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Too Dry? Pastures in the wheat belt:

The benefit of a pasture ley in cereal cropping

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Summary: Material and concepts presented in this paper are drawn from a long term experiment (1986 to 1996) at Warra, in subtropical Queensland. Ley pastures based on grass and legume mixtures increased soil fertility as measured by organic carbon % (OC%), while legume based leys (either annual medics or lucerne) provided sufficient nitrogen for a succeeding crop but did not significantly increase soil OC%. In practice, during a run of poor seasons, the nitrogen provided by leys was available in the subsoil for a number of subsequent crops. Their relevance to the marginal cropping lands is discussed and a method for determining the possible duration of a ley pasture presented.

A prerequisite for sustainable agriculture is the maintenance of soil fertility (Dalal *et al.* 1991). Dalal and Mayer (1986) report the effect of 50 years of continuous cultivation and cropping on a brigalow soil. Long term cropped land was degraded as measured by soil total nitrogen and crop protein (Figure 1). Fertility declined to less than half of its original level after 20 years and one-third after 50 years.

In temperate and Mediterranean agriculture, ley pastures (land temporarily under pasture or the alternate growing of crops and pastures) have been a traditional means of maintaining or restoring soil fertility and crop production. However less was known about the performance of ley pastures in subtropical and tropical agriculture. The purpose of the Warra study, upon which much of this information is based, was to quantify the effect of alternative management practices on soil fertility and on crop performance in a subtropical environment. Ley pastures were one of the alternative practices.

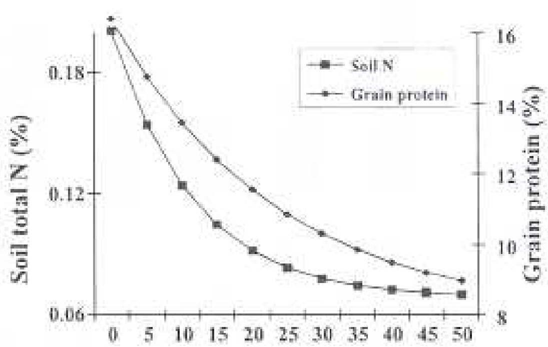

Figure 1. The decline in fertility and wheat protein with continuous cultivation and cropping over a 50 year period (Dahl and Mayer 1986).

This paper summarises the Warra experiment, describing the performance and contribution of three different ley pastures to a wheat cropping system, and discusses the implications for a more marginal environment at St George in Queensland.

The Warra Experiment

The long term (1986-96) study of a melon-hole cracking clay soil (Vertisol) previously supporting brigalow (*Acacia harpophylla)* and belah (*Casuarina cristata)* vegetation was located at Warra approximately 40 km west of Dalby in southern Queensland. It compared alternative management strategies (applied N fertiliser, conventional and zero till, chickpeas in rotation with wheat, and three different legume based pastures in rotation with wheat) with a continuous winter wheat/summer fallow system. The site and methods used are reported by Dalal *et al.* (1991). The effects on subsequent wheat production and on soil fertility were measured.

Seasonal conditions

During the study, seasonal conditions ranged from drought (no crop planted) to above-average rainfall years. However, generally good or average seasonal conditions occurred during the first half of the study and poor (20% below average seasonal rainfall) during the second part of the study (Figure 2).

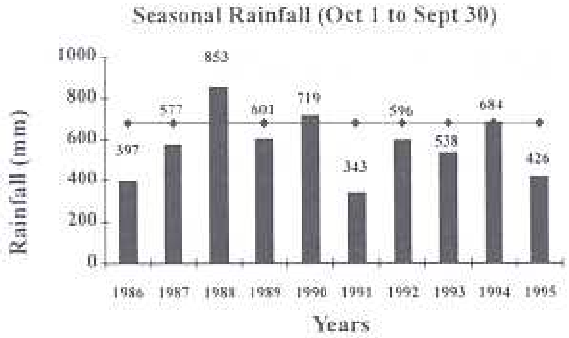

Figure 2. Seasonal rainfall recorded at Warra showing a majority of below-average years. in the two years 1986 and 1991 no crops were planted.

Ley Pastures

Three types of ley pasture-wheat rotations were studied:

- a mixed grass plus legume ley of purple pigeon grass (*Setaria incrassata*), Rhodes grass (*Chloris gayana*), lucerne (*Medicago sativa*), and snail (*M. scutellata*) and barrel (*M. truncatula*) annual medics grown for 4 years, returned to fallow by ploughing in October; followed by continuous wheat
- an annual medic sward of snail and barrel medic sown initially under wheat in June (self-regenerating thereafter), then grown for one winter/spring season and returned to fallow by ploughing in October; followed by one year of wheat (repeated)
- a lucerne sward sown under wheat in June, grown for 17 months and returned to fallow by ploughing in October; followed by one year of wheat (repeated).

Ley pasture production

During the experiment, forage production was removed both by grazing with sheep (two months on/one month off depending on availability of feed) in an associated experiment, and by cutting and removing each three months in an ungrazed core study. These two approaches did not significantly change the build-up of soil nitrogen in this study. Pasture yields were different for different types of leys (short- or long-term), for leys of different composition (grass plus legume or legume alone), for leys of different species (annual medics or lucerne), and for different seasons (good or poor). Annual yields ranged from 0.6 t to 5.8 t dry matter (DM)/ha for lucerne, from 0.6 t to 6.3 t DM/ha for annual medics, and from 1.8 t to 9.6 t DM/ha for grass plus legume pastures. Sheep grazing days reflected these production levels except that lucerne supported more grazing days than annual medics because of its greater period of availability. Grazing was by 'put and take' depending on the availability of feed. During the first half of the experiment (when all ley pasture phases were represented), grass plus legume pastures grazed 12 sheep (DSE's)/ha, lucerne 8 sheep/ha, and medics 6 sheep/ha when grazing days were averaged over the year. No individual animal performance figures were recorded.

Ley pasture benefits

The reported benefits to subsequent wheat crops from ley pastures vary widely in different experiments (Holford 1980; Littler and Whitehouse 1987; Clarkson 1988; Dalal *et al.* 1991). These differences may be due to different starting soil fertilities, different seasonal conditions, different amounts of legume and grass in the leys, to disease factors, and to factors effecting soil nitrogen in the fallow phase to name just some of the possibilities. The latter authors report an additional 60 to 80 kg/ha of mineral nitrogen from one year of good growth of annual medics and 80 to 105 kg/ha from a lucerne ley under the same conditions. The nitrogen which became available in the first year following a grass plus legume pasture was similar to that following a lucerne ley.

Subsequent wheat production following ley pastures

The three different leys all provided improvements in subsequent crop yields and proteins in most season. However, with very low soil moisture conditions, crop yields were depressed and grain proteins elevated.

The benefits to wheat crops were high following grass plus legume pastures. When moisture conditions were favourable, yield responses were significant (Figure 3). However, with poor soil moisture, yield responses were small and in one year negative. The latter (1995) resulted from a progressive accumulation of mineral nitrogen in the soil during poor seasons to an extent which was excessive for the

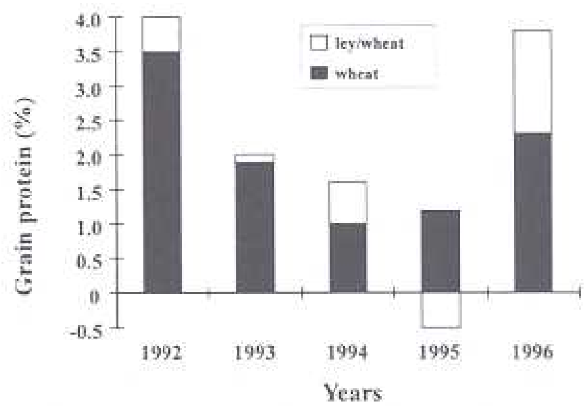

Figure 3. Wheat following four years of grass plus legume pasture gave significant yield increase compared with continuous wheat, except in very dry seasons The number of years of crop response will be determined by the amount of legume grown in the mixed pasture and the yield and protein of subsequent grain crops.

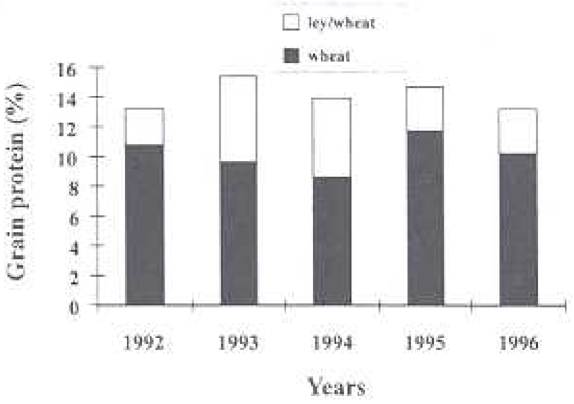

Figure 4. There were major increases in grain protein after four years of grass plus legume pasture compared with continuous wheat.

moisture conditions prevailing (Dalal, Strong, Weston unpublished data). The same effect was recorded for the lucerne and annual medic leys in that season. In all years grain protein following grass plus legume pasture increased in respose to high nitrogen levels (Figure 4).

Annual medics did not deplete soil moisture reserves to the same extent as other leys and in most seasons soil moisture available for the subsequent wheat crop was equal to or greater than that of continuous wheat. Wheat yields and proteins following medic leys (Figures 5 and 6) were significantly higher than for conventional wheat systems. Under the moisture conditions experienced during this experiment, annual medic/wheat rotations out-performed lucerne/wheat rotations marginally.

Lucerne, even as a short ley pasture, had the ability to deplete soil moisture to a level which was lower than that of continuous wheat. In many seasons subsoil moisture levels were not replenished during one summer fallow. When seasonal conditions were favourable wheat yields and proteins following lucerne (Figures 7 and 8) were significantly higher than those of continuous wheat systems. There was however a tendency for wheat protein

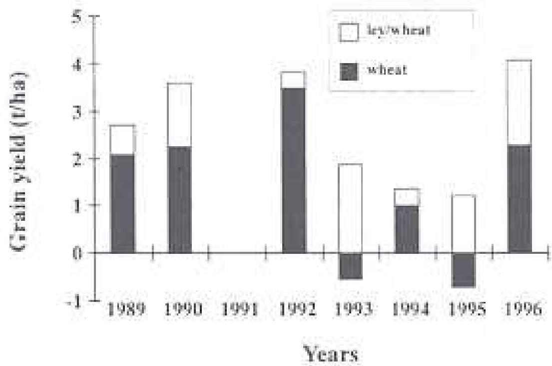

Figure 5. Wheat yield increases after annual medic leys were 24% (averaged over all crops) despite decreases when moisture supply was limiting in 1993 and 1995.

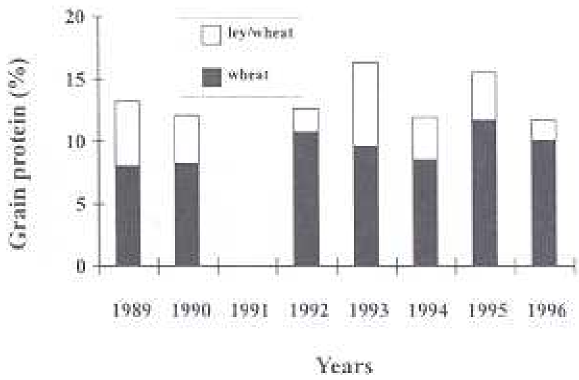

Figure 6. Where annual medics were grown in rotation with wheat, grain protein increased in all years. Increases as large as 71% (low rainfall season in 1993) and as small as 17% (in 1992 following a long fallow caused by the 1991 no planting year) were recorded.

levels to be low in the first year following the ley, except in poor winter seasons. The reason for this is not clear; an allelopathic effect (the detrimental effect of one plant species on the germination, growth, or development of plants of another) is a possible cause.

Changes in soil fertility with ley pastures

In the Warra study all of the pasture treatments did not provide long term fertility restoration of the soil (Dalal *et al.* 1995). As measured by organic carbon %, the leys composed of grass plus legume were effective in increasing fertility, while the lucerne and medic leys and other practices did not significantly increase fertility (Figure 9).

Discussion

The Warra environment compared with the marginal cropping lands

Using Australian Rainman (Clewett *et al.* 1994)

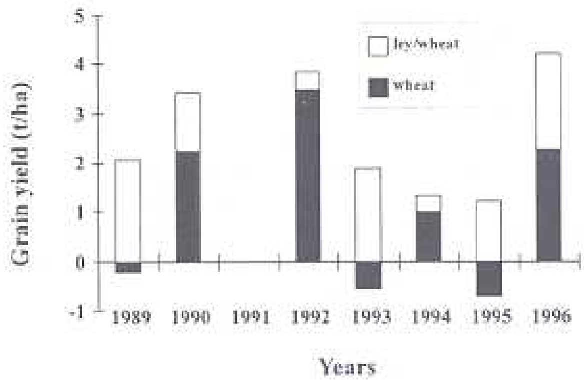

Figure 7. Wheat yield following lucerne were 5% greater (averaged over all crops) than those of continuous wheat systems. Reduced subsoil moisture limited yield in three of seven crops compared with continuous wheat.

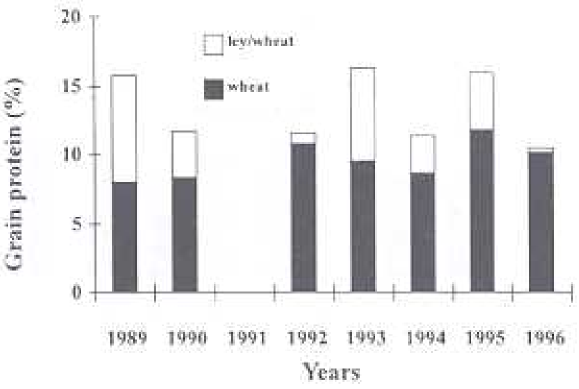

Figure 8. Protein increased by 39% over all crops measured. The greatest increases were in the seasons when moisture was limiting. In more favourable seasons grain protein in the first year following lucerne averaged only 11.3%. The reason for this is not understood.

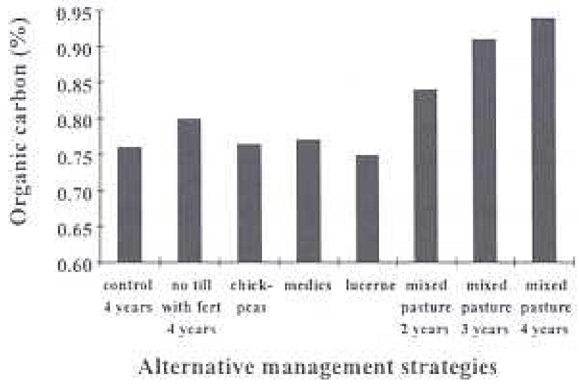

Figure 9. The changes in column height reflect changes in organic carbon for continuous wheat and for alternative cropping systems. There are increases in soil organic carbon % following grass plus legume pasture. While other strategies provided the nitrogen needs of subsequent crops to varying degrees, they did not increase overall soil fertility measured as organic carbon.

the rainfall patterns at Warra and St George (Table 1) are compared (Dubbo and Walgett are included to obtain a southern perspective). Warra receives 32% more rainfall overall and 22% more during the winter cropping period. One interpretation of these differences is that long term grain production and demands on soil nutrients (initially N) in the marginal zone will be lower. This would offset an expected lower pasture production. However, high yielding crops can be achieved as favourable seasonal conditions can be experienced over wide areas regardless of averages. They may however be less frequent and marginal areas will require particular risk management skills to achieve sustainable/profitable farming systems.

While the principles established at Warra can be extrapolated to marginal areas, there is a need to quantify the rate at which changes occur and the level of production for crops and pastures for the lower, more variable rainfall environment. St George is one of the Queensland centres involved in the GRDC funded Western Cropping Project (Sustainable rotations and cropping practices for the marginal cropping lands of NW NSW and southern Queensland). The NSW counterparts are east of Walgett ('Cryon Station') and a site further south is yet to be selected.

Table 1. Rainfall characteristics at Warra, St George, Dubbo and Walgett (mm). Annual rainfall is for the growing season October to September, and in-crop rainfall is June to September inclusive.

Location	Long-term annual rainfall	In-crop rainfall
Warra	681	145 (101*)
St George	514	119
Dubbo	588	179
Walgett	477	125

(* Actual in-crop rainfall for Warra 1986 to 1996 inclusive.)

Management decisions with ley pastures

Why are ley pastures grown in rotation with grain crops? Is it primarily to benefit the cropping system or is it to provide feed for grazing animals? Depending on the answer to this question, there are different methods of managing pastures in farm systems. If it is the former, then the quicker fertility can be restored/enhanced the better; if it is the latter, then the stability and productivity of the pasture over a longer period will be a consideration.

There is an inherent assumption in the use of ley pastures that one important purpose is to improve or maintain soil fertility. On this basis we have assumed that our prime purpose is to satisfy the needs of the cropping system. The feeding of animals will be an added benefit but a secondary consideration in decision making. However, there will be times when animal products attract higher returns and then there will be greater incentive to manage pastures for the benefit of the livestock system. While the need is for soil fertility restoration/maintenance then ley pastures will be judged on how well they provided soil organic matter and nitrogen to satisfy cropping needs.

When to introduce ley pastures; when to remove ley pastures

On what basis can an informed decision be made as to *when to move from crop to ley pasture*, and *when to move from ley pasture to crop*. The Nitrogen Decision Aids Workshops (Lawrence *et al.* 1997) provide a method for managing soil nitrogen in grain cropping systems based on both previous crop performance and on soil tests. They also provide information which can support pasture management decisions. At a time when the soil is not mineralising sufficient nitrogen to satisfy targeted crop requirements, there are a number of options available to grain-growers including fertiliser appli-

Table 2. Effect of age of cultivation on the nitrogen mineralising capacity of a brigalow soil (kg/ha).

Age of cultivation	Mineralisation:	
	Annual	5 year
20 years of cropping	54	270
40 years of cropping	48	240

cation, changing to alternative crops with different nitrogen requirements (barley, chickpeas), maintaining a longer fallow period, and/or using a legume based ley pasture.

If crop-pasture rotation is your strategy, what is the required duration of the ley?. In a marginal environment, ley pastures will only produce useful amounts of forage during favourable seasons; they may go for extended periods with low levels of production. During that time they will add little nitrogen to the soil. Therefore we cannot assume that 'x' years of pasture will lead to 'y' years of high protein grain crop. What can be estimated is the amount of soil nitrogen a measured amount of legume forage will add to the soil and compare this with the expected nitrogen removal by crops. When sufficient nitrogen has been added to satisfy the nitrogen needs for the crop potential of the area, the ley pasture can be removed.

When to introduce a ley

The following example uses the Nitrogen Decision Aid Workshop data and applies it to a brigalow soil in a low rainfall area like St George. The example calculates the amount of nitrogen needed to satisfy the cropping requirements of a partly (20 year) and a severely run-down (40 year) soil, and estimates the amount of legume forage needed to satisfy targeted crop requirements. Estimates are based on a five year period which has been selected as a reasonable time to consider a farm system in this environment.

The nitrogen mineralised annually and for a five year period from cultivations of different ages is shown in Table 2. Growers then need to establish a five year wheat production estimate from their long term records. Assuming that the target protein is prime hard, the nitrogen removed in grain and the nitrogen required in the soil to achieve this can be budgeted (Table 3). The efficiency of use of nitrogen is taken as only 40%, that is, only 40% of the available nitrogen in the soil will be recovered in the grain. It is also relevant that nitrogen not used in one season is available to subsequent crops (Strong *et al.* 1986). Nitrogen which moves into the deeper soil profile is protected from losses due to denitrification.

Table 3. Nitrogen removal in grain and available soil nitrogen requirement for estimated wheat production of 13% protein. Calculation are explained in the Nitrogen Decision Aid Workshops (Lawrence *et al.* 1997).

5 year wheat production(t/ha)	N removed in grain (kg/ha)	Available N required in soil (kg/ha)*
5.0	114	284
6.0	136	341

* The efficiency of uptake of nitrogen is taken as 40% (Verrell 1997).

When to remove a ley pasture

Using the approximate relationship that lucerne and annual medics will fix 1.5% (or other rules of thumb more appropriate for other species and areas) of their dry matter production as nitrogen, it is possible to calculate the amount of legume production needed to provide the targeted amount of nitrogen calculated above (Table 4).

Thus an average legume ley yielding about 5 tonnes of dry matter over two years (the expected yield of lucerne or medics during a short term ley in a marginal cropping environment) will provide sufficient nitrogen for prime hard wheat on the soil of higher residual fertility, but not on the soil which has run-down to the mineralisation capacity of a 40 year cultivation with a target yield of 6 tonnes of prime hard wheat. In this case there is a need to restore soil fertility using grass plus legume pasture so that the average potential yield of lucerne or annual medics will satisfy the requirements of the target wheat yield and protein. The grower needs to estimate the dry matter production of the legume ley, either by using photo standards or by forage sampling, so that the amount of nitrogen contributed to the soil can be calculated. When that production is reached the land can be returned to fallow; thus the time occupied by the ley phase is minimised.

Perennial or annual ley pasture species

In a marginal environment, annual plants have the characteristics needed to accommodate the variable rainfall pattern. Annual medics set a high percentage of hard seed and are able to survive and produce over a number of poor seasons (probably up to five years) without major addition to soil seed reserves. Perennials like lucerne are highly productive when seasonal conditions are favourable but have no survival mechanisms when soil water reserves are exhausted and when rainfall fails. They can however be used like annuals to take advantage of their aggressive growth characteristics and ability to fix high levels of nitrogen. In both cases, these pastures should be treated like crops. Good preparation and planning will lead to maximum ley performance.

In more favoured environments, producers seem to favour either annual medics or lucerne as the legume for their ley legume and the reason is not clear. There are advantages and disadvantages with both and there may even be a case for planting medics in combination with lucerne even though lucerne will dominate in the established ley. At this stage in the

Table 4. The ability of pasture legumes to supply soil nitrogen needs for prime hard wheat production in low rainfall area for different ages of cultivation.

Estimated five year wheat production (t/ha)	Available N required to produce PH wheat (kg/ha)	N mineralised for different age cultivation (kg/ha)	N deficit (kg/ha)	Legume production needs when N fixation is 1.5% of DM (rounded to t/ha)
Age of cultivation is 20 years				
5	284	270	14	1
6	341	270	71	5
Age of cultivation is 40 years				
5	284	240	44	3
6	341	240	101	7

development of ley farming systems in the sub-tropics and tropics, it may be less important which legume is used and more important that the benefits of pastures in rotation are being valued.

Ley pastures and soil physical factors

Pastures are likely to have their maximum effect on the structure of soils of lower clay content (loams and red earths), particularly those which are hard setting. A measure of the benefit of organic matter at the surface of the soil is hydraulic conductivity). This decreases more quickly than soil organic carbon content when soil is cultivated (Connolly, *pers comm.*) and soil water infiltration suffers accordingly. Ley pastures improve the macro-porosity of the soil. When they are followed by zero till and the detrimental effects of cultivation are removed there are multiple benefits; the hydraulic conductivity remains higher for longer and better water infiltration results.

Ley pastures and soil pests and diseases

It is well established that ley pastures act as a break crop, that is they break pest and disease cycles. Stubble borne diseases of winter cereals have increased with the movement to greater retention of stubble (Wildermuth 1997). In wheat the main stubble borne diseases are crown rot and yellow spot and the build-up of pathogens can be reduced by rotating to crops other than wheat, such as ley pastures. The times required to significantly reduce pathogens in the soil can however be quite long (up to 4 years for crown rot).

The current concern about the spread and proliferation of root lesion nematodes (Pratylenchus thornei) appears justified as this nematode has been found to be widespread in the northern grainbelt (Thompson *pers comm.*). This pest can cause up to 50% loss in grain yield. The use of tolerant wheat varieties and rotations with poor hosts are recommended. Ley pastures based on tropical grasses, lucerne and annual medics are possible poor hosts but once again long periods of pasture may be required to cause major changes in the occurrence of the nematode.

Economics

Using a hypothetical mixed farm on the Western Downs, Gaffney (1995) employed a 'with and without' method to compare the 'profitability of change' for implementing alternative management strategies studied at Warra. Based on the trial results his analysis suggested that for farmers on fertility depleted soils (achieving only 2 tonnes/ha of wheat and 8% protein) all of the strategies were more profitable than continuous wheat.

Subsequent development in our understanding of the commercial application of farming system components such as fertiliser N, chickpeas, alternative tillage, ley pastures and alternative grain crops, indicates that future analyses of farming systems could combine rather than compare alternative practices. Based on a better understanding of available soil nitrogen, stored soil water, and an estimate of likely seasonal conditions, farmers may employ strategies which combine several of the management options in their longer term farm systems.

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