Department of Primary Industries

Macadamia integrated orchard management drainage 2017

Jeremy Bright, Stephanie Alt, Bob Howard & Kel Langfield

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‘Red flags’ for macadamia orchards

Noticing ‘Red Flags’ is part of integrated orchard management (IOM). The assessment process for canopy, orchard floor and drainage is in the *Macadamia integrated orchard management practice guide*.

Exposed roots

Bare earth

Scoured channels

Dead tops

Any of these signs are a call to action

Nuts in drain

Trees in drainage lines

Dead (unproductive) centres

Height greater than row width

Macadamia integrated orchard management drainage 2017

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Cover photos

Large photo: Water running on a grassed watercourse.

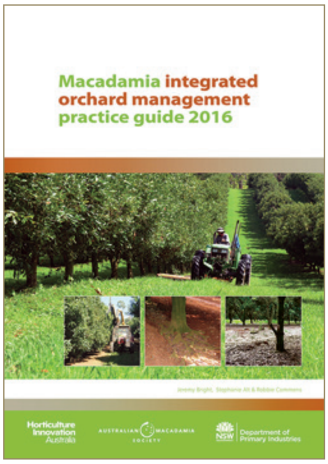
Smaller photos left to right: slope classes map for an orchard; living groundcover in an orchard; excavator removing trees.

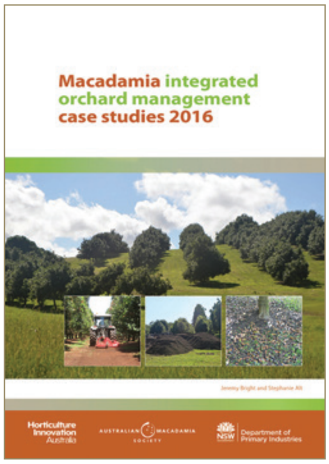
Contents

Foreword

Integrated Orchard Management (IOM) is a framework for maintaining high productivity orchards, and the recovery of orchards in decline.

This toolkit is a companion to the ***Macadamia integrated orchard management practice guide 2016,*** and ***Macadamia integrated orchard management case studies 2016.***





Successful orchard drainage systems create a synergy between the orchard layout and the landscape, ensuring that:

- minimal soil movement occurs in rain events
- concentrated water flows are managed away from macadamia trees
- blocks are protected from run-on water
- good conditions for macadamia feeder roots are maintained
- the orchard floor is trafficable and harvestable.

Effective orchard drainage systems keep productive soil in place.

Putting drainage together

There are three steps that can be used in most orchards to improve drainage systems. Together, these techniques can provide long-term water flow and soil erosion control.

Retrofitting the three steps to existing orchards will involve removing trees. Growers consistently report that they see no net loss of production because the gains in accessibility, harvest ease and water flow control exceed the production value from the sacrificed trees.

Target initial changes to the areas with the worst erosion. The order of steps in each orchard block might change, depending on which **IOM (integrated orchard management) red flags** are present. Stage changes to work gradually towards applying the three steps across the whole farm.

Step 1: Protect blocks from run on

Divert incoming water around orchard blocks into **safe disposal areas**. Diversion drains at the top of blocks are appropriate wherever there is an upslope land area.

Red flags to prioritise this step: exposed roots, scoured channels.

Figure 1. A diversion drain at the top of a macadamia block.

Step 2: Stable watercourses

Manage flowlines to prevent progressive erosion. Unstable watercourses can lose substantial amounts of soil in major rain events.

Red flag to prioritise this step: trees in natural drainage lines.

Figure 2. A grassed watercourse ready to carry water from heavy rain.

Step 3: Slope-specific management

Adjusting groundcover levels to match the IOM slope classes described in this guide.

Red flags to prioritise this step: bare earth, tree height greater than row width.

Figure 3. A sloping macadamia block with groundcover levels consistent with IOM guidelines for slope-specific management.

BEFORE: Predicted soil loss 25.2 t/ha per year.

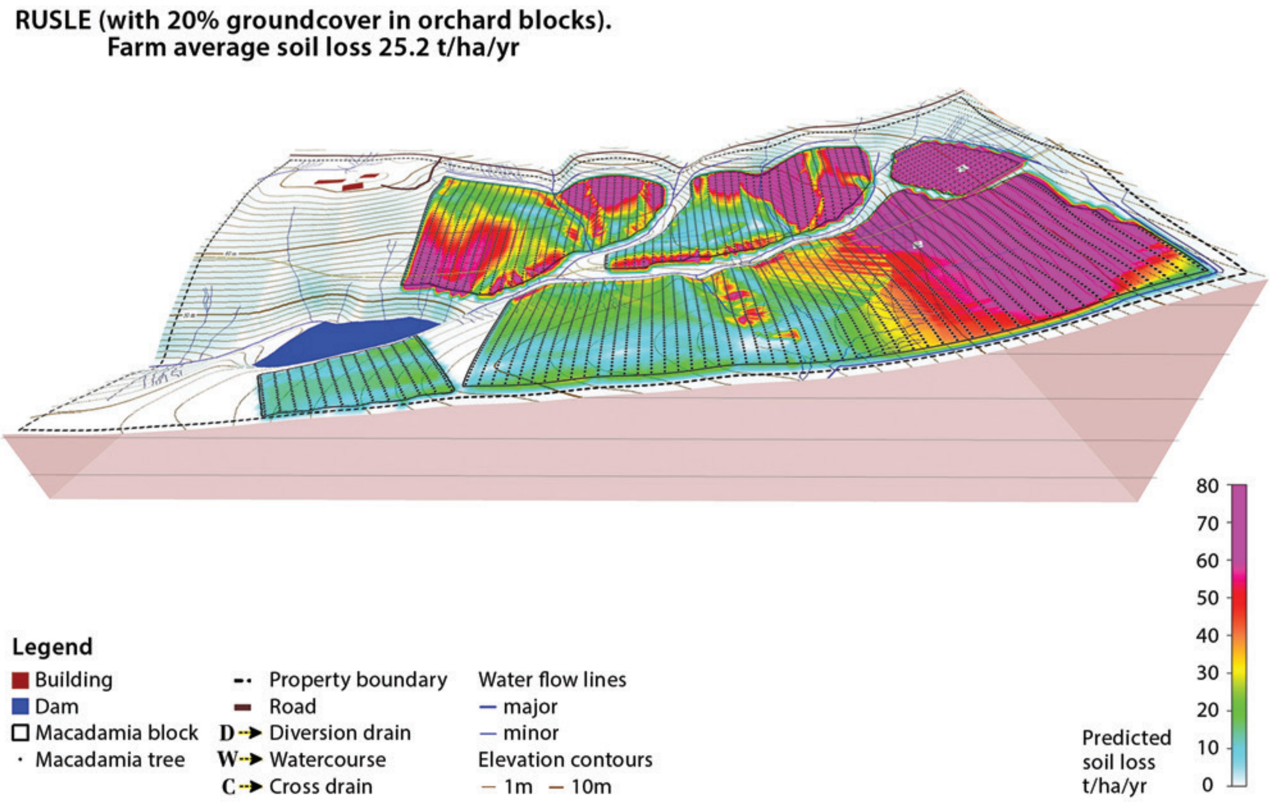


Figure 4. The orchard's predicted soil loss before applying the three steps to reduce soil erosion: Red and purple shading highlight the orchard block areas most affected by erosion – before the three steps.

Modelling predicts over 90% less soil erosion

To illustrate how effective the three steps could be, we developed a digital model orchard. We based the model on the diagram in the 'Drainage toolkit section' of the ***Macadamia integrated orchard management practice guide 2016***.

Our digital model orchard has features similar to many real orchards. In this model, the trees are mature, on 10 x 4 m spacings. There is 20% groundcover in tree block areas and 95% groundcover outside the tree blocks.

We applied techniques that can be used with LiDAR-based digital mapping of real orchards to model the likely soil erosion from the farm. Soil loss is estimated by applying the Revised Universal Soil Loss Equation (RUSLE) to the detailed terrain maps. RUSLE is a robust and widely-used model for predicting soil loss, which considers rainfall and runoff erosivity, soil erodibility, slope length, slope steepness, groundcover and management practice.

We made adjustments to the model farm to represent each of the **three steps**. The results gave us a good basis to promote the three-step framework. Individual results on farm will vary – real farms will refine the story in time.

AFTER: Predicted soil loss 0.9 t/ha per year; production area reduced by 5.2%.

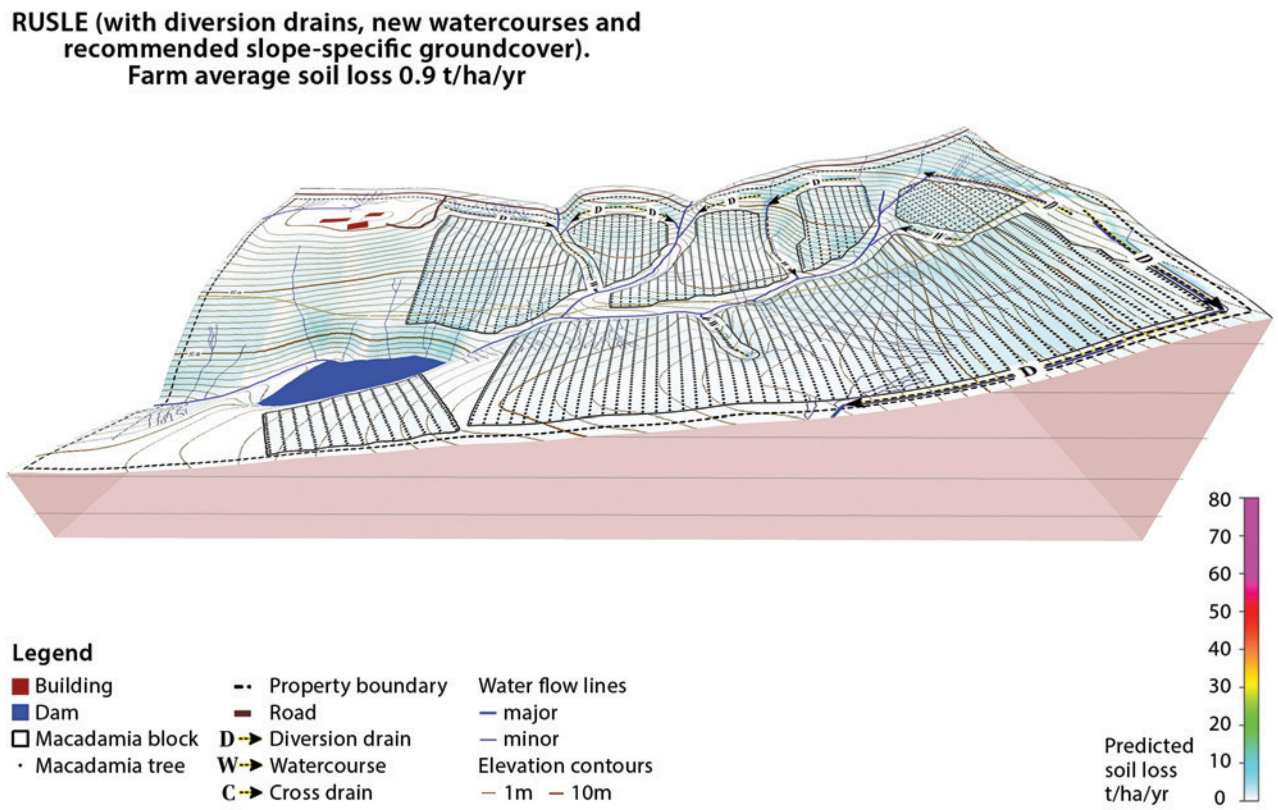


Figure 5. Soil loss predicted from the orchard is reduced by 96% after Step 1: installing diversion drains upslope of orchard blocks (D), Step 2: installing additional grassed watercourses (W), and Step 3: adopting the recommended IOM slope-specific groundcover levels.

LiDAR mapping

LiDAR (light detection and ranging) is a remote-sensing technique that can create detailed terrain and vegetation maps. LiDAR mapping is faster and gathers more terrain detail than a ground survey. Where LiDAR data is available it can be used for:

- detailed farm mapping
- predicting erosion risk
- modelling alternative groundcover strategies and placement of drainage features
- producing detailed, accurate digital elevation models for mapping surface water flows (including flow rate, flow direction and flow accumulation).

Using LiDAR maps combines data for your location with mapping software. For most growers, this will not be a DIY activity.

GES Mapping prepared the erosion models used in this guide. NSW North Coast Local Land Services partnered with GES Mapping in 2016. They worked with macadamia growers to develop LiDAR-based erosion management action plans. These projects are building frameworks to get more out of LiDAR on farms.

LiDAR mapping and digital modelling has enormous potential to enhance how we retrofit drainage solutions for orchards. LiDAR can identify steep areas, long runs of slope, and accurately locate drainage lines where changes in slope are subtle. Using LiDAR to model drainage in the design of new orchards could prevent many drainage problems.

Drainage extras

More options can help where there are obstacles to implementing any of the first three steps, or erosion trouble spots persist within the orchard. Technical advice can help achieve the best results from these methods.

Break up slope length

This manages runoff accumulation within macadamia blocks. Significant erosion can occur when there are very long runs of slope, even on gentle slopes.

Figure 6. A grassed cross bank reduces slope length in a young orchard.

Sediment management

This reduces how far soil moves. Mobile sediments accumulate where they can be easily recovered and reused within the orchard. Less soil material leaves the property.

Figure 7. A sediment trap reduces the amount of soil moving into the neighbour's paddock.

Protect blocks from run on

Figure 8. Water from the road is directed around the tree block.

When orchard blocks receive extra water from upslope it can cause, or worsen, soil erosion. Look for pathways to intercept water that runs into an orchard block from upslope and direct it around the block.

Grassed-over earth banks are the most common way to intercept and divert water. These banks and their channels form part of the orchard's network of watercourses.

Figure 9. This bank protects the lower block from run on and provides an all-weather access road.

Banks and channels need sufficient capacity to accommodate the peak water flow expected at the location. The NSW DPI web page: **Saving soil**, contains a **simple method to estimate peak discharge**. More accurate estimates are achieved using detailed terrain mapping (based on LiDAR).

Some design is needed to make sure that water diversion structures will serve their purpose. The problems from a failing structure can be more serious where large volumes of water are being intercepted.

Constructed dimensions end up being a compromise between:

- being large enough to reduce the risk of failure
- the practicalities of orchard operations
- the cost of construction.

Focus on trafficability rather than space efficiency when designing diversion banks in macadamia orchards. Broad channels have more capacity and require lower banks.

Living groundcover is needed on the bank and channel. As the width of the bank and channel increase, the width of the canopy gap needs to increase to maintain high light levels.

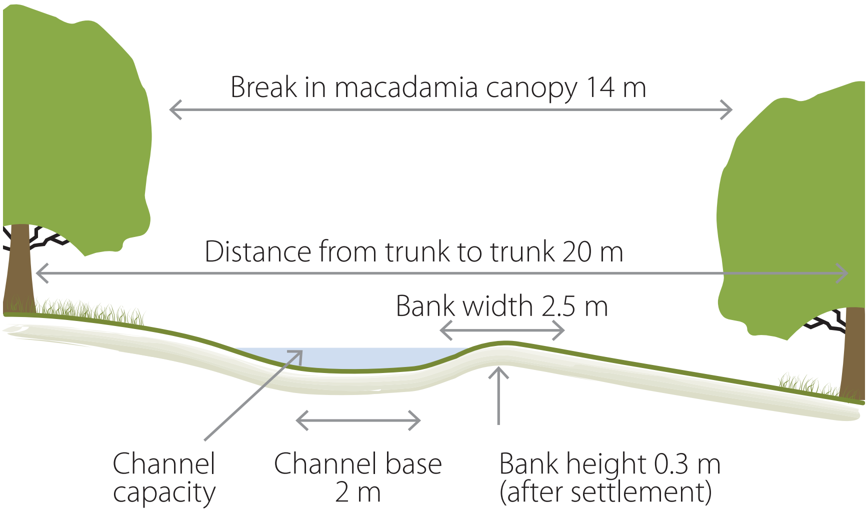


Figure 10. The dimensions of a typical grassed diversion bank between macadamia blocks. Bank and channel configurations narrower than this risk not accommodating harvest equipment. They will also require more maintenance, including pruning to sustain living groundcover.

Managing the collected water

Carefully consider the discharge area for a water diversion. Avoid creating an erosion problem in a new location. Reasonable options for water discharge include a:

- **grassed watercourse**
- **stable riparian zone**
- level spreading sill above a broad, grassed area.

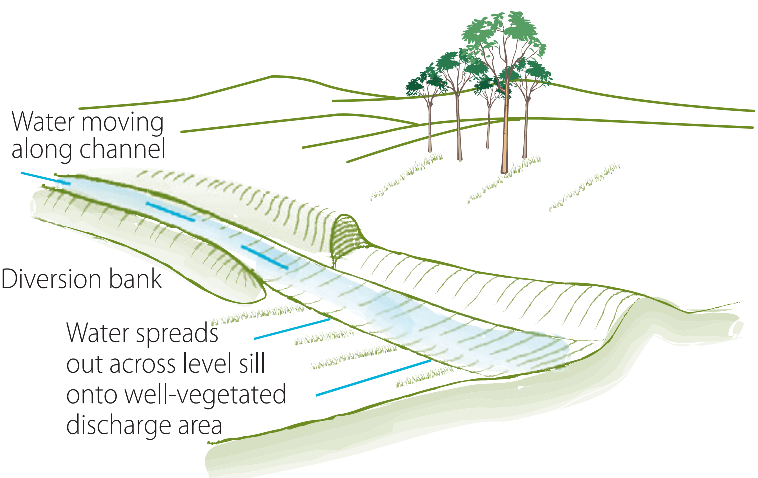


Figure 11. A diversion bank can discharge water to a level spreading sill upslope of a well-vegetated area. Source: *Saving Soil*, NSW DPI.

Adapted from Earthmovers Training Course, Soil Conservation Service of NSW, 1992

Predicted soil loss reduced by 22%: no loss of production area.

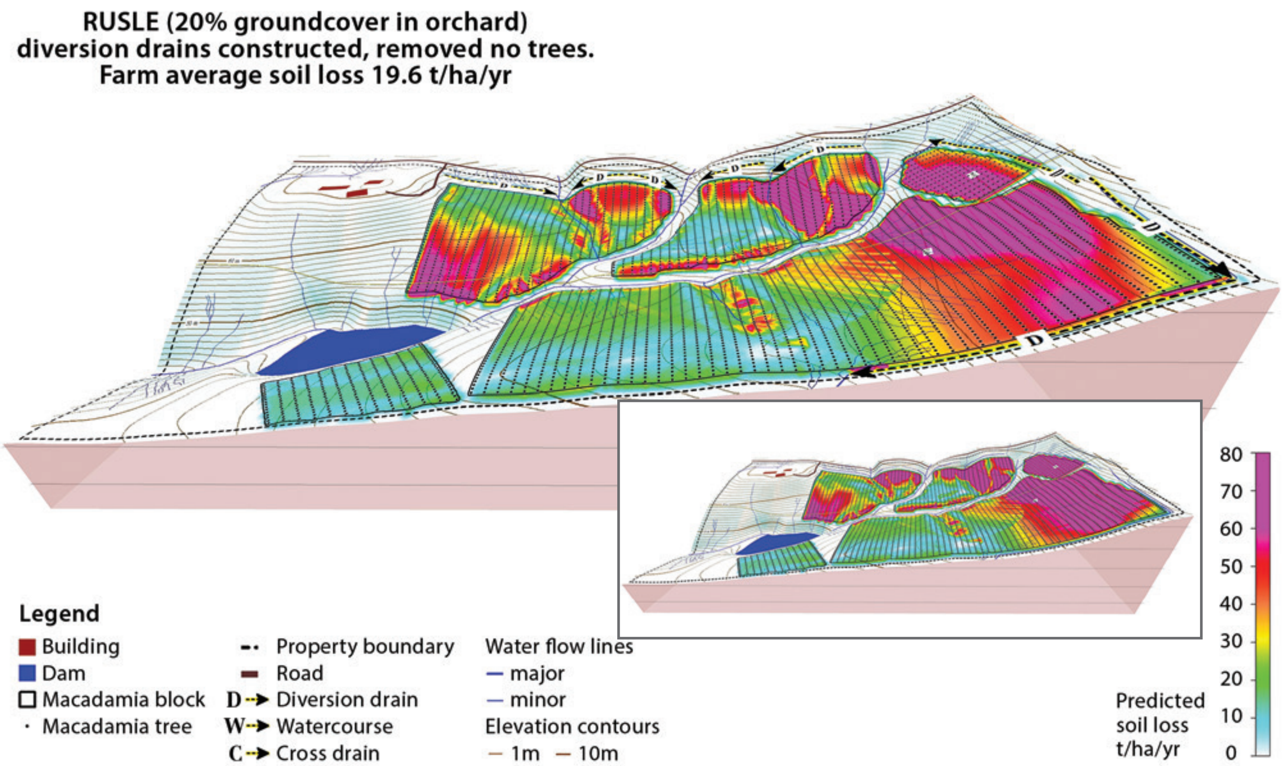


Figure 12. Installing diversion drains (D) above blocks in the model orchard is our first step to reduce soil erosion. These drains reduce predicted soil loss from the orchard by 5.6 t/year. Inset map shows the original erosion risk.

Maintaining diversion banks

Water diversion structures need to be checked and maintained to ensure they discharge water at their intended location:

- Check the height between the base of the channel and the top of bank to see if the bank remains high enough. Rework to increase the bank height if required. Recently constructed banks settle lower than the constructed height. Banks should be constructed 20% higher than the intended final dimensions.
- Check for low spots where water may overtop the bank and end up in the wrong place. Frequently trafficked points are at risk of becoming low spots in the bank.
- Repair low spots by adding material to the low part of the bank.
- Continue canopy management to allow light for permanent grass cover of the bank and channel.
- Remove debris and sediment to maintain the channel’s capacity.

Stable watercourses

Natural flowlines usually form the skeleton of a drainage system. Wherever significant amounts of water accumulate, areas of land need to be managed to carry those flows safely. Intermittent flowlines will be major contributors to soil loss unless >95% groundcover can be sustained.

Macadamia blocks need to be arranged around, not across, natural flowlines. Flowlines can be managed as riparian zones or grassed watercourses.

Where scouring or noticeable soil movement is occurring in a natural flowline within a macadamia block, consider removing some trees to create a grassed watercourse.

The minimum gap in macadamia canopy for a grassed watercourse is 15–20 m. It's not unusual to see the major flowlines in stable, mature orchards with a gap in canopy cover up to 50 m wide.

Production area reduced by 4.35%.

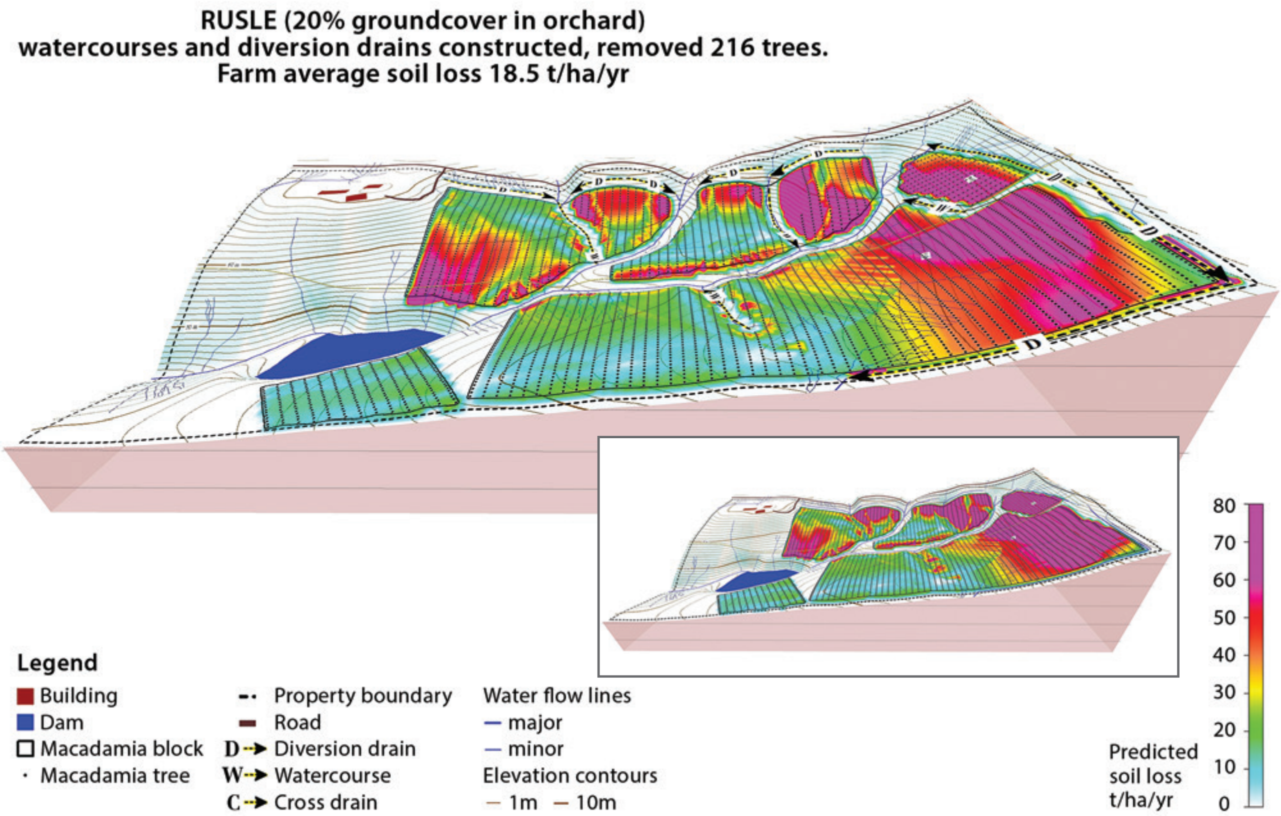


Figure 13. Four, new, grassed watercourses (W) are added to the model orchard. Inset map shows the original block layout.

Figure 14. A grassed watercourse.

Figure 15. A riparian zone.

Table 1. Orchard watercourses

	GRASSED WATERCOURSE	RIPARIAN ZONE
What does it look like?	An open grassed area with a smoothed, wide, shallow channel (see Figure 14 above).	Like a natural creek with rocky sections and diverse fringing vegetation (see Figure 15 above).
Main management activity	Mowing	Weed management
Advantages	Simple to maintain Source of mulch Channel shape can be tailored to mowing equipment	Provides habitat for native species and natural enemies Can support integrated pest management
Risks	Sharp curves in the watercourse might require special treatment.	Can support pest species. Selective weed control within the vegetation can be time consuming.
Best used	For intermittent flow lines.	For permanent and semi permanent water flowlines passing through the property. Where remnant native vegetation is present.

Figure 16. An unmanaged flow line.

Figure 17. Earthworks shape the watercourse.

Figure 18. Grass cover stabilises the watercourse.

Slope-specific management

Slope

Slope describes the steepness of land. Slope controls the rate of surface water flow. Water moves faster on steeper slopes, and fast-moving water has more energy to cause soil erosion. Slope can be assessed by ground measurement or LiDAR. It's the relationship of the rise (the vertical difference in elevation), and the run (the horizontal distance). Measurements of slope are expressed in three ways:

- **Angle** – the internal angle (in degrees) at the lower corner of a triangle formed by the base of the slope and the horizontal run.
- **Ratio** – the rise in relationship to the run. Can be expressed as 1 in 10 or 1:10.
- **Grade** – the ratio expressed as a percentage, e.g. a slope with a rise of 1 m over a 10 m run is a 10% slope.

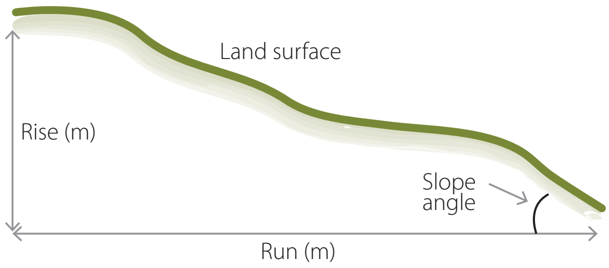


Figure 19. Slope is the relationship of the change in elevation (rise) to the horizontal distance (run).

Figure 20. Measuring slope using a level and a smart phone.

IOM slope-specific management

The IOM slope-specific management guidelines address the slope's contribution to erosion potential by managing the density and type of groundcover. All groundcover is helpful. Living groundcovers with roots in the soil have more capacity to resist the energy of moving water compared with non-living groundcovers.

Table 2. IOM slope-specific management guidelines

SLOPE RANGE	FLAT TO GENTLE	MODERATE	STEEP	TOO STEEP
	 Figure 21. A flat to gentle slope in a macadamia orchard.	 Figure 22. A moderate slope in a macadamia orchard.	 Figure 23. A steep slope in a macadamia orchard.	 Figure 24. A too steep slope in a macadamia orchard.
Slope as percentage	0–13%	13–22%	22–31%	>31%
Slope as ratio	0:10 to 1:8	1:8 to 1:4.5	1:4.5 to 1:3	>1:3
Slope in degrees	0–7.5º	7.6–12.5º	12.6–17.5º	>17.5º
Minimum groundcover (living and non-living)	80%	90%	95%	Not suitable for macadamias
Maximum proportion as non-living groundcover	100%	40%	5%	
	 Figure 25. Mulch cover >80%	 Figure 26. Mixed living and non-living groundcover >90%	 Figure 27. Living groundcover >95%	
Orchard floor priority	Building soil organic matter.	Dense living ground cover in the interrows.	Living groundcover up to the tree trunks.	

Production area reduced by 0.84%.

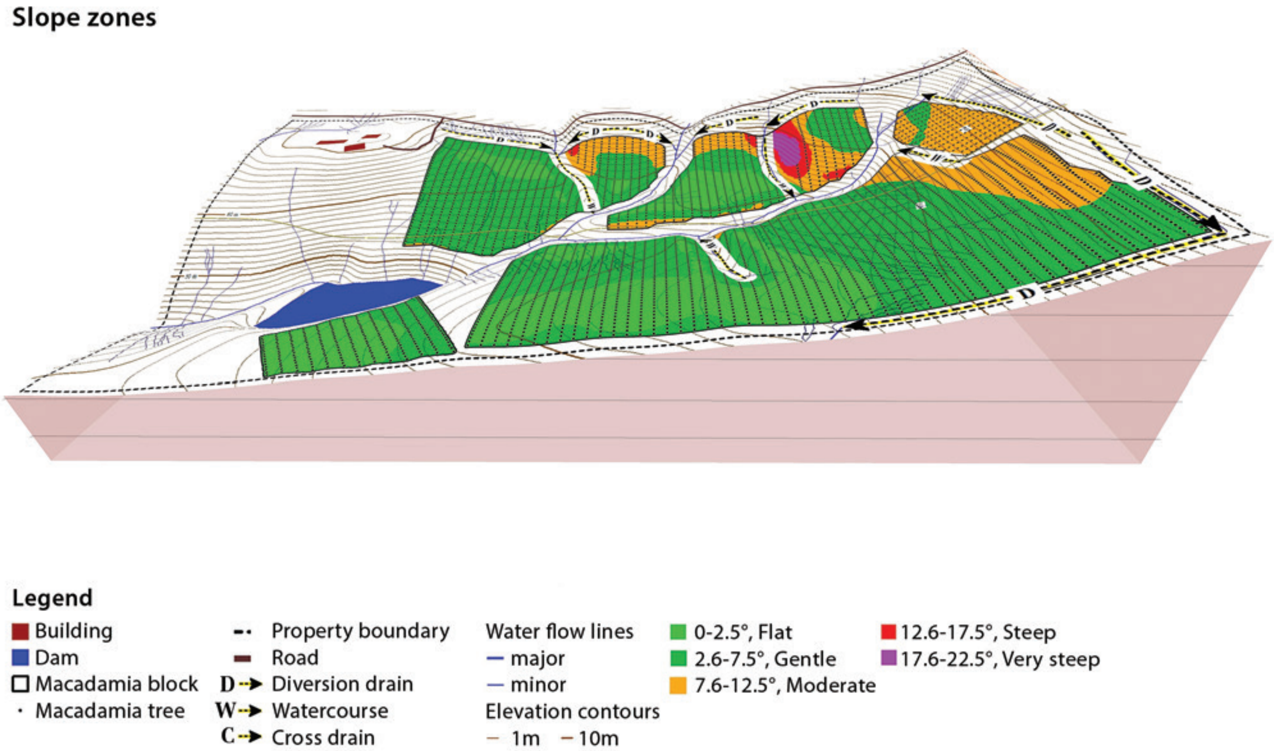


Figure 28. Mapping slope classes within the macadamia blocks sets targets for groundcover for different parts of the orchard. The purple area is too steep for macadamias.

Too steep…

Slopes steeper than 17.5° (1:3 or 31%) are not recommended for planting macadamias. These slopes are extremely challenging to manage productively in the long term. Operating machinery on steep slopes has a greater risk of accidents than performing the same tasks on moderate or gentle slopes. The risks of machinery accidents can be unacceptably high for farm employees.

Where macadamias are farmed on slopes over 17.5° (1:3 or 30%) the recommendations for steep slopes apply. If >95% living groundcover cannot be achieved, consider removing the trees, and focusing effort and investment on more manageable parts of the orchard.

There is a very steep area in our model orchard (shaded purple in the slope zone map). This slope runs across the tree rows, and the steep area is alongside a flowline that would be better managed as a grassed watercourse. This small area will be difficult to manage as part of the macadamia block. Removing macadamias from this area would be recommended.

Canopy management for living groundcover

Maintaining living groundcover on the orchard floor relies on managing the macadamia canopy to allow light through. Left to themselves, macadamias will grow to intercept over 95% of light.

No groundcover plants grow and stem flow (rainfall collected in the canopy to run down tree trunks) causes soil erosion at the tree base.

Figure 29. Nothing can grow on the orchard floor with a closed over macadamia canopy.

- Maintain tree height equal to or less than row width.

The ideal canopy volume for macadamia productivity is thought to be around 36,000 to 38,000 cubic meters per hectare. As trees grow taller than the row width they can exceed this volume, or shift the productive canopy upwards. Pruning operations become more difficult and chemical pest control less effective in these tall canopies.

The canopy management required to optimise canopy volume and achieve groundcover levels to meet IOM slope-specific management guidelines depends on:

- row width
- height of the canopy
- current level of light interception.

The higher the canopy (relative to row width) and the percentage of light currently intercepted, the greater the intervention required. Refer to the *Macadamia integrated orchard management practice guide 2016* for canopy management options.

Living groundcovers, including smothergrass, need extra light to establish. The canopy cover reduction needed to establish living groundcover on a bare orchard floor needs to be factored into the long-term plan for light interception by the macadamia canopy. Prune trees hard and allow the canopy to regrow to the target density. The time between pruning and the redevelopment of the macadamia canopy is a period of strong light to establish living groundcovers on the orchard floor.

Figure 30. Heavy pruning or tree removal might be required to recover living groundcover.

Table 3. **IOM canopy management practices** most suitable for different stages of orchard development (2016 edition).

IOM STAGE 2	IOM STAGE 3	IOM STAGE 4
Light hedging	Limb removal	Row removal
Limb removal	Limb rejuvenation	Replanting
Limb rejuvenation	Hedging and limb removal	
Hedging and limb removal	Hedging and limb rejuvenation	
Hedging and limb rejuvenation	Manual skirting	
Manual skirting	Mechanical skirting	
Mechanical skirting	Phasing out	
	Row removal	

Troubleshooting poor living groundcover

It's normal to see high levels of living groundcover in macadamia orchards with light reaching the orchard floor. Where living groundcovers are not thriving, even though there is adequate light:

- review and amend soil chemistry if required
- reduce herbicide use
- reduce soil disturbance at harvest
- aerate compacted soils.

Herbicide strips between the tree row and interrow risk channelling water down the tree rows. Move towards smoothing the orchard floor surface, and mowing closer to trees.

Figure 31. Water running down the straight edge of grass.

Drainage extras

Breaking up slope length

Reducing the length of slope runs is most useful where:

- tree rows run across the slope
- production style precludes adopting the recommended slope-specific groundcover levels.

Runoff accumulates as it progresses down slopes. Larger volumes of runoff have more erosive power. Drains that intercept water midslope reduce the volume of water running onto lower slopes. Areas with soil erosion in the lower parts of orchard blocks are most likely to benefit.

New orchards

Recognise the erosion risk of long slope runs and design blocks to allow midslope diversion drains.

Figure 32. Newly planted macadamias on a long slope with blocks separated by a diversion bank.

How to protect downslope areas within blocks:

- Intercept water flows upslope of the start of visible scouring.
- Use natural break-of-slope locations to customise drainage and orchard layout to work with the terrain.

Figure 33. A grassed area at this break of slope slows water before it flows onto the steeper area to the left.

Break-of-slope

A break-of-slope is an area where there is a change in the slope, particularly the points of change between the slopes classed as steep, moderate or gentle. The break-of-slope is often the easiest place to install water diversions.

Using break-of-slope locations in orchard design allows:

- areas that require different management approaches to be separated
- drainage and access infrastructure to be integrated.

Refine slope breaks with LiDAR and solution modelling

Detailed terrain mapping can help to identify problem areas and evaluate possible solutions. Computer modelling can test and compare how effectively **cross drains** could be used to reduce soil loss. The best solution achieves the biggest reduction in soil loss with the least number of drains to install.

Slope-specific groundcover not adopted; predicted soil loss is 12.9 t/ha per year.

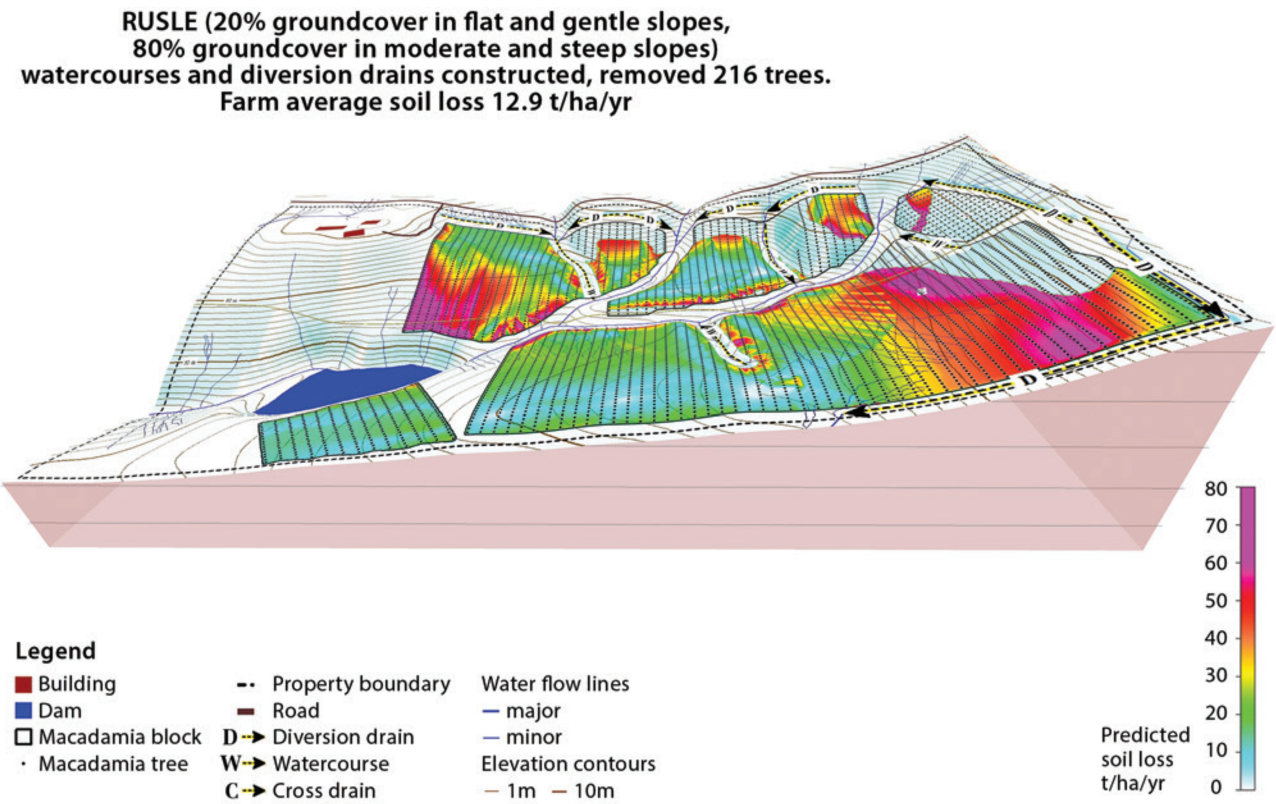


Figure 34. In this scenario, steps one (protect blocks from run on) and two (stable watercourses) are achieved. Groundcover has been improved on the moderate and steep parts of the orchard, but not up to the slope-specific recommended levels. Groundcover on the gentle slopes is unchanged, at 20%. Purple and red areas are still at risk of high rates of soil loss.

Cross drains installed; production area reduced by 11.6%; predicted soil loss is 10.6 t/ha per year.

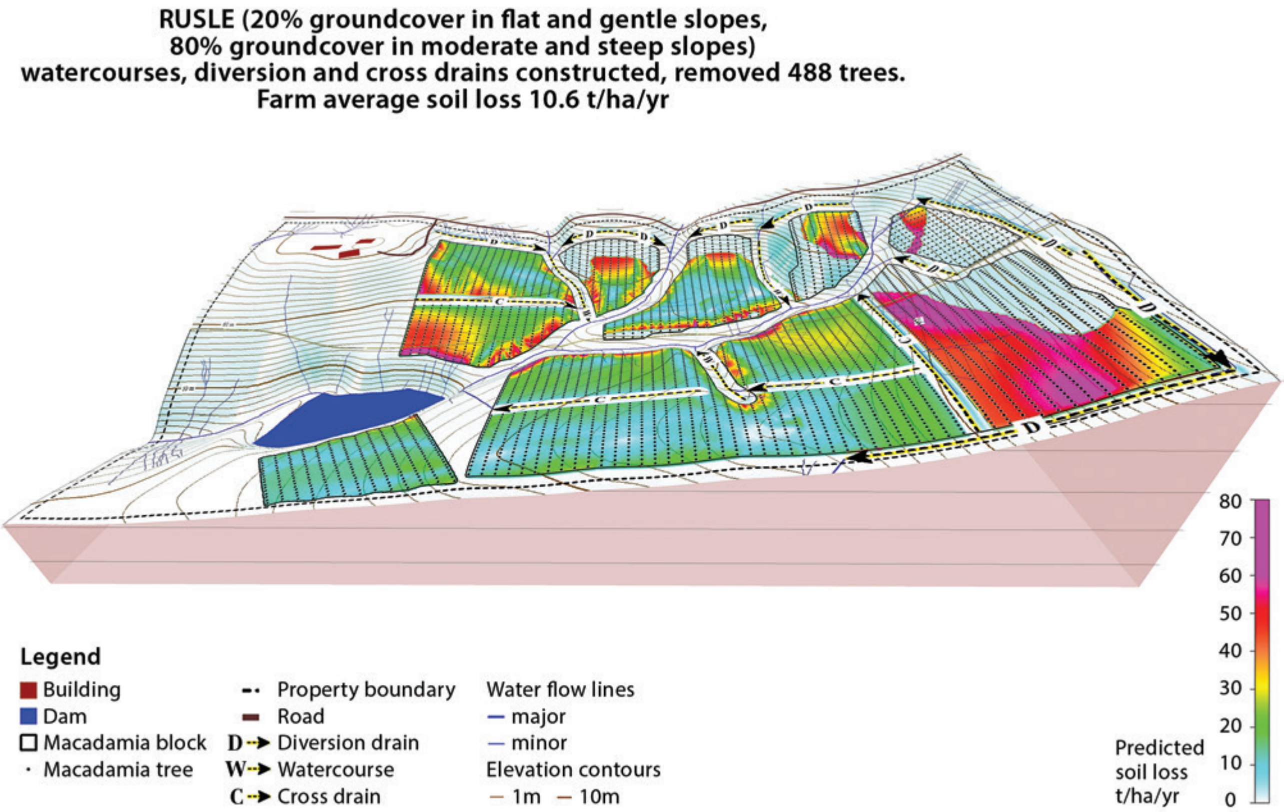


Figure 35. Cross drains (C) strategically reduce slope length and reduce the predicted erosion from the model orchard by 2.3 t/ha per year.

Managing sediment

Drainage management systems reduce the movement of soil by managing the speed and volume of water. In some weather events, substantial movement of soil can occur in macadamia orchards. Sediment management:

- reduces how far soil moves
- directs mobile sediment to accumulate where it can be easily recovered and reused within the orchard.

Efforts to manage sediment are important when transitioning towards a better drainage management system because:

- a recovering orchard will lose more soil than a stable one
- it takes time to increase groundcover percentage within blocks
- new earthworks are vulnerable in the months following reshaping of ground surfaces.

Reduce erosion after earthworks

The greatest risk of soil loss is in the months following any extensive disturbance to the soil surface. As well as takings steps to catch sediment, reduce soil movement by:

- dense sowing (>10 times pasture establishment rates) of a fast growing cover crop e.g. millet in summer, ryegrass or oats in winter
- armouring flowlines with erosion control matting e.g. jute fibre
- installing check structures.

Figure 36. A recently constructed diversion bank where jute erosion control matting has been laid in the flow path and a ryegrass cover crop is emerging.

Drainage extras

Check structures

Check structures are a temporary measure to minimise damage. In the long term, 95% groundcover in flowlines, and possibly a diversion drain upslope to reduce the volume of water at the problem site, are required.

Check structures are breaks within small flowlines that slow water down to reduce scouring. A barrier is placed across the flowline. A small pond forms behind the barrier, catching sediment that would otherwise be moved further downslope.

Check structures can be used in interrows or drainage lines with active scouring. Ideally, they are repeated down the slope so that the pool behind one check structure extends to the base of the upslope check structure. Check structures placed further apart can still help.

Check structures are no longer effective once the pond area is full of sediment. Sediment must be cleared regularly, or additional check structures put in.

Figure 37. An erosion control 'sock' used in a bare interrow drain as an interim measure.

Figure 38. Once filled with sediment, the check structure is no longer effective.

Erosion control socks are increasingly used in macadamia orchards. The socks conform to the shape of the flowline. Socks made of geotextile fabric filled with soil or fine gravel can be moved before harvest and reused as required. Socks made of jute or other natural fibres will biodegrade and can eventually be mowed over. Heavier socks resist movement better than lightweight materials. Where socks have been moved by water flows their locations should be reviewed and the socks secured in place.

Sediment ponds

Sediment ponds are usually placed where water is about to leave the property or flow into a dam. Their purpose is to catch sediment in a location that allows easy recovery. The recovered soil can be reused on the farm and the water-holding capacity of farm dams is preserved.

Sediment ponds are built to fill during heavy rainfall, but not retain water for long afterwards. A discharge pipe drains most of the water from the pond. The pond design is a compromise of terrain and access for the equipment that will clean out the captured sediment.

- A long rather than broad shape is more effective at settling out sediment.
- Cleaning out with a tractor and bucket or dozer requires gentle slopes leading into the sediment catching area.
- Cleaning out with an excavator can work with a steeper-sided pond.

Maintain sediment ponds following major rain events by:

- ensuring the discharge pipe and spillway are not blocked
- removing accumulated sediment
- maintaining a level embankment top.

Figure 39. A sediment pond catches soil before it leaves this property.

How to find a contractor

Talking with other growers is a good first step.

The Macadamia IOM Investigative Committee is compiling a list of contractors who can assist with drainage works in orchards. This list will be at:

www.givesoilachance.com.au/macadamia-drainage

The Australian Macadamia Society lists contractors working in macadamias:

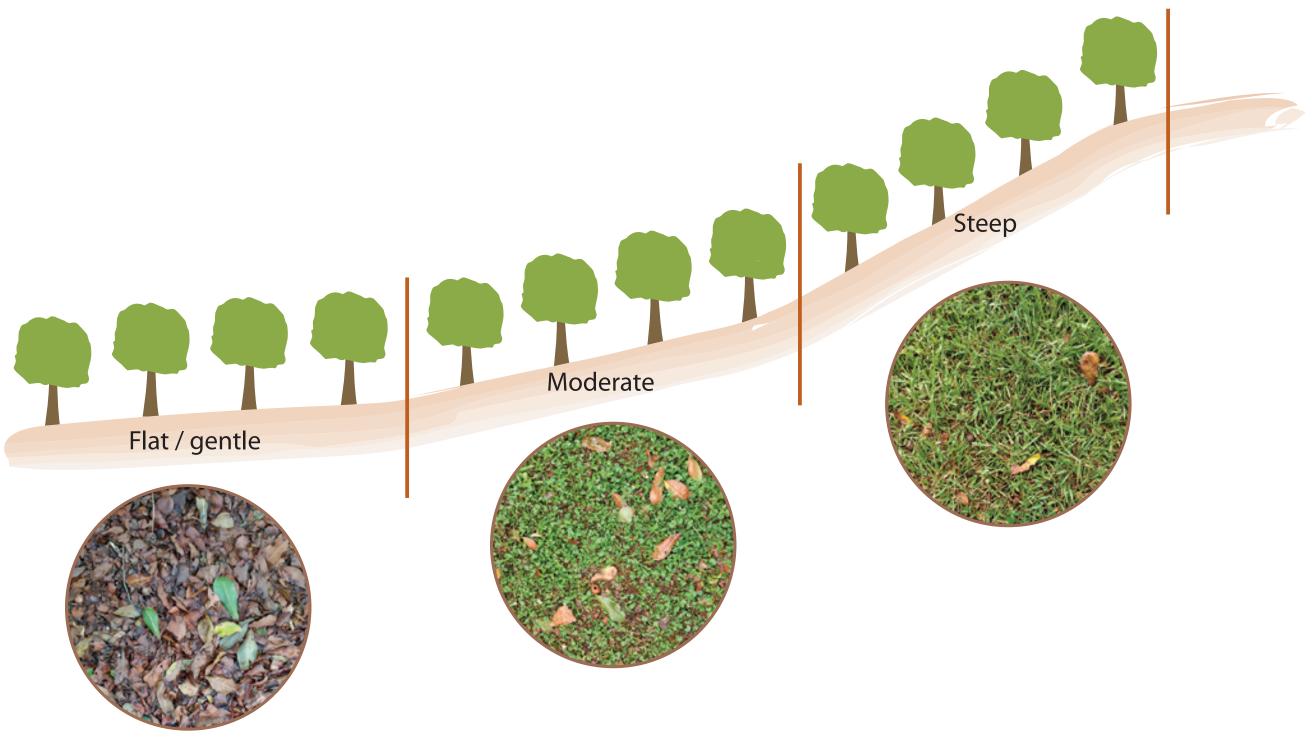
www.australian-macadamias.org/industry/industry-contacts/consultants

Managing drainage in macadamias

1) Protect blocks from run on

2) Stable watercourses

3) Slope-specific groundcover



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