



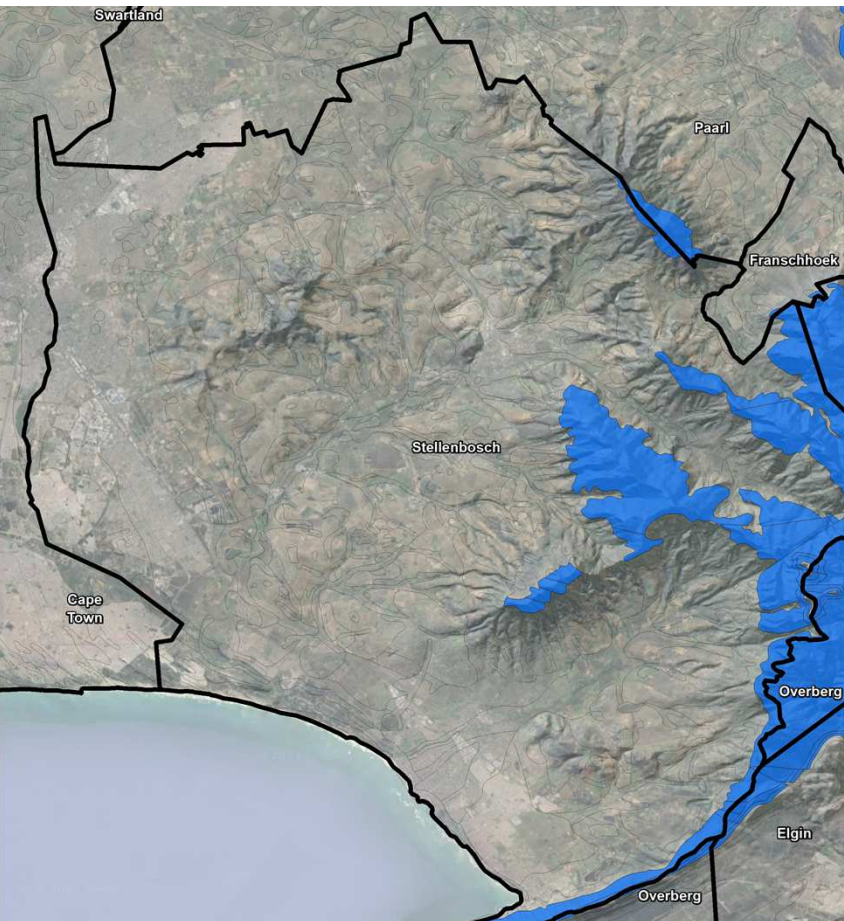
VINPRO
growing together

What happens to applied K ?

Vivian White - Vinpro

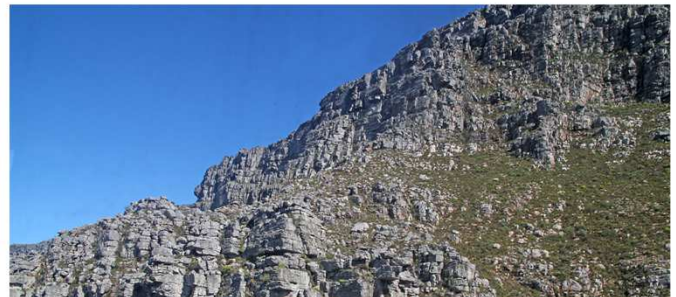
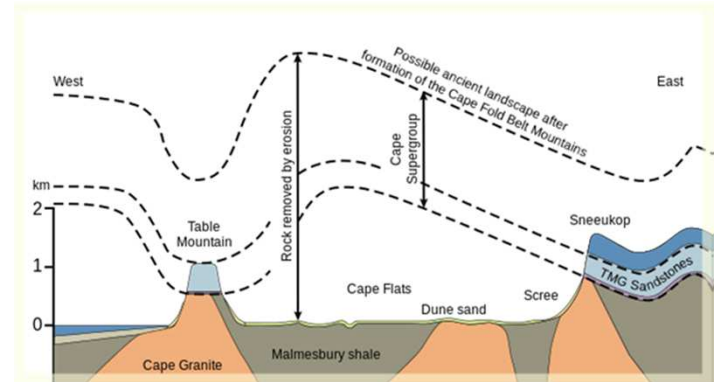
Background: Geology & Soil

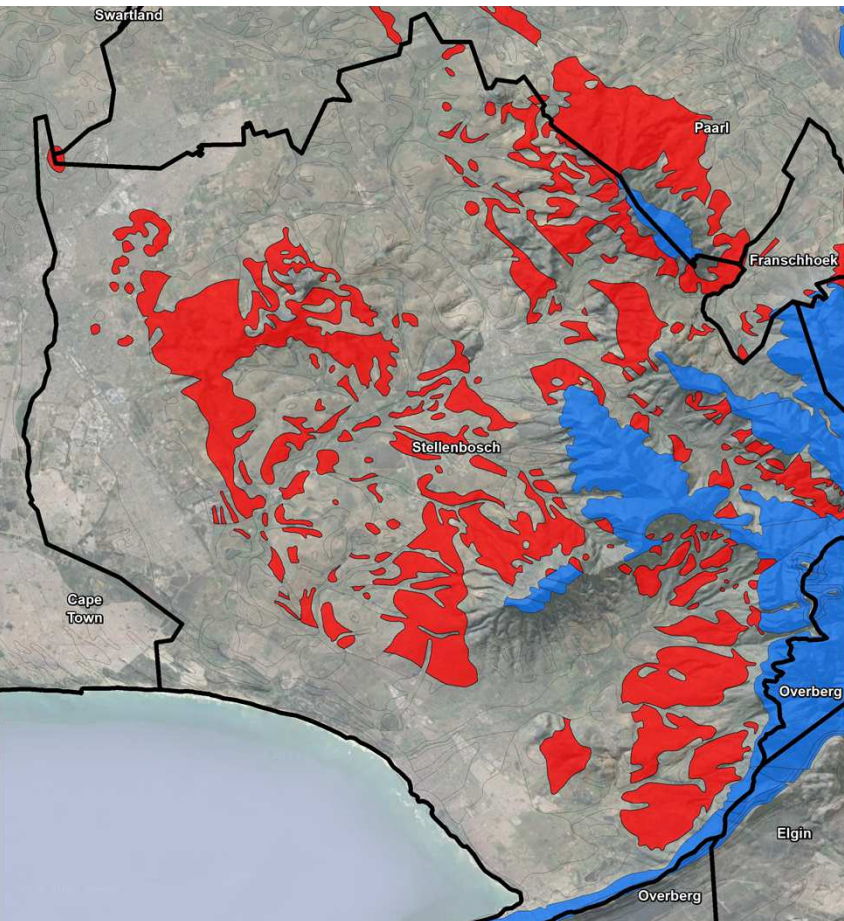




Main Geologic groups of Stellenbosch

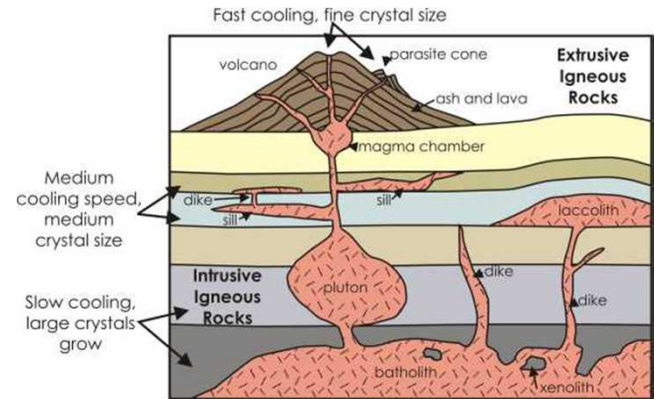
1: **Table Mountain Sandstone** on the mountain tops
(>400m): Low CEC and WHC

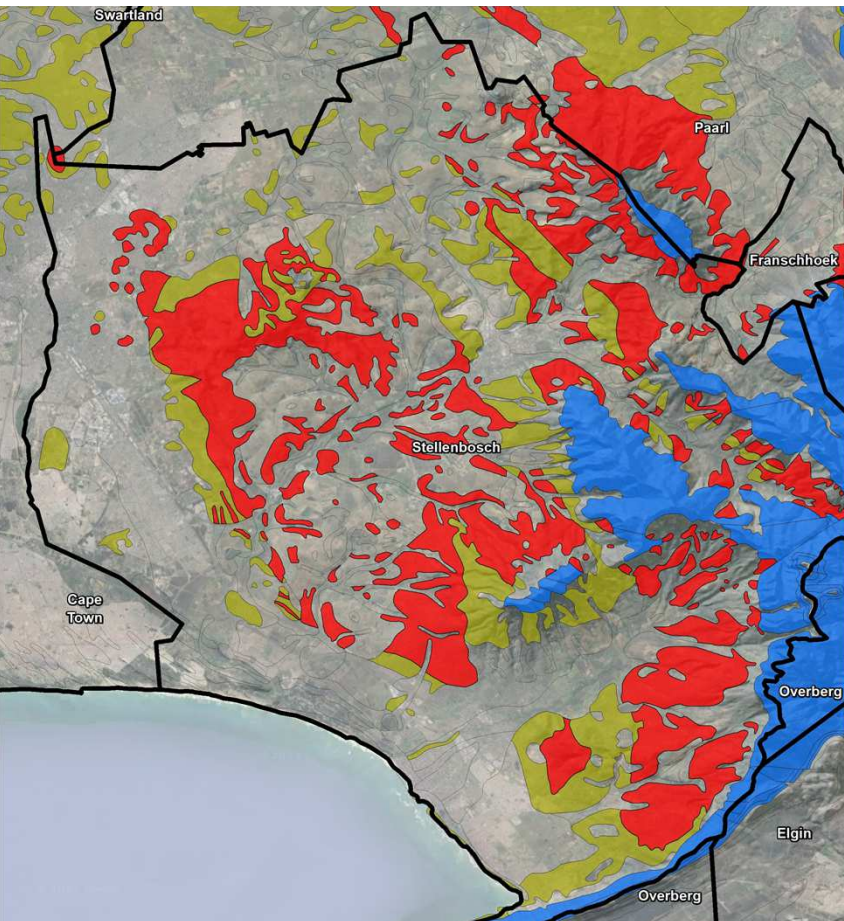




Main Geology groups of Stellenbosch

- 1: Table Mountain Sandstone on the mountain tops (>400m): Low CEC and WHC
- 2: **Granites:** (coarse texture and high in K)

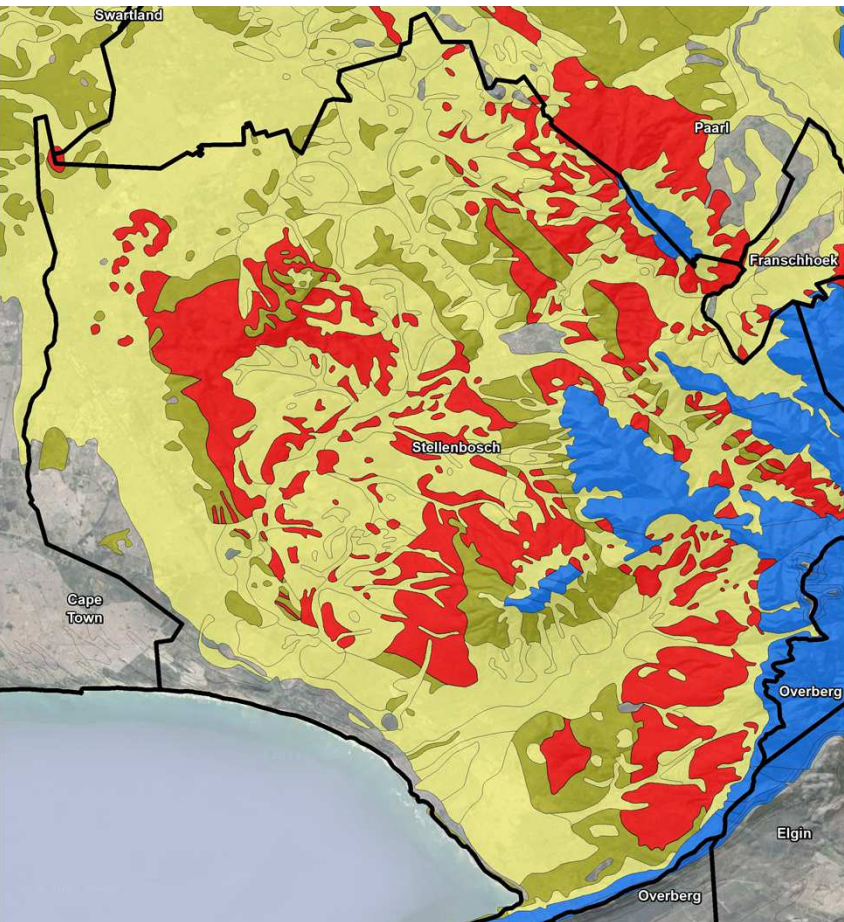




Main Geology groups of Stellenbosch

- 1: Table Mountain Sandstone on the mountain tops (>400m): Low CEC and WHC
- 2: Granites (coarse texture and high in K)
- 3: **Malmesbury Shale** (fine texture with high WHC)





Main Geology groups of Stellenbosch

- 1: Table Mountain Sandstone on the mountain tops (>400m): Low CEC and WHC
- 2: Granites (coarse texture and high in K)
- 3: Malmesbury Shale (fine texture with high WHC)
- 4: **Quaternary sediments** (younger transported soils)

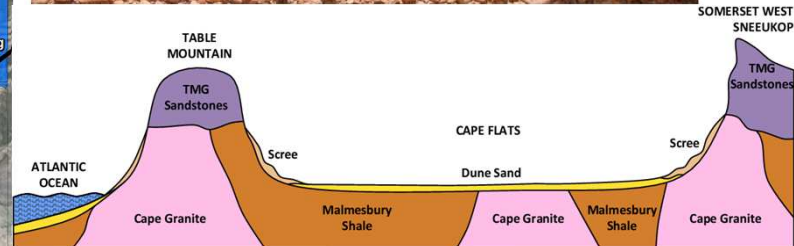


Figure 5.1 - Geological cross-section of Cape Town (Compton, 2004)

STELLENBOSCH PARENT MATERIALS

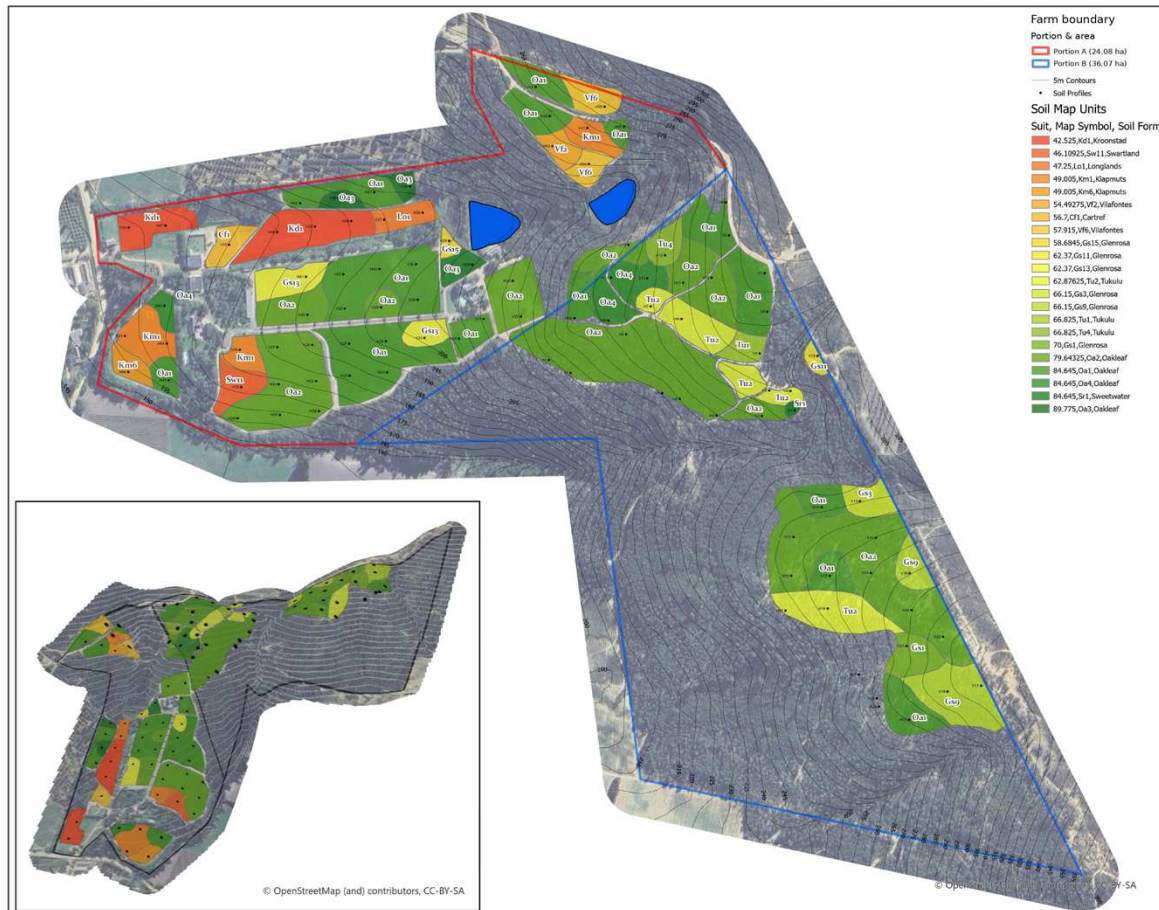
From rock to potassium: how geology shapes K behaviour

Parent material	Cape Granite Suite Intrusive granite ~540 Ma	Malmesbury Group Shale & greywacke (Tygerberg Fm)	Table Mountain Group Quartzitic sandstone	Quaternary sediments Alluvium, colluvium, aeolian sand
K-bearing minerals	K-feldspar (orthoclase, microcline), biotite, muscovite	Fine-grained mica (sericite/illite); minor feldspar	Very little — mostly quartz	Mixed — inherited from the source rocks upstream / upslope
Typical soil forms	Acidic, high clay % <u>coarse textured soils</u> Oakleaf, Tukululu Duplex soils also possible	Alkaline, high clay % <u>fine textured</u> duplex soils Klapmuts, Escourt	Acidic, low clay % <u>medium textured, low fertility soils</u> Fernwood, Cartref, Lamotte, lithic Glenrosa	Neutral-Alkaline, low clay % high, <u>stone %</u> , <u>high fertility soils</u> Dundee, Oakleaf (alluvium); Fernwood (sand); colluvial Tukululu
Texture	coarse sandy loam to sandy clay loam; clayey kaolinitic subsoil	Stony loam to clay; often duplex (clay-rich B horizon)	Sand to loamy sand; gravelly on slopes	Highly variable and layered: gravel lenses to clay
Dominant clay minerals	Kaolinite dominant; some mica/illite; Fe & Al oxides	Illite/mica + kaolinite; some vermiculite, chlorite, interstratified clays	Little clay (kaolinite); organic matter supplies most CEC	Mixed; reflects catchment (granite, shale, sandstone)
K behaviour	K reserve ●●● Fixation ●○○ Leaching risk ●●○ <i>K reserve in feldspar; low CEC</i>	K reserve ●●● Fixation ●●○ Leaching risk ●○○ <i>Large non-exchangeable pool</i>	K reserve ●○○○ Fixation ●○○○ Leaching risk ●●●●	<i>Variable — depends on source and layering; sample per layer</i>

●●● high ●● moderate ●○○ low -Relative, indicative ratings. Sources: Bargmann (IVES); Soil Classification Working Group (2018). 290926 V2

GEOLOGY: A FARM EXAMPLE

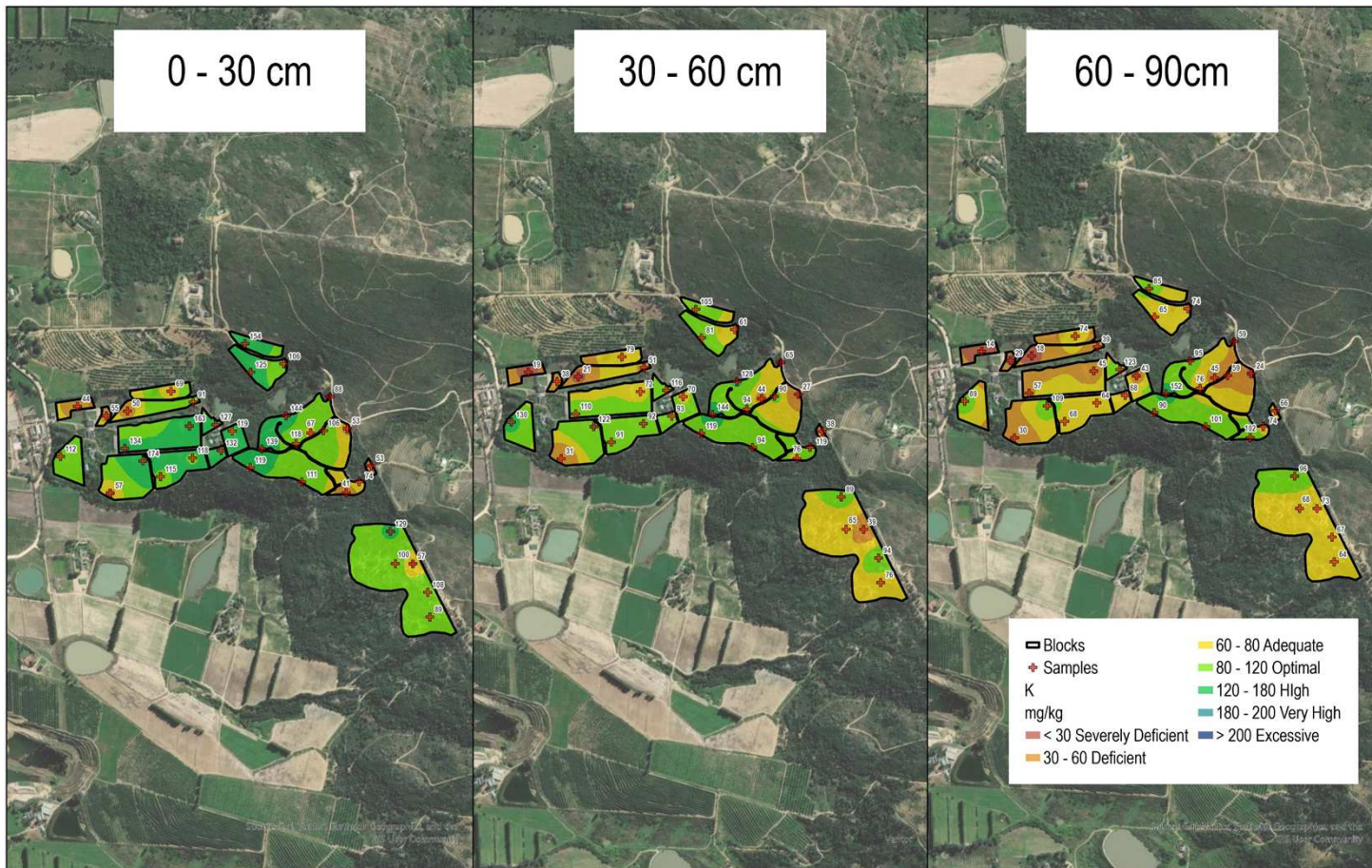




0 - 30 cm

30 - 60 cm

60 - 90cm



Soil Reactions



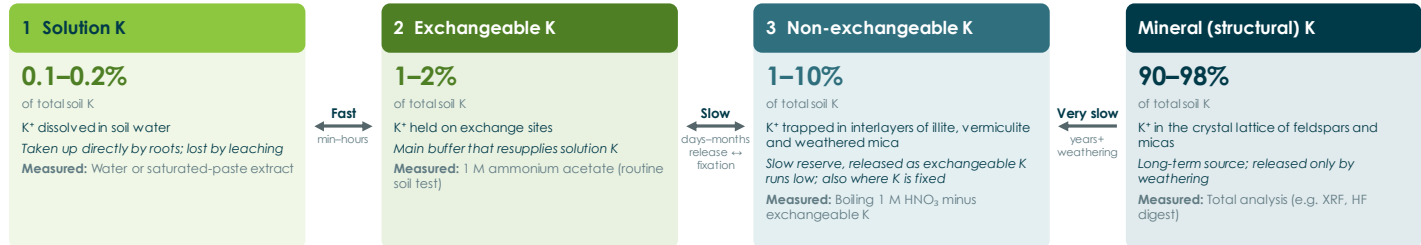
SOURCES OF SOIL POTASSIUM

Mineral and chemical forms

A - MINERAL SOURCES

Orthoclase K-feldspar KAISi_3O_8 K release rate ● ○ ○ ○ ○ <i>Framework silicate: K released only as the crystal dissolves</i>	Microcline K-feldspar KAISi_3O_8 K release rate ● ○ ○ ○ ○ <i>Same formula, triclinic form; common in Cape granite</i>	Biotite Mica (dark) $\text{K}(\text{Mg,Fe})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$ K release rate ● ● ● ● ● <i>Fe³⁺ oxidation weakens the interlayer: fastest K release</i>	Muscovite Mica (white) $\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$ K release rate ● ● ● ○ ○ <i>Resists weathering: K held between the layers</i>	Illite Clay mineral (2:1) $\text{K}_{0.65}\text{Al}_2(\text{Al}_{0.65}\text{Si}_{3.35}\text{O}_{10})(\text{OH})_2$ K release rate ● ● ● ● ○ <i>Clay-size weathered mica: frayed edges release K, and fix it</i>
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B - CHEMICAL FORMS (POOLS)



POTASSIUM LOSSES

crop removal, leaching and erosion

Removal by crops

Harvest and prunings

2–3 kg K

removed per ton of fresh grapes

- Removal scales with yield: 15 t/ha $\approx$ 30–45 kg K/ha per season
- Prunings carted out of the block add to the loss; mulched prunings return their K
- SA guideline: apply $\sim$ 3 kg K/ha per ton of expected crop (Conradie, 1994)
- The only loss that is fully predictable — budget for it

Manage: replace what the crop removes

Leaching

K⁺ in soil solution moves below the root zone with drainage water

Factor

▲ More leaching

▼ Less leaching

Texture

Sand and gravel: fast drainage, low CEC

Loam to clay: slower water flow, higher CEC

pH

Acid: H⁺ and Al³⁺ occupy sites; pH-dependent CEC falls

Limed to target pH: more pH-dependent CEC holds K⁺

CEC

Low CEC: small exchangeable pool, weak buffering

High CEC: exchangeable pool buffers solution K

Organic carbon

Low C

Higher SOC increases CEC (exchangeable K⁺)

Other cations

Ca²⁺/Mg²⁺ from lime or gypsum, and NH₄⁺, displace K⁺ into solution

Balanced cation ratios; K applied in split doses

Manage: lime to target pH, build organic C, split K on sandy soils, avoid large K doses ahead of winter rain

Erosion

Loss of topsoil by water

- Removes the topsoil, where applied K and organic C are concentrated
- Fine clay and organic matter wash away first: the K-richest fraction is lost selectively
- Risk rises with steep slopes, bare interrows, winter storms and weak structure (e.g. duplex soils)
- Losses are hard to reverse: the exchange sites go with the soil

Manage: cover crops, mulch, contourrows,

Fixation is not a loss, K moves into the non-exchangeable pool and can be released again.

Sources: Conradie (1994) in S. Afr. J. Enol. Vitic.; Brady & Weil, The Nature and Properties of Soils.

FACTORS INFLUENCING K AVAILABILITY

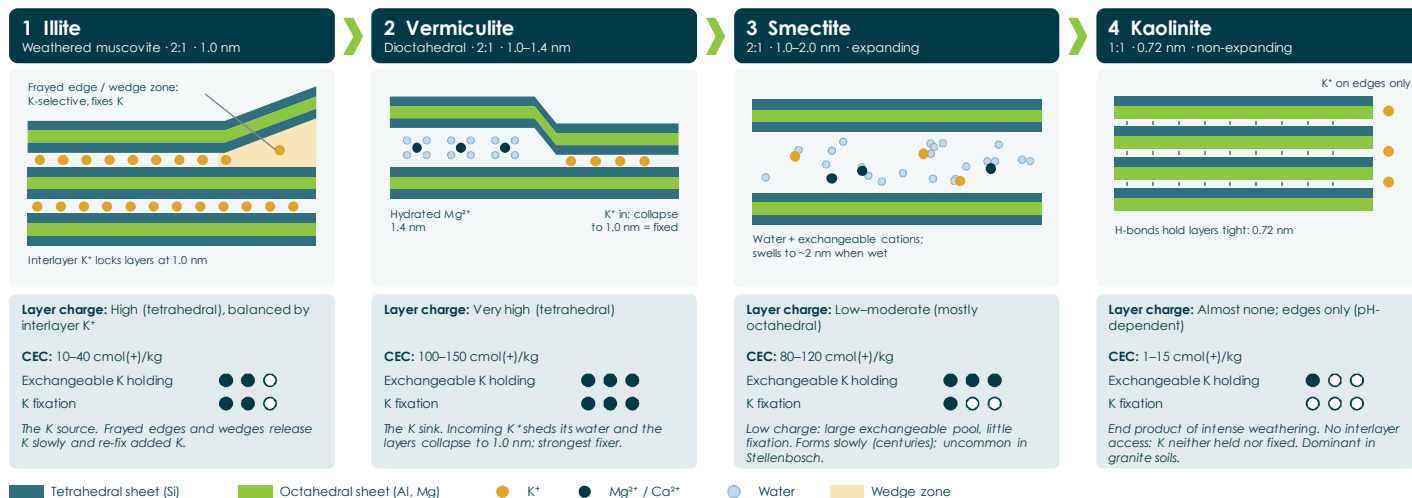
Soil tests measure the K pool; conditions decide what reaches the vine

Soil properties	Soil chemistry	Soil conditions
Texture ▲ Loam to clay: more exchange sites, slower drainage ▼ Sand and gravel: few sites, fast drainage, leaching	pH ▲ pH(KCl) 5,5-6,5: full variable-charge CEC holds K⁺ ▼ Acid: H⁺ and Al³⁺ occupy sites; edge sites lose negative charge	Soil moisture ▲ Moist soil: K⁺ diffuses freely to the roots ▼ Dry soil: diffusion drops sharply; deficiency despite adequate soil K
Clay type ▲ Illite: slow-release K reserve ▼ Vermiculite fixes applied K; kaolinite holds little	Competing cations ▲ Balanced Ca : Mg : K on the exchange complex ▼ High Ca²⁺/Mg²⁺ displace K⁺ and suppress uptake; NH₄⁺ competes for wedge sites	Temperature ▲ Warm soil: faster diffusion, release and uptake ▼ Cold soil: slow K supply in early spring
CEC & organic matter ▲ High CEC: large exchangeable pool, strong buffering ▼ Low CEC: small pool, weak buffering	Liming & gypsum ▲ Lime raises variable CEC, so more K⁺ is held ▼ Added Ca²⁺ displaces K⁺ in the short term: leaching risk	Compaction & aeration ▲ Deep, well-aerated root zone ▼ Compacted or waterlogged layers restrict roots and active uptake
▲ increases K availability ▼ reduces K availability · Most K reaches the root by diffusion: anything that slows diffusion or root growth lowers availability		

Sources: McBride, Environmental Chemistry of Soils (Ch. 2-3, pp. 212-216); Brady & Weil, The Nature and Properties of Soils.

CLAY MINERALOGY & K

Muscovite weathering pathway: K content falls left to right



Tetrahedral sheet (Si)
 Octahedral sheet (Al, Mg)
 K⁺
 Mg²⁺ / Ca²⁺
 Water
 Wedge zone

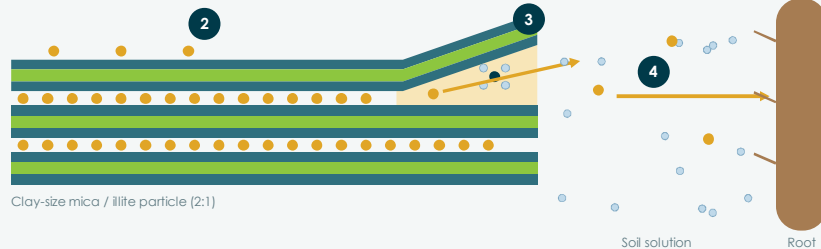
Pathway: muscovite → illite → vermiculite → smectite → kaolinite

(McBride pp. 212–216). CEC: McBride Table 3.1

POTASSIUM RELEASE FROM MINERALS

Most release comes from the clay fraction; feldspars contribute little

How interlayer K reaches the root



1 Uptake: Roots take up K^+ and draw down K in the surrounding soil solution

2 Exchange: Exchangeable K^+ on clay surfaces replenishes the solution (fast)

3 Interlayer release: K^+ diffuses from the interlayer to the frayed edge and is replaced by hydrated Ca^{2+} , Mg^{2+} or H^+ ; the edge opens (slow)

4 Transport: K^+ moves to the root mainly by diffusion down the concentration gradient; mass flow supplies only a small part

Which minerals release K?

Clay-size mica / illite

Main source: fine particles, frayed edges, large surface area

Biotite

~100× faster than muscovite; release stops above ~15 $\mu\text{g K/mL}$

Muscovite

Releases only below ~0.3 $\mu\text{g K/mL}$ in solution

K-feldspar

Little to none within a season; K released only as the crystal dissolves

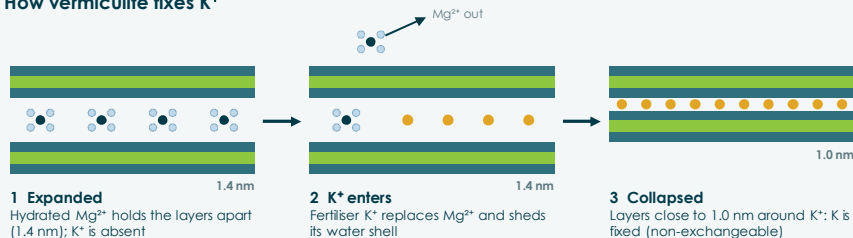
Release is demand-driven: it stops once solution K rises above a mica-specific threshold. High solution K drives fixation.

Thresholds: McBride, Environmental Chemistry of Soils, pp. 212–216. Sources: Sparks (2000); Brady & Weil.

POTASSIUM FIXATION

Illite is the K source, vermiculite the K sink

How vermiculite fixes K⁺



Where the layer charge comes from



Tetrahedral: Al³⁺ for Si⁴⁺ gives -1 at the surface, right next to K⁺: strong bond, drives collapse

Octahedral: Mg²⁺ or Fe²⁺ for Al³⁺ gives -1 deeper in the layer: adds charge, weaker pull on K⁺

Illite = source, vermiculite = sink

Mica / illite $\rightleftharpoons$ vermiculite + K⁺(aq)

- Low solution K drives release (→)
- High solution K drives fixation (←)
- Illite fixes only at frayed edges and wedge zones

What controls fixation

- High layer charge, especially tetrahedral
- Enough K⁺ in solution to start the collapse
- Wetting and drying cycles that close the layers
- NH₄⁺ is fixed the same way and competes with K⁺
- Hydroxy-Al interlayers in acid soils prop layers open: less fixation

What it means for management

- On vermiculitic soils, part of applied K is fixed before the vine can use it
- Fixed K is not lost: re-fixed K is released more easily when solution K falls
- Build K before planting; use higher rates or banding where fixation is high

Schematic, not to scale. Sources: McBride, Environmental Chemistry of Soils, Ch. 2-3 and pp. 212-216; Sparks (2000)

CATION EXCHANGE

Divalent cations are held more strongly than K^+

Exchange happens charge for charge

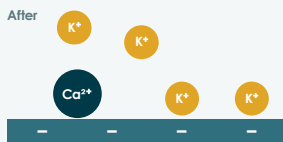
Before



Clay surface (negative charge)



After

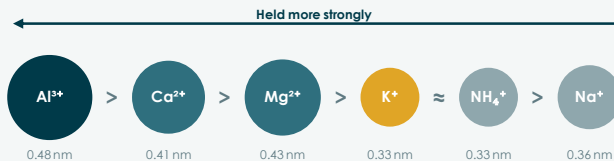


Clay surface (negative charge)



One Ca^{2+} replaces two K^+ . The reaction is fast and reversible.

Replacing power (lyotropic series)



Circle size = hydrated radius. H^+ also behaves as a strongly held cation because it bonds to edge O and OH groups.

Why divalent cations win

- Double charge: twice the electrostatic pull on the negative surface
- At equal charge, the smaller hydrated ion sits closer ($K^+ > Na^+$, $Ca^{2+} > Mg^{2+}$)
- Dilution by rain or irrigation shifts the balance further toward divalent ions

What it means for K

- Ca^{2+} from lime or gypsum displaces K^+ into solution: higher leaching risk on sandy soils
- K^+ holds a small share of the CEC; judge K as % of CEC, not mg/kg alone
- High Mg^{2+} competes with K^+ for uptake; watch the K:Mg balance

The exception: K-selective sites

- Frayed edges and wedge zones of illite and vermiculite prefer K^+ over Ca^{2+}
- K^+ (and NH_4^+) shed water easily and fit the interlayer; hydrated Ca^{2+} is too large
- These sites fix K but also buffer long-term supply

Hydrated radii are approximate; published values vary. Sources: Brady & Weil, The Nature and Properties of Soils; Sparks, Environmental Soil Chemistry.

Cation exchange

Grondkomponent	Beskrywing	Tipiese KUK-reeks (meq/100g)
Organiese Materiaal (Humus)	Ontbinde plant- en dierestereste, hoogs reaktief met baie uitruilplekke.	100–300
Vermikuliet	n 2:1 klei met hoë KUK weens interne en eksterne uitruilplekke.	100–200
Montmorilloniet	n 2:1 smektiet klei met hoë oppervlakarea en uitbreidbare lae.	80–150
Illiet	n 2:1 klei met matige uitruilplekke, algemeen in gematigde gronde.	15–40
Kaolinet	n 1:1 kleimineraal met lae oppervlakarea en minder uitruilplekke.	3–15
Seskwioksides	Yster- en aluminiumoksiede, dra minimaal by tot KUK in meeste gronde.	0–5

MANAGING K BY SOIL TYPE

Clay mineralogy dictates how applied K behaves

Dominant Clay mineral	Kaolinitic Granite soils, TMG sands	Illitic / micaceous Malmesbury shale soils	Vermiculitic Weathered mica-rich soils (confirm by XRD)
Typical soils	Coarse, acidic soils Hutton, Tukululu, Oakleaf, Clovelly on granite; Fernwood, Cartref on sandstone	Fine, alkaline soils Glenrosa, Swartland, Klapmuts, Estcourt on shale	Where mica has weathered past illite; often mixed with illite
K behaviour	Little fixation, small reserve, low CEC; leaching risk in sands	Large non-exchangeable reserve; slow release once solution K is low; some edge fixation	Strong fixation of applied K; less where hydroxy-Al interlayers occur (acid soils)
What the soil test tells you	Exchangeable K reflects supply reasonably well	Ammonium acetate K underestimates supply: add boiling HNO_3 K	Responds slowly to applied K until fixation sites fill
Management	Small, split applications; maintain rather than build; avoid large doses before winter rain; build organic C	Avoid excessive K; rely on the reserve; supply only the expected removal	Build K before planting; higher rates or banding; separate large NH_4^+ and K applications
All soils: mineral release cannot correct an in-season deficit - manage K per soil unit			

Take home & questions raised ?

- ❖ Consider Texture (sandy vs Clayey) when deciding on large corrective K applications, >15% clay corrective K can be considered – what about Duplex soils ? – what about slope ?
- ❖ Soils formed from granitic and shale parent materials have a K reserve
- ❖ Low CEC clays (granitic , weathered soils) won't hold on to applied K as well – smaller, regular installments ?
- ❖ Ca:K and Mg:K ratios – if other cations dominate, leaching can be expected to be higher, in season application based on phenology is better here. Impact of NH_4^+ is also important here.
- ❖ pH – liming is crucial prior to any applications
- ❖ Increase soil K to optimal concentration mg/kg don't chase ideal % BCS
- ❖ Is it necessary to correct subsoil K during establishment ?
- ❖ Are maintenance applications (2-3 years) justified ? Shouldn't we (in deficient soils) over supply demand slightly to facilitate a slight build up ?

THANK YOU



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