Conceptual Model Case Study Series

Gilgai wetlands

What are gilgai?

Gilgai are repeated mounds and depressions formed on shrink-swell and cracking clay soils (or vertosols); water can accumulate seasonally in the depressions to form gilgai wetlands. (A shelf is sometimes found between the depression and the mound, but not always.)

This landform was once common in the Brigalow Belt in Queensland. *Gilgai* is a word from the Kamilaroi, Wiradhuri and related Aboriginal languages in which it means 'small waterhole'. Early settlers in Australia used a number of terms for these microrelief features, the commonest being crabhole, melonhole and gilgai.

Gilgai microrelief occurs when the clay soil layers shrink and swell during alternate drying and wetting cycles. This gradually forces 'blocks' of subsoil material upwards to form mounds. Gilgai commonly form on black and grey vertosols and, to a much lesser extent, brown and red vertosols. The most common soil parent materials of vertosols are alluvial clayey sediments, sedimentary rocks such as shales, mudstones and impure limestones, and basic (alkaline) igneous rocks, particularly basalt.

About this case study:

This case study was created by the Department of Environment and Resource Management (DERM) Aquatic Ecosystem Health Science Integration and Capacity Building Group as part of the Queensland Wetlands Program. The purpose of this case study is to increase awareness and understanding of gilgai, potentially benefiting their management. Glencoe gilgai and Monto Saleyard wetlands are explored as examples of this wetland type.

Gilgai country in wet and dry times

Photo: G. Cobb

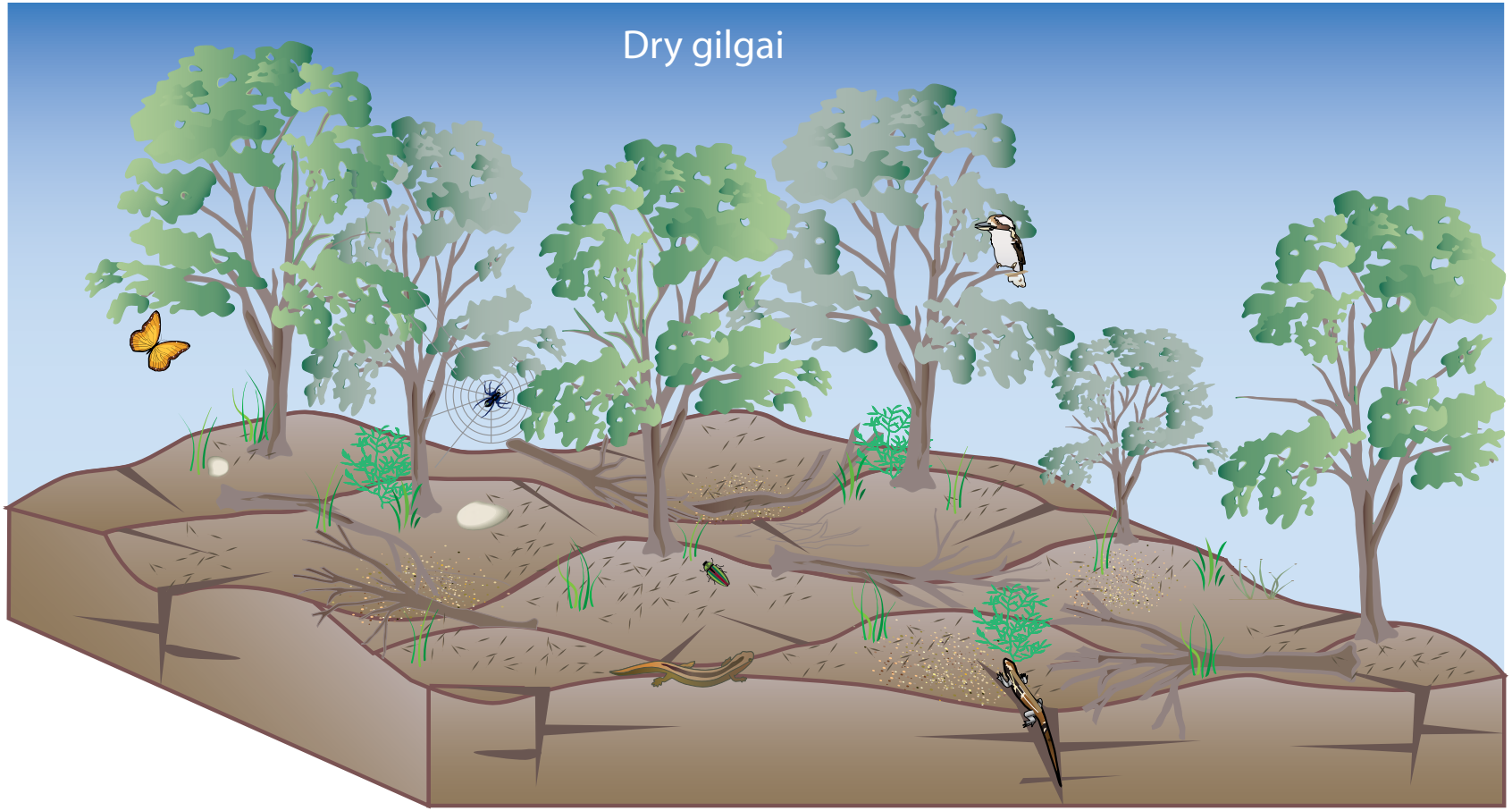
During and following periods of rain, the gilgai depressions fill with water and the landscape is then dotted with an array of shallow wetlands. These wetlands are typically hard to map because they are small, ephemeral and, in many areas, have been prevented from forming by agricultural tillage. The regional ecosystems in which gilgai are typical are therefore listed as 'may contain wetlands'. The smoothing of gilgai by agricultural machinery, and the clearing of their associated vegetation, has occurred to such an extent in Queensland that the regional ecosystems in which they occur are listed as endangered.

In Queensland gilgai are most commonly found in association with the brigalow community.

Surveys estimate that of the five million hectares of soil supporting brigalow (*Acacia harpophylla*) dominant vegetation in eastern Australia, more than 50 per cent had significant microrelief. Vertical intervals (the vertical height of the gilgai from the bottom of the depression to the top of the mound) may be as much as 150 cm and are commonly 60–90 cm. Gilgai with such vertical intervals may also have frequencies of 50–75 mounds per hectare.

Gilgai plants

The area of focus for this study is the Brigalow Belt. Here, the vegetation associated with gilgai tends to be dominated by *Acacia* (most notably *Acacia harpophylla*, commonly known as brigalow) and *Casuarina* (most notably *Casuarina cristata* or belah). *Melaleuca, Corymbia* and *Eucalypt* species are also common and *Astrelba* (Mitchell grass) or *Dichanthium* spp. grasslands are widespread.



Gilgai plants

Grasses and sedges

Low trees for example *Terminalia* spp., *Eremophila* spp. *and Lysiphyllum* spp.

Brigalow (*Acacia harpophylla*)

Trees including *Melaleuca bracteata,* belah (*Casuarina cristata*) and *Eucalypts* like forest red gum (*Eucalyptus tereticornis*) and poplar box (*E. populnea*)

Gilgai formations also occur in other Queensland bioregions, associated with the following plants:

- Mulga lands – gidgee, brigalow and other *Acacia* spp., belah, *Eucalypt* spp.
- Desert uplands – belah, gidgee and other *Acacia* spp.
- Gulf plains – grasslands, *Fimbrystylis* and *Oryza*, *Astrebla*
- Cape York peninsula – tussock grasslands – *Panicum spp*. and *Fimbristylis spp*. Trees – *Melaleuca acacioides* and *Excoecaria parvifolia*
- Mitchell grass downs – *Acacia* (brigalow or gidgee) or *Astrebla* sp.
- Channel country – gidgee, lignum coolabah trees, atriplex grasses
- Central Queensland – *Sporobolus* grasslands

While establishment and growth of young trees occurs throughout gilgai landscapes, only trees growing on mounds of the microrelief reach large sizes. The prolonged waterlogging in the depressions reduces tree survival in these areas. On average, 20 cm of water may lie in the gilgai depressions for three months during these wetter years.

Gilgai animals (not to scale)

Reptiles


Golden-tailed gecko


Yakka skink


De Vis' banded snake


Darling Downs earless dragon


Brigalow scaly-foot


Grey snake

Gilgai attract a variety of reptiles, some of which are threatened. Some reptiles shelter in the cracks of gilgai, while others are attracted to the variety of food supported by inundated gilgai.

Amphibians


Salmon striped frog


Scarlet -sided pobblebonk


Striped burrowing frog


Green tree frog

Frogs are attracted to gilgai pools which hold water well into the dry season. When wet, gilgai provide food, habitat and breeding places.

Birds


Brown honeyeater


Kookaburra


Plumed whistling duck

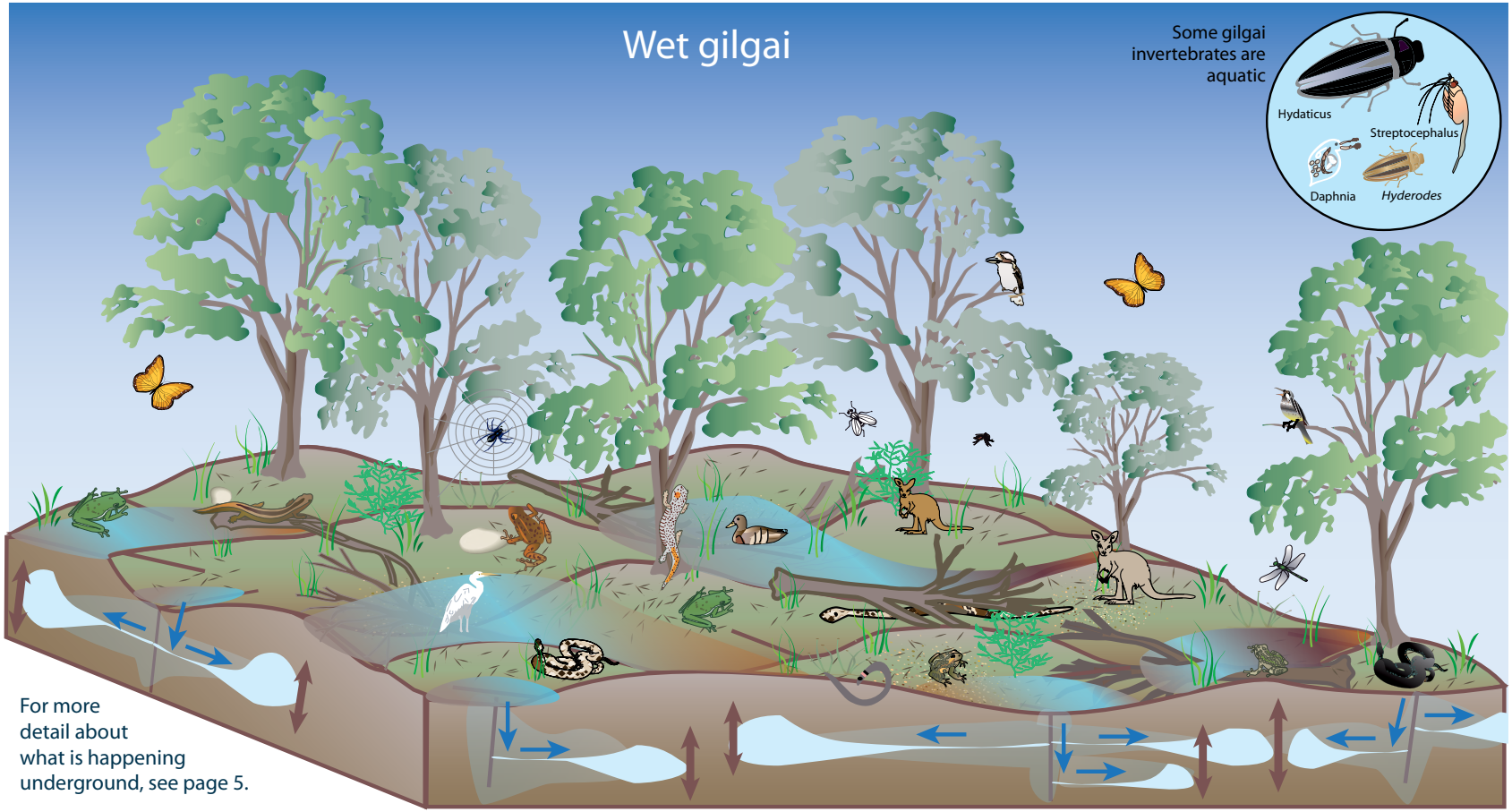
A range of bird species are found in gilgai areas. Many use the vegetation, access seasonal water and prey on the invertebrates, frogs or snakes that are also part of the gilgai ecosystem.

Mammals


Kangaroos and wallabies

Invertebrates

Many aquatic and terrestrial insects and other invertebrates inhabit the gilgai, including butterflies, dragonflys, aquatic beetles and minute crustaceans.



For more detail about what is happening underground, see page 5.

Gilgai animals

The Brigalow Belt is acknowledged as a 'biodiversity hotspot' containing a range of threatened wildlife. Many of these animals would use inundated gilgai as a water source at some stage of their life, while some are closely associated with the cracking clay soil habitat and the wetland depressions. For example, predator species might take advantage of the concentration of water-dependent species that proliferate around the depression wetlands during times of inundation (for example frog-eating snakes).

Species closely associated with the Brigalow Belt vegetation include ground dwelling fairy wrens (*Malurus* spp.), the spotted bowerbird (*Chlamydera maculata*), bridled nailtail wallaby (*Onychogalea fraenata*), black-striped wallaby (*Macropus dorsalis*) and the glossy black cockatoo (*Calyptorhynchus lathami*).

The Brigalow Belt is also home to a range of threatened reptiles (see table on this page). Many of these species live exclusively in the Brigalow Belt and many of them use gilgai habitats as shelters or as a food source.

Photo: Sharon Wormleaton

Table 1 Rare and threatened reptiles of the Brigalow Belt

Common name	***Latin name***	***Habitat***	EPBC	NCA	IUCN
Brigalow scaly-foot	***Paradelma orientalis***	Brigalow and gidgee woodlands on clay soils	V	V	V
Collared delma	***Delma torquata***	Burrows into clay soil, leaf litter and under logs	V	V	V
Common death adder	***Acanthophis antarcticus***	Found in a variety of habitats including brigalow and grasslands		NT	
Darling Downs earless dragon	***Tympanocryptus pinguicolla***	Shelters in the cracks of black cracking clay soil	E	E	
Dunmall's snake	***Furina dunmalli***	Shelters in soil cracks and under fallen timber embedded in cracks	V	V	V
Five-clawed worm-skink	***Anomalopus mackayi***	Associated with floodplain grasslands on deep cracking clays and frequently inundated areas	V	E	V
Golden-tailed gecko	***Strophurus taenicauda***	Found in open forests and woodlands often associated with clay soils; favours areas with high levels of woody debris		NT	
Grey snake	***Hemiapsis damelli***	Favours vegetated floodplains; often associated with gilgaied areas; can live in soil cracks; a key threat is the loss of wetlands		E	
Ornamental snake	***Denisonia maculata***	Can live in deep soil cracks and is often associated with wetlands; feeds exclusively on frogs	V	V	V
Retro slider	***Lerista allanae***	Grasslands on black soil downs	E	E	CE
Woma	***Aspidites ramsayi***	More of a habitat generalist but may be found on brigalow/belah		NT	
Yakka skink	***Egernia rugosa***	Can be associated with clay soils in the Brigalow Belt; dig burrow systems	V	V	

EPBC = Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth), NCA = Nature Conservation Act 1992 (Qld), IUCN = International Union for the Conservation of Nature
CE = critically endangered, E = endangered, V = vulnerable, NT = near threatened

Photo: B. Thomson

Photo: B. Thomson

Page 4: the bridled nailtail wallaby (***Onychogalea fraenata***), closely associated with brigalow vegetation and once thought to be extinct; this page: gilgai reptiles top to bottom: death adder, golden-tailed gecko, De Vis banded snake

Soil and gilgai formation

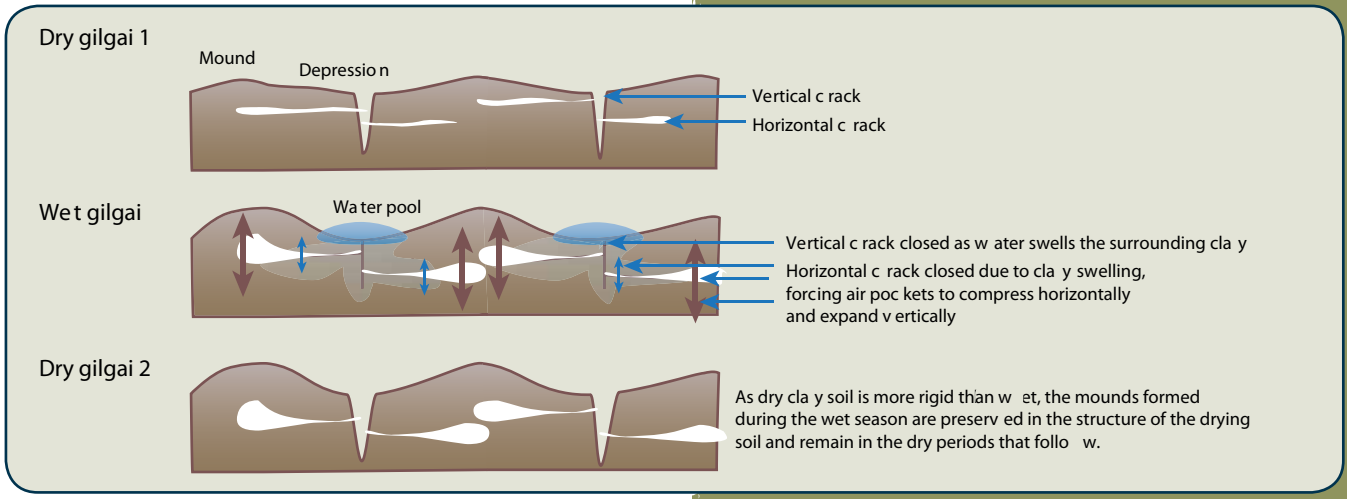
Gilgai formations consist of mounds and depressions, along with shelves that may be present between these first two elements. An important feature accompanying gilgai microrelief is the development of vertical ground-surface cracks in the dry season. These cracks have opening widths up to several centimetres, depths of up to several tens of centimetres and a crack segment up to three metres long. Cracks also occur horizontally below the surface. During wet periods both horizontal and vertical cracks seal but do not always close completely.

These cracks play an important role in the formation of the mounds and depressions. During a wet season, horizontal cracks swell at the surface due to rainwater interacting with the clay. This forces the cracks to close which traps air in the soil profile. As the clay continues to swell, the width of the air filled cracks is forced to enlarge upwards, leading to mound formation during wet periods. As clay soil is more rigid in its dry state than when wet, the mounds remain when they dry out.

Gilgai form in cracking clay soils as they go through dry (photo, top right) and wet (photo, bottom right) phases.

Dry gilgai soil with deep open cracks

Wet gilgai soil with cracks swollen closed at the surface



Gilgai and nutrient cycling

Gilgai soils are commonly referred to as 'self-mulching soils' because they experience a high level of nutrient exchange and cycling between the soil surface and subsurface layer due to the cracking nature of the soil. This allows debris and nutrient rich topsoil to fall into, and become mixed with, the subsurface soil layers. Self-mulching properties also enhance surface condition, reducing compaction.

A feature of intact gilgai country is the large amount of undecomposed material, particularly leaves and wood on the ground. This is due to the arid climate inhibiting their breakdown. Other factors that contribute to the very slow rate of breakdown are the high nitrogen/phosphorus and calcium/potassium ratios in the plant material and a low moisture content in the vegetation.

A feature of intact gilgai country is the large amount of undecomposed material, particularly leaves and wood on the ground.

The relatively low phosphorus content of the soils and of the forest suggests brigalow has adapted to these conditions. The high uptake of calcium is of interest in view of the soil acidity and salinity. Soil acidity increases with depth, probably because brigalow draws calcium (which counteracts acidity) from deep in the soil profile then deposits it at the surface in the form of leaf litter. The calcium is released as the litter decomposes, decreasing the acidity of the surface soil. High salinity and the inability of the soil to compensate for acidity help maintain this pH gradient in the soil profile.

The higher values for soil organic carbon and nitrogen in the upper portions of the microrelief can be attributed to the greater concentration of roots in these areas (Paton, 1974).

Gilgai and hydrology

Cracks in soil initially allow it to accept high rainfall rates but, as the rain is able to enter deeply into the profile, the soil wets from the bottom up, causing the clay to swell and the cracks to close. The initial infiltration rate when the cracks are open can be greater than 25 mm/hour, however after the cracks close the infiltration rate falls to 1–2 mm/hour. Once the cracks have swollen closed, water begins to accumulate in the depressions on the soil surface, forming an extensive complex of small pools in the landscape (if left undisturbed).

Soil water storage is maximised when the cracks are undisturbed and left open. Evaporation losses from an open cracked soil are negligible. The self-mulching soil generates a granular structure and develops wider cracks than other soil types.

Values

Gilgai were an important source of water for Aboriginal people, enabling them to forage seasonally over areas that lacked permanent water. Where gilgai formations remain intact they can provide a water source for animals and play an important role in the local ecology while supporting endangered vegetation communities (brigalow).

Threats

Microrelief offers some advantages for pasture growth. It concentrates water in hollows in low rainfall years and helps prevent run-off in high rainfall years. However, the microrelief limits intensive land use, especially for conventional cultivating, sowing and harvesting of cereals or for coarse grain culture. Also, due to the seasonal pooling of water, not all permanent species can grow in the gilgai depressions where water may be present for many months. The higher parts of the microrelief are much dryer due to run-off into depressions and higher evaporation rates from greater exposure and air movement. These factors mean that native vegetation has had to adapt to variable and sometimes harsh conditions.

The intensification of agriculture in gilgaied areas led to the development of large-scale land planes to smooth gilgai for enhanced pasture growth and cropping. Smoothing removes topsoil from the higher parts, depositing it in the lower parts and exposing areas of subsoil.

Smoothing of gilgai deliberately and dramatically removes the natural contours of the landscape and their capacity to hold water pools. Smoothing also alters the nutrient cycling of the soil. Experiments show that phosphorus availability and soil nitrogen levels in the surface soil decrease significantly with smoothing. Smoothing also increases the acidity of the exposed subsoils.

In addition to gilgai smoothing, the regrowth of native brigalow/belah vegetation often associated with gilgai soils has been deliberately inhibited by broad-scale application of herbicides such as Tebuthiuron in order to enhance agricultural production.

The Brigalow Belt biogeographic region of Queensland has some of the most productive agricultural land in Australia. Despite the unsuitability of gilgai for intensive agricultural production, over 60 per cent of brigalow vegetation has been cleared since European settlement in 1840. Most of this clearing has happened relatively recently.

Until the mid-20th century, agricultural development of the Brigalow Belt was constrained by variable rainfall, exotic weeds and rapid regrowth of brigalow (*Acacia harpophylla*). After this time agriculture in the area expanded rapidly. There was an increased focus on agricultural production for export. Mechanised tree clearing methods were used, supported by government assistance programs to promote economic development. Loss of vegetation in Central Queensland was 1 per cent a year between 1956 and 1993.

As a result of land clearing, many regional ecosystems on fertile soils in the southern Brigalow Belt are now classified as endangered, with less than 10 per cent remaining. These fragmented ecosystems will need to be increased in area and connectivity for their long-term survival. The re-establishment of gilgai soil formations is an important factor in achieving habitat restoration.

Types of gilgai

Several types of gilgai have been identified, based on the combination of the three elements that can occur (depression, mound and shelf). The shelf is not always present and it can only occur with both depression and mound. It is therefore neither the highest nor the lowest part of the gilgai.

The types of gilgai are:

1. Mound and depression equally developed, no shelf present;
2. Mound of much greater extent than depression, no shelf present (sometimes referred to as crabhole);
3. Depression of much greater extent than mound, no shelf present (sometimes referred to as melonhole);
4. Mound, shelf and depression.

Photo: C.A.R.de Moura

Photo: G. Cobb

Gilgai dominated by mounds (top) and by holes (bottom)

Glencoe gilgai

Glencoe is a property approximately 35 km north-west of Chinchilla in the heavily gilgaied brigalow–belah country of southern Queensland (an endangered regional ecosystem). In 1980, a significant proportion of this property was left to regrow and re-establish the gilgai microrelief soil pattern and the associated brigalow native vegetation community. The Glencoe property is therefore a valuble and relatively rare example of intact gilgai soil formations with their associated native vegetation and wildlife community.

When this property is inundated with water, it is one of the most biodiverse ecosystems in the region, supporting a variety of aquatic plants and attracting many animals, including frogs, snakes, birds and butterflies. The intact gilgaied area of Glencoe, in all about 100 ha, was fenced in 1999. In 2007, a Greening Australia project was undertaken to fence a further 44 ha for a wildlife corridor connecting the wetland with other vegetation on the property.

Hydrology and biodiversity

During years with 600 mm of rain or more, and some 'good storms', the gilgai depressions fill with water and start a chain reaction in which local biodiversity booms. Frogs proliferate and reptile populations respond to the abundance of food. Bird numbers increase and the vegetation thrives. Aquatic vegetation grows in some of the deeper wetlands and fish enter from flood flows. Wallabies and kangaroos are drawn to the area and its water pools.

As the pools dry over a period of months, animal communities change and eventually disperse or enter dormant phases of their life cycle. During both dry and wet periods butterflies are abundant, as are other insects.

Vegetation

The Glencoe site contains a mix of several associations of plants, including black tea-tree (*Melaleuca bracteata*) woodlands with brigalow (*Acacia harpophylla*) understorey. The scattered trees include forest red gum (*Eucalyptus tereticornis*), poplar box (*E. populnea*) and

Photo: S. Cochrane

belah (*Casuarina cristata*). Wetland grasses, aquatic herbs (*Damasonium minus*), rushes (*Typha orientalis*) and sedges (*Cyperus* spp.) grow in the lower areas on this site, which has heavy, dark clay soils with broad and deep gilgai that are seasonally ponded and remain wet for long periods.

Glencoe is an example of a gilgai site that is relatively intact; it has mature trees and a high level of regional biodiversity. The Glencoe site also has large amounts of woody debris on the ground and old tree hollows. These are signs of mature brigalow stands and also provide important habitat for fauna, thereby supporting biodiversity.

Far left: Glencoe gilgai in a wet season, Left: Brigalow (***Acacia harpophylla***) flowers,
Above: ***Melaleuca bracteata*** with a grassy understorey, one of the plant associations in the Glencoe gilgai

Glencoe gilgai support a diverse fauna adapted to climates with alternating wet and dry phases.

The striped burrowing frog (***Cyclorana alboguttata***) is usually seen around temporary clay pools such as those found in gilgai. It can survive long periods of dry weather by entering a dormant phase.

The salmon-striped frog (***Limnodastes salmini***) is a large species of frog that burrows (underground or under logs and rocks) to survive periods of drought.

The rough collared frog (***Cyclorana verrucosa***) burrows during dry periods, emerging to breed and feed following extended periods of rain. Males usually call from temporary water pools with a long, moaning growl. Tadpoles are adapted to developing fast in the warmer months to make the most of the surface water before it dries up.

Photos: B. Thomson

Saleyard wetlands

This wetland in Monto, Queensland, is managed by the North Burnett Landcare Group. The wetland is a landscape of gilgai, forming an area without distinct drainage lines, approximately 22 ha in extent. The wetland was one of 42 prioritised wetlands identified by a regional conservation value assessment. It has been categorised as threatened due to its lack of aquatic connectivity, changes to hydrology and invasion by weeds. Nevertheless, it has high species richness and high condition values.

Hydrology

Historically, wet season thunderstorms and floodwaters breaking the banks of Three Moon Creek would have fed the wetland during flood events, however levee banks have been placed on the west of the site to divert these flows away from the wetland into a ring tank to the south. The reduction in frequency, duration and volume of overland flood flows as a consequence of levee banks surrounding the wetland (diverting flows away) have had significant effects on its ecological values.

Photo: North Burnett Landcare

Vegetation

Grasses are a consistent feature of this wetland, which has a fringing zone of larger eucalypt trees. Although the conservation value of the wetland vegetation is high, the site is under pressure from weed invasion. Unmanaged cattle grazing on the site and vegetation clearing have also impacted the native vegetation and wildlife communities. In March 2009, a flora inventory found 93 plant species, of which 53 were indigenous and 40 were weeds.

Photo: North Burnett Landcare

Above: the developed context of the Saleyard wetlands
Right: surveying the site prior to removal of levees

Management

Recommendations to mitigate the threats to Saleyard wetlands include:

- fencing to exclude stock
- a long-term weed control and monitoring program
- encouraging natural regeneration or revegetation with endemic local species
- retention of dead trees and fallen trees/logs as habitat
- control of pest species.

Changes to reinstate overland flow into the wetland should also be investigated.

What's being done?

The North Burnett Landcare Group is systematically removing the levee banks, which will allow the wetland to again receive water from two large stormwater outlets from Monto CBD run-off, as well as from the Three Moon Creek when it floods.

Currently the North Burnett Landcare Group is undertaking weed removal and revegetation trials throughout the site.

Students from the Monto State High School will help monitor and evaluate a variety of management techniques, including cell grazing. These investigations will help determine which rehabilitation methods have the greatest likelihood of success for the wetland. The outcomes will help local landholders with weed management and will be a living example of the positive role wetlands can play in production systems.

This project is a Better Catchments funded initiative and a partnership between WetlandCare Australia, North Burnett Landcare, North Burnett Regional Council, Monto State High School and the Burnett Mary Regional Group for Natural Resource Management.

Photo: North Burnett Landcare

Photo: North Burnett Landcare

Reforming gilgai

In areas with gilgai microrelief, crop and pasture growth is likely to be uneven across a paddock. This is due to soil variations and also poor drainage in gilgai depressions. Continuous cultivation of gilgai paddocks results in the smoothing out of the mound and depression formations. However, this does not always last for long, because even when gilgai-forming soil is smoothed, the forces that create the mounds and depressions are still operating within the soil. Over time, gilgai reform and require re-levelling if cultivation is to continue.

The movement of fence posts that can occur on a cultivated gilgai property is an example of the persistence of the gilgai-forming forces continuing after smoothing. If the land is left undisturbed for a number of wetting and drying seasons the gilgai will reform.

Top: students from Monto State High School monitoring the Saleyard wetlands.

Left: gilgai will reform in the Saleyard wetlands if the land remains undisturbed and more natural drainage patterns are re-established.

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