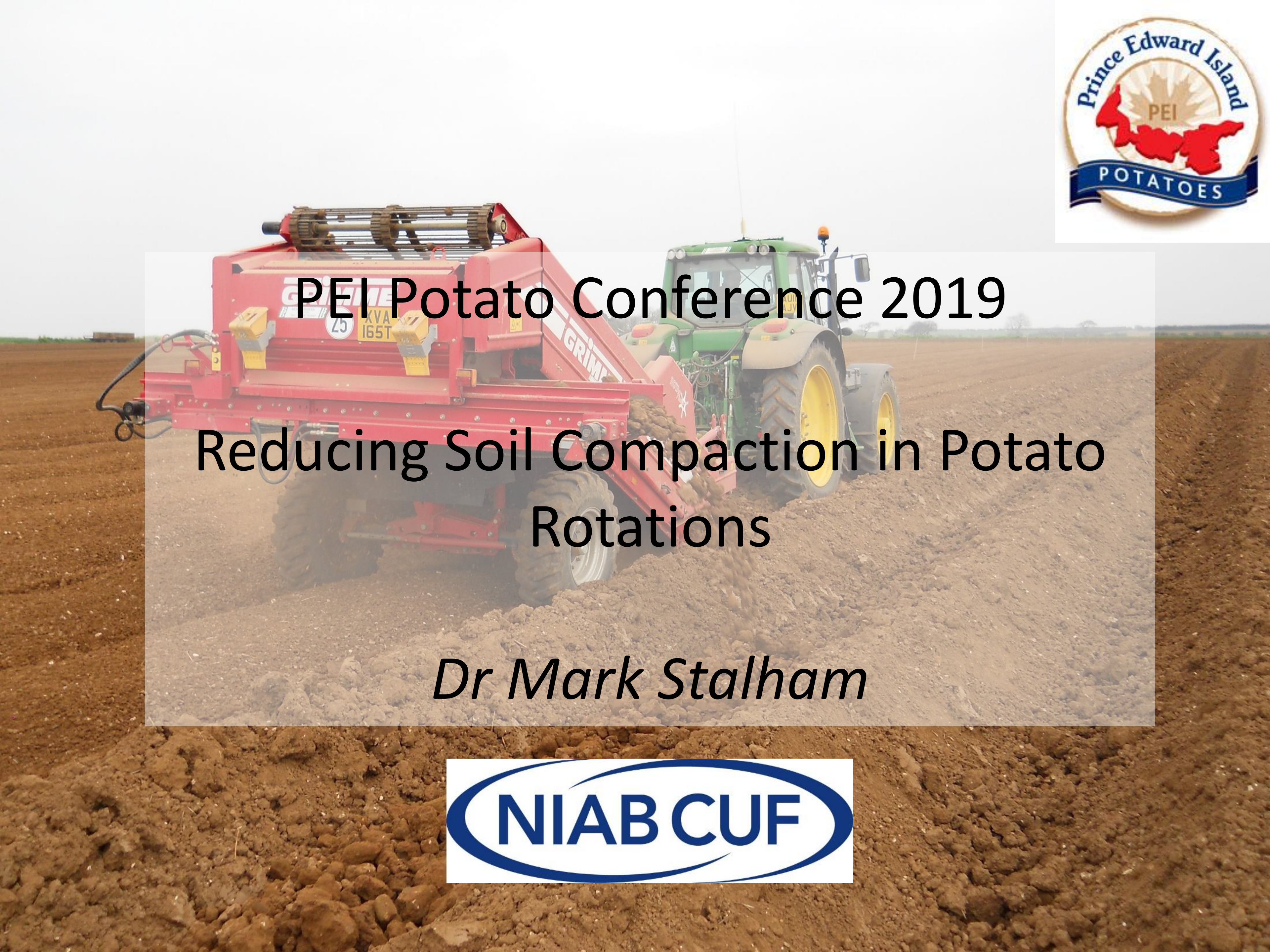


PEI Potato Conference 2019

Reducing Soil Compaction in Potato Rotations

Dr Mark Stalham

NIAB CUF

Requirements of a seedbed

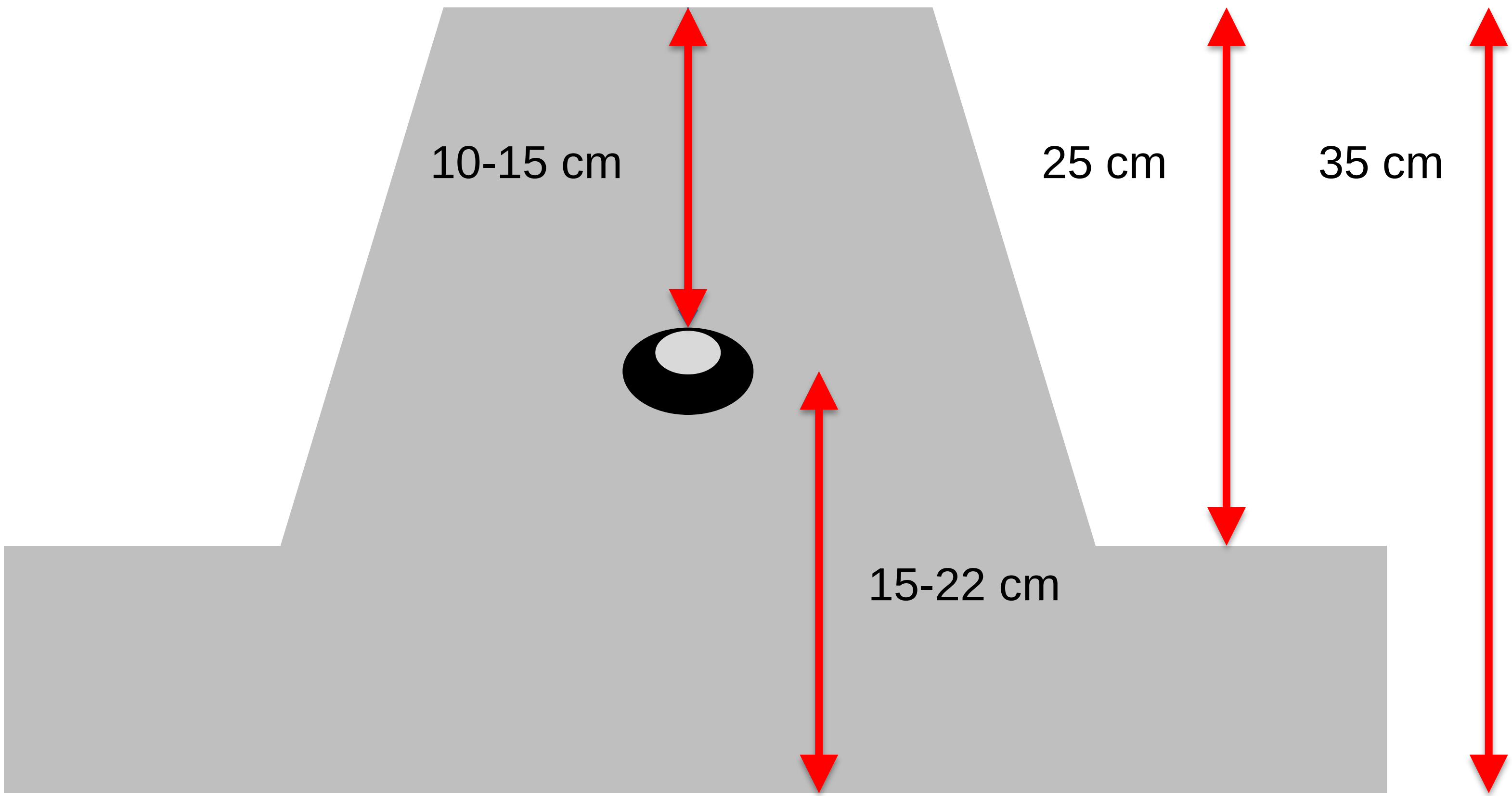
- Optimum air : moisture : soil ratio
- Warm
- Fine tilth
- Freely rootable / compaction free
- Uniform depth to improve planter accuracy
- Allow incorporation of fertilizer / pesticide
- Minimal energy / labour input

Serious issues for potato cultivation

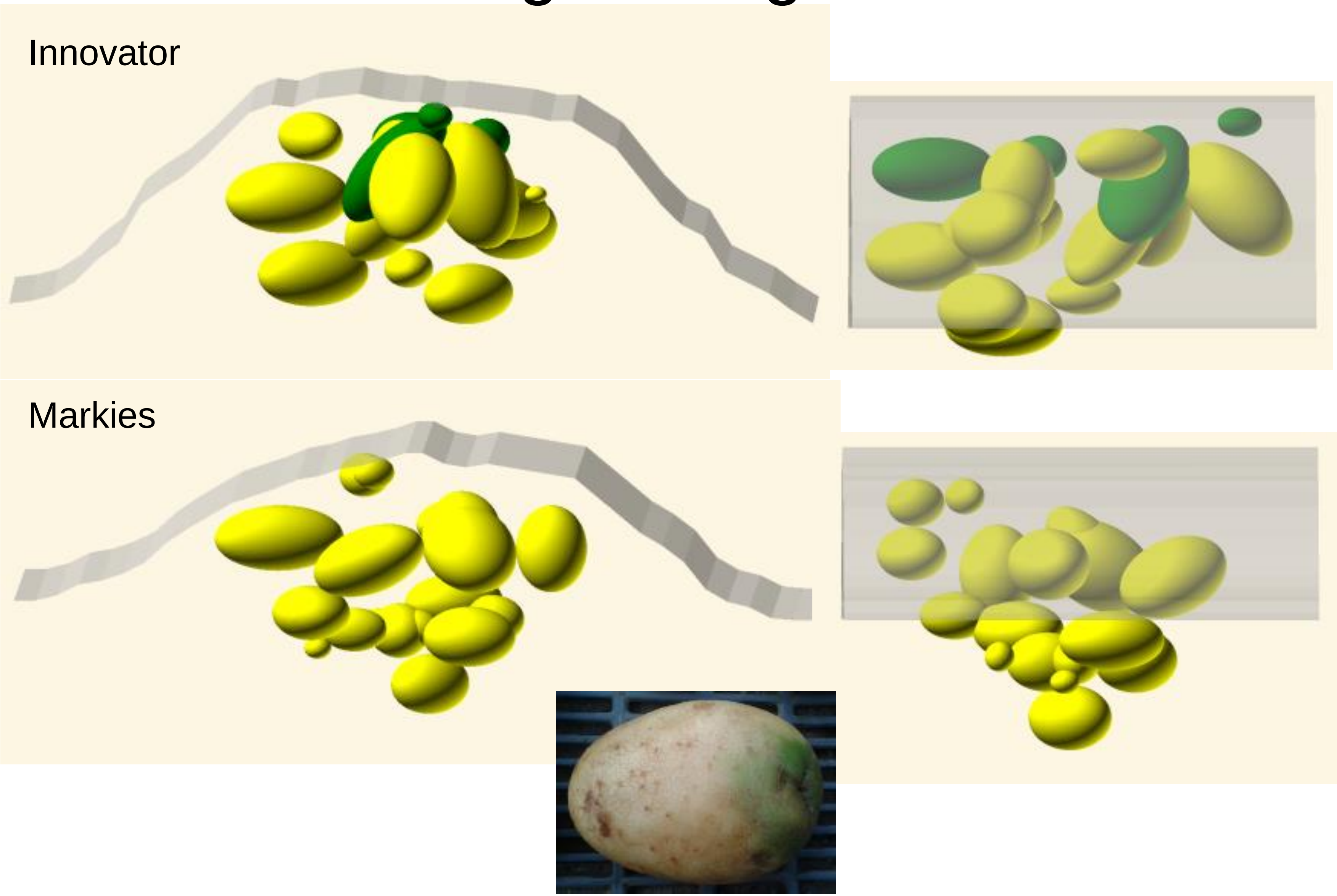
- Highly equipment, labour and energy consumptive and costly (e.g. C$1000-1200/ha)
- Typically involves moving a very large mass of soil (3000-4000 t/ha) on more than one occasion
- Soil structure is being destroyed and compacted over many production areas as a consequence of over-aggressive, powered cultivation in potatoes leading to soil erosion and pollution
- Large operations frequently adopt a "one cultivation combination fits all fields" approach: would the extra management required to adapt to different fields benefit production and profitability as well as improve efficiency?
- Organic matter has decreased in topsoils in the UK in the last 30 years: how important is OM to preventing compaction, maintaining soil structure and lengthening the cultivation window?

Key questions: what depth?

Key questions: why do we cultivate so deeply if we plant at 10-15 cm depth?



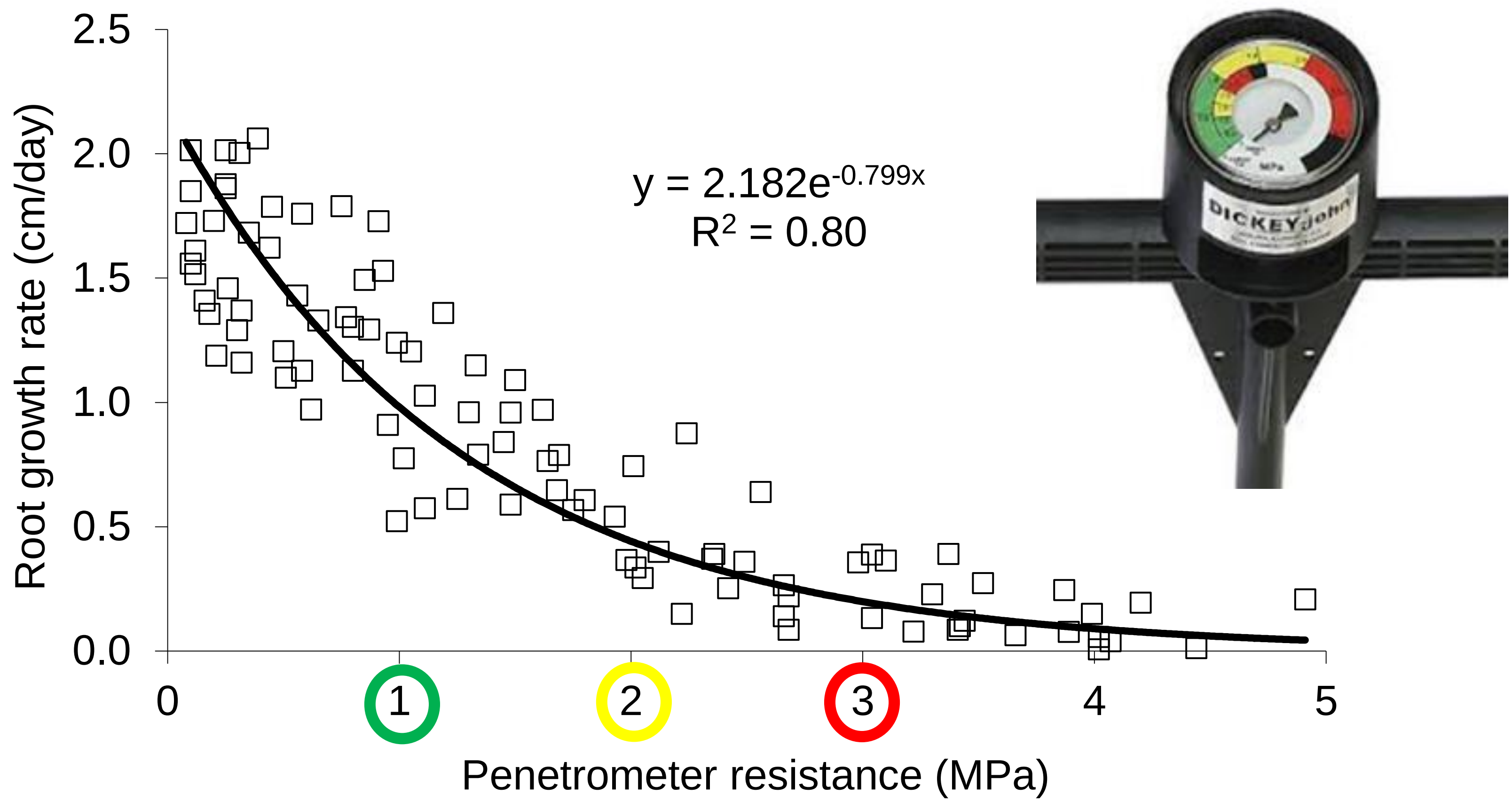
Key questions: what are issues of greening?



Key questions: do we need such perfect ridges?

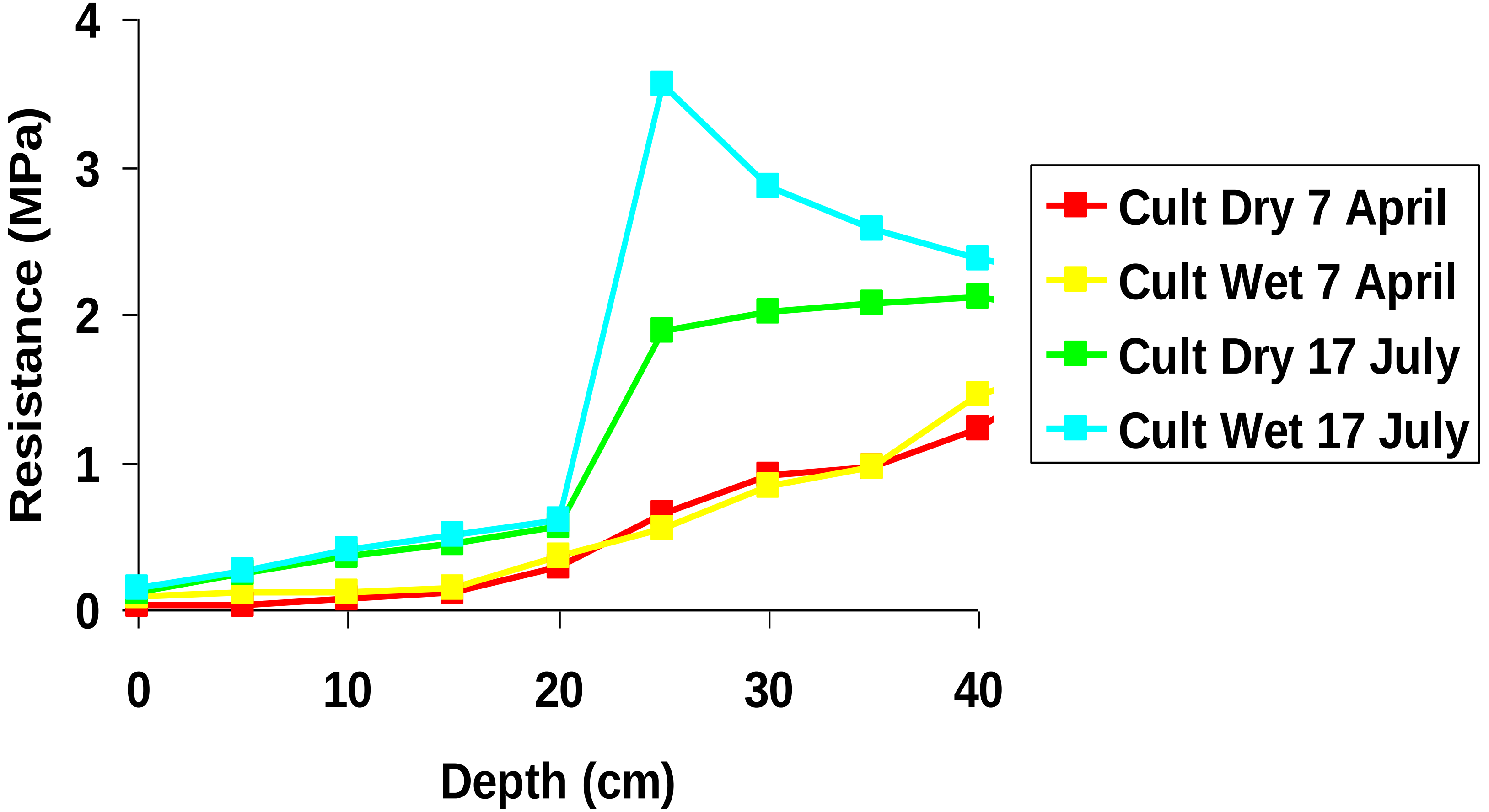
Key questions: what quality of tilth?

Potatoes are more sensitive to compaction than many other crops



Stalham *et al.* (2007)

Compacted layers show up when the soil dries

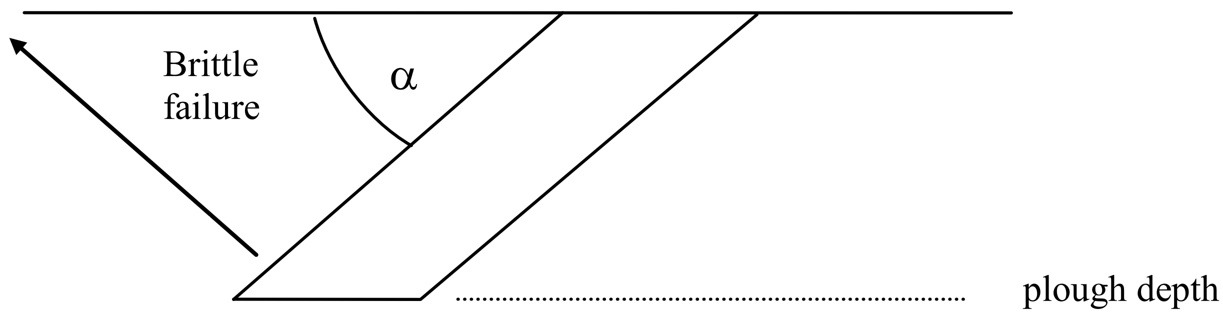


Are all growers creating compaction?

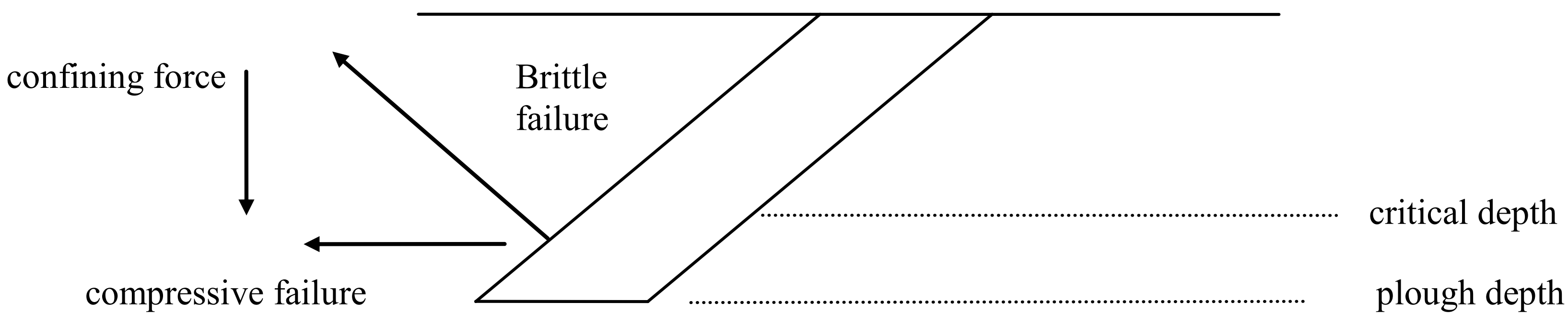
- 925 fields surveyed, 1992-2014
- 65 % had resistances ≥ 3 MPa in top 68 cm (27”)
- At 38 cm (15”), most soils would have benefitted from subsoiling
- 3 MPa typically occurred at 45 cm (18”) depth
- Growth rates of > 1 cm/day only achieved in top 35 cm (14”) in most fields

Critical cultivation depth

(a) above critical working depth



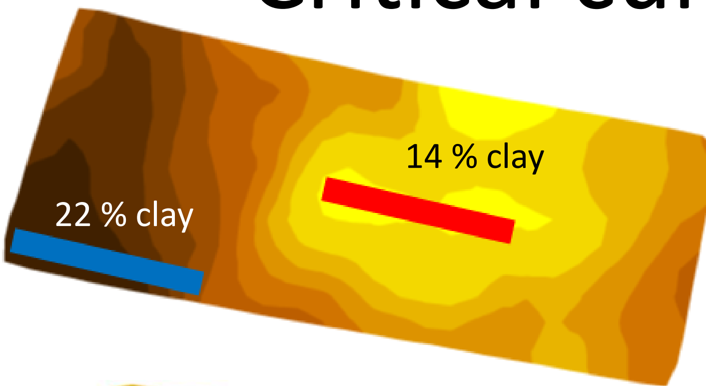
(b) below critical working depth

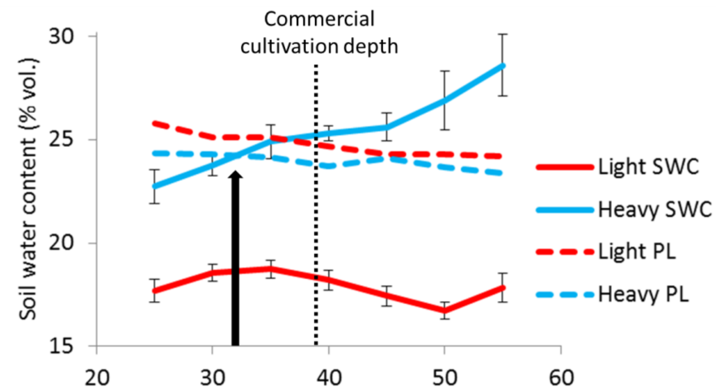


Godwin & Spoor (1977)

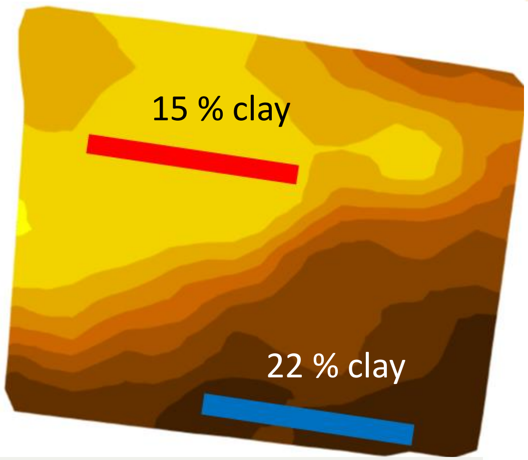
Critical cultivation depth

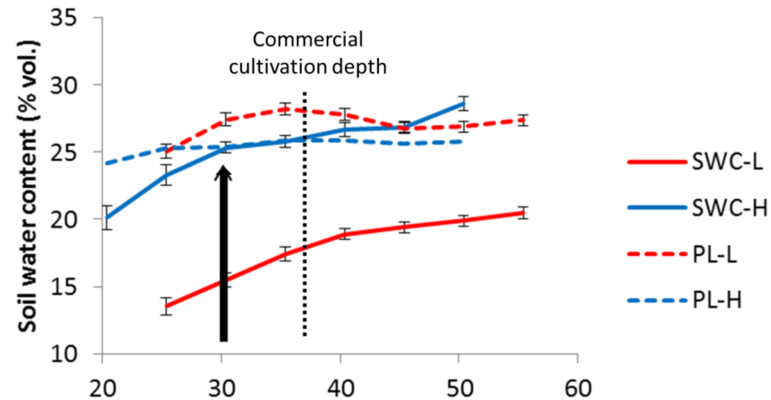
2012



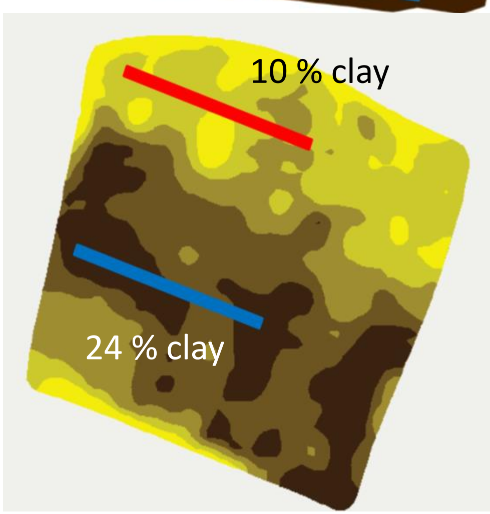


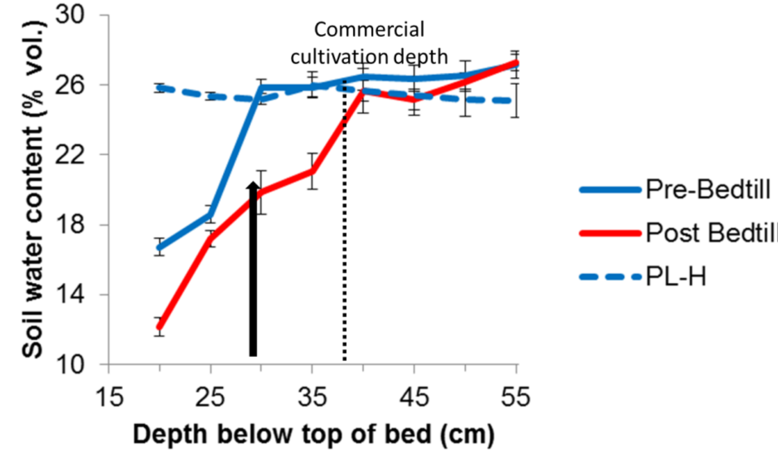
2013





2014

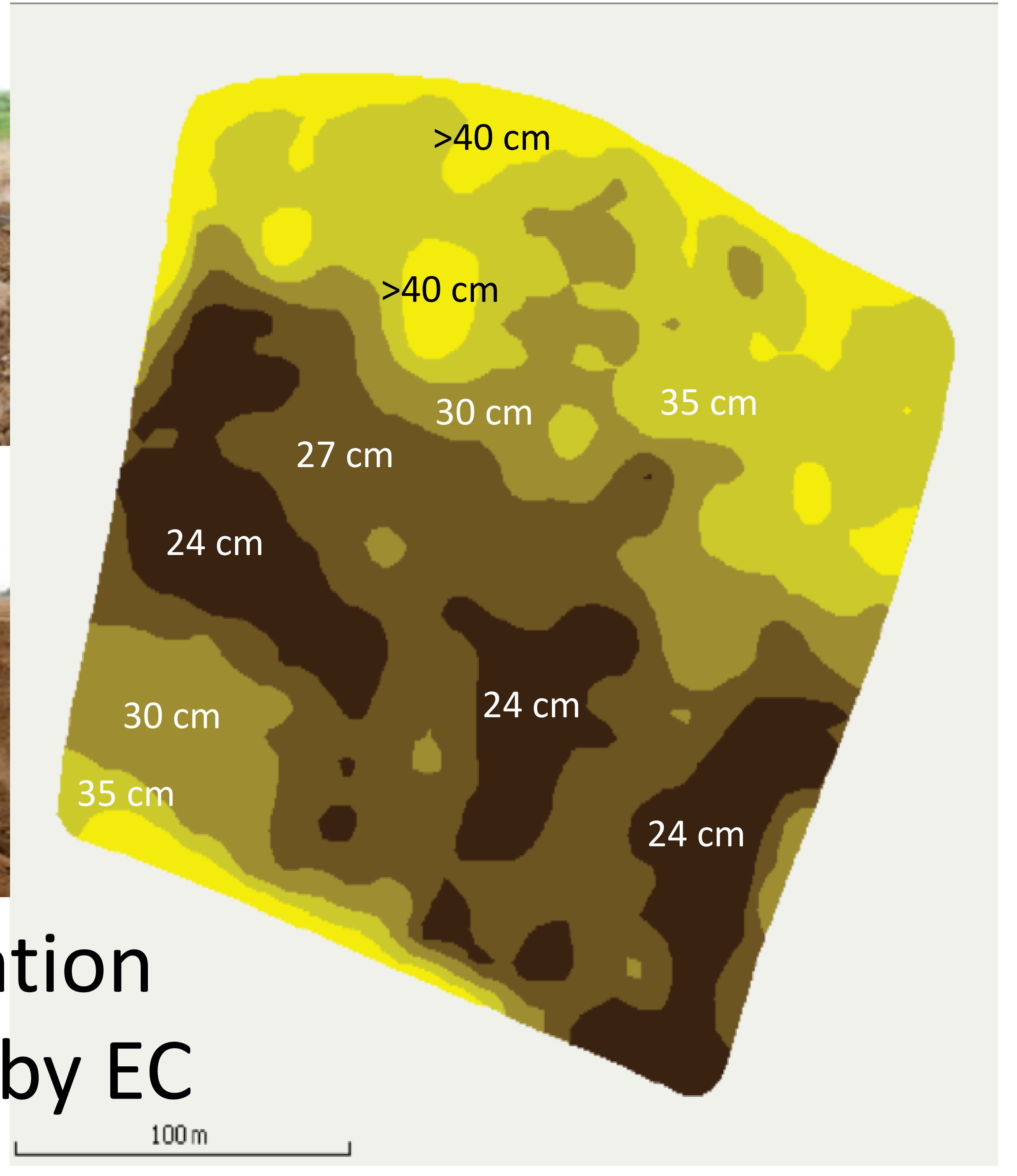




Depth of plastic limit, GVAP-H (sandy clay loam) 2012-2014

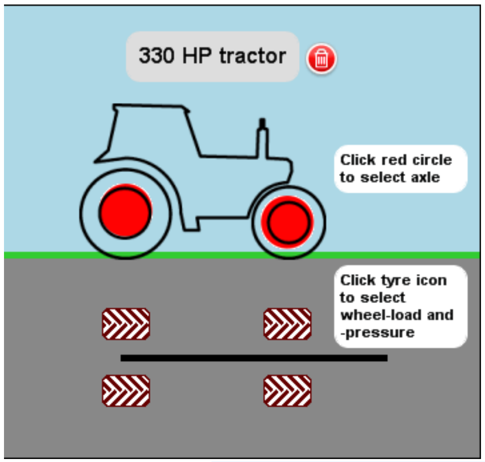
Year	Depth below top of bed (cm)	Depth to flat soil surface (cm)
2012	32	24 (10”)
2013	30	22 (9”)
2014	28	19 (7”)

5 cm variation in critical depth of cultivation



Critical cultivation depths, zoned by EC

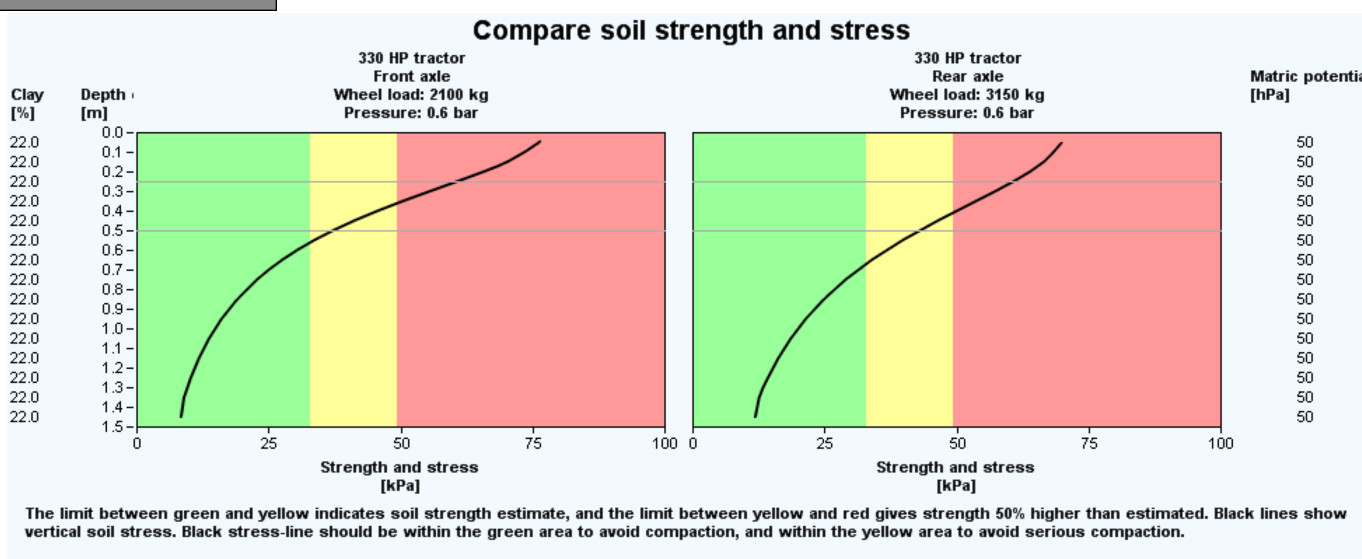
A model to establish risk from loading Terranimo (www.soilcompaction.eu)



Scenario: 330 HP tractor, 10.5 t, 650/85R38 rear tyres at 0.6 bar, sandy clay loam at field capacity, no recent cultivation

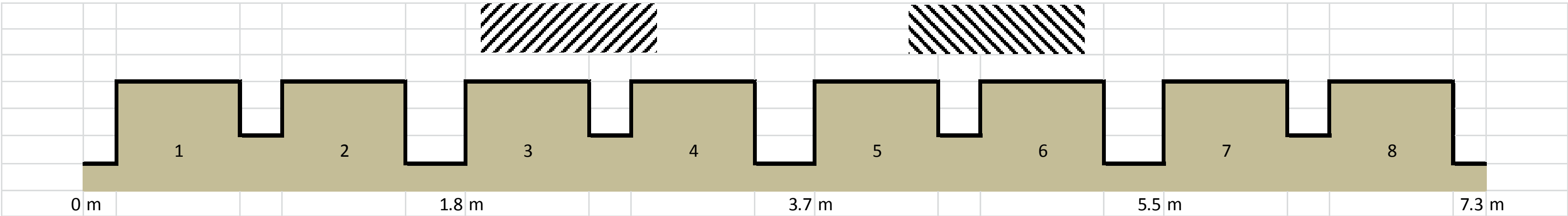
Conclusion: high compaction risk down to 40 cm, intermediate risk down to 70 cm.

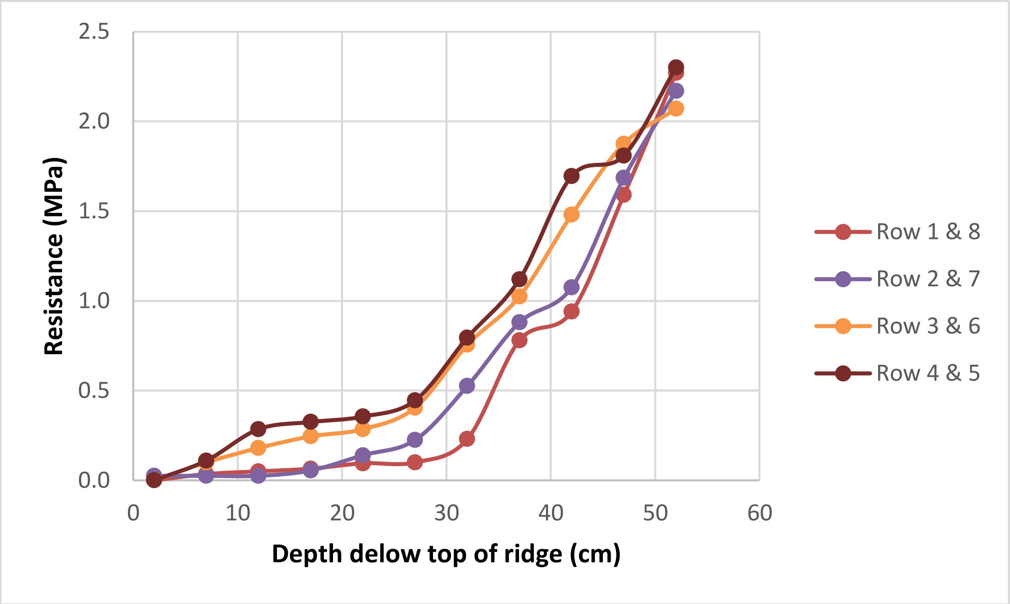
Recommendations: **change tyre, reduce pressure (primarily affecting stresses in upper soil layers), reduce wheel load (primarily affecting stresses in the deeper soil layers), wait until soil has dried (will increase soil strength).**



Traffic management
Greenwell Farms,
Poor Walk, Suffolk, 2017
4-bed bedformer +
Quadtrac 540 (21,670 kg)

91 cm tracks





Effects of compaction on potato yield are much greater than the benefits measured from subsoiling

Compaction

- Range 8 to 38 t/ha
- **Average 18 t/ha**

Subsoiling

- Range -5 to 8 t/ha
- **Average 4 t/ha**

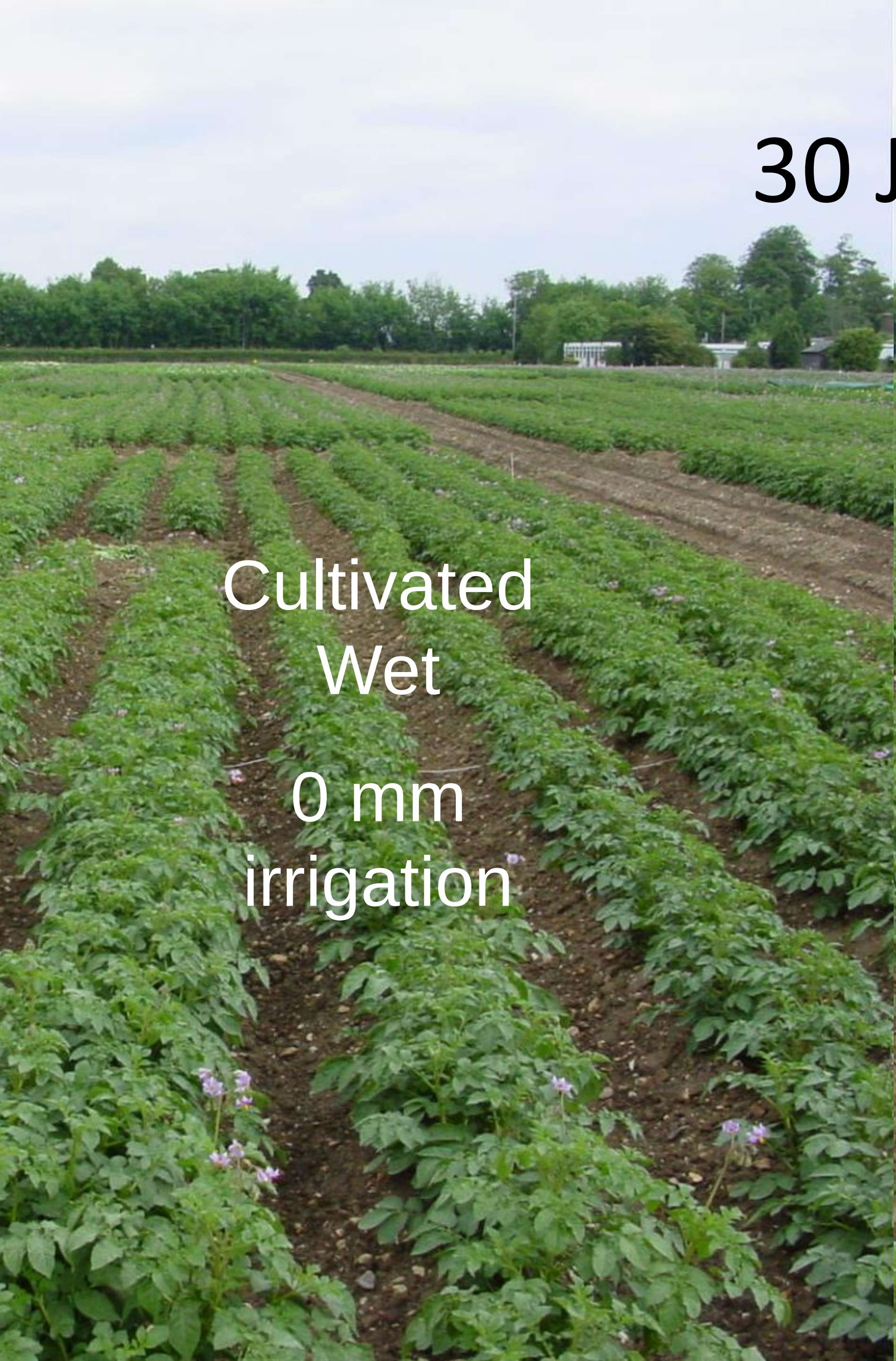
Why the conflict?

- Only ⅓ of researchers measured the soil
- If they did find compaction, ¾ found a yield increase in response to subsoiling
- Subsoiling in wet conditions will not fracture pans or create an extensive network of cracks
- Compaction is often uniform where created artificially: fields are more variable
- You don't need a pit this big!

30 June


AE55
NWJ

30 June

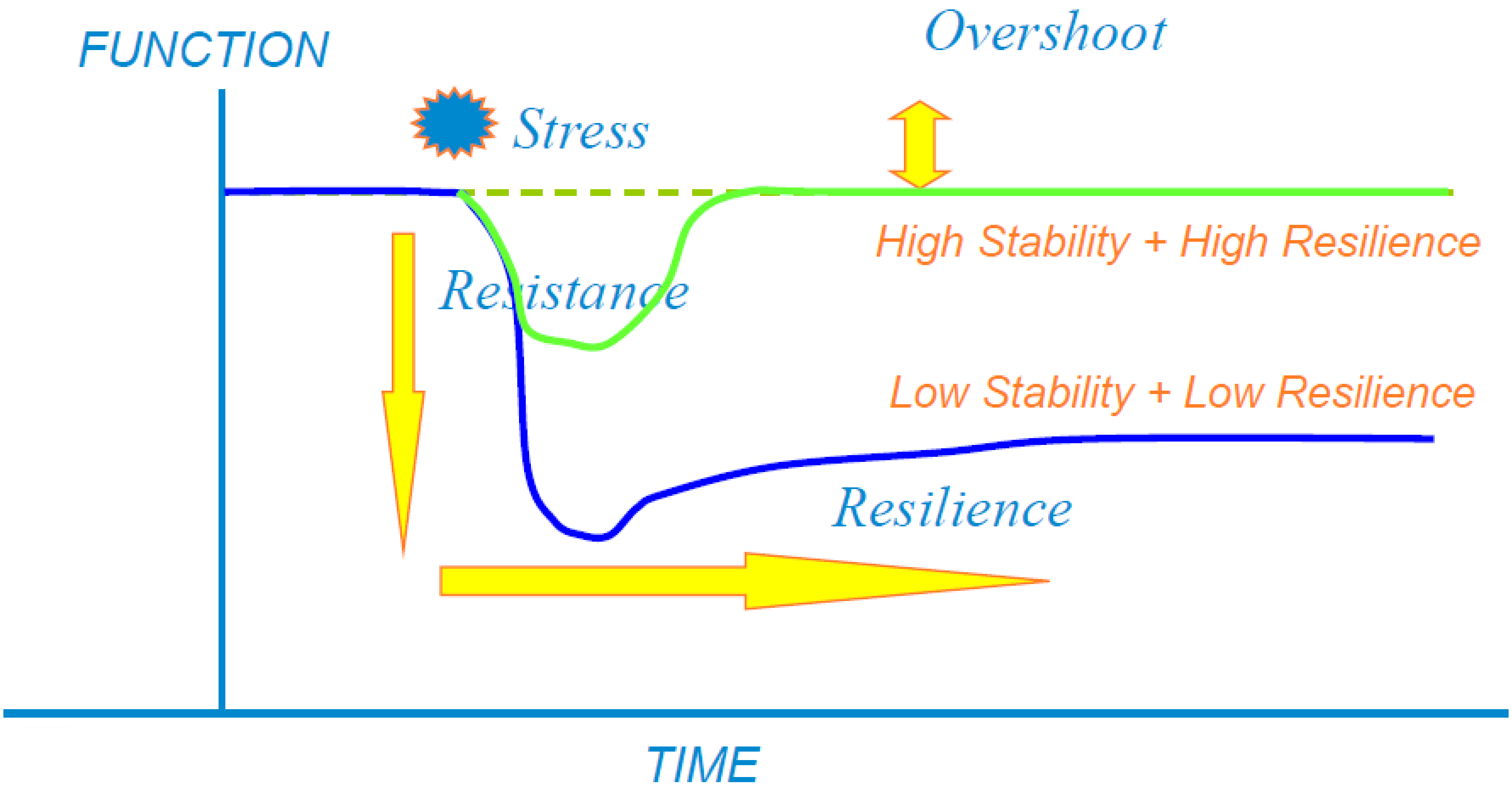

Cultivated
Wet
0 mm
irrigation


Cultivated
Wet
65 mm
irrigation

Effect of soil water content at cultivation on yield under irrigated and unirrigated conditions

Year	2006		2007		2008		2009		Mean	
Irrig. Cult.	-I	+I	-I	+I	-I	+I	-I	+I	-I	+I
Dry	50.0	64.4	50.5	65.7	56.6	77.7	54.0	63.6	52.8	67.9
Wet	41.8	51.9	51.6	64.5	56.5	70.0	52.5	61.9	50.6	62.1
S.E.	2.94		1.74		2.43		2.79		1.76	

Soil resistance and resilience

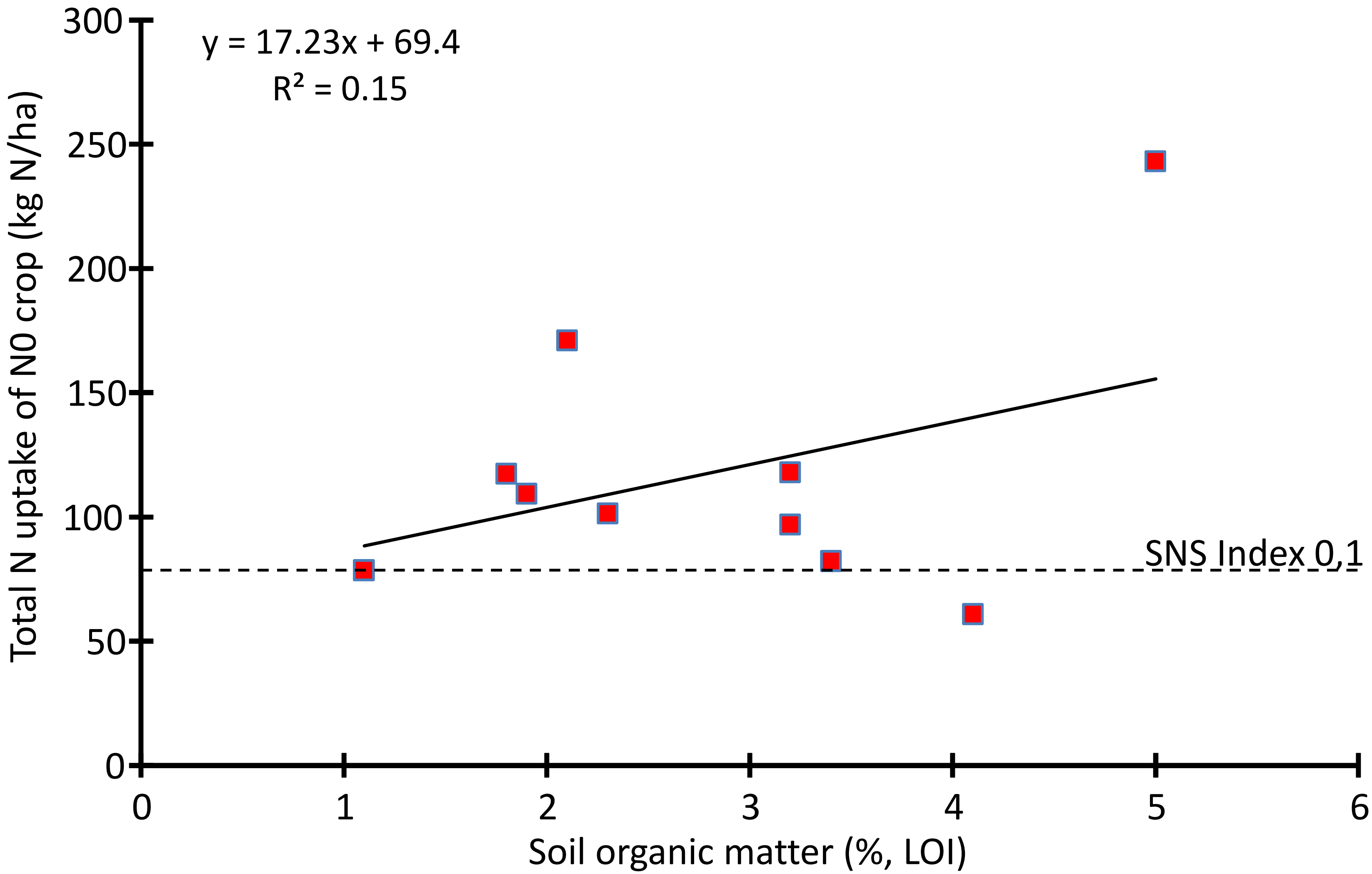


- Will working soil too deeply create compaction which reduces root growth and thereby N uptake?
- Will N applications need to increase if we decrease the depth of cultivation?

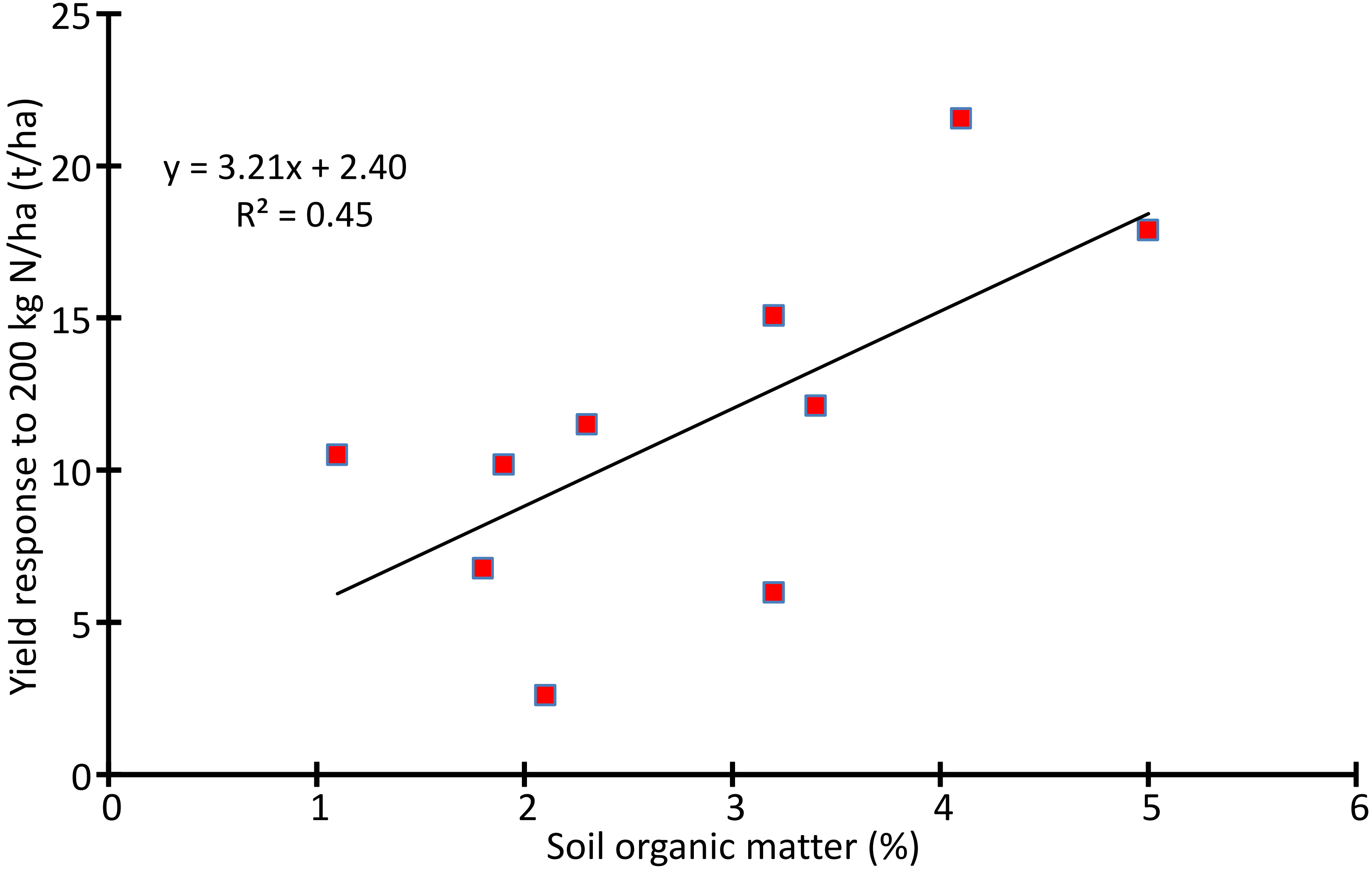
Effect of depth of cultivation on total N uptake (kg N/ha)

Year	Site	Deep	Shallow	S.E.
2014	Daw T30	126	125	3.4
2014	Daw T41	153	143	8.0
2014	SML Caudle	160	159	13.3
2014	Large Danestown	112	107	5.6
2013	CUF-Osier	280	309	13.2
2013	Jolly Dyball	129	127	11.4
2013	Jolly Field 14	106	106	5.6
2013	SML Buchers Stennett	242	259	14.2
2013	SML Top of Curlews	159	153	5.9
2013	Worlick Taylors Bottom	204	206	11.2
2012	SML Buchers Barn	181	165	6.6
2011	SML Buchers Woodyard	198	193	6.4
Mean		**171**	**171**	

Relationship between nitrogen uptake of unfertilized crop and soil organic matter

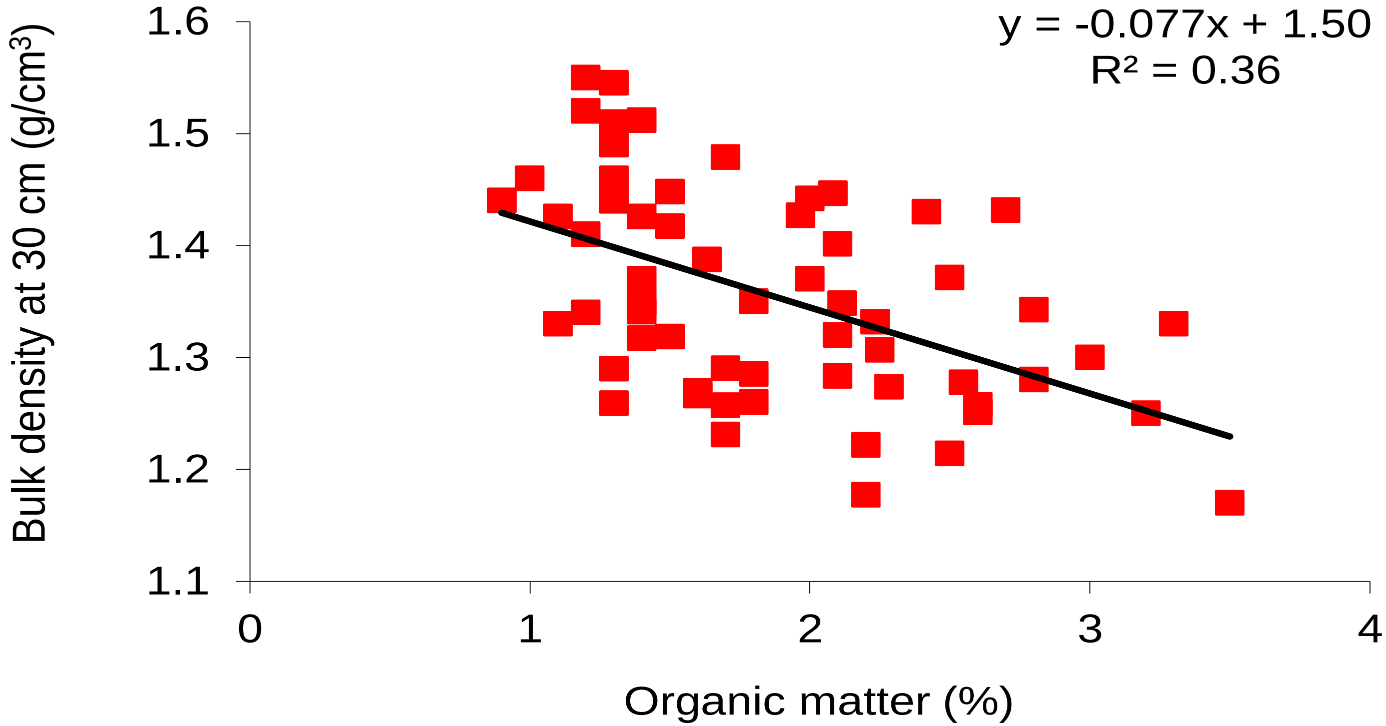


Relationship between response to N fertilizer and soil organic matter



Ameliorating the effect of compaction using compost?

Bulk density decreases as soil OM % increases

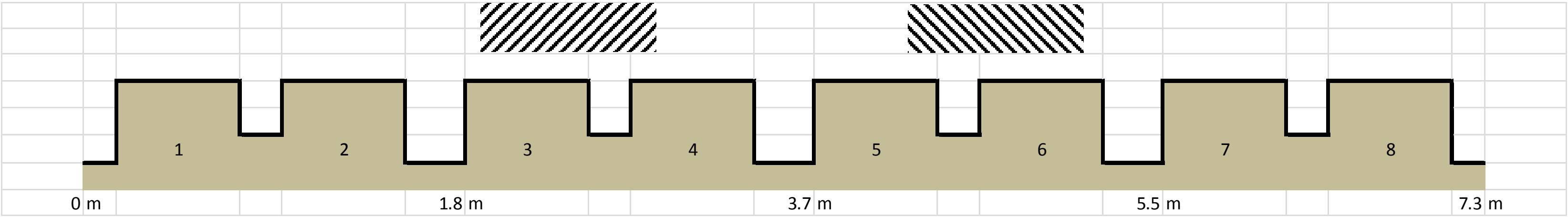


Source: Frontier Agriculture Potato Fields Survey, East Anglia, 2009-2011

Effect of manure and compost amendments on soil bulk density in ridge (11 trials analysed, 2017-2018)

	0-10 cm	10-20 cm	20-30 cm
None	1.17	1.25	1.31
FYM/Compost	1.14	1.24	1.33
Difference	Not significant	Not significant	Not significant
	Significant effect of amendment reducing density in three trials.	Compost reduced density in two trials and long-term FYM reduced density in one trial.	

Does compost reduce the effect of traffic?



Tuber yield (t/ha)				
Amendment	Row 1	Row 2	Row 3	Row 4
None	36.1	37.9	34.8	31.8
Compost	33.5	33.6	29.5	31.2
Mean	**34.8**	**35.7**	**32.2**	**31.5**
S.E.	1.45	1.89	1.49	1.91

NIAB CUF F29 Cover Crop 2018

Effect of cover crops on soil bulk density in ridge (11 trials analysed, 2017-2018)

	0-10 cm	10-20 cm	20-30 cm
None	1.20	1.23	1.20
Cover crop	1.15	1.16	1.17
Difference	Overall, cover crop reduced density.	Overall, cover crop reduced density.	Not significant

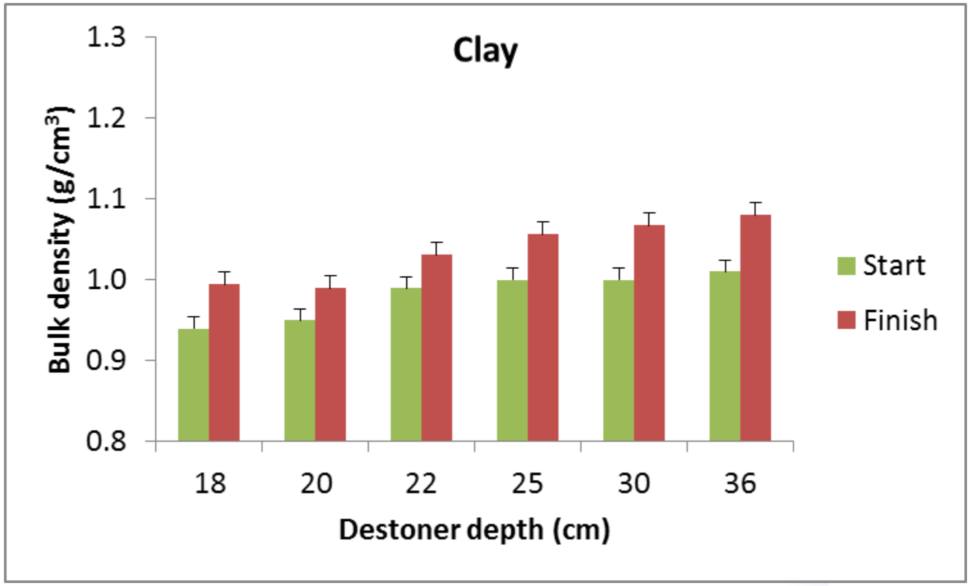
Typical UK soil separation systems

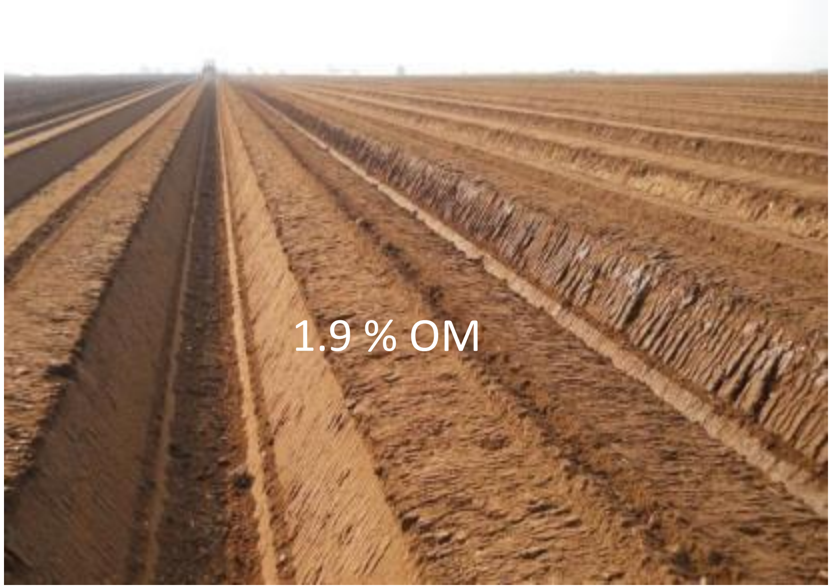
Bed shaping

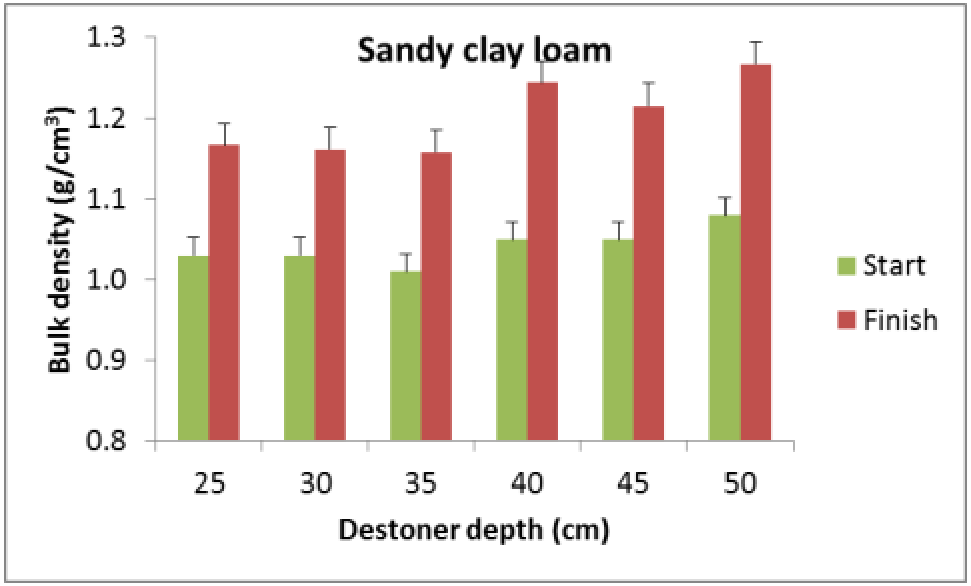
Bed separating

Bed planting

Over-working and 'slumping' following rain after planting







Fuel consumption (l/ha) vs depth (2014)

	GVAP -L	GVAP -H	Stev	Baird	B&C Ox6	B&C Boot	Daw T30	Daw T41	SML Caud	Largo	EGH Moun	EGH BB	SML Cage
Depth	SL	SCL	ZCL	CL	CL	SL	CL	CL	CL	C	SL	SL	LS
Shallow	22.8	31.1	11.4		31.8	28.8	34.0	31.2	22.0	39.0	21.6	19.0	17.5
													22.4
												[illegible]	26.3
	43.0	40.5	24.7		50.3	41.9	40.6	49.4			35.3	28.3	
Deep	49.1	51.5	32.3						54.5				

Difference shallowest to commercial = -8.1 l/ha
@ 70 p/l = £5.67/ha @ 55 t/ha = -10 pence/t
= 20 cents per t

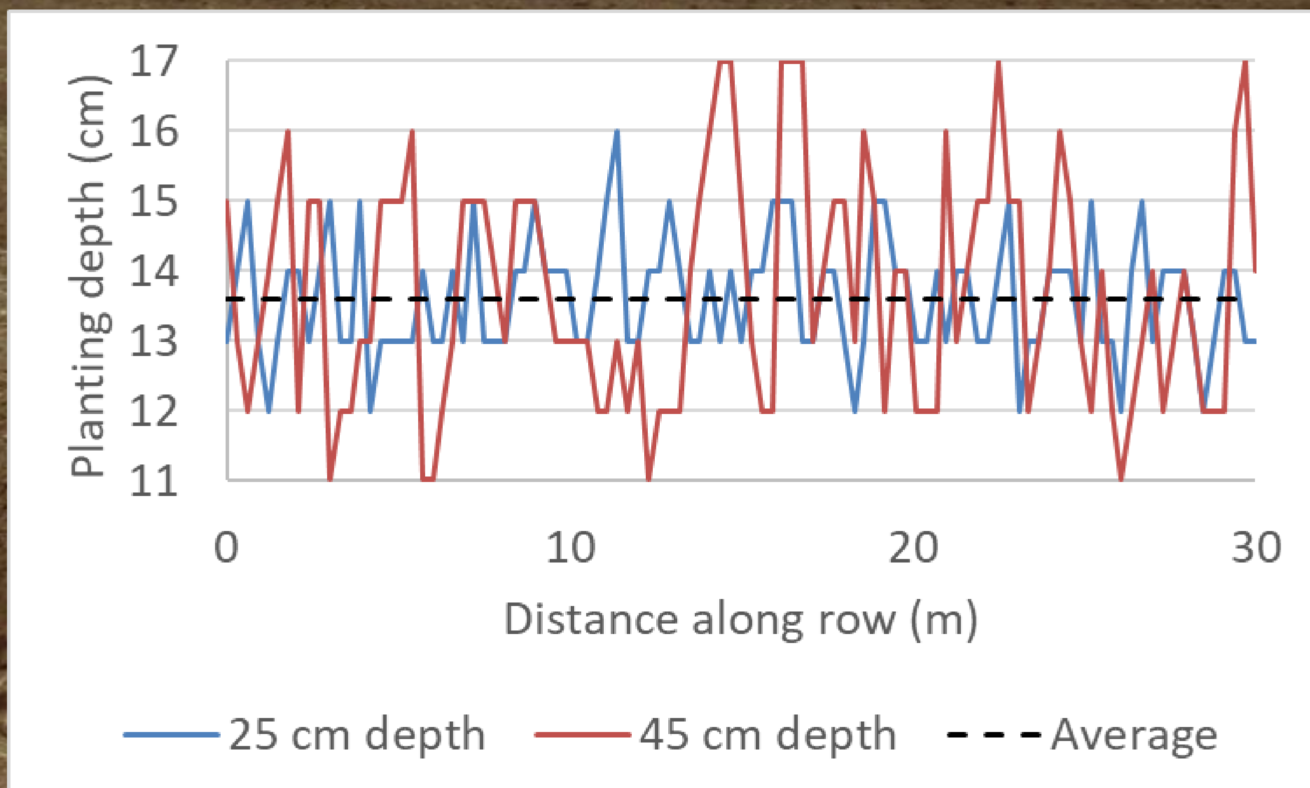
20-25 | 25-30 | 30-35 | 35-40 | 40-45 | >45 | cm

Spot rate of work (ha/h) vs depth (2014)

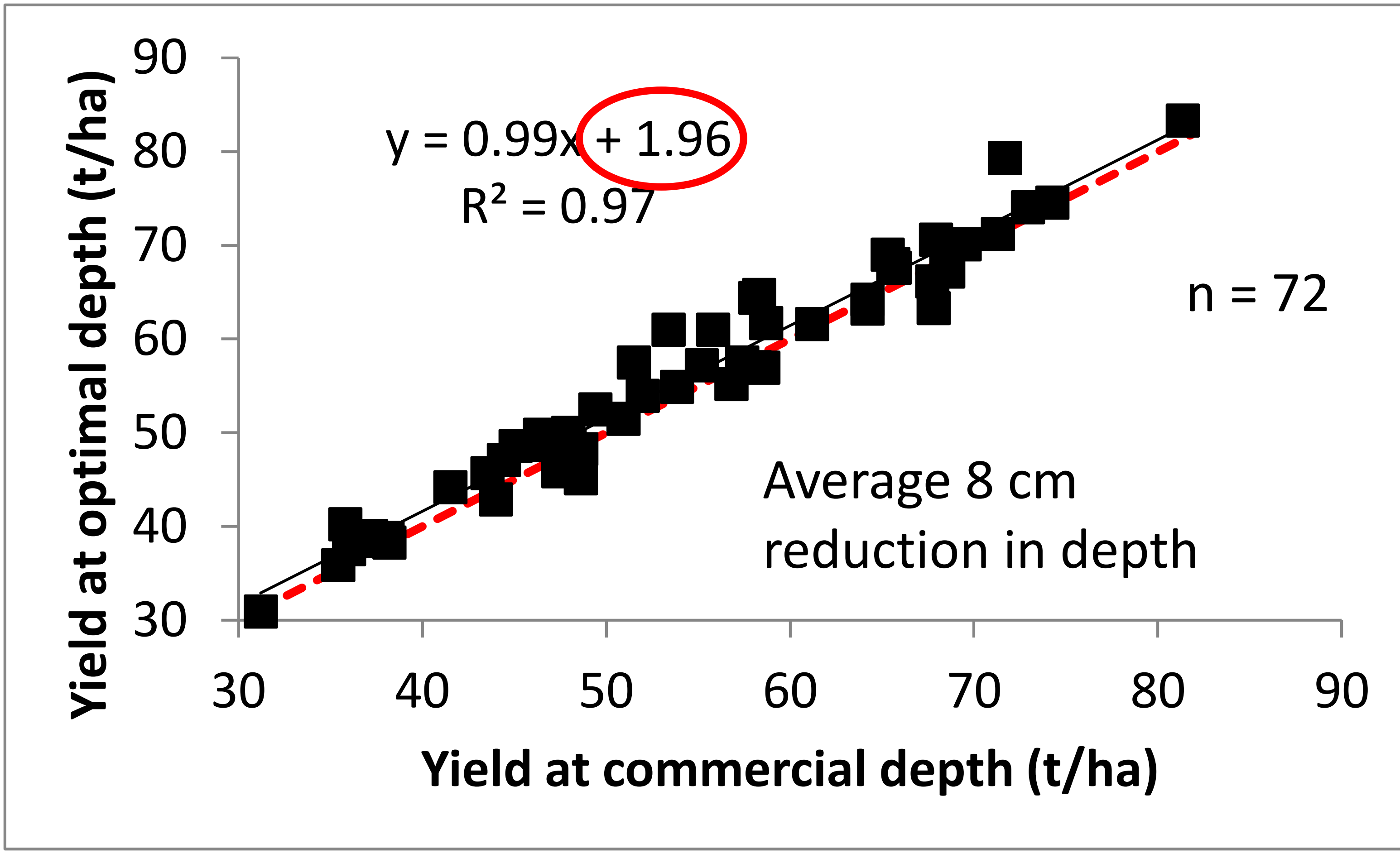
	GVAP -L	GVAP -H	Stev	Baird	B&C Ox6	B&C Boot	Daw T30	Daw T41	SML Caud	Largo	EGH Moun	EGH BB	SML Cage
Depth	SL	SCL	ZCL	CL	CL	SL	CL	CL	CL	C	SL	SL	LS
Shallow	0.52	0.24	0.74	0.65	0.44	0.47	0.52	0.50	0.53	0.36	0.90	1.08	0.65
	0.45	0.22	0.61	0.49						0.35			
	0.43	0.21	0.56										0.64
	0.40	0.21	0.56	0.41	0.33	0.37	0.47	0.39	0.44	0.34	0.79	0.93	0.63
	0.33	0.20	0.35		0.24	0.32	0.47	0.33			0.57	0.74	
Deep	0.29	0.18	0.26						0.33				

20-25 25-30 30-35 35-40 40-45 >45 cm

Planting depth becomes more variable with deep cultivation



Confidence in shallower cultivation?
78 % of trials showed a numeric yield increase



Overall rate, fuel and marketable yield, Sainsbury-Greenvale PDG 2014-2016

17 experiments	Shallow (26 cm)	Commercial (35 cm)	Relative change (Commercial to Shallow)
Destoning rate (ha/h)	0.59	**0.47**	+27 %
Destoning fuel (l/ha)	27.6	**37.1**	-26 %
Marketable yield (t/ha)	57.5	**56.1**	+2.5 %

Overall common scab, Sainsbury-Greenvale PDG 2014-2016

17 experiments	Shallow (26 cm)	Commercial (35 cm)	Relative change (Commercial to Shallow)
Proportion of packable tubers (%)	97.2	**98.0**	0 %
Proportion of greening (%)	5.7	**5.6**	0 %

Costs and benefits of destoning at different depths

Destoner depth	Overall rate (ha/day)	Fuel cost (£/ha)	Labour cost (£/ha)	Tractor cost (£/ha)	Destoner cost (£/ha)	Total cost (£/ha)	Yield (t/ha)
Standard (36 cm)	3.8	23.99	25.91	84.18	90.76	224.84	41.5
Shallow (28 cm)	5.0	16.04	19.69	63.98	68.98	168.69	44.2
Difference	**+1.2**	**-7.95**	**-6.22**	**-20.2**	**-21.78**	**-56.15**	**+2.7**

1. Data from 2013 experiment on sandy silt loam soil
2. N.B. single destoner, 300 m run length, fuel £0.68/l, 10-year depreciation for destoner, 8-year depreciation for tractor, 4 weeks per year, 5.5 days/week, 10-hour day
3. NAAC costs 2013: £284/ha

One good reason to destone (and not pick up stone on the harvester)!


25 cm
harvested at
25 cm


25 cm
harvested at
35 cm

Tillerstar 25 cm

Clod production is more closely related to depth than machine type or pitch

Tillerstar 33 cm

Key to avoiding bruising is matching harvester and cultivation depth

	Bruising incidence (%)	
Depth (cm)	No harvester depth control	Variable depth harvesting
25	51.5	48.1
30	49.1	45.8
35	43.4	44.5
S.E.	3.13	1.44

Summary

- Critical cultivation depth in spring varies between seasons
- Growers can cultivate shallower with:
  - Increased or similar yields, esp. heavy soils
  - Faster work rates (20-40 %) i.e. wider weather window
  - Reduced costs (labour, fuel, **repairs, depreciation**)
- No effect of cultivation depth on N mineralisation, crop N uptake or fertilizer requirement
- Providing harvesting depth was corrected for depth, bruising generally was unaffected except on very stony soils
- Cover crops and organic amendments reduced bulk density, but small effects and no evidence of increased resilience
- Soil structural stability sometimes improved with reduced-depth and intensity of cultivations, but more work still needs to be conducted to determine optimum tilth

Practical recommendations

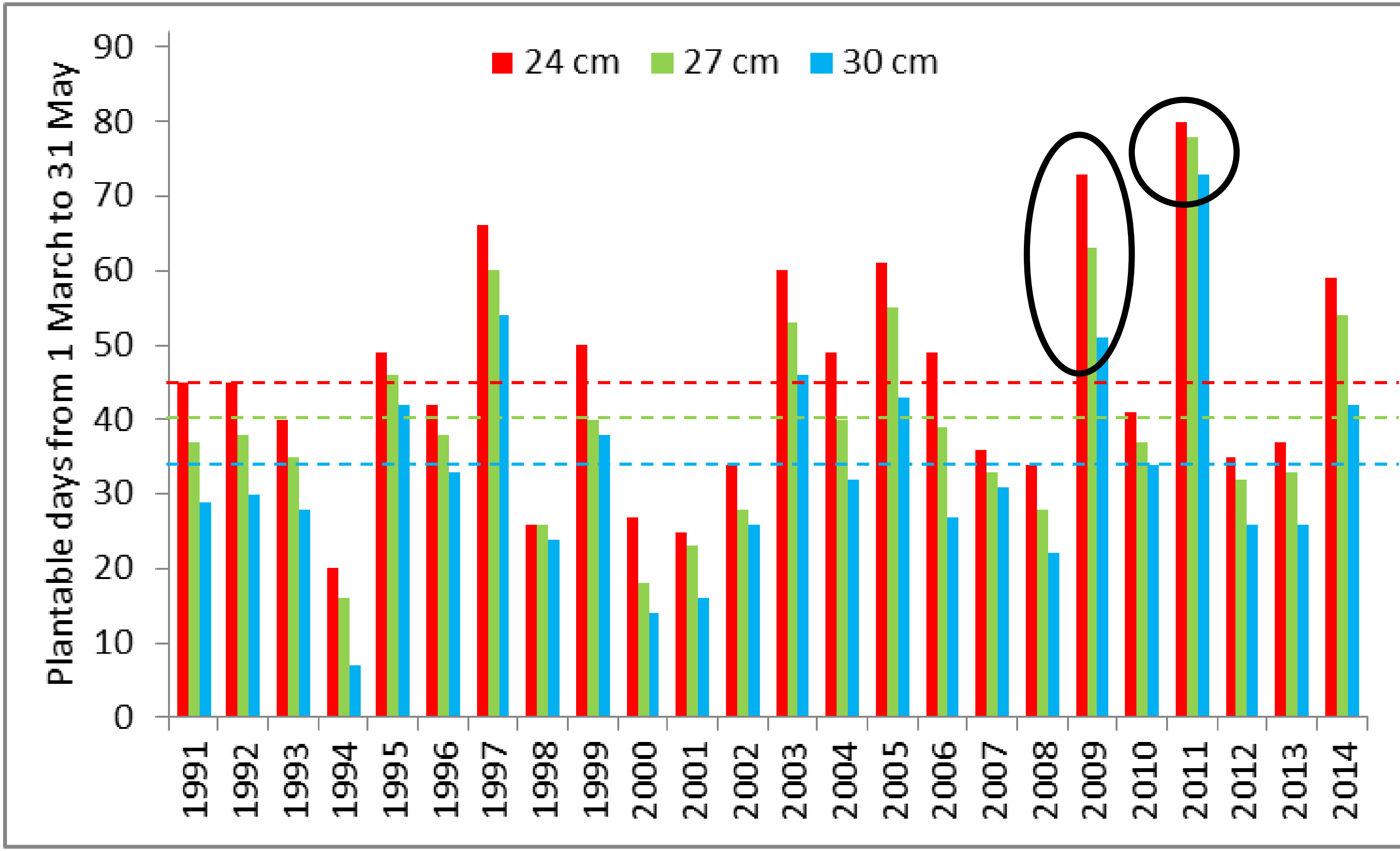
- **Soil should not be cultivated deeper than *c*. 27-28 cm and shallow as 20 cm can produce adequate planting depth for many crops.**
- **Operators should be trained that it is CONSISTENCY of soil depth that is important, not absolute depth.**
- **Shallow cultivation gives greater opportunity for soils to be cultivated closer to their optimum soil water content, avoiding compaction.**
- **Seedbeds can be made appreciably coarser and shallower than current practice without increased harvester damage, greening or scab.**
- **Shallower cultivation reduces wear on machinery, lowers repair and depreciation costs and decreases the chance of breakdown.**
- **Savings in labour costs can be made through 20-40 % faster work rates.**
- **Significant savings in fuel can be made by working soil shallower than is currently being practiced, particularly if bedtillers are not used.**
- **Nitrogen requirements should not be adjusted for the depth of cultivation.**

Industry changes 2011 through 2018

- Ploughing
  - Less inversion and autumn/winter, more fixed tine and spring cultivation
  - No change in spring depth, ploughing depth reduced by 4 cm
- Bedforming
  - Shallower by 8 cm
- Bedtilling
  - Removed from operations in many cases
  - Shallower by 5 cm
- Destoning
  - Shallower by 4 cm (target was 6 cm)
  - Wider webs (e.g. 40 vs 35 mm or 50 vs 45 mm)

Modelling plantable days in spring

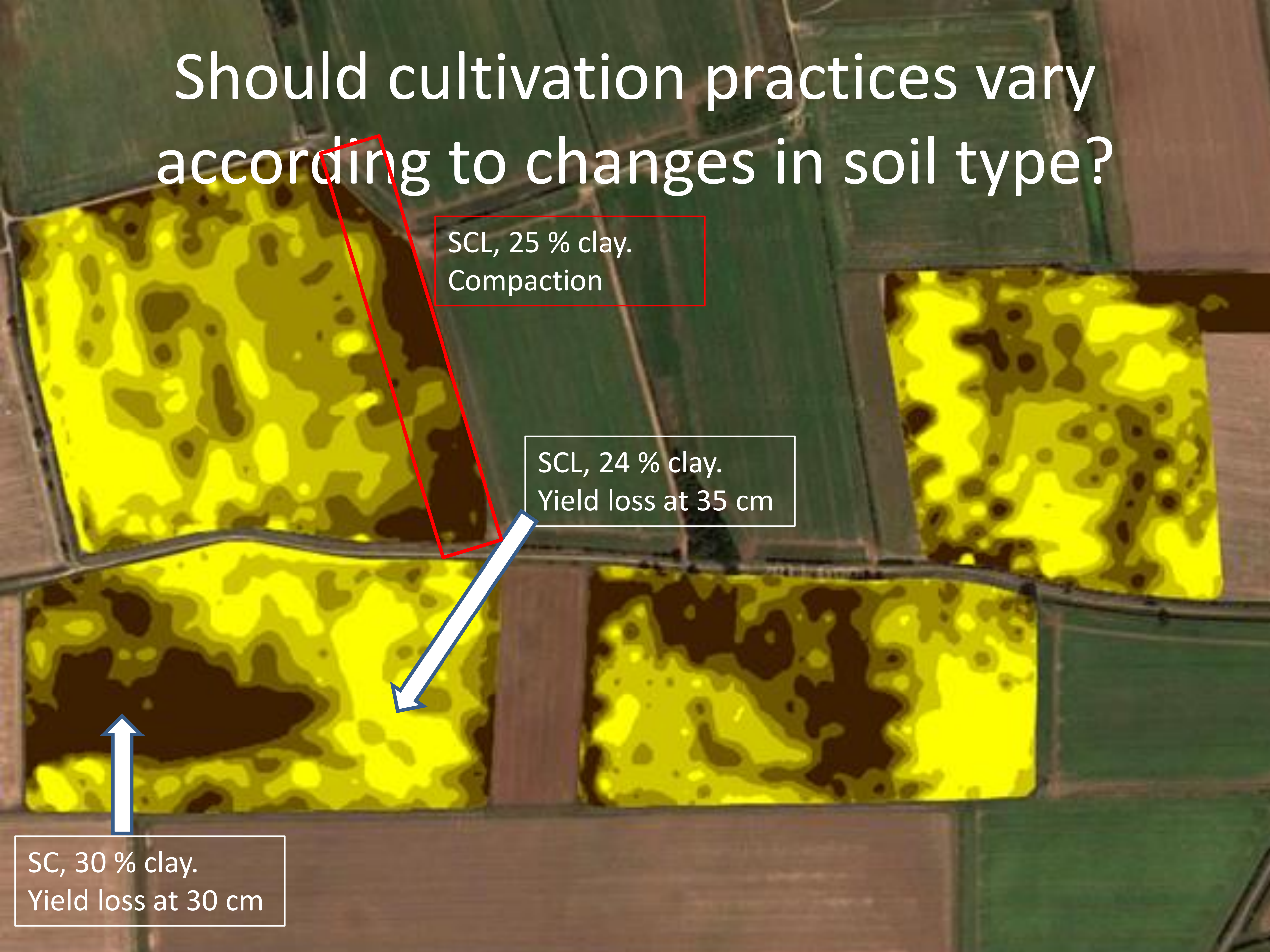
(Conditions: SL (15% clay), soil below PL at d cm, < 3 mm rain)



Cultivatability Index

Field	OM	Sand	Silt	Clay	Texture	Clay Rank	OM Rank	FC water	FC Rank	PL water	FC-PL	FC-PL Rank	Rank points	Rel. Ranking
Black Breck	2.2	80	12	8	LS	2	5	29.3	4	29.3	0.1	3	12	0.10
Church Breck	1.6	79	12	9	LS	3	12	29.2	2	26.7	2.6	6	17	0.15
Calves Close	1.6	77	13	10	SL	5	12	29.6	5	26.7	2.9	9	25	0.22
Spurway	1.3	82	11	7	LS	1	26	28.4	1	25.3	3.1	11	26	0.23
Home Piece South	2.5	72	17	11	SL	6	4	30.8	15	30.5	0.3	4	27	0.24
Tin Pit South	1.8	74	15	11	SL	6	10	30.1	9	27.6	2.6	7	27	0.24
Gypsys Corner	1.5	77	12	11	SL	6	17	29.6	6	26.3	3.3	12	33	0.29
Home Piece North	2.7	69	19	12	SL	9	2	31.4	21	31.3	0.1	2	33	0.29
Groves Close	1.6	74	14	12	SL	9	12	30.2	10	26.8	3.4	13	38	0.33
East Splashes	1.3	78	12	10	SL	4	26	29.3	3	25.4	3.9	18	38	0.33
Shepherds Breck	2.6	68	19	13	SL	13	3	31.6	23	30.9	0.7	5	43	0.37
Claypits B	3.4	65	22	13	SL	13	1	32.4	30	34.1	-1.7	1	45	0.39
Stamper	1.4	76	12	12	SL	9	24	29.8	7	25.9	3.9	19	47	0.41
Church Breck	1.6	73	13	14	SL	17	12	30.6	12	26.9	3.6	16	51	0.45
Aerodrome	1.5	73	14	13	SL	13	17	30.3	11	26.4	3.9	20	53	0.46
Goss 33	1.7	69	17	14	SL	17	11	31.0	17	27.3	3.7	17	57	0.50
West Grange	2.1	68	16	16	SL	21	6	31.7	25	29.0	2.6	8	57	0.50
Centre Islands	1.5	69	18	13	SL	13	17	30.7	14	26.4	4.3	22	58	0.51
Hill House	1.2	74	14	12	SL	9	30	29.9	8	25.1	4.8	26	58	0.51
Spring Breck	2.0	69	14	17	SL	26	7	31.7	24	28.7	2.9	10	64	0.56
Strawberry Pit Hole	1.5	70	15	15	SL	19	17	30.9	16	26.6	4.3	23	67	0.59
Claypits A	2.0	62	22	16	SL	21	7	32.2	29	28.7	3.6	14	68	0.59
Rams Close	1.6	69	15	16	SL	21	12	31.3	20	27.1	4.1	21	68	0.60
66 Acres	1.5	69	15	16	SL	21	17	31.2	18	26.7	4.5	24	72	0.63
South Grange	1.9	66	16	18	SL	28	9	32.0	28	28.5	3.6	15	76	0.67
Heartlands	1.4	68	16	16	SL	21	24	31.2	19	26.3	4.9	27	79	0.70
6 Acres	0.8	69	16	15	SL	19	33	30.6	13	23.9	6.7	32	81	0.71
Sporle	1.5	68	15	17	SL	26	17	31.4	22	26.8	4.6	25	82	0.72
Barn Field	1.5	65	16	19	SCL	29	17	32.0	27	27.1	4.9	28	93	0.81
110 Acres	1.3	63	16	21	SCL	31	26	32.4	31	26.8	5.6	29	104	0.92
Top Field	0.9	63	17	20	SCL	30	32	32.0	26	25.1	6.8	33	105	0.93
Pointers and Steed Mrs H	1.2	61	16	23	SCL	33	30	32.8	33	26.9	6.0	30	111	0.98
West Field (Bottom)	1.3	57	19	24	SCL	34	26	33.5	34	27.4	6.0	31	112	0.99
12 Acres	0.8	59	20	21	SCL	31	33	32.5	32	25.0	7.5	34	114	1.00

Should cultivation practices vary according to changes in soil type?



A nice concluding quote:

"Cultivations – I believe most of the audience will have already bought into the reduced depths, especially due to the conditions we had at planting. 2018 was a good example of a season where this has big benefits and also patience!"

Claire Hodge, AHDB Knowledge Exchange Manager, Scotland

15 February 2019

Reducing Soil Compaction in Potato Rotations

Mark Stalham

Thank you for the invite!