LAND & SOIL MANAGEMENT

Section 1:
Land & Soil Management

The Expected Environmental Outcome for Land and Soil states

All reasonable and practicable measures should be adopted, within the constraints of a sustainable agricultural system, to conserve the sustainable productive characteristics and qualities of the land and its soils (QFF 1998).

1.1 CONSIDER LAND USE SUITABILITY FOR GOOD FARM PLANNING

Deciding on appropriate land management practices and crops to grow in a given area, requires an understanding of the suitability of landforms and natural resources.

Identifying land use suitability involves a detailed assessment of a given area to determine if it can be profitably and sustainably developed assuming average cost/price structures. Characteristics studied include soil types, geology, hydrology, landscape, vegetation, topography and climatic conditions.

Decisions based on land use suitability criteria will help ensure that the integrity of the surrounding environment and natural resources is not compromised.

Information on land use suitability for horticultural production regions is available in the QDNR 'Land Management Manuals'. (QDNR 1995). These manuals contain detailed regional information on climate, vegetation, geology, land resources, current land use and important types of land degradation.

A good farm plan can help with the appropriate placement of infrastructure and use of natural resources

Individual field manuals within each 'land management manual' outline the major agricultural management units occurring for each region with information on land use suitability, land use limitations and land conservation guidelines for each unit.

Other resources available include 'Buying the Farm for Horticulture' and the QDPI's 'Self-Help Landcare' publication that considers land use, planning property development and land protection (Jordan et al. 1993).

Extensive land management information specific to horticultural commodities can be found in the relevant Information Kit from the Agrilink Series (QDPI 1998).

■ *Develop a whole farm plan*

Once basic land use options are decided, a whole farm plan can help with the appropriate placement of infrastructure and use of natural resources.

A whole farm plan is simply information about the farm business enterprise captured through documentation.

A good plan will consider (QFF 1998),

- the needs and expectations of people in the farm business
- the economic and physical resources available to the property
- the potential impact on neighbours and neighbouring areas of farming activity
- potential on-farm and off-site environmental impacts of farming activity

Know your different soil types

Different soil types require different management for irrigation, tillage, fertiliser rates, etc.

Soil sampling, mapping and assessing soil attributes (eg: texture and colour) will assist in developing knowledge of soil types across the farm. Your local QDNR officer will know what local soil classification maps exist.

Knowledge of soil condition is also helpful. Further information on describing soil type and assessing soil condition can be found in the *Soil Check Manual* (Forge 1995). Topics covered include how to assess,

- physical condition (including compaction, dispersion, water-holding capacity, infiltration rates and erosion),
- chemical condition (including nutrients, organic matter, pH, salinity and possible herbicide residues) and,
- biological condition (micro and macro organisms, seed-bank and weeds).

1.2 MINIMISE EROSION OF SOIL

Example:

Downstream impacts of erosion in pineapples.

Trial work on pineapple farms showed that both the eroded soil and suspended sediments carried nutrients off the pineapple site. 10-20% of applied nutrients are lost in the eroded bedload soil, with loss of potassium and calcium the most serious (Ciesiolka 1996).

More nutrients were lost in the runoff water compared to eroded soil, with losses between 30%-50% of individual nutrient applications (Ciesiolka 1996).

Wind, water and mass soil movement can all cause land degradation through erosion processes.

Soil erosion involves the removal of clay sized particles (the most fertile part of the soil) from the organic rich soil surface through these vectors.

Air borne soil particles may cause air pollution. Water borne soil particles may cause siltation and sedimentation of dams, creeks and rivers; increase water turbidity and deposit residual nutrients and pesticides attached to soil particles.

Uncontrolled water runoff builds up quickly, and may cause physical damage to paddocks and waterways. Plants may also be scoured out and have roots exposed to desiccation.

Outlined are principles for minimising erosion.

1.2.1 Consider the elements of planning a good farm layout

1.2.2 Use windbreaks to minimise wind erosion where appropriate

1.2.3 Minimise bare ground to reduce erosion from raindrop impact

1.2.4 Rehabilitate areas of gully and landslip erosion

Reductions in the nutrient and pesticide load bound to clay sized particles and organic matter is important to minimise off site impacts. Section 1.3, Practice good fertiliser management and Section 7, Integrated Crop Management, consider the judicious management of fertilisers and pesticides respectively.

1.2.1 Consider the elements of planning a good farm layout

Forward thinking about farm layout can minimise problems with erosion, transporting machinery around farm and access to paddocks during wet weather. A well-planned layout will provide safe, all-weather access and orient rows in a suitable direction. (Dwyer et al.1994b & 1994c)

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Good planning will also take into account control measures for soil erosion, irrigation design (if applicable) and plant spacings to help dispose safely of excess runoff water.

Individual elements of a good farm layout for orchards and plantations are detailed in the relevant Information Kit from the QDPI's Agrilink Series (QDPI 1998).

Similar issues in planning farm layout for short-term crops are also considered in more detail in the relevant Information Kit (QDPI 1998).

Following is a brief overview of the key elements for a good farm layout from the Agrilink Series.

■ *The best site*

Choosing a site should take into account soil type, aspect, slope, the need for wind protection and access to irrigation water.

■ *A planning map*

This may overlap with whole farm planning, however the focus is narrower. The planning map helps to site windbreaks, on-farm access, erosion control structures, water harvesting and storage structures and the irrigation system.

■ *Good windbreaks*

Options for windbreaks include existing natural stands of timber, planting tall quick growing grasses, planting dense, quick growing trees and shrubs, and artificial windbreaks. More information is contained in section 1.2.2, Use windbreaks to minimise wind erosion where appropriate

■ *All-weather on-farm access*

Locating access roads on ridgelines will help shed water away from the roadway during wet weather. Contour drains can be used to move excess water to stable watercourses or gullies.

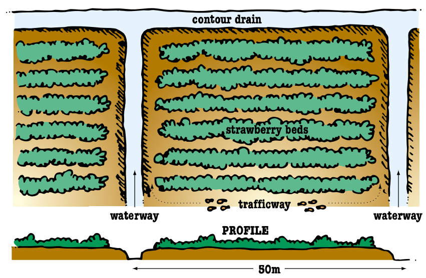
Wide roadways allow the easy movement of farm equipment.

Where slope permits, planting parallel to access roads on ridgelines is recommended. When crossing major drainage lines, concrete pipes may be needed. Most access roads require 'whoa boys' or speed bumps to catch and divert water safely off the track. These are best located where slopes change or suitable outlet points are found (Dwyer et al. 1994b & 1994c).

■ *Erosion control measures*

Surface drainage structures (such as contour drains and v-drains) can help to safely dispose of runoff into stable waterways. By shortening slope lengths these structures help to reduce the impact of erosion and prevent ponding around the plant roots.

Correct design, implementation and maintenance of these structures is essential, as their failure will result in increased levels of soil erosion (Vock et al. 1997).



Example:

Erosion control layout in strawberries

In strawberries if runoff water is not controlled it can wash away strawberry beds and cause root diseases when it pools within rows. (Vock and Greer 1997)

A grassed contour drain at the top of the block is used to help divert runoff water from land above the block into waterways running down the slopes. Waterways are spaced about 50 m apart in strawberry paddocks. They are flat bottomed, at least 2 metres wide and lower than the surrounding land. (Vock and Greer 1997)

One to two weeks after planting, walkways between the beds are mulched with sawdust or bagasse mulch to stop weed growth and soil splash onto the fruit (Vock and Greer 1997).

(Pictured above)

Surface drainage structures such as v-drains can help divert run-off into stable waterways

The best type of layout for a given orchard or plantation is very dependent on slope steepness. Details of row direction for a range of slope steepness from less than 4%, 4 to 15% and greater than 15% are given in the relevant Agrilink Information Kit (Vock et al. 1997) (QDPI 1998).

Suggestions are also made about appropriate soil erosion control structures for orchards, plantations and small crop paddocks. The following erosion control structures are explained in detail, if relevant to the commodity covered in the Information Kit from the Agrilink Series (QDPI 1998).

- diversion drains or banks
- contour drains or banks
- v-shaped drains
- bench terraces
- in-fall access tracks or roads
- low profile mounds
- grassed waterways including suitable species for cover
- the use of strip cropping, cross drains and contour planting

In general, depressions or low points in a paddock should not be used for fruit and vegetable production as these carry runoff water during storms (Dwyer et al. 1994a-c). These areas should be maintained or replanted with low growing, vigorous grass species (ie: carpet grass, couch, African star grass or broadleaf paspalum) or native sedges and herbs.

■ *Water harvesting and storage where possible*

If possible, harvesting runoff water from steep slopes can be beneficial. A farm layout set up to harvest allows runoff water to be directed into a dam and stored for later irrigation use (Vock et al. 1997). Settling out sediments from runoff water in a dam, helps prevent downstream impacts on water resources.

An irrigation system on the farm is best when compatible with erosion control structures, access roads and drainage in the farm layout (Vock et al. 1997). When planning an irrigation system design, specialist advice should be sought from a qualified irrigation designer.

Example:

Using windbreaks to protect melons.

Melon plants and young fruit are easily damaged by strong winds (Lovatt et al. 1997). Planting a windbreak (eg. strips of sorghum between sets of rows) helps prevent twisting and damage.

Smaller fruit and flowers are more easily retained and less wind induced stress prevents fruit drop and blossom-end rot (Lovatt et al. 1997).

The disadvantages include an increased risk of leaf diseases due to settled conditions, interference with spraying and less cooling wind movement in late spring and summer (Lovatt et al. 1997).

1.2.2 Use windbreaks to minimise wind erosion where appropriate

Crops and bearing trees need to be protected from severe winds which can damage limbs, leaves, reduce yields and mark fruit reducing its quality. Wind also contributes to greater water use.

Wind erosion can sandblast young seedlings (eg. melons, tomatoes and vegetables) and remove fertile topsoil, increasing water use and reducing crop growth.

Natural remnant vegetation and stands of timber can provide windbreaks (Dwyer et al. 1994a-c). Alternatives include, planting tall quick growing breaks such as Bana grass, sugar cane or short-term crops like forage sorghum (Dwyer et al. 1994a-c). Dense, quick growing trees or shrubs can provide protection in a short period if more than one row is planted (Dwyer et al. 1994a-c).

Wind susceptibility means unprotected orchards or paddocks may have less flexibility with spray application and be prone to spray drift. A long-term solution for windbreaks may require planting trees.

■ ***Consider trees as long term windbreaks***

Trees can reduce wind-speeds by 25 - 75% minimising sand blasting and leaf-rubbing damage. Animals can also be protected from extremes of cold or heat by a tree windbreak.

Information on suitable species for planted windbreaks in a given region or district can be obtained from the QDNR.

■ ***Design tree windbreaks well***

A tree windbreak needs to take into account wind flow around the windbreak. Maximum protection is 5 to 15 metres away from the tree with distances of up 25 times the height of the tree covered.

Lengths up to 200m reduce wind deflection around the sides of the windbreak while widths should be no more than three times the height of the windbreak. Orientation of the windbreak should be at right angles to the main direction of the wind, with gaps at 45 degrees to the direction of the wind if needed.

Any windbreak trees should be planted at least 10 metres away from the crop or trees to allow machinery access and to reduce shading and root competition for water and nutrients. (Dwyer et al. 1994 a-c).

■ ***Maintain tree windbreaks***

Maintain a weed free area around the trees for at least the first two years. Also, deep rip one metre from the windbreak trees every two or three years to prevent root competition (Dwyer et al. 1994 a-c). This is best done in spring or summer. Tree windbreaks will also require irrigation and pruning.

Example:

Minimising bare ground in banana plantations

The plant phase of growing bananas (first 6 months) needs to be protected the most from soil erosion.

Grass swards can be maintained in the inter-row, providing cover until the banana plant's leaf-area starts to compete with the sward and protect the soil.

Banana debris (from de-leafing and harvesting) can be placed on the mound to reduce slumping and erosion of the mound.

There has been a shift away from placing trash in the inter-row, back to placing it around the plants (Daniells 1995). Advantages of placing it closer to the tree include, less water stress, less inter-row obstruction to machinery and drainage water and greater earthworm activity (Daniells 1995). Disadvantages include banana weevil borer activity, accidental cutting of irrigation piping and interference of the trash with water distribution from undertree minisprinklers (Daniells 1995).

1.2.3 Minimise bare ground to reduce erosion from raindrop impact

Groundcover slows water movement and minimises the impact of raindrop splash on bare soil. Levels of cover above 30% will significantly reduce soil erosion and help increase infiltration.

Other benefits include a more stable year round soil temperature, reduced evaporation losses and increased soil organic matter levels (Dwyer et al. 1994 a-c).

In general, it is the fallow period and the stage just after planting a crop or trees, when vulnerability to soil erosion is highest. At other times the vegetative growth of the crop itself tends to provide more soil protection. Fallow paddocks can be kept under fodder crops (examples include forage sorghum or oats) or pastures to provide maximum groundcover.

In Queensland, several plant species such as Pinto's peanut (*Arachis pintoi*) and wynn cassia (*Cassia rotundifolia*) are still being evaluated as potential groundcovers. Permanent legume cover crops have been used overseas.

Pinto's peanut, used here as ground cover under mangosteens, is being evaluated as potential groundcover.

Example:

Using mulch to protect soil around papayas in central Queensland.

Lucerne and grass hay were mulched in papaya crops in a low rainfall environment (Yarwun and Targinne near Rockhampton). At a rate of one and a half bales every 4 plants, soil loss was reduced to 0.4 t/ha, one twelfth of what is lost under the bare unmulched treatment (Macleod 1997).

Inter-row spaces in orchards generally have a good grass cover. This can be maintained by allowing undertree sprinkler coverage to extend beyond the drip line (Dwyer et al. 1994c). The natural grass cover also helps provide a source of mulch for the trees.

1.2.4 Rehabilitate areas of gully and landslip erosion

Gully erosion is the eventual result where small rills are formed by the concentration of runoff water (Dwyer et al. 1994a-c). Where the soil is sodic (and therefore dispersible), water may also tunnel out the soil creating a gully.

Repairing gully erosion is difficult and costly and should be managed before the event (Dwyer et al. 1994a-c). Don't clear areas subject to landslip and avoid using soil with a dispersible subsoil. Any area where runoff can concentrate, such as drainage lines and access tracks can be susceptible to gully erosion.

To rehabilitate gully erosion, runoff water should be diverted away from the gully into a more stable disposal area (Dwyer et al. 1994a-c). Gullies should be stabilised by widening or reshaping the gully, then planting vegetation on the outside of the gully and groundcover in the gully itself.

Landslip can occur on sloping land during periods of prolonged heavy rainfall (Dwyer et al. 1994a-c). A barrier, such as bedrock or a clay-rich soil horizon, can impede water entering permeable soils and movement of soil above this barrier may occur. Areas particularly susceptible to landslips occur where different geologies overlie each other on steep slopes.

Rehabilitation measures include (Dwyer et al. 1994a-c),

- locating diversion banks or drains above the slip to intercept and divert runoff water;
- re-shaping, if ponding occurs at the back of the slip to remove water from the intake area;
- using agricultural drain pipes to intercept and remove sub-surface flows;
- and establishing good vegetative cover to stabilise and 'dry-out' the slip area.

1.3 PRACTICE GOOD FERTILISER MANAGEMENT

It is important to get fertiliser inputs correct, because if wrongly used, they may contribute to soil acidity, soil contamination and off site degradation of groundwater and waterways.

Objective methods such as soil testing, plant tissue testing, sap testing and diagnosis of the crop or tree are the tools that provide the basis for good fertiliser management. Fertiliser should be applied efficiently, taking seasonal conditions into account.

1.3.1 Avoid too little or too much fertiliser application

1.3.2 Use soil testing

1.3.3 Apply fertiliser for efficient uptake

1.3.4 Use soil testing and plant diagnostic techniques to help work out post planting fertiliser requirements

1.3.5 Apply post-plant fertiliser for efficient uptake

1.3.6 Use irrigation to enable efficient fertiliser uptake when possible

1.3.1 Avoid too little or too much fertiliser application

Both extremes of fertiliser application create problems when growing fruit and vegetables. A nutrient deficiency that led to low yields would incur a large financial loss.

The small cost of fertiliser compared to other inputs means growers have tended to overcompensate with fertiliser application rather than face the risk of high production losses.

Oversupply of fertiliser also brings problems. It is not only an unnecessary cost, but can cause reduced yields through toxic levels of nutrients or an induced deficiency because of nutrient imbalance. Oversupply may lead to other long term impacts like soil acidity, algal blooms, ground water contamination and soil salinity.

Use 'blended' fertiliser products appropriately

The incorrect use of blended fertilisers can cause nutrient imbalances and induce deficiencies. For example, NPK blends often supply sufficient nitrogen for the crop, but the amounts of phosphorus and potassium, which are also being applied in the blend, may exceed crop requirements.

Too much phosphorus in the soil can induce zinc or iron deficiencies, while overuse of potassium can induce calcium or magnesium deficiencies.

Many of the more recent blended products are formulated with specific crops in mind. The use of blended products also helps cut down on the number of passes needed for fertiliser application.

Example:

Incorrect fertiliser application in citrus and strawberries can lead to the following problems (Vock et al. 1997) (Vock and Greer 1997).

- *excessive leaf flushing at the wrong time, reducing fruit quality (citrus)*
- *lower fruit quality (thicker skins, lower juice levels, smaller fruit) from nutrient imbalance (citrus)*
- *greater susceptibility to conditions such as creasing, stylar end rot, degreening burn and some pests such as branch borers (citrus)*
- *excessive plant vigour which delays the early onset of flowering (strawberries)*
- *fruit softening (strawberries)*
- *winter stunting of plants in cold wet soils (strawberries)*
- *albinism or poor colouring of fruit (strawberries)*
- *reduced yields from nutrient imbalance (citrus and strawberries)*
- *contamination of groundwater from excess nutrients being leached out of the root zone (citrus and strawberries)*

Incorrect fertiliser application in strawberries can lead to albinism or poor colouring of fruit (Photo courtesy of QDPI).

1.3.2 Use soil testing to help work out what fertiliser is needed before planting

Soil tests involve taking samples of soil from the field and taking measurements of soil properties that influence nutrient availability to the plant. These include, pH, electrical conductivity (a measure of salt content), organic carbon, individual macro and micronutrients and other elements.

By combining soil test results with calibrated responses from nutrition trials, a fertiliser program can be designed for a given area.

Soil tests are widely available to the fruit and vegetable industry. When a group of banana growers were surveyed in North Queensland, 45% indicated that they used soil analysis to work out fertiliser programs.

In the pineapple industry, soil and plant diagnostic tests have been made widely available through the Golden Circle Cannery. About 65% of the industry by volume are utilising the service (pers. comm. Col Scott).

■ ***Make sure soil samples represent the area tested.***

A soil test is only as good as the sample sent for analysis. When collecting a test sample, make sure it represents the area being tested, by taking into account the total area of the block, soil type (are there mixed soils in one block) and the depth of sampling.

The test sample should be a sub-sample of at least 10 bulk samples over the paddock and should not include any unusual areas such as wet spots. It is important to sample all depths equally and avoid taking wedges.

■ ***Get a test done early enough.***

Soil analysis before planting needs to be done early enough to allow all nutrients to be applied by the time planting or transplanting occurs. This can mean taking a test from 2 to 3 months before planting.

An early test is particularly important when soil amendments such as lime or dolomite may be needed. These products need to be worked into the soil because they are slow to dissolve.

This should occur before other operations such as bed-forming and laying of plastic mulch in the crops where they are used (eg: tomato, melon, strawberry, capsicum).

Lime should also be applied early enough to allow the pH to increase by the time planting occurs.

■ ***Get a good interpretation of the test.***

Test results and optimum soil nutrient levels to aim for should be discussed with an appropriately qualified person, such as a local QDPI extension officer, consultant or accredited rural agent.

A guide to frequency and method of soil testing and general soil nutrient levels for each crop can be found in the relevant Information Kit from the Agrilink Series (QDPI 1998).

■ ***Get a good fertiliser recommendation based on the test.***

Fertiliser recommendations should be clearly linked to an understanding of the soil test, soil type, cropping history, and crop agronomy. Using qualified local experience to help with fertiliser recommendations is suggested.

In the absence of a soil test, the relevant Information Kit from the Agrilink Series outlines a general program of suitable fertiliser products and rates, with tailor-made comments for most fruit and vegetable crops (QDPI 1998).

The Kits also have information on managing pH in short-term crops, with tables of lime or dolomite rates, and gypsum rates based on the calcium and magnesium status in soils (QDPI 1998). For trace elements, soil application rates and commonly used products are also tabled.

1.3.3 Apply fertiliser for efficient uptake

Most soil amendments and fertilisers are applied before planting to ensure availability by the time transplanting or planting occurs. In close planted crops, it is usually broadcast over cultivated land and incorporated to depth with a rotary hoe or rotary tynes.

Alternatively, fertiliser can be banded about 5 cm to the side or 5cm below the seed or transplant.

For many short-term crops grown on beds (eg, melons, vegetables, tomatoes, strawberries) basal fertiliser is incorporated directly into the bed just before planting. They are usually applied in a 30-40 cm band over the row and incorporated to ensure ease of uptake by seedlings (Lovatt et al. 1997) (Vock and Greer 1997).

If phosphorus is likely to be quickly tied up by the soil, starting fertiliser may be drilled into the bed either 10cm directly below the plant line or to one or both sides of the row (Lovatt et al. 1997) (Vock and Greer 1997).

Some tree crops or plantation crops may also have pre-plant fertiliser applied. Fertiliser and amendments can be incorporated in cultivated narrow strips along the intended tree rows. This helps tree establishment and reduces initial weed competition (Dwyer et al. 1994c).

1.3.4 Use soil testing and plant diagnostic techniques to help work out post planting fertiliser requirements

The timing and placement of fertiliser that is added while the crop or trees are growing should be matched to peak growth periods. Working this out can be difficult because the nutritional demand by crops or trees changes all the time and differs for each nutrient under consideration.

Soil testing, plant tissue testing and sap testing can all be used to help work out fertiliser programs after planting.

Leaf or tissue analysis is used to see if the levels of nutrients fall within the right range for adequate growth. An annual tissue analysis is recommended for tree crops at the correct time of year for each crop. The long turn around time for this technique can make it less useful when a rapid diagnosis is needed.

Sap testing is more rapid. It was first developed with nitrate nitrogen in annual fertigated crops. The sap nitrate test has proven to be a sensitive indicator of nitrogen status, and the technique can now be used for other macronutrients such as phosphorus, potassium, calcium and magnesium (Lyons et al. 1994). Local credible knowledge should be used when interpreting what the results indicate about crop performance.

Example:

Sap Testing in Melons

In the Melon Agrilink Information Kit, sap testing is recommended once melons reach first fruit set (Lovatt et al. 1997). The frequency of testing is not fixed but nitrate and potassium should be tested more regularly than other nutrients.

Optimum sap levels for rockmelons in southern Queensland are outlined for the 4 growth stages, vegetative growth, fruit set, fruit fill and harvest (Lovatt et al. 1997).

☞ *Short term crops*

Leaf tissue testing and sap testing (where appropriate) can be used to work out an appropriate fertiliser program for short-term crops. Optimal timing and frequency of tests will depend on the test itself, the crop to be tested, the location of the farm and the soil type. It is best to get the help of QDPI extension officers, qualified reseller agronomists or crop consultants to work this out.

Where sap testing has been developed for a commodity, the relevant Information Kit in the Agrilink Series outlines a general approach to timing sampling, sampling method and recommended optimum ranges for leaf and soil nutrient levels (QDPI 1998).

☞ *Working out fertiliser application for tree crops*

Soil testing and leaf tissue testing can be used to work out appropriate fertiliser programs for tree crops. They can be used to monitor young trees that are not yet mature and are even more useful once tree crops start to bear.

Example:

Boom spray fertiliser application in pineapples

Post plant fertilisers are usually applied in the pineapple industry in a soluble, foliar form using a boom-spray (Col Scott pers. com.). Potassium sulphate, urea, magnesium sulphate, zinc sulphate, solubor and iron sulphate can be applied using this method.

The high volumes of water (up to 3000 L/ha) used with fertiliser application together with leaf arrangement of the plant, assist uptake of nutrients by the plant. Any fertiliser applied to the leaves is delivered down into the root zone.

The use of boom-spray applications after the first 3 months when significant groundcover is reached can reduce the amount of nutrients leaching beyond the root zone. (Pictured below)

Optimal timing and frequency of tests will depend on the test itself, the tree crop to be tested, the production area, and the soil type and tree age. It is best to get the help of QDPI extension officers, qualified reseller agronomists or crop consultants to work this out.

The relevant Information Kit from the Agrilink Series covers general information about how to use each kind of test. This includes timing of sampling, sampling method and recommended optimum ranges for leaf and soil nutrient levels test (QDPI 1998).

1.3.5 Apply post-plant fertiliser for efficient uptake

The diagnostic testing methods outlined above will help to ensure that the amount of post plant fertiliser added to a crop or trees matches plant requirements.

For most short-term crops, post plant fertiliser is applied as a side-dressing or with fertigation. For some of the plantation and tree crops, broadcasting is also used to apply post plant fertiliser. Whatever the method of application, the most important aim is to operate the system as efficiently as possible.

☞ ***Efficient fertiliser application in tree-crops***

After planting, fertiliser is only needed once trees start to grow. For non-bearing trees, the fertiliser program focuses on producing a strong, healthy canopy of branches and leaves that will be able to bare fruit well in ongoing years.

This non-bearing phase takes about,

- 2 years in avocadoes and stonefruit
- 3 years in mangoes and citrus
- 4 years in lychees

The relevant Information Kit from the Agrilink Series for each tree crop outlines a general program for the type and rate of maintenance fertilisers for this non-bearing growth stage (QDPI 1998).

Once trees are established and begin to bear, management of fertiliser application changes. Fertiliser is used, (along with irrigation and pruning in most crops) to assist the tree through an annual cycle of leaf growth, flowering and fruit development. Fertiliser may be broadcast or fertigated through the irrigation system.

Where objective diagnostic tests have not been used, the relevant Information Kit from the Agrilink Series suggests a general fertiliser program for well-grown, high yielding trees (QDPI 1998). More specifically for;

- avocado trees with a canopy diameter from 2m up to 12m
- mango trees up to 10 years old
- lychee trees from 4-5 years old and up to 15+ years old
- citrus trees from 4-8 years of age (while increasing fruit bearing surface) and after 8 years
- stonefruit trees from 3 years and older (rates are for about 1000 trees per hectare on a palmette system)

Rates need to be varied according to tree size, the vigour of leaf growth, the crop load, and the crop variety, plant spacing, climate and soil type.

Macronutrients (eg. nitrogen, phosphorus, potassium, calcium, magnesium) and micronutrients (trace elements like boron and iron) are considered as well as straight and blended fertiliser products (QDPI 1998).

■ ***Foliar fertilisers allow for rapid uptake in specific circumstances***

Foliar fertilisers are taken up quickly by the crop or tree through leaf absorption. Trace elements can be easily supplied at times when the crop or tree can't keep up with nutrient demand, or when it has been stressed (ie: by waterlogging, disease or nematodes) and needs to recover quickly.

■ ***Consider the effects of placement and weather on the efficiency of uptake.***

Broadcasting fertiliser on the surface may be physically easier, but will not always ensure rapid uptake. Surface applications of urea fertiliser should be timed to coincide with irrigation (or impending rain) greater than 13mm to incorporate fertiliser and reduce volatilisation losses (Prove and Lindsay 1996).

Seasonal conditions are important. In North Queensland, the chance of higher rainfall in the wet season means growers are more likely to have broadcasted fertiliser successfully incorporated. The risky side of this practice is that too much rain can lead to the loss of fertiliser in runoff water or high infiltration, leaching soluble nutrients below the root zone and into the groundwater.

Where banana farms in North Queensland are set up for both fertigation and broadcasting, 48% of growers surveyed favoured fertigating in the dry season and broadcasting in the wet season (Daniells 1995).

Soluble forms of fertiliser can be applied through the trickle irrigation tape (fertigation) to the surface feeding root area for rapid uptake by the plant.

1.3.6 Use irrigation to enable efficient fertiliser uptake when possible

Fertigation provides a highly efficient way to apply post-plant fertiliser (Olsen 1995). Nutrient supply can be more evenly matched to significant growth stages in the crop's cycle (eg: vegetative growth, flowering, fruit set and fruit fill in short term crops or the annual cycle of leaf growth, flowering and fruit development in a tree crop).

Soluble forms of fertiliser (eg: potassium nitrate, urea, etc) can be applied through the trickle irrigation or under-tree sprinkler system to the surface feeding root area. The ease of application and small time lag for uptake means a rapid response can be made to peak nutrient demands of crops or trees.

The high cost of soluble fertiliser products means application through fertigation is more expensive than other methods. Gains in overall production efficiency are needed to offset the higher cost.

Careful management of irrigation frequency, duration and timing is needed wherever irrigation is used to optimise fertiliser uptake.

Trial work with strawberries indicated that even fertigation can have significant losses if not applied effectively. Nitrogen was applied to a nitrogen poor site at rates for optimum fruit yield. The rates recovered through the fruit was 8-20% of that applied which indicated that up to 250 kg /ha Nitrogen was lost from the system (Lyons and Yo 1997).

Minimum soil disturbance can be achieved by the use of a minimum tillage planter, specially adapted to plant, in this case beans, directly through mulch into the soil. (Photo courtesy QDPI)

Reduced erosion and soil disturbance can be achieved by using a knockdown herbicide to spray out a summer crop and delay all cultivation until the day of planting (Photo courtesy QDPI)

1.4 MINIMISE THE DEGRADATION OF SOIL STRUCTURE

Good soil structure is typified by many interconnected air spaces. These spaces help with the transport of water and nutrient supply to plants. It is the loss of pore space, especially the interconnected poor space that best defines soil structural degradation (McGarry 1993).

Soils may be poorly structured naturally or become degraded as a result of farming activity (McGarry 1993). Soil structure degradation may occur with the break down of soil aggregates through excessive cultivation or other processes that affect the stability, porosity and infiltration characteristics of the soil.

Poorly structured soils have low infiltration rates, tend to break down quickly under heavy rainfall, may be prone to surface sealing and may be more difficult to cultivate.

There are several principles that can help enhance soil structure.

1.4.1 Minimise harm from tillage and traffic

1.4.2 Cultivate soils at the right moisture content and depth

1.4.3 Green manures, rotations and organic matter add benefits

1.4.1 Minimise harm from tillage and traffic

Most tillage for fruit and vegetable crops occurs prior to planting to enable suitable contact between the soil and the planted material (eg. seed, transplant or vegetative section). This primary tillage is an important part of initial land preparation and cannot really be avoided. However once completed secondary tillage operations should be minimised where possible.

Rotary hoes are generally used to pulverise soil for primary tillage. They along with disc cultivators should be used as sparingly as possible. Tyned and non-inverting implements are kinder on soil structure.

Intensive short term crops that are grown with beds and/or trellises and /or plastic mulch are not suited to minimum tillage (min-till) systems at this stage due to an absence of appropriate machinery suited to permanent beds or a tracking system in these crops. Currently, the small cost of herbicides and cultivation compared to overall inputs means there is little financial incentive to be gained in overcoming the barriers to a controlled traffic system.

However, other systems in fruit and vegetable production like tree crops and plantation crops require much less tillage once plants are established.

Many tree crops are cultivated in 2m wide strips next to the tree rows to incorporate fertiliser, establish trees and reduce early weed competition (Dwyer et al. 1994c). After this the growth of inter-row mulch and the use of herbicides is relied upon for weed control.

Some work to develop min-till systems has been carried out in a non-bedded vegetable crop (beans) in the steepland cropping district around Gympie.

Example:

Changing tillage practices in bean steepland crops

Conventional tillage practice in steepland bean crops of the Gympie district involves land preparation for 10 to 12 weeks before planting using up to 6 cultivations. This occurs early in the year when soils are exposed to a high erosion risk from summer rain (Swete Kelly et al. 1997).

Trying novel treatments has enabled growers to cut down the time cultivated land is exposed to erosion potential from 10-12 weeks to almost nothing (Swete Kelly et al. 1997).

This involves using a knockdown herbicide to spray out a summer cover crop at 10 and 4 weeks before planting. No cultivation occurs until the day of planting where all cultivations are carried out. This reduced tillage practice is now used under approximately 50% of the bean production in the area (Swete Kelly et al. 1997).

1.4.2 Cultivate soils at the right moisture content and depth

The soil moisture content during tillage has an important effect on soil structure. Where the soil water content is greater than the plastic limit the soil acts like plasticine, smearing and compacting with tillage and trafficking. It is better to work soils that are below the plastic limit. The *Soil Check Manual* outlines a quick field test, for working out the plastic limit and assessing the risk of compaction for any soil (Forge 1995).

■ *Hard pans and compaction layers will need extra attention*

If a hard pan or compaction layer is present, then additional steps will be needed. Steps to be taken depend on the soil moisture content, timing and soil type.

Where soil water content is higher than the plastic limit, cultivation will increase the problem. Where the soil water content is below the plastic limit, deep ripping will be beneficial.

Cross-ripping will help shatter the pan, bringing up clods that will breakdown under weather conditions (continuous mellowing). Deep ripping needs to be done early enough to allow natural 'mellowing', rather than using continuous cultivation to achieve the same end.

Ripping in small crops is best done after harvest, to allow deep-water penetration during the fallow, and salts (if present) to be leached out of the profile.

Some soils do not require mechanical ripping. Grey or black self-mulching cracking clays achieve a 'natural' deep rip through frequent wetting and drying cycles. A deep-rooted crop can help to dry the profile enabling natural shattering of the hard pan and degradation repair.

Soils with shallow sodic subsoils should not be ripped. This can bring sodic soils to the surface and create problems with surface crusting.

1.4.3 Green manures, rotations and organic matter add benefits

Using rotations and green manure crops will provide short-term soil structure benefits through better soil aggregation. This helps optimise the soil's water holding capacity, ability to hold nutrients, workability and infiltration.

Rotation crops can provide a pest and disease break and add organic matter at depth as deep roots break down.

While still growing, deep-rooted rotation crops can also recycle excess soluble nutrients like nitrate and sulphur at depth. Crops like peanuts, sugarcane and maize are rotated with vegetable crops across Queensland. Green manure crops used include forage sorghum, oats, and legumes.

A green manure crop like forage sorghum can increase soil water and nutrient holding capacity, workability and infiltration.

Other organic amendments added to soils under fruit and vegetable production include fowl manure, feedlot manure, fish emulsion, and humic acid and filter press or mill mud (eg. for melons in the Burdekin area close to sugar mills).

1.5 MINIMISE SOIL SALINITY

Saline soils have high levels of salts in the soil solution (water in the soil). They may be natural, due to the parent material from which the soil was formed, or can be induced by rising water tables that dissolve salts as they rise.

Irrigating with salty water can increase salt levels in the soil. Where water tables rise to within 1.5 metres of the surface, salts can be drawn to the soil surface by evaporation.

■ *Soil salinity impacts negatively on plant productivity*

Saline soils can impact on plant growth where high amounts of salt make it hard for plant roots to extract water from the soil. Levels may even be high enough to cause plants to die.

For example, rockmelons and honeydew melons are sensitive to saline irrigation water with a medium tolerance of salinity. An efficient irrigation system such as trickle irrigation is essential if water with an electrical conductivity (EC) of 1.5 or more is going to be used.

Identifying the cause of high salt levels is the first step in establishing how to manage the problem. For example, salinity in low-lying valleys may be the result of past tree clearing on hilltops and/or re-charge areas. Once the recharge area is identified, re-plant with trees where possible, but expect a long period (10 to 20 years) before benefits are realised.

Actual discharge areas where salt scalding and salt pans have appeared, will require fencing off and the establishment of deep rooted, salt tolerant trees and grasses.

Further information should be obtained from the QDPI Salinity Handbook or the Fact sheet on Trees for Rehabilitation of Saline Sites in South East Queensland (in preparation).

1.6 MINIMISE SOIL SODICITY

Sodic soils are those where the amount of sodium held onto the clay particles is 5% or more of the total cation exchange capacity (this is called the Exchangeable Sodium Percentage or ESP and represents the proportion of sodium ions held by clay particles compared to other positive ions).

When sodic soils are wet, each clay particle forces the other particles away, causing the soil to disperse (Lines-Kelly 1994). What is left is a milky, cloudy suspension.

This mass of fine individual particles can block soil pores, causing crusting and sealing of the soil surface in some soil types. Once blocked, soils pond causing erosion and restrict root penetration. Where subsoils are sodic they can erode easily causing tunnel erosion and require special construction techniques when building dams. Saline soils are often sodic.

Adding calcium in a soluble form such as gypsum improves the structure of sodic soils in two distinct ways. The first effect is to create an increased salt level in the soil solution around the clay particles, which promotes aggregation.

The second effect is a longer term one. Sodium ions held on the clay particles are swapped with calcium ions from the gypsum. The displaced sodium ion can then be leached out below the root zone.

If the soils have a high cadmium status or where growing root crops, consider other sources of gypsum than phosphogypsum (see section 1.8).

1.7 MINIMISE SOIL ACIDITY

Soil acidity is when the soil pH is below 7. However in practice, it is not until the pH (1:5 *in water*) is equal to or lower than pH 5.5 that soil acidity starts to affect availability of soil nutrients. Some soils may be naturally acidic.

Many factors can increase soil acidity

How rapidly soil pH becomes acid, depends on many factors including soil type, soil texture, organic matter, cation exchange capacity, the amount of crop product removed and the type of acidifying fertiliser used. The intensity and variation of rainfall are also influential.

Older and more highly weathered soils are likely to have become acidic due to the natural processes of time and weathering. Calcium and in particular magnesium can be leached out of the soil profile under these conditions contributing to acidity.

Fertiliser application and cropping practice may increase soil acidity. High rates of some fertilisers and the removal of cations (particularly calcium) in large amounts of plant material will tend to increase soil acidity.

As the soil pH drops, some plant nutrients (like molybdenum and phosphorus) become less available while other elements (like aluminium and manganese) may increase to toxic levels and affect plant growth in sensitive crops.

Recent research looked at how rapidly soils became acidic in agricultural systems of the tropics and sub-tropics (Moody and Aitken 1995). The rates of acidification in tropical and subtropical agricultural soils were significantly higher compared to temperate soils.

These soils often have a low nutrient holding capacity, and in a high rainfall environment, leaching of calcium, magnesium and potassium may occur. This leads to increased soil acidity.

Even though soil acidity is a complex problem, there are some simple things growers can do to minimise the potential for soils to become acidic.

1.7.1 Keep track of pH changes

1.7.2 Minimise the application of acidifying fertilisers

1.7.3 Use lime or dolomite where needed

Example:

Acidification in Bananas

Bananas were studied as an example of what could be expected under a perennial horticultural system in the tropics that is fertigated. Rates of acidification in the subsoil under bananas were found to be 5 to 10 times higher compared to other agricultural systems including summer crops, sugar cane, tobacco and table grapes (Moody and Aitken 1995).

A trial at Jarra Creek plantation in North Queensland ranked the following factors in terms of their % contribution to soil acidification. Addition of ammonium fertiliser (54%), nitrate leaching (23%), trash (14%) and removal of bunches (9%) (Moody and Daniells 1996).

High rates of acidifying ammonium-based fertilisers (500 kg N/ha/yr) are used in banana production (Moody and Aitken 1995). The removal of bunches means large amounts of alkaline (acid neutralising) product is exported out of the paddock. Placing trash in the inter-row, rather than on the mound, may cause nitrate re-cycling through the breakdown of the trash to be lost by leaching because of the limited number of roots in the inter-row.

1.7.1 Keep track of pH changes

Soil tests provide an ideal way to monitor the change in acidity of soils over time. Test results include a measure of,

- soil pH
- the cation exchange capacity
- the buffer capacity
- cations (like calcium and magnesium)
- other cations which may become toxic at a low pH

It is important that pH be determined on soil samples taken to a depth of at least 60-80 cm, because surface lime applications often only increase pH to the depth at which the liming product is incorporated. If only surface soil samples are taken, then acidification occurring deeper in the root zone will go undetected.

Regular testing will monitor changes in pH and provide an early warning of increasing soil acidity. This involves a soil-sampling schedule for each block and records to follow trends in the tests.

Early corrective action will prevent the expense associated with correcting a problem that has become so severe that plant productivity is affected.

1.7.2 Minimise the application of acidifying fertilisers

Trial work has indicated that nitrogen fertiliser management is likely to be the most critical acidification factor in tropical and sub-tropical horticultural systems (Moody and Aitken 1995).

In some fertilisers the conversion from the applied form to a form the plant can take up is a process which acidifies the soil. How potentially acidifying different fertilisers may be is described below.

Severely acidifying: Ammonium sulphate and Monoammonium phosphate (MAP)

Moderately acidifying: Diammonium phosphate (DAP)

Slightly acidifying: Urea and ammonium nitrate

Non-acidifying: Potassium nitrate, calcium nitrate and composted poultry manure

Applying nitrogen in the nitrate form or applying only slightly acidifying fertilisers can reduce the potential for acidification (Moody and Daniells 1996). The use of soluble fertilisers (like potassium nitrate and calcium nitrate) fed through trickle tubing helps to maximise the amount of fertiliser applied in non-acidifying forms.

■ *Prevent nitrates leaching down the profile*

Nitrates are highly mobile under the influence of high rainfall or over-irrigation and will readily leach in permeable soils. This process can cause further soil acidification.

Nitrates are persistent in groundwater and may be an environmental and human health issue in certain areas.

The rule of thumb for efficiency of nitrogen application to crops or trees is to apply smaller amounts more frequently. Fertigation is one technique that can help match fertiliser application more effectively to crop demand.

1.7.3 Use lime or dolomite where needed

Lime can reverse the acidifying process in surface soils. How quickly this happens depends on the soil's pH and buffer capacity (which is a measure of the ability of the soil to resist acidification), organic matter level and clay content.

Other factors are influential in how rapidly lime can reverse soil acidity. These include how much water drains through the soil, where the lime is applied and the quality of the lime product. Dolomite adds magnesium as well as calcium if both are needed.

Soil testing can help indicate how much lime is required and what product to use. Commercial testing labs offer recommendations on what level of liming product is needed to raise soil pH to 5.5 or 6.5 (1:5 *in water*). Local QDPI and QDNR officers can also assist with interpretation of soil test results.

Trial work has indicated that using surface application of lime in a perennial horticultural system (like bananas) does not address sub-surface acidification (Moody and Aitken 1995).

Subsequent project work in bananas is trialing several treatments to determine the best way to manage subsoil acidity under banana systems (Moody and Daniells 1996). Future trial results should indicate which methods are able to ameliorate subsoil acidification most effectively.

1.8 PREVENT THE BUILDUP OF HEAVY METALS IN SOILS

Heavy metals are naturally present in soils usually at low concentrations as a consequence of weathering of parent rock materials.

Some heavy metals (like copper and zinc) are needed at low concentrations for animal and plant life, while others (like cadmium; mercury and lead) are non-essential and can cause problems for plants if at high levels. A recent study examined the total heavy metal concentrations of horticultural soils in Queensland (Barry 1997).

As well as the natural source there are external contaminating sources of heavy metals in soils, which combined with the natural amounts, can give us the typical level found in soils today. Sources of heavy metal inputs in soil include agricultural fertilisers and pesticides, atmospheric pollution, organic manures, sewage sludge, acid sulfate soils and mining industries (Barry 1997). Once heavy metals have accumulated in soils, they persist there for many years.

■ ***Minimise cadmium accumulation in the soil***

High levels of cadmium is the heavy metal of particular concern in agriculture. It is most likely to enter the soil because it is an impurity in phosphatic fertilisers and phosphogypsum (Barry 1997).

The cadmium in fertiliser and phosphogypsum is derived from the rock phosphate used in manufacturing. Rock phosphate sources contain variable concentrations of cadmium and the main source used over the years has been from Nauru (Incitec 1996). It is the use of these fertilisers and phosphogypsum over many years, which can increase cadmium levels in the soil.

Vegetable crops have the greatest potential for cadmium uptake because they have higher annual applications of phosphorus (and gypsum on sodic soils) for a given area compared to most other crops (Barry 1997).

Cadmium is the heavy metal that is available to plants and in general has the highest levels in root crops (carrots, potatoes, and leafy vegetables (spinach) and the lowest in fruits and seeds. To manage cadmium accumulation the following recommendations are advised (Incitec Fertilisers 1996).

- Use low cadmium fertiliser where large amounts of phosphorus fertiliser or phosphogypsum are needed.
- Avoid irrigating with saline (high chloride) water, since experiments have shown that increased chloride in soil can increase cadmium uptake in crops
- Maintain or increase soil organic matter. This helps to reduce cadmium availability to plants.
- Apply zinc at a level that meets any zinc deficiency since zinc and cadmium compete for plant uptake. Where zinc levels are low the potential for cadmium uptake by plants is higher. Do not overuse zinc fertilisers since they can contain appreciable levels of cadmium also.
- Higher soil pH values are generally associated with lower plant uptake of cadmium. Therefore use lime to maintain an appropriate soil pH level.
- High phosphorus fixing soils can also fix cadmium. In general, soils with higher clay contents will have less cadmium available for plant uptake. This means that although the same cadmium level is found in two soils, they may make different amounts of cadmium available to plants.