Economic analysis of the impacts and management of subsoil constraints

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Key messages

- Subsoil constraints have a significant impact on the WA grain industry in terms of lost production and profits.
- This is especially true for subsoil acidity, but also for subsoil compaction and sodicity, and to a lesser extent, transient salinity.
- Strategies to ameliorate these constraints have potential to partly recover these losses in the case of lime for subsoil acidity, deep ripping, deep working with controlled traffic farming for subsoil compaction and, to a lesser extent, gypsum for subsoil sodicity.

Aims

To conduct an economic analysis of the effects of subsoil constraints on yields, cost structures and profits, and to analyse the cost-effectiveness of interventions for their management.

Method

This analysis is concentrated on nine agro-ecological zones (AgZones) that make up the dominant grain-producing regions of Western Australia. The methodology used to conduct economic analysis on each subsoil constraint has two parts:

1. Determination of the current economic impact of each subsoil constraint (including effects on yields, cost structures and profits), and
2. Economic analysis of soil interventions to manage each subsoil constraint.

Determination of the current economic impact of each subsoil constraint

The methodology involves nine steps which are listed below:

1. Estimation of current crop yields and pasture stocking rates (with subsoil constraints),
2. Estimation of the current production value of land (with subsoil constraints),
3. Estimation of the area that is currently affected by each subsoil constraint,
4. Estimation of the probability that each subsoil constraint will have an impact in an average year,
5. Estimation of the production penalties caused by each subsoil constraint,
6. Estimation of average crop yield and pasture stocking rates without each subsoil constraint,
7. Estimation of the production value of land without each subsoil constraint,
8. Estimation of the average cost of lost production due to each subsoil constraint, and
9. Estimation of the total cost of lost production due to each subsoil constraint.

Economic analysis of soil interventions to manage each subsoil constraint

The economic analysis of soil interventions to management subsoil constraints is conducted using bio-economic models relating biological, physical and economic factors to each subsoil constraint in south-western Australia. In the case of subsoil acidity, an established model called Optlime (version 2008.1) is used. In the case of the other subsoil constraints, a bio-economic model has been developed specifically for use in this analysis.

Both Optlime and the specifically-developed model have the following features:

1. The models are relevant to the paddock scale but results can be aggregated to be relevant to the farm and regional scale,
2. They represent a number of years. A 20-year time horizon is used to account for the economic impacts of management practices through time,

3. They include a number of user-specified crop and pastures sequences, rather than fixed rotations. Enterprise options include wheat, barley, canola, lupins, and pasture,
4. Output provided allows the user to examine the likely effect of management strategies on subsoil factors (such as pH, exchangeable aluminium), yields and profits,
5. They are simulation, not an optimisation, models,
6. They simulate an average year, not accounting for seasonal or market variability,
7. They provide a cashflow analysis of the change in benefits and costs attributable to the management intervention. Output includes:
    a. The 20-year future stream of benefits due to the intervention,
    b. The 20-year future stream of costs due to the intervention,
    c. The 20-year future stream of net revenue due to the intervention (benefits minus the costs),
    d. The net present value of the intervention (the net revenue discounted – using a 5% discount rate in the standard version of the model - and summed to a present value,
    e. The benefit cost ratio of the intervention (the present value of the benefits divided by the present value of the costs), and
    f. The equivalent annual profit due to the intervention (the constant periodic profit that is derived from the intervention over the 20-year time horizon not accounting for interest or tax).

Results

A brief summary of the area of south-western Australia susceptible to each subsoil constraint considered in this analysis, and associated yield penalties, were provided by DAFWA experts and are summarised below:

- **Subsoil acidity:** Approximately 70% of south-western Australia is moderately to strongly-affected by acidity (11 million hectares). Yield penalties caused by acidity occur in approximately 94% of seasons and are approximately 46% for barley and canola, and 13% for wheat. Lupins are not susceptible to acidity,
- **Subsoil compaction:** While most of the croppable land in Western Australia is affected by compaction, approximately 75% is estimated to be moderately to highly-affected by compaction (12 million hectares). Crop penalties are between 10 and 30%, occurring in approximately 67% of years,
- **Subsoil sodicity:** Approximately 62% of croppable land in south-western Australia is susceptible to subsoil sodicity (10 million hectares). Yield penalties are in the order of 10 – 30% in most years, and
- **Transient salinity:** Approximately 11% of croppable land in south-western Australia is affected by transient salinity (2 million hectares). Yield penalties range from negligible up to 65% depending on the severity of susceptibility and crop type, with an average of approximately 15%.

Table 1 and Table 2 provide estimates of the average and total indicative value of lost production due to each subsoil constraint, respectively. Subsoil acidity has the highest cost of lost production, both in average terms ($141/ha/year) and in total ($1.6 billion/year - average cost multiplied by area affected). Subsoil compaction and sodicity have similar average costs of lost production at approximately $50/ha/year. Compaction has a higher total cost of lost production compared with sodicity ($880million/year compared with and $580 million/year, respectively). Transient salinity has the smallest average and total cost of lost production at $19/ha/year and $92 million/year.

Table 3 provides a summary of the economic returns of various management strategies. It is estimated that liming increases the indicative equivalent annual profit by $63/ha/year with $11 returned for every dollar invested. The most profitable of the strategies investigated for subsoil compaction is deep ripping and deep working with controlled traffic farming with an indicative equivalent annual profit of $35/ha/year and a $9 return for every dollar invested. Applying gypsum for the amelioration of sodic soils provides more modest returns with an indicative equivalent annual profit of $9/ha/year and a return to investment of $1.4 for every dollar invested.

Table 1: Estimated average indicative value of lost production due to subsoil constraints ($/ha/year)

AgZone	Acidity	Compaction	Sodicity	Transient salinity
Mid West	127	77	31	13
Mullewa to Morawa	141	64	48	49
West Midlands	149	70	12	24
Central-Northern Wheatbelt	114	52	44	18
East Moora to Kojonup	129	48	37	14
Southern Wheatbelt	133	36	68	22
Stirlings to Ravensthorpe	212	45	88	13
South Coast	195	87	56	15
Salmon Gums Mallee	251	48	128	10
Weighted average	**141**	**54**	**52**	**19**

Table 2: Estimated total indicative value of lost production due to subsoil constraints ($million/year)

AgZone	Acidity	Compaction	Sodicity	Transient salinity
Mid West	122	87	15	3
Mullewa to Morawa	82	51	27	7
West Midlands	147	72	2	1
Central-Northern Wheatbelt	381	264	141	29
East Moora to Kojonup	263	113	46	6
Southern Wheatbelt	258	117	160	33
Stirlings to Ravensthorpe	76	27	38	3
South Coast	218	114	49	3
Salmon Gums Mallee	27	39	97	7
Weighted average	**1,574**	**883**	**577**	**92**

Conclusion

Of four subsoil constraints considered, acidity is estimated to have the most significant economic impact, costing WA growers an average $141/ha/year ($1.6 billion/year in lost production potential), followed by compaction ($54/ha/ear or $0.9 billion/year), sodicity ($52/ha/year or $0.6 billion/year) and transient salinity ($19/ha/year or $92 million/year).

Of the strategies considered to manage these subsoil constraints, it is estimated that liming has the most potential to increase profitability (by approximately $63/ha/year), followed by deep ripping and deep working with controlled traffic farming to manage compaction (estimated to increase average profits by $35/ha/year) and gypsum for the amelioration of sodic soils (estimated to increase average profits by $9/ha/year).

These results should be considered as indicative only as there are a number of limitations to this analysis. The methodology assumes that each subsoil constraint is the only constraint present. In reality, a number of constraints can be present in each soil. The analysis assumes an average year and average response times for management strategies. The situation for each farmer is different, so advice from professionals with appropriate skills should be sought before beginning a program of action is developed for individual properties. Given these limitations, the main use for these numbers is to compare across regions and across subsoil constraints. Caution should be used when quoting these numbers in isolation.

Further research could include consideration of multiple constraints in the soils within each AgZone, research into the seasonal impacts of each subsoil constraints (rather than assuming an average year), and improving the accuracy of the underlying assumptions used.

Key words

Subsoil constraints, subsoil acidity, subsoil compaction, transient salinity, subsoil sodicity, economic impact

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Table 3: Indicative equivalent annual profit and benefit cost ratio of management strategies for each subsoil constraint

AgZone	**Indicative equivalent annual profit** ($/ha/year over 20 years)					**Indicative benefit cost ratio** (Over 20 years)				
	Acidity	Compaction			Sodicity	Acidity	Compaction			Sodicity
	Liming (deep-banded with surface applications)	DR and DW alone	DR and DW with gypsum	DR and DW with controlled traffic farming	Gypsum (surface application)	Liming (deep-banded with surface applications	DR and DW alone	DR and DW with gypsum	DR and DW with controlled traffic farming	Gypsum (surface application)
Mid West	57	8	-10	55	4	16	1.6	0.7	12.6	1.2
Mullewa to Morawa	174	-3	-22	27	1	10	0.7	0.3	10.7	1.1
West Midlands	89	2	-17	47	7	25	1.1	0.5	23.1	1.3
Central-Northern Wheatbelt	69	-4	-23	20	4	9	0.6	0.2	4.8	1.2
East Moora to Kojonup	13	9	-9	46	7	7	1.7	0.7	10.2	1.3
Southern Wheatbelt	41	-3	-21	27	12	8	0.8	0.3	7.2	1.6
Stirlings to Ravensthorpe	30	8	-9	48	19	9	1.7	0.7	14.2	1.9
South Coast	122	27	12	78	11	13	3.1	1.4	15.8	1.5
Salmon Gums Mallee	37	7	-11	41	22	10	1.5	0.7	9.2	2.0
Weighted average	**63**	**3**	**-16**	**35**	**9**	**11**	**1.2**	**0.5**	**8.8**	**1.4**

Note: DR = Deep ripping, DW = Deep working