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Cotton Research and Development Corporation

Final Report

"Soil Management Training"

DAN 64 C

July 1991 to June 1994

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NSW Agriculture

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Final Report

Corporation's Code: DAN 64C

Responsible Director:.....

Commencement date: July 91 **Completion date:** June 94

Project Title: **Soil management training**

Field of Research: Technology transfer **Field code:** 6.1

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Abstract:

This project followed on from the production of the SOILpak manual (A soil management package for cracking clays). It is essential to be able to recognise features of soil structure in order to be able to use the SOILpak manual effectively. The "Soil Management Training" project addressed this issue. It trained cotton consultants, extension personnel, farmers and agronomists, in the skills required to diagnose soil structural condition. The trainees now use these skills to make, or help cotton growers to make, informed soil tillage decisions.

Decision support materials in the form of videos, stereoscopic images and field guides were produced as part of the project. These materials are now available for use by the trainees to train others.

Increasing the skill level in soil diagnosis has allowed those making tillage and other soil management decisions to see the results of their management and soil trafficking policies. On farm decision making has been improved as a result.

PROJECT TITLE: **Soil management training**

Objectives:

1. Facilitate the dissemination of soil management skills within the cotton industry.
2. Promote the active adoption of SOILpak.
3. Provide feedback on users' comments to soil researchers.

Industry significance:

Current situation. The SOILpak project (DAN 41) provided the industry with a soil management package. However, SOILpak is not a training tool: it is a decision support system that is complemented by training programs. Project DAN 45 ('Soil management training for advisers to cotton growers') made a start in addressing the training need but was limited in scope in that it was aimed only at cotton advisers. Moreover, there are not enough soil specialists to train the whole industry in a reasonable time.

How this project helped ; This project focused on the training tools as well as the training process. To make effective use of SOILpak, and to promote its active use, we trained key advisory personnel and consultants in soil management skills. The training packages developed under this project facilitated this process. Those key people can now use the training packages to disseminate the skills throughout the industry.

Project summary:

SOILpakβ, a decision-support system for soil structure management in the cotton industry, has been widely accepted (a total of 930 copies printed). However, the manual depends heavily upon diagnosis of soil structure. Users often find diagnosis daunting until they take the first step of 'hands on' experience in soil examination. After taking that first step (at a soil pit training workshop) users rapidly gain confidence, they find that diagnosis is not difficult and they begin to use the manual as a decision-support tool.

This project helped facilitate training by providing the trainers with teaching tools to make more effective use of their time. This training project complemented SOILpak by providing resources that were not (and can not be) in the manual. The project also provided support to those who were new at diagnosis as they developed their soil structural recognition skills.

Objectives to be achieved in each year of the grant:

Year 1:	Establish demonstration sites; prepare course notes and demonstration materials.
Year 2:	Complete training packages; train key advisory staff.
Year 3:	Assist key advisory staff in disseminating skills to other advisory staff and consultants.

Introduction

Soil management is an important aspect of the whole management system for cotton. Bad structural degradation of soils can reduce cotton yield by 30% or more (Daniells 1988). Inappropriate soil management following soil damage associated with wet harvests influenced cotton yields on valley wide scales (Larsen et al 1992). Research was conducted addressed the issues involved with these yield reductions.

Before 1986 the dissemination of the soil management information to the cotton industry was largely restricted to scientific papers (mostly unread by cotton growers) and to articles published in the Australian Cottongrower (too disjointed to give effective decision support). Advisory staff perceived that much work had been done to address the issues involved with good soil management but that it needed to be extended more effectively. From this the idea of SOILpak (package for soil management on cracking clay soils) was born.

The concept of SOILpak was to bring together soil management information into one place in a decision support package. Its aim was to help those who were unfamiliar with soils to describe their structure and then make management decisions based on this description.

Describing and rating soils according to their physical structure is an important part of the soil management process. It is a skill that is difficult if not impossible for many to acquire by just reading literature. Soil management workshops were held for consultants during the development of SOILpak to address this problem. Response from these workshops helped greatly in structuring the SOILpak manual.

This project "Soil Management Training" continued extension of soil management skills from where the SOILpak project and the early soil management workshops finished.

Objectives

There were 3 objectives to the SOIL Management Training Project:

1. Facilitate the dissemination of soil management skills within the cotton industry.
2. Promote the active adoption of SOILpak.
3. Provide feedback on users' comments to soil researchers.

Results and discussion

The Soil Management Training project was in itself an extension exercise aimed at communicating soil research results to advisers and growers within the cotton industry.

Training materials and management aids produced as part of the project were:

- **SOILpak pocket notes** - A summarised field version of the soil diagnosis chapter in SOILpak. The size of the booklet allows it to be kept in a car glove box. A waterproof field sheet was included with the booklet. (See attachment 1)

- **Identifying Soil Structure of Cracking Clay Soils Video.** The identification of structural features in soils uses many visual clues. Moving images can show details and structures that are difficult to identify in 2 dimensional still photos. This video covers ways to access soil structure and what major features to look for. The video also covers diagnosis of structure that is difficult to describe in print. A copy of the video accompanies this report.

- **A Visual Guide to Soil Structural Features of Cracking Clay Soils.** This production includes a set of 25 stereo pairs and a stereo viewer. A booklet that is part of this package describes what you are seeing in the stereo image and the available management options if you have soil in a similar state. Soil structure is difficult to capture in 2 dimensions. The 3D effect of the examples makes structural features much easier for most people to see. A copy of the booklet accompanies this report. The stereo images mentioned are available through the CRC Technology Resource Centre.

• **SOILpak stacks**: A set of software was developed for Apple Macintosh computers using the Hypercard program. Components of the program include a tillage option and costing stack that gives you options for soil management when given variables such as damage level, moisture level of soil and time remaining before planting. This stack can then link to a stack that calculates tillage operation costs.

A Gypsum - Lime expert system was also developed for Macintosh that takes into account surface ESP, clay content, Ca/Mg ratio, EC at the surface and organic matter content. The program determines if a gypsum or lime application will be necessary. It uses a rule based system to determine the likelihood of success of an application of gypsum or lime.

• **Poster displays for meetings and conferences**: A set of posters were produced to complement the set of stereoscopic images and were used at conferences including the 1992 Australian Cotton Conference.

Major presentations and poster displays	ACGRA conference 1992.
	ACGRA posters reworked for Qld Crop production conference 1992.
	ISCO conference Sydney "SOILpak - A decision support system for managing the structure of irrigated cotton soils" 1992.

Field days and workshops:

Mini workshops of usually around 10 people were conducted throughout the cotton growing regions of New South Wales and Queensland. These field days and mini workshops have been the most effective way of extending the skills required to make good soil management decisions. Assistance was given to other researchers who were running soil management workshops. An average of ten workshops a year were run with the assistance of local district agronomists and industry extension workers.

The aim of the workshops was to begin training the next user level, the owners and farm managers, while at the same time reinforcing the skills learnt by consultants, agronomists and extension staff at the first round of soil management workshops run in conjunction with the SOILpak project. They were based around consultants and a groups of their growers, and included the local government extension officer.

The most important part of this project however was the personal backup support it provided for those who were still new to soil assessment. The support allowed users to gain confidence in soil structural recognition before using it as a standard part of the whole farm decision making process. A summary of the workshops and presentations held can be found in the table below.

Workshops and major presentations summary:

	1991/92	**1992/93**	**1993/94**
Workshops:			
	Dalby 2 day Consultant (assist) Moree 2 day Consultant (assist) Cotton D.A. Workshop	Boggabri Bourke Goondiwindi Gwydir (4) Namoi (2)	Bourke Emerald (2) Gwydir (3) Namoi (3) Warren
Total	**3**	**9**	**10**
Major theme field days			Burren Junction "Silt, Salt and Stuffed Soils"

Questionnaire

At the completion of the project a questionnaire was circulated to most consultants through the Qld and NSW consultants associations and to randomly selected growers in the major cotton growing regions. Replies were received from 61 individuals in the following categories :

Cotton growers	14
Consultants	28
Corporate agronomists	9
Sales agronomists	10

The questionnaire covered SOILpak, soil management training and nutrition issues. Name and address on the replies was optional. The full questionnaire and replies can be found in Appendix 2. The questions and summary of replies relating to the soil management training project follow, the numbers in the boxes indicating the number of replies:

Training packages

8. Have you heard of soil management workshops or soil pit field days?

Yes	**53**
No	**4**

9. Have you been attended any soil management workshops or soil pit field days ?

Yes	**45**
No	**12**

10. If so how did you find the sessions? (Select 1 or more answers)

Useless	**0**
Helpful	**18**
Very helpful	**18**
I can now recognise (visually) soil structural problems	**26**
I would still want help in recognising structural problems	**11**
I gained some alternative management options	**15**
I didn't get any new ideas on soil management options	**2**

11. Was there anything not covered at that session that would have been useful?:

Negative replies = 12, Positive replies = 6

12. Have you gained any new ideas on soil management following the discussions at the workshops ?:

Positive replies = 25, Negative replies = 4

13. If more workshops were held (each of half or one day duration) would you want to attend?

1/2 day Yes	**40**
1 day Yes	**15**
No	**4**

14. Have you observed soil pits or dug with a spade to observe soil structure (or tillage efficacy) since the workshops?

Yes	**35**
No	**10**

15. Do you think you would use soil observations if you thought you had a problem with your soil (eg after a wet picking)?.

Yes	**47**
No	**3**

16. Have any of the following aids been of use (or would they be of use)?

Stereoscopic viewers, - Reference shots of good and degraded soil

Yes	**24**
No	**9**
Maybe	**14**

Pocket SOILpak - summary of field chapter from SOILpak

Yes	**26**
No	**6**
Maybe	**15**

Video reference of soil structural features

Yes	**24**
No	**8**
Maybe	**13**

Discussion

The survey indicated a good awareness of the soil management workshops and 79% attendance at soil management workshops. The result here may be biased by the number of replies from the consultant and corporate agronomist group who were integral to the running of the soil pit mini workshops with growers.

Of the 45 attendees at soil management workshops questioned, 80% indicated that the sessions were at least useful, and 57% indicated they felt confident in recognising soil structural problems. There was a significant proportion - 11% who indicated they would still require help with soil diagnosis.

Twenty six percent of attendees could not think of anything else that should have been covered and 13 % indicated that there were some topics that could have heen covered including soil chemistry and the soil as a living medium.

There is still a strong demand for more soil workshops, as indicated by the response to Question 13. It is easy to lose confidence in your soil structure recognition skills if you are not carrying out soil observations on a regular basis. If this confidence is lost, the step of observation before management may be bypassed, leading to less informed soil management decisions. The workshops covered more than just soil structure recognition skills. Soil management issues including moisture for tillage, controlled traffic and organic matter were major discussion points.

It is encouraging to see that 76% of workshop attendees had observed soil structure since attending a workshop. An even larger proportion, 81%, would use soil observations if they had perceived a potential soil problem.

The dry seasons during the term of this project have led to fewer management induced soil problems than occurred during the wet harvest years of the late 1980's. However there is now knowledge of how to deal with problems when they arise again.

Question 16 of the survey regarding the packages produced for the project indicate both a need for resource materials and a need to expose more people to the material. All these materials are available through the CRC for Sustainable Cotton Productions' Technology Resource Centre and are being promoted by it.

Conclusions, Recommendations and Application to Industry

The training of members of the industry in skills required for making effective soil management decisions has been largely successful. There is a good awareness of the soil as a resource and an understanding of management issues. There is also a core of extension personnel, government and private, who are able to diagnose soil condition and are able to assist growers and other extension personnel in soil diagnosis

The dry seasons that have occurred during the life of this project have made soil management decisions relatively easy. When wet harvests and wet growing seasons return there may be an increased demand for soil management workshops or refresher courses which should be anticipated by the Corporation.

Acknowledgments:

We acknowledge the support of the Cotton Research and Development Corporation in providing funds for the running of the Soil Management Training project. We would also like to thank district agronomists and extension personnel with NSW Agriculture and the Queensland Department of Primary Industries as well as consultants and cotton growers, for help in organising and running soil pit workshops.

References:

Daniells I. G. (1988)Update on ripping, Proceedings of the 4th Australian Cotton Conference, Surfers Paradise Qld. pp 257-263

Larsen, D.L., Greenhalgh, S.E., Daniells, I.G., McKenzie D.C. and Abbott, T.S. (1992) SOILpak - A decision support system for managing the structure of irrigated cotton soils. Proceedings 7th ISCO Conference Proceedings. pp 718 - 722

Appendix 1

REQUESTED and APPROVED BUDGET

Item	1991/92 Approved		1992/93 Approved		1993/94 Approved	
	Original estimate $	Now requested $	Original estimate $	Now requested $	Original estimate $	Now requested $
STAFF						
Salaries	34,632		35,184	36312	35,740	36,416
Other costs						
Pay-roll tax (7%)	2,424		2,463	2,541	2,502	2,549
Worker's insur (2.5%)	866		880	907	894	910
Leave loading (1.5%)	519		528	544	536	546
Super. contrib. (3%)	1,039		1,055	1089	1,072	1,457
TOTAL STAFF COSTS	39,480		40,110	41,393	40,744	41,878
TRAVEL						
TOTAL TRAVEL	2,500		2,500	2,500	2,500	2,500
OPERATING						
Computing consumables	1,000		1,000	1,000	1,000	1,000
Other consumables	3,000		3,000	3,000	3,000	3,000
Motor vehicle maintenance and operating						2,500
TOTAL OPERATING	4,000		4,000	4,000	4,000	6,500
CAPITAL						
TOTAL CAPITAL	nil		nil	nil	nil	
TOTAL REQUESTED	45,980		46,610	47,893	47,244	50,878

Estimated income from project: nil

Appendix 2

SOILpak and Soil Management Training survey and results:

1. Do you perceive potential problems with soil structural management that you don't have answers too?

Yes	22
No	3
Not at this stage	30

2. Have you heard of the SOILpak manual for cotton soil management?

I have a copy	36
I have heard of the manual	19
No	2

3. If you have access to a SOILpak manual, have you looked at the it over the last 3 years?

Yes	36
No	10

3a **if so** have you used it :

as a quick reference for management options	22
to help guide you through soil pit observation	18
general interest	26
other(please specify)	-

see reply compilation page 12

3b. Has SOILpak been useful in providing the answer to these queries ?

	26
No	0
Partly	11

please state reasons:

see reply compilation page 12

4. What do you think of SOILpak ?(you may select more than one phrase)

Useless	2
Helpful	23
Very helpful	16
Time consuming	5
Quick	6
Needs a lot more work:	1
Needs a bit more work:	16
No further development required	2
Others:	1

5. Please indicate your reaction to the following chapters (**C** = confusing, **I** = interesting, **R** = revision needed **U**= useful), you may select more than one for each chapter:

Rating	C	I	R	U
Ideal soil for cotton		13	1	17
Harvesting on wet soil	1	6	1	24
Options after a wet harvest		6	2	24
Options after a dry harvest		11	2	15
Applying N to cotton	3	6	7	13
Nursing a cotton crop on a damaged soil	2	10	2	16
Clues to soil structural condition		11	1	18
Digging a soil pit		3		28
Soil pit observations		1	1	27
Determining soil moisture before tillage		8	2	21
Using a neutron probe to detect compaction	2	7	4	19
Chemical tests and soil structure	2	9	2	17
Alternatives to the soil pit		8	3	17
Improving soil structure		9	9	20
Avoiding soil problems		7	2	21
Overview of Australian cotton soils		14	2	12
Compaction, smearing and their effects on plants		9	1	21
Organic matter		8	4	19
Clay minerals		12	1	15
Sodicity and salinity	1	6	3	19
Environmental issues		11	5	8
The soil pit inspection sheet.		7	3	20
Agfact: Soil Management for irrigated cotton		6	1	21
Agfact: Improving soil structure with gypsum		8	1	21

6. Please indicate chapters you would like to see added when SOILpak is revised:

Stubble management,	36
Salinity prevention,	30
Efficient water use under dryland conditions,	25
Erosion control,	17
Regional problems (eg Emerald, Bourke management of silty soils,	11
Site selection & Landforming strategies	15
Soil related environmental problems - (eg nutrient export via plant material - subsoil densification due to clay movement),	19
Details of available soil management equipment (eg tillage gear, mulchers, gypsum spreaders)	21

7. Are there any other topics that could make it more useful to you as a soil reference?:

see reply compilation page 13

Training packages

8. Have you heard of soil management workshops or soil pit field days?

Yes	53
No	4

9. Have you been attended any soil management workshops or soil pit field days?

Yes	45
No	12

10. If so how did you find the sessions? (Select 1 or more answers)

Useless	-
Helpful	18
Very helpful	18
I can now recognise (visually) soil structural problems	26
I would still want help in recognising structural problems	11
I gained some alternative management options	15
I didn't get any new ideas on soil management options	2

11. Was there anything not covered at that session that would have been useful?:

see reply compilation page 14

12. Have you gained any new ideas on soil management following the discussions at the workshops ?:

see reply compilation page 14

13. If more workshops were held (each of half or one day duration) would you want to attend?

1/2 day Yes	40
1 day Yes	15
No	4

14. Have you observed soil pits or dug with a spade to observe soil structure (or tillage efficacy) since the workshops?

Yes	35
No	10

15. Do you think you would use soil observations if you thought you had a problem with your soil (eg after a wet picking)?.

Yes	47
No	3

16. Have any of the following aids been of use (or would they be of use)?

Stereoscopic viewers, - Reference shots of good and degraded soil

Yes	24
No	9
Maybe	14

Pocket SOILpak - summary of field chapter from SOILpak

Yes	26
No	6
Maybe	15

Video reference of soil structural features

Yes	24
No	8
Maybe	13

17. Do you perceive problems with cotton nutrition that you don't have answers too?:

Yes	37
No	4
Potentially	12

18. Please list topics on soil nutrition that could be useful to you

see reply compilation page 15

19. Rank (**1-7**) your preference for extension material :

Numbers scoring 1,2,3	***1***	***2***	***3***
Agfact series	14	15	9
Book	6	4	9
Computer package	5	2	3
Manual with replaceable pages	23	6	7
Video	6	5	8
Private Consultant system	9	5	5
District Agronomist system	8	7	3

20. Tick the categories that apply to you

Cotton grower	14
Consultant	28
Corporate Agronomist	9
Sales Agronomist	10
Researcher / Funded Extension Personnel	

Region:_____

(Name and address Optional)

Name:_____

Address:_____

_____

_____

Feel free to make any comments on the availability of soil or nutrition information:
see reply compilation page 16

Replies to written questions

Question 3 Note: What other purpose have you used SOILpak for:

Background Knowledge to Sodicity Salinity.

To help explain problems and remedies to farmers.

Question 3b: The reasons SOILpak has been useful in answering queries:

RE - use of chisel ploughing to rectify soil problems - what to expect as a result.

It's clear logical and well laid out.

Used own interpretations as well as those of SOILpak.

With the dry harvests we have had - I don't think the interest is as much as it was 4-5 years ago.

Reminder of the alternatives to look for.

Yes gives good insight into recognising problems.

More helpful to farmers.

Technical information relating to salinity and soil structure.

Gave me a series of ideas to combat our particular problem here.

Good but improves as a tool as practical experience improves.

A good practical guide.

Question 4 note What do you think of SOILpak - other:

Haven't had sufficient exposure to it but believe the concept is very good.

Excellent.

Depending on what you are using it for.

Would be great if it looked at management of other soil types ie Red earth, ,silty loam sand.

Promotion of the concept needs to be improved.

The condensed field guide is on the right track.

I would like to see the latest version for further comment. My version from 1989.

I haven't seen it yet!

Would like more reference to dryland soils - Brigalow/belah - Bimble Box ridge soils- Heavy plain clays.

May need shortening or more to the point.

Good for those who need educating.

It could possibly be expanded to be a basic soil and water bible for cotton growing but this is beyond your present version - where to stop!

Time consuming when using it in the field.

Question 5 Extra notes on indicating reaction to existing chapters:

Haven't seen the manual.

I didn't realise how useful the manual was until your questionnaire forced me to re-read and assess it.

Others I do not have.

No comment without seeing the latest version.

Applying N to Cotton - need to explain how to calculate N requirement from soil test levels Salinity in cotton areas- paper 94 cotton conference would be useful. Appendix 3 Checking for Heliothis pupae- When more work is done on survival of pupae under different conditions and cultivating practices and moisture levels- this chapter could be expanded.

Question 7. Are there any topics that would make it a more useful soil reference?

A section on cotton nutrition for the predominant soil types encountered throughout Qld and NSW Include foliar sprays and deficiency situations.

No.

Mulching options Surface crusting management ie organic matter EDA etc Sealing soil water management (Ie silty soils).

no.

There is still a lot of debate on whether to middlebust or not.

Including more info on rotation crops and benefits of these crops on nutrition/ structure & VAM would be of interest to me.

How to measure soil moisture in dryland farming (not on irrigated soils) prior to planting and relating to previous years- What is a full moisture profile?

Control of over wintering pupae ie identification, minimum tillage operations to control.

Soil test interpretation including common conversions eg ppm-Meq/100g etc.

Reservoir placement.

Minimum tillage equipment for areas with high amounts of trash and stubble (eg coulters on planters etc) methods of handling stubble pre plant.

Could add some basic info on nutrition role of major and minor nutrients. Water quality re irrigation.

Question 11. Training Packages, Was there anything not covered in the session that would have been useful?

9 **NO** replies.

Not really - found it very informative & helpful.

Not Really - just repetition to enforce ideas /understanding.

Needed more time on the soil pit observations - one gets rusty in between inspections.

Don't assume all people work with cracking black soils.

Soil Chemistry.

No it covered everything we requested.

Probably heaps but you can only do so much in one session. Teaching people to recognise and understand what they are looking at is still very important.

Maybe soil as a living medium, maybe more info on the "ideal" soil on microfauna and their role - An Agfact on the "ideal soil " could be useful".

Question 12 Have you gained any new ideas on soil management following the discussions at the workshops?

19 **YES** replies.

2 **NO** replies.

Yes - probably just broadened knowledge.

No new ideas - updated on old ideas.

Yes especially if there were a number of people at the day.

Use of crops to improve structure eg Faba Beans.

Must watch compaction and Do something about it.

Dryland moisture management.

No but have better recognition and diagnostic skills.

Importance of reduced tillage.

Question 18, Please list topics on soil nutrition that could be useful to you.

How to rectify nutritional problems (and deficiencies) following adverse weather conditions ie very waterlogged , extended cloud rain etc probably looking at foliar sprays to maintain nutritional status and hopefully preserve the fruit load depending * ***it occurs.

Cation exchange effect on nutrition of all cations and imbalances In season diagnosis for high yield and hailed cotton.

Micronutrients especially Zn K & P.

Potassium
Potassium
Potassium.

Placement of trace elements.

Potassium Phosphorus.

All.

Nutrient interactions pH nutrient interactions Nutrient uptake monitoring.

N-use & uptake & fate K, P, S, Zn.

Effect of rake and burn. Effective stubble management both cotton and wheat.

Foliar applied trace elements - Any good?

Potassium and its effect on Cotton senescence.

K, Trace elements.

Potassium Impact of soil ameliorants on soil salinity.

Value of Foliar fertilisers, Responses to Zinc and potassium.

K, Zinc availability.

Nitrogen loss.

K, Micronutrients.

Phosphorus, Potassium, Zinc, Iron, Copper.

Fertiliser placement.

Salinity, available N present in the soil on an accurate basis.

Nutrient ratios and what would be "ideal".

We still haven't got consistent & useful soil N testing right yet.

N leaching - placement of fertiliser.

Potassium, sulphur, Zinc (in marginal soils).

Ca/B relationship regard fruiting, P responses or the lack of them. Split application of N. (Main +2 to 3 minor) Sulphur levels in relation to N uptake.

Zn and S and their role, they seem to be consistently deficient in these cracking and self mulching clays.

Zinc Potassium.

Micro element nutrition Zn Cu Br P K Sulphur.

Detailed work on N availability with regard to soil type.

Sulphur Potassium.

Soil test interpretation, placement of sulphur.

K & P Deficiencies.

Trace elements in high pH soils.

Potassium uptake and levels in the soil and plant - Micronutrients.

Potassium.

Phosphate zinc and sulphur.

Sulfur/Potassium etc with current pulling raking and burning methods. Address zinc nutrition.

Premature senescence. As listed before basic info on the elements and maybe how they effect quality. info on the nutrient cycle for each element. I think K is going to become more important. More soil showing lower levels.

Interactions between nutrients.

Micronutrients, N availability.

Feel free to make any comments on the availability of soil or nutrition information:

Need more & updated and packaged.

Please send me any additional information that I obviously don't have & Any updates in the future. This would be greatly appreciated.

Soil pits are great but need to involve more farmers they can see what you have told them.

Great reference but I cannot believe that we allowed SOILpak to become out of print, very disappointing to growers and researchers involved no doubt more workshops would be great.

The SOILpak system has been one of the best value for money bits of extension/ research for the cotton industry.

Strip trials should be undertaken again in the Macquarie Valley to prove or disprove claims of fertiliser manufacturers.

Please forward manual - obviously we are prepared to pay for it.

Couldn't answer a lot of the questions as have not had a copy of the manual.

I think the availability of soil info is excellent. SOILpak is an excellent diagnostic tool that only needs minor refinement,

• Needs to be a reminder every year sent in the mail about soils.
• Should be an annual soil pit day, preferably same week of the month so growers can plan for it yearly ~~I have a real problem, I am not satisfied with "A full moisture profile" or part of. I/we need a system where a Dryland farmer can quantitatively measure it (and not a Neutron probe- I've been doing it for 5 years and it is not practical because of tractors etc.).

Your survey is well laid out and thoughtful.

A plain English guide to understanding soil tests and relevant measures and where to get the chemicals and equipment to do the SOILpak tests would be a useful piece of text.

Can this type of information be made available to the dryland growers (cereals etc) and where do I get hold of a copy of SOILpak?

Getting information to be able to solve the trace element problems is impossible from all the sources I have tried.

We do not have a copy of SOILpak manual in our office would it be possible to send us one.

The info is generally available in proceedings and conferences , journals and magazines - The beauty of having it in the like of SOILpak manual is that it is more accessible and useful. These manuals and Agfact series are particularly useful for new people in the industry and there are many of those each year. As a general issue we need to deal with soils as a biological medium and handle with care.

Appendix 3:

Publications and productions associated with 'Soil Management Training'.

Booklets and Training aids:

Larsen D.L. (compiled by) (1993) SOILpak Pocket Notes: NSW Agriculture.

Larsen D.L. (1994) A Visual Guide to Soil Structural Features of Cracking Clay Soils - Stereoscopic slide pairs and descriptions

SOILpak Hypercard stacks.(1992) Apple Macintosh compatible software.

Videos

Identifying soil structure of cracking clays (1994) Produced by NSW Agriculture communications unit. Script Larsen D.L.

Conferences and Technical Bulletins

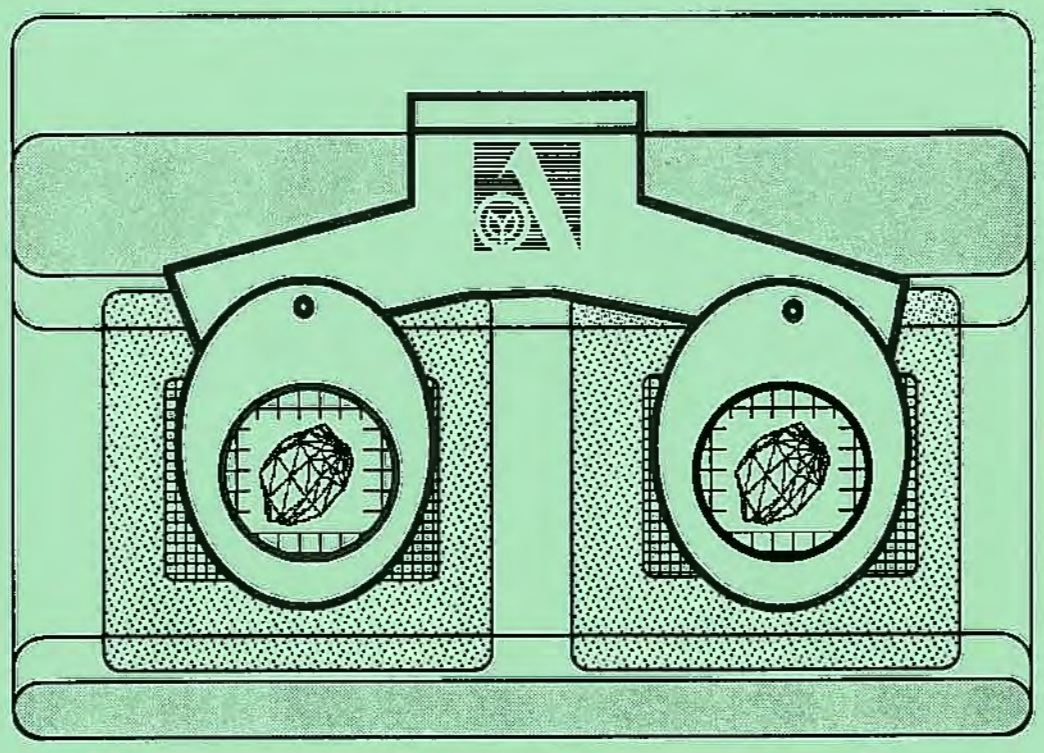
Larsen, D.L., Greenhalgh, S.E., Daniells, I.G., McKenzie D.C. and Abbott, T.S. (1992) SOILpak - A decision support system for managing the structure of irrigated cotton soils. Proceedings 7th ISCO Conference Proceedings. pp 718 - 722

Abbott, T.S. Daniells, I.G., McKenzie, D.C. and Larsen, D.L. (1992) SOILpaks: Soil management decision support systems for sustainable Farming. Conference on Decision support systems for farming Wagga Wagga

Larsen, D.L. and Daniells I.G. (1992) Soil Management Training - Continuing soils extension. Proceedings of the 6th Australian Cotton Conference Broadbeach Qld. pp 51-53

Daniells, I.G., Larsen, D.L., McKenzie, D.C, Anthony, D, and Brooks V.J. SOILpak: increasing awareness of the soil resource (1992) Proceedings of the 6th Australian Cotton Conference Broadbeach Qld. pp 55-57

A Visual Guide to Soil Structural Features of Cracking Clay Soils



Including examples of the SOILpak loose and firm soil rating system for irrigated cotton.

David Larsen
Australian Cotton Research Unit
Narrabri
Funded by Cotton Research And Development Corporation

A Visual Guide to Soil Structural Features Found in Cracking Clay Soils.

Classified with the SOILpak Rating System

Compiled by David Larsen

NSW Agriculture

1994

Funded by Cotton Research and Development Corporation

NSW Agriculture

Contents

Importance of soil structure

The soil profile is a store of nutrients and water, and provides support for both plants and machinery. Consider these roles when observing soil structure.
The development of a plants is largely determined by the amount of water and nutrients that they can extract from the soil. Water and nutrient extraction are proportional to root development and root health. Soil structure can greatly affect this water and nutrient extraction.

The ability of the roots to acquire nutrients is affected by their biological activity. Plant roots are living organisms and require oxygen to function. Waterlogging, which is worsened by poor soil structure, leads to the depletion of oxygen in the soil. As the plant roots and soil organisms use the oxygen, diffusion of oxygen from the surface is slowed by water filled pores. In the case of badly damaged soil, diffusion is further slowed by the lack of continuous interlinked pores from the surface to the rooting zone. The drainage and aeration of the soil can be inferred by observing soil structure.

Root development is also affected by high soil strength below the surface. Areas of high soil strength can effectively lock out foraging roots making the moisture and nutrients stored in these areas unavailable to the plant. Soil strength can be inferred by observing soil structure.

The moisture content of cracking clays also greatly affects soil strength. Adequate moisture through rain or irrigation can lower the strength of the soil enough for plant roots to penetrate compacted layers. However the amount of root penetration in poorly structured soil will be less than for a well-structured soil and the problems of waterlogging will still apply. Soil strength will inhibit root growth at higher moisture levels in a poorly structured soil than in a well-structured soil. This is part of the reason that there is less available water for plant growth in a poorly structured soil.

A change in soil moisture content, following water extraction by plant roots, increases the internal stresses within a soil. This stress encourages the formation of cracks that in turn become new pathways for root penetration. Structural repair of degraded soils can be brought about by the promotion of these swell-shrink cycles.

Whenever you are observing soil structural features think about them in terms of pathways for root development. Soil with many cracks and pores from the surface to depth should be good for root development and soil drainage. Soil that consists of one massive block with few pores or cracks is likely to restrict root development.

Cracks are not always seen as open spaces - their existence has to be deduced from the appearance of clod faces, especially in swollen (ie moist or wet) soil.

In most field situations where machinery is used, and even in some pasture situations, you will come across a mixture of structures indicating good and poor soil structure at the one site. Some areas may be degraded (eg wheel tracks or even the surface of a trampled pasture field), whereas nearby areas may be in excellent structural condition. Therefore sampling location needs to be carefully defined.

This booklet and stereoscopic images have been compiled to illustrate some of the common structures found in cracking clay soils. The booklet is complementary to the SOILpak manual and uses the SOILpak rating system for loose and firm soil to rate individual soil clods and parts of soil profiles.

The SOILpak score used to rate the soils in these examples refers only to the soils architecture, ie its structural form. Other components of the soil for example the soil stability in water, soil salinity, mychorrizal levels, presence of disease and water or nutrient status can adversely affect plant growth even when soil structural form is excellent.

How to use this stereoscopic guide:

The SOILpak scoring system for loose and firm soil (reproduced in this booklet on pages 5 and 6) suggests 3 basic rating levels that can be used; **0** for poor structure, **1** for moderate structure (a mixture of good and poor structure) and **2** for good structure. It also suggests that you can subdivide these ratings as you become more experienced. This subdivision of rating is **subjective** and will require you to make a division of the rating based on the soil's visible characters. Take into account the porosity, clod shape, clod size, and clod face appearance of the soil.

Table 1: Basic 3 part scoring system of SOILpak and the equivalents used in this booklet

Basic SOILpak score	**Poor** 0							**Moderate** 1							**Good** 2						
Subdivision of SOILpak score used in this booklet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0

Very poor structure .....Some barriers to root growth ..... Very good structure

There is scope to subdivide the basic 3 part SOILpak scoring system into smaller units after experience has been gained. This is difficult to describe in words however the stereoscopic slides give good examples of the differences that can be found within one major grouping of the SOILpak score. In the example given below the soil rated as **F1** In the SOILpak 3 part system is subjectively rated at **F0.7** in the subdivided system by weighing the components of porosity, clod shape, ped size, and clod face appearance.

Table 2: An example of a subdivision within the SOILpak rating of Firm1

	SOILpak Score **Firm 1** (F1) (moderate structure)	**Subdivided SOILpak score** **Firm 0.7** (F0.7) (moderate structure bordering on poor)
General	Some natural separation planes but distinct force needed to part the blocks, fracturing taking place mainly along the line of force applied to produce angular corners and mainly non-porous internal surfaces.	Few natural separation planes but distinct force needed to part the blocks, fracturing taking place mainly along the line of force applied to produce angular corners and mainly non-porous internal surfaces.
Porosity	Porosity rating mostly 1.	60 % 1 and 40%with 0.
Clod shape	Mixed shapes.	Mixed shapes but 40% platy.
Clod or ped size	0.5 cm - 5 cm towards the soil surface, larger at depth.	Mostly 4-5cm.
Clod faces	Occasional shiny faces.	Present but small and isolated.

The following examples of individual soil clods and soil profiles show some of the more important structural features you will encounter. As well as pointing out features the soils have been rated according to the scoring system for loose and firm soil used in the SOILpak β manual (Chapter C3). The illustrations and explanations are produced as a guide to the stereo photos included in this kit. Due to the 3 dimensional nature of the soil

structure illustrated the best results will be obtained if you use these examples in association with the stereo photograph pairs and viewer provided.

To use the viewer first centre the slide pairs in the viewer frame. Adjust the lenses in or out to give the best focus for your eyes. Close one eye and ensure the image you see is centred in the viewer. Close that eye and open the other eye without moving the viewer then adjust that eyepiece right or left to centre the second image. Open both eyes and the slides should merge into a 3 dimensional representation of the soil structures. See Table 3.

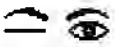
Table 3: How to use the stereo viewer

1. Select slide.

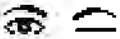
2. Centre slide pair in viewer and look toward a light source (blue sky is good)

3. Close one eye and adjust lens left or right to centre image.

Move lenses in or out for focus.



4. Use the other eye and centre its image by moving the lens if necessary.



5. Open both eyes [1]

6. See explanation in this manual

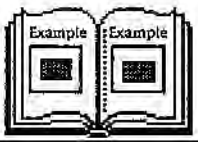


Table 4 lists examples of specific structural features. Table 4 also defines whether the structure is an indicator of root favourable (good) or root unfavourable (poor) structure.

Table 4: Examples of Structural Features

Structural feature	Structural condition for cotton root growth	Example number (Best example first)
Angular polyhedral clods in faces	Good	1, 2
Cracks	Good	17, 19, 24, All
Polyhedral	Good	1, 2
Porosity	Good	15, 1, 2
Shiny faces	Good	1, 2, 7, 12, 16
Conchoidal	Poor	4, 8
Flinty	Poor	5, 10, 19, 17
Massive	Poor	9, 23, 8, 10, 20
Platy	Poor	8, 12, 3, 16
Root bending	Poor	25, 23, 18
Roots external to soil mass	Poor	5, 6, 8, 9,
Smooth faced	Poor	6, 4, 8, 12, 10

[1] Not all people are able to see 3D images. If you are one of those who cannot get the 3D effect then the slides, being of better definition than those in this booklet, will still illustrate the soil structural features well.

Table 5 lists the examples individual clods and whole profiles, ranging from the best to worst soil structure. The rankings for profiles integrate the area affected by structural problems. For example a profile with a small area of highly compacted soil in a furrow but good soil condition in the majority of the profile ranks higher than a profile that is moderately compacted throughout.

Table 5: Rankings for structure

	Example number																			
	Best structure				⇨							⇨	Worst stucture							
Individual clods	1	2						7	3				10			9	8	6	5	4
Whole profiles	20		21	23	24		25	22		14		19	13		15	17	18		16	

The following table (Table 6) lists examples that show the effects of management on soil structure.

Table 6: Examples of management effects:

Management	Example number
Irrigation systems differences	20 and 16
Rotation Biological ripping	21, 22
Moved hills	18, 15

A number of the examples show more than one soil structural rating. Table 7 shows which examples to refer to for a given structural rating.

Table 7: Example numbers for various SOILpak ratings

Loose soil:

L0.0	L0.1	L0.2	L0.3	L0.4	L0.5	L0.6	L0.7	L0.8	L0.9	L1.0	L1.1	L1.2	L1.3	L1.4	L1.5	L1.6	L1.7	L1.8	L1.9
			10										14	19	23	18		20	

Firm soil:

F0.0	F0.1	F0.2	F0.3	F0.4	F0.5	F0.6	F0.7	F0.8	F0.9	F1.0	F1.1	F1.2	F1.3	F1.4	F1.5	F1.6	F1.7	F1.8	F1.9
-	4	8		3	16	11	-	7	-	14	-	15	-	19	23	11	24	1	20
	5	13	14	10		12		20				16		21				2	
	6	15	18	11		16		23				17		22				20	
	9	17	19	13		21		25				18		25					
				15								19							
				17								25							
				22															
				25															

The SOILpak rating system:

Table 8 suggests three ratings of soil structure for loose soil and three ratings for firm soil. Use these as a guide and feel free to subdivide the ratings (e.g. Loose 1.9 for a structure that is not quite ideal). Parts of the photos are rated according to the following system. Note that a soil or part of a profile with larger number will be in better condition than one with a lower rating number.

Table 8:The SOILpak rating system used to describe the stereo photos.

Loose soil: loose seedbed, loose tilled layer (even if cloddy), loose surface mulch; soil that can be removed by scraping with the hand, a trowel or a spade (not digging). N.B. loose soil may be found at depth in association with salinity.

	Loose 0 (L0) (poor structure)	**Loose 1** (L1) (moderate structure)	**Loose 2** (L2) (good structure)
	Moist soil		
General	At least half the soil mass is large, dense and massive clods. The faces of these clods will be finely grained.	At least half of the clods present as larger compound aggregates which can be parted by hand into their constituent natural aggregates.	Comprised wholly of natural aggregates with a range of sizes appropriate to the depth from the surface. These aggregates may be separate or compound (very easily parted by hand into their constituent natural aggregates). When broken the aggregates will separate along many angled often shiny faces. If shiny faces are not evident the soil will have many obvious pores and will be friable.
Porosity	Porosity rating mostly 0.	Porosity rating mostly 1.	Porosity rating mostly 2.
Clod shape	Massive, angular blocky with sharp edges or conchoidal.	Mixed shapes.	Polyhedral or sub-angular blocky.
Clod or ped size	Size of the dominant fraction is usually > 2 cm.	Size of the dominant fraction is between 0.5 cm and 2 cm.	Size of the dominant fraction is usually < 0.5 cm.
Clod faces	Dull.	Occasional shiny faces.	Larger units have shiny faces.
	Extra notes for dry soil.		
	A large proportion of large hard flinty clods with sharp edges.	As above, however compound aggregates will be firmer - perhaps requiring a tap with an implement to assist in parting them. A proportion will be flinty.	As above.

Table 8: **continued.**

Firm Soil: soil below the tilled layer or below the natural loose mulch; aggregates fit together along faces and it requires force to lever them apart. N.B. Firm soil may be found at the surface in association with crusting.

	Firm 0 (F0) (poor structure)	**Firm 1** (F1) (moderate structure)	**Firm 2** (F2) (good structure)
	Moist soil		
General	Difficult for spade or knife to penetrate: lumps of soil levered off made up of large tight fitting blocks. These fracture along the lines of force applied in any direction into units with sharp right angled corners. Finely grained and even internal surfaces with no pores visible or no sub aggregates projecting from the fractured surface. Breaks like heavy dough or plasticine. Low number of new roots.	Some natural separation planes but distinct force needed to part the blocks, fracturing taking place mainly along the line of force applied to produce angular corners and mainly non-porous internal surfaces.	Parts readily into porous sub-units along natural fracture planes which have a smooth and shiny face, or the fractured faces may be polyhedral with the exposed internal surfaces multi-faced and with subangular units protruding. Good penetration by new roots.
Porosity	Porosity rating mostly 0.	Porosity rating mostly 1.	Porosity rating mostly 2.
Clod shape	Massive, platy or conchoidal.	Mixed shapes.	Polyhedral, subangular blocky or lenticular.
Clod or ped size	Usually > 5 cm towards the soil surface, larger at depth.	0.5 cm - 5 cm towards the soil surface, larger at depth.	Usually < 0.5 cm towards the soil surface, larger at depth.
Clod faces	Dull.	Occasional shiny faces.	Shiny.
	Extra notes for dry soil.		
	Requires a very strong blow with an implement to break the blocks, revealing a flat dull grainy surface with angled corners. Flinty.	As above but more force (a firm tap with an implement) required to part the blocks.	You may need to tap the blocks lightly with an implement to part them.

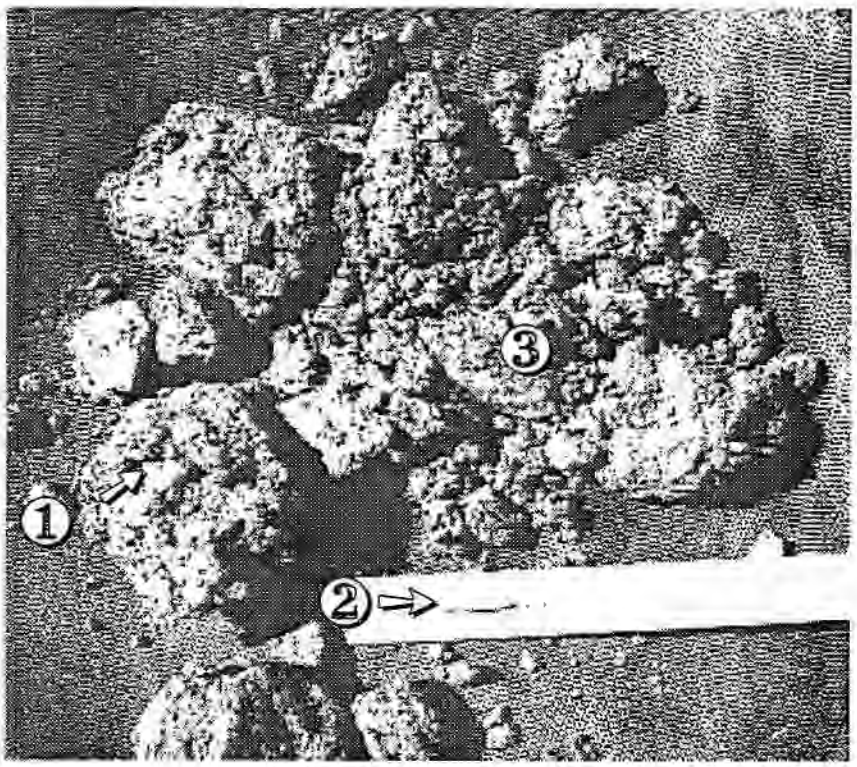
Example 1: Moist soil in excellent structural condition

Key Words: Shiny faces, Polyhedral aggregates, Rod test, Plastic limit +.

This soil sample has excellent structural form. The soil is very moist and easily forms a 3mm rod when rolled between the fingers.

This sample was taken from a depth of approximately 25-30 cm below some very badly compacted soil .

SOILpak rating **F1.8.**



Note:

① Shiny faces on very well structured soil are enhanced by high moisture content.

② Soil is wetter than the plastic limit (PL+) and easily forms a rod when rolled between the fingers. i.e. too wet for tillage.

③ Polyhedral aggregates.

Management options:
This soil is in very good structural condition but it is moist and therefore very vunerable to damage by compaction or smearing. Keep off it if possible. If the soil needs to be worked, only do so when the soil is dry enough to shatter.

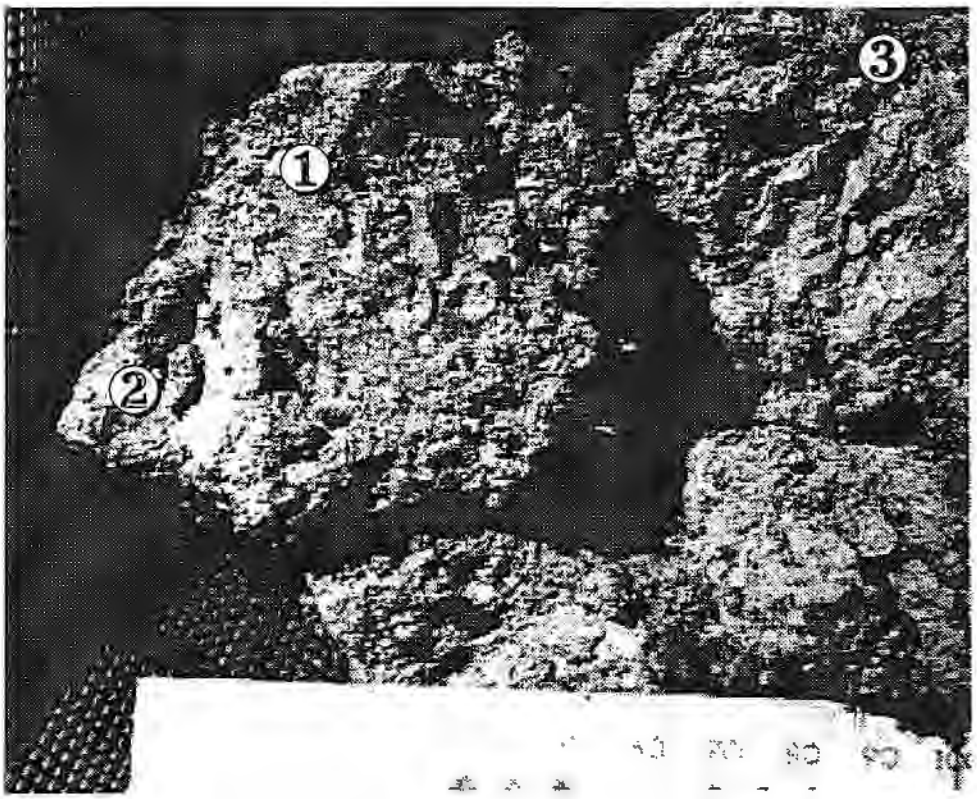
Example 2: Soil in excellent structural condition

Key words: Shiny Faces, Small aggregate size, Polyhedral, Lenticular

This example is typical of reactive sub soils (below 20 cm). The soil is in exellent structural condition.

The soil was wetter than the plastic limit at the time of photographing which highlighted their very shiny faces.

The soil would be classed as a **F1.8 - F1.9** in the SOILpak scoring system.



Note:

① Small aggregate size.

② Shiny faces - (almost every angular face is shiny).

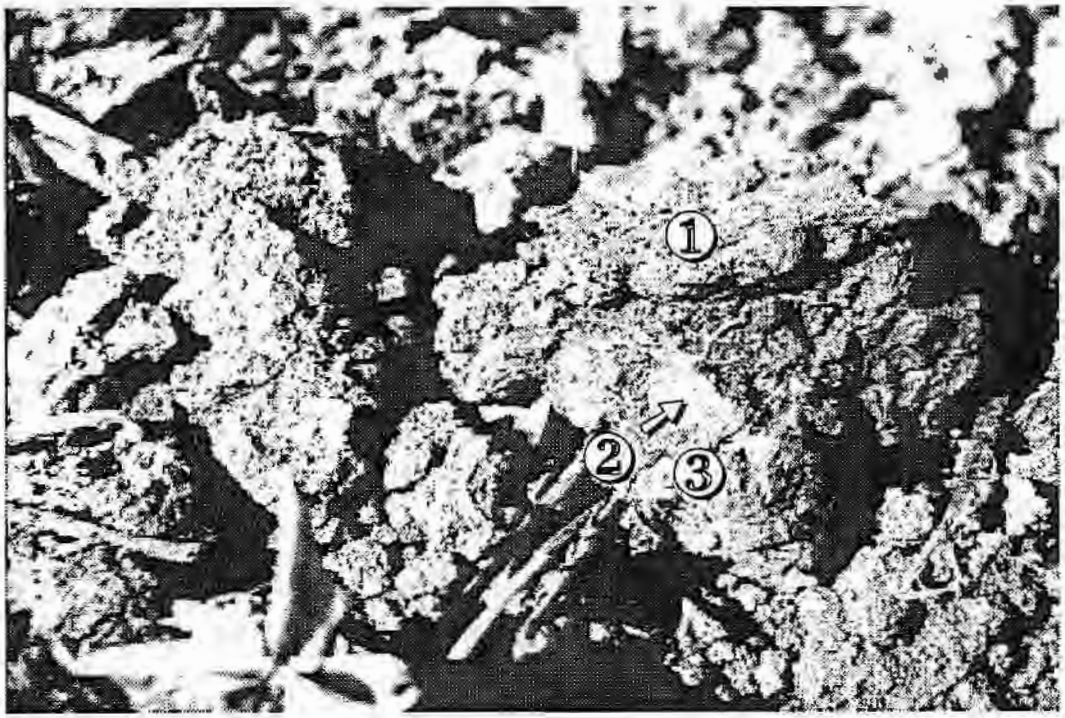
③ Polyhedral and lenticular clods.

Management options:
This soil is in very good structural condition but it is moist and therefore very vunerable to damage by compaction or smearing. Keep off it if possible. If the soil needs to be worked, only do so when the soil is dry enough to shatter.

Example 3: Dense clods altering root shape

Key Words: Platy, Flattened roots, Smooth

A compacted clod from a brown cracking clay soil. This clod from below the plant line shows how roots have to pass around rather than through compacted soil. As well as the extra time and energy required for the plant to do this it also means that there will be little extraction of nutrients from this zone of the soil. Rate the clod at **FO.4** as it size is less than 5 cm and there is some internal cracking.



Note:

① A platy structure on the top of the clod together with roots following the horizontal face of the clod.

② Flattened roots following the outside of the clod.

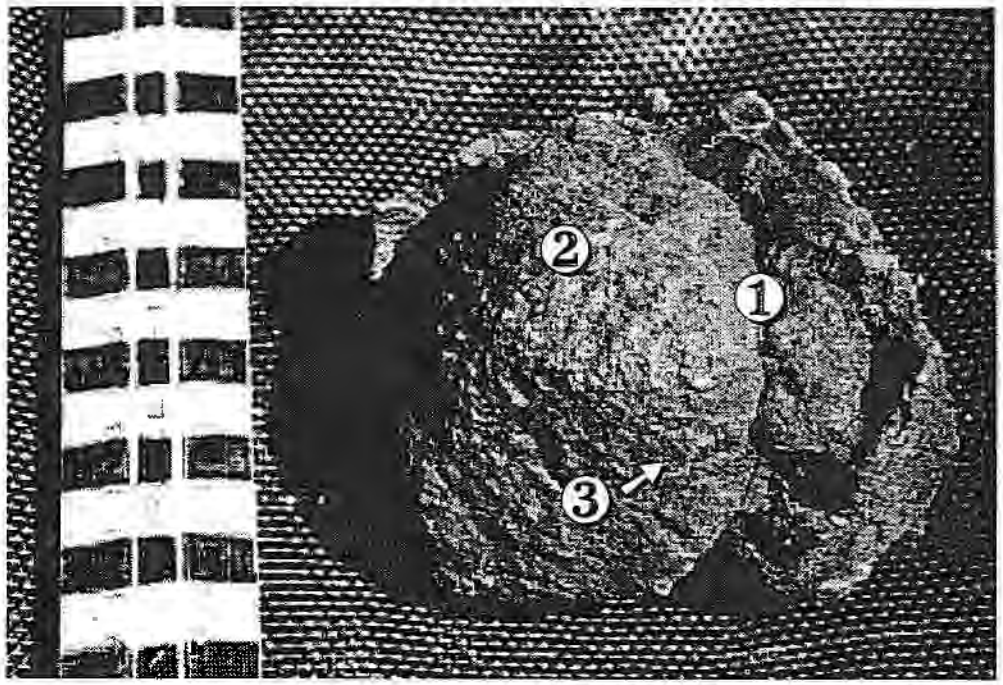
③ A flat smooth face.

Management options:
This clod is directly under the plant line and is not cracking to a great degree despite good root activity around it. It would help if the block was fractured mechanically. Enough disturbance to remove root growth limitations may be achieved by middle busting when the soil is dry.

Example 4: Conchoidal (Cup & Ball) shaped clod

Key Words: Conchoidal, Smooth faced, Platy.

Clods like this are thought to be produced when a relatively dry compacted clod is forced into moist soil. This formation of clod is normally associated with wheel tracks and trafficking while wet.
See also Example 8 for a conchoidal fracture within a compacted clod
SOILpak score `FO.1`.



Note:

① Rounded shape of the clod with few angular faces.

② Finely grained dull face typical of compacted clods.

③ Roots that are present appear to be running along the face of the clod - no roots emerge at angles to the surface.

Management options:
In the Furrow: This clod is showing extreme signs of compaction due to wet trafficking. If the soil has this type of compaction under the furrow as opposed to platey structures be very aware of potential compaction in the hill or shoulder.

In the shoulder: A bad sign - almost certainly compaction will be spreading under the plant line.

In the plant line: BEWARE. This level of compaction has the ability to seriously reduce yields. Try a rotation crop that will dry the soil followed by tillage if necessary when the soil is dry. If a cotton crop is grown don't expect optimum yields even if watering cycles and nutrients are increased.

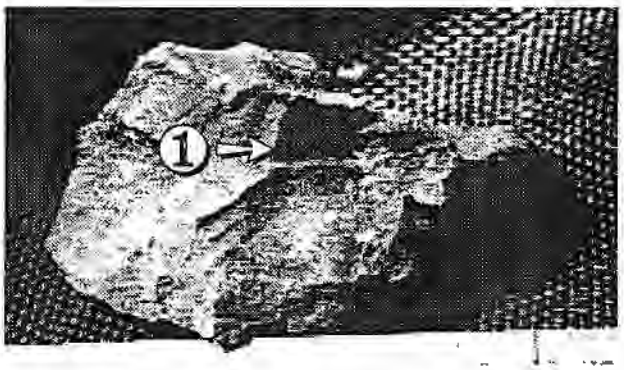
Example 5: Highly compacted flinty clod

Key Words: Extreme compaction, Flinty, External roots.

An example of a highly compacted clod found 10 cm below a wheel track. The flat dull faces and lack of pores indicate little internal structure in the clod and consequently only a small chance of root penetration.

In the slide you will notice that very fine hair roots are present but follow the outside surface of the clod.

Clods in this condition may not be that uncommon in wheel tracks however their presence high in a bed shoulder or under the plant line is cause for concern.



Note:

① Sharp angular corners and flat dull faces are a feature of a highly compacted clod. SOILpak Rating `F0.1`

Management options:
Clod directly under wheel track only: little cause for concern unless you are planning to destroy then rebuild hills.

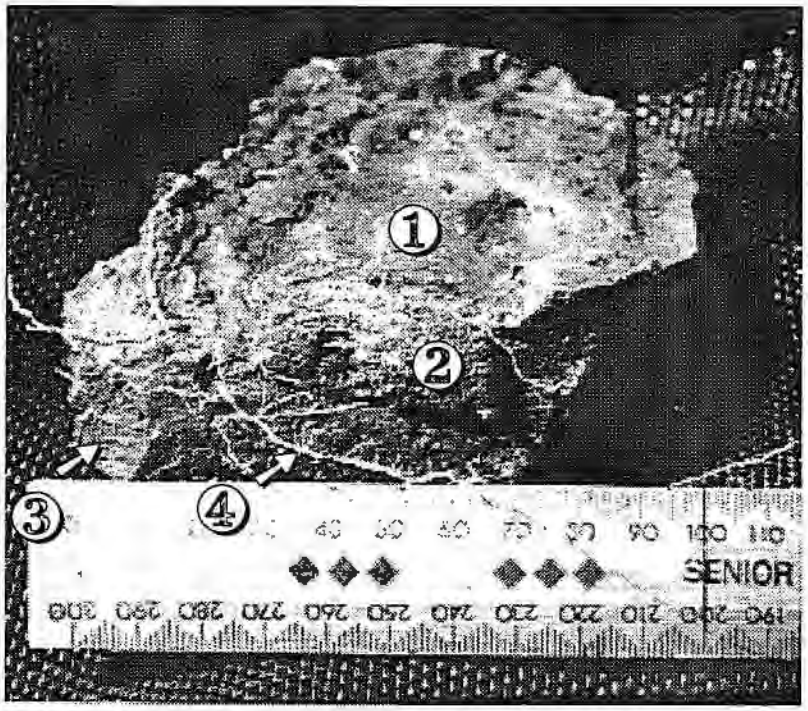
Clod high in bed shoulder: A layer of clods like this example has the potential to limit water inflow.

Clod directly under plant line: A clod in this position has the potential to limit root growth. Plants growing directly over this clod would almost certainly have to bend their roots to bypass this layer. Till below the level that these clods are found to allow exposure and breakdown, especially if the layer is broad.

Example 6: Highly compacted clod

Key Words: Smooth faced, Platy, Blocky, External roots, Flattened roots.

This is a photo of a highly compacted clod taken from beneath an old roadway. The faces are smooth with few pores. Note that the roots that are present on the outside face of the clod are flattened.



Note:

① The clod is a large platy block (larger horizontally than vertically) and has square edges. It is larger than 5cm in size (10 cm in diameter). Note that the top face has few angular structures It is smooth with rounded features. SOILpak rating **F0.1.**

② Flat finely grained face with few pores and sharp right angled corners.

③ Round cup shaped structure is part of a conchoidal join between clods.

④ Roots are external to the clod and flattened. Note that the clod is air dry but there are no obvious cracks.

Management options:

Clod directly under wheel track only: Little cause for concern unless you are planning to destroy then rebuild hills.

Clod high in bed shoulder: A layer of clods like this example has the potential to limit water inflow.

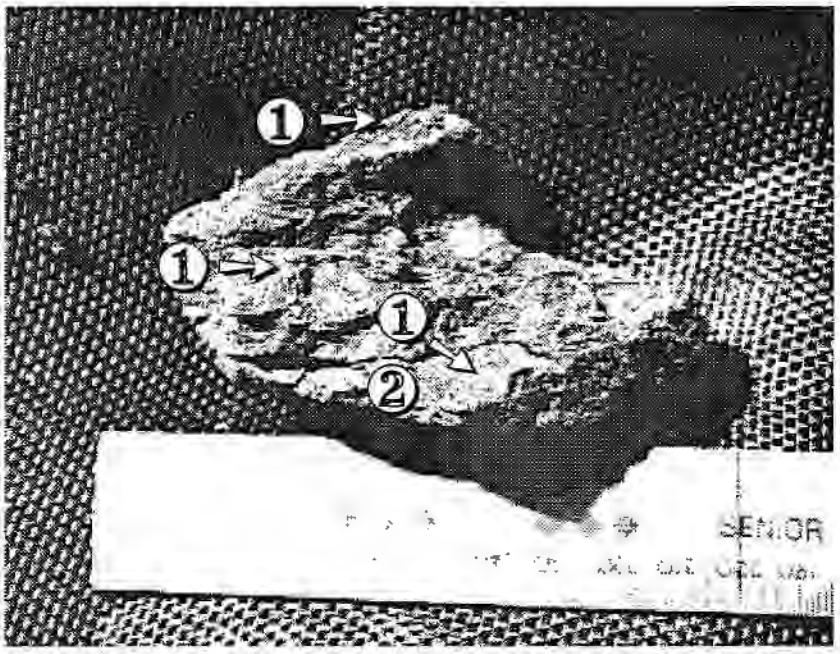
Clod directly under plant line: The visible roots show they have to divert past this clod, flattening in the process. This indicates that the neighbouring clod is also in poor structural condition. Plants growing directly over this clod will have to bend their roots to bypass this layer. Till below the level that these clods are found to allow exposure and breakdown, especially if the layer is broad.

Example 7: Platy clod with horizontal roots

Key Words: Platy, Horizontal roots, Shiny faces

This clod is showing some conflicting signs. On one hand it has a number of shiny faces (a good sign) but on the other hand the clod is composed of flattened platy structures. In this case it is perhaps best to observe root behaviour, if present, in relation to the structures in the clod.

You will notice that the roots are following the shiny faces that correspond to the top of the platy clods. There is little vertical penetration of roots. SOILpak rating **FO.8.**



Note:

① Good root penetration but mainly in the horizontal plane along the top faces of platy clods.

② Slightly angular faces and shiny face on the top of the lower plate but few vertical linking cracks and pores.

Management options:
If this clod is found in the wheel track little should have to be done. If clods like this are found in a continuous band under the plant line however, middle busting to below their deepest extent should help to open more vertical root channels.

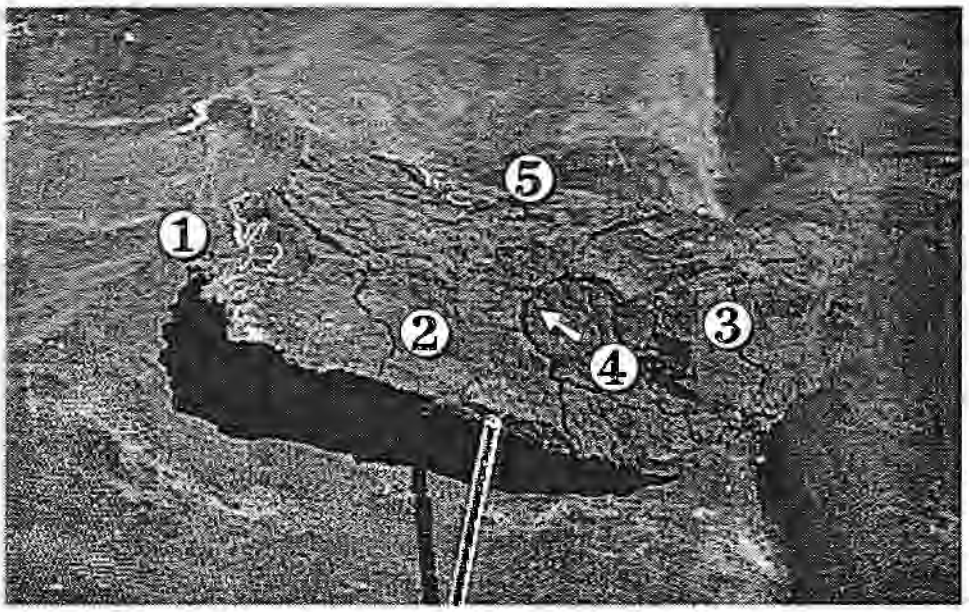
Example 8: Degraded Clod

Key Words: Massive, Blocky, Platy, External roots, Sharp edges, Conchoidal,

This clods shows classical signs of degradation by compaction. The exposed faces are flat and dull with only a small degree of surface roughness. On the top of the clod a number of horizontally flattened or platy clods. There is little in the way of internal pores apart from a few fine cracks (note that this clod was dry when photographed). FO.2.

The circular fracture is associated with a conchoidal (cup and ball structure) within the clod.

The visible roots are to a large degree on the external faces of the clod - meaning that any nutrients within the clod would be unavailable to the plant.



Note:

① Roots running along outside of clod but not emerging from the clod (little internal root development).

② Flat dull face of clod.

③ Sharp angular edges.

④ Round crack of 2cm diameter indicating conchoidal structure within.

⑤ Platy flattened structures on the top of the clod (4cm+ diameter).

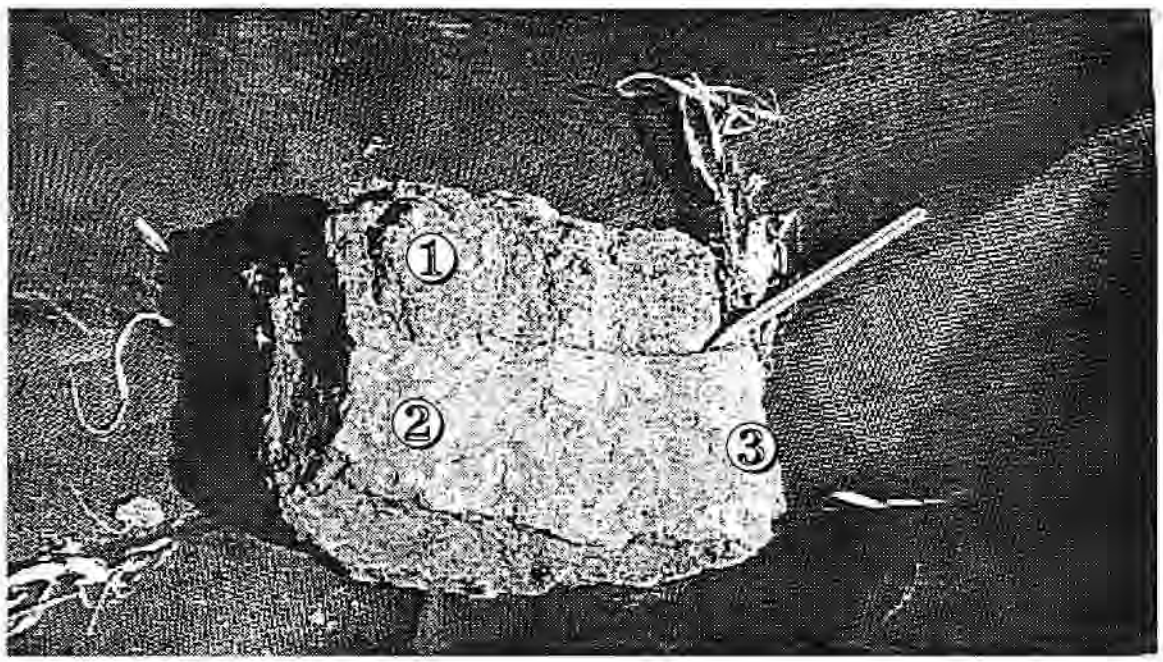
Management options:
The horizontal dimensions and the flat faces on the sides of the clod indicate that this clod is just a part of a larger problem. The flat smooth sides indicate that this clod is surrounded by similar clods which would provide a formidable barrier to root penetration. The problem could be overcome by exposing the large clods to weathering after chiselling, or just by subjecting the soil to wetting and drying cycles using an irrigated crop. Note that there are some cracks forming in this soil unit. If a crop is grown over this damage then expect problems such as poor root and water penetration, as well as a decreased available water.

Example 9: Compacted clod from cereal crop

Key Words: Compaction, Wheel track Tilled layer.

This compacted clod from under a cereal crop was associated with an area of sparse and stunted wheat plants. The clod was removed from the soil in one piece however on observation it appears in 2 halves. The upper half appears more porous than the lower half and does seem to have a greater amount of root penetration.

The marked demarcation between the layers corresponds to the depth of tillage by disk cultivators on this field (a dryland cereal field). Although a cracking clay this soil did have a noticeable silt component that prevented good self mulching.



Note:

① Tilled layer with visible pores and good root penetration around angular faces. As this is not a very reactive cracking clay this layer has not self mulched to a great degree as it dried and consequently is attached to the lower more compacted aggregate. SOILpak rating **F0.8.**

② Compacted layer approximately 10 cm thick. This consists of massive blocks with few soil pores and very few roots penetrating the clod. Rating **F0.1.**

③ Root penetration only around the outside of the massive clod. Roots are developing from the stunted (less than 1/2 of the maximum crop height) plant on the top of this clod.

Management options:
A change to tined implements may help in this case to penetrate the compacted zone.

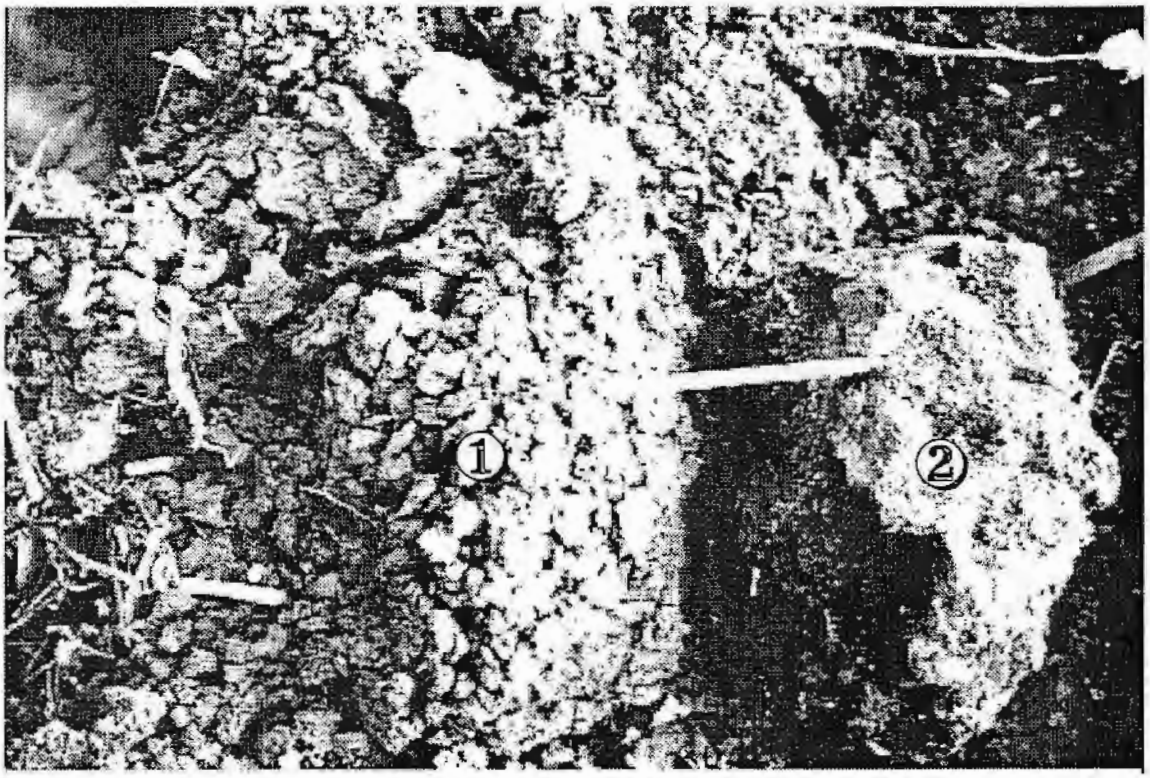
Example 10: Break down of exposed compacted reactive soil

Key Words: Reactive soil, Massive block, Flinty Clods.

This photo shows two similar sized compacted clods from the same field. The field had been ripped two weeks previously to expose the clod on the left. The field was now undergoing a second deep working and exposing massive blocks like those on the right.

The soil here has a high swell shrink capacity (reactive) and the exposed block is cracking well as it dries. Note however that the smaller blocks that are being formed are blocky and flinty in appearance. It will take more wetting and drying cycles to recreate a fine surface typical of good self mulching soils. Topsoil rated as **LO.3**

This photo illustrates that not all compaction will necessarily be loosened in a single pass of tillage implements. A number of passes may be required. In this case a below surface problem has become an above surface problem as a coarse cloddy seed bed is being formed.



Note:

① Compacted clod that has been exposed for 2 weeks. Note the flinty small aggregates being formed from its breakdown. **LO.3**

② Freshly exposed massive clod. SOILpak rating **FO.4** The surface of the clod is angular indicating that there should be a number of weak internal faces along which the clod can break. This clod still contains some moisture although it is drier than the plastic limit. As it air dries the shrinkage of the clod will create the same smaller aggregates as in ①.

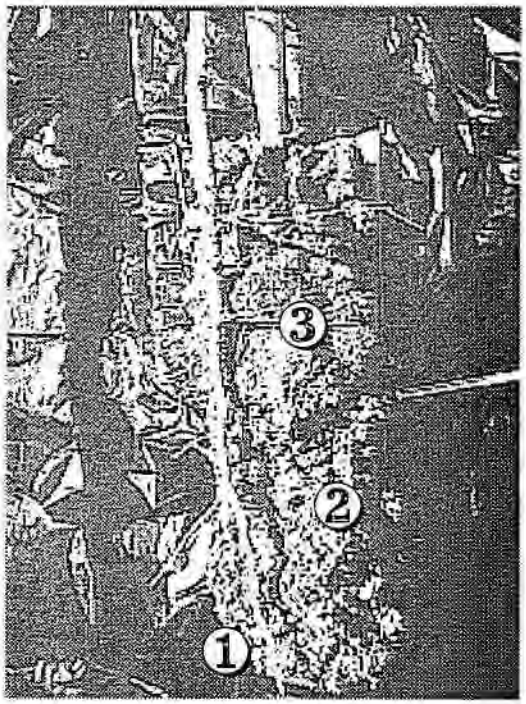
Management options:
As this soil is very reactive it will self mulch fairly quickly with wetting and drying to give a fine surface mulch. Problems with seedling establishment may be encountered with in the short term. The deep tillage operation should be followed with bed formation and the creation of a permanent bed system.

Example 11: Importance of cracks

Key Words: Root penetration, Cracks.

This photograph of a clod and plant at first seems a little confusing as the root development of the plant is good despite what appears to be a compacted zone toward the surface. The soil structure above the pencil would be rated **F0.4** on the SOILpak rating scale. Below the pencil the structure appears better (**F1.6**).

The explanation of this development lies in the presence of vertical cracks between the upper and lower parts of the soil profile that this plant has been able to use to easily access the better structured soil at depth. The plant may still be affected to some degree by the compaction as it may not be able to easily access nutrients stored within this compacted region. The compaction at the surface may also slow down water infiltration.



Note:

① Straight roots of plant penetrating the compacted zone through cracks to well-structured soil at depth.

② Good soil structure **F1.6**.

③ Poor soil structure **F0.4**.

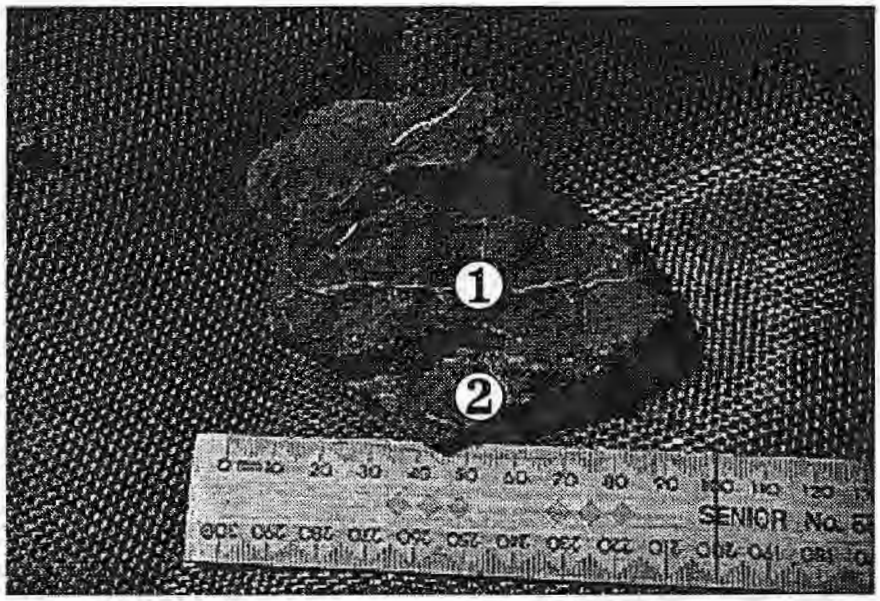
Management options:
Although this plant appears to be growing well there were many plants with bent and twisted roots that coincided with the compacted zone. Using a tined implement along the plant line should remove restrictions to root growth allowing a continuation with a permanent bed.

Example 12: Horizontal penetration of roots in platy soil

Key Words: Platy, Flattened roots, Few pores.

This compacted aggregate shows three distinct platy layers. The clod parted in flat plates, the majority of the roots followed the horizontal surfaces of these plates. There was little root penetration through the plates. The roots that did penetrate appear to be horizontally flattened indicating high forces on the root as it was growing.

The faces of the clod are slightly angular and there is some shininess visible on the lower plate. The root penetration is probably helping to dry and crack the clod. The clod is large, ie greater than 5 cm, and classed as **FO.6** in the SOILpak rating system.



Note:

① Good root penetration but mainly in the horizontal plane. The roots follow the top faces of platy clods. There appears to be little vertical penetration by the roots in this clod.

② The lower plate does show some angularity and a slightly shiny face. Note that the roots appear top be horizontally flattened.

Management options:
Clod directly under wheel track only: little cause for concern unless you are planning to destroy then rebuild hills.
Clod high in bed shoulder: A layer of clods like this example has the potential to slow water inflow.
Clod directly under plant line: This clod has the potential to divert roots in the horizontal plane. Tillage should fracture these clods easily. Also there is good potential for the soil to improve with the swelling and shrinking of the the soil associated with growing rotation crops.

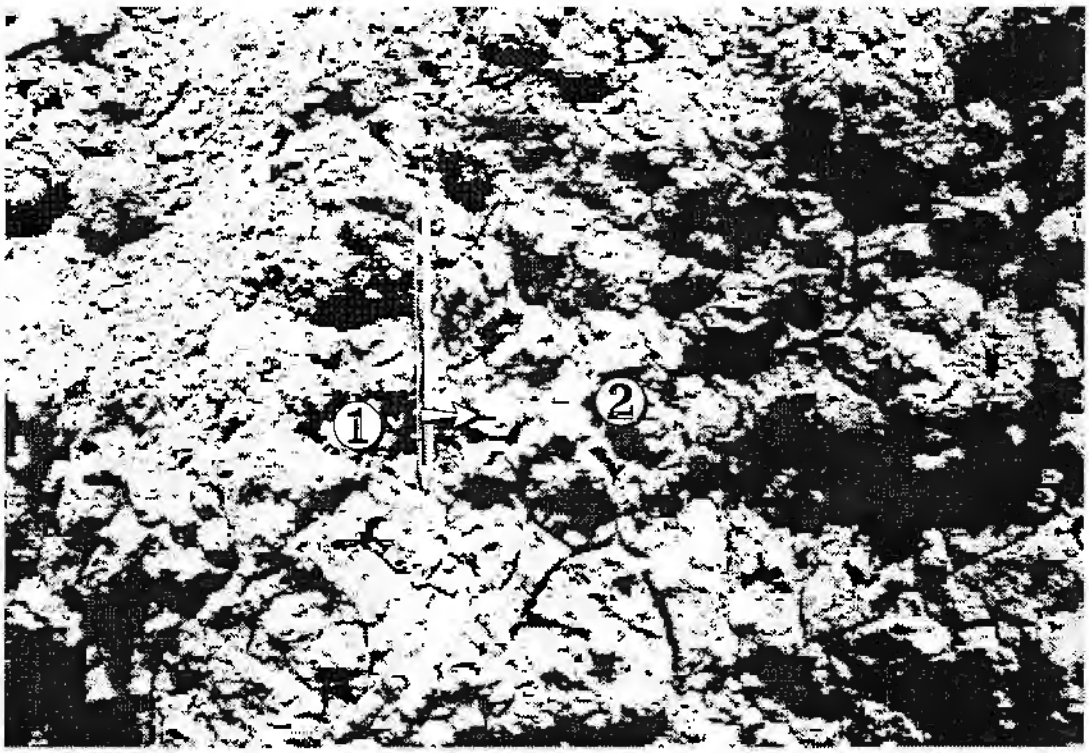
Example 13: Degraded soil under shoulder and bed

Key Words: Bad compaction remnants, Blocky, Flinty, Smooth faced

The pit in this photo is showing signs of old bad compaction. The large numbers of blocky flinty clods side by side indicate that a larger compacted unit is cracking as it undergoes a series of wetting and drying cycles. The clods in the shoulder around the pencil are showing particularly poor structure(they are blocky with very sharp edges and have smooth faced non porous faces).

A good sign is that most of the aggregates are smaller than 5 cm in diameter, there are no very large massive clods.

Note that this photo is of a very dry face in a pit that has been exposed for over a week and has had time to air dry and shrink. Further into the profile where the soil is moist and less shrinkage has occurred the soil profile may be more massive, which creates problems with water infiltration and root penetration.



Note:

① Aggregates in very poor condition, sharp edged finely grained (flinty) They are typical of a massive block that is fracturing on drying, SOILpak score `F0.2`.

② The shoulder of this bed rates at `F0.4` because although individual aggregates are very poor there does appear to be aggregate sizes less than 5 cm in diameter.

Management options:
Sample further into the shoulder to see if massive structures exist. A crop could be grown with critical management including increased N application and decreased irrigation intervals.

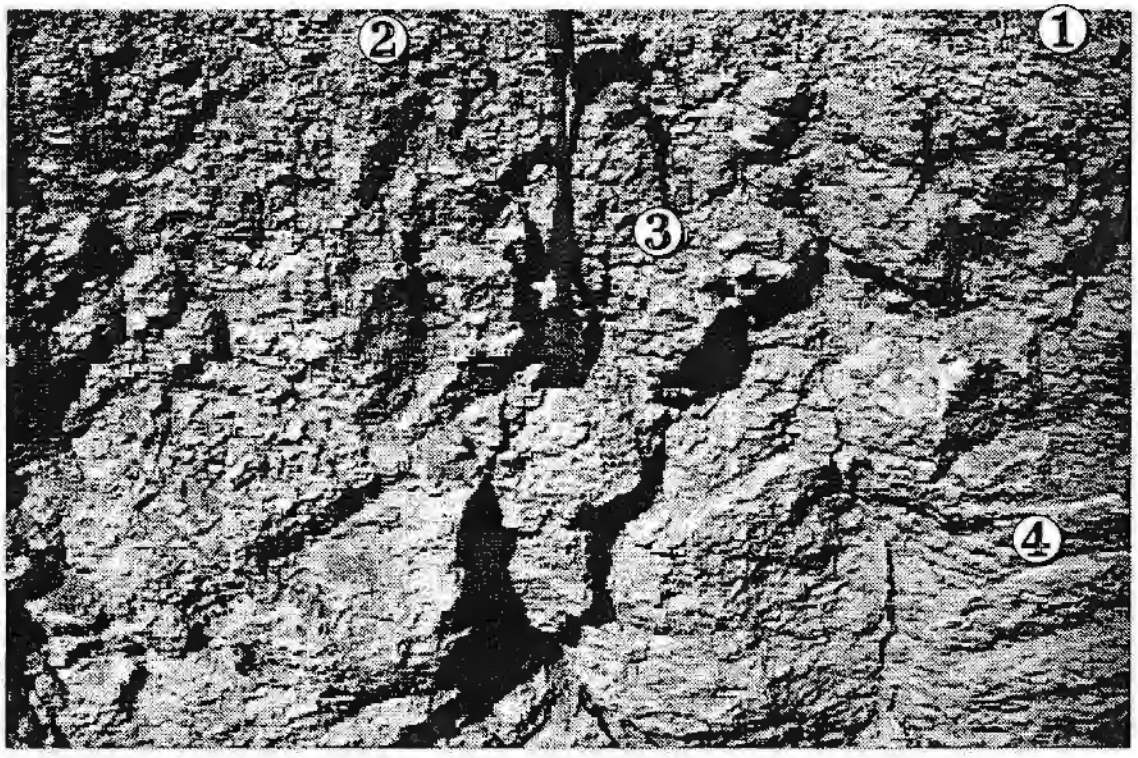
Example 14: Sodic soil in near natural state

Key Words: Massive, Blocky.

This sodic soil from an arid area is in its natural state. The only degrading influences in the past would have been stocking at light rates. Notice the fine crumbly surface. The size of aggregates however increases rapidly with depth. The aggregates although large do have rough, uneven faces, indicating the possible presence of internal faces along finer cracks.

Most of the aggregates are blocky in shape. The aggregates smaller than 3cm should pose no problems to root penetration .

This soil is sodic with Exchangeable Sodium Percentage of greater than 5 and has a content of fine sand and silt that increases the natural blockyness of the soil.



Note:

① Light dry natural ground cover.

② Four cm of soil with fine surface tilth SOILpak rating `L1.3`.

③ Block size increases rapidly with depth. At 20 cm note the blocky units are over 5 cm in size.SOILpak rating `F1.0`.

④ Very large blocks at depth. These blocks have some angular faces but few obvious internal cracks although the soil is very dry. `F0.3`.

Management options:
If this soil is deep worked is is possible to bring sodic soil to the surface which will increase surface sealing problems. Gypsum applications should be considered in conjunction with deep working.

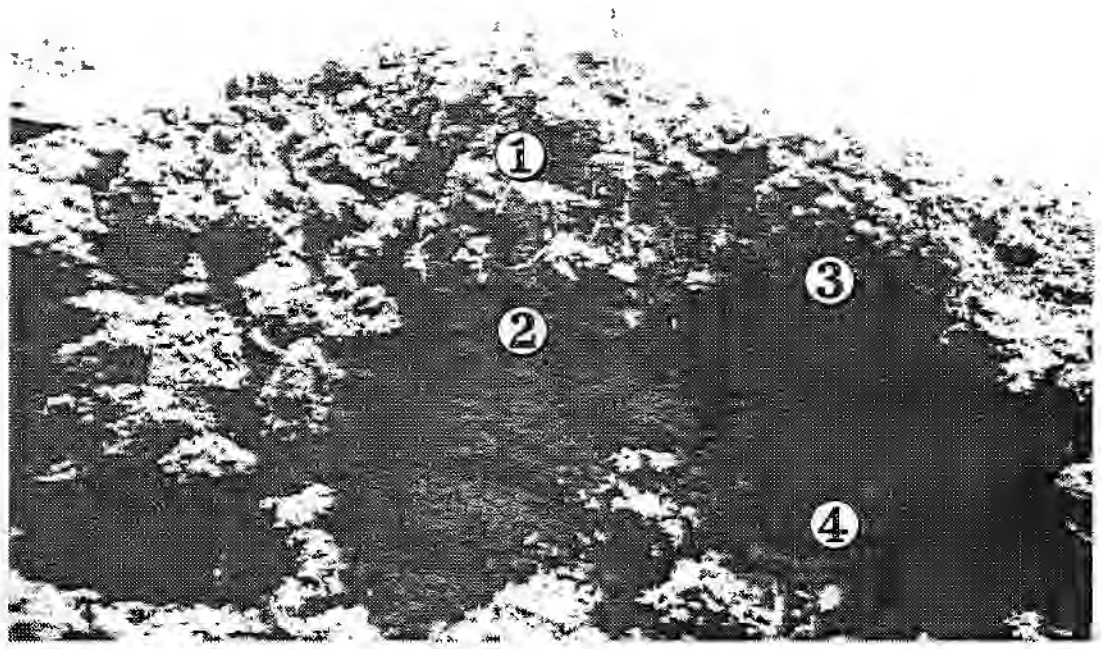
Example 15: Bad compacted layer directly below plant line

Key Words: Old wheel track, Platy, Restricted root area.

The hill in this photograph has been inadvertently built over an old compacted zone. The U shaped zone of compaction directly under the hill indicates that this hill is over the worst compaction formed by previous seasons traffic. There is little root penetration within or below the compacted zone.

This is the result of changing bed widths (30 inch to 1 meter) without addressing existing compaction (in this case due to very wet conditions up to planting).

The pit face had been exposed for 2 days of hot weather consequently there is some cracking within the compacted area (which may not have been as great if the face was not exposed. The clods are platy with smooth faces within this zone, **F0.2.**



Notes:

① Good root development above compacted zone **F1.2.**

② 15 cm thick layer of platy compacted soil preventing good root penetration The upper part of this layer is beginning to crack **F0.4** whereas the layer directly below this appears to be massive for about 5-8 cm **F0.2.**

③ Compacted zone extends to bed shoulder perhaps to affect water infiltration the U-shaped form of the compaction layer suggests that the centre of the hill is built directly over the centre of an old wheel track.

④ Soil directly below this U shaped compacted layer appears to be in better condition **F1.2** (soil is moist here and consequently cracks are not as obvious in the photo).

Management options:
This crop will have to be critically managed to maximise yield. This management will include more frequent irrigation and an increase of N rate by 10% or more.
The crop during its growth may partly restore some structure however it is more likely that deep working below the compacted zone would be the quickest way to at least partly restore the soil condition.

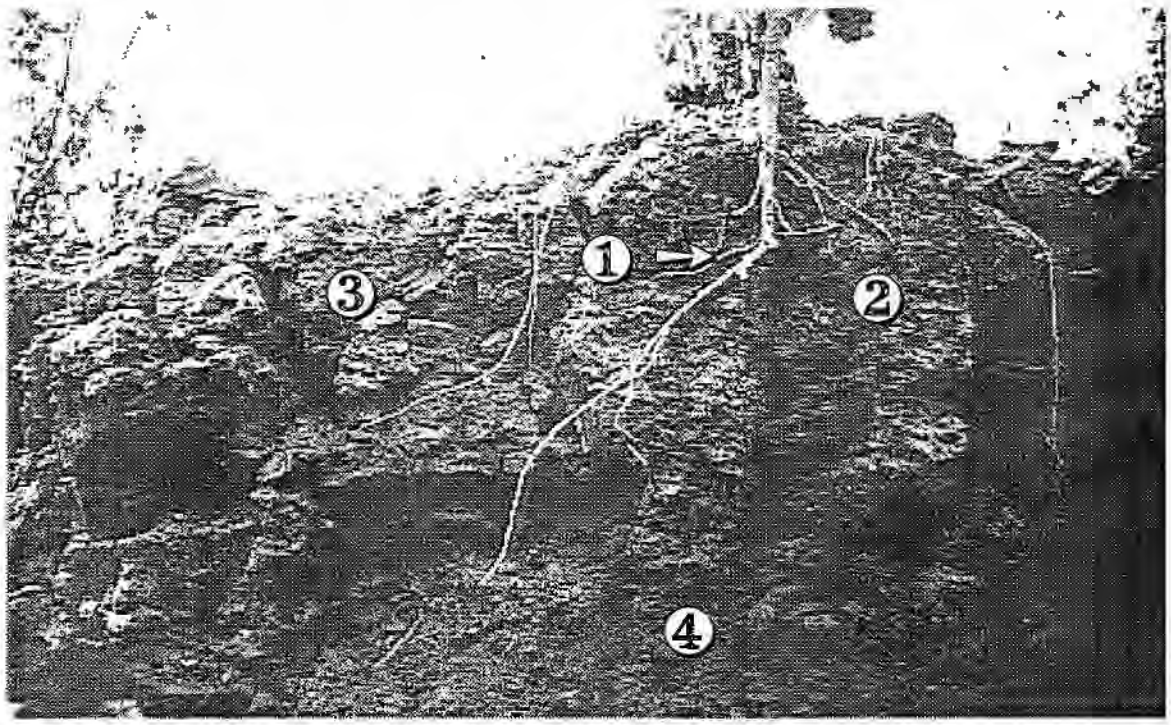
Example 16: Massive blocks below plant line

Key Words: Massive, Bent roots (right angled roots)

This slide pair shows large massive blocks below the plant line in a flood irrigated field. A large proportion of the plants in this field had bent roots. It is interesting that this example is in a field near Example 20 (soil in good condition under drip irrigation). The management of the fields was similar and the farmer could not identify any recent wet trafficking.

The cause if the difference is most likely to be the irrigation system employed. The rapid wetting with the flood system coupled with marginally dispersive soil is probably responsible for greater aggregate breakdown than would be found under drip irrigation. This would lead to more compact aggregates.

It is also noteworthy that the farmer was not unhappy with the yields from this field, despite the apparently poor structure of the soil. Both fields had been under permanent beds for 5 years with no deep working even following wet pick early in their history.



Note:

① Right angled roots.

② Massive blocks either side of the plant line separated by a vertical crack (**F0.5**) Note that the blocks are not completely smooth though not many cracks are visible in this dry soil.

③ Large blocks in the furrow line (**F0.6**) (smaller blocks than under the plant line).

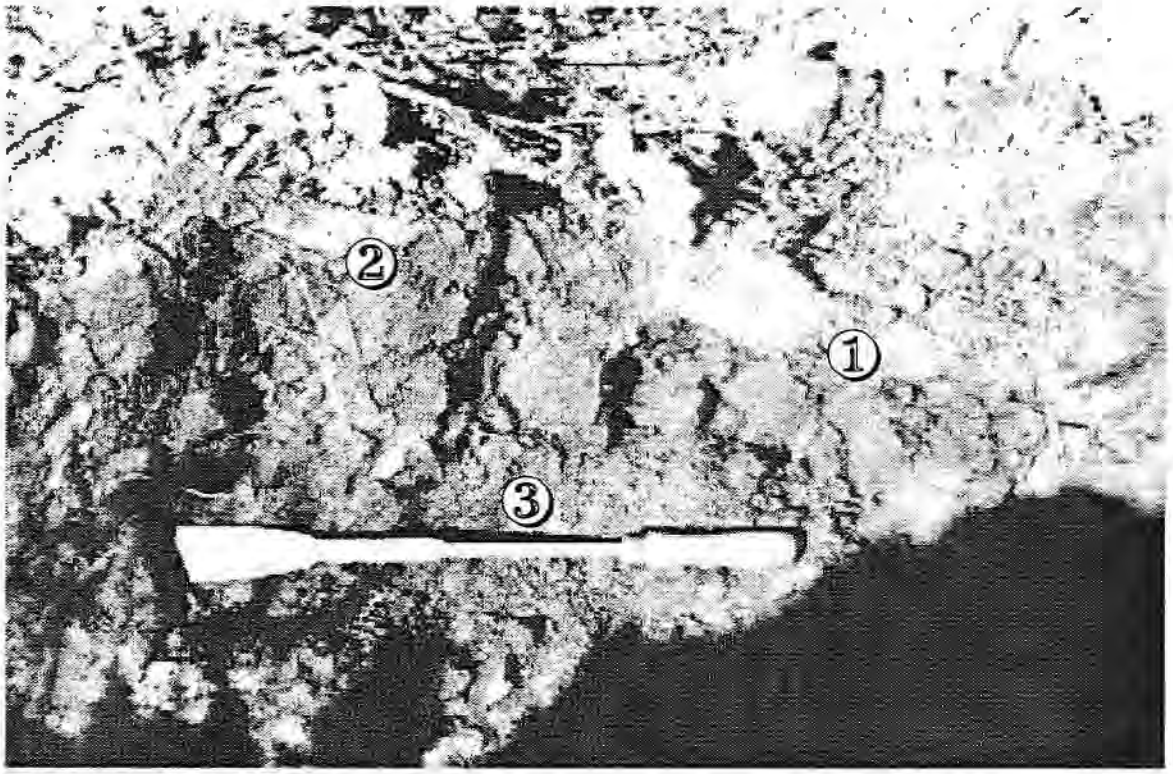
④ Structure below 25 cm appears to be better - smaller average clod size and angular faces with more pronounced cracking (**F1.2**).

Management options:
A rotation crop will help to open the soil structure. The soil appears as if it would respond to deep working at least along the plant line (Middlebusting). It is likely that large blocks will be exposed with deep working so a long period should be allowed for weathering of clods.

Example 17: Bed and shoulder compaction

Key Words: Shoulder, Furrow compaction

Compaction extends from the furrow up the shoulder of the bed to the plant line. The compaction in the shoulder is less than that directly under the wheel row. The soil at approximately 15 cm below the plant line appears to be in better condition together with the soil to the left of the plant line (in the area that is untrafficked).



Note:

① Eight centimetres of badly compacted soil beneath wheel row. Soilpak rating **F0.2.**

② Massive blocks extending into the shoulder of the bed **F0.4** (they have slightly more angular faces than the blocks directly in the wheel track). This is an indication of more cracks and greater potential root penetration than in the furrow bottom.

③ The soil improves in structure with depth to just above the knife **F1.2.**

Management options:
Compaction appears to be severe enough to limit plant growth in the future

Cotton: Expect a reduced yield - critical management for compaction will have to be applied ie. increase irrigation frequency and increased N.

Rotation: Use wetting and drying cycles in association with a drying crop to repair soil structure. Check using a soil pit before next crop to determine if more remedial action is necessary.

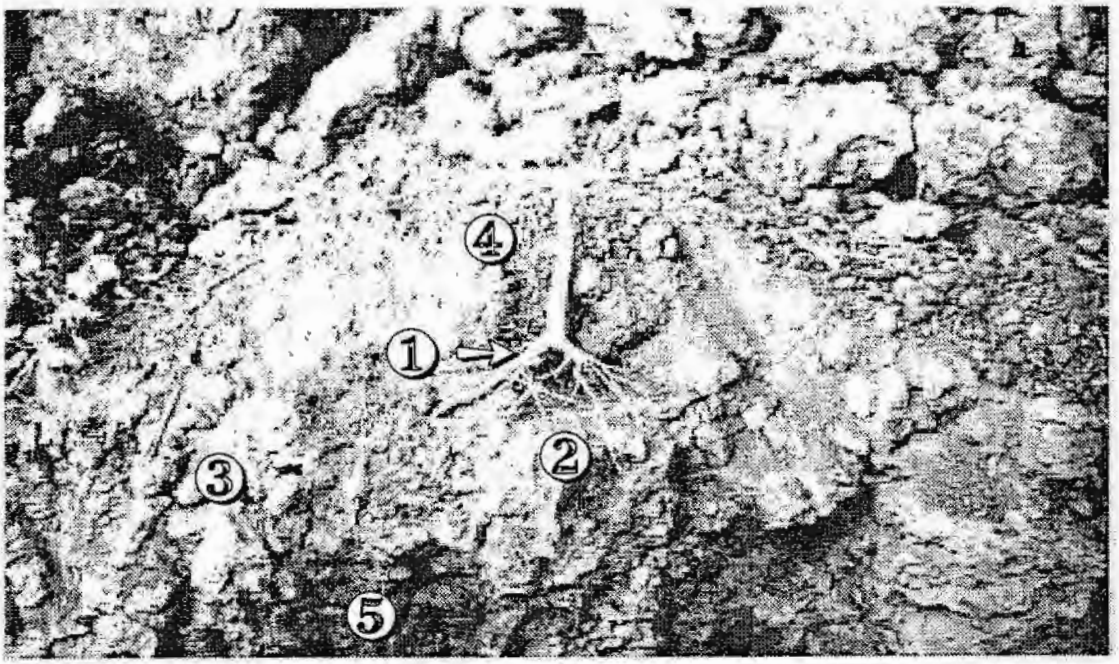
Tillage: At least leave hills in situ and middlebust. Shoulder compaction should be handled at the same time. If hills are to be destroyed ensure the whole field is worked to 25 cm.

Example 18: Result of moved hills

Key Words: Moved hills, Bent roots.

The problems shown in this example stem from the shifting of beds without addressing the problem of wheel compaction in the furrow. The old compacted wheel rows are forming a significant barrier to root penetration. This field had a large number of plants with bent or twisted roots (>30%). The depth of the root malformation coincided closely with a change in soil structure at approximately 12 cm depth.

The soil condition in the furrow to the left of the plant is in structurally better shape than that directly under the plant line.



Note:

① Right angled roots bending at the start of the compacted layer. A high proportion of the roots in this part of the soil were bent in this way - over 30%.

② Massive blocks below the plant line 15cm deep. Rated at **F0.3** they have few angular faces and few pores.

③ Less compacted soil in better condition under the furrow. It has more cracks and a more angular faces than that below the plant line **F1.2**.

④ Good condition in seedbed with porous crumbly structure, peds <1cm **L1.6**.

Management options:
Had the furrow been built 15cm to the left there would be fewer problems than are now evident. A deep tine down the centre of the bed would be required to break out the compacted area under the plant line. The clods formed from this operation would take some time and weather to break down. The compaction in the shoulder is not as extensive as that under the bed and could be removed with a chiselling operation.

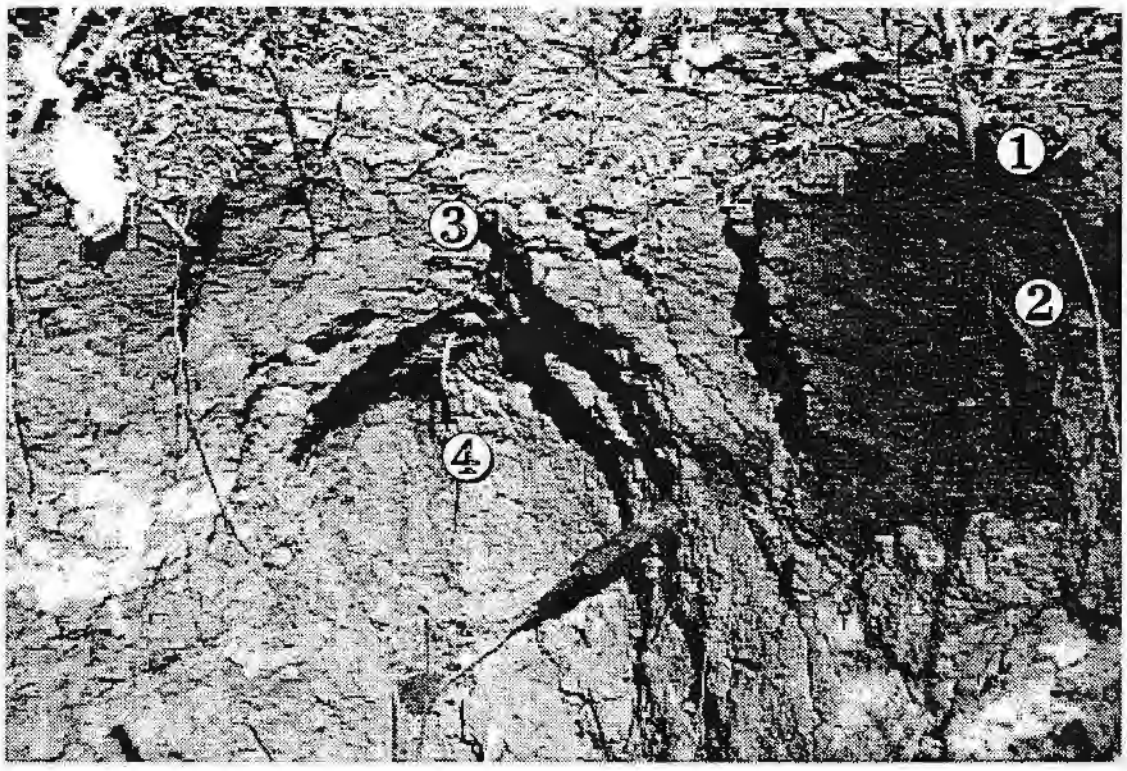
Once this compaction problem has been addressed controlled traffic management should be applied to avoid this problem in future.

Example 19: Soil strength and erosion

Key Words: Erosion, Shoulder compaction.

Water flowing down a soil pit profile (from the wheeltrack above it) has removed well structured soil from beneath a compacted layer. A hollow has been created in the exposed pit face. It is a reminder that if you do produce a good fine tilth and good structure by tillage or rotations it should be protected from erosional forces (eg by leaving standing stubble). There is good root development down to 70 cm.

This pit face also shows good soil condition directly under the plant line but some compaction on the bed shoulder.



Note:

① Soil in good condition at the surface below the plant line, rated as `L1.4`

② Good condition at depth below the plant line, `F1.4`.

③ Non eroded compacted zone under the wheel track, `F0.3`

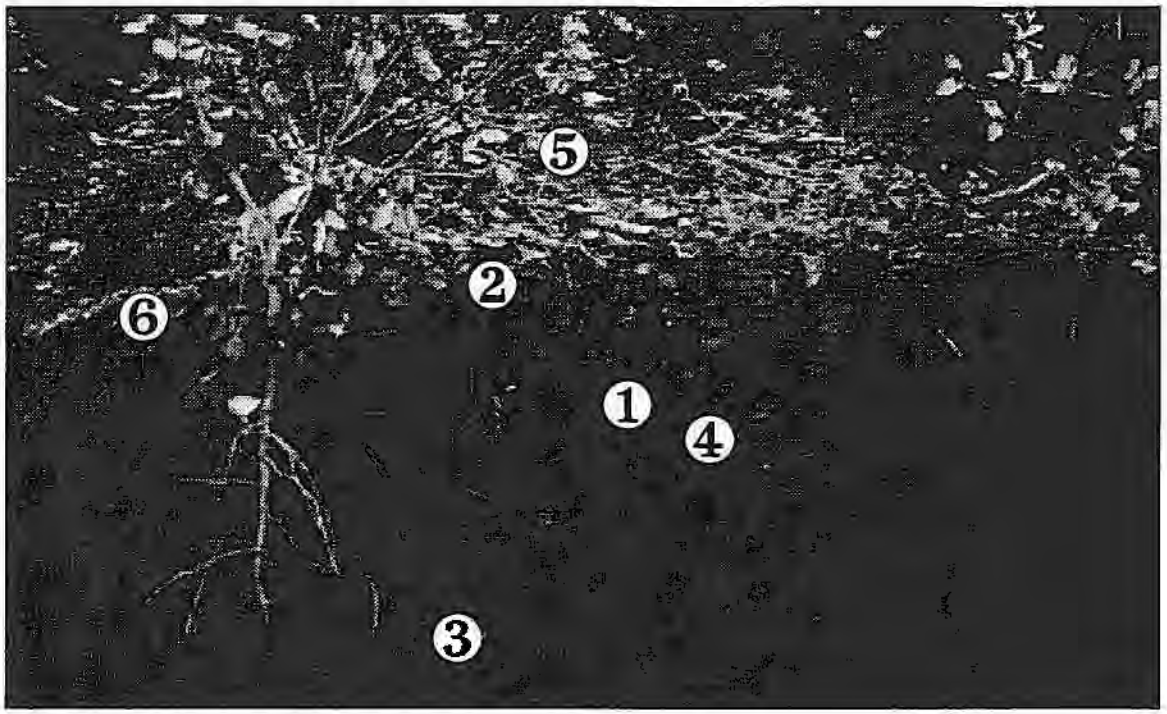
④ Soil in the eroded area below 20 cm, `F1.2`.

Management options:
This field could continue in a permanent bed system as the centres of the beds appear to be in good condition. If the rows are moved it is possible that they would end up being built over the compacted shoulder areas.

Example 20: Soil profile in permanent 2 metre bed in very good condition

Key words: Cracking, Fine surface tilth, Gypsum crystals, Root penetration, Organic mulch, Wheel track compaction.

This photo shows very good soil structure under a 2 meter bed system with drip irrigation. White particles at the bottom of the slide are gypsum crystals. Good structure in the middle of the beds is possibly due to a number of factors: a reactive soil type; no deep working for 5 years; organic mulch; slow wetting of the drip system minimises slaking. Very restricted compaction is visible under the wheeled row but it does not encroach under the plant line. SOILpak rating for the profile as a whole (averaging bed and wheel tracks) **F1.8.**



Note:

① Very good vertical and horizontal cracking within the undisturbed bed with aggregate sizes less than 5 cm. (**F1.9**)

② Fine surface tilth 6 cm deep. (**L1.8**)

③ White granules at depth are gypsum crystals.

④ Very good root penetration within the bed area. There appears to be good rooting toward the surface that is a product of the irrigation system. ie in drip systems the moisture is applied at the surface and is continually available there.

⑤ Surface mulch of organic material including old cotton stalk. Loose mulch like this does have the potential to harbour disease. If disease did start to show in the crop more thorough methods of stubble incorporation may be required.

⑥ Some compaction with clods of greater than 5 cm diameter under the wheel tracks. In this situation it should pose no problem at all as water and nutrients are applied to the centre of the bed. (**F0.8**)

Management options:
Little needs to be done to maintain soil structure other than to retain the existing hills and restrict all wheels to existing traffic lanes in the furrows.

Example 21: Rotations and soil structure improvement

Key Words: Legume rotation, Good soil structure, Compaction remnants, Blocky (flinty).

This shot shows soil in good condition following a legume rotation crop (*Dolichos lab lab*). Nearly all the soil was placed in **F1.4** category or better. The profile has many cracks and the polyhedral faces. The current crop had been sown directly into the existing cotton hills. A large amount of stubble can be seen at the true soil surface - the background soil is the fill from the excavated soil pit.

The remnants of compaction in a wheel track can be seen in the centre of the photo around the pen **F0.6**. The affected region is much smaller than would be expected under a bare fallow situation. The region is noticeable because of larger clod size and smooth faced blocky appearance with sharp edges (flinty).

The crop legume when green manured returned over 80 units of N in this field.

Notes:

① General profile in very good condition. **F1.4**

② Very small remnants of wheel track. Even this poor section of the profile is cracking down to smaller aggregates under wetting and drying cycles that have been enhanced by an actively growing crop. **F0.6**.

③ Good stubble mulch

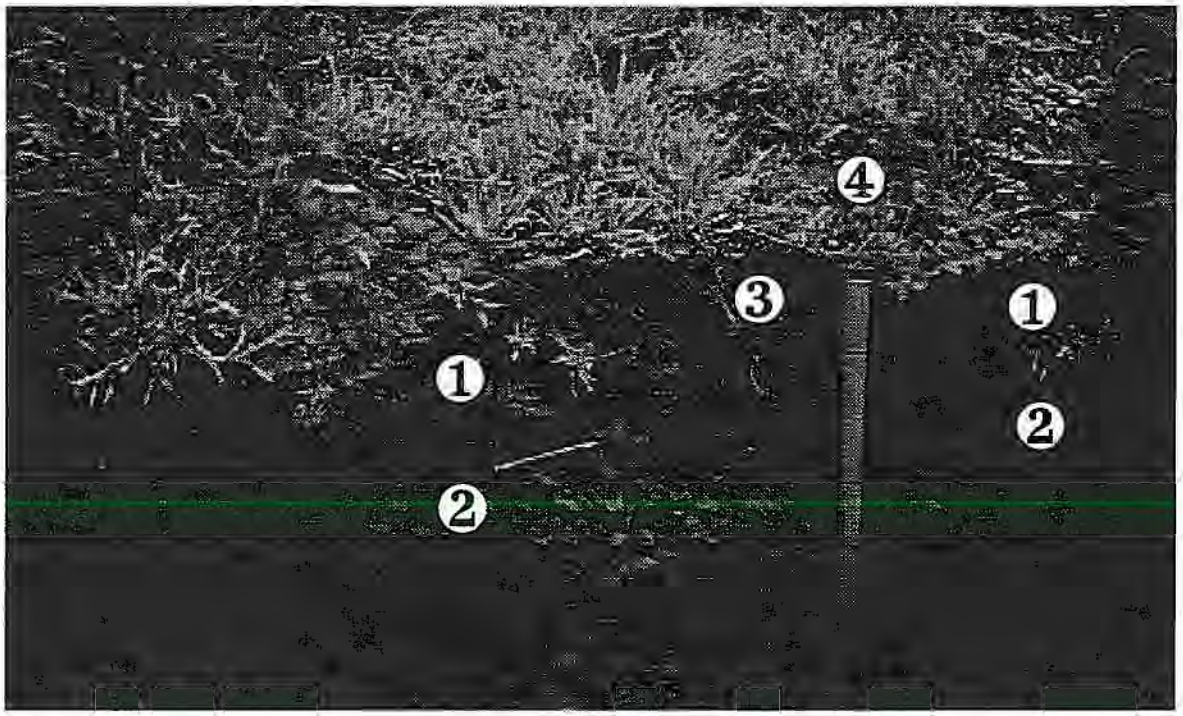
Management options:
The soil is in good condition to grow the next cotton crop. Hills should be rebuilt on existing hills to avoid old compacted zone (Although this should not be too much of a problem on this profile).

Example 22: Blocky structure. Compacted soil on the mend

Key Words: Blocky, Flinty, Sharp Edges, Repair of compaction.

The soil pit in this photograph was once under a farm roadway. The surface is now covered with grass and the top 15-20 cm appears to be becoming more porous as a result of wetting and drying cycles that have been enhanced by the plant cover. The soil is a reactive brown cracking clay.

Below 20 cm the aggregate size increases to 5-10 cm and the clods have dull flat faces with very sharp edges - It is likely that these are the breakdown products of a once massive layer. This region of the soil is still not ideal for root growth however the extent of cracking indicates that self repair is commencing. It should be noted that this face had been exposed for some time and the extensive cracking found here may not be present further into the profile as potential swell shrink movement is limited by the surrounding soil mass and slow drying.



Note:

① Soil above 20 cm repairing well with small aggregates (mixed sizes but generally less than 2 cm). Although faces are not shiny they are full of pores **F1.4.**

② Flat faced dull clods with very sharp edges - often right angled or sharper. These could be described as being *Flinty* (**F0.4**). The presence of cracks below 20 cm show however that compaction is being repaired.

③ Roots active in the top 20 cm and extending within compacted zone.

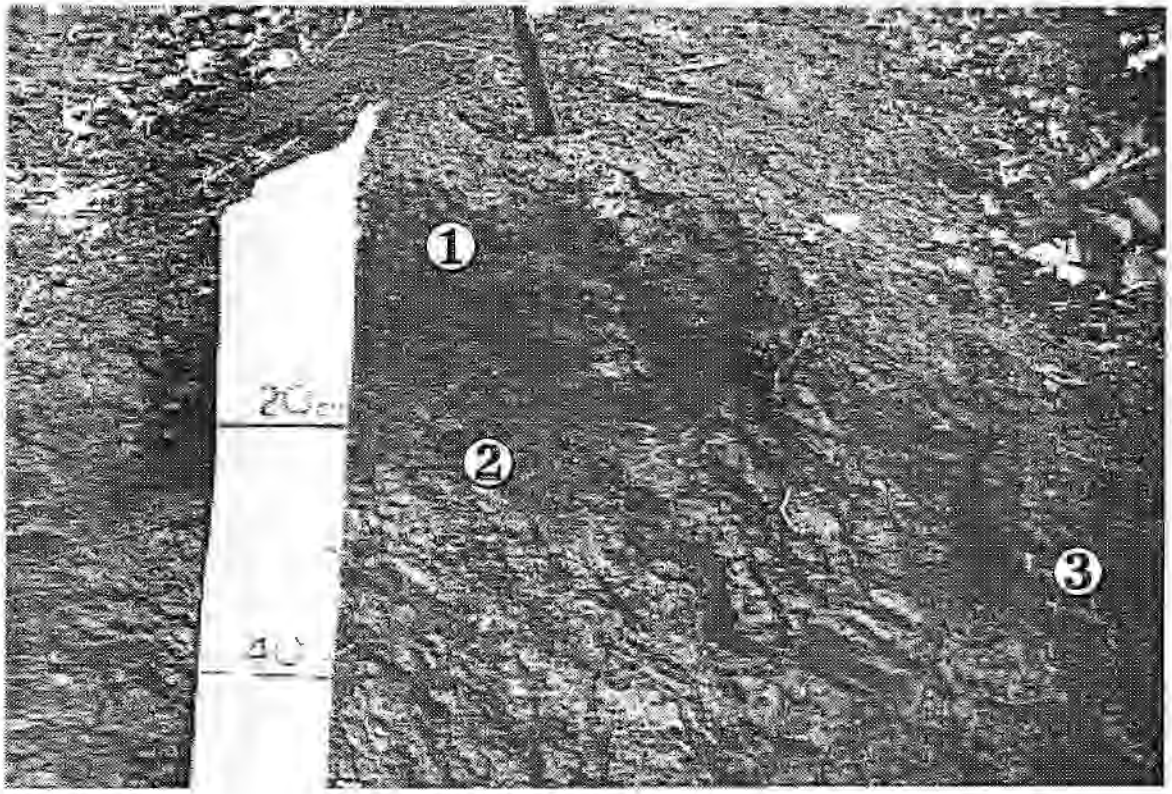
④ Good plant cover would be accelerating the repair process by increasing the amount of water extracted (increased shrinkage).

Management options:
The swelling and shrinking process that are enhanced by the surface plant growth are helping to break out this compacted profile. The aggregate size in the profile appears to be small enough to allow water and root penetration. Critical management is required to overcome the effects of compaction including increased irrigations and increased N rates for the following crop. Chisel ploughing when dry could help to accelerate the repair process.

Example 23 :A soil profile in very good condition

Key words: Fine tilth, Porous.

Five year old hills in good condition. Compaction is evident but constricted to furrows. Good structural stability in water is evident that relates to low Exchangeable Sodium Percentage and a favourable Ca/Mg ratio. A high self repair capacity is associated with the high Cation Exchange Capacity.



Note:

① Very fine tilth in the seed bed down to 25 cm. This area does not show any shiny faces however it is very porous (mechanical disturbance) this area was loose enough to scrape away with your hand, grading into firmer soil. SOILpak rating of this zone **L1.5** to **F1.5**.

②. From 25 cm down the aggregate size increases - this is natural as overburden pressure increases with depth. The soil in this zone does not appear to have been recently disturbed by machinery and consequently more shiny faces are evident. There is good cracking and root penetration.

③ Larger aggregates 5 cm below surface of furrow (SOILpak rating **F0.8**) Perhaps as a result of wheeling or fast wetting from irrigation. This should not adversely affect root growth in the bulk of the soil.

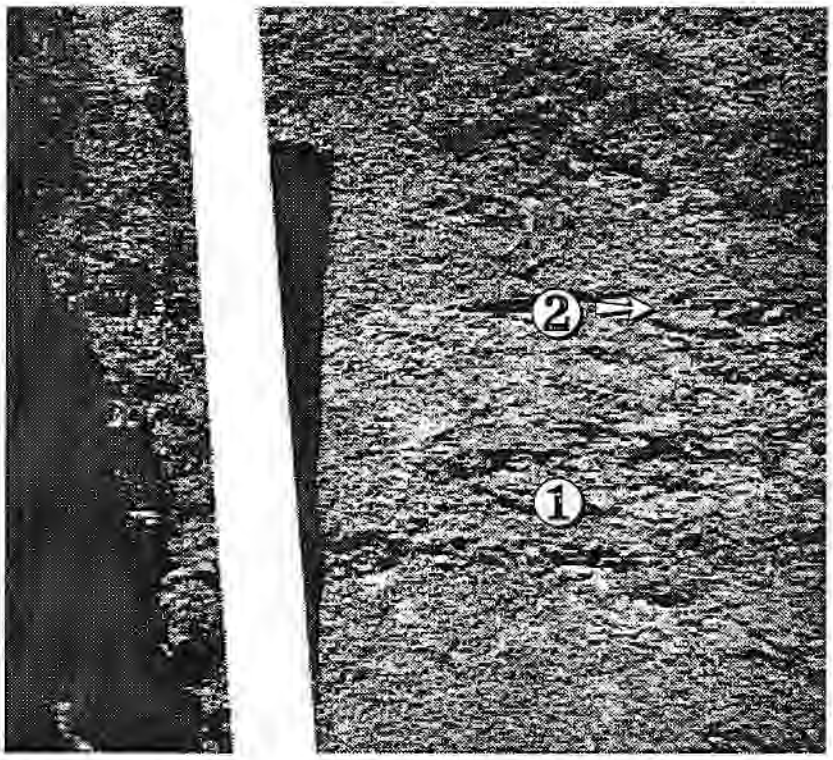
Management options:
This profile is very good structural condition following the use of a permanent bed system and should continue that way with the same management. The main thing to be wary of in this situation is of beds moving over time over old wheel tracks and their associated compaction.

Example 24: Pit face of moist soil in good structural condition

Key Words: Good soil, Platiness

This soil pit profile is good structural condition at depth (around 30 cm). The face shown is aligned along the centre of a plant line in a permanent bed.

The soil is wetter than the plastic limit which may be a contributing factor to the number of shiny aggregates in the profile.



Note:

① Moist Soil in good structural condition. The aggregates have small size <2cm and have many shiny faces. SOILpak rating `F1.7`.

② There is a slight hint of platiness or horizontal layering in the profile.

Management options:
This profile should not cause any problems to a growing crop. Tillage is not required on this profile and with current moisture content of the soil could actually create damage (note that the soil is wetter than the plastic limit and forms a rod easily when rolled in the fingers).

Example 25: Wet and dry soil comparison

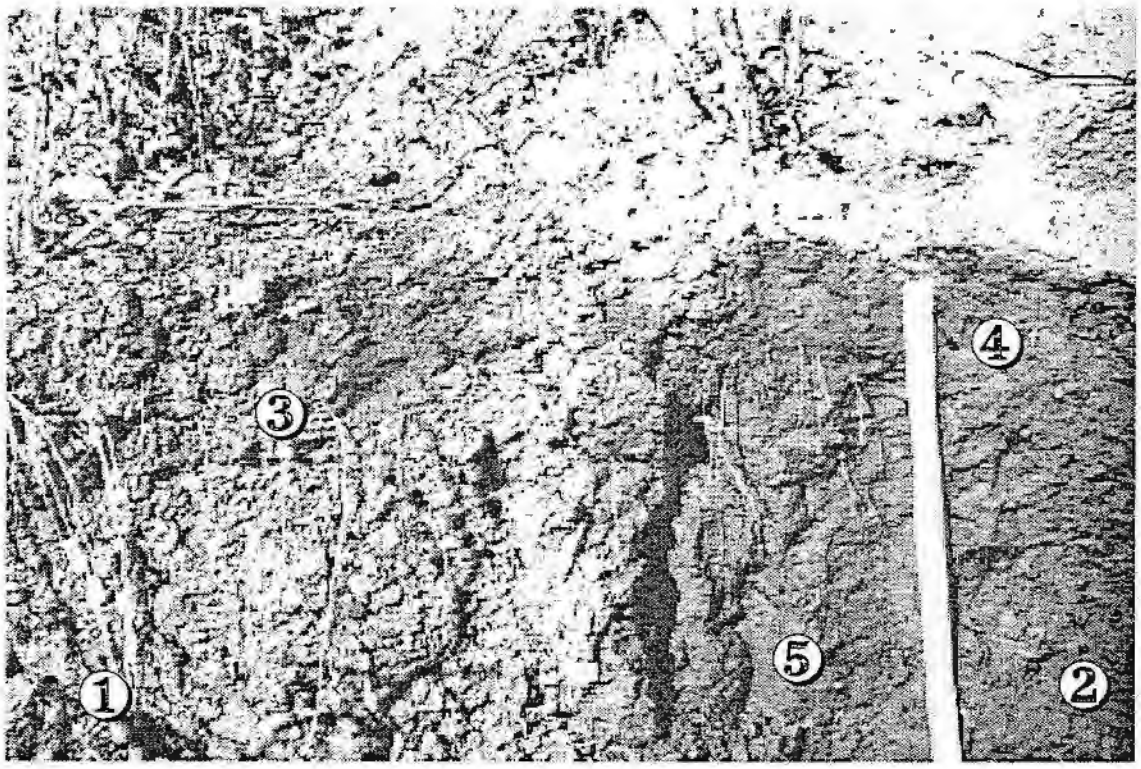
Key Words: Cracking, Swelling, Wide bed, Shoulder compaction, Massive

This is an example of the difference between a cracking clay soil that is wet and one that is dry. The amount of cracking is much more obvious in the dry soil.

It should also be noted that the pit face has dried after it has been exposed. This may lead to more obvious cracking than would be seen if the pit had been dug when the soil was dry.

The soil structure at depth in the moist section of this pit face appears massive. This could be partly due to the stability problems at this level caused by sodicity.
The soil directly under the plant line appears to be porous with good root penetration although there are few shiny faces. SOILpak rating **F1.2.**

In general terms root development appears to be most noticeable above 15 cm in this pit.



Note:

① Exposed pit face showing abundant wide cracks.

② Freshly exposed moist pit face, Cracks are not as obvious as on the dry side. The existance of cracks can be determined by the shape of the pit face and how the soil separates as the pit face is cleaned .

③ Very good root penetration in the centre of the wide bed. SOILpak rating **F1.4.**

④ Compacted layer extends from furrow (wheeltrack) up the shoulder of he hill.

⑤ Massive blocks at depth. **F0.4.** Above this zone there is a region of dense soil up to 15 cm below the plant line **F0.8.**

Management options: Compaction below 15cm may be limiting. Due to its depth the best option to open this area would be to grow a deep rooted rotation crop.

If the massiveness at depth is due to the chemical makeup of the soil little could be done in the short term to overcome the problem.

The shoulder compaction could be loosened by appropriate tillage when the soil dries.

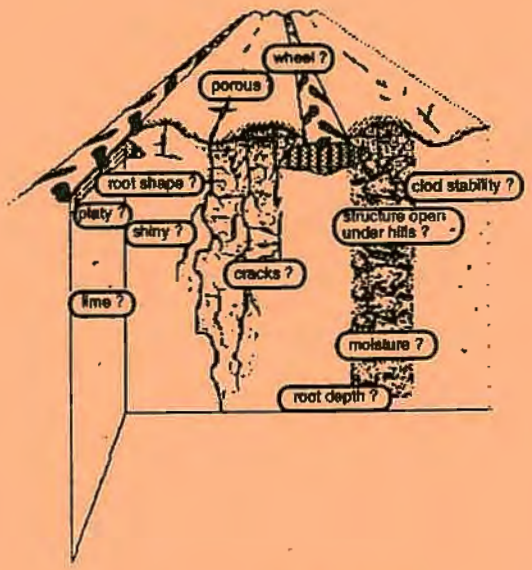
In this example the good soil in the top of the wide bed has provided the most hospitable area for root development. Poor root development at depths below 15cm may limit plant growth if water is a limiting factor.

INDEX

SOILpak
Pocket Notes

Field notes summary from SOILpak β -

- Getting soil science into the field
- Better soils better farms
- Giving you the options



Complied by D. Larsen
NSW Agriculture
1993
Funded by CRDC

SOILpak Pocket Notes

These notes are a summary of information from SOILpak β a soil management package for cotton production on cracking clay soils. The information included here is intended as being a field handy guide for those who are familiar with the SOILpak β mannal.

CONTENTS:

① Clues to soil structural condition

Crop symptoms:
stunted growth
slow growth
short internodes < 5cm
fast irrigation at short intervals
wave - height variation
yellowing following irrigation
bent, quickly tapering roots
sparse plant stand

Tillage History:
relate to weather and irrigation before operations

Surface symptoms:
flinty clods
ruts
glazing
crusting

Cropping History:
comparative yields year to year - field to field
water extraction patterns
water use efficiency - bales / megalitre

Chemical tests:
Sodicity - Gypsum requirement indicators
Ca/Mg<2 & ESP>5% & dispersion test +ve at soil surface
also low O.M.

Salinity.- Cotton, a salt tolerant plant, is adversely affected when:
$EC_{1:5}$ >1.00-1.25 (Medium clay)
$EC_{1:5}$ >1.10-1.45 (Medium Heavy clay)
$EC_{1:5}$ >1.45-1.7 (Heavy clay)
or
EC_e 7.7 dS/m (independent of soil texture)

Organic Matter <1%= very low, 1-2%=low, 2-4% satisfactory, >4% high

High levels of exchangeable sodium or magnesium
possible indicator High Ph >8.5

② Examining the soil profile

Consider three things:

The past. (Field history, Tillage, Crops, Yields)
The present. (What you observe in the pit or spade sample)
The future. (Response to tillage, Necessity for tillage)

Tasks before, during and after pit or spade observations

- Determine if field needs close inspection from clues such as wheel ruts or poor yields
- Find history of field
- Determine wheel tracks picker/cultivator
- Observe preliminary pits with a spade
- Dig soil pit - keep sides straight
- Decide on what to record - see table 1
- Clean smears off pit face, remove smeared sides of pit work across then down removing your implement marks. Use this process to start forming opinions eg moisture content, average aggregate size, root penetration, etc.
- Determine depths to examine
- Set up dispersion test with dry soil crumbs
- Examine roots if available
- Examine surface tilth hills
- Examine below: trafficked furrows, shoulders of hill, plant line
- Follow either poor soil from compacted area to good area or vice versa - mark on sides of pit the extent of degradation (platiness, massiveness)
- Record pit structures on sheet
- Determine whether wetter or drier than the PL at different depths. Take particular note of potential tillage zones
- Note results of dispersion test
- Have soil chemical tests done if necessary

What to record when:

✓ Most important ✓ Useful in forming an opinion

test / time	Prev. Crop	Root shape	Nodule length	Dispersion	Colour	Moisture	Porosity	Clod shape	Clod size	Clod Faces	Texture	Lime	Gypsum	pH	O.M.	Elect Cond	ESP	Ca/Mg
Pasture site				✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
Never sampled		✓		✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
Pre land forming				✓		✓					✓						✓	
Post land forming				✓		✓	✓	✓	✓	✓							✓	
Pre deep tillage	✓	✓	✓	✓		✓	✓	✓	✓	✓							✓	
Testing deep tillage							✓	✓	✓	✓								
Post Wet harvest						✓	✓	✓	✓	✓								
Post Dry Harvest	✓	✓	✓			✓	✓	✓	✓	✓								
Crusting surface				✓							✓				✓		✓	✓
Pre planting						✓	✓	✓	✓	✓								
Post planting							✓	✓	✓	✓								

③ Filling out working sheet.

The are many observations that you can make on a soil profile. (The SOILpak soil profile working sheet takes about one and a half hours to fill out if done thoroughly!). This list shows the more important observations as an introduction to soil assessment.
It is highly recommended that you attempt to make some kind of record, no matter how simple, for future reference.

Section 1 - Grower and field information
Grower's name etc.-
You need a record of where you were!
Field history, anticipated management -
This information often helps you decide what features to concentrate on in the pit.
Tillage history - eg.
Wet pick.
Recently ripped.
Soil prepared in a moist state.
Surface soil symptoms -eg.
Good surface tilth- deep seedbed.
Soil "butter curling" off implements.
Coarse clods.
Ruts.
Water extraction profiles -
Neutron probe results.

Section 2 - Profile observations
surface condition
The soil surface can give broad clues as to the soils structural condition. Particularly, it will point to the need for, and suitability of, tillage.

what to look for:
Presence or absence of: Surface crusting, large coarse clods, a separation of sand and clay on the surface giving a light grey appearance, weeds (size and density), standing stubble, loose trash, field in beds or on the flat, insect pupae, moisture, depth of wheel tracks, wheel tracks over beds.

location sketch of pit
This sketch will be especially useful where the field has variable soil types. For the future, it will warn you against digging another pit in the same place (the mixed soil would be misleading).

sketch of profile
In this box make a rough sketch of the whole profile. Draw features that you see in the pit (you do not have to sketch everything at once - fill in as you make other observations). The sketch is a good way of tying together the features you will record in more detail on other parts of the sheet. It is a means of focussing your attention on the profile, and is a handy place to make notes.

A diagram of 1 metre hills and furrows is printed at the top of this box. The darkened furrows toward the centre represent the furrows used by the planting and cultivating tractors in cotton.

what to look for:
Presence or absence of platiness, massiveness or smearing, bent shallow roots, coarseness of cracking. Mark on the diagram the width of the cultivating set. Sketch in small things such as lime nodules- they are a favourable feature when found on the soil surface.

A warning sign is when damage extends beneath the plant line.

wheel tracks
When examining the soil profile after a wet harvest, mark on the diagram where the harvester wheels passed with relation to the cultivating tracks. Record the percentage of furrows that had neither harvester nor cultivator tractor.

If the hills or beds have been ploughed down, compacted tracks may be harder to spot. You should still be able to see the compaction but it will be harder to relate to the cause.

cracks
If the soil is very moist when the pit is dug, natural crack lines will be closed and hard to see. Wet soil may appear to be massive even though it is in reasonable condition. Combine visual observations with the feel you get from the soil when you are cleaning the face of the pit (i.e. are they massive clods which are hard to prise out, or do they break easily breaking along fracture lines?)

roots
Any roots present will be beneficial in that they can rot and leave continuous pores for penetration of air, water and other roots. Good root development by a crop is a good sign as long as harvesting equipment has not compacted the site.

Section 3a - Profile tests in the pit
Depth
This column is for recording the depths of major features. On a hilled field use the average height between the top of the bed and the bottom of the furrow for starting your measurements. The normal soil surface would be your starting point on a flat field.

Pay particular attention to the following three zones:

1. Seed-bed: from the surface of the beds to about 10 cm depth.

2. Upper subsoil: immediately under the beds and under the furrows, from about 10 cm to 30 cm below the surface of the beds.

3. Deeper subsoil: from about 30 cm below the surface of the beds to the bottom of the pit.

Slaking and Dispersion
Dispersion is a measure of how easily the soil separates into the primary particles of sand, silt and clay when (i) immersed in water and (ii) remoulded when wet. Dispersion is governed by exchangeable cations and can

be affected by soil organic matter. A soil chemical analysis can help to explain a soil's behaviour in this test.

Do this a quick test on entering a soil pit.
Enough time will have elapsed by the time you leave the pit to have some idea of how prone a soil will be to slaking and dispersion. It is preferable to do the test on air dry soil.

The test can be done without digging a soil pit by using an corer or shovel to extract samples from depth. When using a corer make sure that it is of large diameter and take the soil sample for testing from the middle of the core. This is to avoid sampling remoulded soil that tends to disperse more readily.

A soil that is unstable to wetting can form a surface crust or hard clods on drying and subsoil channels may become blocked with dispersed particles.

1: Dispersion on wetting
Place a small crumb of dry soil in a petri dish or saucer of rainwater (distilled water is similar) and leave for 10 minutes. Do not disturb the dish once the crumbs of soil are in the water. Water movement can cause the soil to disperse more readily. Put the water in the dish first and then add the crumb.

The soil may slake (crumble into smaller fragments) within a few minutes. This is not unusual for cultivated Australian soils. If the soil breaks down further, by dispersing, to form a milky halo of clay particles, then the soil is dispersive.

Very dispersive (unstable) soils begin to show dispersion within about 10 minutes in rain water. Within 2 hours a very unstable soil may have dispersed completely into a cloudy suspension of single particles. (See colour photographs in Agfact AC10: Improving soil structure with gypsum.)

Less-dispersive (more stable) soils may show no milky halo or only a slight halo (hard to see) after two hours in rain water. They may however become dispersed after several hours. Stable soils will not show dispersion even by the next day.

Score clay dispersion as follows. (A high value indicates low stability, ie. much dispersion of clay.):

Score 4: for **complete** dispersion within 10 minutes.
Score 3: for **strong** dispersion within 10 minutes or complete dispersion within 2 hours.
Score 2: for **slight** dispersion within 10 minutes or strong dispersion within 2 hours.
Score 1: for **slight** dispersion within 2 hours.
Score 0: for **no** dispersion within 2 hours.

A score of **3** or **4** means that the clay disperses easily when the soil is wetted. As the soil dries, it will either form a surface crust or will set into hard blocks. Gypsum will help to stabilise the clay and improve soil structure.

A subsoil that disperses will swell more when wet. This will in turn close soil pores and make the soil less permeable to water and air.

A score of **1** or **2** also indicates a possible need for gypsum. Investigate further with laboratory testing, especially exchangeable sodium percentage.

A score of **0** means that the soil is stable to wetting. (Even though it may slake, it is most unlikely to form a crust or hard blocks on drying.)

This is a good in-field test that will point to the likely success of a gypsum application to prevent surface dispersion. It is good practice to try a test strip of gypsum for a season before treating the whole field. If the whole field is treated a small strip left untreated will help to show the economic merits of the treatment.

Generally the brown clays are better drained and easier to manage (more 'forgiving') than grey clays. Colour can indicate problems: waterlogging can produce a bluish tint (you may need to improve the surface drainage by re-levelling the field). The colour of soil in the pit can give evidence of mixing eg. where a pit has been dug over a previous pit or where land forming has filled in a hollow.

Observations of soil colour without standards or colour charts (eg Munsell soil colour chart) may be misleading as your memory does not have good recall of fine colour differences. Your colour perception is conditioned by contrasts within the surroundings. Take a sample of soil from one pit to another to compare colours.

The moisture level of the soil will alter colour. If the soil is dry, moisten it. Use broad categories (eg. grey, dark grey, reddish brown). Make note of any mottling of the soil (flecks of one colour against a different background) which often indicated temporary waterlogging.

Moisture (Plastic Limit) test

Do this test whenever you plan to cultivate. You can do the test without digging a pit: use a soil auger to extract samples from different depths. Just because surface is dry don't assume that soil at depth will be dry.

Do the moisture test quickly and with a reasonable amount of soil to prevent the heat from your hands drying the sample. The test is simple: the behaviour of the soil when first made into a ball will tell you if the soil is very dry or very wet. Once the moisture level is determined with the ball test there is no need to do the second part of the test (making a rod).

Make a ball

Take a handful of soil (it could be one clod or loose soil) and try to squeeze and knead it into a golf-ball sized sphere using firm pressure. The characteristics of the resulting ball will indicate soil water content.

Moist soil can be tested. However the amount of dispersion will be greater than with dry soil. If dispersion takes place, take a soil sample and dry it to air dry before re-testing.

2:Dispersion on remoulding

Carry out this test if the soil appears to be stable to wetting. Some problem soils do not disperse spontaneously, as described above, but do disperse after remoulding. Such soils are unstable after excessive cultivation and should be treated with caution.

Mix some soil with rain water to a plastic consistency and remould it with a knife for one minute. Place small lumps of the moistened remoulded soil in rain water, as above.

Score dispersion as above, but add the letter 'R' to indicate remoulding.

A high score (**4**, **3** or **2**) indicates that the soil is very prone to dispersion if tilled when it is moist. Remoulding damages the structure of any soil by closing off or destroying large pores: if compounded by clay dispersion, the damage is extreme. The soil sets into hard, intractable blocks on drying. Take extra care to avoid tillage when wet.

A score of **1** indicates a soil that disperses to some degree if tilled when moist and deserves cautious management.

A score of **0** means that the clay is bound strongly enough to resist dispersion by working when moist. However, this does not mean that the soil is immune to structural damage caused by smearing, remoulding and compaction.

Colour

Colour is a good way of distinguishing different parts of a variable field. A subtle difference in colour may relate to a physical factor that requires a different method of management.

• If the soil is so powdery that the ball will not hold together, or the soil is so hard that you can not reshape it, the soil is drier than the Plastic Limit (PL).
• If the ball is crumbly, the soil sample could be close to the PL. Test further by trying to make a rod (see below).
• If the soil forms a ball easily, feels soft and pliable and you can make a ribbon of soil between thumb and forefinger, the soil is wetter than the PL.

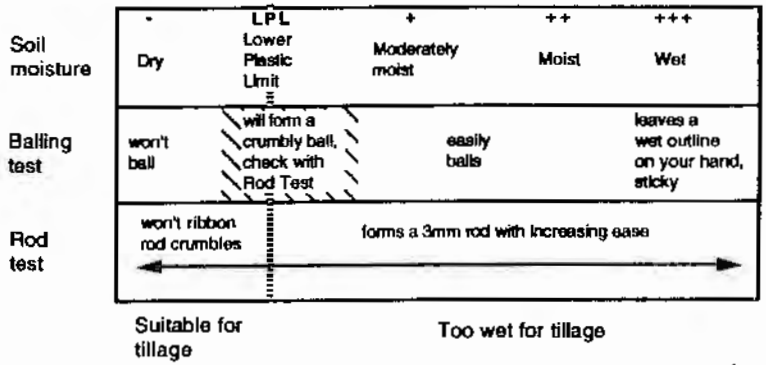
Make a rod
Use the same ball of soil. Work it in your hand to destroy any aggregates (do not work the soil in your hand for too long or it will dry). Then try to roll the soil into a rod of 3 mm diameter. Use some pressure and be careful not to stretch the sample. It is best if you place the soil on a flat surface when doing this. Soil near the PL is quite dry and will feel firm.

•A soil that crumbles before reaching the 3 mm stage is drier than the PL and is safe to cultivate.

•A soil that just forms a rod is at the PL and is just safe to cultivate.

•A soil that easily forms a rod is wetter than the PL and is unsafe to cultivate (see following figure).

Moisture determination for clay soils.



Clod porosity, shape, faces

Pores (cracks, channels), the shape and size of clods and the appearance of the faces of clods are different ways of describing and scoring soil structure. Take all these features into account when assessing the soil. Assessment is semi-subjective. Nevertheless give a score of 0-3 for increasingly good features.

Porosity

Look for cracks and pore spaces between individual units of soil. Rate porosity by the number of potential routes for root penetration by the next crop.

Some pores are too small to see and so you can not, in a soil pit, observe and record total porosity. However you can observe and record the frequency of large pores. Such an observation is relevant to the assessment of soil condition. Large pores are the means by which water, nutrients and air, as well as roots are able to penetrate the soil.

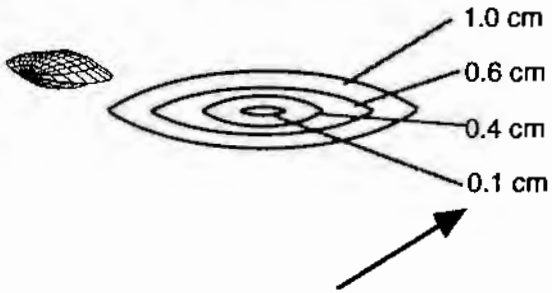
Form your impression of porosity as you clean the face of the pit. Use the feel of the soil as you remove aggregates and the look of the freshly exposed soil face. These observations will tell you if the soil has parted along natural cracking lines, or has been torn apart through the soil fabric.

Roots make channels of many sizes. Decayed tap roots will leave a round hole 1 cm or so in diameter. Look closely at the face of the aggregates and examine them for internal pores such as small "pin" holes formed by old root growth. Note the depth of root growth.

Clod shape

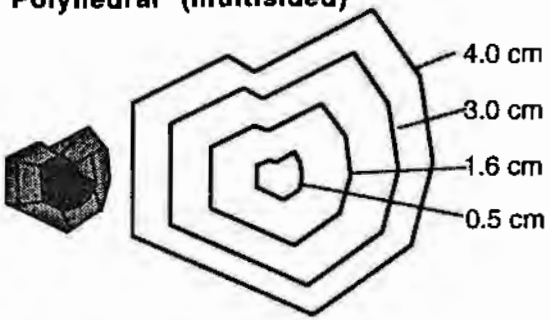
Clod shapes and general interpretation:

Lenticular (2 sided thicker in middle)

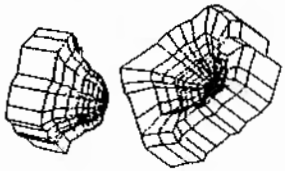


Record the thickness of the clod ie. through its thinnest dimension:

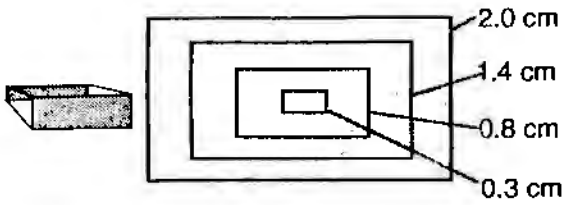
Polyhedral (multisided)



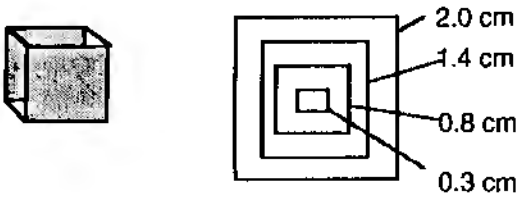
Concoidal (ball and cup) generally larger than 1 cm



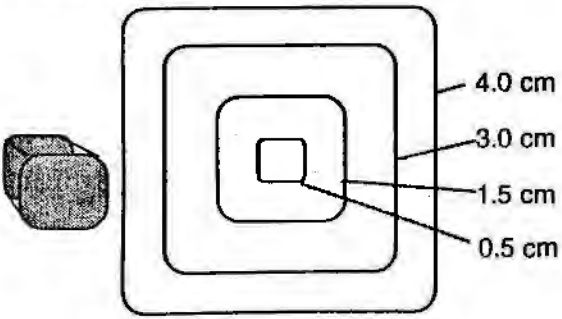
Platy - 2-3 times longer and / or wider than deep



Block - square edges



Sub angular Blocky (approximately cube shaped)



Natural: Polyhedral, sub angular blocky, lenticular

Signs of damage: Platy, concoidal, large massive blocks

• Good clods from the plough layer are very porous and friable and have no definite shape. Lower down they become blocky (they fit together on flat faces, with slightly rounded corners). In the subsoil they are larger and may be wedge shaped.

• Horizontally layered clods are platy. Platiness is mainly caused by horizontal shearing forces eg. spinning wheels. The main effect of compaction from vertical stresses (such as the load of a harvester) is the coalescing of clods into a massive lump.

• Another clue to degradation is round clods. You may find clods that separate along a cup shaped fracture (concoidal), suggesting one clod pressing into another.

Clod faces

• A good sign is many natural shiny surfaces. This is usually associated with much angularity on the pit and clod faces. This angularity should be in all directions and not aligned horizontally. Good clods are easily broken along natural lines of weakness (with shiny faces). Do not confuse natural shiny faces with shiny smeared layers from a tillage implement.

• A bad sign is a face with little in the way of natural surfaces. The face may be dull and may have a fine-grained appearance.

Porosity ratings with approximate size guides

0	1	2
Composed mainly of small numbers of large clods, to extremely large blocks >20cm diameter.	Composed of smaller clods than for **0**. No extremely large blocks, generally less than 5 cm.	Many small clods. 2cm or less in surface layer, larger at depth.
Most blocks break across the line of applied force and leave a flat finely grained face **OR** thick layer of clods oriented horizontally ie. thick platy.	A large proportion of an individual clod breaks with a flat finely grained face **OR** all clods break in horizontal plane only ie. a smaller proportion of vertical to horizontal cracks.	Clods break easily along rough surfaces.
No root penetration since the compaction event, no worm-holes.	Some evidence of root penetration.	Extensive root penetration, worm-holes, etc.

A numerical system for classifying soil structure.

Loose soil

Loose 0 Loose 1 Loose 2

Moist

Some of the larger units are dense and massive clods note the size range of the dominant fraction.	At least half of the clods present as larger compound aggregates which can be broken up by hand into their constituent natural aggregates: note the size range of the dominant fraction.	Composed wholly of natural aggregates with, a range of sizes is possible appropriate to the depth from the surface: note the size range of the dominant fraction.
Porosity rating mostly 0.	Porosity rating mostly 1.	Porosity rating mostly 2.
Clod shape massive or platy.	Mixed shapes.	Clod shapes polyhedral or sub angular.

Extra notes for dry soil.

As above.	As above however compound aggregates are firmer - perhaps requiring a tap with an implement to assist in breaking them apart.	As above.

Firm Soil

Firm 0 Moist	Firm 1	Firm 2
Difficult for spade to penetrate: lumps of soil severed off made up of large tight fitting blocks. These fracture across the lines of force applied in any dimension into units with sharp right angled corners, finely grained and even internal surfaces with no pores visible or no sub aggregates projecting from the fractured surface.	Some separation planes natural but distinct force needed to break the blocks apart, fracturing taking place mainly across the line of force applied to produce angular comers and mainly non-porous internal surfaces.	Breaks up readily into porous sub-units along natural fracture planes that have a smooth and shiny face or the fractured faces may be polyhedral with the exposed internal surfaces multifaceted and with sub angular units protruding.
Porosity rating mostly 0.	Porosity rating mostly 1	Porosity rating mostly 2.
Clod shape massive or platy.	Mixed shapes.	Clod shapes polyhedral or sub angular or lenticular.

Extra notes for dry soil.

A very strong blow is required to break the blocks revealing a flat dull grainy surface with angled corners.	As above but more force required to break the aggregates apart.	You may need to tap the aggregates lightly with an implement to break them apart.

Summary of appearance and feel of remoulded, smeared, compacted, and soil in good structural condition

Soil Condition	**Dry**
Dry Remoulded	Hard lumps, flinty, sharp edges, Little root penetration (if the damage is old) or pin holes.
Dry Smeared	Continuous shiny face that can be at any angle but often 45° but can be vertical and horizontal too. Soil separates easily along this face Dense layer immediately under shiny face
Dry Compacted	Soil appears dense with few cracks and few shiny faces. Clods are hard to break with no natural crack lines. Surface of soil appears finely grained
Dry Good	Penetrated by numerous roots, cracks, and pinholes. Soil aggregates are small and separated by small many angled shiny faces. These angles are random (although large slickensides are often 45°). The soil breaks along these, into smaller and smaller pieces fairly easily revealing natural shear lines and shiny faces
	Moist
Moist Remoulded	Heavy dough - raw pastry plasticine like
Moist Smeared	Continuous shiny face usually vertical or horizontal. Density decreases away from the shiny face Soil on the face moulds rather than crumbles under slight pressure. Easy separation of soil along shiny face
Moist Compacted	Soil appears dense with few cracks and few shiny faces. Surface of soil appears finely grained. Clods are harder to break than soil in good condition (natural fracture lines have disappeared)

Moist Good	Penetrated by numerous roots some cracks obvious Small natural shiny faces on the surface of the clods are very obvious. Breaks into smaller pieces with a small amount of applied force. Soil tends to break rather than mould under pressure
	Wet
Wet Remoulded	Puggy plasticine / dough (softer as water content increases)
Wet Smeared	Continuous shiny face, usually vertical or horizontal. Dense layer under shiny face. Soil either side of the smeared face is puggy . Soil separates along shiny face
Wet Compacted	Soil appears dense with few cracks and few shiny faces. Surface of soil appears finely grained with very few natural shiny faces. Soil is puggy - but not as bad as remoulded soil. It tends to shear across the fabric of the soil rather than separating easily along fracture lines.
Wet Good soil	Penetrated by numerous roots. Small natural shiny faces on the surface of the clods are very obvious. Cracks may not be obvious. Soil can be easily removed from larger soil units by separation along natural lines - Natural faces are still visible

Section 3b - Profile tests continued

Texture

Texture is a measure of the proportions of gravel, coarse sand, fine sand, silt and clay in the soil. The texture will help to explain differences between fields or parts of a field.

Texture of the surface of the soil may determine the structure of the surface layers eg. silty soils are more prone to crusting and hard setting. This will affect emergence of seedlings and infiltration of irrigation water as well as cultivation and trafficability. The texture

of the soil will affect the water holding capacity and internal drainage of the soil. As clay content increases, soil the water holding capacity usually increases and the amount of internal drainage becomes lower. Thus texture can influence irrigation scheduling. Note that good soil structure will overcome the potentially poor internal drainage of a heavy clay.

Texture method
Take a sample of soil sufficient to fit comfortably into the palm of the hand. Moisten soil with water (a little at a time) and work until it just fails to stick to your fingers. This is when its water content is approximately "field capacity".

Continue working until there is no apparent change in the ball of soil (usually 1-2 minutes). Re-wet the ball if it starts to dry out. The behaviour of the worked soil and the ribbon, produced by pressing out between thumb and forefinger, characterises the texture.

Behaviour of moist bolus (ball) for some common heavy soils.

Soil texture	Behaviour of moist bolus
Sandy clay loam (SCL)	Strongly coherent bolus, sandy to touch; medium size sands grains visible in finer matrix; will form ribbon of 2.5 - 3.8 cm.
Clay loam (CL)	Coherent plastic bolus; smooth to manipulate; will form ribbon of 3.8 - 5 cm.
Silty clay loam (SiCL)	Coherent smooth bolus, plastic and silky to the touch; will form ribbon of 3.8 - 5 cm.
Fine sandy clay loam (FSCL)	Coherent bolus, fine sand can be felt and heard when manipulated; will form ribbon of 3.8 - 5 cm.
Sandy clay (SC)	Plastic bolus, fine to medium sands can be seen, felt or heard in clayey matrix; will form ribbon of 5 - 7.5 cm.

Continued next page

Soil texture	Behaviour of moist bolus (Continued)
Silty clay (SiC)	Plastic bolus; smooth and silky to manipulate; will form ribbon of 5 - 7.5 cm.
Light clay (LC)	Plastic bolus; smooth to touch; slight resistance to shearing between thumb and forefinger; will form ribbon of 5 - 7.5 cm
Light medium clay (LMC)	Plastic bolus; smooth to touch, slightly greater resistance to ribboning shear than light clay; will form ribbon of about 7.5 cm
Medium clay (MC)	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture; has some resistance to ribboning shear; will form ribbon of 7.5 cm or more.
Heavy clay (HC)	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear; will form ribbon of 7.5 cm or more.

Reference: Northcote, K.H. (1979).

④ Conclusions

Section 4: conclusions
The conclusions section allows you to summarise your observations of the soil profile.

If you found any degraded soil structure, it could have come from tractor or harvester wheels or from cultivating implements used in moist soil.

Wheel damage occurs under the wheeled furrow and may extend under nearby beds.

Damage from implements may cover the whole of the field (for example if the field was disc ploughed or levelled when wet) or may be confined to the centres of beds (for example if the beds were middle-busted when wet).

Wheel damage;
The option selected here will depend on the worst compaction seen. Rate using the diagrams on the working sheet as a guide.

• When there is little damage from wheels (a very small amount of massiveness or platiness under the trafficked furrows is acceptable) then rate tillage/wheel damage as slight or none.

• When wheel compaction spreads only partly under the beds next to the wheel track, the soil can be rated as having moderate compaction. The key here is that there will be some pathways for roots to penetrate.

Be cautious when forming your recommendations from this conclusion. If the following crop is planted onto the same beds there should not be any great problem. However, if the beds are removed and then reformed over the compacted wheel furrows, the crop will suffer.

• Class pits that show platiness extending right under the beds from wheel damage (usually due to the sideways

movement of the beds during land preparation) as having severe compaction.

Tillage damage
Rate here the effects of tillage damage as opposed to wheel damage.

• If the soil shows no obvious damage from tillage, rate in the friable, small clods, shiny faces category.

• If there is some moderate damage from tillage implements, sporadic patches or very thin layers, rate as moderate damage

• If the tillage damage is extensive and severe, or if the centres of the beds are badly smeared, class as continuous, thick degraded layer and / or cloddy bed.

Soil moisture for tillage is:
The box you tick here will depend upon your observations of moisture at different levels in the pit using the Plastic Limit (PL) test.

The whole profile that is observed in the backhoe pit may be drier than the PL (rated as 'minus' (-) in the moisture column of Section 3a). In this case rate the soil as 'whole profile dry'. All options for tillage are open in this case, and remedial tillage options using appropriate equipment can be tried on deep levels of compaction if present.

The soil may be dry at the surface but wetter at depth. An example of this may be when weeds have helped to dry out the upper layers of soil. Rate this as "shallow depths OK". Also record the depth to which the soil is dry to aid in the setting of tillage tools.

If the soil is at, or close to, the PL throughout the profile (rated as PL or + in the moisture column) rate as marginal. Avoid working this field until it dries further.

If the soil is wet throughout the profile and is much wetter than the PL (rated as ++ or +++ in the moisture

column) rate as too wet. The field will remain wet for a long period unless a crop is sown on it, or weeds help to extract moisture from depth. Note that a bare fallow will not achieve significant drying below 10 cm or so.

Dispersion

Record your results (0-4) from the dispersion tests (Section 3a).

Percentage non-wheeled rows

Record the proportion of non wheeled furrows, i.e. rows not compacted by harvesting equipment or cultivating tractors.

⑤ Recommendations

Section 5: recommendations

Tillage:

Your options will be influenced by a number of factors, including the degree and depth of damage and soil moisture. Some examples follow.

deep tillage:

Damaged layer under beds, soil profile is dry throughout. Deep tillage is called for. Possibly deep rip or chisel, scarify and reform beds.

shallow tillage:

Surface soil is dry but soil at depth is still moist. There is no damaged layer present but weeds and stubble needs to be incorporated and hills or beds need to be reformed.

no tillage (1):

Soil is in good condition. Keep it that way by disturbing it as little as possible. Leave existing beds in place.

no tillage (2):

Soil is not in good condition, but is still moist throughout. Under-hill tillage will cause more damage. The recommendation would be to leave existing beds in place. However furrow ripping to produce loose soil to build up the hills or beds may be acceptable.

Crop Type:

The condition of the soil and the need to plant a crop in a particular field for the coming season will determine your option here. Options include:

irrigated crop:

If the soil condition is good then grow as much crop as the water supply allows. If water is limiting, the fields with the greater amount of damage should be rejected first as management on these fields will be more difficult and costly and yields lower.

irrigated crop, critical management;:
You can choose to nurse a crop in compacted soil. Add extra nitrogen and monitor the crop very carefully to avoid sudden water stress. Even so, the yield will not be as high as on a good soil.

alternative crop
A vigorous rotation crop can repair damaged structure by drying and cracking the soil. Even if it does not repair the damage to your satisfaction the soil is likely to be dry enough for deep tillage. Check soil structure following the crop with spade or backhoe pit.

For the crop to be effective, it needs to be vigorous. You should fertilise it and give it at least one watering to stimulate rapid growth.

Gypsum application:
Your choice here will be determined largely by the results of the dispersion test (Section 3a), and by results of chemical tests for exchangeable cations. When the field has had previous problems with seedling emergence due to crusting, or problems with poor infiltration of irrigation water, gypsum may help. Be aware that gypsum will not cure crusting caused by a silty or fine sandy surface.

Gypsum application has to be followed by an improvement in soil structure, and higher yields that cover extra costs, to be viable.

Critical levels for element nutrition

Soil Test	Adequacy	Critical Level	Notes
N nitrogen		20 - 30 mg/kg	As nitrate September (see Nrate)
P phosphorus		10 - 20 mg/kg	Bicarbonate
S sulphur		5 - 10 mg/kg	Acetate buffer
K potassium		100 - 150 mg/kg	Ammonium acetate
Ca calcium		400 - 700 mg/kg	Ammonium acetate
Mg magnesium		120 - 140 mg/kg	Ammonium acetate
Cu copper		2 mg/kg 0.3 mg/kg	EDTA eg quantum DTPA eg CFL, AFL, NSW Ag
Zn zinc		4 mg/kg .5 mg/kg	EDTA DTPA
Mn manganese		65 mg/kg 2 mg/kg	Quinol acetate DTPA
Fe iron		80 mg/kg 2 mg/kg	EDTA DTPA
B boron		1.5 mg/kg 0.4 mg/kg 0.15 mg/kg	Magnesium Chloride $CaCl_2$ /Mannitol Hot water
Leaf Test			
N nitrogen	3.75 - 4.5	3 0%	
P phosphorus	.25 - .5 %	0.2 %	
K potassium	1.5 - 3.0 %	1 0 %	
Ca calcium	0.4 - 3.0 %	0.4 %	
Mg magnesium	0.4 - 0.9 %	0.2 %	
S sulphur	0.2 - 0.4 %	0.2 %	
Mn manganese	50 - 350 mg/kg	10 - 15 mg/kg	
Fe iron	50 - 350 mg/kg	30 mg/kg	
Zn zinc	20 - 60 mg/kg	11 mg/kg	
Petiole Test			
N nitrogen		19000 mg/kg	Run N rate
P phosphorus		12000 mg/kg	Little local data available
K potassium		10000 mg/kg	"
Mg magnesium		2000 mg/kg	"
Ca calcium		5000 mg/kg	"

Check list of implements and reagents to have on hand before beginning pit observations (! = essential).

	Implement / reagent	Use
!	Knife /screwdriver /trowel /chisel (depending on personal preference) and a small pointed knife	For cleaning the face of the pit has been compacted by the backhoe bucket. Also to expose structural features.
!	SOILpak soil pit working sheets.	For recording observations.
!	Pens and pencils.	Easy to forget!!!
	Tape measure or ruler.	For depth recording.
	Water 2 litres- either distilled (de-ionised) or rainwater.	For carrying out stability tests, also for moistening soil to do texture tests and remoulding tests, as well as washing out gear, especially acid receptacles.
	Acid. Vinegar or Sulphuric (battery) acid. & eye-dropper	To test white nodules for lime.
	Two petri dishes or saucers labelled: **"water", "remoulded water"**	For carrying out stability tests.
	Towel.	For cleaning equipment / hands.
	Plastic bags and labels.	For collecting soil samples.
	Munsell colour chart (not essential).	For determining soil colour.
	Camera (not essential).	Recording of features (NB lighting may be difficult within a pit).
	Auger (Edelman)	Quick soil moisture probing
	Spade	Moisture probing, examining features close to the surface, & for removing loose soil at top and edge of the soil pit
	Pry bar	For use in very hard dry soil
	Hand lens	To examine microstructure