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Cover photos

Large photo: Mowing ground cover Valla macadamia farm
Smaller photos left to right: A mechanical hedger trimming trees, a macadamia tree with exposed roots, an orchard with non-living groundcover.
Photos by Jeremy Bright, NSW DPI, Wollongbar

Disclaimer NSW DPI

The information contained in this publication is based on knowledge and understanding at the time of writing (June 2016). However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up to date and to check the currency of the information with the appropriate officer of the Department of Industry, Skills and Regional Development or the user’s independent adviser.

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Contents
The Australian macadamia industry recognises successful growers are using integrated management approaches that sustain high productivity. Integrated management means combining many aspects of production into a coherent system.

In November 2014 the Australian Macadamia Society (AMS) organised an investigative committee to visit highly productive orchards across Australian macadamia regions. Growers, consultants, processors, government agencies and other stakeholders were represented on the study tour. The tour looked into the mix of orchard management practices that individual growers were using to achieve consistently good production.

The group identified three key areas of integrated management that they felt contributed to these growers’ success: **canopy, orchard floor and drainage**.

Integrated management requires change as an orchard develops, and timely responses to any problems that are observed.

**This guide:**
- Introduces **canopy, orchard floor and drainage** management as the three pillars of Integrated Orchard Management.
- Introduces the **Stages of orchard development**.
- Provides a framework for assessing orchard blocks across the three pillars of **canopy, orchard floor** and **drainage**.
- Encourages growers to recognise important ‘Red Flags’, signs that production decline is imminent.
- Describes currently used management practices in the macadamia industry, and the appropriate circumstances for their use.

Members of the 2014 study tour were: Andrew Pearce, Bob Howard, Brice Kaddatz, Chris Cook, David Harris, David Rodgers, Graeme Fleming, Guito Conte, Jeremy Bright, John Pretorious, Kevin Quinlan, Kim Wilson, Paul O’Hare, Rob Colefax, Robbie Commens, Steve McLean and Warren Elvery.

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**About this guide**

Grower David Rodgers explains to the group his practices for canopy management.

**Three pillars of good management**

A productive macadamia orchard is the result of appropriate management strategies and actions. What’s appropriate can be complex, and is based on the interplay of observation and strategic actions. When looking at the physical aspects of the orchard there are ‘pillars’ of management that support and sustain orchards to achieve their yield potential.

Good management of all three pillars is required. The three pillars are equally important, but the efforts and actions required to manage them will not be the same for every orchard, nor within individual orchards as they develop.
Canopy management

Successful canopy management achieves:

- Access for machinery and sprays
- Light penetration into tree canopies and through to the orchard floor
- Productive canopy at manageable heights

How tall is too tall?

Tree height and row width

Conventional horticulture for tree crops suggests optimal tree height is around 80% of row width. At this height around 80% of light is being intercepted by the trees, and this optimises production in many tree crops. Macadamia nuts usually develop on 2 to 3 year old wood, so pruning strategies aim to achieve a continuous renewal of this kind of growth.

Management challenges grow with tree height

- As trees grow it becomes harder to achieve spray coverage with crop protectants. Today’s common spray equipment is inefficient above 8m.
- NSW DPI research has shown that many macadamia pests prefer the dark shady areas supported by tall trees.
- Low light levels make it difficult to maintain living groundcover on the orchard floor.
- Concentrated stem flow from large trees causes soil loss around trees.

Researchers are currently looking at 6m as an ideal tree height for macadamias. This height is the upper limit for selective limb removal from the ground (using a long-handled chainsaw), and allows for high levels of light interception by mature canopies, across the common row spacings used by industry.

Orchard floor management

The orchard floor is both a work surface for orchard operations, and an important biological zone that supports productive trees.

Successful orchard floor management is a balancing act that maintains:
- protection for the soil,
- good conditions for macadamia feeder roots,
- a harvestable surface to collect nuts,
- ease of access following rain.

An orchard floor should have friable, organic rich topsoil, especially out to the canopy drip lines. Macadamias have feeder roots that enable the tree to take up nutrients from the soil and structural roots that hold the tree up and access water from deep in the soil. Macadamias extend their feeder roots near the surface of the soil - sometimes just below the leaf litter. You should be able to easily see feeder roots by scuffling the soil in the drip line with your fingers.

How tall is too tall?

Tree height and row width

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Healthy roots require healthy soil. Healthy soils are sustained by monitoring the physical, chemical and biological constraints. Management action should address soil constraints when they are observed.

Bare, compacted or eroded soil does not provide suitable conditions for feeder roots. Macadamias growing in environments without good conditions for their feeder roots suffer:
- reduced capacity to take up nutrients and water
- increased risks of pests and diseases including phytophthora
- reduced yield and nut quality
- dead tops, dieback.
Groundcover, whether living plants or mulch, maintains conditions that support macadamia feeder roots. A mixture of applied organic materials are a groundcover that promotes feeder root development.

**Groundcover**, whether living plants or mulch, maintains conditions that support macadamia feeder roots.

A mixture of applied organic materials are a groundcover that promotes feeder root development.

- **Drainage management**
  - Drainage management is the intentional design and maintenance of pathways for water movement through an orchard. Drainage is about making sure that concentrated flows of water are directed through stable pathways, and only small volumes of water travel outside these pathways. Good drainage management slows down the flow of water to dissipate the energy that causes erosion, keeping soil and nutrients in the orchard. Poor drainage practices can undermine orchard floor management, and make an orchard less productive in the long run.
  - **Successful drainage**:
    - manages water through the farm,
    - minimises soil erosion,
    - enables access and safe operation of machinery.
  - The drainage needs of an orchard block are mostly based on its size, slope, position in the landscape and rainfall patterns. All of this is known before the block is planted. The most cost effective time to do earthworks for drainage infrastructure is prior to planting, so it makes sense for a drainage plan to be one of the first jobs in orchard establishment.
  - Good drainage management results in clean water flowing where it is designed to run, with minimal soil erosion.

- **Retrofitting drainage features with earthworks** is harder, more expensive and less successful compared to integrating drainage into an orchard set up. It is still necessary to act on drainage even if you have missed the optimal time. Unmanaged flows of concentrated runoff through orchard blocks create ‘Red Flags’ (see back cover), and can cause major productivity losses.
  - Some drainage flow patterns change as orchards develop. This happens when large trees collect a lot of rainfall and deliver it to the orchard floor as stem flow. Over 1000L has been recorded running down individual tree trunks in a single 32 hour rain event in the Northern Rivers. Soil erosion occurs at the base of trees and down tree rows. This compromises management of the orchard floor that supports feeder roots and tree health.
  - Large macadamia trees collect rainfall in their canopy that comes to the ground as stemflow.

- **An ideal orchard floor with living groundcover right up to the base of the tree.**

- **Living and non-living groundcovers used together.**
**Orchard Stages**

An orchard transitions through several stages over its life. These stages are affected by the age of the orchard, growing region, soil type and management, variety and horticultural practices.

Five stages were observed by the AMS 2014 study tour group across Australian macadamia growing regions.

- **Stage 0 - Preplant**
- **Stage 1 - Early production**
- **Stage 2 - Peak production**
- **Stage 3 - Declining production**
- **Stage 4 - Poor performance**

Typical pathway through stages of orchard development.

Older trees do not in themselves lead to yield decline. There are many orchards over 30 years old that still deliver good production. Yield decline is typically the result of canopy management that has led to diminished productive canopy, lack of functional drainage infrastructure, and poor orchard floor condition (see 'Red Flags').

Moving through all the stages does not have to be the orchard’s destiny. The ideal system would remain in Stage 2, at peak productivity, indefinitely. Yield decline is not necessarily irreversible. Many orchards have been at Stage 3 and 4, and have come back to Stage 2 through integrated orchard management of canopy, orchard floor and drainage. Integrated orchard management means establishing a cycle of assessment, review and management action that is driven by what we observe in each block.

The keys to maintaining or restoring productivity are:

- recognising signs associated with decline,
- investigating their causes on a block by block basis, and
- integrated, responsive and timely management across the three pillars.

Orchards can recover from production decline with strategic management actions.

What sort of things are happening at each Stage?

**Stage 0 - Preplant**
- Drainage planning and installing drainage infrastructure and access tracks.
- Soil testing and applying amendments that are best incorporated.
- Set out of tree rows.
- Planting of trees and groundcovers.

**Stage 1 - Early production**
- Trees are getting larger.
- Towards the end of Stage 1 tree canopies will be joining up within the row.
- Between rows there is plenty of light to the orchard floor and living groundcover.
- Yields are heading towards what is expected as average yields for industry.

**Stage 2 - Peak performance**
- Tree canopies are now fully joined within the row, but their height is less than or equal to the row width.
- Orchard floor still has living ground cover.
- Non-living groundcovers are an increasing part of the total groundcover.
- Everything is humming along nicely.

**Stage 3 - Declining production**
- Yields are not as good as expected for the season.
- ‘Red Flags’ are becoming apparent.
- Canopy is starting to join up between the rows.
- Trees are taller than the row width.
- It’s difficult to spray all of the productive canopy because of height.
- Exposed roots appear.
- Scouring from water flows is seen.

**Stage 4 - Poor performance**
- Yield over several seasons has declined substantially compared to peak yields.
- Canopies may be competing strongly for available light by growing upward.
- There is full shade to orchard floor.
- Many roots are exposed.
- New water courses have created gullies.
- All or most of the ‘Red Flags’ can be observed.

Diminishing living groundcover should trigger the development of strategies to maintain groundcover.

Doing nothing is not an option. Doing the same thing indefinitely won’t work either.
Orchard Stages by management pillar

This guide provides an assessment framework to assign Stages for each of the three management pillars, canopy, orchard floor and drainage. Assessing orchard condition across the three management pillars ensures growers are alerted to problems, ideally before they impact significantly on yield. The results of the assessment indicates which areas are the highest priority to address.

The last section of this guide on the fold out back cover shows you how to assess an orchard block. By looking at different features of the canopy, orchard floor and drainage you can work out which Stage (from 0 - 4) each block is in for each of the three management areas.

The assessment looks at orchard blocks individually, and distinguishes their performance in canopy, orchard floor and drainage management. The block may not be at the same Stage for each management area. It is possible for a block to be at Stage 2 (peak production) for canopy, but at the same time be at Stage 4 (poor performance) for orchard floor and drainage, highlighting the need for changed management in those areas.

Once you have used the assessment to establish priorities you can go to the Canopy, Orchard floor and Drainage toolkits in this guide to explore what practices might be useful for the orchard.

Case study: Greg James, ‘Deenford’ plantation, Newrybar NSW

This case study shows how the assessment of Stages for the three pillars worked for one farm that undertook some major renewal works to sustain production.

What alerted you to there being a problem?

All the indicators (Stage 3 for canopy, orchard floor and ‘Red Flags’) were there. It was more a matter of what made us start. We have owned or managed the orchard since 1989 and since the 2007 rain event (aftermath of east coast low) we started to have many dying trees, mainly from phytophthora, which is a result of root exposure and drainage management issues. In fact we saw lots of root exposure and drainage issues as well as bare earth on water drainage channels.

How did you decide on which problems to address?

It was a block by block decision. Each block should be treated individually as it has differences that will not fit in a ‘one size fits all’ solution. There are differences in row width, aspect, degree of slope, variety and even soil types. The trigger in most cases was not production, as it stayed pretty stable, it was the exposed roots. Exposed roots are extremely difficult to harvest from.

How did you decide on a plan to rejuvenate the orchard?

I identified the drainage issue, and where work was required we got in and did it. At the same time we were managing canopy and added further to our orchard floor mulches. We were having to work on drainage for a second time and realized we won’t be able to do this again as we would have no soil left to use.

What action did you take?

We worked on drainage first, but canopy and orchard floor were worked on pretty much at the same time. We worked on a block by block basis as we also have blocks that don’t require drainage work.

Where water runs down the treeline, that was where the sick trees were. If we diverted water away from the trunk, it assisted in getting the trees healthy. But where we had water running too long down the interrow drain line it then made it hard to harvest. The water flow would gouge them out too deep. So we shorten up long runs with diversions so water doesn’t get up momentum.

Prunings and removed trees were chipped to provide mulch for the orchard floor.
We removed two trees, every 25th tree down the row. Some blocks had steeper slopes so we would install drainage every 10 trees down the row. Steeper slopes meant a steeper drain.

It was also important for us to have drains we could harvest from. We prefer to have drains that are grassed. Grassed drains are fairly self-sustaining. Where drains are bare earth they require yearly maintenance and cleaning.

We addressed tree health through orchard floor profiling and mulch, and canopy maintenance through hedging. We considered tree removal within rows, e.g. every 2nd tree every 2nd row, but we are now more inclined to remove every 2nd tree row. This adds up to more mulch for the orchard floor.

Trees have been removed to promote light to the orchard floor and provide mulch.

How is the orchard different now?

Water flow is managed, roots are covered and stay covered, tree health is improving with covered roots complemented by treatments. Production is sustained.

Some concrete was used to allow an access road to cross this grassed watercourse. The trafficked pathway had been scouring out, needing more than grass cover to protect it.

What will you do next?

Getting up the confidence to do row removal on our 7m plantings to make them into 14m plantings.

‘Red Flags’ - troubleshooting

The ‘Red Flags’ on the back cover of this guide are visible signs that processes are in play that will cause productivity losses. The ‘Red Flags’ are not the only problems that can occur in macadamias, but they are issues that need action. Integrated responses across the three management pillars are the best response.

What does it mean if you are seeing ‘Red Flags’ in an orchard?

**Exposed roots**

Management pillar: Orchard floor and/or drainage

This signals that the function of the tree roots may be diminished, or are in danger of becoming so. The productive capacity is being degraded by the loss of soil. The cause of the soil erosion must be identified and managed.

Severely exposed roots caused by water flow channeling down the tree row.

**Bare soil**

Management pillar: Orchard floor and/or drainage

Bare soil is vulnerable to erosion. Eroded soils do not provide good conditions for feeder roots and this eventually reduces the productive output of the trees. Yield loss through washing away of fallen nuts may occur. Groundcover needs to be increased through a balance of mulching and measures to promote living groundcover.

On level country, a maximum of 30% bare soil can be tolerated without risk of severe erosion. On sloping country even less bare soil is tolerated and steep slopes can not be stabilised without full groundcover. The drip lines are a key area for feeder roots to take up water and nutrients, so bare soil in the drip line is a major concern.

Bare soil under the trees is a risky practice.

Greg James’ story is an excellent example of integrated management. Greg had good production from his trees, but was concerned with his loss of soil and scouring within his blocks, before it caused yield losses.

Canopy was not the priority issue. Drainage was clearly a problem and Greg understood that if drainage was corrected then his orchard floor would stabilise. As he tackled drainage he divided the farm into blocks with changes in aspect, variety and soil types to enable better block by block actions.

Greg still worked on canopy to allow more light to the orchard floor to support more living groundcover. He sought professional advice to help decide on the best to use.
Scoured channels

Management pillar: Drainage
This signals that the drainage infrastructure is not managing runoff well enough, and needs review, repair or upgrading. The block’s productive capacity is being degraded by the loss of soil.

Dead tops

Management pillar: Orchard floor and/or drainage
This is a sign the tree is suffering stress from soil loss, disease, nutrition, subsoil constraint or a combination of factors. The roots have been affected. Look for exposed roots, and an absence or minimal presence of feeder roots around the drip line. Investigate the cause before you decide what action to take, e.g. is it a drainage issue allowing erosion, or is the erosion caused by harvest practices such as blowers? In the absence of exposed roots consider if long term crop nutrition has been inadequate.

Nuts in drains

Management pillar: Drainage
Too much concentrated water is flowing over the orchard floor, picking up and moving nuts out of the harvest zone. If you look closely there are probably other signs of drainage problems. The drains where the nuts are collecting are not the problem. Look upslope, and think about how and where to intercept and divert the run on. Seek advice on drainage design.

Trees in natural drainage lines

Management pillar: Drainage
Shade from trees planted in drainage lines will lead to a loss of living groundcovers that protect the drainage line from scouring. Soil will be lost and trafficability of the orchard floor will be compromised. Trees should be removed, with a set back of 10m either side of the drainage line.
Dead (unproductive) centres
Management pillar: Canopy
Nut production is moving away from where it can be adequately managed with crop protectants, and yield losses from pest or disease issues increase. Productive canopy may be less than desirable for the tree size, with fruiting wood only on the perimeter of the canopy. This is a canopy management issue that needs to be addressed with practices appropriate for the block’s stage of canopy development.

Tree height is greater than row width
Management pillar: Canopy
Very little light reaches the orchard floor once tree height exceeds the row width. This restricts living groundcover and makes orchard floor management more difficult. Spray access for crop protectants may be limited. The risk of erosion problems from stemflow increases.

There is no further yield to be gained as mature trees grow upward, and it becomes difficult to apply crop protectants effectively and maintain groundcover.

Canopy toolkit
The following canopy management practices are currently used in the macadamia industry. Detailed information on each practice follow the summary table. Each practice is coded for its use at each Stage of orchard growth, and how it contributes to the major aims of canopy management. The coding covers the majority of situations, exceptions will exist in unusual circumstances.

Canopy management practices maintain:
- Access for machinery and sprays
- Light penetration into tree canopies and through to the orchard floor to support living ground cover
- Productive canopy at manageable heights

Major renewal practices that disturb the soil, such as row removal should be treated with the same precaution as all earthworks. Earthworks should take place at times where the risk of a high rainfall event is low, and bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed, use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Summary of Canopy practices and their Stage suitability

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Red = not appropriate for stage
Yellow = may be of benefit for stage, but best undertaken with specialist advice
Green = strategically optimum stage to use practice
**LIGHT HEDGING**  
Tipping up to 60cm off the sides of the tree. Commences once the canopy begins to encroach on the planned alley width. Should be performed at least 10 weeks after flowering so that new shoot growth that follows hedging does not compete heavily with nutset.

**Purpose**  
Improve access for machinery and spraying and allows more light to orchard floor.

**Other benefits**  
Promotes fruiting wood, and improves air flow through the orchard (which can speed up drying of the soil and facilitate harvesting after rain). May help with orchard hygiene.

**Industry recommended stage**  

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**HEAVY HEDGING**  
Removing more than 60cm from the sides of the trees. Generally performed where the canopy is meeting over the interrow. Heavy hedging is often considered a practice of last resort, and can be a precursor to row removal.

**Purpose**  
To allow spray access and light penetration and to promote fruiting wood.

**Other benefits**  
Can be used strategically to recover production while spreading yield loss across seasons. For example one sided heavy hedging over 4 years (seek advice before doing this).

**Caution**  
Promotes strong tree vegetative regrowth which requires further hedging the following year. The photosynthetic capacity of the newly exposed leaves is low.

**Industry recommended stage**  

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A typical hedging machine in a mature orchard.

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**LIMB REMOVAL**  
Removes the large branches supporting the top of the canopy, the woodier side-branches, branches with narrow crotch angles, branches that cross other branches, and any unwanted watershoots. These branches are ideally pruned flush with a major adjoining branch deep within the canopy in order to minimize and weaken the subsequent regrowth around the cut.

Usually only a few branches are removed each year, to open up strategic gaps in the canopy. Limb removal is often measured in terms of the percentage of canopy removed.

**Purpose**  
Control tree height, and allows better light distribution through the canopy.

**Other benefits**  
Removes woodiness at the sides of the trees, improves canopy structure and promotes fruiting wood.

**Caution**  
Allowing too much light into the canopy can create excessive flush and regrowth which will fill the created space quickly.

**Industry recommended stage**  

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Heavy hedging has been performed on one side of these trees.

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**LIMB REJUVENATION**  
Similar to limb removal except a stump maintained to promote regrowth from that point. A limb (usually dominant) is cut back within the semi shaded part of tree canopy.

**Purpose**  
Controls tree height and allows greater light penetration through the canopy.

**Other benefits**  
Stimulates regrowth on the cut limb, encouraging fruiting wood back to the lower semi-shaded, section of the tree.

**Caution**  
Allowing too much light into the canopy can create excessive flush and regrowth which will fill the created space quickly.

**Industry recommended stage**  

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Cut location for limb removal
ALTERNATE SIDE HEDGING

A repeating pattern of light hedging where the upper quarter on one side of tree and the lower quarter on the opposite side is hedged one year, with hedging in the reverse pattern the next year.

**Purpose**
Allow light into the orchard floor, preserve access below and control height of the upper canopy.

**Other benefits**
Spreads production losses from canopy management evenly through seasons.

**Caution**
Research into yield effect for this practice has not taken place.

**Industry recommended stage**

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HEDGING AND LIMB REJUVENATION

This form of limb rejuvenation (sometimes called major limb removal) involves taking out the large dominant branches of the tree to get a desirable height reduction. This is followed by heavy hedging cutting back to within 1 meter of the trunk of the tree. This technique allows a lot of light into the tree and there is extensive regrowth at the cut point.

**Purpose**
To reduce tree height, promote fruiting wood, allow light into the canopy and to the orchard floor.

**Other benefits**
The new flush then pushes from low in the tree and after several years the tree may be productive again.

**Industry recommended stage**

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HEDGING AND LIMB REMOVAL

Involves limb removal (see above) one year and hedging the next. Limb removal is selective to create ‘dappled light’ within the canopy, with the limb cut back flush to major adjoining branch to avoid regrowth at that point. If too much light is allowed to enter the canopy it will result in a sudden push of growth from new limbs and eventually overcrowding of the centre of the tree. Light hedging follows limb removal.

**Purpose**
Allows light through the canopy and facilitates access.

**Other benefits**
Promotes new fruiting wood.

**Industry recommended stage**

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MANUAL SKIRTING

The removal of low branches from the tree. Usually performed with a chainsaw. Branches are cut back flush to an adjoining branch.

**Purpose**
To facilitate machinery access to the orchard floor.

**Other benefits**
Minimal regrowth low in the tree.

**Caution**
In early tree development most nut production occurs on the lower branches, so early skirting may cause production losses.

**Industry recommended stage**

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MECHANICAL SKIRTING

Trimming the lower branches with a mechanical hedge, normally done as part of a hedging operation.

**Purpose**
To facilitate machinery access.

**Other benefits**
Less labour intensive compared to manual skirting.

**Caution**
Mechanical skirting leaves a rougher cut than manual skirting and will also have heavy new shoot regrowth coming from the skirting cut. In early tree development most nut production occurs on the lower branches, so early skirting may cause production losses.

**Industry recommended stage**

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ROW REMOVAL
The complete removal of a tree row. Most commonly every second row is removed. Under this scenario, if an orchard had an original row spacing of 7m, it would become 14m rows after row removal. Tree numbers will halve and productive hectares will remain the same.

Purpose
To allow remaining trees more space and light. While it does not reduce the height of the remaining trees, the row width has doubled, and so the appropriate height for the trees is greater.

Other benefits
The trees left behind tend to spread their branches horizontally, and the rate of upward growth slows.

Caution
Should take place at times of low risk of high rainfall events. Bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Industry recommended stage

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PHASING OUT
A phased approach to row removal that allows a final harvest before removing the tree. Trees are pruned heavily, manually or mechanically, and the neighboring row allowed to grow into the space that was taken by the foliage of the hedged tree. Yields are taken off the hedged trees and then they are cut out, i.e. every second row removed.

Purpose
Reduce canopies to allow light and access.

Other benefits
Sometimes the very heavily pruned trees are not removed, and eventually return to production.

Industry recommended stage

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STUMPING
Cutting a tree back to a single stump of about 1-2 meters. A single nurse branch is usually retained. Sometimes called ‘staghorning’.

Purpose
To make use of the existing root system to regrow a new canopy.

Caution
New branches may be prone to breaking in heavy winds a few years after practice.

Industry recommended stage

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TOPWORKING TREE TO ANOTHER VARIETY
Stumping of an older tree and grafting a new more productive variety to the stump. A single nurse branch from the original canopy is usually retained to support the tree until the grafts are developed enough to take over. Sometimes more of the original canopy is kept.

Purpose
To make use of the existing root system to regrow a new canopy of a more productive variety.

Other benefits
There is already a good root system ready to support a new variety. Turn around to a more productive orchard may be only a few years compared with replanting which may take 7 years.

Caution
Potential for weak graft unions that may separate in high winds. Challenges of grafting in the field can lead to low percentages of successful grafts.

Industry recommended stage

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Trees are stumped for either ease of removal or to encourage new growth on established roots.

New growth developing from grafts.
WITHIN ROW TREE REMOVAL

Generally refers to the removal of a single or multiple trees within a tree row often in a diamond pattern through the block.

**Purpose**
To allow more space for remaining trees, and increase light penetration of the canopy.

**Other benefits**
May be necessary in specific locations to allow retrofitting of drainage infrastructure.

**Caution**
NSW DPI research shows long term yield drop. An increase in individual tree yield is seen, but there is yield reduction per hectare.

**Industry recommended stage**

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TOPPING OR HEADING

Hedging back the tops of tall trees to a desired height, either through angled or horizontal cutting.

**Purpose**
To reduce canopy height.

**Other benefits**
Can be used where height reduction is required for a non production purpose such as under power lines.

**Caution**
NSW DPI research trials in older, taller trees showed strong regrowth of multiple leaders and lower yields. Topping is reportedly used in the Bundaberg region on younger trees, repeated annually. Research into the yield effect in younger trees has not yet taken place.

**Industry recommended stage**

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REPLANTING

Removing all trees and replanting. Starting over gives the opportunity to replace trees with more productive varieties and make optimal choices for drainage management and row spacing.

**Purpose**
To establish a ‘new’ orchard block.

**Other benefits**
New varieties will be released in 2018, reported by QDAF to be up to 30% more productive.

**Caution**
QDAF research trials have shown that if old rotting macadamia stumps or roots are left in the ground they can be a source for the fungus Phellinus, which may then infect new plantings and cause dieback.

**Industry recommended stage**

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In this orchard every second row is being replanted. This approach allows for some income from older trees during establishment of the new trees.
Orchard floor toolkit

The following orchard floor management practices are currently used in the macadamia industry. Detailed information on each practice, and any other benefits or cautions follow the summary table. Each practice is coded for its use at each Stage of orchard growth, and how it contributes to orchard floor management. The coding covers the majority of situations, exceptions will exist in unusual circumstances.

- Red = not recommended for stage
- Yellow = may be of benefit for stage, but best used under specialist advice
- Green = strategically optimum stage to use practice

Orchard floor management practices contribute towards:
- Protection for the soil
- Favourable conditions for macadamia feeder roots
- A harvestable surface to collect nuts
- Ease of access following rain

Summary of Orchard floor practices and their Stage suitability

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LIVING GROUNDCOVER

Low growing plants that spread over the soil surface. Smothergrass is a common orchard groundcover. Even undesirable species help with providing groundcover.

Purpose
Provides a protective cover that reduces soil erosion. Absorbs impact of raindrops hitting the soil, slows down the flow of run-off, and plant roots physically hold soil in place.

Other benefits
Supports nutrient cycling and soil biology, reduces compaction by machinery, bind soil particles. Legumes can contribute nitrogen. Having a range of species in living groundcover can support beneficial insects.

Caution
An mowing regime needs to be in place prior to harvest to develop a dense, low cover to harvest from. Green Vegetable bug is attracted to nightshade.

Industry recommended stage
0 1 2 3 4

MOWING

Cutting living groundcovers

Purpose
Manage groundcover, maintain harvestable surface, stimulate cycling of nutrients in the soil.

Other benefits
Throwing to tree rows moves organic matter and nutrients into the tree rows. Letting some groundcovers grow long when close mowing is not required for harvest can provide habitat for beneficial insects.

Caution
Weight of mower can compact soil, risk is greatest for wet soils. Beneficial outcomes of leaving strips of longer groundcovers on insect populations are not yet confirmed by scientific study.

Industry recommended stage
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MULCHING
A layer of organic material on top of the soil that provides a protective cover. Forms of organic matter include:
- woodchip
- grass clippings
- compost
- manures
Sometimes mixtures of different forms of organic matter are used.

**Purpose**
Protects bare soil from erosion and promotes development of feeder roots and soil biology. Different types of organic material have different qualities as soil amendments. Woodchip provides mostly physical protection to the soil, compost boosts the nutrient and water holding capacity of the soil, while manures supply nutrients.

**Other benefits**
Increases moisture retention and suppresses weeds.

**Caution**
Non-living groundcovers can be moved around by concentrated water flows. Use of non-living groundcovers works best in orchards with good drainage infrastructure in place. Organic materials vary in terms of their nutrient contents, the degree of decomposition, and their resilience to erosion.

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**BARE SOIL**
Scarce living groundcover or non-living groundcover present.

**Purpose**
Can facilitate harvest in blocks without living groundcover.

**Caution**
Usually detrimental to tree health. High risk of soil erosion.

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**MOUNDING**
Soil is built up to form raised tree rows leaving a shallow spoon drain shape between rows. Performed prior to planting with earth moving machinery. Especially important when establishing new blocks in low lying or very flat areas.

**Purpose**
Assists with drainage, directing runoff out of the tree rows to the interrow.

**Other benefits**
Larger volume of prepared soil supports early growth of young trees, provides an opportunity to integrate soil amendments such as lime if needed.

**Caution**
Should not be performed when the soil is too wet - above the plastic limit. Mounding height is constrained by row width, and the need for the interrow drain to be shallow enough for harvest.

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**INOCULANTS**
Living microbes applied with the intent that they continue living in the soil.

**Purpose**
Fill gaps in microbial ecology.

**Caution**
Suitable soil conditions, food sources and sometimes host plants for the introduced microbes must be present or they will not persist. Care must be taken to ensure survival of microbes during transport and application. Benefits beyond providing suitable conditions and food resources for in situ soil microbes are not well established except for rhizobia associated with legumes. Few products have quality assurance processes.

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**BIOSTIMULANTS**
Liquids, including irrigation water, nutrients, carbohydrates and microbial cells applied to the orchard floor, often to newly applied mulches.

**Purpose**
Supports and accelerates microbial processes in mulches and soils. Can help stabilise disturbed bare soil.

**Caution**
Generally non-harmful but the evidence base for yield benefit beyond irrigation benefit is not well established.

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*WARNING*
For at least four months prior to mature nut drop and until the completion of harvest, avoid applying animal manures that have not been properly composted or nut husk from heaps. They are a food safety risk. Salmonella can persist in animal manures that have not been properly composted for up to four months and has also been found in nut husk heaps.

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Trees produce some of their own mulch.

Biostimulants are usually applied with irrigation or by water carts.

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The right inoculant can make a big difference in some situations.

Where there is not enough cover to protect the soil from erosion it is bare.

Mounding of tree rows during preplant ground preparation.
### PROFILING

The cultivation and movement of soil and organic material from the interrow onto the tree row, generally to cover exposed roots of trees. Can be performed using a grader, rotary hoe or other specialised profiling machines.

**Purpose**

To cover exposed tree roots, promote development of feeder roots, create elevation in tree row and a shallow spoon drain shape in the interrow.

**Caution**

Should not be performed when the soil is too wet - above the plastic limit. Bare soil should be revegetated or covered as quickly as possible.

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### SWEEPING

Using a harvest sweeper or road broom to sweep loose soil and organic matter from the interrow to the tree row.

**Purpose**

To cover exposed tree roots, promote development of feeder roots, and maintain a shape that directs surface water flows from the tree row into the (ideally grassed) interrow.

**Other benefits**

Recover some soil, mulch material and nutrients moved by water flow back into the tree row. May aid access by moving built up organic material in the interrow away from the wheel tracks.

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### AERATION

Core aerators remove small cores of soil from interrow. Cores are left on the surface. Spike aerators penetrate the topsoil and create disturbance without major damage to living groundcovers.

**Purpose**

To repair soil compaction and promote grass growth in the interrow.

**Other benefits**

Assists in increasing water infiltration and moving amendments such as lime deeper into the soil.

<table>
<thead>
<tr>
<th>Industry recommended stage</th>
<th>0</th>
<th>1</th>
<th>2</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
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<td>✓</td>
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</tr>
</tbody>
</table>

### Moving nuts means moving soil

Using machinery to move nuts from under trees out into the interrow for harvesting also moves soil and non-living groundcovers. It’s important to review any practices that affect the orchard floor frequently, and switch to less destructive options that conserve the orchard floor.

NSW DPI research confirmed that blowers move around 2.5 tonne of soil per hectare per year (measured at an 8 by 4m tree spacing), and move the soil a long way from the tree row.

Sweepers move around 1.3 tonne of soil per hectare per year (measured at an 8 by 4m tree spacing), and the soil moved is retained in the interrow. So sweepers are the less destructive option. Sweepers do create a depression in their path, and affect drainage patterns. Over time reshaping of the interrow profile may be required to ensure runoff is directed away from the drip line to the centre of the interrow.

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Drainage toolkit

The following drainage management practices are suitable for most macadamia orchards. Detailed information on each practice and any other benefits or cautions follow the summary table.

Successful drainage:
- Red = not recommended for stage
- Yellow = may be of benefit for stage, but best used under specialist advice
- Green = strategically optimum stage to use practice

All the listed drainage practices are coded green, as strategically optimum features to have in place at all stages of orchard development.

Drainage design is a specialised technical process, and obtaining advice from a suitably qualified and experienced person is recommended for drainage plans, as well as to inform the installation of drainage infrastructure.

Earthworks should take place at times of low risk of high rainfall events. Bare soil should be revegetated or covered as quickly as possible. When establishing grass from seed use up to 10 times the rate recommended for pasture establishment to achieve rapid surface cover.

Summary of Drainage practices and their Stage suitability

<table>
<thead>
<tr>
<th>Practices</th>
<th>Stages: 0 1 2 3 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage plans</td>
<td>ü ü ü ü ü</td>
</tr>
<tr>
<td>Grassed watercourse</td>
<td>ü ü ü ü ü</td>
</tr>
<tr>
<td>Diversion banks</td>
<td>ü ü ü ü ü</td>
</tr>
<tr>
<td>Graded banks</td>
<td>ü ü ü ü ü</td>
</tr>
<tr>
<td>Interrow drains</td>
<td>ü ü ü ü ü</td>
</tr>
<tr>
<td>Check structures</td>
<td>ü ü ü ü ü</td>
</tr>
</tbody>
</table>

DRAINAGE PLANS

Detailed plans of where water is to flow through orchards, often prepared by specialist consultants. They find a balance between the ideal control of water and the practicalities of operating a farm. Drainage plans are best created prior to planting, but are recommended at all orchard stages where they have not been prepared previously. Drainage plans often include:
- the intended grade and surface condition of watercourses,
- setbacks to tree blocks,
- where and how water will be diverted around orchard blocks,
- where and how runoff will be slowed to reduce erosion,
- where water will be retained for storage or detained to improve water quality of runoff,
- where trees need to be removed (in established orchards).

Purpose
To guide the establishment of orchards and blocks with durable drainage infrastructure. This reduces soil loss and provides good conditions for feeder roots throughout the orchard’s lifespan.

Other benefits
Opportunity to identify areas that will be difficult to harvest.

Caution
Ensure that your advisor is suitably qualified and experienced. Poorly designed drainage infrastructure can suffer damage in heavy rain events, and require costly repairs.

Industry recommended stage

<table>
<thead>
<tr>
<th>Stages</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tr>
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<tr>
<td>Diversion banks</td>
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<tr>
<td>Graded banks</td>
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<td>ü</td>
</tr>
<tr>
<td>Interrow drains</td>
<td>ü</td>
<td>ü</td>
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<td>ü</td>
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</tbody>
</table>

This example drainage plan shows how grassed watercourses, diversion banks, graded banks, and interrow drains can work together to move water through a property.
GRASSED WATERCOURSE

A constructed watercourse maintained with living groundcover, usually mowed. The grade and width should be designed at a minimum to be sufficient to carry the runoff from a 1 in 10 year rain event. In order to avoid erosion within the diversion waterways, grass is planted as a protective lining. A planting set back of 15–20m is required, or the removal of trees.

**Purpose**
Provide stable pathways for water to move through the orchard.

**Other benefits**
To receive runoff diverted around, and from within orchard blocks. Longer grass left in the channel can help with biodiversity and offer habitat for beneficial insects.

**Caution**
Erosion of the channel is likely without living groundcover. Canopy from adjacent trees must be managed to avoid shading the watercourse.

**Industry recommended stage**
<table>
<thead>
<tr>
<th>SLOPE %</th>
<th>0</th>
<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>GRADED BANK SPACING M</td>
<td>not required</td>
<td>120</td>
<td>80</td>
<td>64</td>
<td>60</td>
</tr>
</tbody>
</table>

DIVERSION BANKS

Diversion banks built to intercept and convey concentrated runoff water from upslope areas. They are usually higher and wider than graded banks, and must be grassed to carry high speed water flows safely. Usually placed at the top of orchard blocks where there is run-on from upslope.

**Purpose**
Protects orchard blocks from gullying by diverting concentrated run-on from upslope to stable watercourses.

**Other benefits**
Can form part of a network of grassed watercourses, and accept discharges from other banks and drains.

**Caution**
Banks should not be allowed to overtop. They must be maintained to discharge water only at the intended location. Frequently trafficked points are usually at greater risk of becoming low spots in the bank where overtopping can occur.

**Industry recommended stage**
<table>
<thead>
<tr>
<th>SLOPE %</th>
<th>0</th>
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<td>80</td>
<td>64</td>
<td>60</td>
</tr>
</tbody>
</table>

**Special circumstances**
Smaller graded banks (sometimes called cross banks) can be used at closer intervals, and run at up to a 5% grade. These are used when an intermediate feature is required between existing graded banks, or the slope is too steep for the larger graded banks. These have a higher maintenance requirement compared to graded banks and can be difficult to traffic with mowers and harvesters. Specialist design is usually required.

GRASSED WATERCOURSE

Grassed watercourses established throughout an orchard.

Clean runoff flows through a grassed watercourse.

A diversion bank breaks up a long slope in a young orchard.

Suggested spacings for graded banks in orchards without bare soil

<table>
<thead>
<tr>
<th>SLOPE %</th>
<th>GRADED BANK SPACING M</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>not required</td>
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<td>2</td>
<td>120</td>
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<td>4</td>
<td>80</td>
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<tr>
<td>6</td>
<td>64</td>
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<tr>
<td>8</td>
<td>60</td>
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<tr>
<td>10</td>
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</table>

There is enough of a break in the orchard canopy to maintain grass cover on this graded bank.

How soil is moved in constructing a graded bank. The dashed line shows the shape of the finished graded bank and channel. Adapted from Earthmovers Training Course, Soil Conservation Service of NSW, 1992.
### Graded Banks (continued)

**Purpose**
Reduced the concentration of runoff in vulnerable blocks. Graded banks break up long slope lengths where runoff would otherwise develop too much speed and erosive power.

**Other benefits**
A well designed bank will be suitable to drive over, and harvest from the bank and channel. This allows harvest of any nuts that have moved there from upslope.

**Caution**
Banks should not be allowed to overtop. They must be maintained to discharge water only at the intended location. Frequently trafficked points are usually at greatest risk of becoming low spots in the bank where overtopping can occur.

**Industry recommended stage**

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<thead>
<tr>
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</tbody>
</table>

Trees were removed to create this graded bank in an established orchard.

Profile of a bank with enough freeboard to reduce risk of overtopping the bank. Adapted from Earthmovers Training Course, Soil Conservation Service of NSW, 1992

### Interrow Drains

**Purpose**
Shaping of the tree row and interrow so that the tree rows are mounded and the interrow has a shallow spoon profile to direct water to flow down the centre of the interrow. Living ground cover should be maintained on the flow line. The interrow drain discharges water to a grassed watercourse, or other stable disposal area. Most effective when the rows are oriented up and down slopes.

**Other benefits**
Keeps most of the soil or mulch material moved from under the trees in heavy rain events close to where it came from, enabling it to be replaced to the tree rows.

**Caution**
Living groundcover is required on the flow line to prevent scouring of the channel. Long runs should be broken up with graded banks at the appropriate spacing for the steepness of the slope.

**Industry recommended stage**

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</table>

### Check Structures

**Purpose**
Bars placed across the path of small water flows. Check structures interrupt the water flow, slowing it down to reduce erosive power. The barriers can be made of any material including straw bales, wood, rock. Silt socks of various fabrics and fillings are an easy to adjust option. Check structures are usually temporary, site specific measures while living groundcovers are establishing.

**Other benefits**
Traps some sediment, organic material and nuts within the orchard. Can be removed for harvesting.

**Caution**
The centre of the check must be lower than the sides, and wide enough to prevent flows cutting around. Scouring can occur immediately below check structures; closer spacing of check structures may help. Once sediment fills behind a structure it is of no further benefit, and must be replaced or cleaned out.

**Industry recommended stage**

<table>
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</table>

Temporary check structures made from geotextile fabric, filled with blue metal, slow water on a bare interrow drain. These are removed for harvest.

Check structures that fill with sediment must be cleaned out for continued benefit.
Further reading

Canopy

http://horttech.ashspublications.org/content/23/1/64.full

How to reduce stemflow in macadamia orchards

Orchard Floor

Establishing and managing smothergrass on macadamia orchard floors

Macadamia harvesting with sweepers and blowers: effect on soil movement

Drainage

Saving Soil - a landholder’s guide to preventing and repairing soil erosion

Soil Health Card - macadamias

General

Australian Macadamia Society (AMS) - factsheets, news, contractors and consultants
http://www.australian-macadamias.org/industry/industry?lang=en

macSmart - information from leading macadamia producers, researchers and processors

Australian Macadamia Industry Code of Sound Orchard Practices

Assessing your orchard

Answer sheet continued. Directions on how to do the assessment are on the following page.

<table>
<thead>
<tr>
<th>Block ID</th>
<th>Canopy Stage</th>
<th>Orchard Floor Stage</th>
<th>Drainage Stage</th>
<th>‘Red Flags’ (how many)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. West</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |

| e.g. West | 2            | 3                   | 4              | 2                      |
Assessing your orchard

This section provides a framework for looking at individual macadamia orchards to ‘check’ their condition. After completing the assessments you will:

• know what management pillars are most important to focus on for each block,

• be able to use this booklet’s Toolkit sections to shortlist practices to address the orchard’s problems, and to maintain or improve orchard productivity.

Assess orchard blocks independently as there can be significant variation from one block to another. Deciding on management practices should ideally be done on a block by block basis. Use the fold out reference pages to classify canopy, orchard floor and drainage. Then check whether you have seen any ‘Red Flags’ in that block.

Once you have determined Stages for each of your blocks and possible ‘Red Flags’, you can use this to decide on priority areas, and go back to the toolkits in this guide to look at possible practices for your orchard.

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<table>
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<tr>
<th>Block ID</th>
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<td>2</td>
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</tbody>
</table>

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Orchard floor features by Stage

Use a best fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block may have features spread across more than one Stage. Not all the features need to be present.

**Stage 0 Preplant**
- No bare soil
- Groundcover is almost entirely living plants

**Stage 1 Early Production**
- No bare soil
- Groundcover is almost entirely living plants

**Stage 2 Peak Production**
- No bare soil
- Groundcover is a combination of living plants and non-living mulches

**Stage 3 Declining Production**
- Some of the orchard floor has bare soil, unprotected by any groundcover
- Some trees have exposed roots
- Some trees have dead (unproductive) tops

**Stage 4 Poor Performance**
- Most of the orchard floor has bare soil, unprotected by any groundcover
- Exposed roots are obvious everywhere
- Further exposure of roots is easily visible after rain events
- Friable, organic rich topsoil is not present
### Drainage features by Stage

Use a best fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block may have features spread across more than one Stage. Not all the features need to be present.

<table>
<thead>
<tr>
<th>STAGE</th>
<th>FEATURES</th>
</tr>
</thead>
</table>
| Stage 0 Preplant | • Drainage plan is prepared  
                             • Any required earthworks to direct water flows are in place  
                             • Planned flowlines have vegetative cover or other stable surface |
| Stage 1 Early Production | • Drainage system is working as planned  
                                      • No significant soil movement is visible  
                                      • Runoff leaving the block contains little visible sediment |
| Stage 2 Peak Production | • Drainage system is working as planned  
                              • Some maintenance of drainage infrastructure is required |
| Stage 3 Declining Production | • Drainage system is not working as planned  
                                        • New water flow lines can be seen within blocks  
                                        • Soil mound at drip line  
                                        • Runoff leaving the orchard is coloured with eroded soil |
| Stage 4 Poor Performance | • Drainage features are absent or in disrepair  
                               • Gullies have formed down tree lines and interrows  
                               • Heavy rains move lots of nuts out of harvestable areas  
                               • Large deposits of eroded soil can be seen downslope of blocks |

### Canopy features by Stage

Use a best fit approach. Look through the features for all stages and decide which Stage, on balance, the block you are looking at most belongs in. Sometimes a block may have features spread across more than one Stage. Not all the features need to be present.

<table>
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<tr>
<th>STAGE</th>
<th>FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 0 Preplant</td>
<td>• No canopy, or canopy cover is a small proportion of orchard</td>
</tr>
</tbody>
</table>
| Stage 1 Early Production | • Tree height is well under row width  
                                    • Tree canopies are independent or just starting to meet up within rows  
                                    • Nuts grow throughout the canopy |
| Stage 2 Peak Production | • Tree height is less than, or equal to, row width  
                                   • Nuts grow throughout the canopy |
| Stage 3 Declining Production | • Tree height is greater than, or equal to, row width  
                                        • Dead (unproductive) centres are present  
                                        • Nuts grow mostly at the top of the canopy |
| Stage 4 Poor Performance | • Tree height greatly exceeds row width  
                                • There is no gap between row canopies  
                                • Most trees have dead (unproductive) centres  
                                • Nuts grow only at the top of the canopy |
‘Red Flags’ for macadamia orchards

Are any of these signs of trouble visible in your orchard?

Exposed roots, Bare earth, Scoured channels, Dead tops, Nuts in drain, Trees in drainage lines, Dead (unproductive) centres, Height greater than row width

Any of these signs are a call to action

This guide provides a framework for the physical management of macadamia orchards, at different stages of their development. Recognising and addressing problems sustains macadamia orchards at high productivity.