MANAGING MARGINAL SOILS FOR SUSTAINABLE GROWTH OF OIL PALMS IN THE TROPICS

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Temperate Area

- Alternating high and low temperature
- Wet/dry season
- Weathering/Leaching Seasonal

Fersiallitic Weathering

- Weathering/Partial leaching of bases/silica
- Weathering zone often < 2 m

Tropical Area

- Continuous high temperature
- Wet throughout year
- Continuous weathering/leaching

Ferallitic Weathering

- Intensive weathering and leaching of bases and silica
- Weathering zone > 10 m

TROPICAL SOILS:
Most considered to be problem soils

- Acidic – pH <5.5
- Low Cation Exchange Capacity [<12 cmol (+) kg^{-1} clay]
- Often Low Base Saturation (<10%)
- Profiles deep (>2m)
  – leaching losses are high
- High rainfall (>200 mm/month)
  – leaching and soil erosion

WHAT IS A PROBLEM SOIL?

Problem soils

Need special management techniques/practices to have sustainable productivity

IMPORTANCE OF SOIL SURVEYS

- Identify the different soil types in estate
- Determine their physical and chemical characteristics
- Produce a soil map/soil management group map
- Yield potential
- Identify soil limitations present
- Recommend amelioration practices for sustainable cultivation

TYPES OF PROBLEM SOILS

- Soils on steep terrain
- Soils of the dry regions
- Highly weathered soils
- Lateritic soils
- Acid sulfate soils
- Saline soils
- Sandy soils
- Organic soils
- Soils after specific land use change

SOILS ON STEEP TERRAIN

SOILS ON STEEP TERRAIN

Land Conservation Act 1960. Revised 1989 (Government of Malaysia, 1989)

"Any land above 18° slope as hill land for conservation and protection from soil erosion"

This law seldom implemented

Jabatan Pertanian (Agriculture Department)

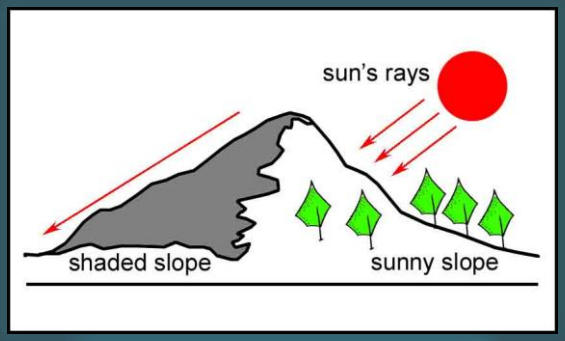
Steepland – land greater than 25° or 50%. Pockets of land for shifting cultivation excepted

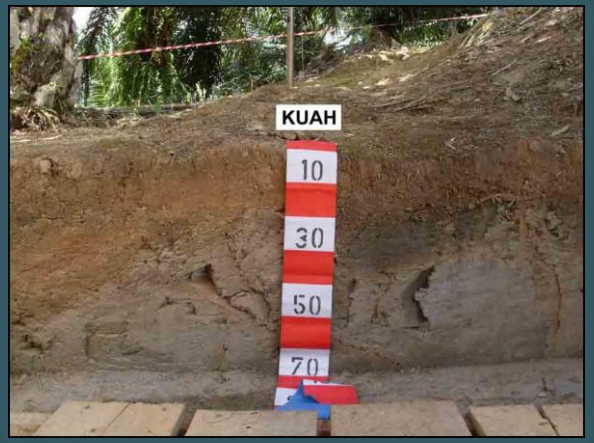
SOILS ON STEEP TERRAIN
Characteristics

- Strongly dissected with V-shaped valleys
- Often at elevations >75 m
- Lower sunshine hours
  - lower photosynthesis
- Palms etiolated
  - smaller bunches
  - lower yield
- Shallow (<50 cm soils)
  - poor anchorage
  - wind damage
- Increased soil erosion / landslips
- Increased harvesting cost / loss

SOILS ON STEEP TERRAIN

Characteristics





SOILS ON STEEP TERRAIN

Mitigation Measures

- Do not plant above 25° or 50% slope
- Ensure terraces constructed
- Establish cover crops
- EFB
- Regular inspection / Mitigation of terraces
- Selective thinning
- Proper fertilization
- Proper harvesting

SOILS ON STEEP TERRAIN

Effect of Slope on Yields

Year of Harvest	Wet Region			Moderately Wet Region			Dry Region		
	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)
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SOILS OF THE DRY REGIONS

SOILS OF THE DRY REGIONS

Rainfall Data

Total monthly rainfall (mm) and raindays for Melor Estate Tradewinds Kuching (2007-2011)

Year / Month	2007		2008		2009		2010		2011		5-Year Mean (2007-2011)	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan	912	27	403	18	1,044	24	641	18	718	19	744	21
Feb	764	22	375	18	344	10	281	13	410	10	435	15
Mar	485	18	451	25	242	16	193	17	507	21	376	19
Apr	260	14	44	7	324	19	408	17	405	18	288	15
May	234	11	188	10	289	14	234	12	212	12	231	12
Jun	401	11	211	9	144	7	99	11	176	9	206	9
Jul	396	17	276	16	62	4	302	17	159	6	239	12
Aug	261	11	309	9	325	16	242	15	192	13	266	13
Sept	410	12	156	13	101	8	251	19	390	14	262	13
Oct	514	21	219	19	415	16	602	16	432	21	436	19
Nov	313	24	344	20	372	21	397	18	442	17	374	20
Dec	485	25	402	24	698	22	289	15	526	22	480	22
Total:	5,435	213	3,378	188	4,360	177	3,939	188	4,568	182	4,337	190

Dry month (<100 mm)

SOILS OF THE DRY REGIONS

Rainfall Data

Total monthly rainfall (mm) and raindays for Tradewinds Ladang Sisek, Johor (2001-2010)

Year / Month	2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		10-Year Mean (2001-2010)	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan	212	12	192	10	150	21	501	11	170	6	283	15	671	18	117	4	117	3	70	7	248	11
Feb	-	-	6	1	14	2	7	2	19	3	98	11	21	1	135	4	226	10	-	-	53	3
Mar	30	4	106	10	50	7	435	15	227	7	61	8	160	6	660	18	232	14	178	10	214	10
Apr	135	17	124	14	177	19	128	8	91	8	319	21	121	15	295	12	262	11	254	13	191	14
May	247	17	127	17	82	14	136	7	210	14	147	11	131	12	393	14	128	9	137	14	174	14
Jun	163	11	133	11	86	10	172	8	61	7	98	13	215	14	274	18	247	11	97	10	155	11
Jul	133	9	129	16	132	10	383	13	157	15	257	15	93	10	148	13	199	14	189	21	182	14
Aug	97	9	113	15	128	14	256	7	217	13	140	15	229	14	396	19	102	17	117	14	180	14
Sept	165	18	144	18	136	12	234	18	287	16	270	14	93	8	147	13	212	10	128	12	182	14
Oct	65	10	116	16	181	11	261	18	248	14	98	9	182	15	356	17	190	16	235	12	193	14
Nov	18	3	160	15	56	8	217	12	285	15	382	18	290	10	146	15	271	18	212	18	204	13
Dec	324	13	149	15	138	9	177	11	120	12	748	20	359	10	254	9	92	14	105	19	247	13
Total:	1,589	123	1,499	158	1,330	137	2,907	130	2,092	130	2,901	170	2,565	133	3,321	156	2,278	147	1,722	150	2,223	145

Dry month (<100 mm)

SOILS OF THE DRY REGIONS

Rainfall Data

Total monthly rainfall (mm) and raindays for Ladang Sungei Ahning, Tradewinds Corridor Sdn. Bhd., Kedah (2007-2011)

Year / Month	2007		2008		2009		2010		2011		5-Year Mean (2007-2011)	
	mm	days	mm	days	mm	days	mm	days	mm	days	mm	days
Jan	160	5	8	1	3	3	51	3	100	7	64	4
Feb	114	4	140	4	38	2	38	3	14	1	69	4
Mar	162	5	153	7	193	4	70	4	237	18	163	8
Apr	347	14	172	7	190	9	74	10	134	8	183	10
May	220	10	202	7	218	10	231	11	212	15	217	11
Jun	341	14	137	5	29	13	83	13	53	11	129	11
Jul	213	13	156	4	158	12	173	16	191	5	178	10
Aug	172	7	167	6	347	7	128	11	209	15	205	9
Sept	267	12	263	7	164	18	380	18	319	14	279	14
Oct	282	15	333	12	375	15	436	16	183	25	322	17
Nov	237	16	243	11	550	12	286	12	208	19	305	14
Dec	341	8	334	8	43	15	110	12	137	9	193	10
Total:	2,856	123	2,308	79	2,308	120	2,060	129	1,997	147	2,307	122

Dry month (<100 mm)

SOILS OF THE DRY REGIONS

Characteristics / Problems

- Most plantation crops affected by long dry season
- Dry month rainfall less than 100 mm
- More than 3 consecutive dry months **NOT SUITABLE** for oil palm
- Moisture stress during dry period
- Family of Euphorbiaceae: Rubber / Jatropha will winter
- Lower rainfall often higher solar radiation.

SOILS OF THE DRY REGIONS

Effect of Rainfall on Oil Palm Yield

Year of Harvest	Wet Region			Moderately Wet Region			Dry Region		
	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)	Level to Undulating (0-12%)	Rolling (12-24%)	Hilly and Somewhat Steep (24-50%)
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SOILS OF THE DRY REGION

Mitigation Measures

- Crop selection
  - Mango > Sugar Cane > Jatropha > Oil Palm
- Irrigation
  - Where water is available
  - expensive

HIGHLY WEATHERED SOILS

HIGHLY WEATHERED SOILS

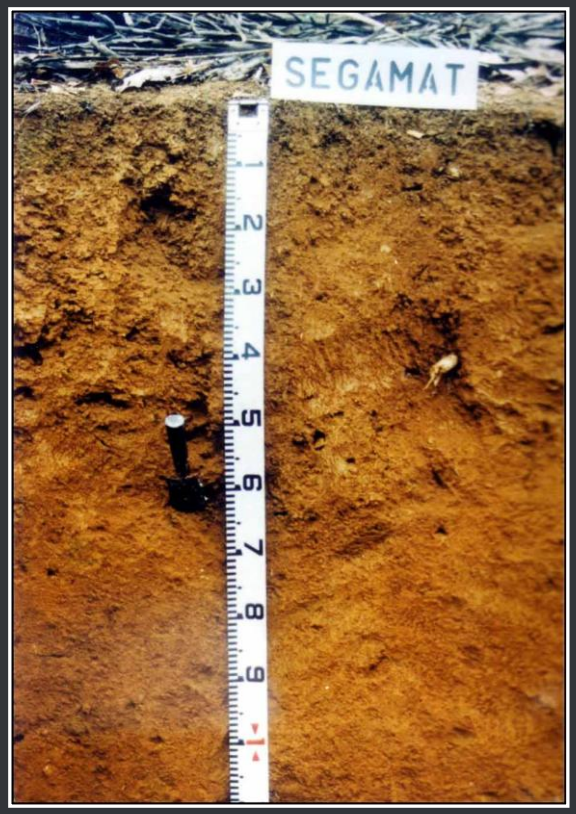
(e.g. Segamat Series / Prang Series / Kuantan Series)

Characteristics / Limitations

- Deep, red coloured soils
  - P fixation
- High porosity
  - leaching losses / moisture stress
- Very low Cation Exchange Capacity
  - <2 cmol (+) kg^{-1} clay
- Very low base saturation
- Micronutrient toxicity
  - Ni, Cr

HIGHLY WEATHERED SOILS

Segamat Series / Prang Series / Kuantan Series



HIGHLY WEATHERED SOILS
Management

- Time of planting
  - EFB mulching
- Additional P application
  - band placement / organic mulching
- Organic mulching
- High fertilizer rates / split application
- Crop selection in relation to rainfall
- Frond spreading

LATERITIC SOILS

LATERITIC SOILS

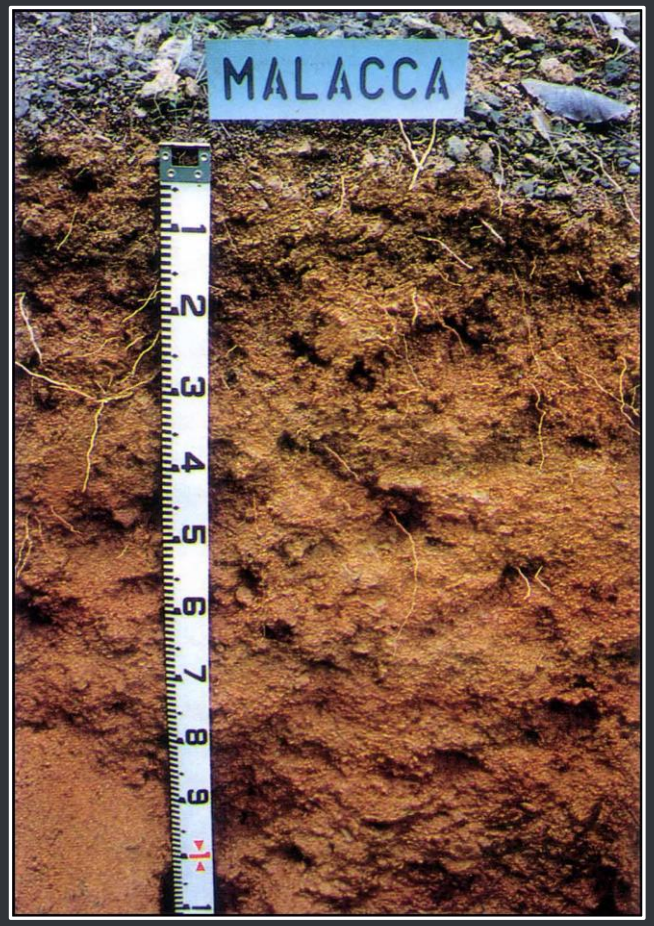
(e.g. Malacca Series / Gajah Mati Series)

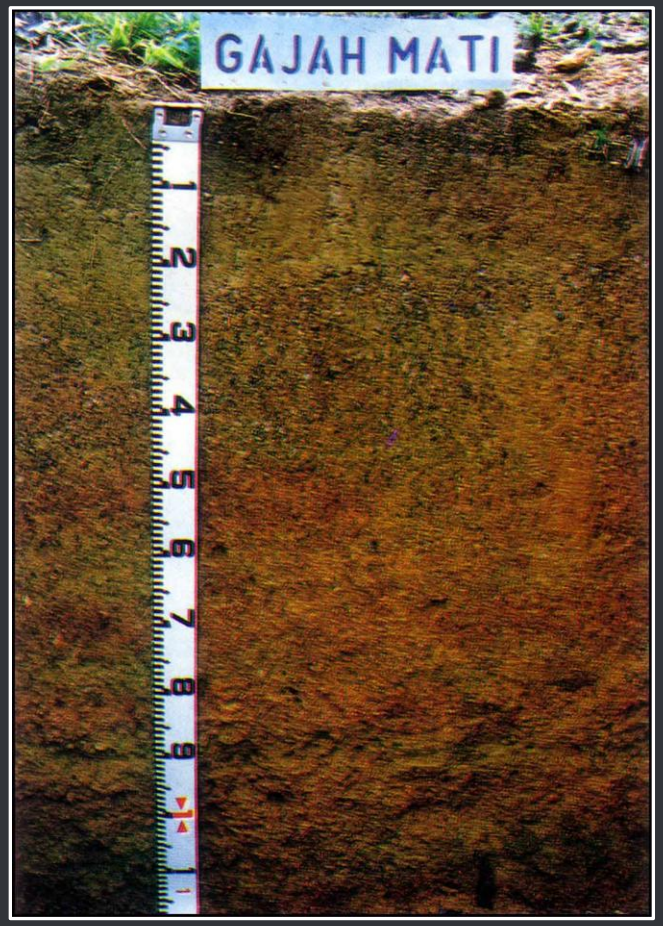
Characteristics / Limitations

- Presence of dense layer (>35%) of ironstone/lateritic gravels at shallow depth
- Effective soil volume is decreased
- Moisture stress
- Low fertility status
- Oil palm production
  - 2 years later
  - yields ⅓ of deep soils

LATERITIC SOILS

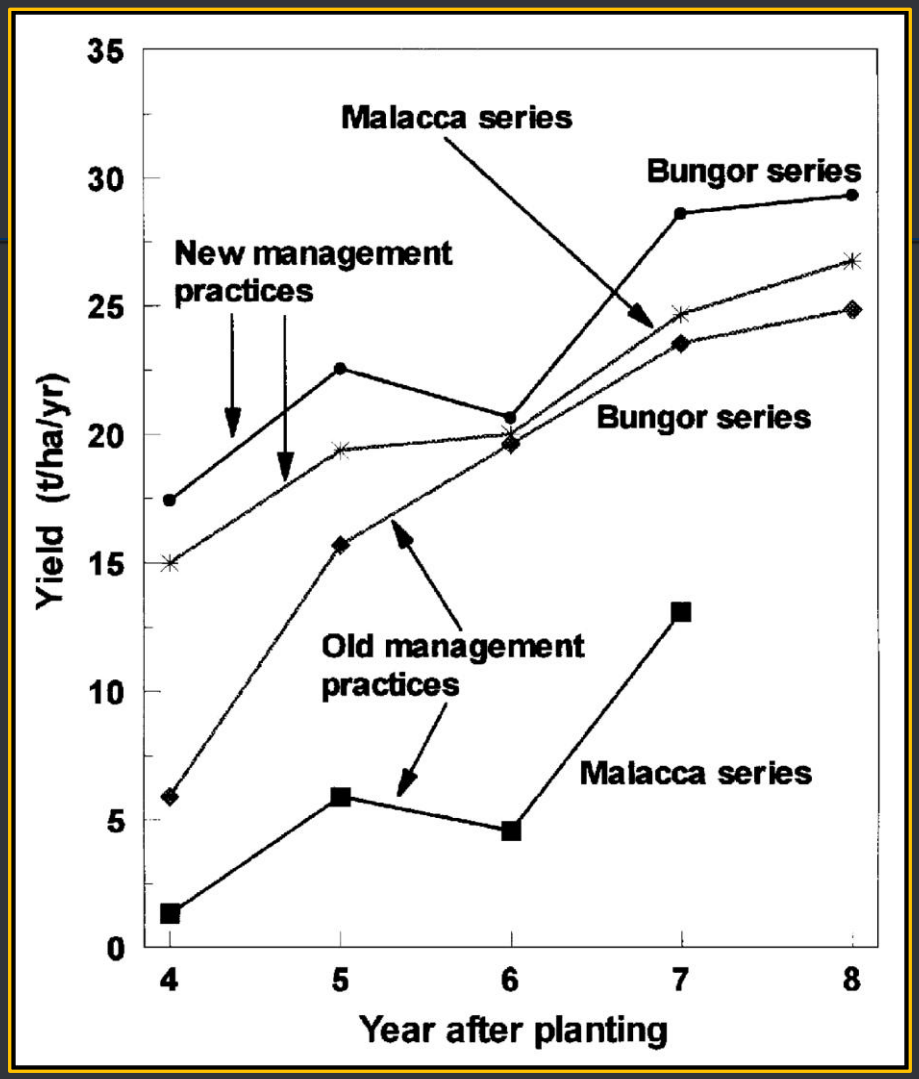
Malacca Series / Gajah Mati Series





LATERITIC SOILS
Management

- Map the estate and delineate shallow lateritic soil areas
- Maintain ground cover
- Spread fronds
  - L-shaped in flat areas
  - On terrace lip/between palms
- Terraces must have back-slope to trap water
- EFB mulching



Comparison of yield performance of oil palms on Malacca and Bungor Series soils
(*Source:* Phang *et al*., 1977; Goh *et al*., 1994)

ACID SULFATE SOILS

ACID SULFATE SOILS
Characteristics / Limitations

Potential Acid Sulfate Soils
e.g. Kranji Series / Linau Series

- Water logged soils
- High sulfide content
- Smell of hydrogen sulfide (rotten eggs)
- Organic rich / organic poor

True Acid Sulfate Soils
e.g. Sedu Series / Parit Botak Series

- Very low pH < 3.5
- Yellow jarosite mottles
- Moisture stress due to poor rooting
- Organic rich / organic poor
  - Organic rich (brown, well structured and friable)
  - Organic poor (light gray, poor structured, sticky)
- Low K
- Affects uptake of other nutrients due to low pH

ACID SULFATE SOILS

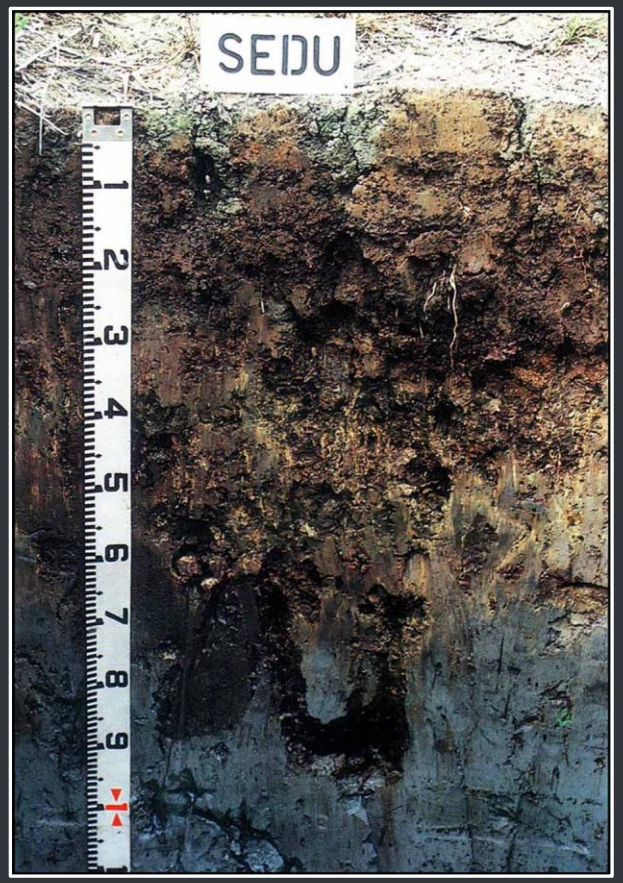
Potential Acid Sulfate Soils

Kranji Series / Linau Series

ACID SULFATE SOILS

True Acid Sulfate Soils

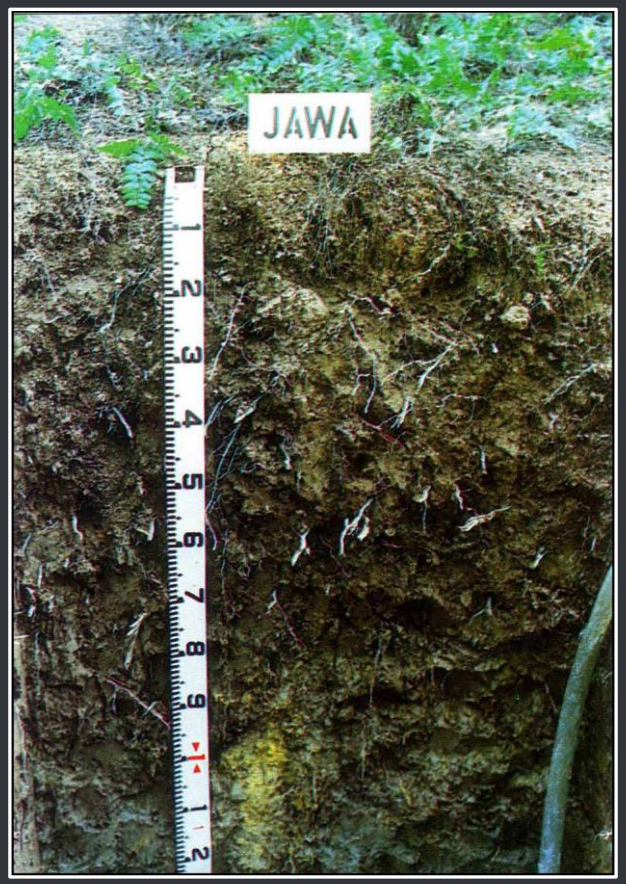
e.g. Sedu Series / Parit Botak Series



ACID SULFATE SOILS

True Acid Sulfate Soils

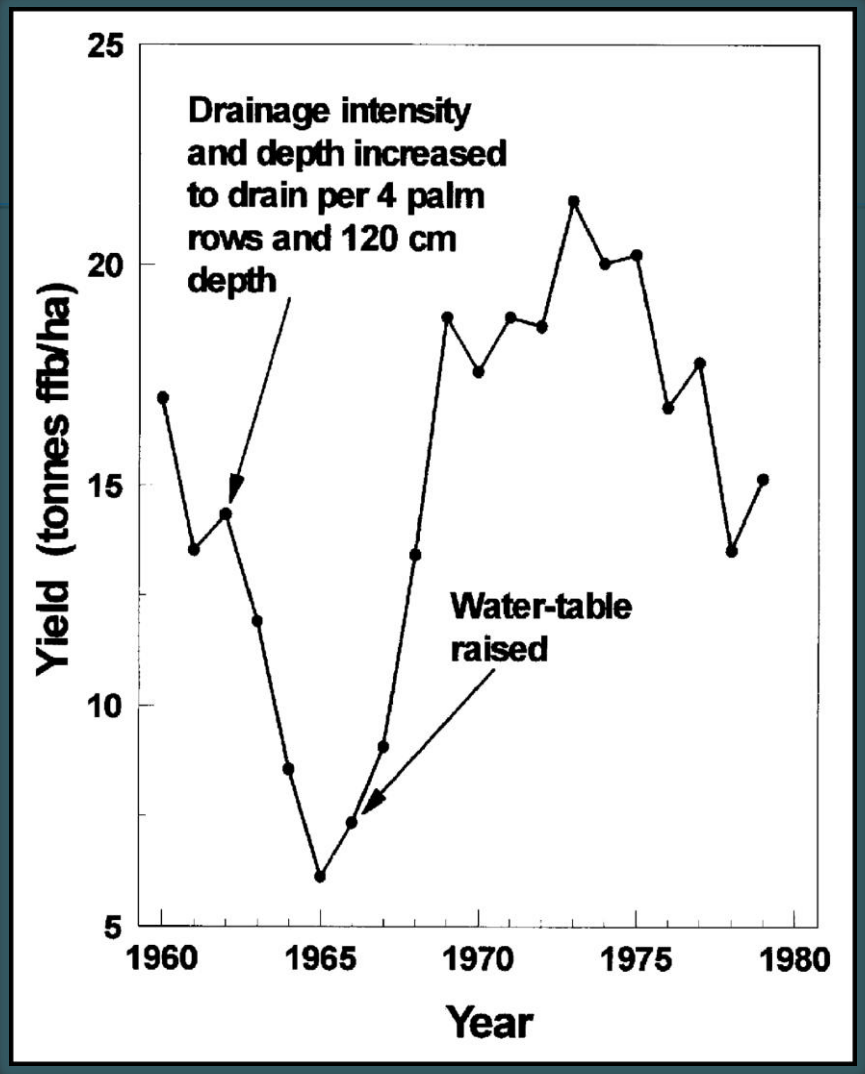
Jawa Series / Tongkang Series



ACID SULFATE SOILS

Management

- Map the estate
- Liming is ineffective
- Water management is critical
- Keep watertable around 45-60 cm using 1°, 2° and 3° drains with controls
- Flush acidity in rainy season
- Retain water at end of rainy season
- Use bunch ash (if available)
- Prudent EFB application (23 kg/palm)
  - too much causes water logging
  - pests/disease problems



Effect of increased drainage and subsequent raising of water table on yield of oil palms on severe acid sulphate soils

(*Source:* Toh and Poon, 1982)

SALINE SOILS

SALINE SOILS

Characteristics

- Soils occur along coast
- Inundated by sea-water
- A/C profile
- Conductivity can be 10 dSm^{-1}
- Soluable sulfate > 0.35%

SALINE SOILS

Management

- Crop selection
- Materials for bunds must be available
- Land preferable higher than tide levels
- Rainfall > 1,700 mm/year to flush salinity
- Area must be large to recover reclamation costs

SANDY SOILS

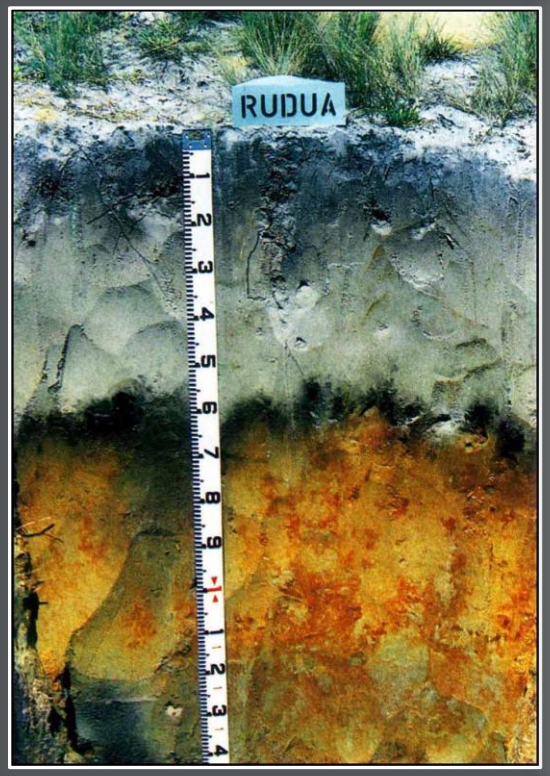
SANDY SOILS

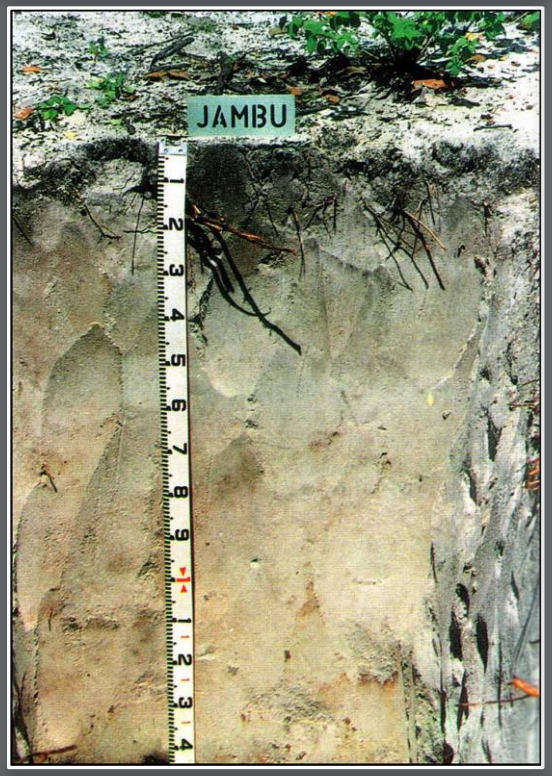
Spodic Horizon / Albic Horizon

- Spodic horizon is a subsurface horizon formed by the accumulation of humus, iron or both through a process of leaching (Humus-rich horizons are most common).
- They occur commonly over sandy textured materials.
- They are often overlain by a white sandy albic horizon.
- Where the white sandy textured horizon extends to more than 1.0 m the soil is a deep sandy soil.
- Spodic horizons can be strongly cemented or weakly or non-cemented.
- Spodic horizons can occur within 50 cm or between 50-100 cm of the soil surface.
- Sandy soils can occur over beach ridges, sandy terrace alluvium or over *in-situ* rocks.

SANDY SOILS

Rudua Series / Jambu Series / Tika Series





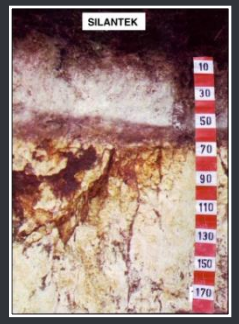
Common Malaysian Soils With Humus-Rich Spodic Horizons

(after Paramananthan, 2007)

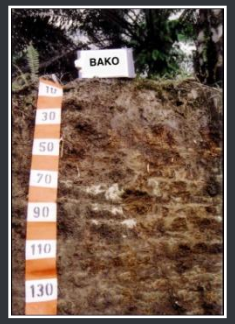
Depth to Spodic (Humus-rich)	Cementation	In-situ Residuum (Sedimentary Rocks)	Sandy Terraces	Beach Ridges
Shallow (Less than 50 cm)	Weak (w)	Sibuga (w)	Baiayo	Rhu Tapai (w)
	Strong (s)	Sibuga	Buso	Rhu Tapai (s)
Moderate (50-100 cm)	Weak	Silantek	Karamatoi	Cherating
	Strong	Bako	Miri	Rudua
Deep (More than 100 cm)	No spodic to 100 cm	Tika Matang	Serai Lintang Sungei Buloh Kilong Pisau Siar	Baging Jambu Rompin Usukan

Note: **w = weakly cemented or non-cemented**
s = strongly cemented

IN-SITU SOILS



Silantek Series (moderately deep spodic)



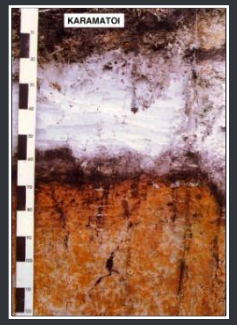
Bako Series (moderately deep spodic)

Tika Series

SANDY TERRACES

Baiayo Series (shallow spodic)

Buso Series (shallow spodic)

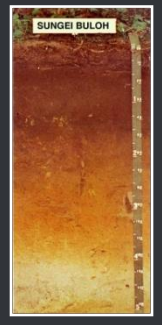


Karamatoi Series (moderately deep spodic)

Miri Series (moderately deep spodic)

Lintang Series (deep sandy)

Serai Series (deep sandy)



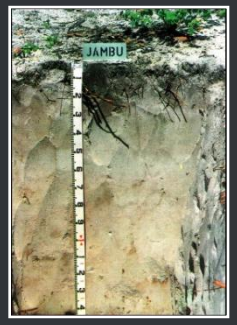
Sg. Buloh Series (deep sandy)

Organic Sand

BEACH RIDGES

Rudua Series (moderately deep spodic)

Baging Series (deep sandy)



Jambu Series (deep sandy)

SANDY SOILS
Main Limitations

- Sandy textures above spodic or extend to over 100 cm
- Cemented spodic horizon (shallow / mod. depths)
- Flooding in wet season (shallow cemented spodic)
- Dry / Moisture stress in dry season / prone to fires
- Erosion above cemented spodic horizon on sloping land

SANDY SOILS (cont'd)
Main Limitations

- Poor rooting due to shallow cemented spodic
- Wind damage
- High surface temperatures
- Poor natural vegetation – heath forests / keranggas / gelam forests / grasses and shrubs
- Low nutrient holding capacity

Physical Problems of Sandy Soils

Fragile, unstable and highly erodable

COMMON VEGETATION

Sandy soils with spodic horizon

Fibrimstylis sp

Gelam (Melaleuca)

Terrestrial Orchid

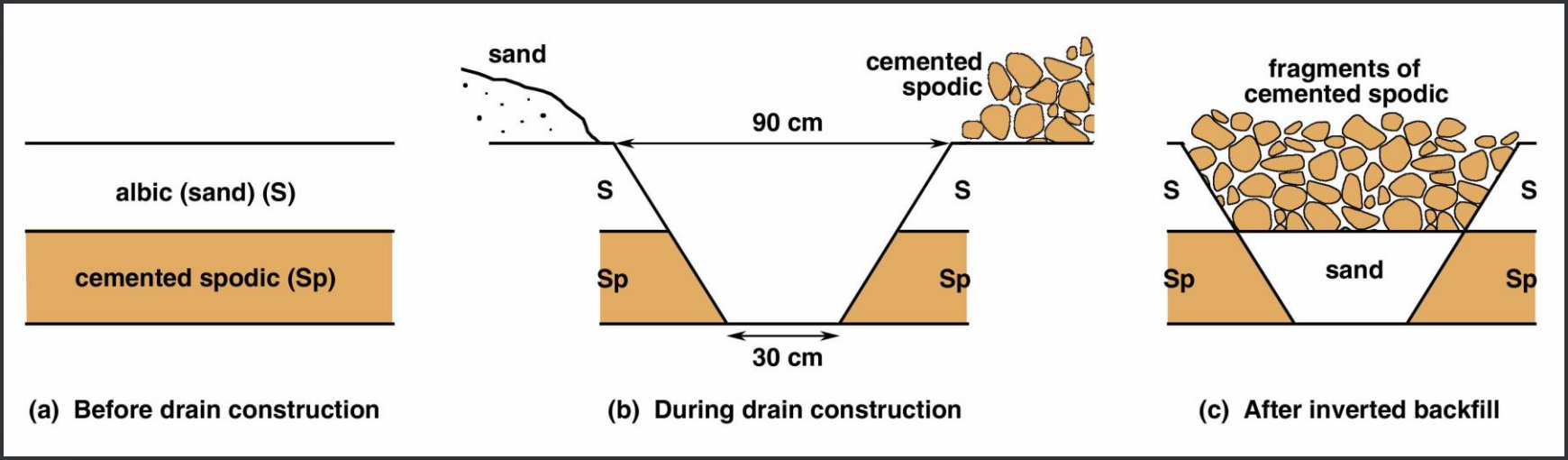
VEGETATION
Deep Sandy Soils

Keranggas Forest

Shrubs

Sheet Lallang

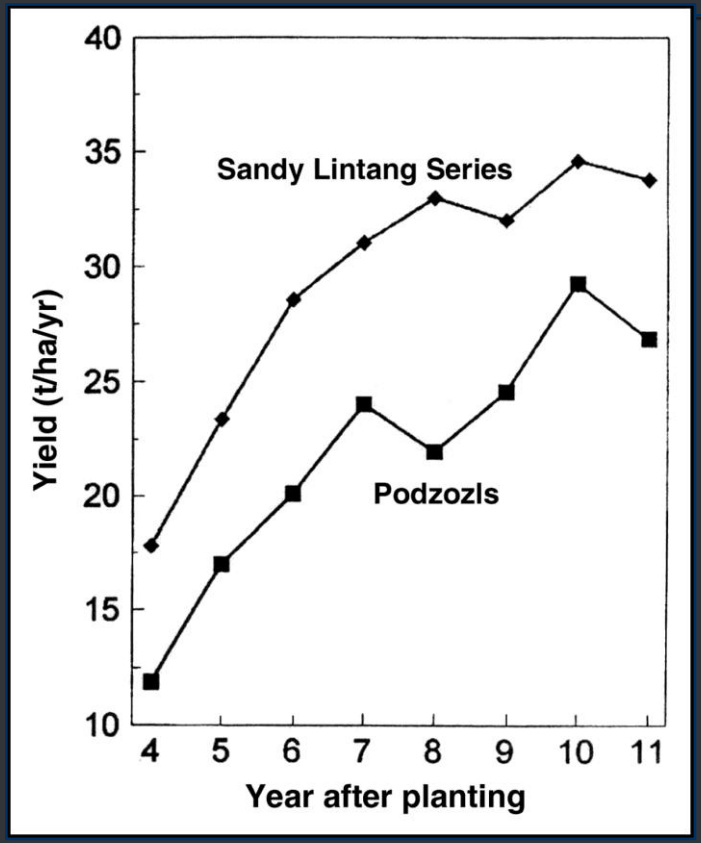
Scupper Drain Construction



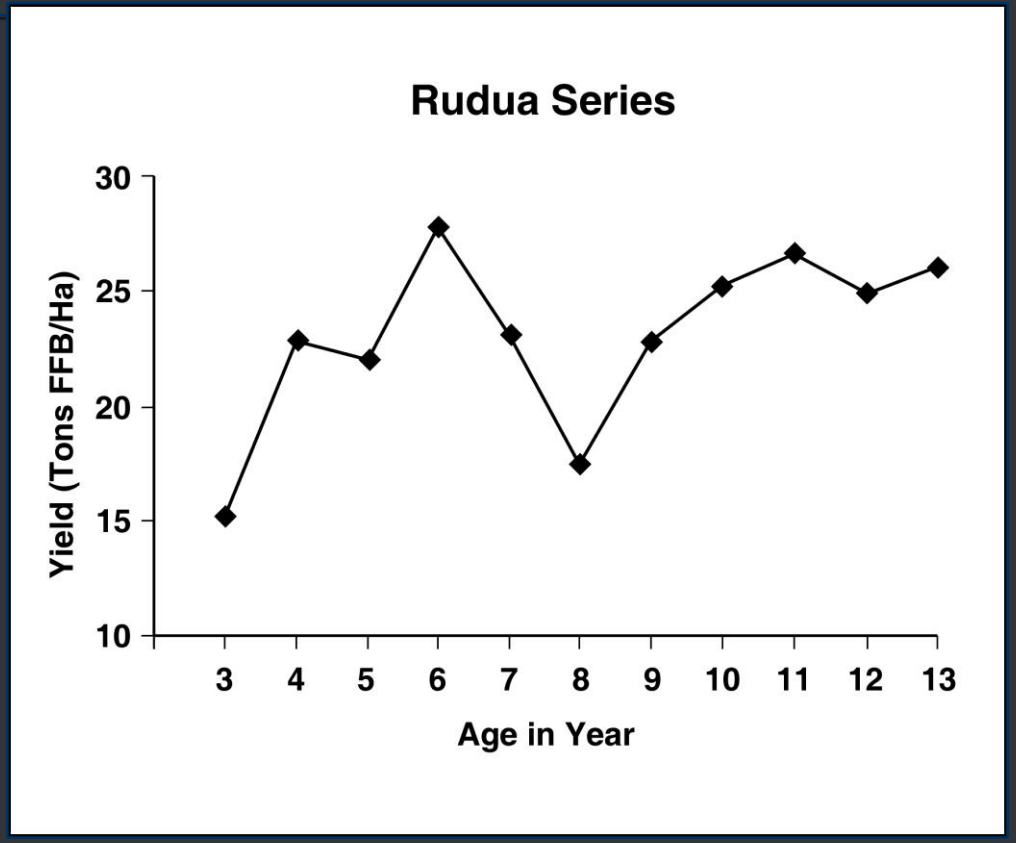
SANDY SOILS
Management

- Mulching
  - ► reduce surface temperature
  - ► increase moisture
- Split application/Higher rates of fertilizers
- Rock phosphate
- Maintain ground vegetation
- Crop selection
  - ► tobacco, coconuts, mango, watermelon

Current Yield



Yield Performance of Oil Palms on podzols and deep sandy soils (after Goh *et al.*, 1994)



Yield Performance on Rudua Series (Xaviar *et al.*, 2004)

ORGANIC SOILS

ORGANIC SOILS
Characteristics

- Organic soil materials dominate the soil
- Deep (>150 cm)
- Material can be:
  - ► highly decomposed – sapric
  - ► partly decomposed – hemic
  - ► undecomposed – fibric
- Naturally waterlogged – poor aeration
- When excessively drained – irreversible drying
- Slow availability of N due to high C/N ratio
- Low K, Cu, Zn, B; very acid (pH < 4.0)
- Shrinkage/decomposition on drainage
- Leaning palms
- Complex nutritional problems
- Dome-shaped areas
- Presence of wood – decomposed / undecomposed

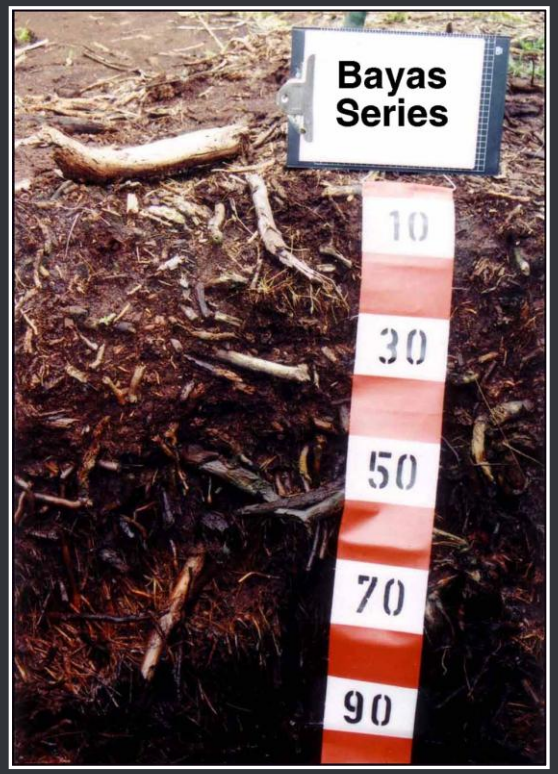
PEAT

- Poor Accessibility / High Cost
  — Difficult to use heavy machinery due to low bearing strength
  — Difficult to clear/excavate manually due to high water table and presence of wood
- Physical and chemical properties cause problems
- Contains excessive amounts of water
- Low bulk density (<0.15 g cm^{-3})
- Irreversible drying if excessively drained
- Extensive subsidence almost 0.5-1.0 m in first year and about 3-4 cm/year subsequently
- Major and trace element problems
  — Low K, Cu, Zn and B
- High acidity

ORGANIC SOILS

Penor Series / Gondang Series / Bayas Series

Gondang Series

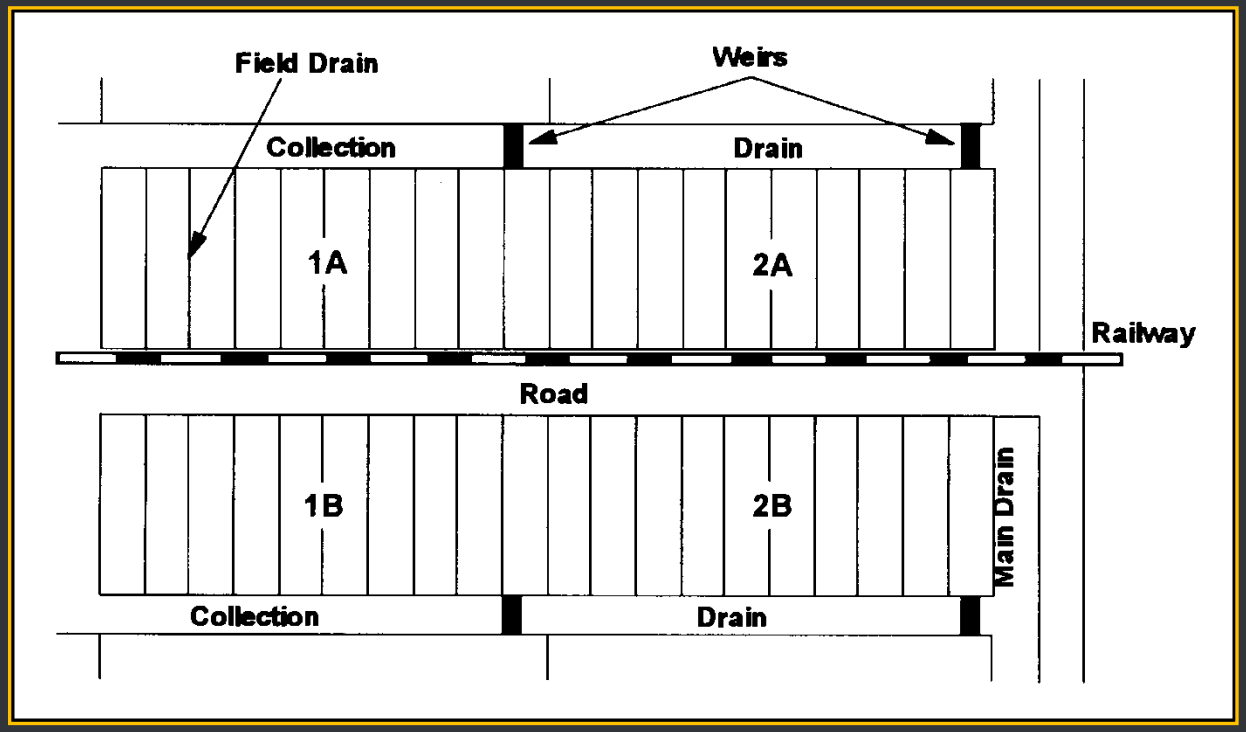


ORGANIC SOILS
Management

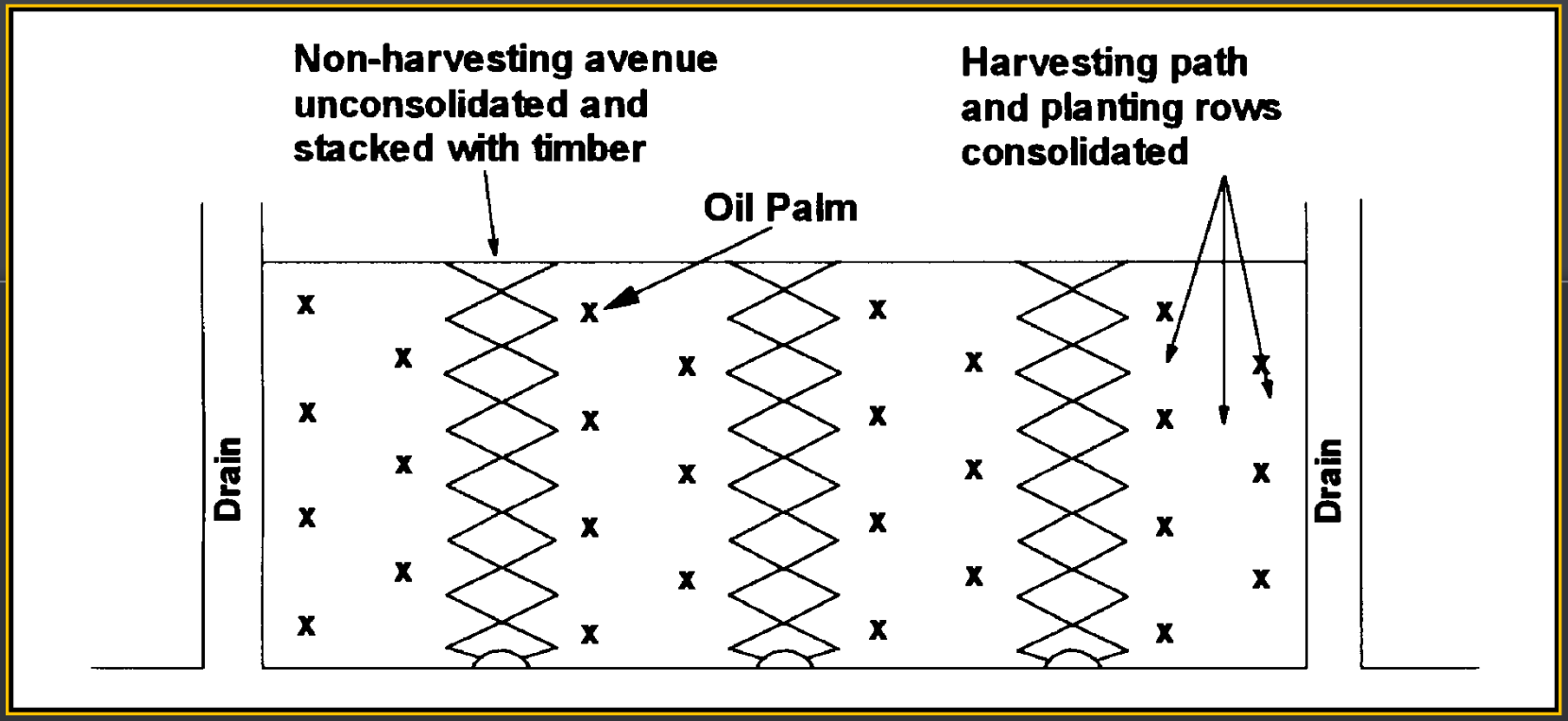
- Soil map of Area
- Look at whole peat basin
- Drainability
- Water control using 1°, 2° and 3° drains with controls (watertable at 50-70 cm)
- Regular desilting of drains/flushing
- Compaction of planting rows/harvesting path
- Peat fires
- Increase planting density to 160 palms/ha
- Monitor major/minor nutrients (especially K)
- Trace elements (Cu, Zn, B)
- P rates can be low
- Construct main drains and wait at least one year for initial subsidence
- Then construct Field and Collection Drains — watertable 50-75 cm depth
- Compact planting rows

Types of Drains

Type of drain	Width (m)		Depth (m)
	Top	Bottom	
Field	1.0-2.0	0.5-0.6	0.9-1.0
Collection	1.8-2.5	0.6-0.9	1.2-1.8
Main	3.0-6.0	1.2-1.8	1.8-2.5



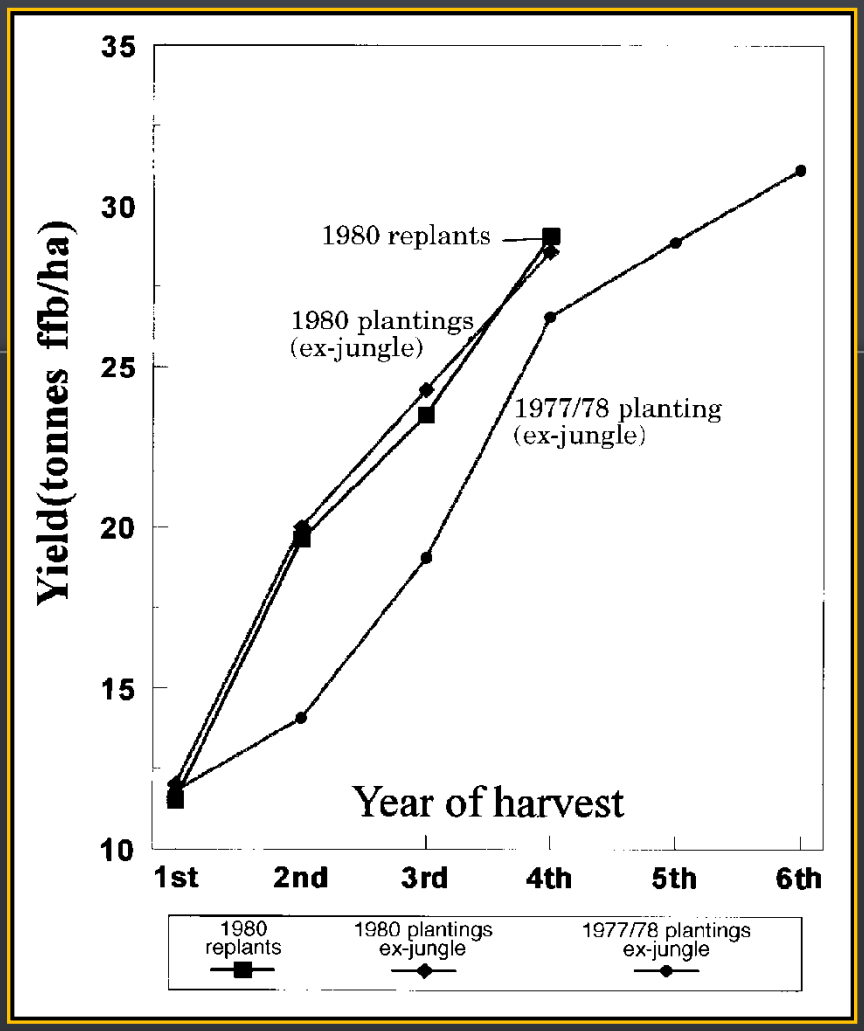
Layout plan of the drainage system in peat swamp



System of consolidation of harvesting paths and planting rows in peat swamp

Complex Nutritional Problems

- Total N high but availability low
  - apply high rates of N in initial years
- Low rates of P to be applied
- K is very deficient
  - high rates of MOP
- Deficient in Cu, Zn and B
  - apply these in early years

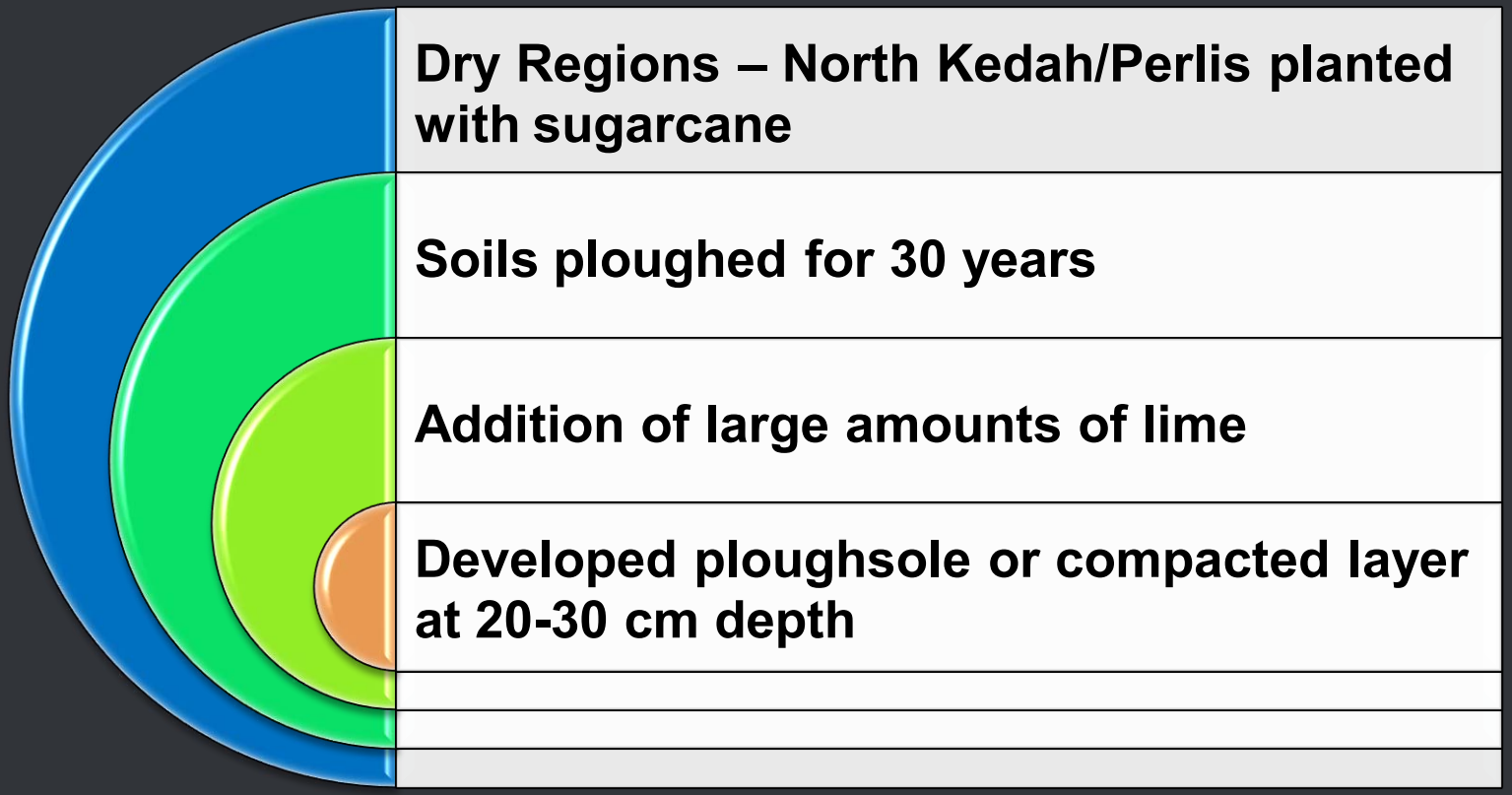


FFB yields on deep peat in United Plantations

SOILS AFTER SPECIFIC LAND USE CHANGE

AREAS WITH SPECIFIC LAND USE CHANGE

Characteristics



AREAS WITH SPECIFIC LAND USE CHANGE

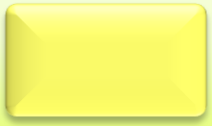
Limitations

Ploughsole – impervious

- **no root penetration**
- **water logging in rainy season**
- **dry in dry season**

Wind damage to rubber

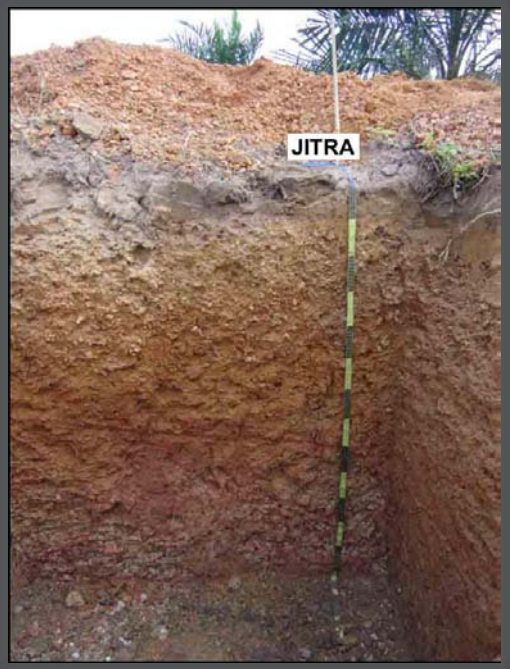
High Ca-levels in rubber leaves



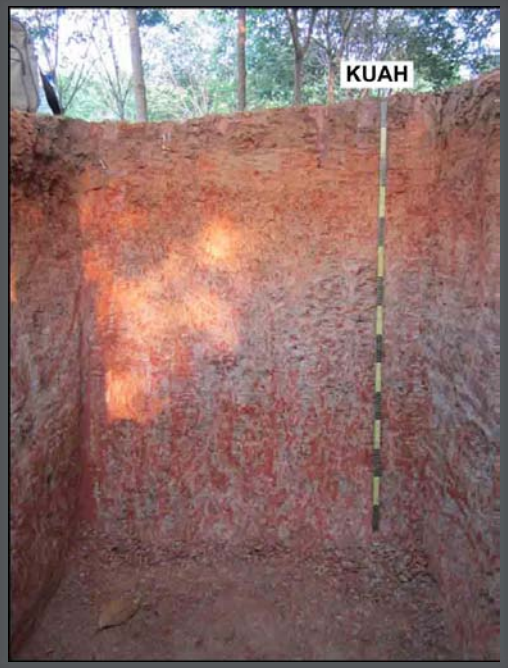
Poor girth – longer immature period

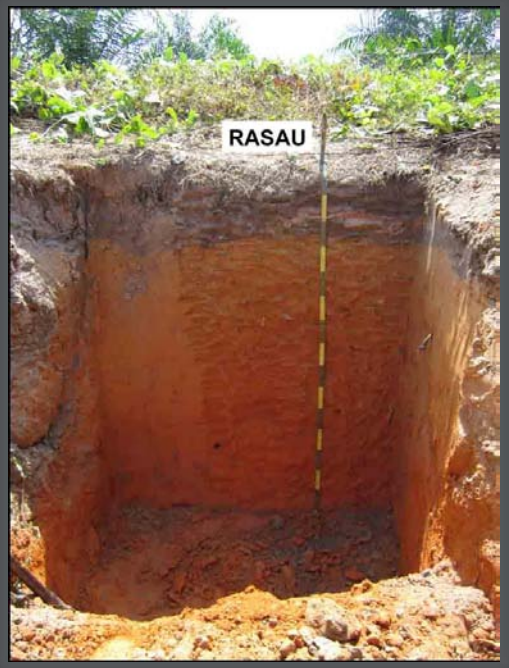
Oil palm less affected (still young)

SOILS AFTER SPECIFIC LAND USE CHANGE



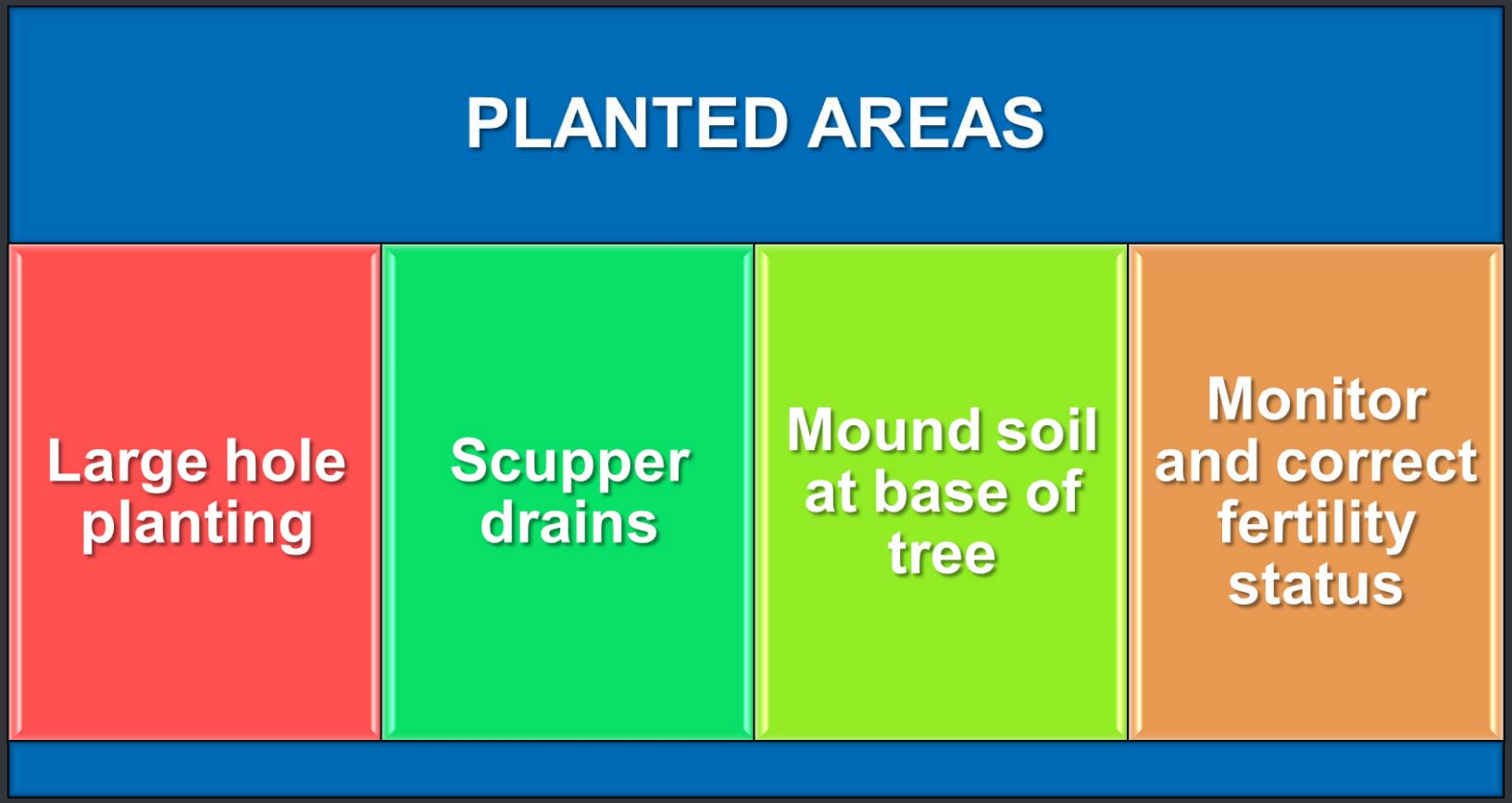
SOILS AFTER SPECIFIC LAND USE CHANGE





AREAS WITH SPECIFIC LAND USE CHANGE

Management



AREAS WITH SPECIFIC LAND USE CHANGE

Management

NEW AREAS

- Deep ploughing in planting line
- Break plough pan
- Mound soil at base of tree
- Monitor and correct fertility status

Thank You!