed by farmers applying no-till systems in North America. Detailed quantification of a whole-farm plan including changes in related farming practices, showed $60/ha increased annual net return to land and management under no-till sowing in Tennessee[28] for example. Reduced costs with generally comparable or increased crop yields have also apparently motivated many Western Australian farmers to change to no-till sowing.

3.4.1 Alternative crops

Including more legumes such as faba beans, chickpeas, narrow-leaved and albus lupins, in rotations to improve the nitrogen budget, may enhance profits under no-till sowing, particularly through improved timeliness of sowing. A disease break and other benefits from longer rotations possibly in some circumstances including warm-season grasses (eg sorghum), may prove even more important than nitrogen fixation.

Economically, a wider range of crops grown with no-till sowing relies on the development of satisfactory markets. In North America, "organic", reduced and minimum-tillage farms have sometimes returned decreased profits because of lower prices and poorly-developed markets for the alternative crops[32]. In order to maximise returns from new crop rotations under no-till sowing in Western Australia, satisfactory markets must be developed - possibly including new crops such as grain sorghum or safflower, in addition to already-established crops such as canola in rotations including legumes on suitable soils.

In view of the apparent desirability of rotational cropping for improved soil biological status, particularly under no-till sowing, it would appear that the possibility of warm-season grass and broad-leaved crop production and marketing should be further investigated in Western Australia, in addition to the alternative pulse crops currently being developed. Warm-season crops sown to avoid lethal frosts in August or September, may also use deeper soil moisture Therefore more of the following season's rainfall may be stored in their dried-out root zones, reducing deep-drainage to saline aquifers.

Incorporating a range of alternative crop rotations into different farm systems requires much experimentation, with all available data made available to farmers. The various crop yields with no-till sowing, in different rotations should be included as a research priority in Agriculture Western Australia programs.

3.4.2 Costs of adopting no-till sowing

The cost of new seeders was cited as a strong restraining influence on the adoption of no-till sowing, particularly by smaller-scale farmers, in North America. A new 3 m-wide no-till drill typically costs $30,000-$40,000, for example. Therefore, early adopters have tended to be larger farmers, who can reduce unit costs per hectare by economies of scale, with the larger areas sown. In Western Australia, on the other hand, many farmers who already own - or can buy, second-hand - late-model tined seeders, can readily change to no-tillage sowing merely by fitting narrow tine points. Sometimes they may even experience a **reduced** cost per hectare, because of

improved wear characteristics of tungsten carbide-protected, narrow points. Disced no-till seeder openers, on the other hand, typically require a more substantial capital outlay in Western Australia, as in North America, dampening adoption rates by smaller-scale producers.

Four local tined seeder opener manufacturers have assisted in the relatively rapid development of no-tillage seeder openers in Western Australia, (Primary Sales Australia, Ausplow Pty Ltd and Agmaster of Collie and Nichols Triple-Action No-Till) and one disced opener manufacturer (Walkers of Merredin). In addition, numerous imports have been introduced, for example, Keech Castings® points from New South Wales, and Great Plains®, K-Hart®, Conserva-Pak®, Flexicoil, Morris, Bourgault, Harmon and Concord as well as John Deere and other seeders from North America.

3.5 Sociological aspects

Nitrogen input from legumes in rotation, together with improved disease and pest control and other benefits, have led to further consideration of agricultural systems in Ohio[11,15]. The relatively stable and profitable biological and social systems of Amish agriculture may be viewed as perhaps a harbinger of things to come with no-till systems. Sustainability clearly depends on social as well as biological and economic systems. The three-part goal of Holistic Management (i) quality of life, (ii) forms of production, and (iii) future landscape, are clearly relevant to long-term sustainability.

The development of legume-based rotations in minimum and no-till sowing in North America, has been likened to the process which immediately preceded the industrial revolution in Europe.[12] Both the forebears of the Amish, as religious heretics in Europe, and "organic", reduced, minimum tillage and no-till farmers in North America, have generally had little communication with official agronomic and soil conservation research and extension personnel. It is argued that such fringe, marginalised people could therefore more readily think of developing farming systems outside the bounds of the conventional wisdom of the day, and relatively free of peer pressure from the mainstream society. As a result, groups such as the Practical Farmers of Iowa and Innovative Farmers of Ohio, sprang up to provide communication and mutual reinforcement.[14] Parallels exist in Western Australia, in the Western Australian No-Tillage Farmers Association Inc. (WANTFA) and the Land Management Society of Western Australia, for example.

No-till groups such as the cross-border Manitoba-North Dakota Zero Tillage Farmers Association, evidently foster a camaraderie in the face of relatively slow adoption of no-till sowing, compared with adoption rates since 1990 in Western Australia. Complex crop rotational benefits may take some years to become evident. Most farmers initially adhere to traditional practices for economic survival, until the benefits of the new practices become evident. Somewhat paradoxically, the marginal economic conditions in Western Australia -with both wool and wheat prices simultaneously drastically low, starting in 1990 - appears to have increased the adoption of no-till sowing, to cut costs and increase potential yields with earlier sowing in Western Australia.

It is evident that shared cultural values in North American communities, facilitate the adoption of stable land treatment systems.[43] Amish communities, for example, have

maintained essentially pre-industrial values by means of an internal community discipline, through a series of arrangements with the modern world.[44]

The Amish are not necessarily against technology, but they refuse to be dominated by technology[40]. That there are less restrictions on the use of herbicides, even among the Old Order Amish, than on many other agricultural aids (such as the total ban on field use of tractors, and on trucks, cars and mains electricity and computers) testifies to the open-mindedness of such communities. Artificial insemination for their dairy cattle, for example, and modern medical and pharmaceutical services are acceptable, but all government social security - including agricultural price support - is rejected on principle. The local Soil Conservation Service agent at Millersburg, Holmes County, Ohio - the largest Amish Community in the world - even developed a boom sprayer towed by a horse, in order to further conservation farming, showing how accepting the community was of herbicide technology, for example. The "father of no-tillage," S.H Phillips also observes that Amish and less-strict Mennonite farmers, actively sought information on, and were among the first to apply, no-till cropping practices in Kentucky.

However, the Amish find little need to use herbicides in reduced and minimum-tillage farming systems, perhaps because of healthy, relatively stable cropping rotations. The dominance of large, frequently manipulative corporations, together with the evident deaths of birds and other wildlife following the application of some herbicides, [40] raise suspicions among the Amish about the wisdom of dependence on herbicides for their agricultural stability.

Greater profits from no-till sowing in North America and Western Australia may result in decreasing tillage under a continuing cost-price squeeze. If so, a major benefit will be that soil will be conserved for future generations. It is, perhaps, curious that soil conservation authorities have reportedly, so far, generally ignored the benefits of no-till sowing - particularly since there may well be more soil erosion in the United States today than there was when the US Department of Agriculture's Soil Conservation Service was first established with the express aim of reducing soil erosion, some 50 years ago[45].

US farmers not achieving the required 30% vegetative ground cover will automatically be excluded from all Federal Farm Program price and other support for produce from highly credible land from 1995 Under the 1995 provisions of the US Farm Bill, no-till farmers such as Jim Kmsella of Lexington, Illinois consider that there is simply no need to make his soils more erodable by carrying out even a single tillage operation. He considers that the Natural Resource Conservation Service "are not going to hold anyone's feet over the fire" until they achieve 30% vegetative ground cover. A Service county agent observed in North Dakota that he would be shot if he tried! He therefore endeavours to work with likely non-complying farmers, advising and encouraging them to reduce tillage intensity so that they can comply with the 30% vegetative ground cover requirement from 1995. A US Department of Agriculture visitor to the Pacific Northwest on a fact-finding trip noted, for example " It is the most serious erosion I ve ever seen I can't believe we're paying compliance to farmers with this level of soil runoff."[46]

Farmers have to consider their whole farm system As Indiana no-till farmer Stanley Smock says "No-tilling is something you really have to believe in You have to believe

in your heart that it is right before you begin You have to become almost numb to peer pressure "[47] No-till farmers and farmer groups tend to build on both local experience and scientific information, using available specialist information when required. Such a "bottom-up" approach differs markedly from the traditional "top-down" model of agricultural extension. Extension scientist Niels Rohng, for example has been proclaiming for some years50 that:

"….the best way to improve extension is not to train extension workers, provide them with cars, overhead projectors and otherwise increase their intervention power, but to mobilise organise and train farmers and farmer leaders so that they can become an effective countervailing constituency for government intervention. One way to do this, and 1 suggest no more than a normal practice in such countries as the US, France, Denmark Germany and the Netherlands, is to give control over (part of) the budget for extension and research to farmers' organisations " [49]

He discusses the situation of integrated pest management,[49] which shares many biological characteristics with no-tillage sowing

"The nature of integrated pest management, as a 'technology', is totally different from Green Revolution technology, in that it is not a set of instructions, with concomitant inputs for maximising components of the farming system, but a set of principles which farmers appK to the total farming system. The nature of the technology implies certain expected farmer behaviours such as regular observation of what happens in their fields, informed decision making about what to do, understanding of principles (ecological processes such as balance between 'pests' and their predators), and knowledge (e g, which insects are pests, stages of development and damage caused at what stage of nee plant). The perceived role of farmers changes from users to experts in their own fields, empowered to be masters over the decisions about their farming. Instead of'labourers' who do as they are told for maximum production to feed the nation, they become managers who optimise their own benefit (e g , profit, continuity as farmers) "

On-going research will plainly be required into problems arising with relatively widespread adoption of such new techniques as no-till sowing. Research has so far been earned out in an ad hoc manner in Western Australia, unlike in Canada, where the federal Agriculture and Agri-food Canada appears to have pro-actively assisted with no-till research.

In Western Australia, direct drilling had been used by up to 40% of farmers in the early 80s.[48] However, only some 19% of farmers direct drilled in the 1993 season[7], with about a further 3.8% sowing without tillage. The adoption of no-till sowing awaited both the application skills with improved herbicides and the development of no-till seeders, by farmers and machinery manufacturers.

The professional input of scientists and engineers, was central to the process of no-till adoption in Western Australia. The subsequent formation of the Western Australian No-Tillage Fanners Association Inc. (WANTFA) in 1992, has evidently facilitated the spread of no-tillage practices among farmers, as shown by attendances of hundreds of people at joint regional no-till meetings with local groups. Agriculture Western Australia was then forced to hold three regional Crop Establishment

Workshops in September 1995, in order to discuss priorities for research into no-till sowing.

No-till sowing also appears to be increasing in acceptance in South Australia and Victoria and in rotations including soybeans in New South Wales[51] and South America in Parana State in Brazil and, since about 1989, on the Pampas of Argentina.[52] Adoption of no-till sowing of wheat was estimated at only about 3% in Argentina in 1994, partly because suitable seeders are only becoming available, and partly because of a slowly-developing understanding of no-till practices by farmers.[52] Gradual increases are anticipated, driven mainly by decreased wind and water erosion, reduced costs and comparable or higher crop yields.

In view of the now-proven track record of farmer groups such as Western Australian No-Tillage Farmers Association Inc. in successfully fostering further adoption of no-till sowing, with large soil conservation benefits, it would appear logical to continue to assist in WANTFA's operation, in order to minimise soil erosion while maintaining or increasing crop yields. Agriculture Western Australia employees already involved include its Newsletter Editor, Bill Crabtree, (Development Officer, Esperance) - who will exchange work for a year with Bob Bradley of Agriculture Canada, Brandon, Manitoba - an adviser since 1981 to the Manitoba-North Dakota Zero Tillage Farmers Association. The author - a Development Officer working on minimising water erosion, has been promised 50% of his time in continuing to work as Foundation Secretary of WANTFA. Agriculture Western Australia provided the author's time and travel costs in hosting visitors such as soil conservationist Bob Bradley in 1992, Holistic Management farmers George and Elaine Work from California and Ben Dyck (agricultural engineer) from Saskatchewan in 1995. The Minister for Primary Industry, Hon. Monty House, has also made available a grant to bring Professor Dwayne Beck from South Dakota State University to speak at WANTFA regional meetings and Annual Conference early in 1996.

Water erosion and, with full stubble residue retention, wind erosion can be minimised profitably under no-till sowing. No-till sowing improved soil structure and biological conditions, thereby furthering the achievement of a sustainable agriculture.

4. Recommendations

1. That no-till sowing techniques be encouraged in order to conserve Western Australian farmland soils, enabling sustainable agriculture in the long-term.

2. That new legume and other rotational crops such as warm-season grasses (eg sorghum) and broad-leaved crops (eg safflower) be investigated for use with and no-till sowing in Western Australia, including assessments of market prospects and development, and effects on groundwater recharge and the imminent salinisation crisis.

3. That exchange work visits by relevant no-till specialists be encouraged and assisted, such as that by Canadian area soil conservationist Bob Bradley and development officer Bill Crabtree of Agriculture, Western Australia, together with continuing visits such as by no-till specialists Ben Dyck, and Dwayne Beck – and by Western Australian scientists, engineers and farmers to relevant overseas destinations.

4. That every available assistance be provided to farmer groups such as the Western Australian No-Tillage Farmers Association Inc., in order to maximise the adoption of no-till sowing, thereby furthering sustainable agriculture in the long-term in Western Australia.

5. Acknowledgments

A travel grant from the Grains Research and Development Corporation covered costs of attending the CIGR (International Agricultural Engineering Conference (see *Appendix 1*) during a private trip, and of the Ohio and Kentucky sections of the study tour, (*Appendix 2*). Agriculture Western Australia provided five weeks and two days official leave. The Winston Churchill Memorial Trust and Wesfarmers Ltd. had previously provided financial support to enable a 1991 study tour from which the current study tour derived, building on previous professional and farmer contacts and experience.

Farmers - Graeme Malcolm (WANTFA Vice-President), Ray Harrington (Immediate Past-President) and members - John Cunningham of Morawa, Tony White of Miling, Bruce Hobbs of Brookton, Ray Honey of McAlinden and Darryl and Garry Mine of Wellstead, provided stimulating and entertaining company throughout the sometimes-exhausting program over travel distances exceeding 10,000 km.

Our various hosts in the United States and Canada, many of whom are mentioned in Appendices 2 and 3 provided the most unstintingly generous assistance throughout the 1994 WANTFA No-Till Study Tour. The touring party, time and again, enjoyed not only their informative company, but were wined and dined most generously - and then referred on to stimulating visits to further no-till farmers en route.

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7. Appendix 1.

Attendance at the XII CIGR (International Agricultural Engineering) World Congress and Ag Eng 94 Conference on Agricultural Engineering, Milan, Italy, 29 August-3 September, 1994.

The professional agricultural engineering body, Congress Internationale du Genie Rural (CIGR) (International Agricultural Engineering Congress) held its five-yearly conference jointly with the European Society of Agricultural Engineering "Ag Eng 94" Conference in Milan, Italy from 29 August - 3 September 1994. The opportunity was taken to attend, with Grains Research and Development Corporation travel grant funding to cover conference costs, following a private trip to Europe, on leave.

The world-wide distribution of attendees was a particularly pleasing feature of the Conference. Some 612 people were enrolled from 50 countries (including seven from Queensland, New South Wales and South Australia). The largest number (136) were from Italy, with several dozen from each of Germany, France, Sweden, Poland, the Netherlands and the United States

Up to 10 concurrent sessions ran during seven technical meetings, with 310 poster displays, with attendant authors lining three sides of the large quadrangle in the University of Milan Conference venue, during a further afternoon session. Sixteen CIGR Working Groups and seventeen Eur Ag Eng special-interest panels, met during a further two sessions. A choice of five technical visits and two post-conference tours completed the Program. The Conference language was English, spoken impeccably by many non-native English-speaking delegates!

Several stimulating papers were presented relevant to minimum and no-tillage sowing systems, leading to more exhaustive private discussion afterwards. Tillage in Brazil, Sweden, Switzerland, Morocco and the United States was discussed with an emphasis on soil compaction, particularly in intensive fodder-conservation systems. Tillage is sometimes required on much-trafficked soils in intensive farming areas, in order to alleviate undesirable agronomic effects arising from compaction by heavily laden forage wagons.

Many papers dealt with the wide range of topics in agricultural engineering. CIGR Working Groups discussed appropriate extension techniques, and other world issues, such as the reconstruction of agricultural engineering following political adjustments in Eastern Europe and Russia. A CIGR Working Group on "Cooperation for the development of indigenous technology in developing countries" worked through the development of appropriate strategies to optimise adoption of improved techniques. On-going discussions have since been carried on by correspondence.

Notable technical information was presented in papers on the stripper header front, which greatly increases the effective work rate of headers by only taking material from the seed heads, leaving the straw standing. Further discussion suggested that a lighter front would shortly be available, capable of widths wider than the 6 m previously commercially available because of weight restrictions - enabling more economical harvesting. Smaller combine harvesters (headers) may then be capable

of a work through-put comparable with large harvesters using conventional header fronts, with considerable cost savings.

A further interesting paper, which has since received widespread consideration in Western Australia, (after I forwarded Agriculture Western Australia herbicide resistance Research Officer, John Holmes, a copy) was on the use of grinders to destroy grass seeds collected from the sieves of headers in research work in northern Italy. Such cross-fertilisation of ideas can be of substantial benefit to local industry, warranting attendance at such world conferences!

Contact with engineers on the wider, world scene for future liaison purposes was particularly appreciated as a major benefit of attendance at the Conference - particularly since, together with other native English speakers, Australians have a privileged position in speaking in our native language while attending many such technical conferences. The XIII CIGR World Congress is scheduled to be held in Morocco in 1998.

A post-conference tour across the agriculturally-rich, intensively-farmed Po Valley to Florence, returning through Genoa and the rice-growing areas in the Upper Po Valley, then completed the Conference program.

8. Appendix 2.

No-till Study Tour of Ohio and Kentucky and with Holistic Management discussions and Amish Community Visit.

Monday,	5 September	Visit the North Appalachian Experimental Watershed, at Coshocton, Ohio and Amish farmer David Kline at Fredericksburg, Ohio.
Tuesday,	6 September	Visit USDA research hydrologist Bill Edwards at Coshocton, and drive to Lexington, Kentucky.
Wednesday,	7 September	Visit S.H. Phillips (formerly Assistant Director, Cooperative Extension) and Drs G.W. Thomas, R.L. Blevins and R.E. Phillips (Associate Professors), at the Agronomy Department of the University of Kentucky.
Thursday,	8 September	Drive to Marler, North Carolina via Knoxville, Tennessee and Columbia, South Carolina.
Friday,	9 September	Return to Coshocton, Ohio via Christiansburg, Virginia and Charleston, West Virginia.
Saturday,	10 September	Visit Amish farmer David Kline at Fredericksburg, Ohio.
Sunday,	11 September	Visit Cleveland, Ohio and Erie and Pittsburgh, Pennsylvania.
Monday,	12 September	Visit farmers Neal and Nellie Stringer at Mt Vernon, Ohio with research hydrologist Bill Edwards.
Tuesday,	13 September	Visit Ben Stinner (Associate Professor and Deborah Stinner (Adjunct Assistant Professor), Ohio Agricultural Research and Development Centre, Ohio State University, at Wooster.
Wednesday,	14 September	Fly to Kansas City and meet with WANTFA North American No-Till Study Tour participants.

9. Appendix 3.

Itinerary and Participants - Western Australian No-tillage Farmers Association Inc. 1994 Study Tour of North America.

Wednesday,	14 September	Meet John Cunningham and Graeme Malcolm (Morawa), and Tony White (Miling) at Kansas City.
Thursday,	15 September	Drive to Jonesboro, Arkansas.
Friday,	16 September	Visit John Bradley (Superintendent) Milan Experimental Station, University of Tennessee.
Saturday,	17 September	Drive to Naperville, Illinois and meet Garry and Darryl Mine of Wellstead.
Monday,	19 September	Visit farmers Al Rickerts at Hinkley, Illinois, Eugene and Mary, and Al and Joanne Adams at Sandwich, DL and Jim Kinsella at Lexington IL.
Tuesday,	20 September	Visit Yetter Manufacturing Co. at Colchester IL and no-till farmer Steve Berger at Wellman, Iowa.
Wednesday,	21 September	Visit Archer Daniels Midland Inc. grain ethanol plant at Cedar Rapids, Iowa and Craig Hartbourne at Kinze Manufacturing Inc., Williamsburg, Iowa.
Thursday,	22 September	Visit Jack Borcher's Ag-Chemicals at Hawarden, Iowa and meet Ray Harrington (Darkan), Ray Honey, Collie and Bruce Hobbs (Brookton) with Howard Dahl, President, of Concord® Inc. at Fargo, North Dakota.
Friday,	23 September	Visit Paul Johnson at Haybuster® Manufacturing Inc., Jamestown ND and John Gardner (Superintendent) and Elaine Schotz (Research Agronomist) at Carrington Research Centre, North Dakota State University.
Saturday,	24 September	Visit farmer Dennis Haugen (Immediate Past President, Manitoba-North Dakota Zero Tillage Farmers Association) and neighbouring farmers.

Sunday,	25 September	Visit farmers Robert and Ellen, and Richard Stevenson, at Oak Lake, Manitoba with Bob radley, (Area Soil Conservationist, (Prairie Farm Rehabilitation Administration, PFRA) Agriculture Canada, Brandon, MB.)
Monday,	26 September	Attend all-day seminar with Manitoba-North Dakota Zero Tillage Farmers Association farmer-members and scientists organised by Bob Bradley at Brandon Research Centre, PFRA, including Dr Lorraine Bailey, (Principal Research Agronomist, Agriculture Canada, Brandon), Dr Cindy Grant (Soil Scientist, Brandon) and Ian Morrison (Chairman, Plant Science Department, University of Manitoba, Winnipeg.)
Tuesday,	21 September	Visit farmers Bob McNab at Minnedosa, MB, Ron Bell and Garth Butcher at Birtle, MB and Daryl Domitruk (Research Manager) at the Manitoba Zero Tillage Research Association Field Station with Bob Bradley, for evening barbecue and discussions.
Wednesday,	28 September	Visit farmers Don O'Dell, Jim Hutchison and Trevor Patamon at Virden MB with Bob Bradley. Visit Drs Guy Laford (Research Agronomist) and Doug Derksen (Weed Ecologist) at Agriculture, Canada's Indian Head Experimental Farm with Dr Keith Head (Agricultural Consultant). Visit Vale Farms® Ltd. and Valcon Equipment's Conserva Pak® no-till seeder manufacturing facility and farm with Keith Head and Blair McClinton (Saskatchewan Soil Conservation Association).
Thursday,	29 September	Visit Bob Purton (Director, Research and Development) at Morris® Industries Ltd., Yorkton, Saskatchewan, and Perry Weisberg, Sales Manager at Bourgault(r) Manufacturing Inc., St Brieux, SK.

Friday,	30 September	Visit Albert Painchaud at Flexicoil®, Lewis M. Carter Manufacturing Ltd. (seed cleaners), Professor Mike Ingledew (Department of Applied Microbiology and Food Science, University of Saskatchewan), Cal Moneo (President) and Denis Bergeron (Vice-President -Marketing) at Harmon® International Industries Ltd, at Saskatoon, and farmer Hugh Barton at Conquest, SK.
Saturday,	1 October	Visit Kim Hartman (K-Hart Industries Ltd) at Elrose SK and Ben Dyck (formerly Supervising Soil Scientist) at Swift Current Research Station of Agriculture and Agri-Food Canada.
Sunday,	2 October	Visit farmers Bob Ekre, Darryl Oech, John and Denise Raisler and Mike Zook with Dale Ferebee (United States Department of Agriculture - Soil Conservation Service) at Beach, North Dakota.
Monday,	3 October	Visit Mandan Research Centre (USDA-Agricultural Research Service) with farmer Gerry Presser for field visits and talks by Officer-in-Charge, Dr Ardell Halvorsen, Soil Scientist-hydrologist Dr Don Tanaka and various agronomy researchers.
Tuesday,	4 October	Visit Professor Dwayne Beck (Manager, Dakota Lakes Research Farm, South Dakota State University, Pierre SD and its West River Rotation Study Area, Dick Cone (Cone Ag Service Inc.) and farmers Ralph and Melvin Holtzworth, and Ken Kinkier at Gettysburg, SD.
Wednesday,	5 October	Visit farmers Martin, Greg and Bryan Jorgensen at Ideal SD, and drive to Minden, Nebraska.
Thursday,	6 October	Visit Dr Ray Ward (Ward Laboratories, Inc.) at Kearney NE, discuss geographical positioning system (GPS) operation at a commercial fertiliser distributor at Holdrege NE, and farmer Ron Lichty at Carleton NE.
Friday,	7 October	Visit Paul Drummond (Vice President – Marketing) for discussions and tour of Great Plains Manufacturing, Inc. factory at Salina, Kansas. Return to Kansas City.

Saturday,	8 October	Fly to Los Angeles (Ray Honey, Ray Harrington and Bruce Hobbs fly home). Visit farmer David Zeiders, at Menifee, California.
Sunday,	9 October	Visit farmers George and Elaine, Ben and Cath, and Jody and Colleen Work at San Miguel CA.
Monday,	10 October	Inspect no-till and holistic resource management practices at the Work ranch, and visit farmer Marvin Miller with George Work and Mike Smith (Co-operative Extension, University of California) at Paso Robles, CA.
Tuesday,	11 October	Return to Los Angeles - end of Study Tour.