Guide for use of environmental characteristics data sets

Burdekin priority catchment

Science Delivery
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Introduction

In 2010, the Queensland Government introduced the Reef Protection Package to assist in reducing the level of sediment, nutrients and herbicides (contaminants) reaching the Great Barrier Reef (GBR). The primary aim of this package is to encourage cane growers and graziers across the Wet Tropics, Burdekin Dry Tropics and Mackay-Whitsunday catchments (priority catchments) to manage their farms in a way that reduces the risk of contaminant loss (sediment, nutrients and herbicides).

To support implementation of the package, the Department of Environment and Heritage Protection (EHP) is coordinating science projects focused on answering the following questions:

1. What and where are the natural features that predispose landscapes to contribute above natural levels of sediment and deliver nutrients and herbicides offsite through water movement?
2. What systems/practices are being used on cane and grazing properties to take account of the landscape features (environmental characteristics)?
3. Within the priority catchments, what and where are the main risks associated with cane and grazing activities?
4. What are the management systems that should be adopted to minimise risk?
5. What information on environmental characteristics could be provided to assist landholders in determining appropriate practices to minimise movement of contaminants off-site?

EHP is coordinating a project to identify landscape features ('environmental characteristics') that influence soil and water movement in cane growing areas. This is identifying and mapping some of the natural features ('environmental characteristics') within sugarcane growing areas of the Burdekin catchment as the first step towards answering questions 1 and 5 above. Other landscape features also influence contaminant transport, but are not able to be mapped at this time.

Environmental characteristics mapping for the Wet Tropics catchment was produced in 2011. As part of that process, a technical workshop reviewed the conceptual model and natural resource data used to produce the four environmental characteristic maps. Workshop attendees, including representatives from industry and NRM groups, accepted the information and concepts as technically sound and agreed the data sets are generally suitable for use at the strategic, regional and property level. It was also acknowledged that environmental characteristic maps can assist users to understand the variability and general features of soils found across cane farms (e.g. farms of 50 hectares or greater). However, these maps do not precisely identify the location of soil boundaries and cannot support detailed property planning, e.g. precision agriculture.

The products developed to date include spatial data, a technical report and user information for all priority catchments. This user guide provides advice on how to use the currently available environmental characteristic maps within the Burdekin priority catchment.

If users require further information about the process used to map environmental characteristics, they should refer to the technical report - '*Mapping environmental characteristics important for Reef water quality – Wet Tropics priority catchment*" (DERM 2011).

The Wet Tropics methodology is available to download through the EHP library catalogue
http://dermqld.softlinkhosting.com.au/liberty/libraryHome.do

The aim of this user guide

The aim of this guide is to assist users to understand and interpret environmental characteristic data sets (maps) currently available across cane growing areas of the Burdekin priority catchment.

This guide focuses on four environmental characteristics that influence the way soil and water moves across the landscape, including:

- Erosion potential (i.e. the inherent potential of soil to erode according to slope and soil features)
- Flooding potential (i.e. the flooding regime of landscapes that may transport contaminants to watercourses)
- Water pathway (i.e. the potential of soils to generate runoff and deep drainage which can mobilise and transport contaminants)
- Soil transport potential (i.e. the inherent potential for soil fractions to be transported long distances).

The above characteristics were assessed because they could be mapped using existing natural resource data.

Intended audience

Environmental characteristics maps are intended to assist EHP Reef Protection Officers (RPOs), extension officers and other organisations to:

- Understand the occurrence and implications of natural features that can influence soil and water movement across cane growing areas
- Support growers to adopt best management practices appropriate to their local conditions
- Prioritise education, extension and awareness activities across the Burdekin catchment.

While these maps were primarily developed to support property planning for cane growing, a similar approach could be adopted for other cropping systems.

Environmental characteristics and their impact on water quality

The environmental characteristic maps that accompany this guide describe and map a range of inherent landscape features that remain relatively unchanged over time. These maps can help users gain an initial understanding of landscape features that could be managed to reduce the water-borne loss of soil, herbicides and nutrients. However, to fully understand the likelihood that these contaminants will be transported off farm, the interaction between environmental characteristics and human activities (management factors) needs to be considered.

Environmental characteristics and management factors interact in complex ways to produce an effect (‘drive a response’) in the landscape. The management factors used on farms can have a neutral, positive or negative effect on the quality of water leaving the farm. For example, implementing green cane trash blanketing—instead of burning the cane trash—on a farm with erodible soils could result in a rapid improvement to the quality of water leaving the farm. Some management practice changes may take longer to show an effect, i.e. there may be a lag period following the change. The interaction between environmental characteristics and management factors is illustrated in Figure 1.

To understand the risk that contaminants will be transported off-site, you need to consider the interaction between management factors and a range of environmental characteristics.

The four environmental characteristics in this guide are not the only landscape features that influence soil and water movement. Environmental characteristics such as rainfall, vegetation cover, proximity to watercourses and groundwater can also affect the quality of water leaving cane farms. Although these characteristics are not able to be mapped at this time, the influence of these characteristics should be considered as part of property planning.

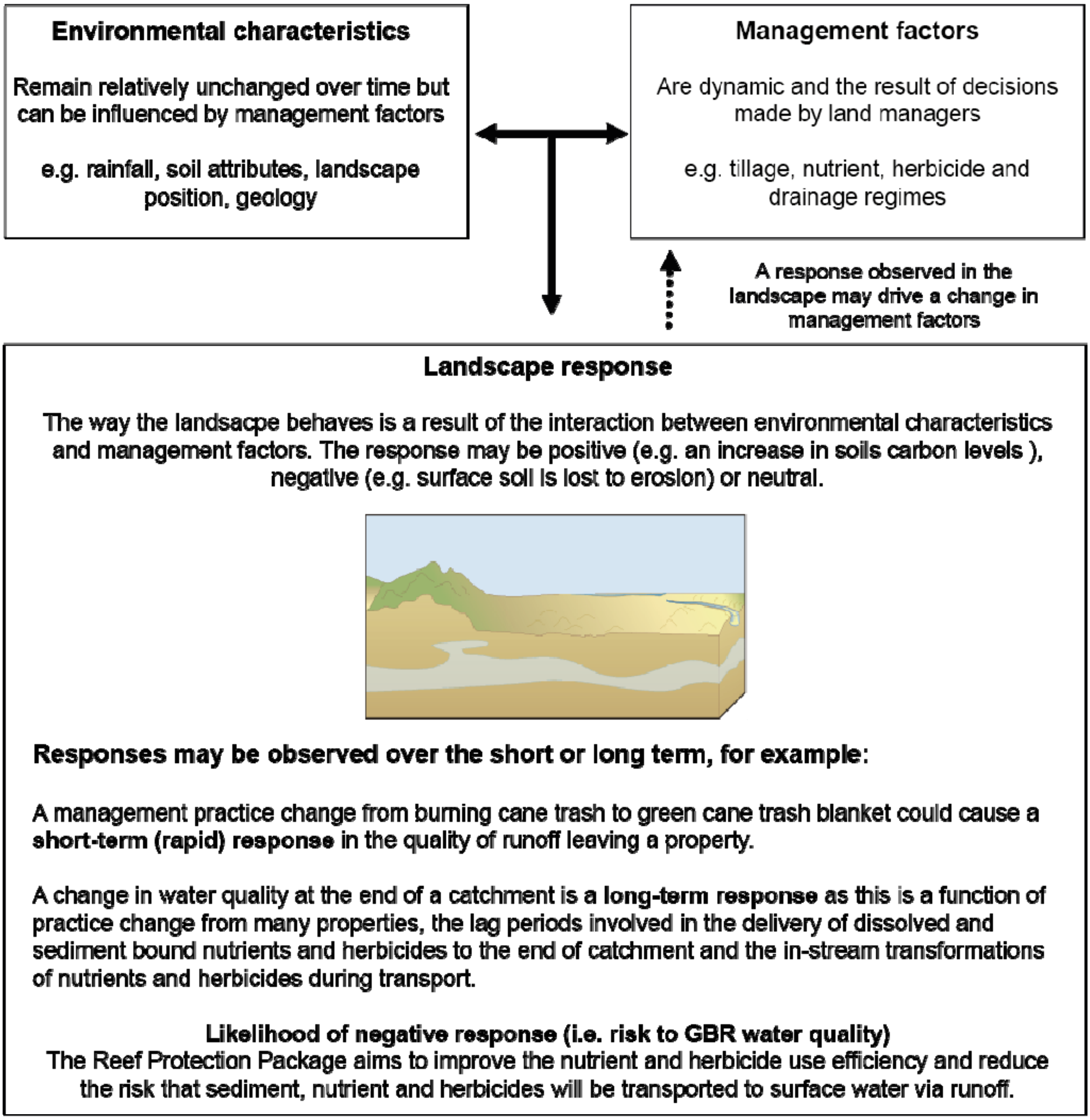

Figure 1. Overview of the interaction between environmental characteristics, management factors and landscape response.

How to use this guide

This guide explains how to use the four available environmental characteristic maps, which include:

Erosion potential – indicates the susceptibility of landscapes to erode, which can contribute sediment and associated nutrients and herbicides to waterways.

Flooding potential – describes the potential of landscapes to experience inundation caused by flood events. Areas under cane that flood more frequently represent greater potential sources of contaminants.

Dominant water pathway – indicates the potential of landscapes to generate runoff, as inferred by the drainage and permeability characteristics of soils.

Soil transport potential – indicates the potential for soil to be transported long distances, as inferred by the relative proportion of sand, loam and clay soil particles in the surface soil. Clay particles (<0.002 mm) are more easily transported over longer distances than larger silt and sand particles.

Sections 4 to 7 of this guide describe the above characteristics and provide information on:

- How the characteristic may affect water quality (background)
- A description of the data sets used and information products
- Information to support on-property interpretation of the characteristic (additional considerations)
- General implications for management (management)
- Other sources of information.

Section 8 gives an overview of the soils orders found across cane growing areas of the Burdekin, as defined by the Australian Soil Classification.

The study area for the Burdekin is outlined in Figure 2.

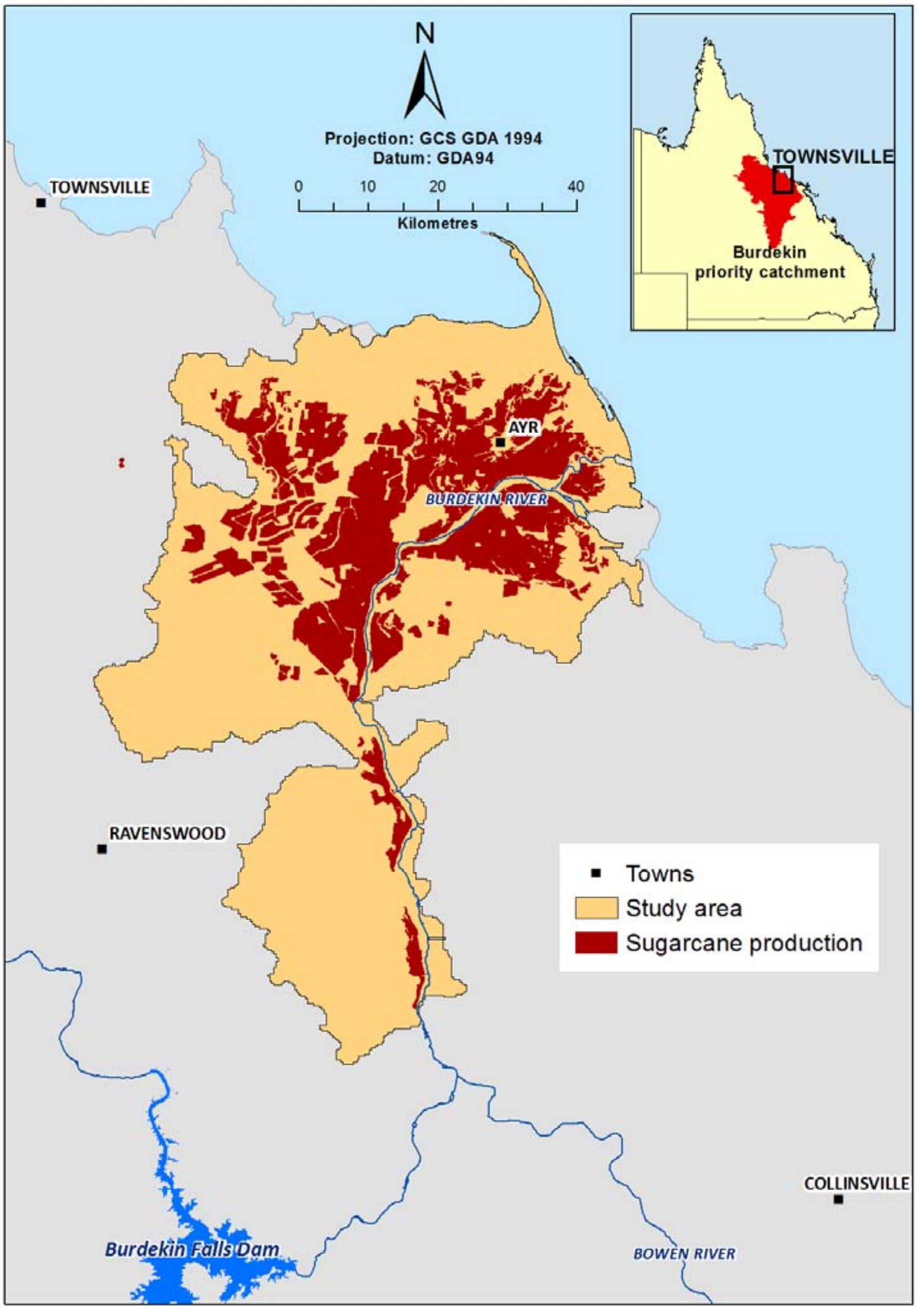

Figure 2. Burdekin study area and extent of sugarcane production taken from DERM 2009 land use data (DERM 2009)

Data used to assess environmental characteristics

Environmental characteristic maps are based on soils information collected during natural resource surveys (refer to Appendix 1 for a list of surveys). Table 1 indicates the soil attributes used to assess environmental characteristics. For further information about the process used to assess the four characteristics, refer to the technical report produced for the Burdekin area (Bryant *et al* 2012).

Table 1. Summary of soil attributes used to assess environmental characteristics.

Environmental characteristic	Attributes assessed	Description of environmental characteristic
Erosion potential	Soil erodibility Slope	This data describes erosion potential from hillslope erosion processes (rill, sheet and scald) based on soil attributes and slope. This data also identifies known eroded land ('mapped eroded land'), including gully and streambank eroded areas, recorded at the time of surveys. Information on erosion potential and known eroded land is derived from the land resource surveys which focused on areas suitable for intensive agricultural production and therefore data is limited to these areas.
Flooding potential	Potential extent of inundation	These data describe the areas which are potentially subject to inundation as interpreted from two data sets Pre-clear vegetation mapping of land zones 3 (Alluvium) and 1 (Estuarine); highlighting the active floodplain. Land resource surveys focused on areas suitable for intensive agricultural production describe the extent and frequency of flood eventsSoils mapping. Which describes the extent and frequency of flooding recorded during land resource surveys. In areas where soil mapping is at a scale better than 1: 100 000 the soil data is used instead of the vegetation mapping. The soils mapping provides an indication of flood frequency. Areas that are covered by vegetation mapping do not indicate flood frequency on potential flood extent.
Water pathway	Drainage class Permeability class	Water pathway is derived by combining drainage and permeability attributes of soil, as collected during land resource surveys. The decision matrix used to identify runoff and drainage landscapes is described in the technical report.
Soil transport potential	Surface soil texture	This data describes the generalised soil texture for the surface horizon in terms of sand, loam or clays. The classification of soil texture codes into four categories (sand, loam, clay and other) is provided in the technical report.

Rules for using maps and supporting information

Environmental characteristics maps form part of a suite of spatial information that can assist RPOs, extension officers and other organisations to understand the natural features of farms across the Burdekin. Through the use of spatial information, users can start to identify features that could be managed to improve water quality. This can support a number of tasks, e.g. preparing for field assessments or having effective conversations with growers. It is important that users are aware of the following conditions when using maps and supporting information:

1. Each map should be considered separately. Combining data sets obscures the importance of each characteristic and does not adequately represent the natural features of farms.

2. Information about the four environmental characteristics should be considered in conjunction with other property features that influence soil and water movement, for example:
   a. Users may access other information sources to gain an understanding of characteristics such as rainfall, vegetation cover, location of watercourses and streambank stability. Satellite or aerial imagery can be useful to identify some of these features. This guide provides contextual information about the influence of rainfall and vegetation cover.
   b. If users are aware of the management system used on farm, e.g. through an environmental risk management plan, they can check how well growers understand and manage the water quality implications of natural features on the farm. Where it is clear that growers are using reasonable and practical measures to manage risk associated with environmental characteristics, it is not necessary to investigate farm management further. However, where a management system does not seem appropriate, the maps can support a conversation with the grower about their farm.
3. Environmental characteristic maps are a guide to the types of features present on farm and may not always reflect the on-ground environment for a range of reasons, such as scale limitations or influence of human activities. These maps were developed using natural resource data mostly at scale of 1:50,000. This scale of mapping can assist users to understand the variability and general features of soils across, or between cane farms, e.g. farms of 50 hectares or greater. However, this scale does not precisely identify location of soil boundaries and should not be used to support detailed property planning, such as nutrient/herbicide use within block.

   Some areas in the Burdekin catchment are mapped at a coarser scale (1:100 000), as shown in Figure 3. Soil surveys at 1:100 000 scale are still considered to be appropriate to identify possible landscape features present on a property as a guide only for property planning/ERMPs.

   Users should check with growers if the maps represent the level of variation found on farm and if management has influenced the inherent environmental characteristics. For example, an area described as ‘poorly drained’ on the water pathway map could become well drained following the construction of farm drains. At times, growers will have access to more detailed soil information, which can better inform landscape assessment.

In light of the conditions described above, the environmental characteristic maps are not intended to support ranking of properties for any purpose.

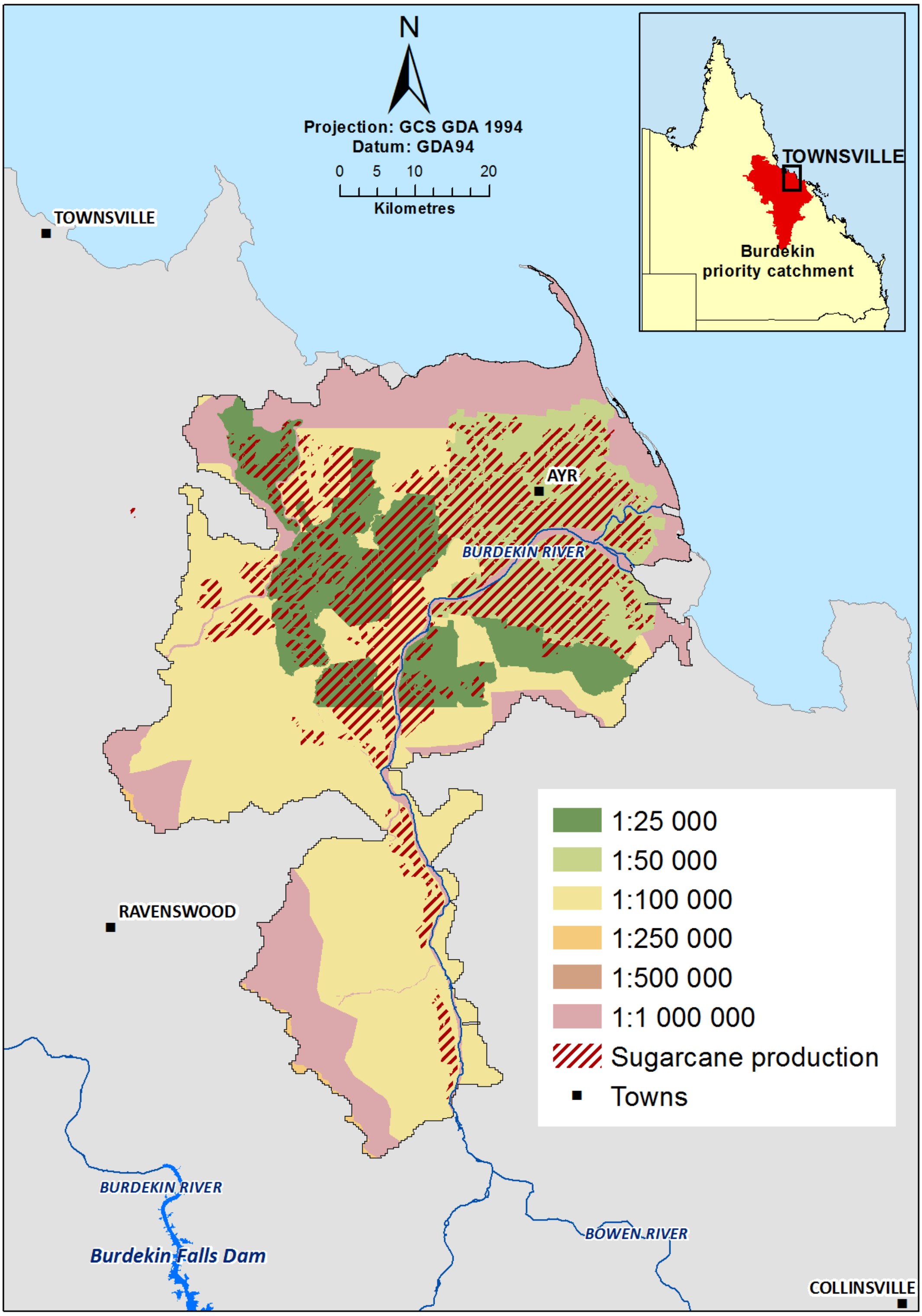

Figure 3. Land resource survey scales for the Burdekin catchment

Scale of land resource surveys

The scale at which land resource data is collected (survey scale) is a reflection of the sampling density or number of observations taken throughout the survey. Therefore, data collected at a fine scale, e.g. 1:10 000 provides a higher level of detail about soils on a farm than data collected at a broader scale, e.g. 1:100 000.

The number of sites required to accurately map an area is prescribed in the standard *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al* 2008). Table 2 shows the number of observations required for different map scales and Figure 4 demonstrates the appropriate use of different map scales.

Attendees at a technical review workshop to review the methodology used in the Wet Tropics catchment agreed that land resource surveys at 1:50 000 scale are generally appropriate for use at the farm level, e.g. farms of 50 hectares or greater. This scale indicates the variability of soils found on farms, which can then be fine-tuned through onsite observations and conversations with growers. However, workshop attendees agreed that the maps are not suitable for use at the individual block scale. Table 2 describes how maps at different scales support different purposes.

Table 2. Map scale and purpose

Type of map:	Environmental characteristics maps e.g.**1:50 000 or 1:100 000 scale**	EM map, yield map, NDVI map, e.g. **1:5 000 scale**
For use at:	Catchment/property scale	Individual block scale
Purpose:	Identify the possible landscape features present on a property as a guide only for property planning/ERMPs.	Inform site specific management of drainage, fertiliser inputs at the block/ property scale.

When using environmental characteristics maps, it is also important to be aware of the scale at which the map is displayed, whether this is on a paper map or via a GIS application such as ArcMap. For example, when viewing environmental characteristics at a scale of 1:50 000, a 1 mm line on the map represents 50 metres on the ground. This means that while variations in soil type may appear linear on the map, in reality soils change gradually across the landscape.

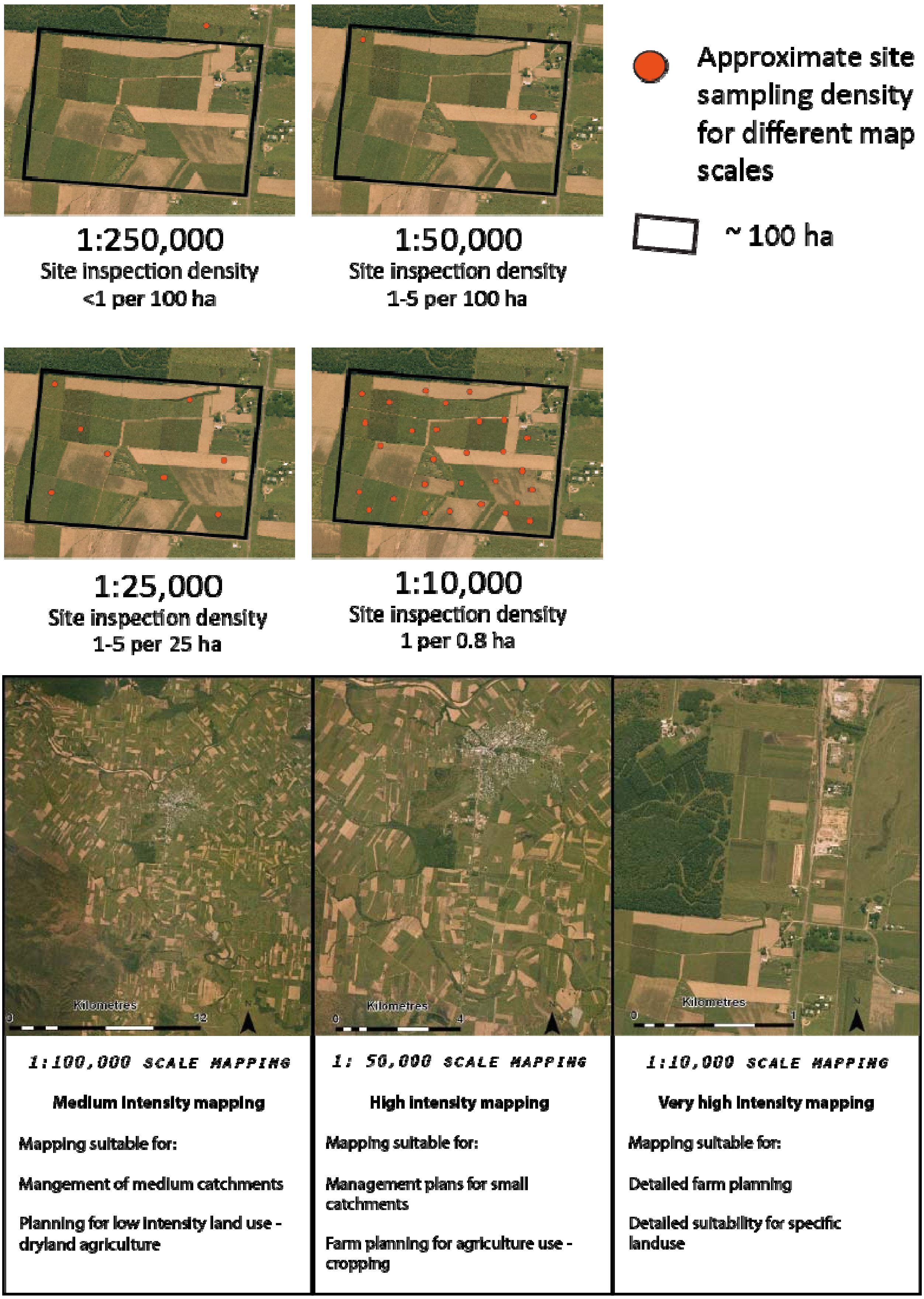

Figure 4. Site sampling density required for different mapping scales (above) and appropriate use of mapping at different scales (below) (Source: Gallant et al 2008).

(Note: Figure 4 shows the relative influences of scale, but are printed smaller than the scales indicated.)

Access to information

Spatial information (EHP officers)

EHP officers can access the spatial layers environmental characteristics mapping through SIRQRY. The options for viewing spatial information are:

ArcMap/ArcView

The spatial layers are best accessed using ArcGIS (e.g. ArcMap or ArcView), therefore a basic knowledge and understanding of ArcGIS is required. If RPOs need assistance to obtain ArcGIS software or learn how to use it, advice can be sought from a Principal RPO or a regional GIS officer.

ArcReader

RPOs can view and query spatial layers using ArcReader. This is a desktop mapping application that allows you to view, query, and print spatial information, and is free to download. However the data cannot be manipulated using ArcReader (as for ArcMap or ArcView).

A few points about ArcReader:

- It is easy to search and zoom via a lot and plan or coordinate search.
- A standard layout (including date stamping and adding disclaimers) can be applied when printing maps.

PET Tool

The PET tool can produce maps for a farm or at sub catchment / catchment scale if information is required at a broader scale.

Spatial information (external parties)

External parties can obtain spatial layers for the four environmental characteristics as ArcGIS compliant files, e.g. shape-files. Environmental characteristics spatial information can be downloaded from the Queensland Government Information Service website http://dds.information.qld.gov.au/dds/

Technical report

The supporting technical report – *Mapping environmental characteristics important for GBR water quality: Burdekin and Mackay Whitsunday* (Bryant *et al* 2012) – explains how the four environmental characteristic maps were developed.

The Technical report – Mapping environmental characteristics important for GBR water quality: Burdekin and Mackay-Whitsunday is available to download through the EHP library catalogue http://dermqld.softlinkhosting.com.au/liberty/libraryHome.do

Glossary

Alluvial

Alluvial refers to soils formed by the deposition of sediment in riverine landscapes.

Australian Soil Classification (ASC)

Australia's official system for classifying and identifying Australian soils. The system is based around 14 soil orders: Anthroposols, Organosols, Podosols, Vertosols, Hydrosols, Kurosols, Sodosols, Chromosols, Calcarosols, Ferrosols, Dermosols, Kandosols, Rudosols, Tenosols. Information regarding the ASC is available at:
http://www.clw.csiro.au/aclep/asc_re_on_line/soilhome.htm

Deep drainage

The volume of water that moves below the root zone which may or may not enter the saturated zone and become recharge to the groundwater system.

Drainage

It is the rate of removal of water from the soil profile. It describes the 'local soils wetness conditions' and is determined by soil properties, and the position of the soil within the landscape (e.g. topography, slope etc).

The following terms are a description of drainage attributes:

- **Very poorly drained** – water is removed from the soil so slowly that the water remains at or near the surface for most of the year.
- **Poorly drained** – water is removed very slowly from the soil in relation to supply which may result in seasonal ponding. A perched water table may also be present.
- **Imperfectly drained** – water is removed slowly from the soil. Intermittent waterlogging throughout the soil results in many profiles having a gleyed, mottled colour or rusty root channel linings.
- **Moderately well drained** – water is removed relatively slowly after supply. Some horizons may remain wet for as long as one week after water addition.
- **Well drained** – water is removed readily but not rapidly from the soil. Some horizons may remain wet for several days after water addition.
- **Rapidly drained** – water is removed from the soil rapidly. The soil is not normally wet for more than several hours after water addition.

Duplex soil

Is a soil where there is a sharp texture contrast between the A and B horizons.

Electromagentic induction (EM) map

EM maps measure the ability of soils to conduct electricity (conductivity). If combined with soil sampling, EM maps can be used to indicate soil properties such as texture, moisture and salinity.

Environmental characteristics

Characteristics of the landscape which remain relatively unchanged but can be influenced by management factors (e.g. rainfall, soil properties, landscape position, geology and geomorphology).

ERMP

A property management plan to minimise the risk of sediment, herbicide and nutrient run-off affecting the health of the Great Barrier Reef, while keeping the land in optimum productive condition.

Estuary

A semi-enclosed coastal body of water which has a free connection with the open ocean and within which sea water is measurable diluted with fresh water derived from land drainage. They form a transition zone between river and ocean environments.

Field capacity

Is the amount of water that is held in soil after it has been fully wetted and all gravitational water has been drained away. In practice, field capacity is reached about one to two days after heavy rainfall or irrigation ceases.

Gradational soil

Is a soil with a gradual increase in texture (i.e. becomes more clayey) as the profile deepens.

Groundwater

Water beneath the surface contained in saturated soil or porous rock. Groundwater systems are connected to surface water and the marine environment, but further research is required to quantify this connectivity. Groundwater is not considered in this assessment, but may be incorporated in future work.

HowLeaky

Is a daily simulation model based on a crop cycle of: plant cane, ratoon cane, soybean fallow crop.

Landscape response

The combination of environmental characteristics and management factors will drive a response in the landscape. For example, burning trash (management factor) on an erodible soil (environmental characteristic) can lead to erosion and sediment movement (landscape response).

Management factors

Land management practices which are dynamic, require input, and are influenced by decision making (e.g. green trash blanket, controlled traffic farming, timing and rate of fertiliser or herbicide application).

Mottles

Mottles are spots, blotches or streaks of subdominant colours which are different to the matrix colour. Mottles are an indication of water fluctuation throughout a soil profile.

Normalised Difference Vegetation Index (NDVI) map

NDVI maps are derived from satellite imagery and measure vegetation density and condition.

PAWC (Plant Available Water Capacity)

The amount of water stored within the soil that can be extracted by plants, expressed as millimetres of water within the root zone. A soil with a high water-holding capacity may store water in the profile for periods of time and not require additional inputs of water for plant growth. Soils with a low water-holding capacity may require frequent irrigation to support plant growth. DERM's land resource data provides an indication of the PAWC of Burdekin soils. Information on PAWC is also provided in the ERMP map package supplied to growers.

Permeability

Refers to the potential of a soil to transmit water internally. Permeability is related to the saturated hydraulic conductivity of the soil profile and is independent of the soils' position in the landscape. The following terms are a description of permeability attributes:

- **Very slowly permeable** – transmission through the soil profile is very slow. It would take at least a month for the profile to reach field capacity after wetting.
- **Slowly permeable** – transmission through the soil is slow. It would take at least a week or more after wetting for the soil to reach field capacity.
- **Moderately permeable** – transmission through the soil profile is relatively fast, field capacity is reached between 1–5 days after wetting.
- **Highly permeable** – transmission through the soil profile is very fast, field capacity is reached within 1–12 hours after wetting.

Pre-clear vegetation mapping

Pre-clearing vegetation is simply the vegetation present before clearing. The term equates to what is generally mapped as 'pre-1750' or 'pre-European' vegetation.

Rainfall erosivity

Rainfall erosivity is a climatic factor which can be determined from local rainfall data. It is highly related to soil loss. Soil erosion by running water can occur when the intensity and duration of rainfall exceeds the capacity of the soil to soak up the water. Rainfall intensity is extremely variable over very small areas and is not regularly measured.

Regolith

Is the term used to describe all the components that exist between fresh air and fresh rock (bedrock). It includes weathered rock, volcanic materials, gases, sediment, water and biota (e.g. plant roots, worms, bacteria and other organisms that live in the soil).

Sodic soil

Soil with a high percentage of sodium ions (in exchangeable form), which may exhibit degraded soil behaviour such as dispersion when wet and crusting when dry. Sodicity can occur at any depth in the soils. The effects are more pronounced if the sodicity is exposed to the surface.

Soil erodibility

Is the susceptibility of soil particles to detach and be transported by rainfall, runoff and flooding. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion.

Soil structure

Refers to the way soil particles group together to form aggregates (or peds). These aggregates vary in size and shape from small crumbs through to large blocks. Where there are no peds present, the soil is described as 'structureless' and may be either loose (single grain) or hard (massive). Soil structure has a major influence on water and air movement, biological activity, root growth and seedling emergence.

Soil texture

Refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of a soil. For example, a light soil refers to a soil high in sand relative to clay, whereas heavy soils have a higher proportion of smaller clay particles.

Uniform soil

A soil in which the profile has limited, if any texture change throughout.

Water pathway

Describes the dominant pathway or movement of water, when it comes into contact with the soil surface. This is inferred from the drainage and permeability characteristics of soils

Erosion potential

Background: Types of erosion

Rill erosion (a form of hillslope erosion)

Small channels are eroded in soil as runoff water concentrates down a slope.

Sheet erosion (a form of hillslope erosion)

A sheet of water running over the landscape carrying eroded sediments. This form of erosion may be less visible as it happens uniformly across a slope.

Streambank erosion

The direct removal of soil from banks by flowing water, exacerbated during periods of high streamflow or lack of vegetation cover.

Tunnel erosion

Dispersible subsoils with naturally high levels of sodium are removed through subsurface water movement. Surface soil initially remains intact, but may collapse and form gullies.

Gully erosion

Caused by the concentration of runoff water until flow velocity is sufficient to detatch soil particles along a drainage line. A waterfall may form over the gully head, and splashback causes the gully to migrate its way up the slope.

Queensland’s high-intensity summer rainfall means there is a significant risk of erosion by water, which may take any of the following forms:

Hillslope, gully and streambank erosion processes are considered in this assessment of Burdekin cane areas.

The erosion potential from **hillslope erosion processes** (i.e. rill, sheet and scald) is described during land resource surveys and assessed according to slope (which can increase the velocity of runoff), and the natural erodibility of the soil. The soils with the highest potential to contribute to sediment loss are those which are erodible on steep slopes.

Existing **gullied** areas and areas of **streambank erosion** were also mapped during land resource surveys in this catchment. Areas mapped as having existing gullies and streambank erosion are not allocated an erosion potential category, because it cannot be determined from the original land resource reports whether the erosion is a result of the inherent characteristics of the landscape (soils and slope) or from management practice. Instead, these areas are identified as ‘mapped eroded land’ on the erosion potential map. The ‘mapped eroded land’ category includes a range of undifferentiated known eroded land, gully and streambank eroded areas identified at the time of surveys and could range from minor to severe occurrences. However, there have been subsequent changes to land use and land management since the surveys were undertaken (refer to Appendix 1 for the list of land resource surveys); more information about these soils has been obtained from high intensity surveys in other parts of the district, which may affect the current accuracy of mapping. Consequently, this ‘mapped eroded land’ category does not indicate current state of activity, type or extent of erosion and users should check with growers to understand more about these areas.

Environmental characteristic maps for erosion potential only refer to propensity of a soil to erode in its natural state. No consideration is given to land use or management practices applied to an area.

Users can access other information sources, such as aerial imagery and information provided in an Environmental Risk Management Plan (e.g. farm maps and Part F) to help understand farm lay-out and management practices used on farm to minimise erosion.

The important factors to consider when managing land to minimise erosion are:

- **Soil** – some soil types are inherently more erodible than others.
- **Slope** – steeper slopes increase the velocity of runoff water, which can increase erosion. Longer slope lengths also increase the likelihood that soil particles will travel further from the point of origin.
- **Rainfall** – high intensity rainfall events can facilitate large erosion events on susceptible soils.
- **Cover** – vegetation cover protects the soil surface from raindrop impact and slows runoff water.

Description of erosion potential mapping

The erosion potential map indicates the natural susceptibility of landscapes to erode. However, the likelihood that soil will erode is largely dependent on land use and management practices. Hence soils that are naturally prone to erosion may not erode under good land management practices and conversely soils with low erosion potential may erode under poor management practice.

The classification of erosion potential is summarised below.

The attributes that contribute to each category of erosion potential are detailed in Table 3 and the spatial extent of these categories is shown in Figure 5.

Table 3. Description of erosion potential categories

Category	Description of soil and slope[1] attribute	Other mapping units included in erosion potential category
Lower potential	0.5 – 1% slope for texture contrast soils with a sodic horizon by 60 cm soil depth or 1.0 – 2.0 % slope for other soils 1.0 - 2.0 % slope for texture contrast soils with a sodic horizon by 60 cm soil depth or 2.0 - 4.0 % slope for other soils No erosion risk. < 0.5 % slope for texture contrast soils with a sodic horizon by 60 cm soil depth or < 1 % slope for other soils	Urban Miscellaneous water map units Swamps Rock
Moderate potential	2.0 - 3.0 % slope for texture contrast soils with a sodic horizon by 60 cm soil depth or 4.0 - 5.0 % slope for other soils 3.0 - 5.0 % slope for texture contrast soils with a sodic horizon by 60 cm soil depth or 5.0 - 10.0 % slope for other soils	Disturbed land other Hills Miscellaneous mining quarry units
Higher potential	> 5.0 % slope for texture contrast soils with a sodic horizon by 60 cm soil depth or > 10.0 % slope for other soils	
Mapped eroded land	Eroded land Minor existing gully or streambank erosion Moderate to severe existing gully or streambank erosion	
Not assessed	NA - Out of detailed soil mapping area	

The effects of rainfall and vegetation cover are not represented in the erosion potential map. However, these characteristics also influence the potential of landscapes to erode and it is important to consider these as part of property planning. Some contextual information about the effect of rainfall and vegetation cover is provided in the 'Additional considerations' section below.

[1] Each slope class was analysed separately, therefore they are not grouped together within each category of erosion potential.

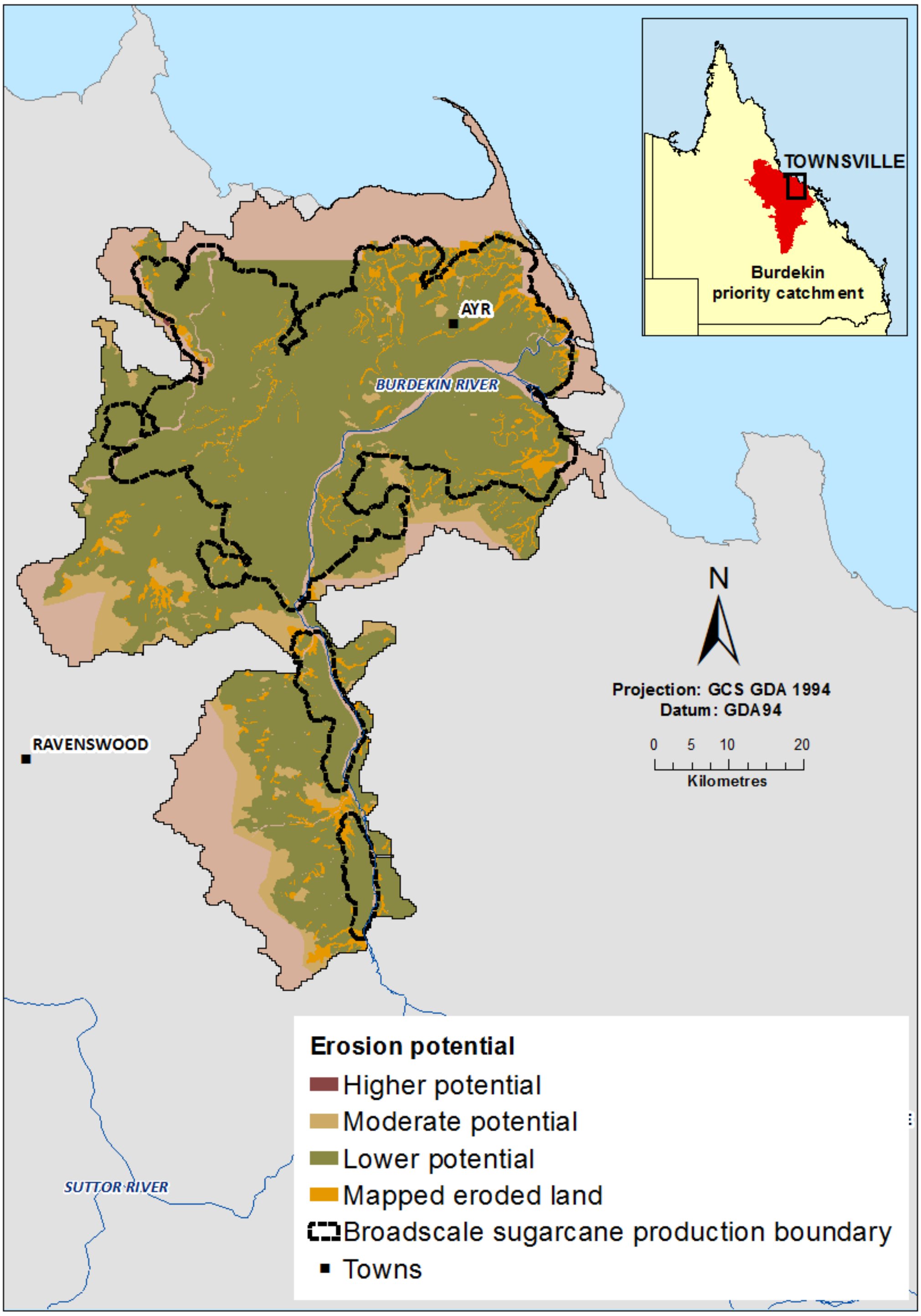

Figure 5. Erosion potential – Burdekin catchment

Note 1. The scale of map does not allow precise location of soil boundaries and is not indicative of actual erosion as many areas are well managed and in good conditions.

Note 2. The erosion potential was assessed according to slope and the natural erodibility of soils. The majority of mapped land is in the lower erosion potential category. This is largely because most of this lower Burdekin floodplain is relatively flat and doesn't have steep slopes.

Note 3. The mapped eroded land category includes a range of undifferentiated known eroded land, including gully and streambank eroded areas, recorded at the time of land resource surveys (refer to Appendix 1 for the list of surveys).

Additional considerations

Rainfall

Patterns and intensity of rainfall events can have a strong influence on erosion rates:

- Landscapes in different rainfall zones (Figure 6) may experience different rates of erosion despite similar management practices. The average rainfall for key areas in the study area (Ayr and Giru) is outlined in Table 4. Information on daily, monthly and annual rainfall is also available from the Bureau of Meteorology website.
- Rainfall intensity, in addition to amount of rainfall, influences erosion. High intensity rainfall events increase the potential for erosion to occur.

For example, 100mm of rain delivered in one hour is likely to cause greater erosion than the same amount delivered over one day.

- Rainfall intensity is variable across small areas, and is best discussed with property owners. When considering intensity, it may be sufficient to acknowledge that rainfall events are likely to be more intense during the wet season and in high rainfall areas, and ensure management practices are seasonally appropriate.

Table 4. Average rainfall at Ayr and Giru

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Giru	277	234	215	66	56	27	17	15	13	31	66	171	**1188**
Ayr	182	184	184	54	44	27	46	17	11	32	53	142	**976**

Long-term average monthly rainfall statistics for the period 1961–90 (BOM 2012)

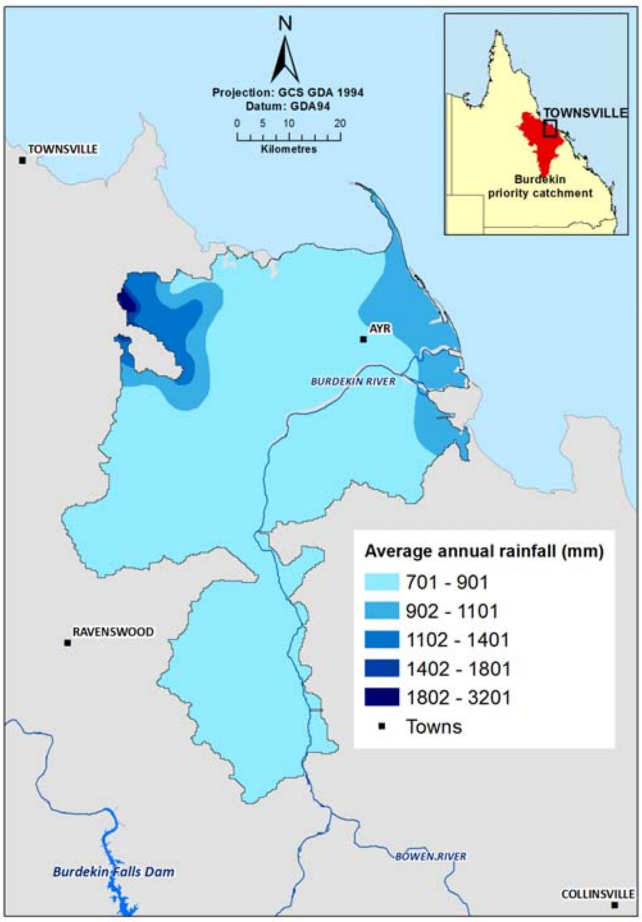

Figure 6. Average annual rainfall in the Burdekin (DERM 2012)

Vegetation cover

Erosion is influenced by the level of vegetation cover present, i.e. full crop, ratoon, break crop, fallow etc. Greater levels of cover reduce the chance of erosion exponentially, meaning less than 100% cover can still significantly reduce erosion (Figure 7).

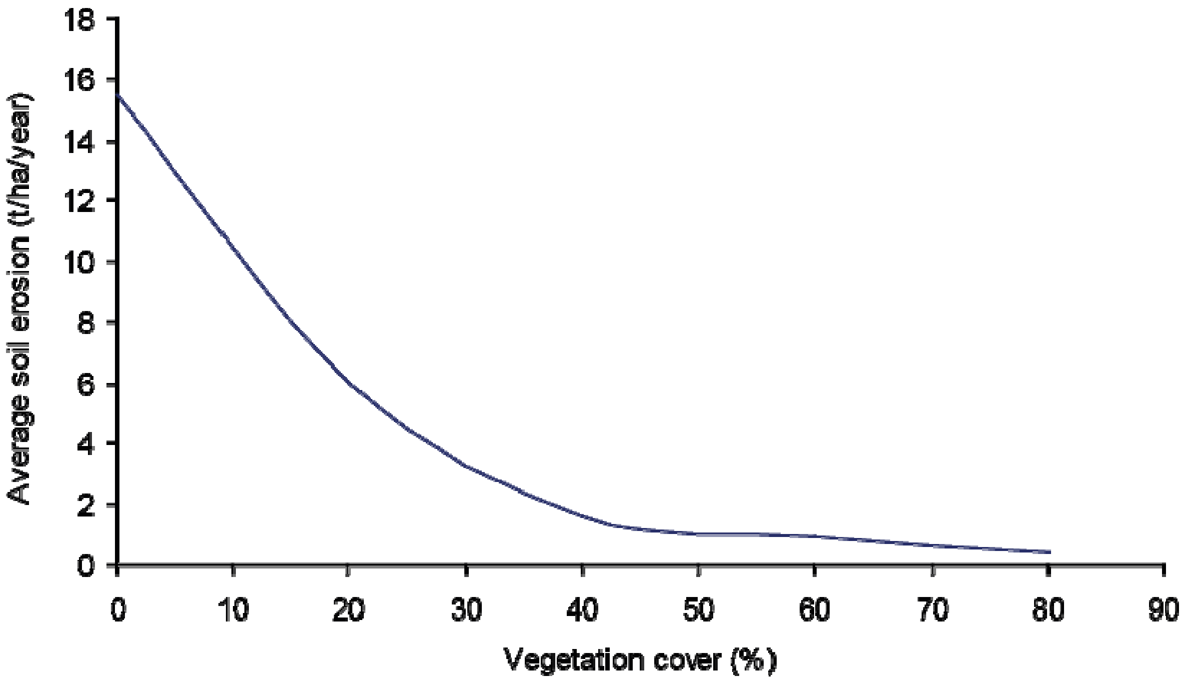

Figure 7. The influence of vegetation cover on soil erosion for a Dermosol in Ayr. This relationship is similar for other soil types (graph produced using outputs from How-Leaky).

At any point in time, approximately 15% of cane paddocks may be in fallow. Paddocks without appropriate cover have greater potential to erode, which increases if the soils are also prone to erosion

Trash blanketing (Figure 8) has had a major impact on reducing erosion across cane farms as it:

- reduces the effect of raindrop impact, which can dislodge soil particles
- slows the velocity of runoff, which reduces the likelihood of sediment being dislodged and also allows suspended sediment to settle out.

A number of cane farms in the Burdekin do not employ green cane trash blanketing as a management technique cane is burnt before it is harvested (Figure 9).

Figure 8. Trash blanketing on a cane paddock – Burdekin (photo courtesy of CSIRO)

Figure 9. Cane being burnt before harvest – Burdekin (photo courtesy of CSIRO)

Soil type

The greatest potential for erosion occurs during the wet season (approximately December – April); however soil type also influences the degree to which soils will erode (Figure 11).

For example:

- sodic soils (e.g. Sodososls) can erode rapidly, if exposed, because of their highly dispersive nature when wet
- highly permeable basaltic soils (e.g. Ferrosols) are less susceptible to erosion because they are well structured
- sandy soils (e.g. Podosols) tend to erode less as they are very permeable and have large soil particles which are less susceptible to movement by water.

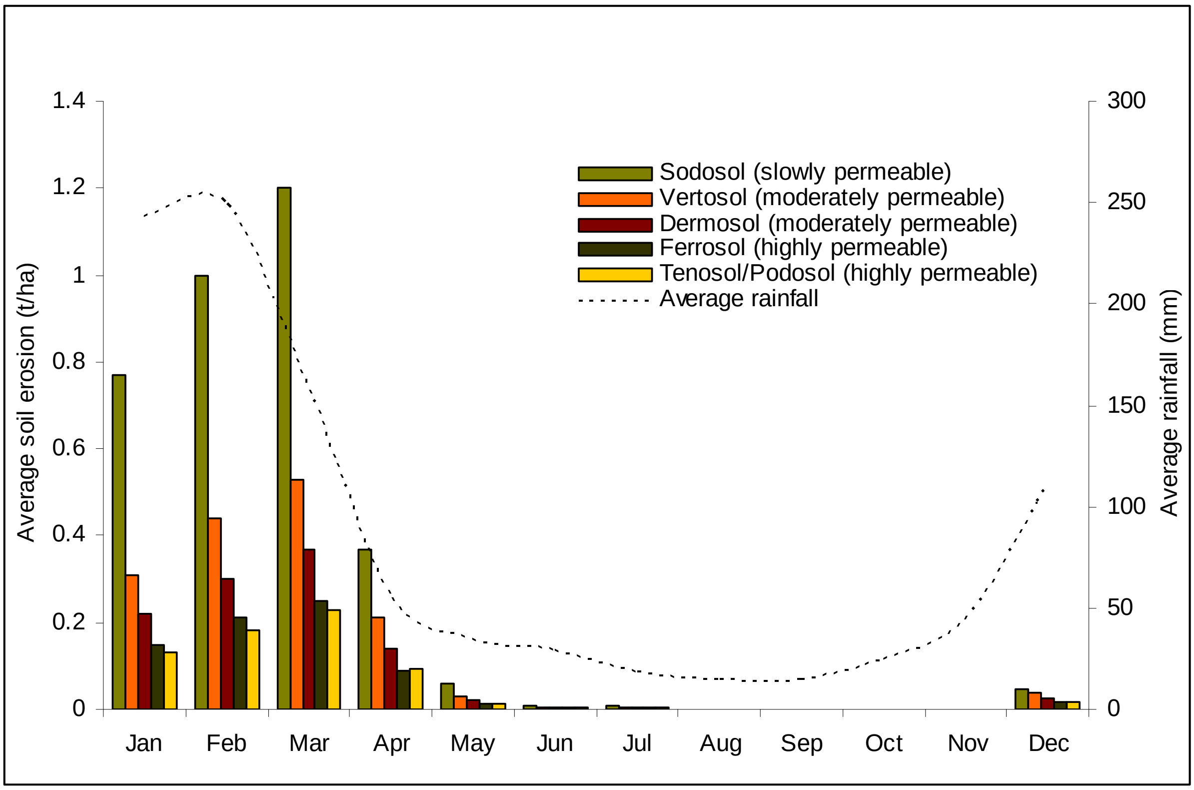

Figure 10. The variability in erosion rates according to soil type, comparing average monthly soil erosion for five different soil types at Ayr (graph produced using outputs from HowLeaky).

Constructed farm drains as a source of sediment

Many cane farms in the priority catchments are located in flat floodplain environments and improved drainage can be required to minimise water-logging of cane crops.

Constructed farm drains, such as deep square drains, spoon drains and sub-surface mole drains are designed to collect and divert surface runoff and groundwater from cane crops. Drains generally connect to natural watercourses, which can result in efficient delivery of water and mobilised contaminants. Drains may also be a source of sediment where the banks have slumped.

Management

The likelihood that soils will erode is largely dependent on management practices. Soils that are naturally prone to erosion may not erode under certain land management practices and conversely, soils which are naturally quite stable may erode under poor land management practices.

To reduce erosion potential, management practices must consider the implications of slope, soil type, rainfall, and cover. Table 5 outlines example management principles that could be employed to address these factors and minimise the risk of erosion.

Table 5. Management options for mitigating impacts of erosion

Erosion factor	Erosion principle	Examples of management principles to minimise erosion
Slope	Steeper slopes = increased chance of erosion	Manage fallow to retain topsoil by providing cover, a well-managed legume crop during the fallow can help protect the soil when heavy rain occurs. Wider row spacing allowing for controlled trafficking of machinery to aid infiltration and reduce runoff. Reduce tillage operations, consider zonal or zero tillage. Maintain green cane trash blanket throughout ratoons. Installing berms or contour banks will help to reduce the velocity of the flow of runoff across the farm, thus will reduce erosion and allow sediments to be deposited before they leave farm.
Soil type	Erodible soils = increased chance of erosion	Minimum or zero till adopted. Wider row spacing allowing for controlled trafficking of machinery. Use double disc opener planters for reducing soil disturbance during planting. Maintain green cane trash blanket throughout ratoons. Ensure areas vulnerable to erosion or upstream from the erosion are well vegetated All drains are well vegetated. Manage fallow effectively and maintain vegetative cover on soil. Maintain well vegetated spoon drains, headlands and grassed treatment areas. The timing of cultivation on erodible soils is specifically managed for high rainfall periods.
Rainfall	Higher rainfall intensity = increased chance of erosion	Manage fallow effectively and maintain vegetative cover on soil. Consider rainfall forecasts prior to planting operations or tillage to reduce the risk of heavy rainfall coinciding with operations. Adjust time of cultivation to avoid high rainfall periods. Maintain green cane trash blanket throughout ratoons for avoiding direct exposure of soil to high intensity rainfall. Maintain well vegetated spoon drains, headlands and grassed treatment areas.
Cover	Less cover = increased chance of erosion	Fallow managed effectively to protect soil through crop cycle either by growing a legume cover crop or to promote other vegetative cover. Prior to establishing plant crop, spray out cover crop with knockdown herbicides and leave as standing stubble or slash cover crop and leave on surface for minimising soil loss. Maintain green cane trash blanket throughout ratoons. Riparian vegetation is maintained.

Further information

Erosion fact sheets < http://www.derm.qld.gov.au/services_resources/index.php >

- Soil conservation planning in cropping lands
- Runoff control measures for erosion control in cropping land
- Controlled traffic farming – soil conservation considerations
- Maintaining contour banks
- Contour bank specifications
- Soil conservation waterways – planning and design
- Soil conservation waterways – Construction and management
- Soil conservation waterways – Plants for stabilisation
- Erosion control in cropping lands
- How healthy is your watercourse?
- Streambank planting guidelines and hints
- Streambank vegetation is valuable
- What causes bank erosion
- What causes stream bed erosion
- Catchments and water quality.

Soil conservation measures—Design manual for Queensland

A web based publication – '*Soil conservation measures—Design manual for Queensland*' is being produced. It provides current information on: planning, runoff estimation, channel design and special application. Refer to the Environment and Heritage Protection website: <www.derm.qld.gov.au/land/management/erosion/index.html#design_manual>

Land resource reports for the Burdekin catchment

Land resource reports provide information on the soils of the Burdekin area. See Appendix 1 for a list of the soil surveys used to assess environmental characteristics.

Land resource reports can be viewed and downloaded through:

- the EHP library catalogue at: < http://dermqld.softlinkhosting.com.au/liberty/libraryHome.do >
- the Queensland Digital Exploration Reports system (QDEX) at: <www.dme.qld.gov.au/mines/company_exploration_reports.cfm>

Alternatively, reports and fact sheets can be requested by emailing: Soils@derm.qld.gov.au

Flooding potential

Background

Flooding occurs when a river can no longer be contained within its banks and spreads over adjacent land as floodwater. Wet season floods have a high capacity to transport contaminants, particularly those in dissolved forms, and are the major delivery mechanism of land-derived contaminants to the GBR (Brodie *et al* 2008). Where cane farms are located in areas that flood relatively frequently, e.g. annually, there may be a higher potential for contaminants to be mobilised and delivered off-farm in floodwaters, compared to cane farms located in areas that do not flood frequently (Figure 12). Floods can also facilitate transport and spread of weeds, which may mean more herbicides are used.

Figure 11. Floodplain showing cane growing in areas that may flood relatively frequently.

Description of flooding potential mapping

Flooding potential is derived from two sources; soils mapping and vegetation mapping. Where detailed soils mapping is available the flooding potential layer indicates potential flood extent and frequency. Where detailed soils mapping is not available vegetation mapping is used to indicate potential extent of inundation (the active floodplain) but **NOT** frequency. The classification of flooding potential is outlined in Table 6 and mapped in Figure 13 for the Burdekin catchment

Table 6. Categories for flooding potential Burdekin Catchment

Category	Description	Source
Annually flooded areas	Flooding at least or almost annually or areas subject to erosive flooding	Soils mapping
Less than annually flooded areas	Areas subjected to local flooding at frequency of 1 in 5 -10 years Area subjected to local flooding at frequency > 1 in 5 years Areas subjected to local flooding at frequency <1 in 10 years	Soils mapping
Indicative floodplain (no frequency data)	Approximate inundation extent but not frequency	Vegetation mapping
Not assessed	Miscellaneous mining quarry units	Soils mapping

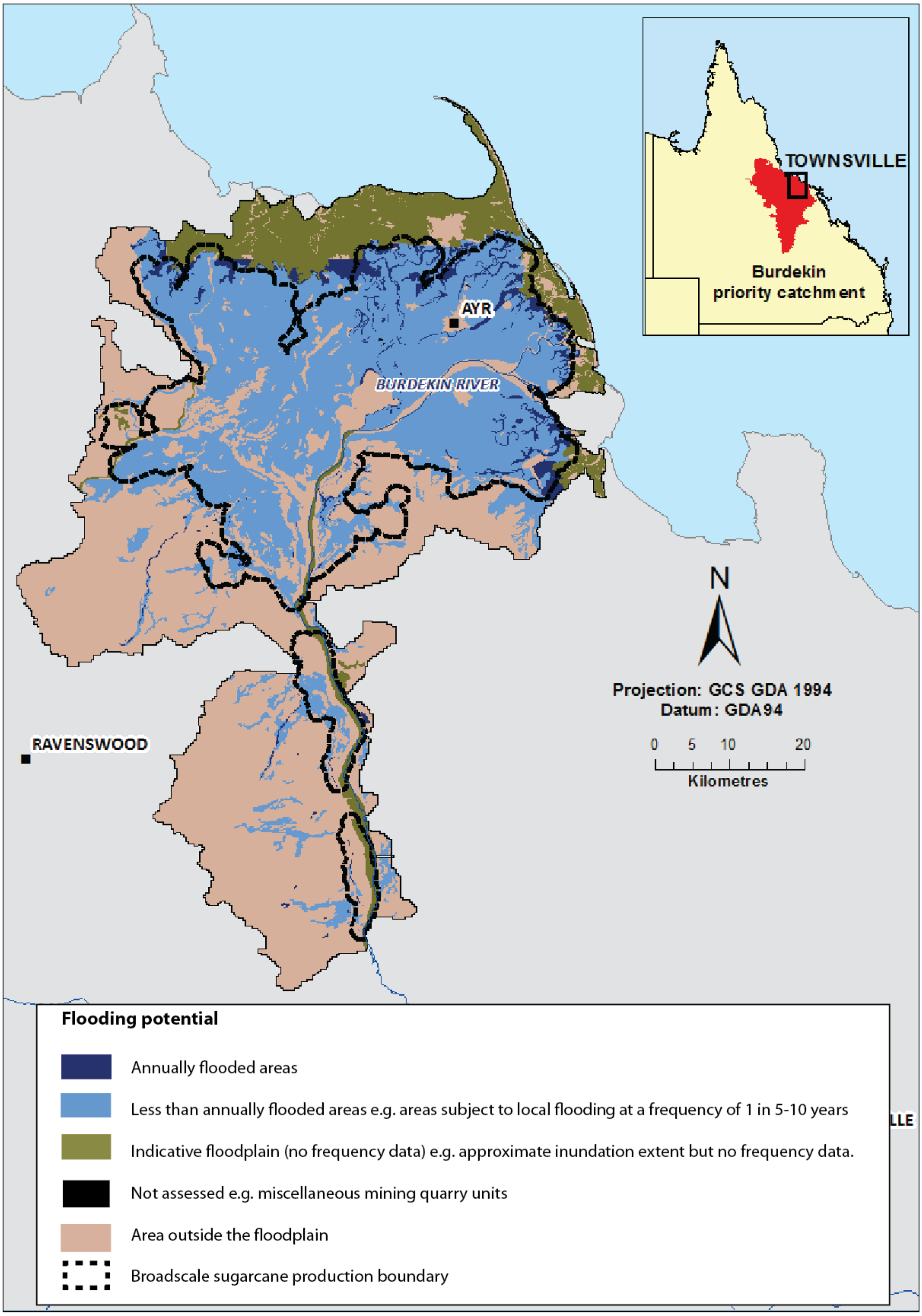

Figure 12. Flooding potential – Burdekin catchment

Management

Nutrients and herbicides applied on the floodplain can be mobilised in their dissolved forms and transported by floodwaters. Dissolved contaminants are the most likely to reach the GBR because there is no potential for them to settle out of suspension. Sediment and associated nutrients and herbicides may also be mobilised and transported shorter distances. It is therefore critical to consider timing of land management practices to reduce the movement of contaminants in floodwaters, either via sediment or in dissolved forms. Table 7 outlines example management principles that can assist to minimise the movement of sediment, nutrients and herbicides in floodwaters.

Table 7. Management options for mitigating impacts of flooding.

Transport process	Principle to reduce movement in floodwaters	Example of management principles to mitigate impacts of flooding
Nutrients and herbicides transported attached to sediment	Reduce offsite movement of sediment	Fallow managed to promote vegetative cover, so that bare soil is not exposed during wet season. Maintain well-vegetated spoon drains, headlands and grassed treatment areas. Incorporate sediment traps, retention ponds or constructed wetlands to collect first flush and prevent discharge of contaminated runoff. Promote growth of native deep-rooted vegetation and control weeds in riparian zone.
Nutrients and herbicides transported in dissolved form	Minimise soil concentrations during times of likely flooding	Consider rainfall forecasts prior to herbicide spraying and placement of fertiliser, particularly surface banded fertilisers. Where possible, spot spray small weed infestations and avoid applying during high risk periods (wet season). Incorporating fertiliser applications through irrigation (overhead vs flood irrigation) improves the likelihood that nutrients and herbicides will be incorporated before wet season arrives. Use soil, leaf testing to inform fertiliser application rates. Manage fallow effectively so that bare soil is not exposed to rain and subsequent floods. Schedule fertiliser application to coincide with crop demand. Consider sub-surface application of fertiliser in plant and ratoon. Consider weed type and pressure prior to spraying of residual herbicide application. Use trash blanketing to suppress weeds. Use of water treatment infrastructure to collect first flush and prevent discharge of contaminated runoff.

Dominant water pathway

Background

Water pathway indicates whether soils are more likely to drain or generate runoff, based on the drainage and permeability characteristics of the soil. Impermeable or poorly drained soils are more likely to generate runoff, which can transport sediment, nutrients and herbicides to nearby watercourses. Figure 14 displays the difference in appearance between a well-drained soil and a poorly drained soil. The bright red colours of the basaltic soils (Ferrosol) on the left are an indicator of good drainage. The pale colours and mottling (see glossary) in the soil on the right (Hydrosol) indicates that this soil is poorly drained.

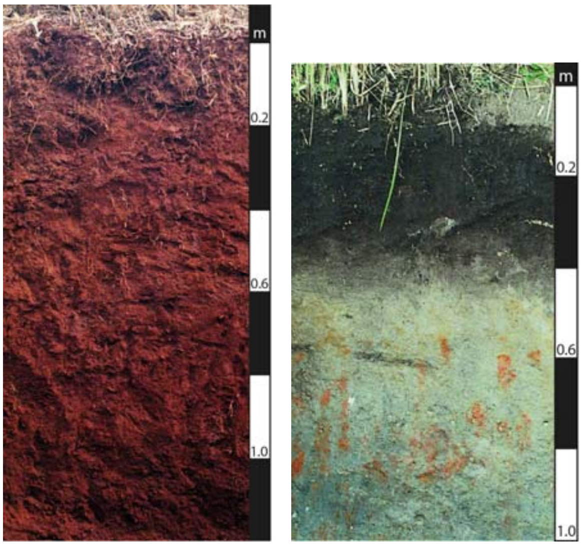

Figure 13. Example of a well-drained soil (left) and a poorly drained soil (right).

Description of water pathway mapping

To generate water pathway data, soil permeability and drainage classes (see glossary) were combined to identify the dominant pathway of water when it contacts the soil surface (Moody and Cong 2008).

The classification of water pathway is summarised in Table 8 and the dominant water pathway for the Burdekin priority catchment is mapped in Figure 15.

Table 8. Description of water pathway categories.

Dominant water pathway	Description	Implications*
Drainage	Highly permeable and well or rapidly drained soils	Nutrients such as nitrate may leach - resulting in accelerated soil acidification and groundwater (see glossary) contamination
Drainage/runoff	Permeable and imperfectly drained soils	
Runoff/ponding	Poorly drained and slowly permeable soils	Runoff can lead to accelerated soil erosion, which can impact on surface water quality

* Source: Moody and Cong 2008

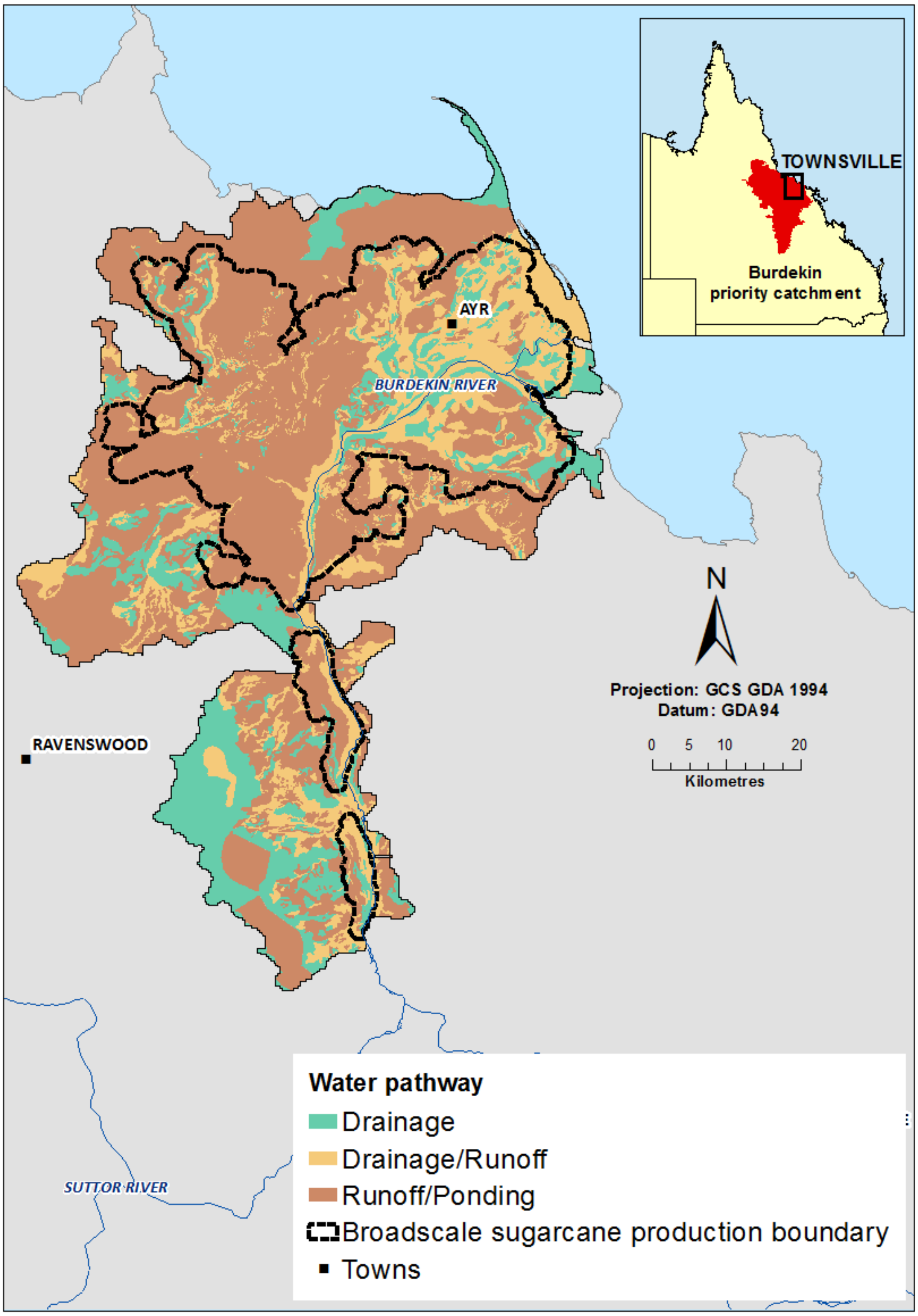

Figure 14. Dominant water pathway – Burdekin catchment

Note 1. The scale of map does not precisely identify soil boundaries for water pathway, it indicates the likely water pathway based on soil characteristics

Additional considerations

Rainfall

The quantity of rainfall during the wet season, and therefore the time taken for soils to reach saturation, varies significantly across the Burdekin catchment. Once soils are saturated, they are more likely to generate runoff, regardless of whether they are naturally well drained or not. Many farms in the Burdekin catchment are furrow-irrigated, which also influences the time taken to reach saturation (refer to section on furrow irrigation below).

Farm drains

Soil drainage and permeability characteristics are described in their natural state during land resource surveys. However, properties with farm drains can alter the drainage characteristics of soils, i.e. poorly drained soils can become well drained following the construction of cane drains.

Amelioration of sodic soils

Many soils in the Lower Burdekin exhibit high levels of sodicity. Often amelioration with gypsum or mixing saline water with fresh river water for irrigation is used to increase infiltration into the surface soil to improve the productivity of the root zone. These treatments, over time, may have increased the permeability of soils (Reading 2010). Soils which were considered to be slowly permeable may become more permeable with the application of such treatments.

Furrow irrigation

Most of the sugarcane in the Burdekin catchment is grown using furrow irrigation techniques (Thornburn *et al* 2007) (Figure 16). Inefficiencies in furrow irrigation can lead to water-logging and deep drainage (see glossary) (Raine and Bakker 1996). The use of furrow irrigation may alter the drainage and permeability characteristics of soils (as described during land resource surveys), i.e. poorly drained soils may have increased deep drainage under furrow irrigation.

Figure 17 demonstrates the difference between a moderately permeable and slowly permeable soil under two irrigation amounts. The irrigation requirement of sugarcane in the Burdekin area is 980 mm/ha/yr (Raine and Bakker 1996). The amount of water applied to sugarcane in the Burdekin can vary from between 600 mm/ha/yr and 2100 mm/ha/yr (Raine and Shannon 1996).

Figure 17 shows that when irrigation levels are increased, there is a significant increase in deep drainage for the slowly permeable soil (Sodosol). Deep drainage rates between the two different soils become similar with the higher irrigation amount.

Figure 15. Furrow irrigation on a cane paddock

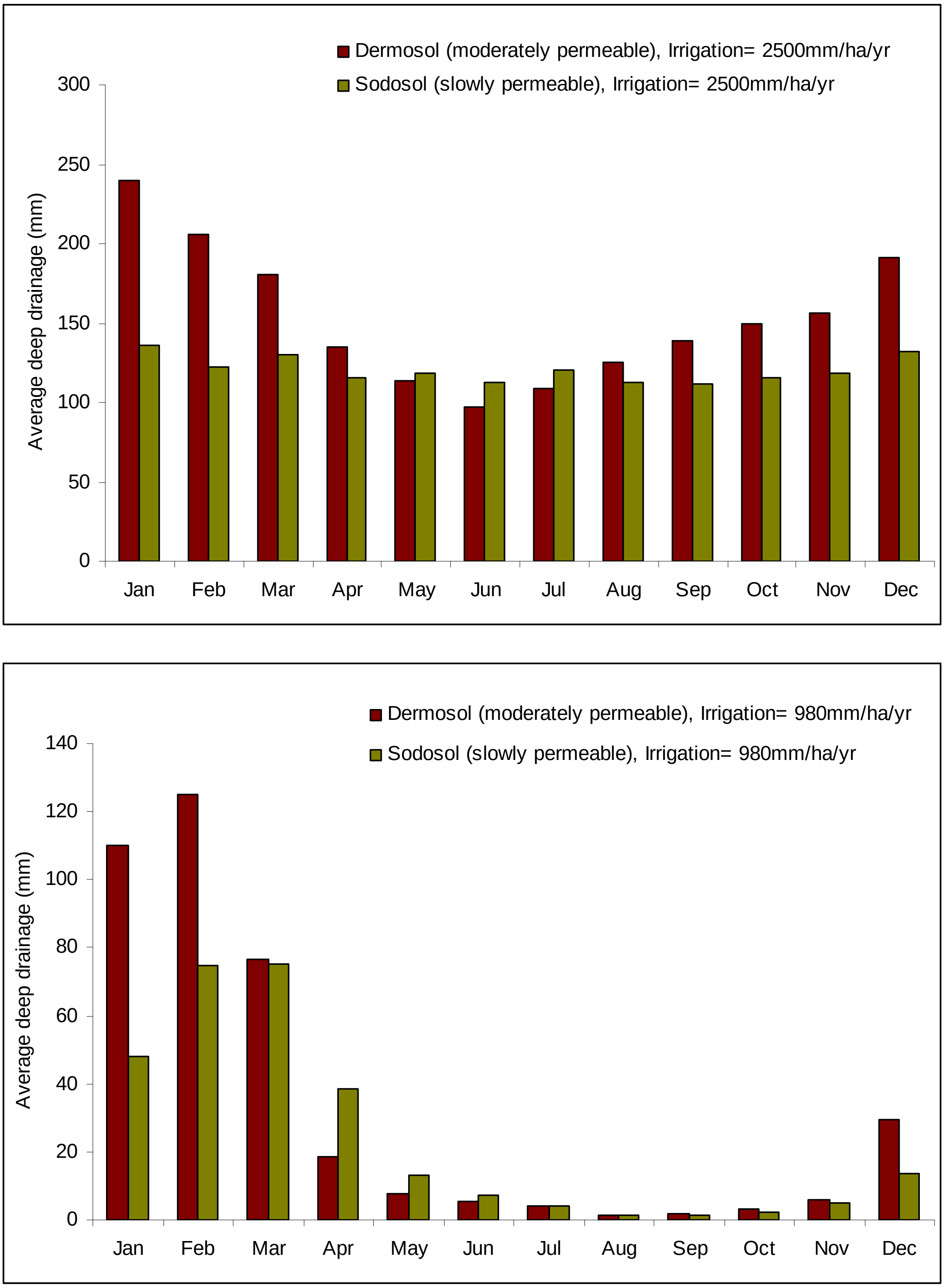

Figure 16. Differences in deep drainage between a slowly permeable and moderately permeable soil over varying irrigation amounts in a furrow irrigation system (graphs produced using outputs from HowLeaky).

Management

Management principles should be adapted depending on whether landscapes are likely to drain (e.g. sandy soils) or generate runoff (e.g. heavy clays). In all instances, it is important to optimise inputs (nutrients and herbicides) to reduce the volume of contaminants available for transport – whether via surface water run-off or leaching past the root zone. Table 9 outlines example management principles for mitigating impacts of water pathway.

Other environmental characteristics: groundwater contamination

Environmental characteristic maps focus on the potential for contaminants to be transported off farm via surface water. However, nutrients and herbicides can also be transported to the GBR via groundwater pathways.

Users can start to identify areas vulnerable to groundwater contamination by considering parts of the landscape that facilitate drainage (as shown on the water pathway map). The focus in these areas should be to minimise leaching of nutrients and herbicides past the root zone.

The likelihood that contaminants will actually be transported to groundwater is influenced by a range of features, e.g. rainfall, soil and regolith properties, and proximity to aquifers. Some of these features are not well understood at this time; however work is ongoing to improve understanding of groundwater transport processes across the GBR catchments.

Table 9. Management principles for mitigating impacts of water pathway.

Dominant water pathway	Principle to minimise runoff and leaching	Examples of management principles that mitigate the impact of water pathway
Drainage	Minimise leaching of excess water and nutrients /herbicides	Consider weather predictions of rainfall prior to the placement of fertiliser, particularly surface banded fertiliser. Fertiliser application should take place when the crop is actively growing to promote more rapid uptake of nutrients by the crop. Optimise timing and rates of nutrient/herbicide application, e.g. accounting for inputs from legumes and mill mud, timing application of nutrient/herbicide with irrigation application, sub-surface fertiliser application. Irrigate optimally based on soil types in blocks. Avoid fertiliser application when soil profile is very wet.
Drainage/runoff	Maintain water balance	
Runoff/ponding	Minimise erosion and contaminant transport associated with runoff	Match irrigation application rate and volume to the infiltration rate and capacity of the soil type. Manage fallow effectively so that soil is not exposed during the wet season when flooding potential is greatest. Include spoon drains, sediment traps, filter strips and headlands for effective treatment of water leaving the farm by to collecting first flush and prevent discharge of contaminated runoff. Install sediment traps at appropriate locations, i.e., in the lowest part of the blocks, prior to drainage into riparian areas or adjoining waterways. Using irrigation recycle pit to capture irrigation runoff will help to detain first flush surface run-off, thus assisting in nutrient retention and sediment trapping. Structures need to suit farm specifics including soil type, runoff rate and volume. Optimise timing and rates of nutrient/herbicide application to reduce the volume of contaminants available for transport.

Further information

Soil Constraints and Management Package (SCAMP)

This publication provides a decision-support framework that bridges the gap between taxonomic soil surveys and informed management strategies for sustainable production on upland soils in the tropics. Available to download at: http://aciar.gov.au/files/node/8946/MN130%20full%20text.pdf

Fact sheet < http://www.derm.qld.gov.au/services_resources/index.php >

- Soil limitations to water entry

Soil transport potential

Background

Soils vary in their potential to be eroded (erosion potential – see chapter 4) and their potential to be transported over long distances (soil transport potential). Smaller soil particles such as clays are transported more easily and over longer distances than larger silt and sand sized particles, which are more likely to fall out of suspension (Figure 18). Soils with high clay content therefore have a greater potential to reach the GBR (Figures 19 and 20). Furthermore, soils with high clay content are more likely to bind nutrient cations and electro-positively charged pesticide compounds, due to the negative charge of clay particles, which can also be delivered to the GBR.

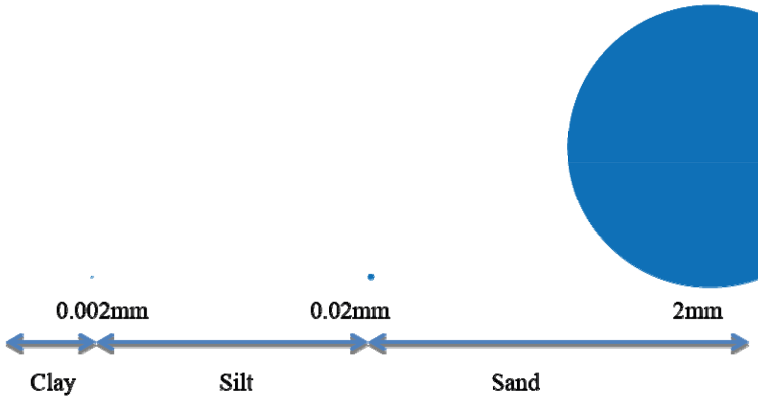

Figure 17. Relative difference in particle sizes for clays, silts and sands.

Figure 18. Sediment plume in the Burdekin catchment. Smaller soil particles will be transported further and are more likely to reach the GBR.

Figure 19. Clays particles may remain suspended in rivers giving them a turbid appearance. These soil particles can be transported long distances in suspension.

Description of soil transport potential mapping

The amount of sand, silt and clay particles in the surface soil is determined by soil texture tests in the field (see further information section). Table 10 divides surface soil texture into sand, loam and clay classes. The soil transport potential map for the Burdekin catchment is shown in Figure 21, recognising that soils over 35% clay have a higher potential to be transported over long distances. All field textures and their equivalent categories are listed in appendix B.

Table 10. Description of surface soil texture classification.

Surface soil texture	Field texture
Sands (lower transport potential)	Sand, loamy sands, clayey sands
Loams (moderate transport potential)	Sandy loams, loam, clay loams, silty loams
Clays (higher transport potential)	Light clays, medium clay, heavy clays

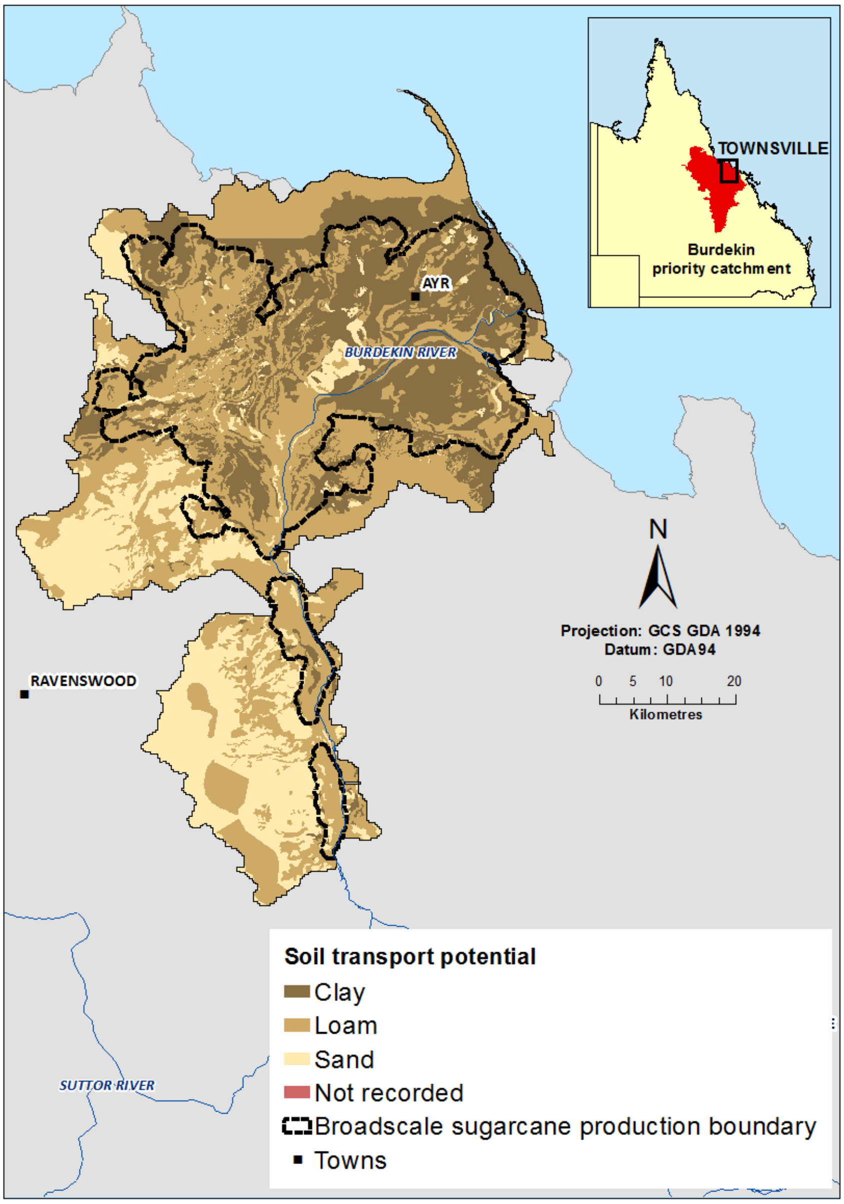

Figure 20. Soil transport potential – Burdekin catchment

Note 1. The scale of map does not precisely identify surface soil texture boundaries, it indicates the likely soil transport potential based on soil texture.

Additional considerations

Soil structure

Soil structure influences the stability of soils and their behaviour while in suspension. For example, a well-structured soil allows water to infiltrate and excess water to drain. This reduces the likelihood that water will runoff and transport mobilised contaminants off-farm. Environmental characteristic maps do not currently consider soil structure as this characteristic is not accurately mapped for cane growing areas. Although soil structure is described during land resource surveys, it is easily influenced by land management practices and therefore the soil structure present in cultivated situations is likely to be different to that described by surveys.

The Soil Constraint and Management Package (SCAMP) describes (see further information section below) a range of simple field tests that can assist growers and field officers to gain an understanding of the soil structure of a farm.

Clay types

The mineral composition (or mineralogy) of clays influences their ability to attach to contaminants. Clays can be divided into two broad groups based on their mineral composition – 1:1 clays (e.g. kaolinite and serpentine) and 2:1 clays (e.g. illite and smectite). Mineralogy affects the capacity of clays to draw water and positively charged ions (e.g. Na+) between layers and therefore the capacity to absorb water and bind to nutrients. Generally, 2:1 clays have a higher capacity to bind to nutrients and herbicides; however this process is highly complex and influenced by other features such as organic matter content and chemical characteristics of nutrients and herbicides.

Clay mineralogy can be broadly correlated to soil orders of the Australian Soil Classification (ASC), as outlined in Table 11.

Table 11. Approximate clay mineralogy according to soil orders of the ASC (Blosch et al. 2005, unpublished).

Soil Order	Approximate mineralogy
Anthroposol	Mixture
Calcarosol	Illite and kaolinite
Chromosol	Illite and kaolinite
Dermosol	Mixture
Ferrosol	Mixture
Hydrosol	Illite and kaolinite
Kandosol	Illite and kaolinite
Kurosol	Illite and kaolinite
Organosol	Mixture
Podosol	Illite and kaolinite
Rudosol	Mixture
Sodosol	Mixture
Tenosol	Mixture
Vertosol	Smectite

Silt contents of the Burdekin Delta soils

Soils of the Burdekin Delta can sometimes be observed as being heavier textured in the field than what is assessed in the laboratory. This is because of the higher silt content and has been observed in soils of the Burdekin Delta. For example field textures that present as a light clay in the field may be assessed in the laboratory as only having 25% clay.

Management

To minimise soil transport potential it is important to ensure that soils with high clay content are not exposed to erosive processes. Options for managing different soil textures are broadly outlined in Table 12.

Table 12. Management options for mitigating impacts of soil transport potential.

Surface soil texture	Principle to minimise erosion and leaching	Examples of management principles to mitigate impact of surface soil texture
Sands	Minimise leaching of excess water and nutrients /herbicides	Fertiliser application should take place when the crop is actively growing to promote more rapid uptake of nutrients by the crop. Optimise timing and rates of nutrient/herbicide application, Check product label with regard to efficacy of different product for different soil types and weed species. Include spoon drains, sediment traps, filter strips and headlands for effective treatment of water leaving the farm.
Loams	Maintain water balance	
Clays	Minimise erosion/runoff	Manage fallow effectively by inclusion of well managed legume crop in break year at the end of cropping cycle, so soil remains covered during entire cropping cycle. Include spoon drains, sediment traps, filter strips and headlands for effective treatment of water leaving the farm. Adoption of controlled traffic has been found to reduce run-off and the amount of sediment (clays) in run-off. This leads to minimum tillage – eventually to zero till. Grass headlands maintained

Further information

Soil Constraints and Management Package (SCAMP)

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Fact sheet < http://www.derm.qld.gov.au/services_resources/index.php >

- Paddock guide to determining soil texture

Additional information

Common soils of Burdekin cane growing area (as described by Soil Orders of the Australian Soil Classification)

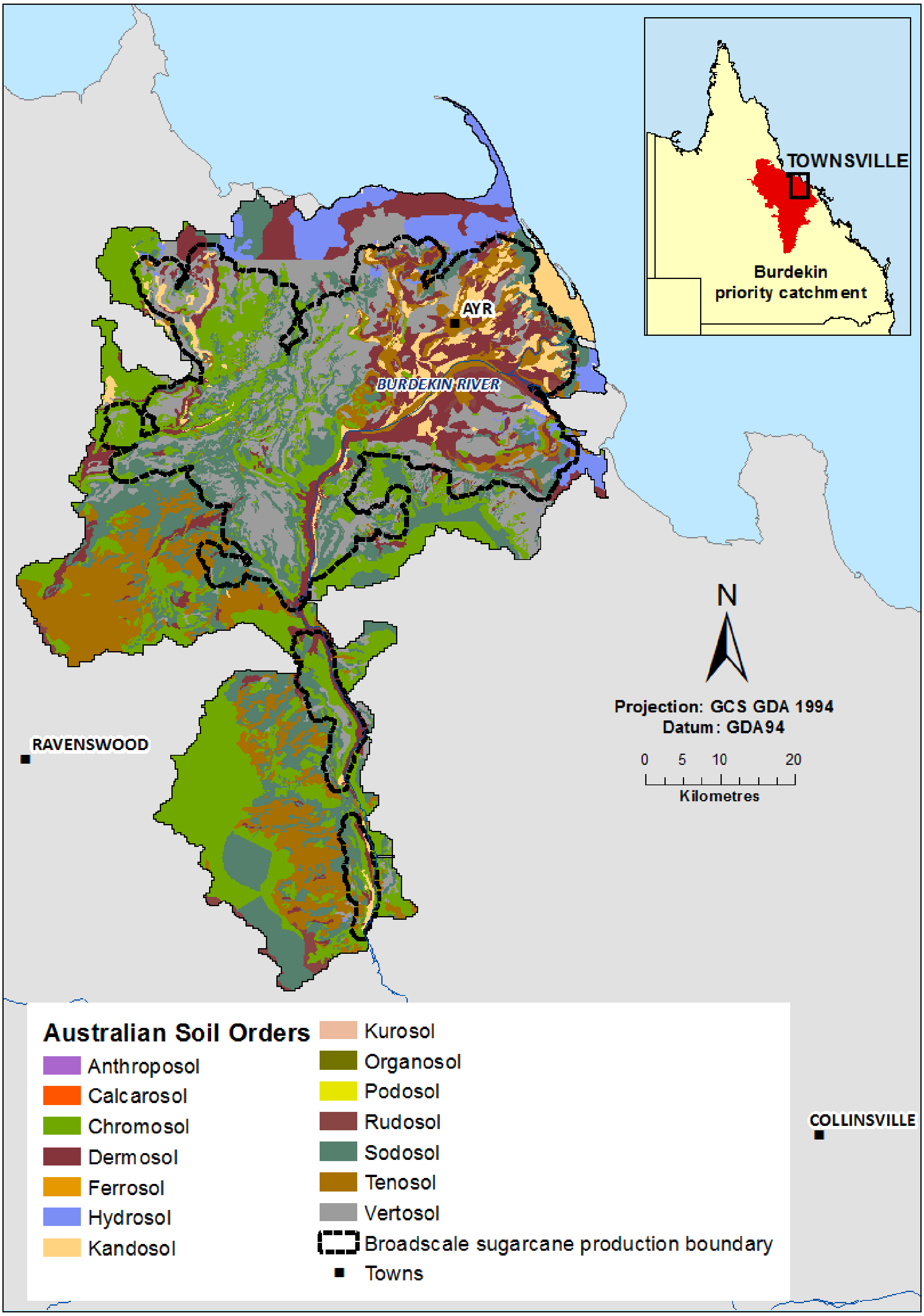


Figure 21. Soil Orders across the Burdekin catchment (DERM 2012b).

Table 13. Local soil types and corresponding ASC soil orders and Great Soil Groups for cane soils in the Burdekin catchment.

Soil name	Australian Soil Classification - Soil Order (Isbell 2002)	Great Soil Groups (Stace *et al* 1968)
1Dba	Sodosol	Solodic soil/Solodized solonetz
1Dbb	Sodosol	Solodic soil/Solodized solonetz
1Dda	Sodosol	Solodic soil/Solodized solonetz
1Dya	Sodosol	Solodic soil/Solodized solonetz
1Dyb	Sodosol	Solodic soil/Solodized solonetz
1Dyc	Sodosol	Solodic soil/Solodized solonetz
1Dyd	Sodosol	Solodic soil/Solodized solonetz
1Uga	Vertosol	Black earth/Grey clay
1Ugc	Vertosol	Black earth/Grey clay
1Ugd	Vertosol	Grey clay
1Ugf	Vertosol	Grey clay
2Dba	Sodosol	Solodic soil/Solodized solonetz
2Dbb	Sodosol	Solodic soil/Solodized solonetz
2Dbc	Sodosol	Solodic soil/Solodized solonetz
2Dbd	Sodosol	Solodic soil/Solodized solonetz
2Dbe	Sodosol	Solodic soil/Solodized solonetz
2Dda	Sodosol	Solodic soil/Solodized solonetz
2Ddb	Sodosol	Solodic soil/Solodized solonetz
2Ddc	Sodosol	Solodic soil/Solodized solonetz
2Ddd	Sodosol	Solodic soil/Solodized solonetz
2Dya	Sodosol	Solodic soil/Solodized solonetz
2Dyb	Sodosol	Solodic soil/Solodized solonetz
2Dyc	Sodosol	Solodic soil/Solodized solonetz
2Uga	Vertosol	Grey clay/Black earth
2Ugb	Vertosol	Black earth /Grey clay
2Ugc	Vertosol	Grey clay/Brown clay
2Ugd	Vertosol	Grey clay/Brown clay/Black earth
2Uge	Vertosol	Grey clay/Brown clay/Black earth
2Ugf	Vertosol	Grey clay
2Ugg	Vertosol	Grey clay/Brown earth/Brown clay
2Ugh	Vertosol	Grey clay/Brown clay/Black earth
2Ugj	Vertosol	Grey clay/Brown clay/Brown podzolic soil
2Ugk	Vertosol	Grey clay/Black earth
3Uga	Vertosol	Black earth
3Ugb	Vertosol	Black earth
3Ugc	Vertosol	Black earth/Grey clay
3Ugd	Vertosol	Black earth
3Uge	Vertosol	Black earth
3Ugk	Vertosol	Grey clay
4Dga	Chromosol	Gleyed podzolic soil
4Dyd	Chromosol	Soloth/Solodic soil/solodized solonetz

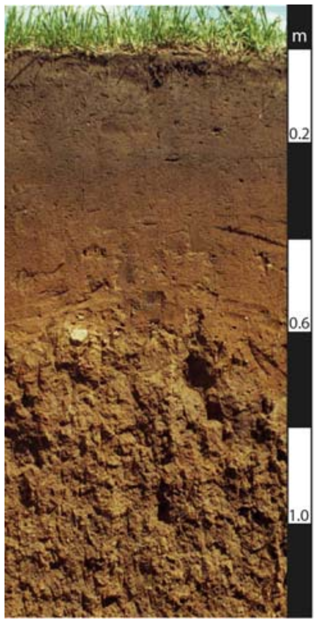
4Dyf	Sodosol	No suitable group
4Dyg	Sodosol	Solodic soil/Solodized solonetz
4Dyh	Sodosol	Solodic soil/Solodized solonetz
4Dyi	Sodosol	Solodic soil/Solodized solonetz
4Dyj	Sodosol	Solodic soil/Solodized solonetz
4Dyk	Sodosol	Soloth
4Gnb	Dermosol	Red podzolic soil
4Uca	Tenosol	No suitable group
4Ucc	Tenosol	Not recorded
4Ucf	Tenosol	No suitable group
5Dra	Chromosol	Non-calcic brown soil
5Dya	Chromosol	Not recorded
5Dyb	Chromosol	Not recorded
5Dyc	Sodosol	Solodic soil/Solodized solonetz
5Dyd	Sodosol	Solodic soil/Solodized solonetz
5Dye	Chromosol	Solodic soil
5Dye	Sodosol	Solodic soil
5Uga	Vertosol	Black earth
5Ugb	Vertosol	Grey clay/Black earth
6Dba	Sodosol	Solodic soil/Solodized solonetz
6Dbb	Sodosol	Solodic soil
6Dbc	Chromosol	Brown podzolic soil
6Dbd	Chromosol	Brown earth
6Dbe	Chromosol	Brown earth
6Dbf	Chromosol	Brown podzolic soil
6Dbg	Chromosol	Brown podzolic soil
6Dbh	Sodosol	Solodic soil/Solodized solonetz
6Dbi	Chromosol	Solodic soil/Solodized solonetz
6Dda	Sodosol	Solodic soil/Solodized solonetz
6Ddb	Sodosol	Solodic soil
6Dga	Hydrosol	No suitable group
6Dra	Chromosol	Red podzolic soil
6Drb	Chromosol	Red podzolic soil
6Drc	Chromosol	Solodic soil/Solodized solonetz
6Dya	Chromosol	Yellow podzolic soil
6Dyb	Chromosol	Solodic soil/Soloth
6Dyc	Chromosol	Yellow podzolic soil
6Dyd	Chromosol	Brown podzolic soil
6Dye	Chromosol	Solodic soil/Solodized solonetz
6Dyf	Chromosol	Solodic soil/Solodized solonetz
6Dyg	Sodosol	Solodic soil/Solodized solonetz
6Dyh	Sodosol	Solodic soil/Solodized solonetz
6Dyj	Sodosol	Solodic soil/Solodized solonetz
6Gna	Chromosol	Black earth/Brown earth/Grey earth
6Gnb	Dermosol	Red podzolic soil

6Gnc	Dermosol	Yellow podzolic soil/Grey earth
6Gnd	Dermosol	Brown earth/Yellow earth
6Gne	Dermosol	Black earth/Grey earth
6Uca	Tenosol	Earthy sand
6Ucb	Tenosol	No suitable group
6Ucc	Tenosol	Earthy sand
6Ufa	Dermosol	No suitable group
6Ufc	Dermosol	Alluvial soil
6Ufd	Dermosol	No suitable group
6Ufe	Tenosol	Alluvial soil
6Uga	Vertosol	Black earth/Grey clay
6Ugc	Vertosol	Grey clay
6Uma	Kandosol	Earthy sand
6Umb	Dermosol	No suitable group
BDba	Chromosol	Not recorded
BGna	Kandosol	No suitable group
BGnb	Dermosol	No suitable group
BGnc	Dermosol	No suitable group
Black (Bl)	Kandosol	No suitable group
BUca	Tenosol	Silaceous sand/Alluvial soil
BUcb	Tenosol	Silaceous sand/Alluvial soil
BUfa	Kandosol	No suitable group
BUfb	Kandosol	Not recorded
BUfc	Kandosol	Not recorded
BUfd	Kandosol	No suitable group
BUfe	Kandosol	Not recorded
BUga	Vertosol	Black earth/Grey clay
BUma	Tenosol	No suitable group
BUmb	Kandosol	No suitable group
BUmd	Kandosol	No suitable group
CDba	Chromosol	Brown podzolic soil
CDbb	Chromosol	No suitable group
CDra	Chromosol	Red podzolic soil
CUca	Tenosol	Silaceous sand/Alluvial soil
CUfa	Dermosol	No suitable group
CUfb	Dermosol	No suitable group
CUfc	Dermosol	No suitable group
CUma	Rudosol	Alluvial soil
CUmb	Tenosol	Not recorded
Gillian (Gi)	Not recorded	Not recorded
Manton (Mt)	Sodosol	Solodic soil/Grey clay
MUca	Tenosol	Silaceous sand
MUcb	Tenosol	Silaceous sand
Purono (Pu)	Sodosol	Solodic soil
RDya	Sodosol	Solodic soil/Solodized solonetz
RUfe	Dermosol	No suitable group

RUff	Hydrosol	No suitable group
RUga	Vertosol	Grey clay/Black earth
Rugb	Vertosol	Grey clay/Black earth
RUgc	Vertosol	Black earth/Grey clay
RUgd	Vertosol	Black earth/Grey clay
Sachs	Vertosol	Black earth
Scrubby	Sodosol	Solodic
Stockyard loam	Not recorded	Not recorded

Brief description and agricultural limitations of Australian Soil Orders

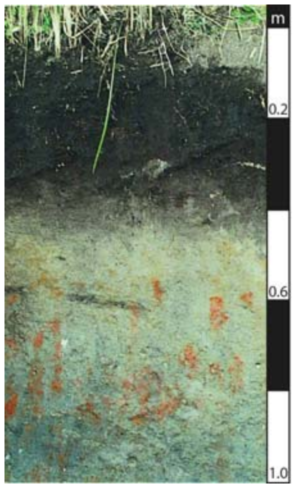
CHROMOSOL	
Brief description	Chromosols have a distinct texture-contrast between the surface and subsoil. Chromosols have sandy or loamy surface soils overlying a yellow, brown, red-brown or sometimes black clay subsoil, which is generally neutral to alkaline. In contrast to Sodosols, the subsoil is not sodic (see glossary), at least in the upper section.
Agricultural implications	Where there is adequate rainfall these soils constitute important grain producing areas, particularly on lower slopes. They are generally used for sown pastures on moderate slopes and native pastures on drier or steeper slopes. Chromosols have a reasonable agricultural potential with moderate fertility and water-holding capacity. They can be susceptible to soil acidification and soil structure decline and may experience poor local drainage.
Percentage of cane soils in Burdekin	18%
Local soil types	4Dga, 4Dyd, 5Dya, 5Dyb, 5Dye, 6Dbd, 6Dbe, 6Dbf



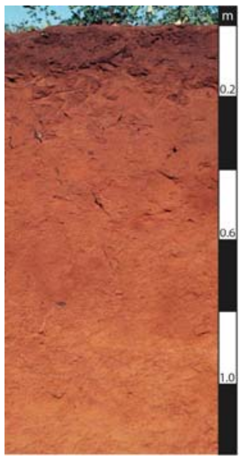
DERMOSOL	
Brief description	Dermosols are a diverse group of soils with loam to clay textures that may be of varied red, brown, yellow, grey or black coloured. They have structured subsoils. This soil order mainly occurs throughout the higher rainfall coastal and sub-coastal regions of Queensland.
Agricultural implications	Dermosols are commonly quite fertile and, in the drier sub-coastal areas, used for intensive horticulture. Dermosols generally have high agricultural potential with good structure and moderate to high fertility and water-holding capacity, and are generally well drained.
Percentage of cane soils in Burdekin	20%
Local soil types	4Gnb, 6Gnb, 6Gnc, 6Gnd, 6Gne, 6Ufa, 6Ufc, 6Ufd, 6Uma, 6Umb, CUfa, CUfb, CUfc, RUfe

FERROSOL	
Brief description	Ferrosols do not have a strong texture-contrast between the surface and subsoil. They are well drained soils with clay-loam to clay textures throughout the surface and subsoil. They are high in iron and can be red or yellow coloured and are generally well structured.
Agricultural implications	Good structure with moderate to high fertility and water-holding capacity. Prone to compaction and nutrient leaching and in high rainfall areas they may suffer from acidification. Ferrosols also have a high phosphorus fixing capacity which affects the application of fertilisers.
Percentage of cane soils in Burdekin	NA
Local soil types	NA

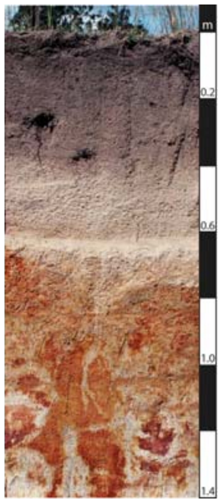
HYDROSOL	
Brief description	Hydrosols are soils that are saturated with water for long periods of time (for at least 2-3 months). They are typically grey (or greenish-grey) in colour with strong yellow, brown, orange or red mottling. Hydrosols can vary in texture.
Agricultural implications	This soil type is mainly found in coastal areas however, many inland wetlands are dominated by Hydrosols even though these areas may only be intermittently inundated. Saturation by a water table may not necessarily be caused by low soil permeability. Often site drainage will be the most important factor, while in other cases tidal influence is dominant.
Percentage of cane soils in Burdekin	<1%
Local soil types	6Dga, Ruff



KANDOSOL	
Brief description	Kandosols are porous sand to loamy soils that may be red, yellow or grey. They have unstructured subsoils, (and are also known as massive earths) and usually have a gradational increase in clay content with depth.
Agricultural implications	They generally have low fertility and low water-holding capacity, however physical properties are favourable for plant growth. A wide range of crops can be grown on these soils where rainfall is higher or where irrigation is available. Generally, Kandosols have a low to moderate agricultural potential and land use is more suited to the grazing of native pastures.
Percentage of cane soils in Burdekin	8%
Local soil types	Uma, BGna, Black, BUfa, BUfb, BUfc, BUfd, BUfe,

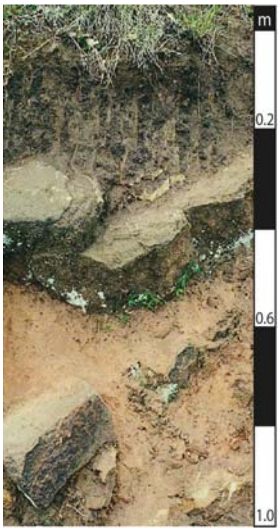


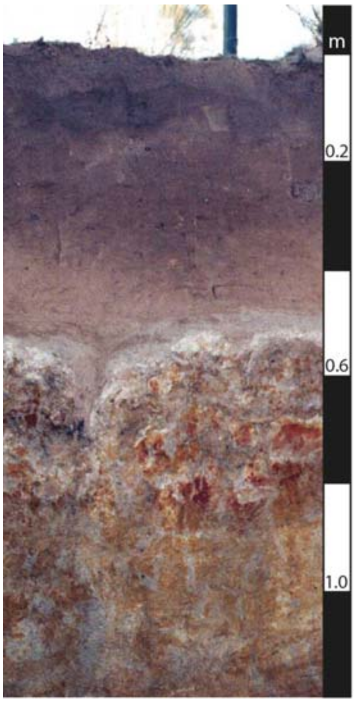
	BUmb, BUmd	

KUROSOLS		
Brief description	Kurosols are texture-contrast soils with a strongly acidic subsoil. The sub-soil is generally moderately permeable and may vary in colour from red, in well-drained situations, to yellow and mottled-grey in poorly drained areas.	
Agricultural implications	They generally have lower agricultural potential because of their acidic sub-soil (pH < 5.5) and lower fertility and reduced water-holding capacity. However the physical characteristics of a Kurosol are often satisfactory for plant growth. Primary uses are grazing, in steeper drier areas, and cane, horticulture and softwood forests elsewhere.	
Percentage of cane soils in Burdekin	NA	
Local soil types	NA	

ORGANOSOL		
Brief description	Organosols occur in wetland areas along the coast in high-rainfall zones. Organosols are rich in peat and other humus rich layers. Areas of these soils are quite small.	NO PHOTO AVAILABLE
Agricultural implications	Often site drainage will be the most important factor.	
Percentage of cane soils in Burdekin	NA	
Local soil types	NA	

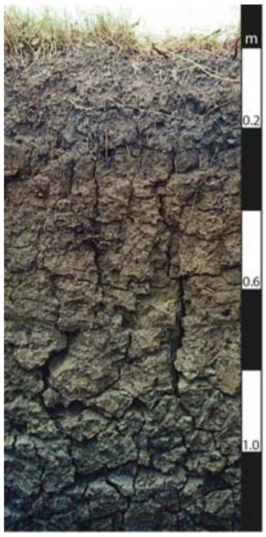
PODOSOL		
Brief description	Podosols ocur in the more humid coastal regions where annual rainfall is greater than about 700 mm. The subsoil of a Podosol is dominated by compounds of organic materials, aluminium and/or iron and may contain an irregular dark pan called 'coffee rock'. Podosols are uniform textured soils of loamy sand to sand, which are usually very permeable unless continuous hard setting pans are present in the subsoil.	
Agricultural implications	Generally, Podosols have little agricultural potential with very low fertility and water-holding capacity. They are also susceptible to wind erosion if vegetation is removed. Groundwater contamination may be a problem due to the high permeability of these soils.	
Percentage of cane soils in Burdekin	NA	
Local soil types	NA	

RUDOSOL		
Brief description	Rudosols have virtually no soil profile development apart from the slight accumulation of organic matter at the surface. They are usually young soils in the sense that soil forming factors have had very little time to modify the parent materials. They are commonly found adjacent to watercourses where flooding is frequent.	
Agricultural implications	Rudosols are usually sandy and may also be shallow and stony.	
Percentage of cane soils in Burdekin	1%	
Local soil types	CUma	

SODOSOL		
Brief description	Sodosols are texture-contrast soils (also known as duplex soils) with sodic (see glossary), low permeability subsoils. The sodic subsoil is dispersible and prone to gully erosion if exposed to the surface or tunnel erosion if drainage conditions are altered. Most Sodosols have hardsetting surfaces that reduce infiltration. Seasonal perched water tables are common.	
Agricultural implications	Sodosols generally have low fertility and are susceptible to erosion and dryland salinity if vegetation is removed. The key to managing these soils is reducing disturbance and being aware of how thick the protective surface soil is. These soils are more suited to grazing of native or improved pastures but are used for both dryland and irrigated agriculture, though they commonly experience poor drainage.	
Percentage of cane soils in Burdekin	16%	
Local soil types	1Dba, 1Dbb, 1Dda, 1Dya, 1Dyb, 1Dyc, 1Dyd, 2Dba, 2Dbb, 2Dbc, 2Dbd, 2Dbe, 2Dda, 2Ddb, 2Ddc, 2Ddd, 2Dya, 4Dyf, 4Dyg, 4Dyi, 4dyk, 5Dyc, 5Dyd, 5Dye, 6Dba, 6Dbb, 6Dbh, 6Dda, 6Ddb, 6Dyg, 6Dyh, 6Dyj, Manton, Purono, RDya, Scrubby.	

TENSOSOL	
Brief description	Tenosols have weakly developed soil profiles (that show very little change with depth). The group includes deep sands and shallow stony soils.
Agricultural implications	Tenosols generally have lower agricultural potential due to very low fertility, poor structure and low water-holding capacity. Hence these soils are more suited to grazing of native pastures. Ground-water contamination can be a potential problem due to the high permeability of these soils. Some of the deep sands have agricultural potential if groundwater is at a depth that crop roots can access without being waterlogged.
Percentage of cane soils in Burdekin	4%
Local soil types	4Uca, 4Ucf, 6Ubc, 6Ucc, 6Ufe, BUca, BUCB, buma, CUca, CUma, MUca, MUcb

VERTOSOL	
Brief description	Vertosols are cracking clay soils. By definition they must have a clay content of at least 35% throughout the whole profile. Vertosols are divided into subgroups based on colour (e.g. black, grey, brown) and/or wetness. They sometimes have a hummocky microrelief called gilgai, and many have a loose crumb like surface (known as a 'self-mulch'). They are the most common soil type in Queensland.
Agricultural implications	A moderate to high fertility and high water-holding capacity. Heavy clays can be difficult to cultivate especially when they are wet. Vertosols are extensively used for dryland agriculture but are also irrigated for a variety of crops such as cane and cotton. Vertosols feature significantly in the grazing areas of Queensland
Percentage of cane soils in Burdekin	33%
Local soil types	1Uga, 1Ugc, 1Ugd, 1Ugf, 2Uga, 2Ugb, 2Ugc, 2Ugd, 2Uge, 2Ugf, 2Ugg, 2Ugh, 2Ugi, 2Ugk, 3Uga, 3Ugb, 3Ugc, 3Ugd, 3Ugd, 3Uge, 3Ugk, 5Uga, 5Ugb, 6Uga, 6Ugc, BUga, RUga, RUgb, RUgc, RUgd, Sachs



References

Bloesch P, Le Grand J, Moody P, Moss J & Searle R (2006) 'Soil erosion and soil condition hazard maps for Great Barrier Reef Catchments of Queensland', Natural Resources, Mines & Water, Brisbane, Australia, QNRM06214 (unpublished).

BOM (2012) Bureau of Meteorology: Climate data online, accessed [13/01/12], available at <www.bom.gov.au/climate/data/>

Brodie J, Binney J Fabricius K, Gordon I, Hoegh-Guldberg O, Hunter H, O'Reagain P, Pearson R, Quirk M, Thorburn P, Waterhouse J, Webster I & Wilkinson S (2008) 'Synthesis of evidence to support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef', Reef Water Quality Protection Plan Secretariat, Brisbane, Queensland. Available at www.reefplan.qld.gov.au/publications/scientific_consensus_statement.shtm

Bryant K, Philip S, Hughes K and Willis, R (2012) Mapping of environmental characteristics important for Reef water quality Burdekin and Mackay-Whitsunday priority catchment: Assessment methodology, Land Resource Assessment, Department of Science, Information Technology, Innovation and the Arts, Brisbane.

DERM (2009) Queensland Landuse Mapping Program, Department of Environment and Resource Management, Brisbane.

DERM (2011) 'Mapping environmental characteristics important for GBR water quality: Wet Tropics- Assessment methodology', Brisbane: Department of Environment and Resource Management, Queensland Government

DERM (2012) 'Queensland Isohyet Lines', Available from Departmental SIRQRY database, Department of Environment and Resource Management, Brisbane.

DERM (2012b) Soil and Land Information database, Department of Environment and Resource Management, Brisbane.

Gallant JC, McKenzie NJ & McBratney AB (2008) Chapter 3 Scale, in McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ (2008) Guideline for Surveying Soil and Land Resources, CSIRO publishing, Collingwood Victoria.

Isbell RF (2002) The Australian Soil Classification, CSIRO Publishing, Collingwood, Australia.

McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ (2008) Guideline for Surveying Soil and Land Resources, CSIRO publishing, Collingwood Victoria.

McKenzie NJ, Jaquier D, Isbell R & Brown K (2004) Australian Soils and Landscapes – an illustrated compendium, CSIRO publishing, Collingwood Victoria.

Moody PW & Cong PT (2008) 'Soil Constraints and Management Package (SCAMP): guidelines for sustainable management of tropical upland soils', ACIAR Monograph No. 130, 86pp.

Neldner, V.J., Wilson, B. A., Thompson, E.J. and Dillewaard, H.A. (2005) Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.1. Updated September 2005. Queensland Herbarium, Environmental Protection Agency, Brisbane. 128 pp.

Raine, SR and Bakker, DM (1996) Increased furrow irrigation efficiency through better design and management of cane fields. Proc. Aust Soc. Sugar Cane Tech. 18, 119-124.

Raine SR and Shannon, EL (1996). Increasing the irrigation efficiency of Burdekin canegrowers through participatory action learning. Proc. 13th Conference, Irrigation Association of Australia, 14-16th May, Adelaide. pp5.

Reading LP (2010) Impacts of Amelioration on Sodic Soil Hydraulic Conductivity and Potential Consequences for Deep Drainage in the Lower Burdekin, North Queensland, Thesis, School of Engineering, University of Queensland, Brisbane.

Stace HCT, Hubble GD, Brewer R, Northcote KH, Sleeman JR, Mulcahy MJ & Hallsworth EG (1968) A Handbook of Australian Soils, Rellim, Glenside, SA, Australia.

Thornburn P, Davis A, Attard S, Milla R, Anderson T and McShane T (2007) Best Management Practices to improve the quality of water leaving irrigated sugarcane farms: Guidelines for the Burdekin region, Australian Centre for Tropical Freshwater Research report No 07/36, James Cook University.

Appendix A List of land resource publications relevant to the Burdekin cane area

Land resource reports provide information on the soils of the Burdekin catchment and can be viewed and downloaded through:

- The EHP library catalogue at: < http://dermqld.softlinkhosting.com.au/liberty/libraryHome.do >
- the Queensland Digital Exploration Reports system (QDEX) at: <www.dme.qld.gov.au/mines/company_exploration_reports.cfm>

Alternatively, reports can be requested by emailing: <Soils@derm.qld.gov.au>

SALI[2] project code	Title
BURDEKIN PUBLICATIONS	
BDS	Burdekin Delta Soils
BER	Soil Survey - Elliot River to Bowen, Molongle Creek to Elliot River
BRB	Land Resources Survey of the Burdekin Right Bank, QLD
BRL	Soils of the Lower Burdekin River Barratta Creek - Haughton River Area
BSA	Soils of the Lower Burdekin Valley, North Queensland Redbank creek to Bob's creek and south to Bowen River
CCL	Land Resources and Evaluation of the Capricornia Coastal Lands, Broadsound Shire, QLD
GRU	Soils and agricultural land suitability of the Giru area, North Queensland
HTC	Survey of the Burdekin River Irrigation Area - Haughtons Central
HTN	Survey of the Burdekin River Irrigation Area - Haughtons North
HTS	Irrigated land suitability assessment of Haughton Section – Stage 1 Nine Mile Lagoon to Oaky creek
INK	Soil Survey of the Burdekin River Irrigation Area - Inkerman Section
JFD	Soil Survey of the Burdekin Irrigation Area (BRIA) - Jarvisfield Section
LDR	Soil Survey of the Burdekin River Irrigation Area - Leichhardt Downs Relift, QLD
MAJCK	Land Resources of the Major Creek Area North Queensland
MLG	Burdekin River Irrigation Area - Mulgrave Section
NBS	Nebo Broadsound Survey
NHC	Land Resources Survey of the Burdekin River Irrigation Area - Northcote Section
NLH	Soil Survey of the Burdekin River Irrigation Area - Leichhardt Downs
RBO	Sugar-cane land suitability assessment Burdekin River irrigation area Right Bank – Yellow Gin creek to Elliot River
SLK	Land Resources Survey of the Burdekin - Selkirk Area
WTC	Wet Tropical Coast - North Queensland - Ingham and Herbert River Section
ZDK2	Survey of the Isaac-Comet Area - Version 2

[2] Soil and Land Information system (SALI) –corporate data base which stores all soils and land resource information

ZEB	Survey of the Burdekin-Townsville Region Soils
NON-REGIONAL PUBLICATIONS	
ATLAS	Atlas of Australian Soils - Queensland Coverage

Appendix B Surface soil texture categories

Soil texture codes were generalised into four categories (sand, loam, clay and other) as described in the table below. The category ‘other’ incorporates non-soils (e.g. gravel) and non-mineral soils (e.g. peats).

Texture code	Texture description	Notes	Category
AP	sapric peat	non-mineral soil	other
CFS	clayey fine sand	clay content < 10%	sand
CKS	clayey coarse sand	clay content < 10%	sand
CL	clay loam	30–35% clay	loam
CLFS	clay loam, fine sandy	30–35% clay	loam
CLKS	clay loam, coarse sandy	30–35% clay	loam
CLS	clay loam, sandy	30–35% clay	loam
CLZ	clay loam, silty	30-35% clay, with silt 25% or more	loam
CS	clayey sand	clay content < 10%	sand
FS	fine sand	clay content < 10%	sand
FSC	fine sandy; clay	assume 35 % clay	clay
FSCL	fine sandy clay loam	20–30% clay	loam
FSHC	fine sandy heavy clay	> 40% clay	clay
FSL	fine sandy loam	10–20% clay	loam
FSLC	fine sandy light clay	35–40% clay	clay
FSLMC	fine sandy light medium clay	> 40% clay light medium clay	clay
FSMC	fine sandy medium clay	> 40% clay	clay
FSMHC	fine sandy medium heavy clay	> 40% clay	clay
HC	heavy clay	> 40% clay	clay
IP	fibric peat	non-mineral soil	other
KS	coarse sand	clay content < 10%	sand
KSC	coarse sand, clay	5-10% clay	sand
KSCL	coarse sandy clay loam	20–30% clay	loam
KSL	coarse sandy loam	10–20% clay	loam
KSLC	coarse sandy light clay	35–40% clay	clay
KSLMC	coarse sandy light medium clay	> 40% clay	clay
KSMC	coarse sandy medium clay	> 40% clay	clay
KSMHC	coarse sandy medium heavy clay	> 40% clay	clay
L	loam	25% clay	loam
LC	light clay	35–40% clay	clay
LCFS	light clay, fine sandy	35-40% clay	clay
LCKS	light clay; coarse sandy	35–40% clay	clay
LCZ	light clay; silty	35–40% clay	clay
LFS	loamy fine sand	25% clay	sand
LFSY	loam; fine sandy	25% clay	loam
LKS	loamy coarse sand	clay content < 10%	sand
LMC	light medium clay	> 40% clay light medium clay	clay
LMCFS	light medium clay; fine sandy	> 40% clay light medium clay	clay

Texture code	Texture description	Notes	Category
LMCS	light medium clay, sandy	40-45%	clay
LS	loamy sand	clay content < 10%	sand
LSY	loam, sandy	25%	loam
MC	medium clay	> 40% clay	clay
MCFS	medium clay; fine sandy	> 40% clay	clay
MHC	medium heavy clay	> 40% clay	clay
S	sand	clay content < 10%	sand
SC	sandy clay	assume 35 % clay	clay
SCL	sandy clay loam	20–30% clay	loam
SCLFS	sandy clay loam, fine sandy	20-30%	loam
SL	sandy loam	10–20% clay	loam
SLC	sandy light clay	35–40% clay	clay
SLMC	sandy light medium clay	> 40% clay light medium clay	clay
SMC	sandy medium clay	> 40% clay	clay
SMHC	sandy medium heavy clay	> 40% clay	clay
ZC	silty clay	assume 35 % clay	clay
ZCL	silty clay loam	30–35% clay	loam
ZL	silty loam	25% clay	loam
ZLC	silty light clay	35-40% clay	clay
ZLMC	silty light medium clay	> 40% clay light medium clay	clay
ZMC	silty medium clay	> 40% clay	clay
ZMHC	silty medium heavy clay	> 40% clay	clay