“Pasture Cropping”

Profitable Regenerative Agriculture

Colin Seis

"Pasture Cropping"

Agriculture, based on chemical inputs of fertilisers, herbicides, insecticides and fungicides is promoted as "best practice agriculture" in many countries around the world. Not only is "best practice agriculture", responsible for the world wide destruction of grasslands it is also responsible for many of the problems in human, animal and soil health. There may be other ways that we can feed and the growing human population without destroying our farms and planet.

Concerns about declining profitability, poor soil structure, dry land salinity, soil acidification and increasing numbers of herbicide resistant weeds have prompted over 2000 farmers throughout eastern, southern and Western Australia to adopt 'Pasture Cropping'. 'Pasture Cropping is also being adopted in many countries such as the USA, South Africa, and South America.

The year-round ground cover created by using 'pasture cropping techniques, results in reduced wind and water erosion, improved soil structure, reduced weed numbers, increased nutrient availability and increased levels of soil organic carbon. The soil health benefits from plant root exudates and a significant increase in organic matter derived from a mix of shallow rooted crops and deep-rooted perennial pastures are numerous and include substantial improvements of soil microbiology.

In an era when dry land salinity, soil acidification and loss of soil carbon are having increasing impacts on the productivity and profitability of farming enterprises, 'Pasture Cropping' is providing one option for addressing these issues.

The rationale behind 'Pasture Cropping': *Farmers for centuries have either grown and grazed pastures or grown crops on bare soils or tilled seedbeds. To try to get the best of both, many farming systems have also integrated alternate cropping and ley regenerative pastures stages in their farm management plans. However, this has required the periodic killing of the pastures by cultivation or bio-cides to allow crops to grow. Few have been able to integrate both in one perennial ecology and farming system.*

This is because perennial pasture and crop systems operate via different ecological and competitive processes that are assumed to be incompatible with each other.

Whereas perennial grasses compete through maximising their root soil interfaces to survive periods of stress, annual crop plants compete as pioneers, rapidly and opportunistically exploiting suitable soil niches to produce adequate seed for their survival when stresses return. While both strategies can be highly effective, it may be difficult for one plant to compete through both.

However, these distinct competitive strategies may enable farming systems to be designed where the two types of plants can co-exist synergistically in time and space to benefit soil health and plant production.

For the past 20 years Colin Seis from, Winona, Gulgong in central NSW, Australia has been at the forefront of refining and evaluating such 'Pasture Cropping' strategies. Outstanding results and benefits have been confirmed in leading research trials, including:

1. *High crop yields of up to 4 tonnes per hectare when oats were sown into grassland.*
2. *Sustained high pasture and animal production from the periodically cropped land.*

3. *Marked improvements in the structure of and carbon levels in the 'Pasture Cropped' soils with Carbon bio-sequestration rates of up to 9 tC/ha/annually, plus significant improvements in the water holding capacity, nutrient dynamics and natural capital value of the landscape.*
4. *Marked improvement in perennial native grass numbers and species diversity.*
5. *Marked improvements in the biodiversity and resilience of the pasture cropped lands enabling them to sustain relatively higher pasture and crop yields even under stress.*
6. *Significantly reduced input costs and risks on-farm in producing these outcomes thereby markedly improving the economic and social viability of these farming systems.*

What is pasture cropping? 'Pasture Cropping' is an innovative land management technique that enables annual crops to be grown opportunistically into dormant perennial pastures or pastures whose competitive capacity have temporarily been repressed by grazing, and /or selective herbicides to allow the successful growth of annual crops.

In contrast to conventional cropping that is sown into bare soil or stubble, 'Pasture Cropping' creates and exploits temporary competitive niches in the root ecology of the perennial pastures to enable the optimal growth of the short term annual grain crop. 'Pasture Cropping' avoids the need to kill the competitive pastures prior to sowing the crop thereby maintaining living plant cover of the soil to enhance its biological health, water retention and their protection from wind and water erosion relative to conventional crop practices.

Originally developed in 1993, by Colin Seis and Daryl Cluff the practice has now spread to all states of Australia and in a growing number of countries worldwide.

What went wrong with Agriculture? The destruction of Australia's grasslands started over 150 years ago with inappropriate grazing management and later, the use of disc ploughs being used to prepare the soil to sow wheat crops, to feed Australia's growing nation.

Together with the introduction of many annual introduced plants, this management changed the water and nutrient cycles with dramatic results. The vast grasslands no longer existed to be able to control excess water, and much topsoil was lost together with its precious organic matter and humus. The soils declined to such a degree that problems such as compaction, acid soils, declining soil health, declining soil nutrients and erosion became a major problem in the period from the 1920s onward.

During the last 150 years very little has changed in the methods of how crops are sown and how animals are grazed. Many paddocks are still prepared by ploughing and cultivating the soil numerous times, months before the crop is due to be planted.

There is, however, one excellent innovation- sowing crops with zero tillage. This technique is a significant step forward so that crops can be sown in one pass. The only problem is that we are still using many of the ground preparation methods in this system that we have had for the last 200 years.

Instead of ploughing and cultivating the ground 5 – 6 times, now weeds, which supposedly threaten the wheat crop, are often sprayed with 5 –6 chemical herbicide applications. These methods have mitigated much of the erosion problems and improved soil structure, but still, haven't addressed most of the soil health problems. In other words, the plough has been replaced with the boom spray and herbicides, but very little of the underlying philosophy of farming has been altered.

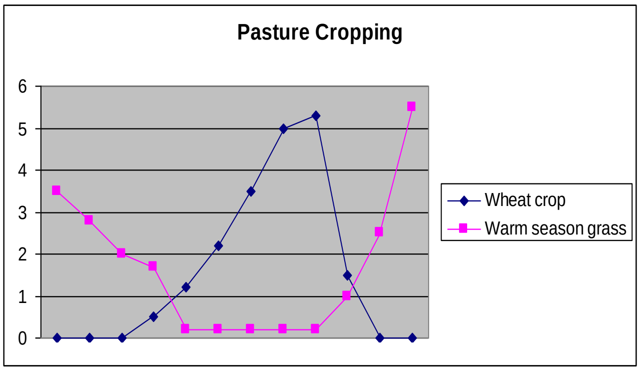
Photosynthesis, C3 & C4 species (cool season & warm season plants)

Photosynthesis is the bonding together of carbon dioxide (CO_2) with water to make carbohydrate and oxygen, using the sun's energy. The carbohydrate, often described as sugar, contains stored energy and serves as the raw material from which other compounds are made.

There are three types of photosynthesis; C3, C4 and CAM. (CAM photosynthesis is used by plants such as cacti and will not be discussed as cacti and pineapples are not common pasture plants.)

C3 (cool season) plants first fix Carbon Dioxide into 3-Carbon molecules which after another step inside the leaf becomes the carbohydrate or sugars that form roots and leaves. To enable plants to control how much CO_2 they breathe in and how much O_2 they breathe out, they have holes in their leaves called stomata. Since they also lose water through stomata, plants have evolved the capability to close the stomata to prevent too much water from leaving their cells. In C3 plants, once the stomata have closed, photosynthesis stops. C3 species are cool season growers that perform well in mixed plant communities; they become less active or dormant as temperatures and light intensity increases. Wheat, rice, oats and barley are C3 plants.

C4 (warm season) plants, however, have a two stage process that is thought to have evolved to deal with hot, dry conditions. Firstly, the photosynthesis process fixes a 3-Carbon molecule in the same way that C3 plants do, and then they chemically fix some more CO_2 by using an enzyme within the leaf to add CO_2 to the 3-Carbon molecule. This means that C4 plants can produce more sugar than C3 plants in hot, dry conditions. Most C4 plants function best within a temperature range of 25 – 35 degrees C. Examples of C4 crop plants include corn, sorghum, sugarcane and millet. 'Pasture Cropping' utilises the niche created by C3 and C4 plants. When most C4 perennial plants have become dormant because of temperature (below 15 degrees C) the conditions are ideal for a C3 plant to grow. This is when a C3 wheat crop is sown into the C4 perennial species.



The graph at left shows C3 wheat crop (blue) growing amongst dormant C4 perennial native grass (pink). ***Note:*** *'Pasture Cropping' mimics the function of grassland. C3 and C4 grass species interact in grassland, growing when the other is dormant*

How soil ecosystems provide nutrients to plants?

After over 150 years of abuse and inappropriate land management, much of the worlds farming soils have become biological deserts and are propped up by expensive soil additives such as fertilisers. These biological desserts have been caused primarily by the absence of perennial plants, litter and ground cover, which are necessary to maintain the myriad of micro and macro soil organisms which are required for the growth of healthy pastures and crops.

There are over 6 billion micro organisms in a spoon full of healthy soil. Fungi, bacteria, protozoa, nematodes and micro arthropods are the main groups of micro organisms in the soil. The interaction of all of these species helps create healthy nutrient rich soil.

The myriad of organisms (both micro and macro) such as bacteria and fungi use organic matter as a source of their nutrients. As they decompose organic material, they release nutrients into the soil in forms that plants can use. This soil biomass is an integral part of the healthy ecosystem that makes 'pasture cropping' work. Although it is a complex and challenging system to understand it is vitally important. The biomass is easy to destroy by cultivation, over use of fertilisers, herbicides and simple exposure to surface light surface and heat.

Soil biomass is dramatically improved by 'pasture cropping' methods, and subsequently, this plays a very real role in a healthy soil ecosystem. This is because the soil is only lightly aerated by the zero till sowing points and not turned over and ripped apart as in a traditional ploughing method. This leaves the increase in surface vegetative matter and the perennial grasses and their root matter intact, and the soil microbiology can continue to perform its role in the soil ecosystem.

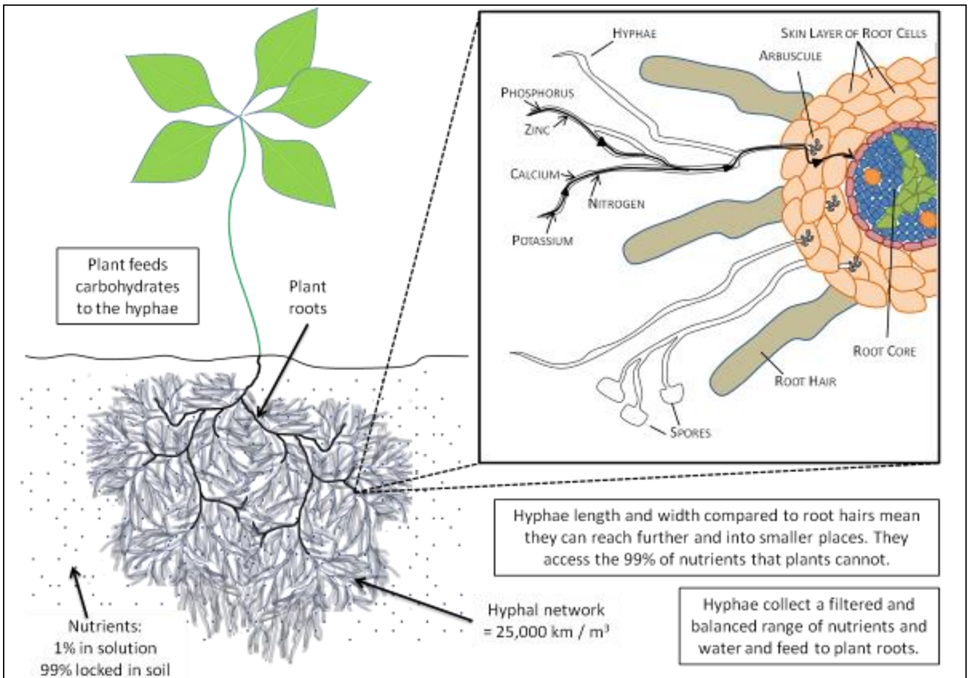
Plants grow via photosynthesis. Their ability to photosynthesize is driven by:

- Water availability
- Nutrient availability (N, P, K, Calcium, Magnesium, Zinc, Boron, etc.)
- Temperature (above 37^{o}C photosynthesis drops)
- Root growth – plant root growth is limited by factors such as compaction (roots can't penetrate more than 350psi) and water-logging (which prevent air from being available to the ecosystems around roots)

98% of plants evolved to function in a symbiotic relationship with Fungi. Plants that have their symbiotic partner extinguished are forced to operate on their own to get soluble nutrients. In this situation, plants have no capability to select for particular nutrients. For example, they can't distinguish between Potassium and Sodium. This means that plants grown in imperfectly balanced soils will have imperfectly balanced nutrients in their leaves.

There are many different Mycorrhizal fungi associations with plants depending on plant type and climate. Grasses evolved a symbiotic relationship with the fungi best suited to help them to locate and transport scarce nutrients (including water) from beyond the nutrient depletion zone and from crevices and rocks the roots can't access. Many types of fungi form symbiotic relationships with grasses. They form highly branched structures (arbuscules) within the cells of grass roots and are known as Arbuscular Mycorrhizae (AM) and sometimes also called Vesicular Arbuscular Mycorrhizae (VAM).

The diagram right shows how the plant roots and AM work together in the soil.



Plant – AM symbiotic relationship

In AM symbiosis, the grass root cell membrane envelops the fungus. Inside the root cell, the fungus creates a compartment like an energy transfer station to allow efficient transfer of nutrients from the AM hyphae to the plant; the plant provides sugars to the fungi, and the fungi provide nutrients such as N, P, K, Ca to the plant. The hyphae produced by the fungus are extensive – they have been recorded at 25,000km/m^3. So they cover a much greater area than plant roots. They are much smaller than even the hairs on the roots of most grasses and can access nutrients and water molecules hidden in tiny spaces. They also exude organic acid which can dissolve nutrients locked into rocks and transport these to the plant.

AM fungi also form a synergistic relationship with the rhizobia and free-living nitrogen-fixing bacteria that fix N. This results in greater N and P content in combination than when each is inoculated onto a legume alone. The amount of N fixed by rhizobia is often only a very small proportion of the total amount of N fixed in soils. The soils under crops (such as wheat) grown in a biology-friendly manner often contain more N at the end of the cropping phases than at the beginning, when none has been added and the crop does not have any legumes in it.

How AM symbiosis is suppressed

AM fungi can only obtain sugars (their food) from their host plant. If the host plant is killed, they also die. They are thought to have a life span of up to 15 days and are therefore reliant on continual replenishment of new hyphae from the spores (propagules) in the soil. The spores are adversely affected by fertiliser and lime application, pesticide use, fallowing, and tillage. AM fungi are also affected by crop rotations that include monocultures of plants that aren't hosts for AM (Canola, Spinach, Brassicas and Lupins).

While the addition of fertiliser is considered to have a positive impact on plant productivity, this positive impact is usually short term. The fact that the inputs damage or kill the AM fungi means that plants are back to being dependent upon the soluble nutrients for food. These soluble nutrients need to be resupplied to maintain productivity – thus continuing the cycle of fertiliser application. Treatments that kill off the plants in the soil (pesticide use, fallowing, tillage, burning) have an adverse impact on the AM fungi by removal of their food source and destruction of the hyphal network. Without food, the AM fungi will not survive in significant numbers, thus being slower to recover once a new crop or pasture is sown.

How AM is optimised

Recovering an AM ecosystem in soil that has been managed with ploughing, fertilisers and herbicides can happen quickly and cheaply. In fact, done cleverly, the resulting decrease in fertiliser input costs can result in improved profitability. Recovering AM populations is done through the application of simple principles that remove limitations to AM and provide suitable habitat and nutrition for it. These principles are:

- 100% ground cover of host species (perennial pastures are ideal) to provide constant food supply (sugars) for the AM. Mechanisms for profitably doing this include:
- "Pasture Cropping". Zero tilling cereal crops into dormant summer-active (C4) perennial pastures. **The cereal crops supply sugars (root exudates) to the AM fungi while the pasture is dormant and the AM fungi feed the cereal crop in return.**
- Maximise the capacity of plants to photosynthesise (the energy source that drives the soil ecosystem)
    - "Time control grazing". Manage the timing of grazing to allow the full recovery of root energy reserves in perennial grass plants (a key to drought resilience).
    - Increasing nutrient cycling in the paddock
    - Perennial plants will improve soil compaction over time.
- Reducing evaporation
    - Protection of pastures from prevailing winds reduces evaporation from pastures and increases the effective rainfall.
- Moderating temperature
    - Mild shading of pastures and protection from prevailing hot winds can reduce high temperatures and increase the number of growing days for pasture and crops.
    - Maintaining constant ground cover through plants and mulch shades the soil surface, moderating soil temperature swings and optimising conditions for soil microbes.

Research by Tim Wiley

(Western Australia DPI) showing differences in plant available nutrients directly beneath the crowns of perennial plants compared to the bare soil between perennial plants.

Plant available nutrients	Bare Soil	Beneath plant	Difference
Organic Carbon (%)	0.24	1.04	433% Higher
Phosphorus (Colwell	21	71	338% Higher
Potassium (Colwell	44	150	341% Higher
Sulphur	2.7	7.9	293% Higher
Nitrate N	4	2	50% Lower
Ammonium	2	3	50% Higher
pH (Ca Cl)	5.8	7.1	
pH (water)	6.4	7.8	

Our farms as ecosystems:

In most parts of the world agriculture is practiced as a monoculture. To maintain farms as a monoculture or with a limited number of plants is very difficult to do because nature wants to function with a very diverse range of plants and will continue to add plants to our farms to find an ecological balance. The plants that nature uses to do this, we call weeds.

Before Industrialized agriculture was developed the world grasslands and farms contained hundreds of plant species (C3, C4, forbs and herbs). The grasslands and farms functioned with very few problems like disease, insect attack and weeds because it was a balanced ecosystem. The vast diversity of plants also created healthy, microbial rich soil with high soil carbon levels creating excellent water holding capacity. With many of today's farms functioning as monocultures with a few crops, it should be no surprise that agriculture is battling on going problems with crop and pasture disease, insect attack and herbicide resistant weeds.

In other words, many of agricultures problems are ecological problems.

For us to maintain a crop monoculture requires inputs of herbicides to control the weeds and the addition of fertilisers to help dysfunctional soil. Also required is the addition of insecticides to control insects and fungicides to control crop disease. **The easier way to manage our farms is not to have monocultures and to allow nature to function closer to how it wants to**

There are a few ways of doing this.

1. Sowing perennial grass species.
2. Change grazing management.
3. Change Cropping management.

Improving grazing management to encourage perennial species and discourage annual weed species is an excellent way of restoring perennial species in grassland. This is achieved by allowing plants to recover from the grazing event before re-grazing. These techniques are commonly called time control grazing, cell grazing and planned grazing. The originator of these grazing methods was Alan Savory who developed the techniques by observing the way animals grazed in South Africa.

With the development of 'pasture cropping,' it is now possible to sow crops into grassland instead of killing the grassland with ploughs and herbicides. The "Pasture cropping" process has been shown to stimulate perennial grass seedling recruitment and as well as being a very effective method of sowing crops. It is being used in Australia and other countries to stimulate perennial grass species and restore grasslands.

Both Regenerative grazing techniques and "Pasture Cropping" are being used together to further stimulate the regeneration of Grasslands in many countries of the world.

Goals and Aims

Much of global agriculture has become productivity based, that is, using large scale monocultures and high inputs to produce a profitable outcome. Dependence on artificial factors such as monocultures and inputs is increasingly risky with oil and phosphate prices forecast to rise coupled with increasingly variable weather. In intensive monoculture systems, there is also the legacy of having unproductive paddocks for significant periods of time while the paddock is being "prepared" for sowing. Whichever way current agriculture is viewed, it is constantly fighting against nature to produce a more productive outcome.

'Pasture Cropping' uses the presence of perennial pasture grasses to enhance the growth of crops while providing ground cover all year round. The paddocks can be grazed until the day of sowing the crop and grazed again immediately after harvesting the crop because the perennial pasture grasses are growing amongst the harvested crop. Although the yield from a grain crop can be 15-20% lower than traditionally sown crops, the real gains from 'Pasture Cropping' are greater profitability, and reduced risk as the input and labour costs can be very low when compared with traditional cropping methods.

The goals of Pasture Cropping can be as simple as growing a low-cost crop of oats while retaining the perennial pasture that already exists, however, 'Pasture Cropping' can achieve much more than this. Practiced correctly it stimulates pasture growth and through this, profit from grazing enterprises while improving soil health. Improved soil health is due to increased organic matter, and litter from the ground cover of plants and sugars exuded through the cereal crops roots which feed soil microbes, especially Mycorrhizal fungi (AM). This, in turn, improves water and nutrient cycling, reducing the need for artificial fertilizers and herbicides on crops and pastures and making better use of available rainfall. 'Pasture cropping' will add building elements to the ecosystem (such as carbon, nitrogen and many more elements) and is, therefore a regenerative system.

Pasture cropping' can be very low input to grow livestock forage where no fertiliser or herbicide is used, or it can be higher input by using optimum fertiliser rates and the use of pre and post sowing herbicides to control weeds, to maximise grain yields. Whatever 'pasture cropping' method is used perennial plants are not to be killed.

Pasture Cropping' is a system that requires management to achieve success. Practitioners of pasture cropping need to learn how to manage their grazing, pastures, cropping systems and farms as ecosystems.

'Pasture Cropping' Techniques

Ground preparation

Livestock are a very important component of Pasture Cropping. Large mobs of sheep or cattle (sheep @ 100 –

150 sheep / Ha) are carefully used in a time controlled or rotational grazing method, to manage weeds, create litter and mulch and prepare areas for cropping. Using stock in this manner is not only a very useful weed controller it is also a very efficient method of running stock over the whole farm.

If the height of the perennial grasses is more than 300mm, they may shade the emerging crop as it germinates. Grazing of the pasture immediately before sowing will prevent shading and this use of animals will create mulch, control weeds and add fertiliser as dung and urine. The preparation of the paddock in this manner does not have to be performed in one operation. It is often better for the health of the animals to use two or three grazing events over a two or three month period.

Using animals to prepare a paddock before sowing has the following benefits.

1. Control weeds by grazing. (consuming the plants)
2. Create litter and ground cover. This will impede weeds and also improve soil health, reduce soil water evaporation and control water and wind erosion.
3. Supply a pulse of nutrients for the crop from the manure and urine provided by the stock.
4. The removal of dry plant material by animals and replacing it with manure and urine will help to reduce soil nitrogen depletion.

Having a layer of plant material (litter) amongst perennial plants over a summer will conserve soil moisture better than a bare fallow. Using large mobs of stock for ground preparation and weed control is very controversial. It has been stated many times that stock will cause soil structure problems in cropping paddocks. This is only the case when there are very low levels of ground cover, litter and plant roots. 'Pasture Cropped' paddocks show minimal compaction and soil structure problems from grazing stock where there is good perennial pastures and ground cover. However, care should be taken with large mobs of animals on very wet ground with minimal amounts of litter. Soil compaction and pugging could occur. Wait until the soil dries before putting stock onto the area. If Animals (cattle or sheep) are not available in sufficient numbers or not available at all, slashing (mowing) the area can be a good option to gain a similar effect, although without the benefit of manure and urine and the mulching effect of animals more fertiliser may be required.

Weed Control: The reasons why annual weeds invade pastures and crops are often not understood. Annual weeds and plants are nature's colonisers and will invade areas of bare ground. Nature's intent is to have a one hundred percent ground cover of plants one hundred percent of the time. Most annual weeds usually grow in large numbers, which provides ground cover. The weeds are generally not very competitive against other pasture species and having abundant perennial species in the pasture will help the weeds to diminish in number.

Annual plants (weeds) also require soil with high nitrogen levels in nitrate form. As more perennial plants dominate pastures the type of nitrogen changes from nitrate to ammonium which discourages annual plant growth. The objective is to have one hundred percent ground cover with perennial pasture species and litter one hundred percent of the time. With sound management of perennial pasture species, weeds will usually be reduced to almost zero percent over time with very little financial outlay.

Herbicides: Herbicides can be used to control weeds but must be used very carefully and selectively. It is important to know what plants a particular herbicide will kill. It is also important to know which plants it will not kill, and it should also be assessed whether it is necessary to place controls on a weed at all if it is not going to affect the growth and quality of the crop. This also applies to weeds in a crop planted prior to sowing and after sowing. For example, broadleaf summer growing weeds can be sprayed with a broadleaf herbicide, but they should **never** be sprayed with glyphosate with perennial species present. Glyphosate has been found to be not very suitable for 'pasture cropping' because it is not selective and will kill most plant species including perennial species. Paraquat is a more suitable herbicide to use pre sowing the crop because it will kill most annual weed species and will suppress perennial plants without killing them. Unfortunately, paraquat is classified as a poison, and great care is required when using it.

Winter growing broad-leaf weeds usually require controlling in a crop that is to be harvested for grain, and this is done relatively easily in a cereal crop by spraying with a broadleaf herbicide after the crop is well established. If the crop has been sown for fodder only, it may not be necessary to spray for weeds at all. Advice on the choice, application rate and timing of herbicides should be sought from your herbicide supplier or agronomist. Be very careful that the supplier or agronomist understands exactly what is trying to be achieved and that they understand that perennial grass in the cropping area is not to be killed. As this goes against the popular concepts and teachings of cropping methods, many of the suppliers of herbicides do not understand "Pasture Cropping" and think the only way to grow crops is to kill everything except the crop.

Above shows a pasture cropping sequence where a crop of oats has been sown into the dormant litter of warm season C4 perennial grass. The crop yield was 3 ton/ ha

Sowing: The plant species present in a pasture need to be identified and assessed before a crop can be sown into that pasture. The assessment needs to determine if the pasture plants are perennial or annual and if they are a useful grazing plant. You also need to determine if the plant (or weed) is going to affect the yield of the crop.

The period of active growth of the plants in the pasture is also very important. This knowledge is important to determine the grazing values and whether a crop can be grown successfully in the pasture without limiting the growth of the pasture species to get the best crop yield. Winter growing perennial species are more difficult to 'pasture crop' into and achieve good crop yields than summer growing perennials. This particularly applies to plants like phalaris, perennial rye grass and lucerne etc.

The sowing process is a critical part of 'pasture cropping', and the following steps should be followed

1. Have the paddock rapidly grazed to 3 – 4 inches high with large mobs of stock.
2. The grazing process should create as much litter covering the soil surface as possible. This will control weeds and conserve moisture.
3. If grazing animals are not available or the mob size is too small slashing (mowing) the paddock can be a good option. However, it does not have the benefit of added manure and urine that the animals provide and it is more expensive.
4. If weeds are going to affect the crop yield, spray them with an appropriate herbicide, being careful that the herbicide application does not kill the perennial pasture. (The herbicide is usually applied usually within 1-3 days before sowing).
5. It is more desirable not to use herbicide, and use thick ground cover to control weeds.
6. If the crop is sown after the first frost, and perennial grass is dormant weeds can be sprayed with glyphosate with low risk of killing summer growing perennial species. It will, however, kill any winter growing perennial species if present and will lead to a grassland/ pasture dominated by warm season C4 species without the diversity of winter growing cool season (C3) species. Glyphosate is not normally recommended for that reason, and more selective herbicides should be used to create perennial species diversity. In this situation, paraquat is a better option.
7. Use zero till sowing equipment to sow at the correct depth and row spacing.
8. Sow the right crop for your application, soil type and district.
9. Conduct a soil test and use the correct fertiliser at the recommended rate.
10. Crops sown by "pasture cropping" methods are sometimes slower to develop; the crops can be sown up to 2 weeks earlier than the usual recommendations.

In Crop. The importance of having living plant ground cover, plant litter and mulch all combined, to maximise organic matter, cannot be stated strongly enough. It is this organic matter in 'pasture cropped' paddocks that conserve moisture, prevent weeds and improve soil health. Most of this organic matter will come from the perennial grass pastures.

Most summer growing perennial species (C4) in a pasture do not actively start to grow until early summer or late spring in most areas. When they are in a crop, they usually don't start to actively grow until even later in the year because they are sunlight and temperature dependent and will usually be suppressed by shading of the crop until after harvest. The shading effect and suppressing of perennial (C4) plant growth during the crop grain filling period allows the cereal crop seed to fill better thus avoiding pinched grain and also reducing any green matter contamination in the grain at harvest.

'Pasture cropping' wheat or oats into cool season C3 plants like phalaris, perennial rye grass and lucerne can be more difficult because they will grow at the same time as the crop and this growth can compete with the crop resulting in lower grain yields. However many people are sowing crops into these plant species with good grazing results, improvements in soil structure, soil health and stimulation of perennial grassland plants from seed in the soil.

Machinery: **Never, never, never use a plough.** It is very damaging to soil structure and soil biological health. A plough will also kill the perennial grass species.

Never use tillage equipment with wide points. These cause too much ground disturbance, destroying perennial grass species and will also encourage weed growth.

Never use a boom spray that is incorrectly calibrated and always use the correct chemical at the correct rates. Herbicides should be considered as a means to a short term end. The aim should be to spray only when necessary and eventually use no herbicide at all.

Most zero till machinery can be used for 'Pasture Cropping'. The cost of new zero till seeders can be prohibitive, but this can be offset in some ways:

1. 'Pasture Cropping' uses minimal machinery (usually a tractor, seeder, and boom spray). Old machinery such as ploughs, scarifiers and cultivators sold and the money gained from their sale used to purchase zero till machinery.
2. Converting existing seeders to zero till can be done with most seeders. The cost of the conversion can range from $3000 to $20,000 depending on whether new tines or discs are needed, and press wheels are required.

Sowing Points: Zero tillage points are not designed to invert soil or control weeds. They are designed to open a slot and loosen the soil to provide sufficient tilth for germination. The selection of sowing points to be used for 'pasture cropping' is very important and can vary depending on the amount of perennial grass present in the pasture and soil type and soil structure. Soil with poor soil structure or with a hard pan will need a point that is more aggressive to improve the soil structure and allow water infiltration.

Soil which has good soil structure will require a point that will not significantly disturb the soil or sowing discs could be used.

As a generalisation, a point that will penetrate deep if necessary (such as a 100-125mm /4-5inch knife point) but disturb the soil very little in width is suitable for many soil types. It is important to be aware that the seed, which is being sown, should be placed at the correct depth – usually 50mm and not at the bottom of the sowing trench.

Sowing Tines: Conventional seeder tines have been developed to sow into tilled seedbeds, and usually do not have adequate breakout force to sow into pastures. When seeders are being converted to 'Pasture Crop', it is critical that correct tines are used in conjunction with suitable points. If the tine is not appropriate for the operation, inadequate soil tilth and incorrect seed placement will result in reduced crop germination and yields or even crop failures. Tine breakout force requirement varies with soil type and condition, but a force of 100kgf is usually regarded as the minimum for most soils. This compares with most old seeders having a kgf of less than 50kgf and most scarifiers at around 130 kgf.

Disc Seeders: Disc seeders are very good for 'pasture cropping' if the soil structure is good.

Disc seeders often do not create tilth (loose soil) under the seed and crops that are sown into poor structured, unhealthy soil can be disappointing. However if soil structure is good, disc seeders have many advantages and will produce good crops.

- Less tractor horsepower required

- More suitable to plant through thick,dense litter
- Less soil disturbance
- Less weeds

Insects: Attack of crops by red-legged earth mite and other insects can be a problem in the first few years of pasture cropping as the ecosystem balances itself to the new management. Insecticide sprays can control them but should be done only when there is a danger of the crop being destroyed. As the ecosystem balances, the invading insect population usually decline as predators move in and help create a balance between damage causing insects and the naturally occurring beneficial insects. A wide and diverse range of insects in a pasture is a sign of a healthy pasture. Over the longer term, serious consideration should be given to not using insecticides because they kill beneficial insects and have significant negative effects on soil microbial populations.

Crop Disease: Fungal crop diseases like "crown rot" can be a problem in conventionally sown crops. Plant root diseases in 'pasture cropped' paddocks are usually not a problem if there is a diverse mix of perennial pasture grass and the soil is in a healthy condition. However, when starting "Pasture Cropping", the soil and pasture are transitioning from one ecological state to another, and during this transition, common sense about fungicides, insecticides and herbicides and recommended crop rotations are good policy.
Colin Seis' property "Winona" has been sowing a variety of crops like wheat, oats, lupins, cowpeas and cereal rye using 'pasture cropping' methods since 1993. There has been no evidence of crop diseases in pasture cropped paddocks on 'Winona' in that time. Low incidence of crop disease and reduced insect attack is also being reported by 'pasture croppers' around Australia and in other countries.

Pasture Cropping organically (without chemicals)

One of the problems with sowing organic crops is that paddocks are usually ploughed and cultivated to control weeds. This practice is very destructive to soil life (bacteria, fungi, protozoa, etc.) and consequently very damaging to soil health. It is possible to "Pasture Crop" without the use of herbicides, but there are a few important things to remember. Annual weeds require controlling if crops are to be harvested for grain. Controlling weeds is not as important when the crop is only to be used for grazing. But there are other ways of controlling weeds other than using herbicides or ploughing.

Any reduction of fertiliser or pesticides should be done gradually and should transition to a lower or no chemical input over time. Trying to reduce or eliminate chemicals from farming too quickly will usually result in disappointing results because the farm is not yet functioning as an ecosystem.

Litter: Plant roots draw nutrients from depth then plants return nutrients to the soil surface as litter or plant residues. As well as producing good ground cover and controlling annual weeds, litter controls soil temperature, feeds decomposer soil microbes and is important for the creation of humus. A critical technique used with "Pasture Cropping" is creating mulch from perennial plants and large mobs of animals. This mulch will control many of the weeds in the crop, especially those that grow after sowing.

Soil disturbance: Soil disturbance and bare ground encourage weeds to grow, so creating as little disturbance as possible during the sowing process will create fewer weeds. This can be done more efficiently with a disc seeder, which creates very little soil disturbance.

Crop Competition: Good competition can be achieved by sowing fast maturing crops and/or planting at closer row spacing (150-170mm) with a higher seeding rate (20% - 25% higher) to increase plant density. At close row spacing and higher seeding rate, the crop canopy closes over the rows quickly and creates shade over any emerging weed seedlings. Disc seeders are better for close row spacing because of less ground disturbance and less perennial plant damage.

Sowing crops organically using "Pasture Cropping" techniques is possible, but when paddocks are first "pasture Cropped "organically there are some things to be aware of.

- *Weeds in the crop will affect crop yield.*
- *Low nutrient soil will not produce good crop yields.*

There are some ways of controlling weeds and supplying nutrients to the crop organically.

Weed Control.

1. Ground cover and litter are the best way of controlling weeds. Create as much ground cover as possible with good grazing management and "pasture Crop" into the litter.
2. Sow a vigorous growing crop at a higher than usual sowing rate. This will create more competition for weeds. Crops like cereal Rye, triticale, oats, and barley are usually good for out -competing weeds.
3. Sow the variety of crop at the recommended time (too late or early will give disappointing results.
4. Create as little ground disturbance as possible, to reduce weeds.
5. Sow with a seed drill that creates very little soil disturbance. (Disc seeder)
6. Seed drills with close row spacing will achieve faster canopy closure of the crop. (Quick canopy closure helps to 'shade out' weeds.)
7. Excess nitrogen, in nitrate form, will encourage weeds.
8. When "Pasture Cropping" into thick summer growing native grass species, Wait until the grass has become dormant before sowing (around April- May)
9. 'Pasture crop' with multi- species. (More information below)

Nutrient requirements.

- There are excellent organic fertilisers available, some of these are Guano, Twin N and organic Dynamic lifter.
- Increasing soil organic carbon and increasing soil microbe numbers and diversity will encourage natural nutrient cycling.
- Sowing a legume with the crop will supply nitrogen for the crop.

Multi Species 'Pasture Cropping.'

Since 2011 Colin Seis has been developing 'multi species pasture cropping' with the aim of producing better quality forage and improving soil health even more than single species pasture cropping does. The technique has the added advantage of still being able to harvest a grain crop after the multi species crop is grazed.

'Multi Species Pasture Cropping' uses a group of plant species that produce good quality forage, have a range of different root systems, includes, legume species, flowing plants and species that will add to organic matter on the soil surface and in the soil as root mass. The plant mixture also produces a variety of plant root exudates which feed soil microorganisms which further enhances soil health and soil carbon.

Since developing 'Multi Species Pasture Cropping,' Colin Seis has achieved the following results when comparing 'Multi Species Pasture Cropping' to single species 'Pasture Cropping' on his property Winona. Both crops were sown into native grassland.

'Multi Species Pasture Cropping' using a mix of oats, forage brassica, daikon radish, turnip, annual vetch, and field pea produced*: (The addition of more species such as lupins, canola, cereal rye and wheat will further enhance soil health and stock forage quality.)*

- Produced better quality stock feed with improved fattening value and superior stock health benefits, than a single species of oats. (*The sheep did not develop scours on a mix of species.)*
- The multi species plants grew better and produced more forage than oats on its own.
- The soil structure and water infiltration were improved.
- Improved soil nutrient cycling
- Fewer weeds. (*This is due to the shading effect and quick canopy closure of the faster-growing brassica species)*
- More beneficial insects observed in the crop.
- After grazing the Multi species crop, the cereal crop can be harvested for grain.

The photos below show 'multi species pasture cropping' on Colin Seis property 'Winona' in 2014. The crop is a mix of oats, forage brassica, daikon radish, turnip, annual vetch, and field pea sown into native grassland of around 40 species.

Multi Species crop pre grazing.

Multi Species crop after two grazing events

Note: After one more grazing the oats was allowed to mature, then harvest for grain

'Multi species pasture cropping' can also be used to sow summer forage crops into cool season C3 pastures. The mix can be millet, forage sorghum, cow peas, lab- lab beans, and sunflowers.

‘Pasture Cropping’ Advantages

- Greater profit by combining enterprises.
- Maintain existing livestock numbers while cropping
- Improved soil health
- Increase soil carbon
- Improved ground cover with the potential for eliminating soil erosion
- Increased number and diversity of perennial grassland species
- More efficient use of rainfall
- Improved soil nutrient cycling
- Improved soil structure
- Fewer plant diseases
- Flexibility and low risk
- It is a regenerative farming process

Challenges presented by Pasture Cropping

- Conventional thinking and training is challenged
- The need to change
- Crop yields can be lower, by up to 20%.
- Initially, insect attack to crops can be a problem.
- The need to change or modify machinery, but this can be offset by selling unnecessary machinery.
- The use of chemical herbicides. (Herbicides are reduced as more ground cover and litter is produced, and there are fewer weeds.)

The reasons for ‘Pasture Cropping’ can be very diverse.

- Reducing costs
- increasing profit
- Growing fodder and grain crops
- Growing dual purpose crops (feed and grain)
- Improving pastures/grasslands
- Stimulating pasture diversity
- Repairing soil structure
- Creating litter and ground cover
- Improving soil biological health
- Increasing soil organic carbon levels
- Improving soil nutrient cycling.

The crops can be as diverse as winter growing wheat, oats, lupins, canola, etc. or can be summer growing such as sorghum, cowpeas, lablab beans, etc. The ‘Pasture Cropping’ technique takes advantage of the natural dormancy of perennial plants by zero tilling an annual crop into the dormant perennial plants. Although most crops, to date, have been sown into perennial Australian native grass this system will work almost as well with most grass species provided that the fundamental ‘Pasture Cropping’ principle of sowing into the dormant grass, is applied.

Gross Margins: For many years agriculture has concentrated on production as a measure of the amount of money made. Although production or the amount of product produced is significant, it is not necessarily an indication of profit.

When farms start to function in an ecologically sound manner a lot of inputs like insecticides, fungicides and excessively high rates of fertiliser can be reduced and in some instances can be eliminated.

When these inputs are reduced there does not need to be a reduction in profit or production, but it is important to not reduce inputs until farms, and individual paddocks are functioning well, other wise production and profit can be compromised.

Below are some examples of what has been achieved on Colin Seis' property 'Winona' with 'pasture cropping' and 'Holistic planned grazing' over a 20 year period.

The chart shows the difference in money spent today compared to 20 – 50 years previously when Winona was being managed with a high input agricultural system. The costs have been converted to 2016 values

	1960 -1992	1993- 2014	Difference
Superphosphate fertiliser on pasture	$51,000	0	$51,000
Sheep veterinary costs	$12000	$7000	$5000
Pasture seed and pasture establishment	$5500	nil	$5,500
Cropping Expenses 200 ha (500 acres)	$40,000	$20,000	$20,000
Dollars saved on Winona annually (2000 acres)			**$81,500**

The cost of production on 'Winona' (sheep, wool and grain) is $81,500 less annually for fertiliser, pesticides and veterinary expenses. Combined with fewer expenses 'Winona' is generating more income, by running more livestock, more grain and producing and selling native grass seed. This is all being achieved while the grassland and ecosystem on 'Winona' are being restored and soil health, soil carbon and soil minerals are increasing.

Agriculture can be productive, profitable and regenerative but it needs to function much closer to natural design.

Soil and Pasture changes on 'Winona':

After 50 years of high input agriculture, Colin Seis' 2000 acre farm "Winona", had become degraded, dependant on high fertiliser and pesticide inputs and lacking production and profit as well as having ongoing problems of insect attack and fungal disease in crops. The granite soil on "Winona" had become compacted, lacking structure, acidic, high in aluminium and had organic carbon levels below 1.5%. The top soil had declined to less than 100 mm (4 inches) deep, and the sub soil was sodic. The poorly structured soil allowed very little water to infiltrate and consequently very little nutrient cycling.

Small saline areas were first noticed on Winona in the 1920's and by the 1970's the saline area had expanded to cover over 100 acres.

Over a 50 year period, introduced pastures like sub clover and rye grass were sown annually to maintain production. These pastures were maintained with increasing amounts of fertiliser to a point where 125 kg/ha of superphosphate (112 lbs/acre) was applied to pastures annually and 100 kg/ha DAP fertiliser applied to annual crops like wheat and oats. The advice in 1970 to apply 200 kg/ha of superphosphate fertiliser to pastures was thankfully, not adopted.

From the early 1990s, Colin Seis started to look for other ways of farming and grazing on "Winona", that did not require high levels of fertiliser and pesticides to maintain and would restore the farm to a regenerative grassland. The restoration of Winona was achieved with a combination of "pasture cropping" "holistic planned grazing" and reduction of fertilisers, fungicides and insecticides.

"Pasture Cropping" combined with "holistic planned grazing" changed "Winona" from a farm dominated by annual plants that required high levels of fertiliser to maintain, to grassland dominated by native perennial plants that improved soil structure, increased organic carbon levels and increased soil nutrient cycling.

The data and photo below are the results of using these techniques

In 2010 The University of Sydney, Australia, conducted the following research on Winona and neighbours adjoining paddock to evaluate the effects of different land management techniques on soil and ecosystem function. The "Winona" paddock was "pasture cropped" in 2000 (wheat), 2004 (oats) and 2009 (cereal rye). A large mob of merino ewes is 'holistic planned grazed' on the area with a grazing period of 2-3 days and allowed to recover from the graze for 90 – 120 days before re-grazing. This grazing technique has been used over all of 'Winona' for more than 20 years. The large mob of sheep was also used to prepare the paddock pre "pasture cropping" by mulching and manuring the grass.

The adjoining paddock was sown to oats in 2000, 2004 and 2009, using traditional disc ploughing once, scarifying once and cultivating twice. The sheep are grazed using traditional 'set stock' grazing (no rotation). The only fertiliser applied to either of the paddocks during the last ten years has been with the crops. 40 kg/ha DAP on Winona and 60 kg/ha DAP on the neighbouring farm.
No lime has been applied to either farm.
The results of this management technique are:

- Winona's paddock is dominated by 82.9% native perennial grass species.
  (82.9% compared to 11% on the neighbours)
- The neighbouring paddock is dominated by 88.1% annual weed species.
- Improved ecosystem and landscape function on Winona.
- Production has increased, (double) with the number of sheep carried on Winona at eight dse /ha compared with 3.7dse/ha on the adjoining paddock.
- Crop yields are similar on both sites
- Improved water infiltration
- Improved nutrient cycling.
- Almost double soil nitrogen
- Soil microbial counts showed that the Winona soil had significantly higher numbers of Fungi *(46% increase)* and actinomycetes bacteria *(over 100% increase)*

Note: The above data is the result of a "communities in landscape" project by Peter Ampt, Rebecca Cross, and Sarah Doornbos from the University of Sydney NSW in 2010.

The soil photo and samples (below) were taken 15 meters apart and a half meter (500mm) deep on 28th September 2010 The soil on the left is from Colin Seis farm "Winona" the other sample from the neighbouring farm. (Fence line comparison) *(The same paddocks as the data above)*

The following increases in soil minerals have occurred on Winona: Calcium 227%, magnesium 138%, potassium 146%, sulphur 157%, phosphorus 151%, zinc 186%, iron 122%, copper 202%, boron 156%, molybdenum 151%, cobalt 179% and selenium 117%

The average increase in total nutrients in the Winona soil is 162 %
E.g. Calcium: 12768 kg/ha on Winona and 4602 kg/ ha on the neighbouring farm (277% change) Phosphorus: 837kg/ha on Winona and 554 kg/ha on the neighbouring farm (151% change).

Soil organic carbon has increased by 203.5% over the ten year period. There is 90.1 ton/Ha on Winona, and 43.41ton/Ha on the neighbouring farm which is equivalent to 168.5tonnes of CO_2/Ha sequestered to a depth of half a meter (18 inches) of which 78% of the newly sequestered carbon is in the non labile (humic) fraction of the soil.

The water holding capacity of the soil has increased by 200%, now storing over 360,000 lts/ha on every rainfall event.

Pasture Cropped ***Traditional crop***

The benefits of 'Pasture Cropping' are way beyond the short-term crop yields. They contribute to the development of vitally needed topsoil, water management, stabilising the many forms of soil erosion, controlling weeds, increasing pasture plant numbers and diversity as well as great potential for increasing soil carbon levels and improving soil health. It gives farmers and graziers a tool to effectively manage their farms while individually contributing to a healthier environment.

Colin Seis

'Winona'

Gulgong NSW Australia 2852

Email: colin@winona.net.au

www.winona.net.au

Ph: 0263 759256. Mob: 0428 759256

Notes