Healthy Country

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Monitoring of sediment removal from horticultural production fields

Lockyer Valley, South-east Queensland

June 2010

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June 2010

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Introduction

Horticultural production in the Lockyer Valley has been identified as a potentially significant source of sediment and nutrients into tributaries that ultimately deliver into Moreton Bay (South East Queensland Healthy Waterways Partnership, 2007). Recent sediment modelling of the Lockyer Blackfellow Creek Focal Area predicts a sediment contribution of 373 t/year (Olley, et al. 2010). Predictions of sediment loss from cropping land which is predominantly horticulture indicates that up to 18 tonnes per hectare per year can be mobilised from these production areas (Olley, et al. 2010).

While this recent research suggests that a proportion of this mobilised material will fail to enter waterways due to localised storage in farm dams and sediment traps; it does represents a significant and ongoing loss to the agricultural system which has the potential to culminate in a rundown of the soil resource and associated farm profitability.

In the 1980–90s Ciesiolka, Freebairn et. al. sought to better understand the relationship between rainfall intensity, slope, soil type and management practices, sediment loss and soil structural decline (disaggregation) throughout South East Queensland. Despite this pioneering work the influence of raindrop impact and soil loss in intensive horticulture remains an area requiring further research and perhaps more importantly extension programs.

While the loss of sediment and other problematic pollutants (nutrients and pesticides) from intensive farming operations remains a serious issue for water quality managers and overall catchment health, it is clear that management at the paddock scale can strongly influence water quality for the whole catchment (Freebairn and Wockner 1986). It is also well understood that the use of cover cropping on fallow areas remains one the easiest and affordable methods that can be employed by land managers for erosion minimisation and soil health benefits. Though incorporating cover cropping into fallow management still presents difficulties for vegetable producers, with the main issues cited being that of time pressure and the impact (perceived or real) on the overall farming system.

Horticultural (e.g. vegetable) production in the Lockyer Valley is characterised by intensive land preparation and cultivation with associated high water and fertiliser use. These practices lead to a decline in soil structure with increased risk of erosion and contributions to waterways through sediment and nutrient loading. As winter is the primary production period for vegetables in SEQ the summer rainfall period also coincides with reduced cropping activity. This period is primarily associated with seedbed preparation for the subsequent cropping period or opportunity cropping. Cover cropping during this period is also dependent on sufficient rainfall or antecedent soil moisture to establish the crop and also on seedbed preparation activities.

Summer rainfall (Dec–Feb) in the Lockyer Valley typically comprises short and intense rainfall events (up to 85 mm/hr) that have large potential to mobilise soil through raindrop impact and entrain sediment. This leads to soil structural and quality decline and reduced infiltration through the clogging of soil pores with fine particles, further accelerating runoff and sedimentation.

Whilst there has been recent attention to soil health related issues (e.g. soil carbon) in horticulture there is a paucity of local quantifiable data available to assess sediment losses from production areas which can inform catchment scale modelling and producers. Similarly, there is a lack of quantifiable data on the impact that recommended best management practices (BMPs), such as cover cropping, may have on sediment and nutrient movements out of the production system and soil health parameters such as nitrogen fixing via leguminous crops and carbon building potential.

The primary aim of this monitoring site/trial was to assess the soil and nutrient losses from horticultural fields under different management practices (bare fallow and living cover crop) during the high risk summer rainfall period (December–February). A secondary aim was to use the site and subsequent results as an extension tool.

Methods

Site

A sediment loss monitoring site was established in December 2009 on a commercial horticulture farm adjacent to Blackfellow Creek, Lockyer Valley, Southeast Qld (Figure 1) to collect sediment and nutrient losses (wash and suspended loads) from a horticultural production system. The farm produces a range of horticultural crops including carrots, broccoli, seedless watermelon, celery and pumpkins.

Photo 1: Location of monitoring site.

The site was located in the upper Lockyer Valley (Blackfellow Ck.) and was associated with a second river terrace. The soil type is a brown dermosol. It is an alluvial soil and classed as a light to medium clay with a moderate to high plant available water capacity and high native fertility. A compaction layer as evidenced by 'massive' soil aggregations was found at a depth of approximately 600–700 mm. A massive soil structure is typically associated with poor infiltration.

A plot with a 5% slope and 90 m in length was instrumented with three Gerlach sediment collection troughs, each trough was 10 m in length collected material from a 900 m^2 catchment area. While 300–400m^2 is the preferred catchment area for Gerlach style troughs, due to cooperator preference we were unable to reduce the size of the catchment area with structural measures. In some of the more extreme rainfall events this caused bare fallow troughs to overflow with sediment. Readers should keep this in mind when interpreting results, particularly those of the bare fallow plot.

Slopes of 5% are typical of Blackfellow Creek and is representative of horticulture in the Bremer catchment and the upper reaches of the Lockyer catchment.

Treatments

It was proposed to assess three different management practices including:

Treatment 1 consisted of a lablab cover crop (*Lablab purpureus* formerly *Dolichos lablab*) hand broadcasted at a rate of 60 kg/ha across the entire treatment area as a cover crop option. This was higher than the recommended rate of 30 kg/ha for forage lablab in high rainfall areas based on feedback from the grower cooperator that increasing the rate was a typical practice for cover crops to ensure good cover. Achieving 30 kg/ha would also have been difficult to achieve via hand broadcasting. Lablab was selected so an assessment of the nutrient budget of using a legume green manure crop could be undertaken.

Treatment 2 was a bare fallow block with prepared beds. The treatment is indicative of a post harvest plough out and one pass with a rotary hoe and initial land preparation (bed forming), with the block available for planting and cropping opportunities as per commercial horticultural practices.

Treatment 3 was a ripped bare fallow plot. In the vegetable production area of the Lockyer and Bremer post harvest ripping is a common response to overcome the soil compaction and subsequent infiltration problems associated with harvest and haul out operations.

Due to circumstances beyond the project team's control the ripped bare fallow treatment was not established. The first rainfall event occurred before the grower co-operator was able to get this plot ripped. For the rest of the monitoring period the rainfall events were regular and frequent therefore limiting opportunities for the grower co-operator to undertake this management practice while at the same time completing commercial field operations between rainfall events.

After each rainfall event the sediment in the trough was removed and weighed. As this sediment was often wet the total sediment was weighed in the field and a subsample taken to obtain a dry matter percentage so that the total dry soil loss could be calculated. This total soil loss was then presented as a tonnes per hectare value.

Soil samples were taken prior to planting the lablab and prior to spraying out of the lablab to determine what contribution the lablab may have on residual nitrogen levels.

Samples of sediment were collected from each trough for nutrient analysis to determine nutrients lost from the field. Sample results were then related back to the amount of soil lost in that rain event.

Water samplers were also put in place to sample the suspended load and any associated nutrients for some of the rainfall events.

Trial limitations

Runoff/suspended load sampling

To better understand the relationship between rainfall and runoff volume and to facilitate suspended load sampling the project initially considered equipping the plots with tipping bucket mechanisms. Given the project length and budget this was not a possibility, the grower co-operator was also unsure of future uses (opportunity cropping choices) for the site and the trafficability issues that such mechanisms would present.

As a consequence we only have limited suspended load sample data. The lack of a runoff volume measurement also means that we are unable to quantify the suspended load and can only present data as a concentration rather than a total value.

Photo 2: Sediment collection trough set up.

Photo 3: Lablab cover crop.

Results

Soil loss

There were six major rainfall events over the monitoring period. The total sediment lost from each management practice section is presented in Figure 1. Less than 0.1 tonne/ha of soil was lost from the lablab cover crop treatment over the duration of the monitoring period. In contrast, the bare fallow bedded up section (treatment 2) lost up to 11 tonnes/ha over the monitoring period. When these amounts are calculated as a depth of soil, the bare fallow block lost the equivalent of 1mm soil and the lablab block 0.01 mm soil.

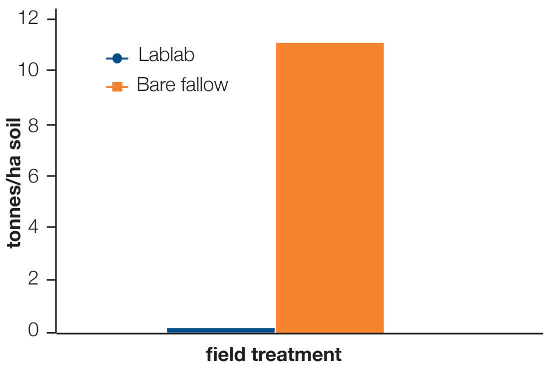


Figure 1: Sediment loss over summer from the lablab cover block and the bare fallow block.

Each of the six major rainfall events varied in amount and intensity. As expected the amount of soil lost also varied with these differences in rainfall (Figure 2).

In each event the bare fallow treatment lost significantly more soil relative to the lablab treatment and in most cases the differences were orders of magnitude greater. Interestingly the cover crop was effective in reducing soil loss even at 18 days after sowing (DAS) when only just established (see event 28 Dec 2009 in Figure 2). A photographic series in Attachment 1 documents the visual differences in sediment collection between the lablab cover crop and bare fallow bedded blocks for each rainfall event.

This monitoring site has indicated that providing cover effectively reduces soil loss due to raindrop impact and surface erosion. It is likely that the lablab was able to protect the soil from raindrop impact and also anchor soil in the furrow and on the beds through its root system. It is also clear that significant amounts of soil can be moved off bare fallow fields during rainfall events.

Photo 6–7: Runoff from the bare fallow block during the 29–31 January 2010 event.

Photo 4: Lablab plot 29-31 Jan 100 mm event (left).
Photo 5: Bare fallow plot 29-31 Jan 100 mm event. Note the sediment fans that have formed in the trough (right).

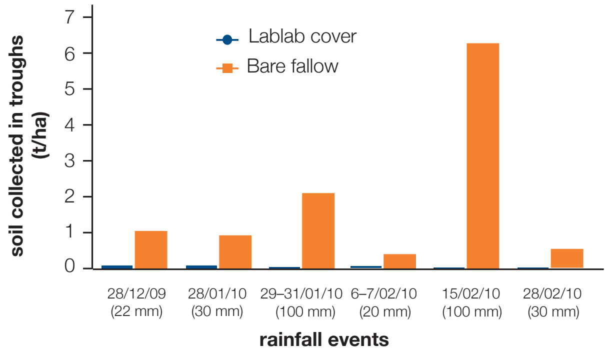


Figure 2: Soil loss from the lablab cover block and the bare fallow block with each rainfall event.

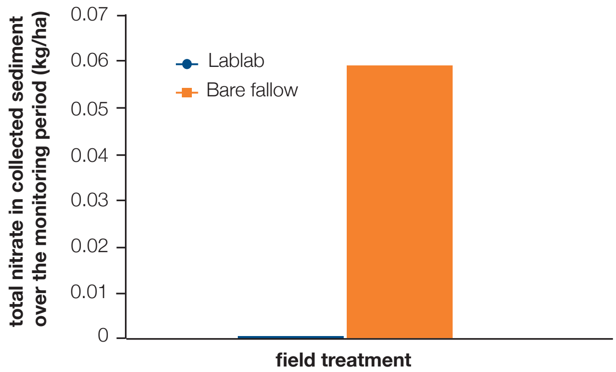
In this case, the grower co-operator has in place sediment loss mitigation infrastructure such as a sediment trap, grassed drains and grassed buffer strips to filter sediment and minimise movement off farm.

Nutrient loss—wash load analysis

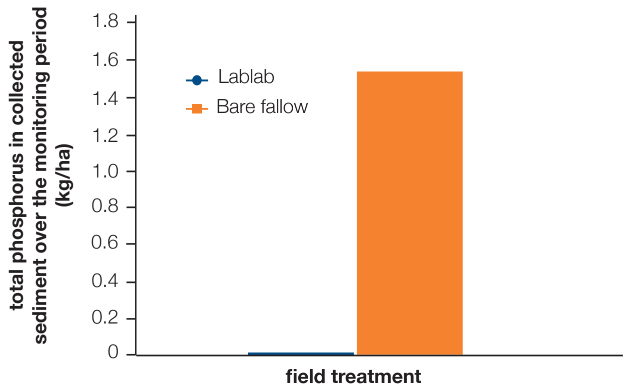
Initial soil testing indicated that soil nitrate levels were not high at 7 mm/kg. Very little nitrogen measured as nitrate nitrogen was detected in the sediment collected from the bare fallow plot, only 0.06 mg/kg. Due to the high solubility and mobility of nitrate nitrogen this was expected. Depending on the rainfall amount, intensity and duration nitrate would move through the soil profile or be solubilised into runoff waters.

Photo 8–9: Runoff from the lablab block during the 29–31 January 2010 event.

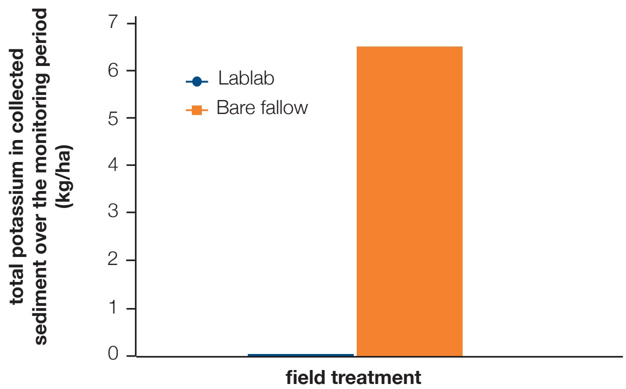
Results for phosphorus and potassium did not indicate significant amounts moving off the field with the sediment. Over the total monitoring period 1.5 kg/ha of phosphorus and 6.5 kg/ha of potassium were lost from the bare fallow block in sediment.



a) Nitrate nitrogen in sediment over the monitoring period.



b) Phosphorus (Colwell) in sediment over the monitoring period.



c) Potassium in sediment over the monitoring period.

Figure 3: a) Total nitrate nitrogen, b) phosphorus c) potassium loss in sediment over the monitoring period.

As the lablab block lost significantly less sediment over the monitoring period, nutrient analyses also demonstrated significantly less nutrient loss. Less than 0.05 kg/ha of phosphorus and potassium was lost in sediment over the monitoring period. As phosphorus is bound to sediment particles the results obtained are likely to reflect the reduced amount of sediment collected in total rather than difference in concentrations in the sediment.

Organic carbon levels were also analysed in the sediment. Organic carbon is the measurement utilised as the indicator of organic matter in soil. Results ranged from 0.95–1.6% indicating that organic matter is also being lost from the field in sediment. Initial soil testing at commencement of monitoring found organic carbon to be 1.1%.

Nutrient loss—suspended load analysis

Three suspended load samples were taken over the monitoring period and total nitrogen and phosphorus results are presented as a concentration value (Table 1). In all sampled events the results for the cover crop are less than those of the bare fallow, demonstrating that the cover has a strong effect on reducing suspended load concentrations of TSS, TN and TP.

It is interesting to note that for the 15 February 2010 event the lablab block did not produce any wash load in the sediment trough, however, concentrations of suspended load very similar to that of the bare fallow were obtained. We deduce that may be due to several reasons. It is possible that this may be a sampling artefact as a result of soil surrounding the trough (e.g. out of the defined catchment area) entering the suspended load samples, it may also indicate that in extreme rainfall events (< 80 mm/hr) the cover crop has a 'attenuation threshold' or the result is related to a combination of the following:

- depth to compaction layer (aquitard),
- antecedent soil moisture levels,
- degree of surface crusting pre event,
- soil field capacity,
- increased surface sealing occurring throughout the event.

Table 1: Concentrations of suspended solids, total nitrogen and phosphorus in suspended load samples.

	Suspended solids (mg/L)	Total nitrogen (mg/L)	Phosphorus (mg/L)
28 January 2010			
Lablab	2224	8	3
Bare fallow	17 900	18	22
29–31 January 2010			
Lablab	1100	6	3
Bare fallow	15 030	16	21
15 February 2010			
Lablab	4705	7	6
Bare fallow	4950	8	13

On the 15 February 2010 a 100 mm rainfall event was received, the intensity was 85 mm/hr. Across the 900 m^2 treatment areas this would have equated to 90 000 L of rainfall. If we assume that 50% of this could have been run off on the bare fallow blocks then 45 000 L of runoff would be a possibility with this sort of rainfall event. Based on the concentrations above for the 15 February 2010 event then approximately 220 kg suspended solids could have also been lost in the runoff from the bare fallow block with this event.

The provision of a ground cover (lablab treatment) that provides 100% groundcover has the potential to attenuate the vast majority of the TSS through negating the influence of raindrop impact on the soil surface and a providing a more complex soil surface.

Lablab nitrogen contribution

Lablab (*Lablab purpureus* formerly *Dolichos lablab*) is one summer cover crop option for intensive horticultural producers in SEQ. This legume crop can contribute between 20–140 kg residual nitrogen per hectare. In this case the lablab block did have three fold higher nitrate nitrogen (7 mg/kg versus 21 mg/kg) following incorporation compared with sampling prior to planting the lablab (Table 2). This does not equate to any significant input of nitrogen and may, however, be due to mineralisation of soil nitrogen during the monitoring period. Though, when combined with the soil management benefits provided by the crop it still represents an overall benefit to the producer.

Table 2: Nitrate (NO3) results for the lablab treatment block.

	Lablab treatment pre-plant	Lablab treatment post harvest
Nitrate nitrogen (mg/kg)	7	21
Organic carbon (%)	1.1	1.2

As the lablab had been incorporated at the end of the monitoring period it would be expected that soil nitrate levels would have experienced some drawdown during breakdown of the lablab residues. The expected nitrogen benefits of the lablab would not be expected until after residues were broken down, however, by this time the field had been fertilised and planted to a subsequent canola crop so it is difficult to quantify the nutritional benefit of the lablab. This represents one of the challenges in undertaking trial work on commercial farms where production pressures take precedence.

Cover cropping—at what cost?

An economic analysis of the cost of the lablab cover crop demonstrates that providing cover is not significant in terms of overall farm business costs.

Table 3: Cost of including lablab cover crop.

Farm operation	Cost ($/ha)
Lablab seed	$158.40 #
Sowing (FORM+labour)	$24.38/ha
Spray off (FORM+labour) + chemical	$8/ha
Seedbed preparation 2 operations x $32.83 /ha (FORM+labour)	$65.66/ha
TOTAL (FORM+labour) + chemical	$256.44/ha

The recommended rate of sowing for lablab as a fodder crop in high rainfall areas is 30 kg/ha, in this trial 60 kg/ha rate was used, therefore the cost would be half.

Significant amounts of phosphorus and potassium do not appear to be lost with sediment movement off the field. However, it is still a loss to the farming system that can potentially impact on waterways without appropriate infrastructure in place to prevent movement off farm and from a production point of view will need to be put back into the system in the future.

There are other costs to the producer that also need to be considered. In the absence of a cover crop but with infrastructure in place to trap sediment the producer will have to move and spread soil from drains and sediment traps back onto the field. Preventing it from moving off the field in the first place is the best management practice. There will also be an opportunity cost if the field is planted to a cover crop.

To replace the nitrogen lost in sediment with the commonly used fertiliser, Nitrophoska Blue, would require an application of 0.5 kg/ha at a cost of $0.57/ha. The same fertiliser contains phosphorus and potassium.

To replace losses of phosphorus and potassium using this same fertiliser, would require an application of 46.1 kg/ha of fertiliser at a cost of $53.02/ha. This would replace both the phosphorus and potassium as well as the small amounts of nitrogen detected.

The potassium could be replaced separately by application of muriate of potash at a rate of 13 kg/ha and a cost of $6.63/ha.

Discussion

Despite decades of scientific enquiry and extension programs sediment loss from agricultural systems remains the most challenging land management problem in Australia and arguably the world. In most cases land managers are time poor and fail to see the causes and consequences of losing soil.

This trial/demonstration has again highlighted that even in low landscape relief situations (> 5%) rainfall induced soil loss can be significant. The results are consistent to those obtained by Ciesiolka et. al. (1995) and Layden & Nicholls (2008) on pineapple farms in SEQ. While the cover cropping effect on mass soil movement was significant, the effectiveness is likely to vary with rainfall intensity and other site characteristics (e.g. antecedent soil moisture, presence of a compaction layer). This highlights the need for more detailed studies if incorporation into complex cropping systems is the goal.

The trial has also highlighted that sound extension methodology that employs participatory action research principles (PAR) can be strong modifiers of land management behaviour. Similarly, as soil losses typically occur 'out of sight' of most land managers and indeed it is only when these losses are able to visualised by the land manager that actions can be taken to address the problem. The axiom of 'you can't manage what you can't measure' holds true in this regard.

The majority (approximately 70%) of growers engaged thus far through the Healthy Country program are aware of the benefits of cover cropping for reducing the erosion potential of their soil and the high risks associated with the summer rainfall period. The value of this demonstration site has been in quantifying the amount of sediment. While growers may be aware of the risk of erosion losses, the sheer quantities of sediment that can be lost over six events would be unexpected and the most compelling information.

Benchmarking of current horticultural practices in the Lockyer and Bremer catchments indicates that the majority (approximately 80%) of vegetable producers will grow a cover crop when they can. However, this process has also identified those factors that constrain the incorporation of a cover crop into the farming system. Cover cropping is dependent on sufficient rainfall and/or adequate soil moisture to establish the crop. As irrigation water is the most limiting resource in their production system producers will not irrigate a cover crop that they will not see significant financial return on. The area of economics of cover cropping (e.g. the long term soil health benefits, water and nutrient holding capacity) remains an area for further consideration.

The decision whether to cover crop or not also depends on the vegetable crop rotation. Seedbed preparation for some crops (e.g. carrots) is traditionally very intensive and this summer period may be set aside for these operations depending on the rotation and planting windows. A cover crop may present issues for seedbed preparation prior to planting. The impact of soil organic matter on product quality is also a concern for growers of some crops. Bulb and root crops such as potatoes, carrots and onions can have serious quality issues if there are large amounts of crop residues in the soil during development. These can cause skin imperfections or deformations that can make the product unmarketable and therefore raises the question of supply chains and market forces affecting soil and catchment management as a whole.

A positive has been the feedback from local vegetable producers which has repeatedly highlighted an interest and requirement for more information on cover cropping for vegetable production systems. This includes cover crop options, soil health benefits (soil carbon and nutrient contributions, soil structure, water holding capacity) and interactions with other aspects of their production system (stubble and residue management, disease and pest implications).

Recommendations

This small trial has highlighted several areas that require further work. The majority centre around the need to better convey to land managers the risks (both economic and biophysical) associated with uncovered soil during high risk periods; and providing more definitive and local answers to issues that surround the use of cover cropping.

It is therefore recommended that future RD&E focus on a participatory action research (PAR) model involve:

- a strong emphasis on extension and participatory action learning (PAL) techniques focussed on sediment loss and management activities (including waterway restoration),
- well publicised long term sediment loss trials across a range of soil types and slopes using a variety of cover cropping options that target horticultural producers,
- analysis of how cover cropping can be incorporated into multi-cropping situations (e.g. whole of farm systems approach),
- embedding of cost-benefit economics into trials to further develop decision support tools to demonstrate to landholders that sediment loss and sediment management practice make economic sense.

Acknowledgements

The cooperation of the Lockyer Valley grower, Brian Crust of Mt Sylvia Fresh Vegetables, in allowing us to establish this monitoring site on his property is very much appreciated.

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References

Ciesiolka, C. A. A., Coughlan K. J., Rose C. W. and Smith G. D. 1995. Erosion and hydrology of steeplands under commercial pineapple production. Soil Technology 8(3):243-258

Freebairn, D.M., and Wockner, G.H., (1986a). A study of soil erosion on vertisols of the eastern Darling Downs, Queensland. I. Effect of surface conditions on soil movement within contour bay catchments. Aust. J. Soil Res., 24, 135-158.

Freebairn, D.M., and Wockner, G.H., (1986b). A study of soil erosion on vertisols of the eastern Darling Downs, Queensland.II. The effect of soil, rainfall and flow conditions on suspended sediment losses. Aust.J.Soil Res., 24, 159-172.

Layden, I., and Nicholls, Z. (2008) Living Mulch: disease and erosion research. FarmFLOW Fact sheet #2. Internet: http://www.healthycountry.com.au/HealthyCountry/Resources/SustainableLandManagementResources.aspx

Olley, J., Ward, D., Pietsch, T., McMahon, J., Laceby, P., Saxton, N., Bengtsson, F. and Rose C. (2010) Phase 2c report: Rehabilitation priorities Lockyer focal area. eWater Cooperative Research Centre, South-east Queensland

South East Queensland Healthy Waterways Partnership (2007b). Non-urban Diffuse Source Pollution Management Action Plan, South East Queensland Healthy Waterways Strategy 2007 -2012.

Internet: http: //www.healthywaterways.org/FileLibrary/2_nonurban_diffuse_action_plan.pdf

Attachment 1:

Photographic series of sediment monitoring from horticultural fields under different management practices.

Rainfall event—28 December 2009

Lablab cover crop (left); bare fallow beds (right).

Rainfall event—28 January 2010

Lablab cover crop (left); bare fallow beds (right).

Rainfall event—29–31 January 2010

Lablab cover crop (left); bare fallow beds (right).

Rainfall event—6–7 February 2010

Lablab cover crop (left); bare fallow beds (right).

Rainfall event—15 February 2010

Lablab cover crop (left); bare fallow beds (right).