Department of Primary Industries

Macadamia integrated orchard management drainage 2022

NSW DPI MANAGEMENT GUIDE

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Image acknowledgements

Large cover photo: water running on a grassed watercourse.

Smaller photos left to right: slope classes map for an orchard; living ground cover in an orchard; an excavator moving mulch.

The images in this guide have been sourced from the NSW Department of Primary Industries, except for the centre image on page 4 and figures 42–43 (Chris Fuller) and figures 46–49 (Chris Searle).

Department of Primary Industries

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Foreword

Integrated orchard management (IOM) is a framework for maintaining high productivity orchards and the recovery of orchards in decline.

This updated guide is a companion to the '*Macadamia integrated orchard management practice guide*' (2016) and '*Macadamia integrated orchard management case studies*' (2016).

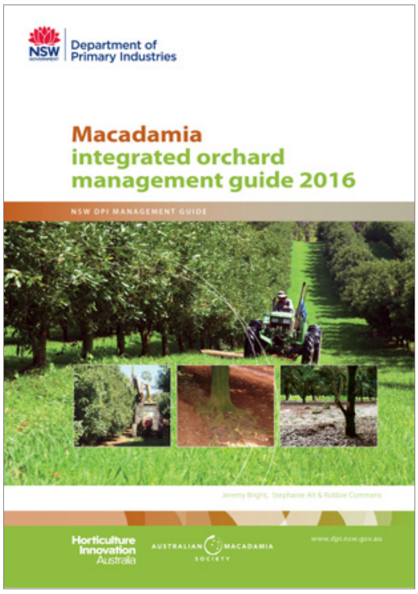
Successful orchard drainage systems create a synergy between the orchard layout and the landscape, ensuring that:

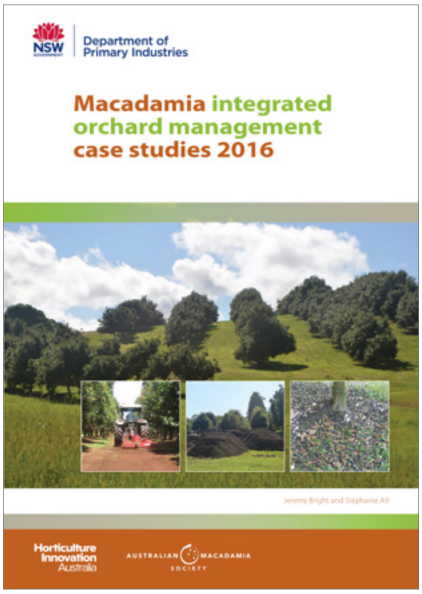
- there is minimal soil movement during heavy rain
- concentrated water flows are managed away from macadamia trees
- blocks are protected from run-on water
- good conditions for macadamia feeder roots are maintained
- the orchard is suitable for machinery and harvesting.

Effective orchard drainage systems keep soil in place and support healthy macadamia feeder roots.

First published in 2017, the 2022 edition of '*Macadamia integrated orchard management drainage*' includes new material on sub-surface drainage.

This publication outlines the major elements of managing drainage. Individual orchards vary and can be complex. Many growers work with specialist consultants to develop and refine their drainage management.





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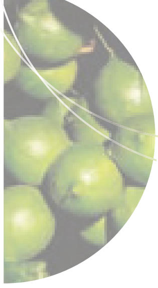


‘Red flags’ for macadamia orchards

Any of these signs is a call to action

Noticing red flags (Figure 1) 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*' (2016).

Figure 1. Seeing any of these signs in a macadamia orchard indicates that action needs to be taken to improve the canopy, orchard floor and drainage.

Putting drainage together

There are 4 steps to improve drainage systems. Together, these can provide long-term control of surface water flow and soil erosion, and ensure enough oxygen in the soil for healthy roots.

The first 3 steps outline how to manage surface water and the fourth considers poorly drained soils that constrain tree health.

Orchard establishment is the best time to create a drainage system. Retrofitting an existing orchard usually involves removing trees.

Growers consistently report no net production loss because the gains in accessibility, harvest ease and health of the retained trees exceeds the production value from the sacrificed trees.

Target the areas with the worst erosion or tree health first. The order of steps in each orchard block might change, depending on which integrated orchard management (IOM) red flags are present (Figure 1). Plan the changes to work gradually towards applying all 4 steps across the whole orchard.

Step 1: protect blocks from run-on

Divert incoming water around orchard blocks into safe disposal areas. Use diversion drains at the top of blocks wherever there is land upslope (Figure 2).

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

Figure 2. A diversion drain at the top of a macadamia block.

Step 2: stable watercourses

Manage flow lines to prevent progressive erosion (Figure 3). Unstable watercourses can lose substantial amounts of soil in heavy rain.

Red flags to prioritise this step: trees in natural drainage lines, scoured channels.

Figure 3. A grassed watercourse ready to carry run-off from heavy rain. The channel has not been scoured from previous storms.

Step 3: slope-specific management

Adjust ground cover levels (Figure 4) to match the IOM slope-specific guidelines described in Step 3.

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

Figure 4. A sloping macadamia block with ground cover levels consistent with IOM guidelines for slope-specific management.

Up to 90% less soil erosion with Steps 1, 2 and 3

To illustrate how effective the 3 steps could be, we developed a digital model orchard. The model is based on the diagram in the 'Drainage toolkit section' of the '*Macadamia integrated orchard management practice guide*' (2016).

The digital model orchard has features similar to many real orchards. In this model, the trees are mature and on 10 x 4 m spacings. There is 20% ground cover in tree block areas and 95% ground cover 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 (Figure 5 and Figure 6). RUSLE is a robust and widely-used model for predicting soil loss. It considers rainfall and run-off, erosion, soil erodibility, slope length and steepness, ground cover and management practices.

We made adjustments to the model to represent each of the first 3 steps that manage surface water flows. The results are a good basis to promote the three-step framework. Individual results on farm will vary; real farms will continue to refine the model.

Before: predicted soil loss 25.2 t/ha per year.

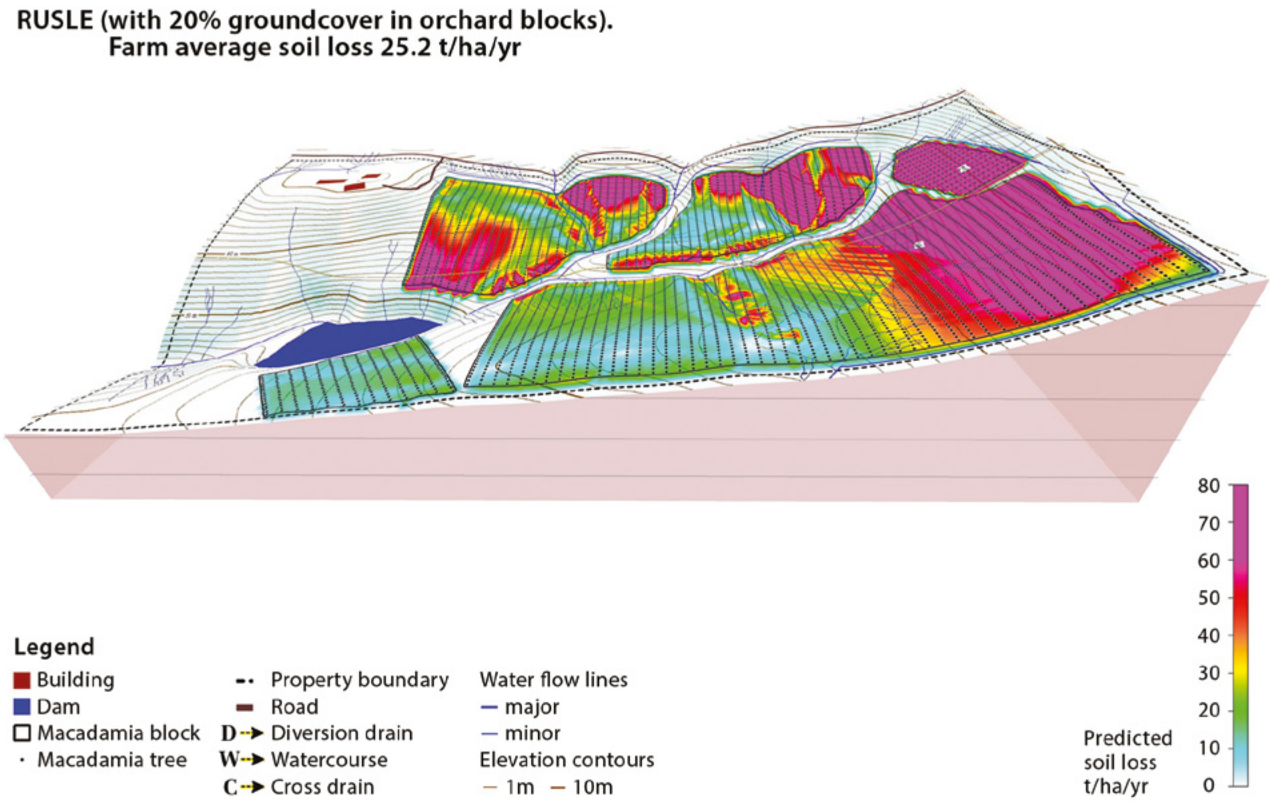


Figure 5. The orchard's predicted soil loss before applying the 3 steps to reduce soil erosion. Red and purple shading highlight the orchard block areas most affected by erosion – before the 3 steps.

After steps 1–3: predicted soil loss 0.9 t/ha per year (reduced by 96.5%); production area reduced by 5.2%.

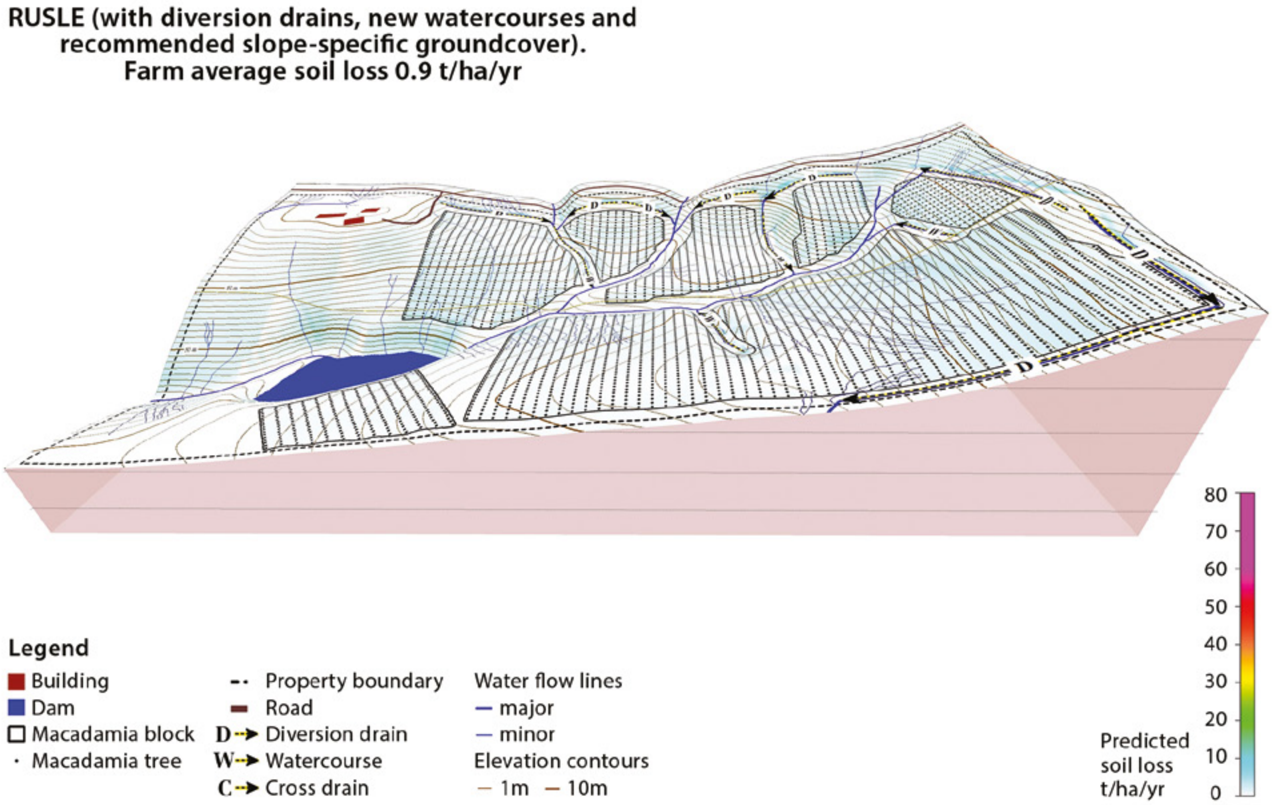


Figure 6. Soil loss predicted from the orchard is reduced by 96% after Step 1: installing diversion drains upslope of orchard blocks (D), Step 2: installing additional grassed watercourses (W), and Step 3: adopting the recommended IOM slope-specific ground cover levels.

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 are available, they can be used for:

- detailed farm mapping
- predicting erosion risk
- modelling alternative block design ground cover strategies and placing 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 a specific 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 from LiDAR on farms.

LiDAR mapping and digital modelling have enormous potential to enhance how to 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 when designing new orchards could prevent many drainage problems.

Drainage extras

More options can help where there are obstacles to implementing any of the first 3 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 run-off accumulation within macadamia blocks (Figure 7). There can be significant erosion when there are very long runs of slope, even on gentle slopes.

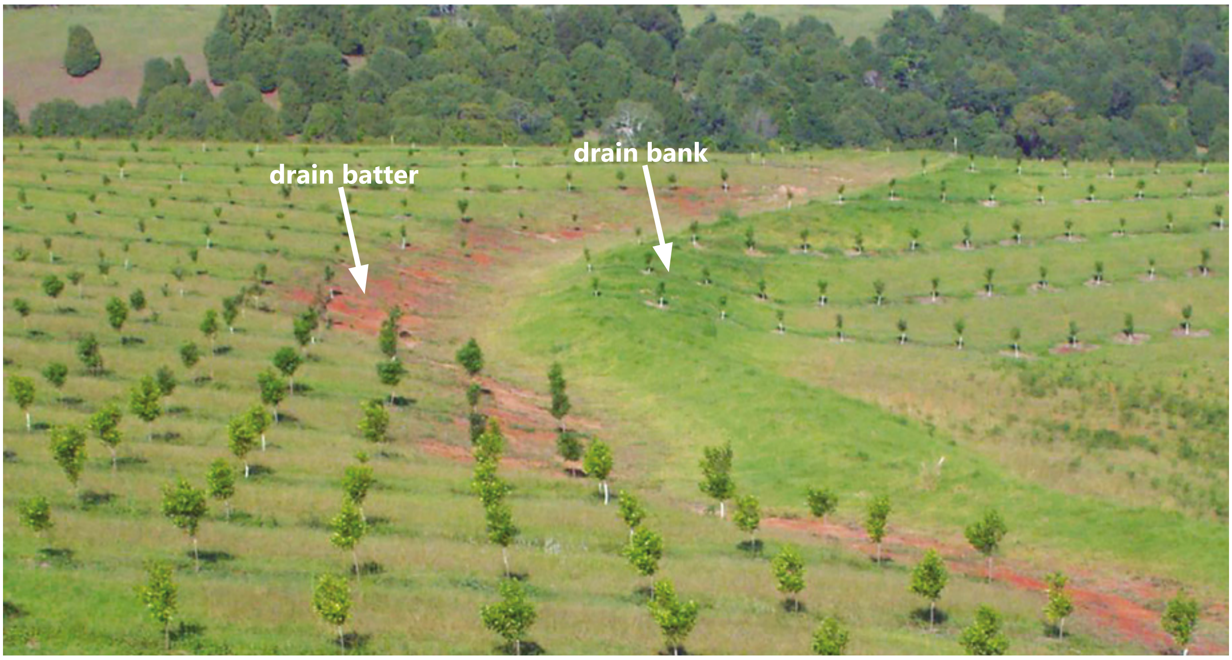


Figure 7. A grassed cross bank reduces slope length in a young orchard. Here, the trees have been planted on the drain batter and bank. There could be problems later with poor growth of the trees on the batter, harvesting ease and maintaining living ground cover.

Managing sediment

This reduces how far soil moves. Mobile sediments accumulate where they can be easily recovered and re-used within the orchard. Less soil leaves the property (Figure 8).

Figure 8. A sediment trap reduces the amount of soil moving into the neighbour's paddock.

Step 4: mitigate poorly drained soils

Poorly drained soils do not provide enough oxygen to grow healthy macadamia roots. This compromises tree health and productivity. Trees can be stunted or show dieback (Figure 9).

Red flags to prioritise this step: water ponding for more than 2 hours after rain, dead tree tops.

Figure 9. Tree growth on the lower slope is compromised by poorly drained soils.

Step 1: Protect blocks from run-on

Figure 10. 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 (Figure 10).

Grassed-over earth banks (Figure 11) 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 11. 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 publication: '*Saving soil*', contains a simple method to estimate peak discharge. More accurate estimates are achieved using detailed terrain mapping (based on LiDAR).

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 (Figure 12) 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 accessibility for machinery rather than space efficiency when designing diversion banks in macadamia orchards. Broad channels have more capacity and require lower banks.

Living ground cover 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.

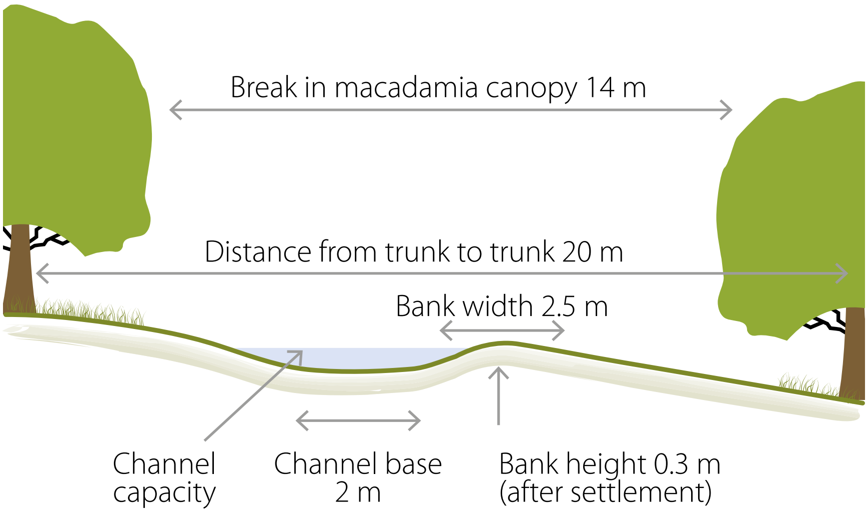


Figure 12. The dimensions of a typical grassed diversion bank between macadamia blocks. Bank and channel configurations narrower than this risk not accommodating harvest equipment. They will also require more maintenance, including pruning to sustain living ground cover.

Managing the collected water

Carefully consider the discharge area for a water diversion (Figure 13). 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.

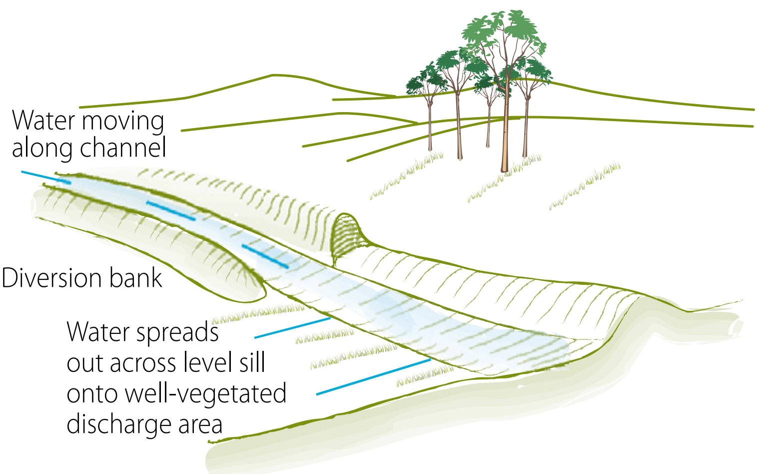


Figure 13. A diversion bank can discharge water to a level spreading sill upslope of a well-vegetated area. Source: Adapted from Marshall and Norvill (1992).

Improvement from step 1: protect blocks from run-on. Predicted soil loss reduced by 22%, no loss of production area.

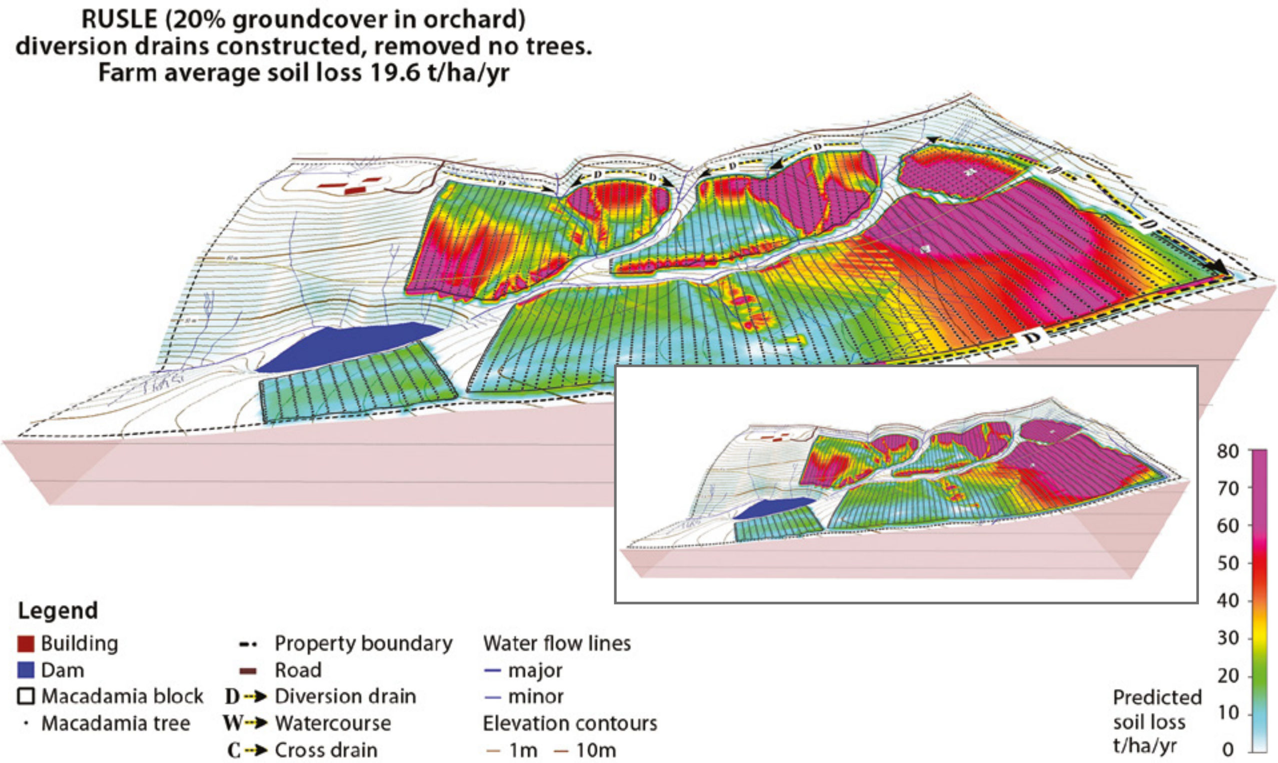


Figure 14. Installing diversion drains (D) above blocks in the model orchard is the first step to reducing soil erosion. These drains reduce predicted soil loss from the orchard by 5.6 t/year. Inset map shows the original erosion risk.

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 the 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 might go over the top of 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 managing the canopy to allow light for permanent grass cover of the bank and channel.
- Remove debris and sediment to maintain the channel's capacity.

Step 2: Stable watercourses

Natural flow lines 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 flow lines will be major contributors to soil loss unless more than 95% ground cover can be sustained.

Arrange macadamia blocks around, not across, natural flow lines. Flow lines can be managed as riparian zones or grassed watercourses (Table 1).

Where there is scouring or noticeable soil movement in a natural flow line 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 is not unusual to see the major flow lines in stable, mature orchards with a gap in canopy cover of up to 50 m wide.

Improvement from step 2: stable watercourses. Predicted soil loss reduced by another 4%; production area reduced by 4.35%.

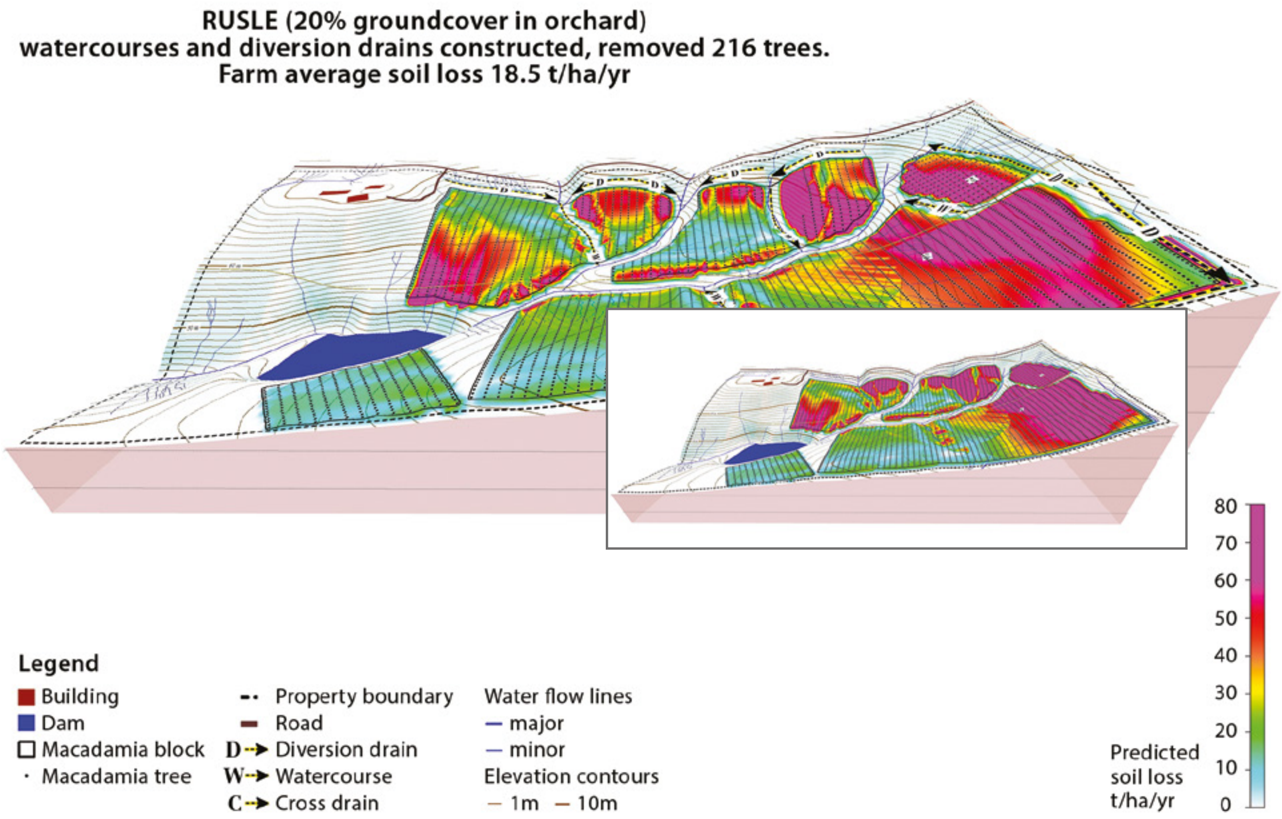


Figure 15. Four, new, grassed watercourses (W) are added to the model orchard. Inset map shows the original block layout.

Figure 16. A grassed watercourse.

Figure 17. A riparian zone.

Table 1. Orchard watercourses.

	Grassed watercourse	Riparian zone
What does it look like?	An open grassed area with a smooth, wide, shallow channel (Figure 16).	A natural creek with rocky sections and diverse fringing vegetation (Figure 17).
Main management activity	Mowing	Controlling weeds.
Advantages	• Simple to maintain • Source of mulch • Channel shape can be tailored to mowing equipment.	• Provides habitat for native species and natural predators. • 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 flow lines passing through the property. • Where remnant native vegetation is present.

Figure 18. An unmanaged flow line.

Figure 19. Earthworks shape the watercourse.

Figure 20. Grass cover stabilises the watercourse.

Step 3: Slope-specific management

Slope

Slope describes the steepness of land. It is the relationship between the rise (the vertical difference in elevation), and the run (the horizontal distance) (Figure 21). 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 (Figure 22) or LiDAR. Measurements of slope are expressed in 3 ways.

1. **Angle** – the internal angle (in degrees) at the lower corner of a triangle formed by the base of the slope and the horizontal run.
2. **Ratio** – the relationship between the rise and the run, which can be expressed as 1 in 10 or 1:10.
3. **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.

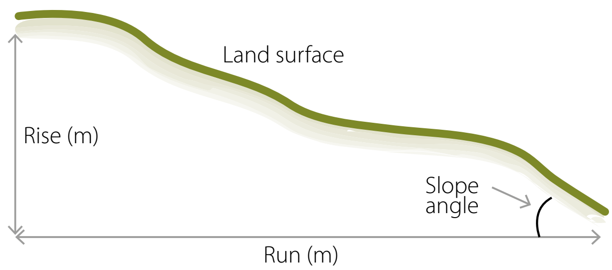


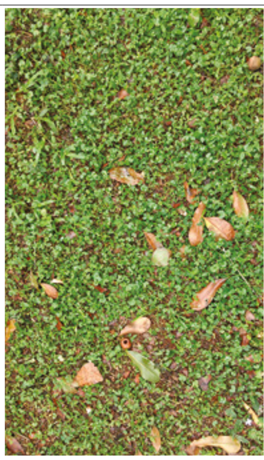
Figure 21. Slope is the relationship between the rise (elevation) and run (horizontal distance).

Figure 22. Measuring slope using a level and a smart phone.

IOM slope-specific management

The IOM slope-specific management guidelines (Table 2) consider the slope's contribution to erosion potential by managing the density and type of ground cover. All ground cover is helpful. Living ground covers with roots in the soil have more capacity to resist the energy of moving water compared with non-living ground covers.

Table 2. IOM slope-specific management guidelines.

Slope range	Flat to gentle	Moderate	Steep	Too steep
	 Figure 23. A flat to gentle slope in a macadamia orchard.	 Figure 24. A moderate slope in a macadamia orchard.	 Figure 25. A steep slope in a macadamia orchard.	 Figure 26. A too steep slope in a macadamia orchard.
Suitability	Preferred.	Workable with higher management costs.	Do not plant on these slopes. If already planted, manage the canopy to promote living ground cover.	Do not plant. Consider decommissioning blocks on these slopes.
Slope as percentage	0–12%	13–21%	22–30%	>31%
Slope as ratio	0:10 to 1:8	1:9 to 1:4.5	1:5 to 1:3	>1:3
Slope in degrees	0–7.5º	7.6–12.5º	12.6–17.5º	>17.5º
Minimum ground cover (living and non-living)	80%	90%	95%	Not suitable for macadamias.
Maximum proportion as non-living ground cover	100%	40%	5%	
	 Figure 27. Mulch cover >80%.	 Figure 28. Mixed living and non-living ground cover >90%.	 Figure 29. Living ground cover >95%.	
Orchard floor priority	Building soil organic matter.	Dense living ground cover in the inter-rows.	Living ground cover up to the tree trunks.	

Too steep…

Do not plant macadamias on slopes steeper than 17.5° (1:3 or 31%). These slopes are extremely challenging to manage productively in the long term. The risks of machinery accidents can be unacceptably high for farm employees.

Consider removing trees already growing on steep slopes. Focus effort and investment on more manageable parts of the orchard.

There is a very steep area in the model orchard (shaded purple in the slope zone map). This slope runs across the tree rows, and the steep area is alongside a flow line that would be better managed as a grassed watercourse. This small area will be difficult to manage as part of the block, so it would be better to remove the trees.

Improvement from step 3: slope-specific management. Predicted soil loss reduced by 80%; production area reduced by 0.84%.

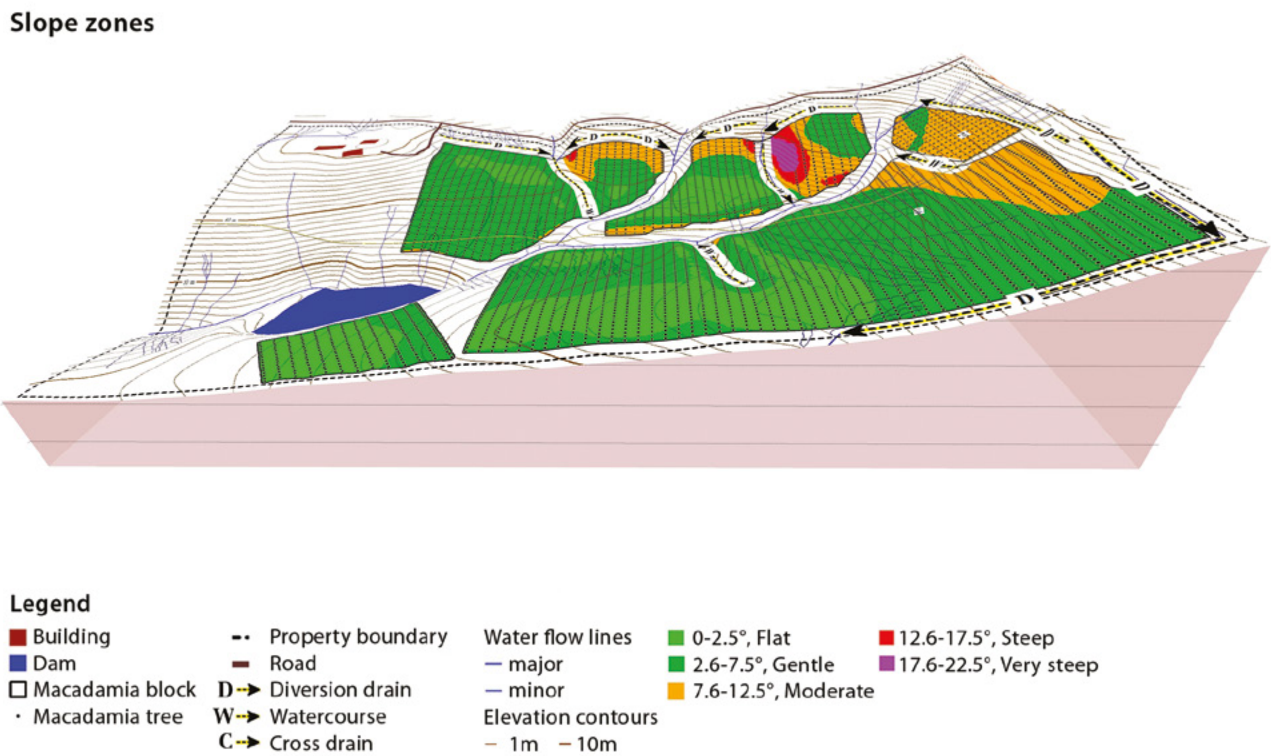


Figure 30. Mapping slope classes within the macadamia blocks sets targets for ground cover for different parts of the orchard. The purple area is too steep for macadamias.

Canopy management for living ground cover

Maintaining living ground cover 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 (Figure 31).

If there is stem flow (i.e. rainfall collected in the canopy that runs down the tree trunk/stem) where there is no ground cover, the tree base will be eroded.

Figure 31. 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 is less effective in tall canopies.

The canopy management actions to optimise canopy volume and achieve ground cover levels to meet IOM slope-specific management guidelines depends on:

- row width
- canopy height
- 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 (Table 3).

Living ground covers, including smother grass, need extra light to establish. The canopy cover reduction needed to establish living ground cover 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 canopy redeveloping is a period of strong light to establish living ground covers on the orchard floor.

Table 3. IOM canopy management practices most suitable for different stages of orchard development. Source: '*Macadamia integrated orchard management practice guide*' (2016).

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 ground cover

It is normal to see high levels of living ground cover in macadamia orchards where light is reaching the orchard floor. Where living ground covers 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 inter-row risk channelling water down the tree rows (Figure 33). Move towards smoothing the orchard floor surface, and mowing closer to trees.

Figure 32. Heavy pruning or tree removal might be required to recover living ground cover.

Figure 33. 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
- recommended slope-specific ground cover levels are not adopted
- poorly drained soils would benefit from less water seepage from upslope.

Run-off accumulates as it moves down slopes. Larger volumes of run-off 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 34). Protect downslope areas in blocks by:

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

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 (Figure 35) and can coincide with changes in soils. Water diversion between a better draining upslope soil and a poorer draining lower slope soil can improve conditions in the lower area.

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 fewest number of drains to install.

Figure 34. Newly planted macadamias on a long slope with blocks separated by a diversion bank.

Figure 35. A grassed area at this break-of-slope slows water before it flows onto the steeper area to the left.

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

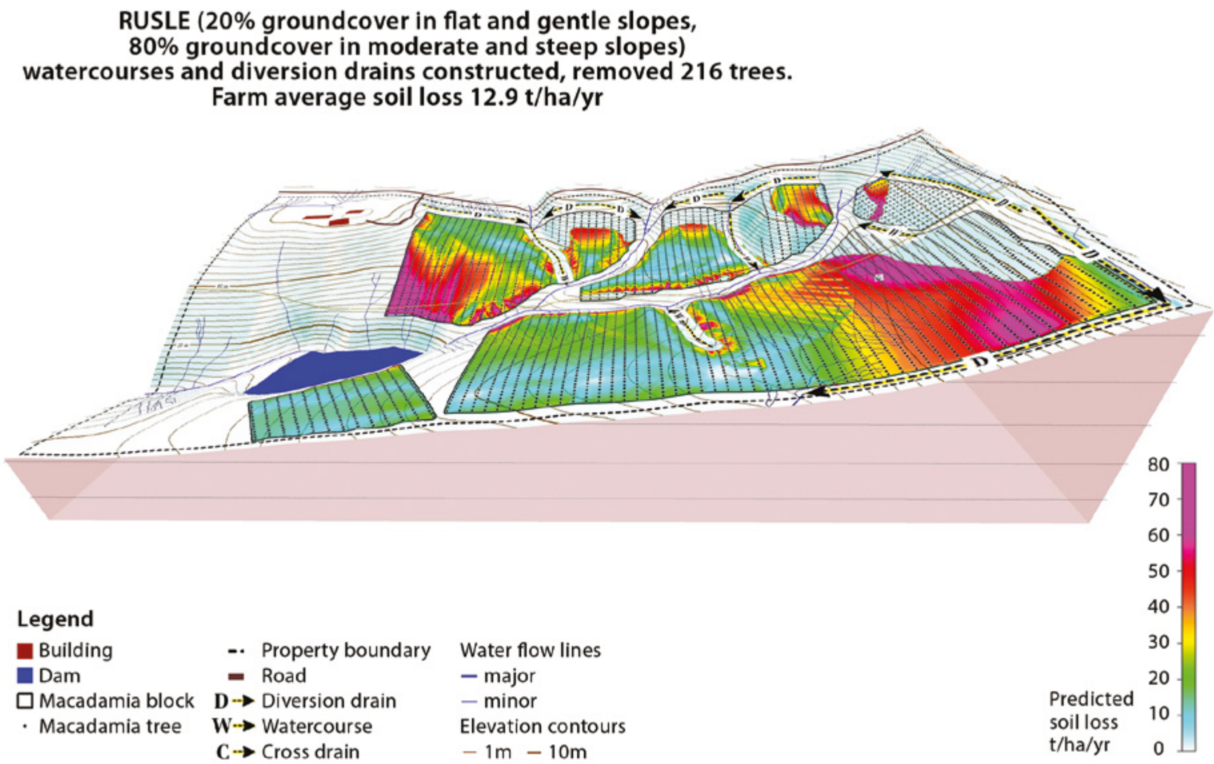


Figure 36. In this scenario, Steps 1 (protect blocks from run-on) and Step 2 (stable watercourses) are achieved. Ground cover has been improved on the moderate and steep parts of the orchard, but not up to the slope-specific recommended levels. Ground cover on the gentle slopes is unchanged, at 20%. 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.

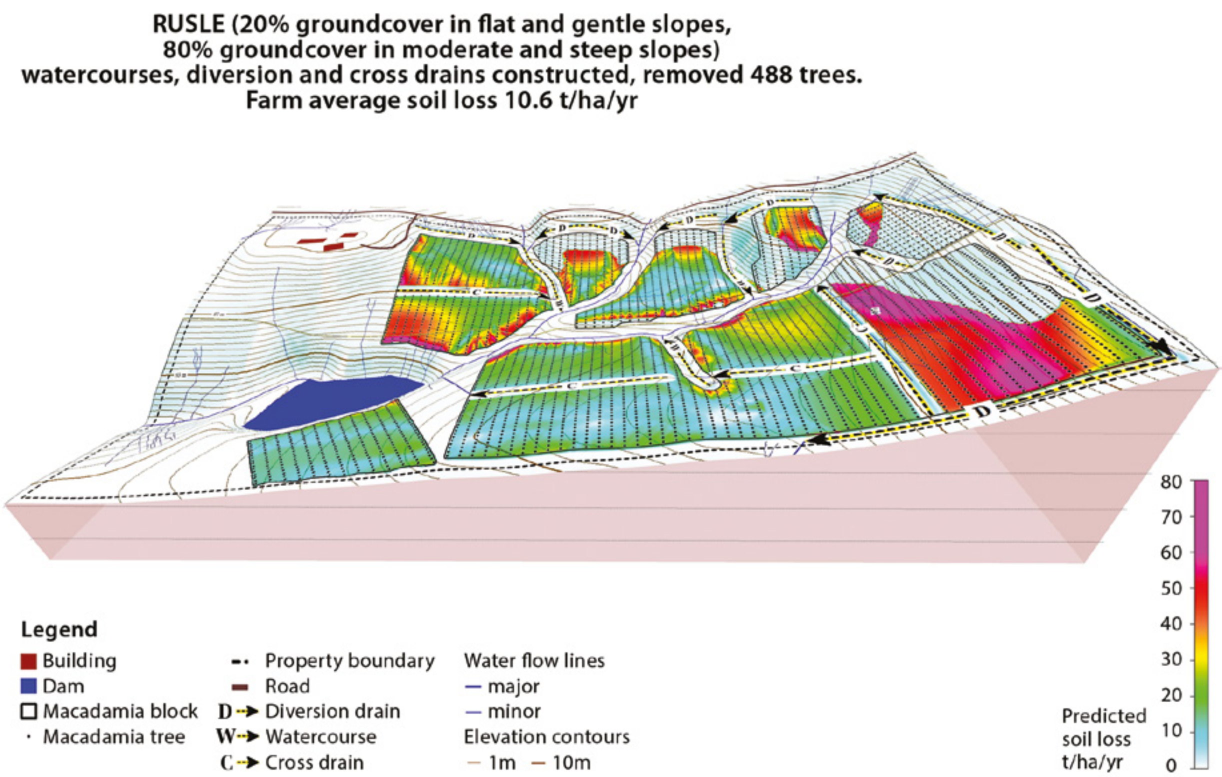


Figure 37. Cross drains (C) strategically reduce slope length and reduce the predicted erosion from the model orchard by 2.3 t/ha per year.

Managing sediment

Drainage systems reduce soil movement by managing the speed and volume of water. In some weather, substantial movement of soil still might happen. Managing sediment:

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

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

- a recovering orchard will lose more soil than a stable one
- it takes time to increase ground cover 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 flow lines with erosion control matting, e.g. jute fibre (Figure 38)
- installing check structures.

Figure 38. A recently constructed diversion bank where jute erosion control matting has been laid in the flow path and a ryegrass cover crop is emerging.

Check structures

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

Check structures are breaks within small flow lines that slow water down to reduce scouring. A barrier is placed across the flow line (Figure 39). A small pond forms behind the barrier, catching sediment that would otherwise be moved further downslope.

Check structures can be used in inter-rows 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. Placing check structures further apart can help.

Check structures are no longer effective once the pond area is full of sediment (Figure 40). Clear the sediment regularly or add check structures.

Figure 39. An erosion control 'sock' used in a bare inter-row drain as an interim measure.

Figure 40. 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 flow line. Socks made of geotextile fabric filled with soil or fine gravel can be moved before harvest and re-used 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, review their locations and ensure the socks are secured in place.

Sediment ponds

Sediment ponds are usually placed where water is about to leave the property or flow into a dam (Figure 41). Their purpose is to catch sediment in a location that allows easy recovery. The recovered soil can be re-used 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 heavy rain by:

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

Figure 41. A sediment pond catches soil so it does not leave the property.

Step 4: Mitigate poorly drained soils

Macadamia roots need oxygen

Macadamias naturally grow in well-drained soils that have a mix of air- and water-filled pores. Poorly drained soils often have pores full of water. They might also have small pores with limited connectivity (Figure 42). Small, poorly connected pores reduce infiltration of incoming water and drainage once it is in the soil.

Poorly drained soils are too wet for long periods. Trees do not get enough access to air and moisture at the same time and this impairs growth and nut production. Poorly drained soils increase the risk of diseases, such as fusarium and phytophthora root rot. At critical times, such as at harvest or for spraying, poorly-drained soils can limit machinery access

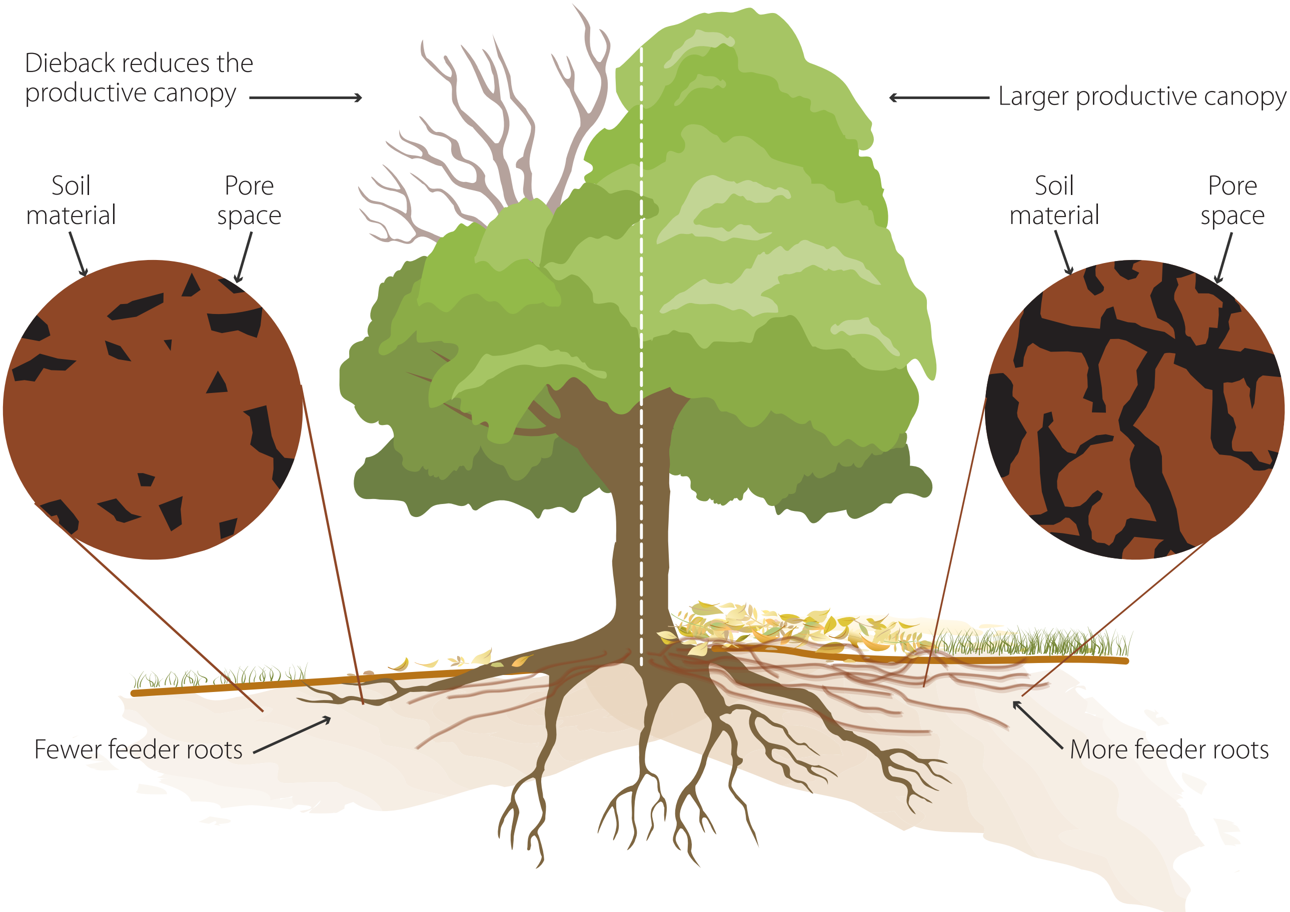


Figure 42. The left side shows the limited pore spaces in a poorly drained soil. The right side shows the interconnected pore spaces in healthy soil.

Identify poorly drained soils

Poorly drained soils can be identified by:

- detailed elevation mapping
- low elevation relative to the surrounding landscape
- wetland plants such as rushes or sedges (Figure 43)
- a change of soil type across the slope
- soil survey
- impaired tree growth (Figure 44)
- digging soil pits in the problem areas to investigate the soil condition.

Figure 43. Wetland plants close to this newly planted tree could indicate future problems with poorly drained soils.

Figure 44. A tree affected by poorly drained soils.

Repair compaction

Compacted soils contribute to poor drainage. Treat soil compaction separately from intercepting sub-surface water flows. Compaction can occur in the topsoil or subsoil. Treat compacted topsoil with a spike aerator (Figure 45), adding organic matter and maintaining dense ground cover. Treat compacted subsoils by ripping to below the compacted layer.

Figure 45. A spike aerator makes vertical cuts into the soil to increase aeration with minimal soil disturbance.

Mechanical compaction treatments are an opportunity to apply lime if the subsoil is below the target pH ranges (5.5–6.0 pH_{Ca} in acid soils or 6.0–6.5 pH_{Ca} in alkaline soils), or another calcium source if needed.

Mounding

Mounding shapes the topsoil to form continuous ridges for the tree rows (Figure 46). The mounded rows increase the favourable soil volume available for tree roots. Mounding is only practical when there is enough suitable soil material. Do not include heavy clay or hardpan material in tree mounds.

Row width needs to be proportional to the height of the mound for ease of harvesting and mowing. On the floodplains of NSW, mounds need to be 600 mm high after settling. The centre of the inter-rows serve as drainage lines to carry excess water away.

Figure 46. Mounded tree rows on the NSW floodplain.

Sub-surface drains

Sub-surface drains are trenches with gravel and ag-pipe at the base (Figure 47). They run sub-surface water away from trees to create a more aerated soil environment. They are best installed before planting.

Sub-surface drains are best used as part of a system to improve growing conditions. They will not completely resolve the limitations of the site.

Sub-surface drains need to:

- be deep enough to create an adequate oxygenated root zone above them and not be disturbed by orchard operations, usually >0.5 m deep
- have risers at least every 100 m or less of drain run to allow clean out
- run water to a stable discharge point, preferably discharging to on-farm water storage for recycling.

Set up the drain outflow point so water samples can be collected (Figure 48 and Figure 49). This could become a valuable part of monitoring the nutrition management program, especially if fertigation is being used.

Figure 47. A sub-surface drain being constructed; an excavator opens the trench, ag-pipe is laid into the trench, backfilled with gravel via a slot-shaped funnel that can be slid along inside the trench.

Figure 48. This outlet for a network of sub-surface drains brings water into a storage dam and provides a convenient water sampling point for nutrient monitoring.

Figure 49. Sub-surface drains can branch together to collect water from broad areas.

Figure 50. This drain will prevent the surface soil in the lowest areas from being waterlogged for long periods.

How to find a consultant

Talking with other growers is a good first step.

The Macadamia IOM Investigative Committee's list of contractors who can assist with drainage works in orchards: www.givesoilachance.com.au/macadamia-drainage

The Australian Macadamia Society lists contractors working in macadamias: www.australian-macadamias.org/industry/industry-contacts/consultants

NSW Department of Primary Industries
Department of Regional NSW

Managing drainage in macadamia

1) Protect blocks from run-on

2) Stable watercourses

3) Slope-specific management

4) Mitigate poorly drained soils