The landscape and marginal cropping lands — inherent and induced

ANDREW BIGGS
Natural Resources and Water, Toowoomba, Queensland, Australia

Abstract
Marginal cropping soils in Queensland are defined by one or more limiting landscape, pedological or climatic factors interacting with agronomic requirements. Limitations may be inherent in the landscape or induced by farming activities. Common limitations include subsoil sodicity/salinity, low moisture availability and poor surface condition. The latter is often exacerbated by poor management practices.

Introduction
Marginal cropping soils in Queensland are defined by one or more limiting landscape, pedological or climatic factors interacting with agronomic requirements. Limitations may be inherent in the landscape or induced by farming activities. The concept of marginality should, however, be considered in light of the concept of suitable use. For instance, the brigalow-belah lands could be considered marginal for growing carrots, but inherently the landscapes are not suited to that purpose. Thus, when considering why a landscape is marginal or unsuitable for a particular purpose, one should also consider what the landscape is inherently suitable for. These concepts have been explored historically in Queensland via land suitability and/or capability mapping. Land capability assessment (Rosser et al. 1974) was applied to much of the land systems mapping across regional Queensland, while land suitability mapping (LRB 1990) has been applied to more detailed soils mapping, e.g. Ross and Crane (1994).

Both land suitability and land capability assessments have the same general intent — examination of the factors that constrain an intended purpose. Limitations typically described include climate, soil chemical and physical attributes and characteristics of the landscape, e.g. rainfall, soil salinity, depth, texture, rockiness, soil surface characteristics, slope, etc. Some of these factors function singularly, while others interact, e.g. rockiness, soil depth and subsoil physical and chemical properties all affect plant available moisture capacity.

The key factors influencing crop production in inland Queensland are climate variability and soil moisture storage (Webb et al. 1997). Farming systems trials such as those reported by Thomas et al. (2004) have repeatedly shown that erratic rainfall, the capacity of the soil to store water, and the ability of a crop to extract water are key constraints. Factors such as rainfall can be regarded as inherent limitations in the landscape, whereas other limitations are either reduced or increased by activities associated with cropping.

Inherent limiting factors
Climatic variability and its impacts on crop success and yield have been studied extensively in Queensland and elsewhere in Australia, e.g. Freebairn et al. (1990). Within Queensland, a general trend of decreasing rainfall and increasing variability exists from east to west. North-south gradients also exist to varying degrees. For instance, in southern inland Queensland, rainfall declines to the south, while localised ‘wet’ or ‘dry’ spots occur, as influenced by topography and other factors. Whether climate is the primary limiting factor is determined by both rainfall parameters and soil parameters. For example, wheat yield is climate-limited in the Maranoa, but soil-limited on the eastern Darling Downs (Freebairn et al. 1990).
Change in climate patterns may increase the significance of rainfall variability over a wider area.

Inherent limitations such as subsoil salinity and sodicity have been poorly recognised in much of the cropping lands in Queensland (Dang et al. 2006). A significant proportion of the cropping lands are on heavy-textured soils (primarily Vertosols). Natural deep drainage rates within these soils are very low (Tolmie et al. 2003), resulting in accumulation of sodium and salts over geological time scales. While the presence of these general limitations has been well understood by pedologists for decades, it has been poorly understood by the farming community, in particular with regard to specific ion effects vs reduction in plant available water. Recent research, e.g. Sheldon et al. (2006), has explored some of these issues, finding interactions between temperature, humidity and salinity for chickpeas.

Poor knowledge regarding such problems has lead to an artificial increase in the marginal cropping lands through the selection of incorrect crop species/cultivars.

Factors such as soil depth, rockiness, high bulk density and other obvious/visual limitations have generally (but by no means always) been avoided in the development of cropping lands. Thus, the more likely constraints are generally the ‘invisible ones’, usually related to soil chemistry. Most of the inland croplands of Queensland are relatively well supplied with nutrients (in comparison with other cropping soils in Australia), but specific nutrient limitations are still important, particularly in the well leached soils. Nitrogen is the most commonly applied nutrient in cereal cropping areas, while potassium is a major additive in coastal canelands.

**Induced limiting factors**

Cropping has a wide range of effects on both physical and chemical properties of soils, as well as more obvious landscape degradation processes, e.g. erosion, secondary salinity. In general, these effects are gradual, but often lead to the same end-point — significant degradation of the resource, potentially to the point where it is no longer suitable for that use. Changes in land management practices associated with cropping have led to changes in the importance of various processes. For instance, erosion was once the preeminent concern in upland cropping areas, particularly those on Vertosols, but also in coastal soils, e.g. canelands. Adoption of reduced tillage practices, changes in crop types and a reduction in burning of stubble (as well as the drought!) have significantly reduced (but not removed) the significance of erosion as an issue (Figure 1).

Significant study into fertility decline, in particular organic carbon decline over time, has occurred in the dryland cropping lands of Queensland, with studies such as Dalal and Mayer (1986) producing strong relationships between period of cultivation and organic carbon decline. The rate and overall degree of decline are influenced by factors such as rainfall, soil texture, mineralogy and farming practices. Vertosols are generally more resilient than Ferrosols and Kandosols. Figure 2 shows the differences in organic carbon and total nitrogen for some Darling Downs soils.

![Figure 1](image_url). Relationship between soil loss and cover. Source: Freebairn et al. (1996).
Reduced tillage and ley pasture phases are essential tools in reducing organic matter decline.

Poor surface condition is a common problem in cropping lands, with an equally common poor understanding of the causes. Gypsum is the oft-promoted ‘cure all’, but it is, in fact, often ineffective and/or not economic. Soil surface condition is a function of inherent properties such as particle size ratios, sodicity, salinity, mineralogy, organic matter content and biological activity. Particle size, in particular, is very important, and is the primary driver for the natural hard-setting and crusting nature of many of our soils (Figure 3). Management of soil organic matter levels through options such as pasture rotation is often the only economic way to manage soil surface condition, and has more associated benefits than amelioration with gypsum.

Declines in surface condition and soil organic carbon often go hand in hand, as organic matter

Figure 2. Relationship between total N, organic carbon and soil type for some Darling Downs soils.

Figure 3. Particle size distribution in relation to soil surface characteristics for some Darling Downs soils.
Andrew Biggs plays an important role in aggregate stability. Common by-products of poor soil surface condition (crusting, hard-setting) include poor seedling emergence, poor soil-seed contact and reduced infiltration.

Compaction is a well known problem in nearly all crop lands, and can lead to reduced establishment, growth and yield of crops and pastures. New technology and the increased adoption of controlled traffic has substantially reduced the impacts of compaction in many cropping areas, particularly in irrigated lands, but it is an unavoidable consequence of most farming practices. Associated declines in soil biological activity and organic matter can affect structure and soil water movement. Figure 4 illustrates the difference in rate of reduction of matrix hydraulic conductivity over time for 2 different soil types — cracking and non-cracking clays — showing the importance of inherent soil properties such as mineralogy.

Soil acidification is an induced problem of some cropping lands in Queensland, particularly those in the tropics and in soils with a low buffering capacity, e.g. Ferrosols, Kandosols (Bruce 1997), although natural high acidity at fairly shallow depths may be more of a problem than generally recognised in some brigalow soils. Associated problems include aluminium and manganese toxicity. No comprehensive study has been conducted in Queensland to determine the extent of acidified soils, but the problem has been observed most frequently in the tropics, although it also occurs in some soils on the Darling Downs and in the Burnett.

The development of dryland salinity as a result of cropping is a well recognised problem in Australia. Most of the problem areas in Queensland are in the Darling Downs, Lockyer and Burnett (both coastal and inland). Conversion of native vegetation to annual cropping increases deep drainage, with resultant changes in shallow and/or deeper groundwater systems. Conversion to perennial pastures/deep-rooted species is the most commonly recommended practice to reduce risk from dryland salinity. Such a conversion does not always need to be permanent, and may dovetail with other requirements for maintenance of soil condition.

**Distribution of marginal cropping lands**

A number of authors have depicted suitable cropping and grazing lands in Queensland at a regional scale, e.g. Weston and Harbison (1980); Harbison and Weston (1980). Such evaluations remain current in a general sense, particularly with respect to inherent limitations such as landform characteristics. Short- and long-term changes in climatic variables and economics have changed both the types of crops grown in some areas, and their geographic distribution. Using a basic interpretation of regional-scale mapping, the marginal cropping lands are invariably Kandosols, Chromosols and Sodosols, with about 500–550 mm annual average rainfall. Landscapes...
such as the poplar box-wilga-sandalwood woodlands and the heavily gilgaied brigalow lands in the Moonie catchment are typical examples of marginal cropping lands.

Significant expansion of cropping lands often occurs during runs of wet years, with a contraction during drought. Despite these fluctuations, there has been an overall trend of increasing areas under cropping in Queensland. This increase has often been into what was historically regarded as unsuitable or marginal land. There has also been a contraction of cropping in some eastern upland landscapes (e.g. southern Darling Downs, Lockyer Valley, Bauhinia), particularly those that were settled and intensively farmed in the 1800s. Poor farming practices led to significant degradation of these lands to the point where they were retired to pasture. In the Condamine catchment, about 76 000 ha of land that was cropped in the early 1950s is now under pastures.

Figure 5 illustrates the change in land use in the Border Rivers-Moonie catchments over time (Biggs et al. 2005). Early clearing largely resulted in conversion to grasslands/pasture, but from the 1960s onwards, substantial conversion to cropping occurred. The brigalow-belah landscapes were more heavily exploited for cropping than the eucalypt woodlands, as they were perceived to be more suitable for this purpose because of higher fertility and moisture retention. Many brigalow soils were initially cropped to control regrowth and it was coincidence that grain prices encouraged continuance. The presence of high subsoil salinity/sodicity and low pH was not well recognised. Development of cropping on lower fertility/moisture retention soils has been sporadic, generally related to wet phases, or as an attempt to recover costs of clearing.

The expansion of cropping has not correlated exactly with a decrease in stock numbers (Figure 6), although stock numbers have declined overall. Further development of croplands will be limited by both the availability of suitable land and changes to remnant vegetation management in Queensland.

**Conclusion**

An understanding of climatic, landscape and agro-nomic factors is essential to understanding the suitability of landscapes for cropping. The potential constraints are many, but climate, soil moisture availability and fertility decline are the most common. Failure to fully understand these limitations can lead to decline of the soil resource to the point where it is no longer suitable for cropping. Pasture phases may be adopted to suit a variety of management purposes, and are likely to be a key component of future farming systems.
Figure 6: Areas under crop, livestock numbers and rainfall in Waggamba Shire over time.

References


