Managing Hostile Subsoils in Western Australia

Compaction

Acidity

Nutrient & Water Storage

Salinity

Alkalinity

Waterlogging

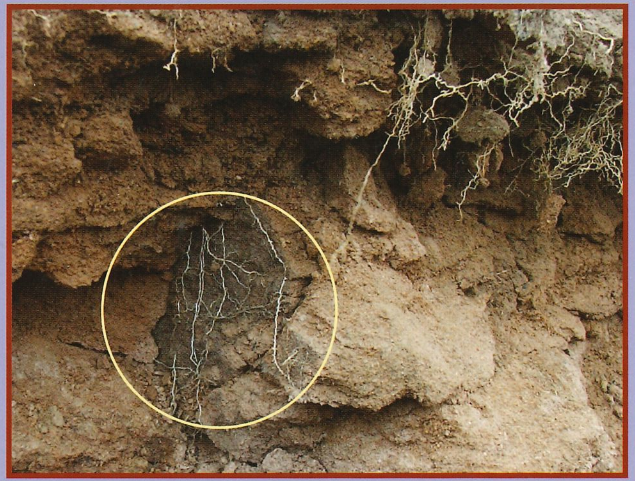
Boron toxicity

Structure

SUBSOIL CONSTRAINTS IN WESTERN AUSTRALIA

Hostile Subsoils

Subsoil constraints are the soil physical or chemical characteristics below 10 cm that limit or reduce the ability of crop or pasture roots to access water and nutrients deeper in the soil profile. These constraints may be naturally occurring or induced by agricultural practices.



Poorly structured subsoil restricts roots to cracks

Occurrence

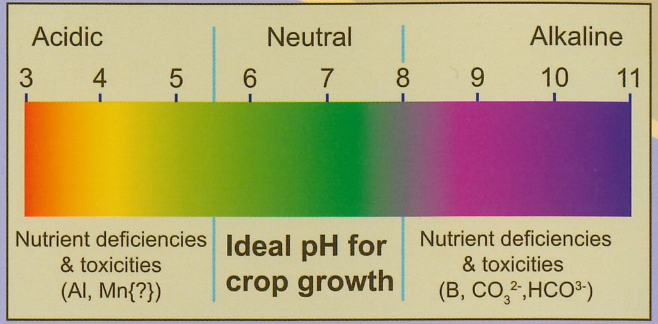
Agricultural soils in Western Australia are ancient, highly weathered and fragile. They often contain one or more subsoil constraints or are susceptible to them developing.

Duplex soils can have combinations of almost all the constraints and also be susceptible to waterlogging.

The sandy and sandy earth soils can often have low water storage and nutrient holding capacity and be susceptible to acidification and compaction. Alkaline subsoils can have high levels of salt, exchangeable sodium (sodicity) and dense poor structure. Duplex soils can have combinations of almost all the constraints and also be susceptible to waterlogging.

Root Growth and Productivity

Root growth may be physically constrained or physiologically constrained by toxicities such as aluminium or salinity. Root growth may either slow or stop, depending on the nature and severity of the constraint, and the sensitivity of the crop type and variety being grown.



Extremes of pH induce nutrient deficiencies or toxicities

Generally, subsoil constraints will restrict productivity more in seasons with a dry finish as crops have limited access to stored subsoil moisture for grain filling at the end of the season, however exceptions do occur. For example, in deep sands, in low rainfall environments, compacted subsoil layers can slow root growth, thus reducing early season growth and water use; leaving more stored water available for grain filling at the end of the season.

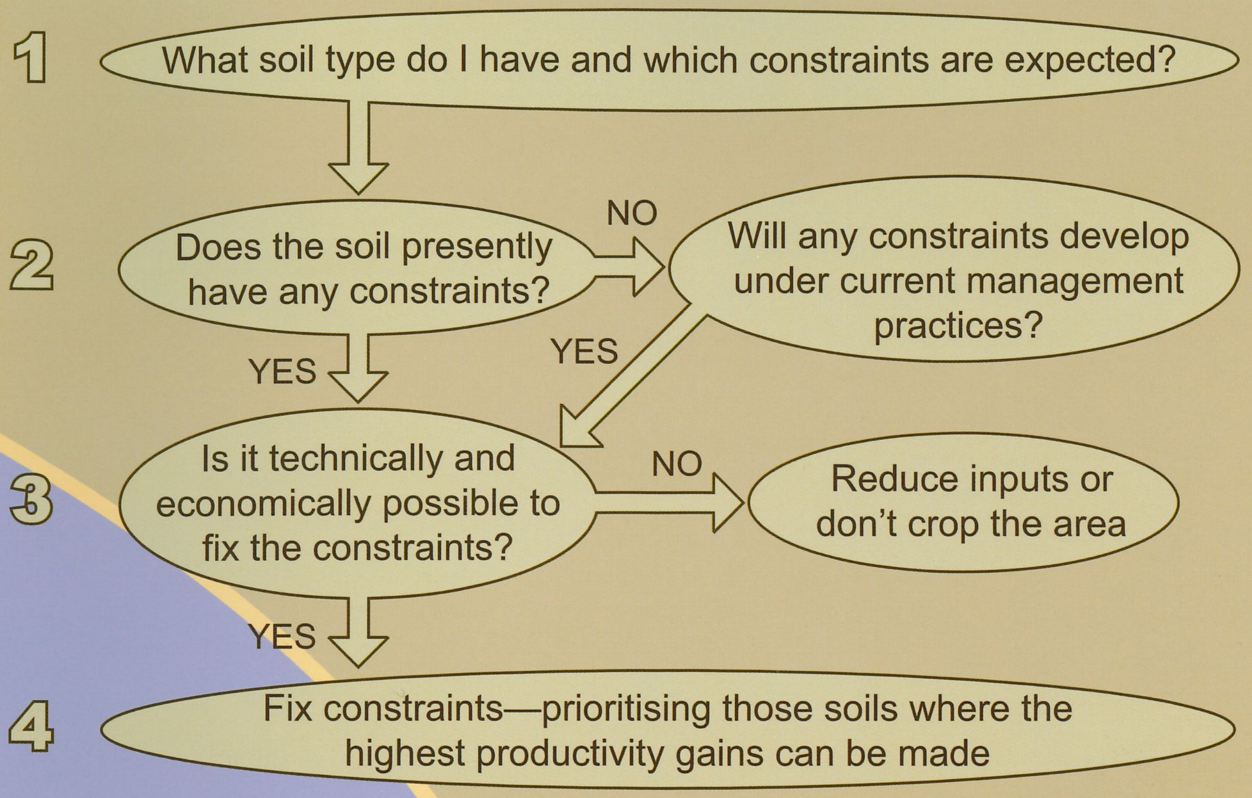
Economic Impact

The impact of subsoil constraints on crop yield will depend on the nature of the constraint, crop type/variety and seasonal conditions. Crop yield losses can be estimated by comparisons with tolerant varieties or responses to amelioration (e.g. liming, deep ripping or raised beds). We have estimated yield losses for wheat of up to:

- 40% due to subsurface acidity
- 30% due to compaction
- 60% due to waterlogging
- 15% due to boron toxicity

MANAGING SUBSOIL CONSTRAINTS IN WA

There are four key decision making stages when deciding how to manage subsoil constraints.



To diagnose specific constraints see: D Patabendige (2005) "Diagnosing and ameliorating problem soils" (Decision tree on how to diagnose and ameliorate problem soils). Miscellaneous publication 25/2005, Department of Agriculture Western Australia.

Successful and profitable amelioration is likely when:

1. The subsoil constraint occurs within the top 40 cm of the soil as a distinct layer (such as a compaction pan or acid layer).
2. There is good potential for root exploration of the soil profile below the constrained layer.
3. There are no other constraints limiting crop production.

Large response to liming likely
Sandy loam (Moora)

Soil Depth (cm)	*pH $CaCl_2$*	*Al (ppm)*	
0–10	4.9	1.0	Normal root growth
10–20	3.9	7.5	High Al restricts root growth
20–30	3.9	6.9	
30–40	4.4	2.1	Hospitable soil unavailable to roots

Management:
Correct acid layer by maintaining surface pH above 5.5 with lime.

Large response to liming less likely
Loamy sand (Ajana)

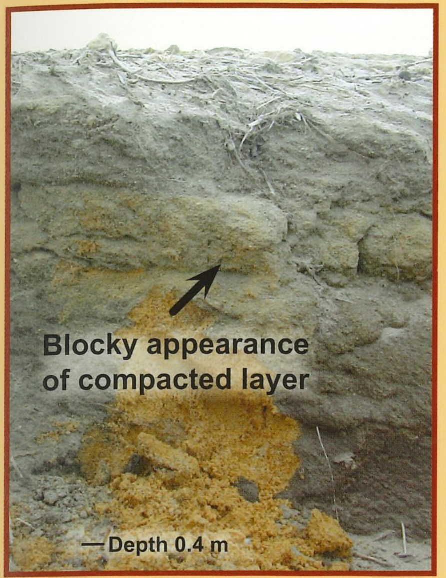
Soil Depth (cm)	*pH $CaCl_2$*	*Al (ppm)*	
0–10	4.2	7.6	High Al restricts root growth throughout profile
10–20	4.0	17.0	
20–30	4.0	20.0	
30–40	4.0	21.0	

Management:
Use acid tolerant crops and varieties. .
Adjust fertiliser and amelioration inputs, given that high Al constrains yield.

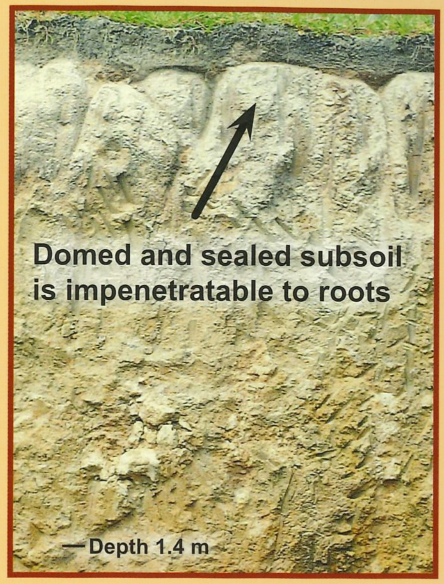
SOILS AND CONSTRAINTS

Soil groups	Major agricultural soils in group	Location	Subsoil constraints
DEEP SANDS and SANDY EARTHS	Calcareous sands	Coastal fringe	• Low water and nutrient storage • Alkalinity • Compaction
	Pale yellow and grey sands	Western half of the northern agricultural region	• Low water and nutrient storage • Compaction • Acidity
	Yellow and brown sands and sandy earths	Central and eastern part of the northern and central agricultural regions	• Compaction • Acidity
LOAMY EARTH SOILS	Calcareous loamy earths	Eastern part of the central agricultural region	• Compaction • Salinity • Alkalinity
	Red shallow loams and red-brown hardpan soils	Eastern part of the northern agricultural region	• Cemented hardpans • Poor subsoil structure • Shallow soil depth • Boron toxicity • Compaction
TEXTURE CONTRAST (DUPLEX) SOILS	Sandy and loamy duplexes	Southern agricultural region	• Alkalinity • Sodicity • Poor subsoil structure • Waterlogging (perched water tables)
	Sandy and loamy duplexes with non-alkaline subsoils	Central and southern agricultural regions	• Acidity
GRAVELLY SOILS	Sandy gravels	Western half of the south coast and significant areas in northern and central agricultural regions	• Low water and nutrient storage
	Loamy and shallow gravels	Western half of the south coast and significant areas in northern and central agricultural regions	• Low water and nutrient storage • Cemented gravels (ferricrete) • Shallow soil depth

Compacted layer



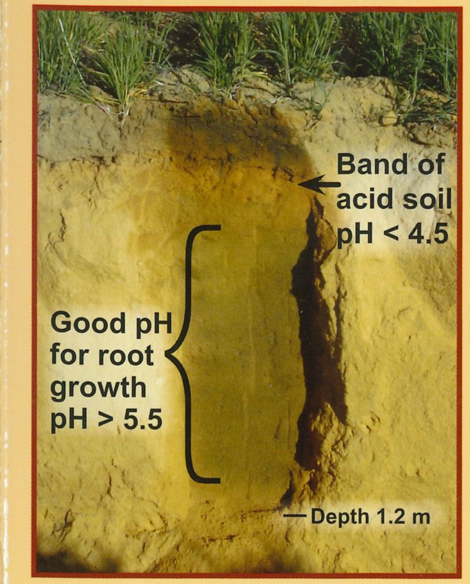
*Poor subsoil structure



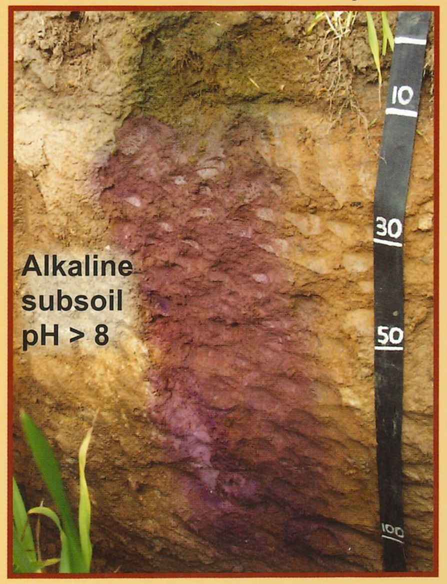
*Poor water & nutrient storage

*Waterlogged

#Subsurface acidity

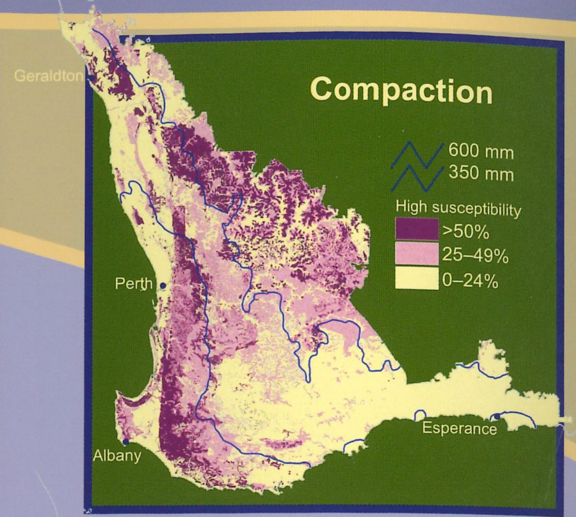


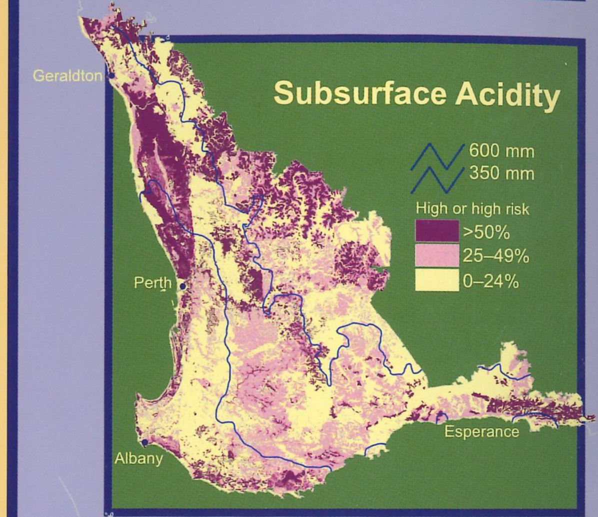
#Subsurface alkalinity

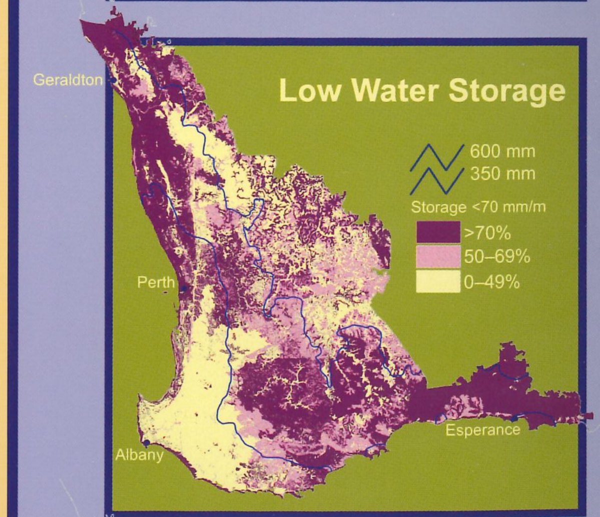


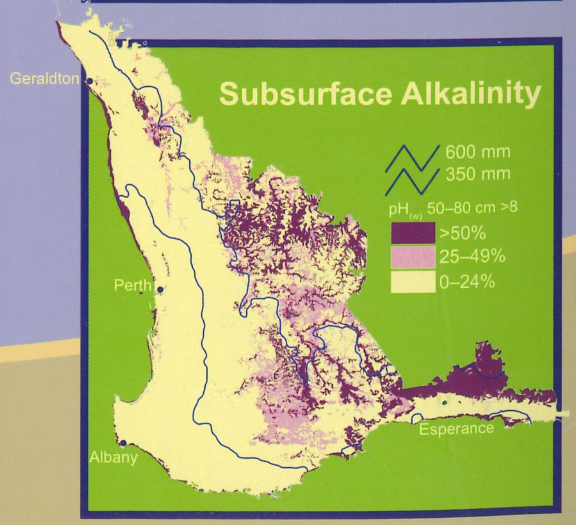
#Soil profile stained with universal pH indicator

*Photos courtesy of Noel Schoknecht









SUBSOIL CONSTRAINTS AND IMPACTS

Subsoil Constraint	Susceptible Soil Type	Soils at Risk (%)[A]	Characteristics and Diagnosis[B]	Impact on Root Growth and Consequences for Productivity	Decline in Wheat Yield (%)[C]
TIGHTLY PACKED SUBSOILS and COMPACTED LAYERS (hardpan)	Deep sands, sandy earths and red-brown hardpan soils	70	• Induced, mostly from machinery; or inherent through soil cementation and packing processes. • To diagnose, use penetrometer, push probe or visual assessment.	• Dense (hard) soil layers physically slow or prevent root growth. • Strength of the hardpan or compacted layer can decline as the soil becomes wet. • Some inherent cementing agents in sands can dissolve when the soil gets wet. • Water and leached nitrogen (N) can escape the root zone in sandy soils with a high infiltration rate when the root growth is slowed.	20–30
SUBSURFACE ACIDITY (aluminium toxicity)	Gravels, sandy earths and siliceous sands	30	• Inherent in some WA soils but is also induced by agriculture. • Test pH of 10–20 & 20–30 cm layer in 0.01M $CaCl_2$. Subsurface acidity is a problem if pH in either layer is < 5.	• Acidification increases aluminium solubility. Aluminium is toxic to root growth. • Impact is dependent on crop sensitivity, tolerance increases in the order of barley<canola<wheat<narrow-leaf lupins. Within crop variation in aluminium tolerance also exists between varieties. • Water and leached nitrogen (N) can escape the root zone in sandy soils with a high infiltration rate when the root growth is slowed.	20–40
LOW WATER & NUTRIENT STORAGE	Deep sands	60	• Inherent in sandy textured soils with low clay and organic matter content. • Determine clay content by field texturing soil to depth.	• Root growth isn't directly restricted by this constraint but root access to water and nutrients is limited by the inability of the soil to hold (store) these resources. • Crops can readily become N deficient due to leaching.	Extent of impact is seasonally dependant
POOR SUBSOIL STRUCTURE	Duplexes	30	• Inherent or induced through structural decline or instability. • Visually assess soil structure and test for dispersion or slaking.	• Low porosity and high bulk density physically restrict root growth. • Root growth is often restricted to pre-existing channels or cracks. • Root access to stored soil water and nutrients is limited by poor soil structure.	*
WATERLOGGING	Shallow duplexes	15	• Inherent or induced. • Check for perched water tables (using dip well or hole) within 30 cm of surface or N deficient crops.	• Low oxygen in waterlogged soil results in the death (pruning) of submerged roots. • Waterlogging can increase weed competition (eg toad rush) and nitrogen leaching from the soil, resulting in N deficient crops.	35–60 (incidence is seasonally dependent)
SUBSURFACE ALKALINITY	Duplexes and calcareous loamy earths	10	• Inherent. • Test pH to depth; considered highly alkaline if pH >8 and usually increases with depth.	• Commonly associated with other constraints such as sodicity, boron toxicity and poor structure, all of which limit root growth and access to water and nutrients.	*
SUBSURFACE SALINITY (primary salinity)	Calcareous loamy earths	*	• High salt levels inherent in the subsoil (as opposed to secondary salinity associated with rising water tables). • Test electrical conductivity (EC); saline if EC>40–80 mS/m.	• High salt levels in the soils limit root growth by decreasing water availability and through toxic concentrations of sodium (Na) and chloride (Cl). • Salinity impact is reduced at higher soil water contents. • Crop tolerance to salinity varies.	*
BORON TOXICITY	Red shallow loams and red-brown hardpan soils	15	• Inherent, incidence is restricted to fine-textured alkaline subsoils (annual rainfall <450 mm). • Observe sensitive crops for toxicity symptoms.	• Toxic concentrations of boron (B) reduce root growth particularly in sensitive crops and varieties. • B toxicity causes necrotic lesions on leaf tips and margins and sometimes death of the older leaves thereby reducing the green leaf area. • Severity is increased in seasons with dry periods although yield impacts are minimal if toxicity occurs late in the growing season.	0–15 (incidence can be seasonally dependent)

[A] Proportion of WA's dryland agricultural soils at risk, estimated using the DAFWA Map Unit Database (25-05-06). For details see D. van Gool *et al.* (2005).
[B] For detailed diagnosis techniques see D. Patabendige (2005).
[C] Estimate based on published and unpublished field trial and experimental data collected throughout the WA wheatbelt.
* Insufficient data available for estimation.

This Brochure has been produced by the 'Managing Hostile Subsoils WA' project.

Managing Hostile Subsoils WA is a Grains Research and Development Corporation (GRDC) funded research project with researchers from the Department of Agriculture and Food Western Australia and The University of Western Australia. *The aims of the project are to:*

1. *Review the current knowledge of subsoil constraints in WA soils and conduct targeted, relevant and practical research.*
2. *Identify, characterise and map the dominant subsoil constraints in WA wheatbelt soils.*
3. *Provide comprehensive information about the best management practices for subsoil constraints in the WA wheatbelt.*

Research Priorities

Develop an understanding of the potential for current practices to create or worsen constraints.

Develop practical management practices to either ameliorate (treat) or avoid subsoil constraints.

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Other Publications

Diagnosing and ameliorating problem soils (Decision tree on how to diagnose and ameliorate problem soils).
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