AdvancedPotashTechnologies

HydroPotash

A Disruptive Technological Development

April 2017

AdvancedPotashTechnologies

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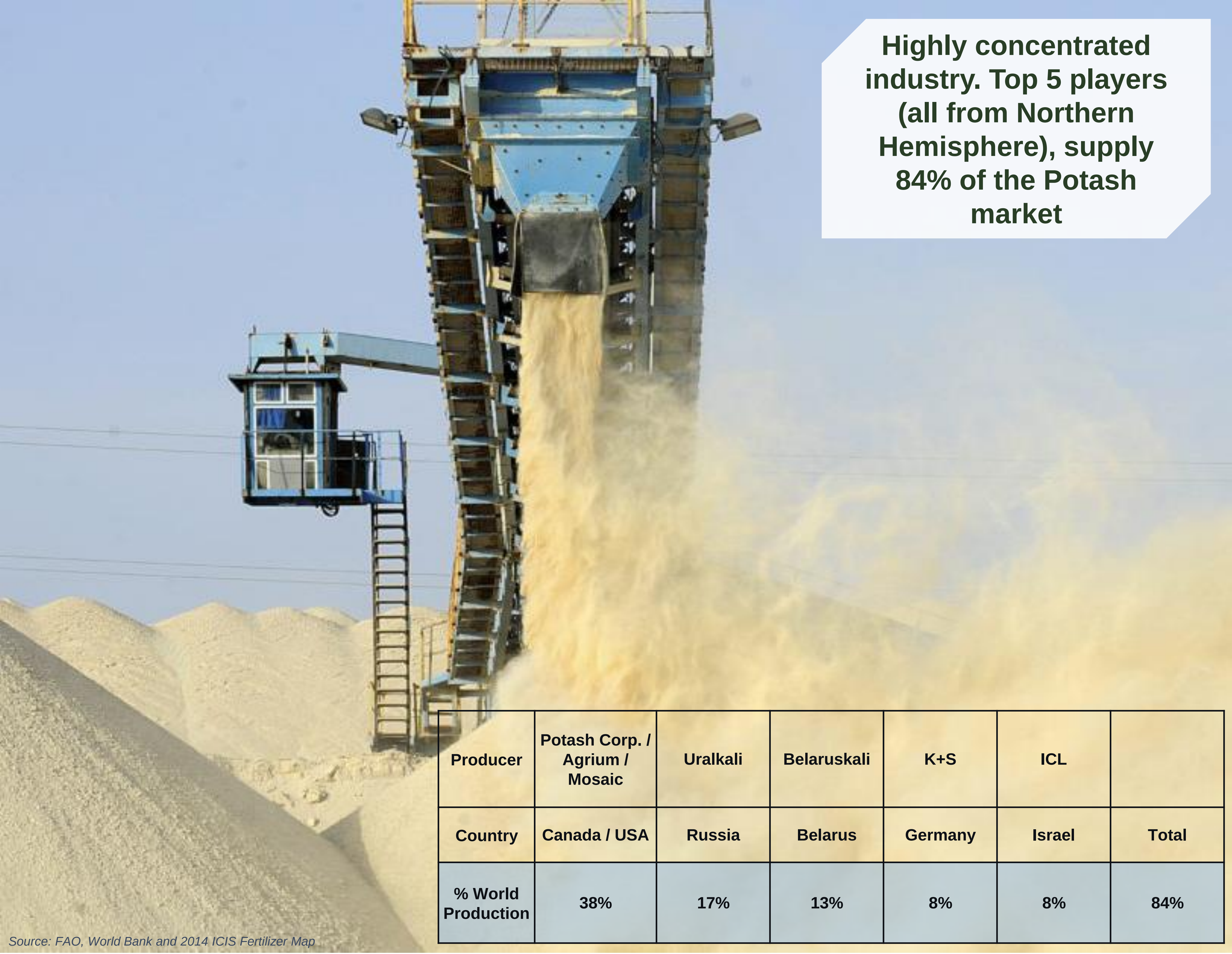
		2014 Tonnage Produced (Mt) Major Crops	Imports of Potash as % of Total Consumption (2014)
1	China	824	c.50%
2	USA	622	>85%
3	India	440	>95%
4	Indo	307	>95%
5	Brazil	232	>95%
6	Russia	184	Self-sufficient
7	Nigeria	151	>95%
8	France	127	>95%
9	Malaysia	124	>95%
10	Ukraine	120	>95%

8 out of the 10 largest agricultural producers import >85% of their Potash demand

Source: FAO Database as of 2014



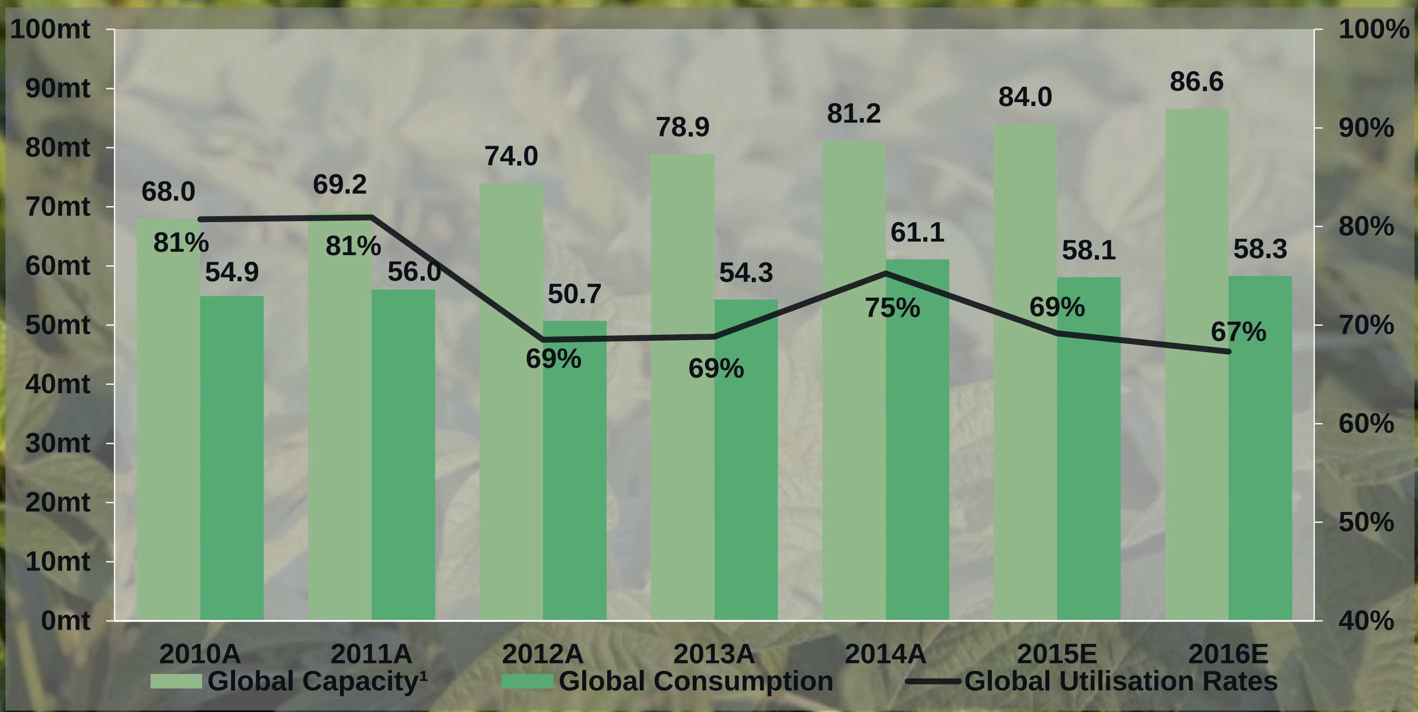
Highly concentrated industry. Top 5 players (all from Northern Hemisphere), supply 84% of the Potash market

Producer	Potash Corp. / Agrium / Mosaic	Uralkali	Belaruskali	K+S	ICL	
Country	Canada / USA	Russia	Belarus	Germany	Israel	Total
% World Production	38%	17%	13%	8%	8%	84%

Source: FAO, World Bank and 2014 ICIS Fertilizer Map

Idle production capacity, despite of significant unserved demand,

Global Potash Nameplate Capacity and Consumption (MOP in Mt)



Source: Fertecon and JP Morgan Estimates as of 2015

More production simply won't solve the unserved demand

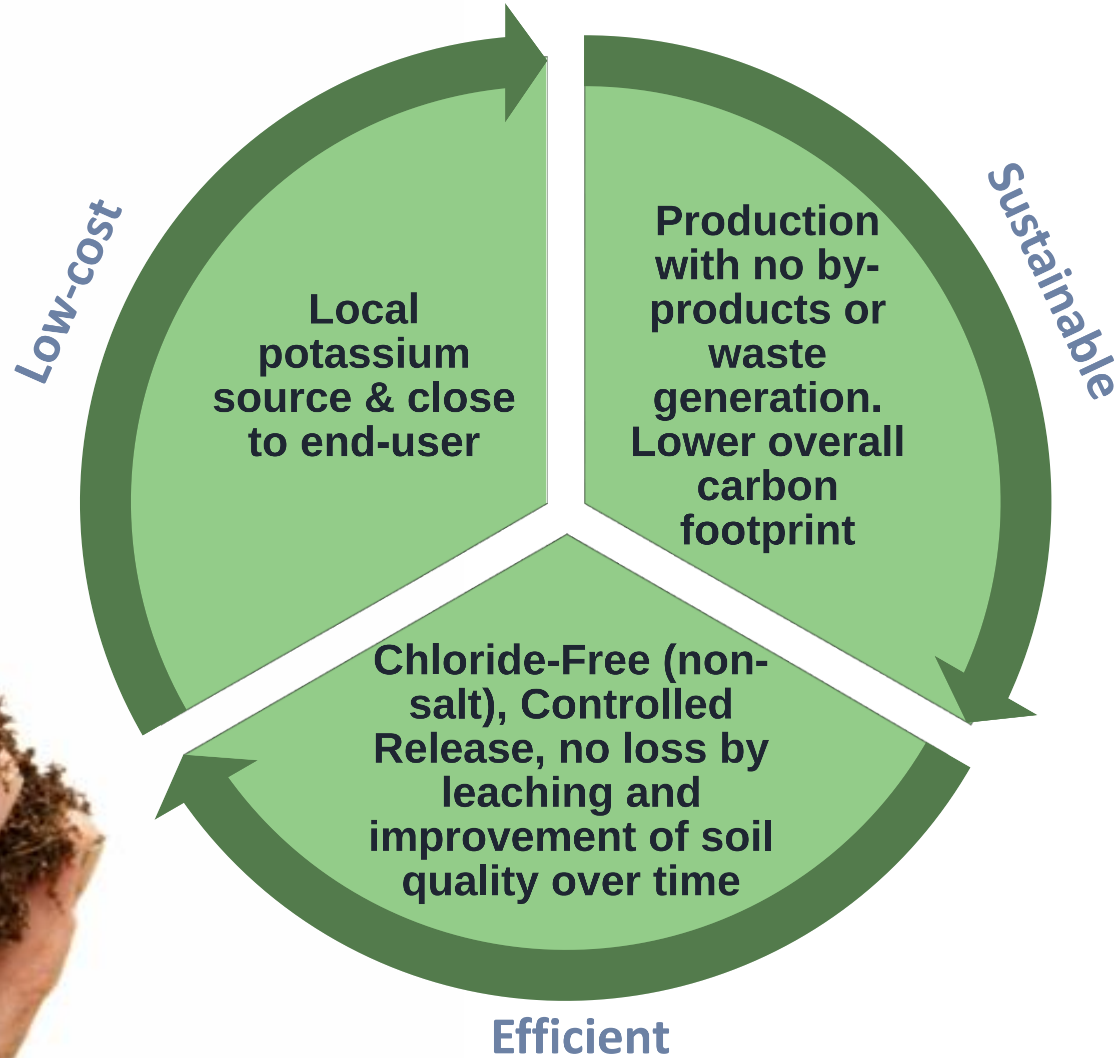
Estimate of Worldwide Potential Potassium Unserved Demand

Source: FAO

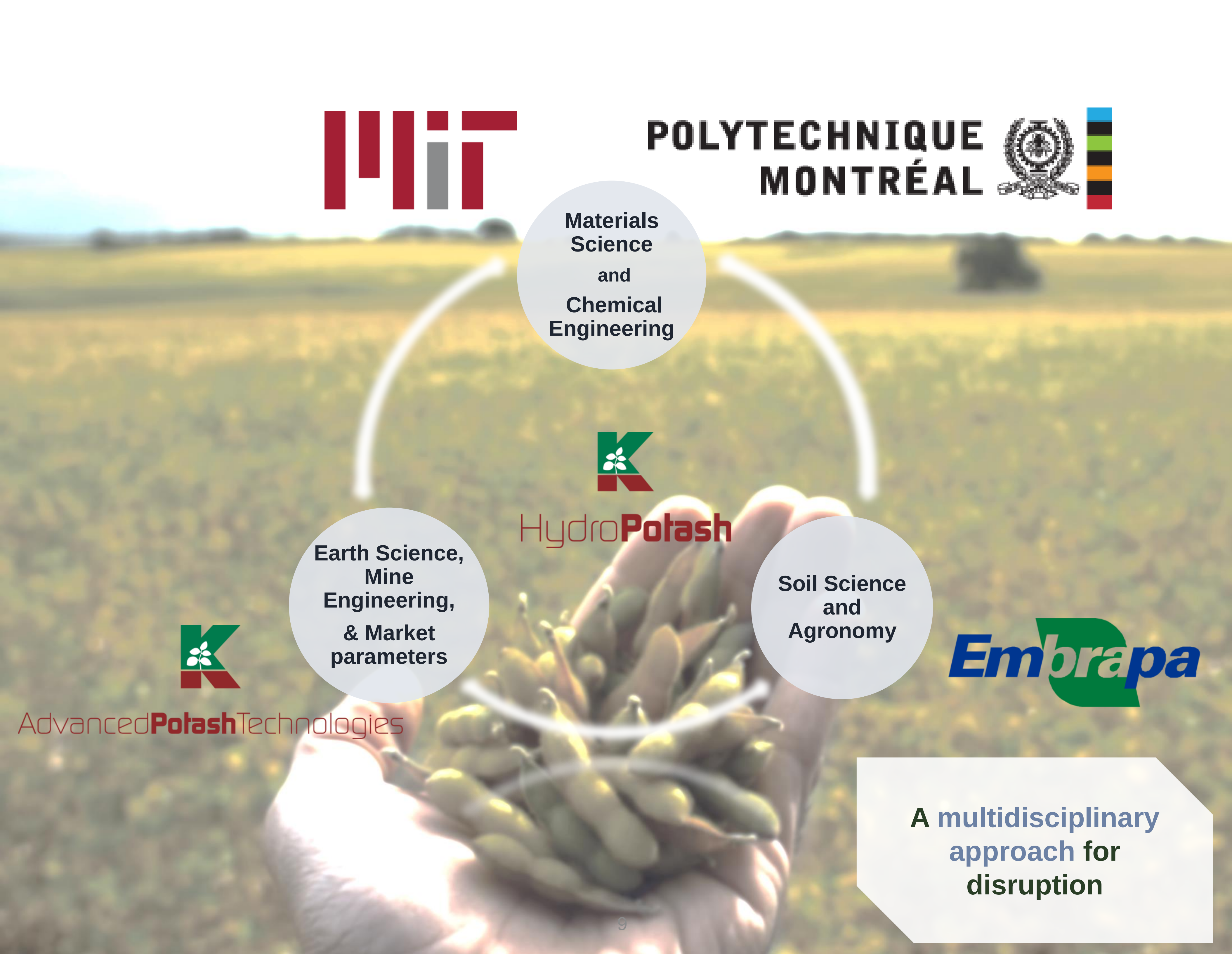
What needs to change and how to reach the World's unserved demand for Potassium?

Unserved potash demand requires new solutions

Demand for a New Potassium Fertilizer



Source: APT

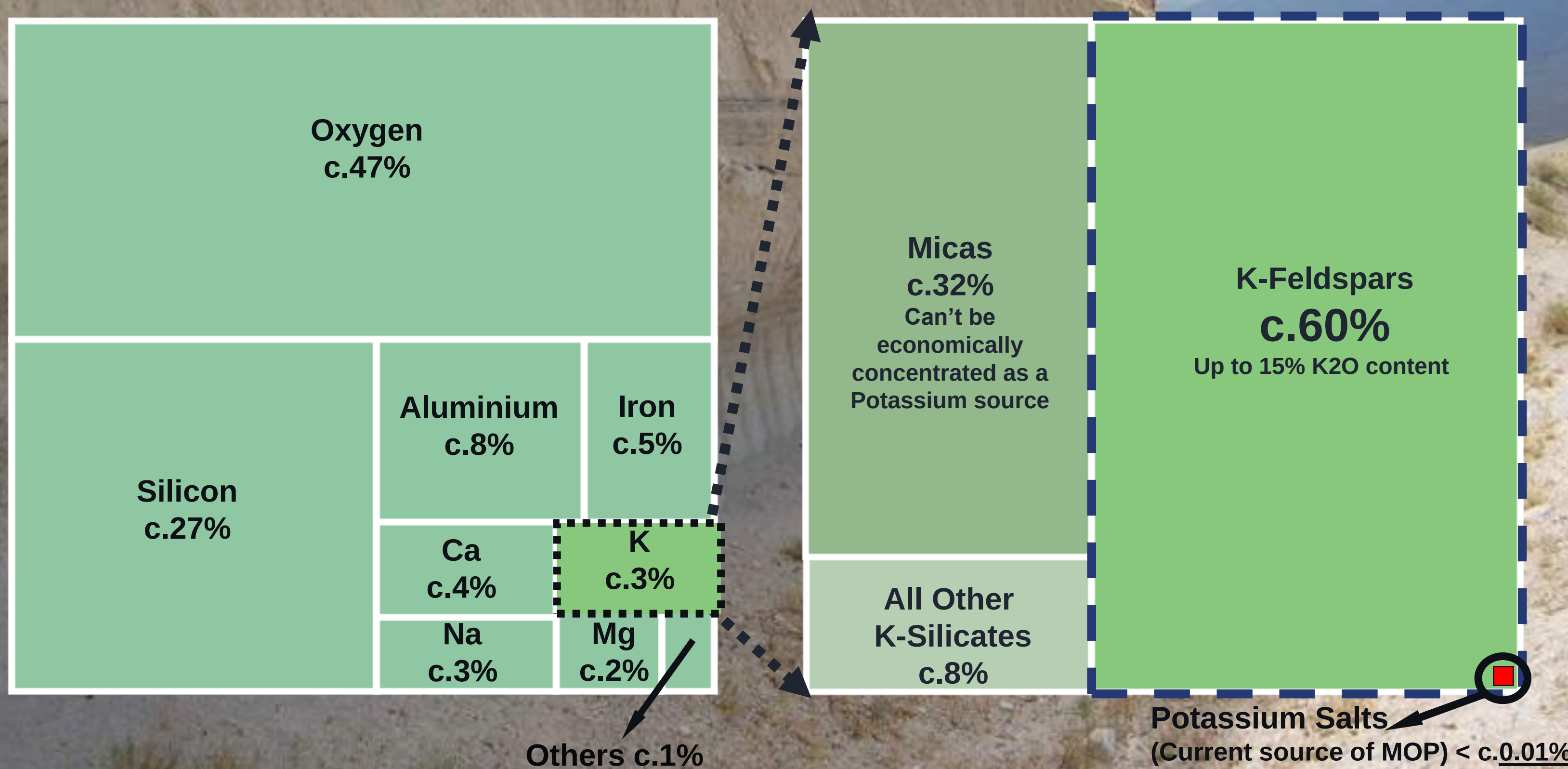


POLYTECHNIQUE MONTRÉAL
Materials Science and Chemical Engineering
HydroPotash
Earth Science, Mine Engineering, & Market parameters
Soil Science and Agronomy
AdvancedPotashTechnologies
Embrapa
A multidisciplinary approach for disruption

A new potassium fertilizer source

K-Feldspar is an abundant and chloride-free silicate mineral

Earth's Crust Mineral Composition | **World's Potassium Distribution in Minerals**

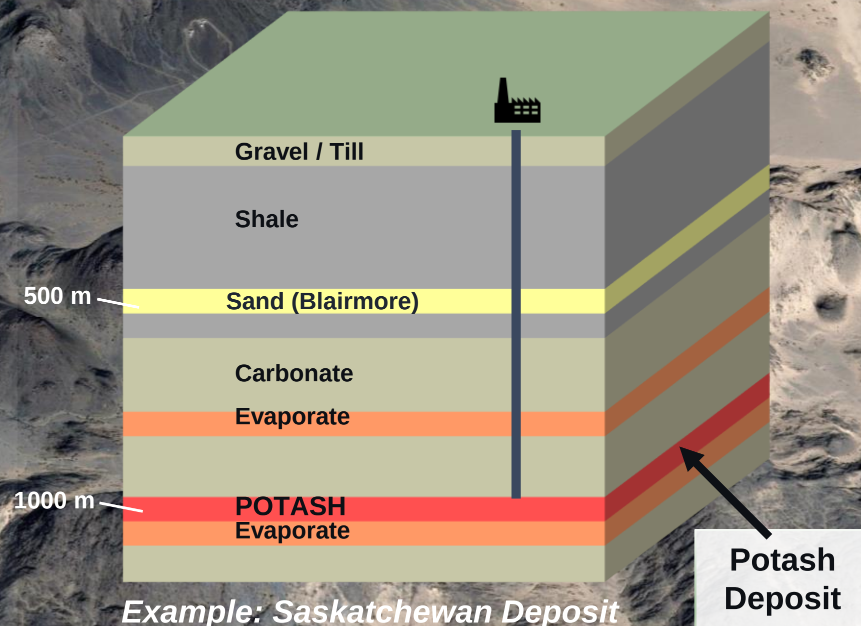


Source: Mason & Moore (1982); Yaroslavsky (1969); Poddervaart (1968), APT Analysis

No need for complex and expensive deep mining operations

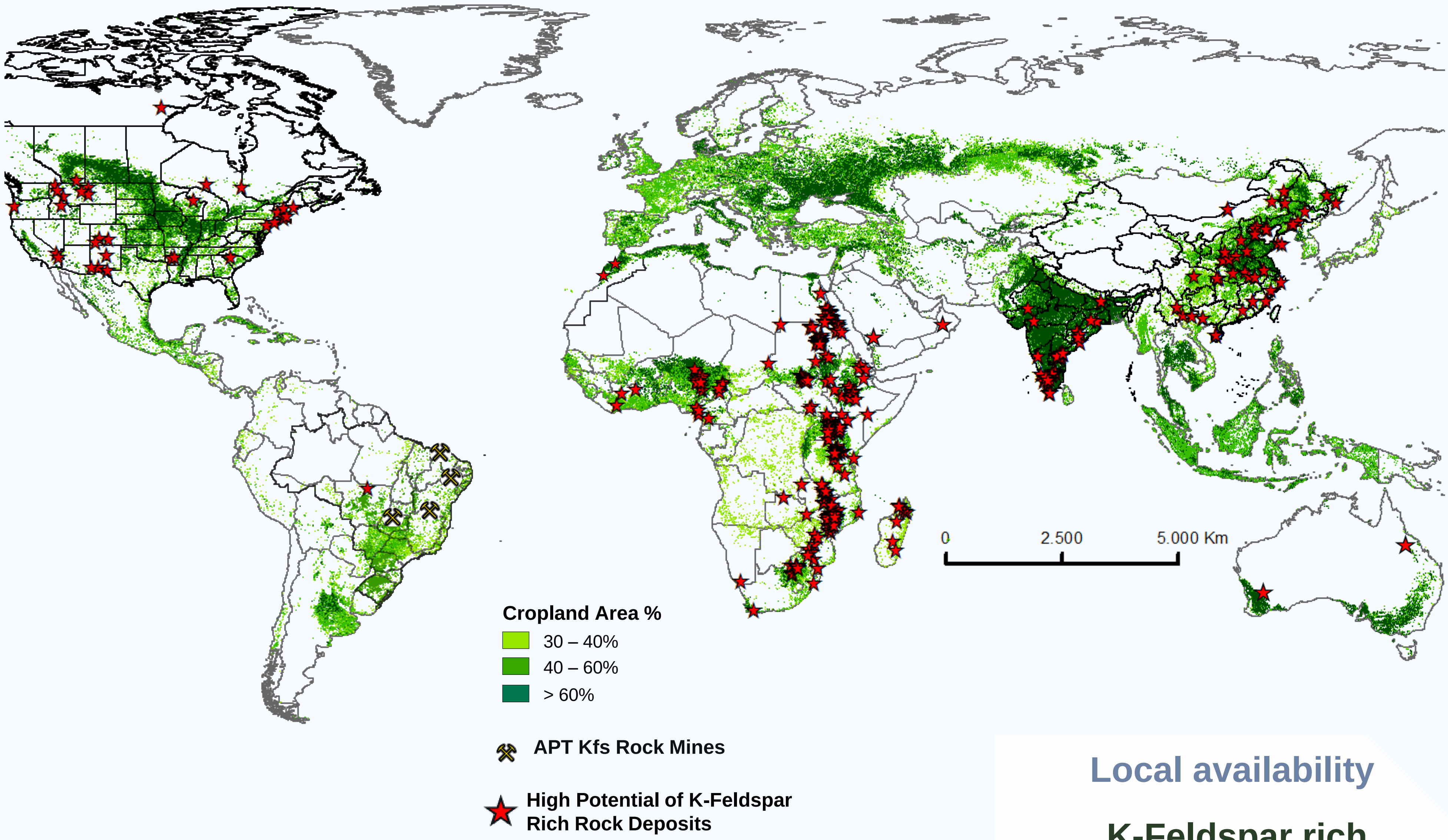
Example of Kfs Deposits – Brazil

Typical Potash Evaporite Deposits



Example: Saskatchewan Deposit

Source: APT, IPNI-International Plant Nutrition Institute (October 2010)

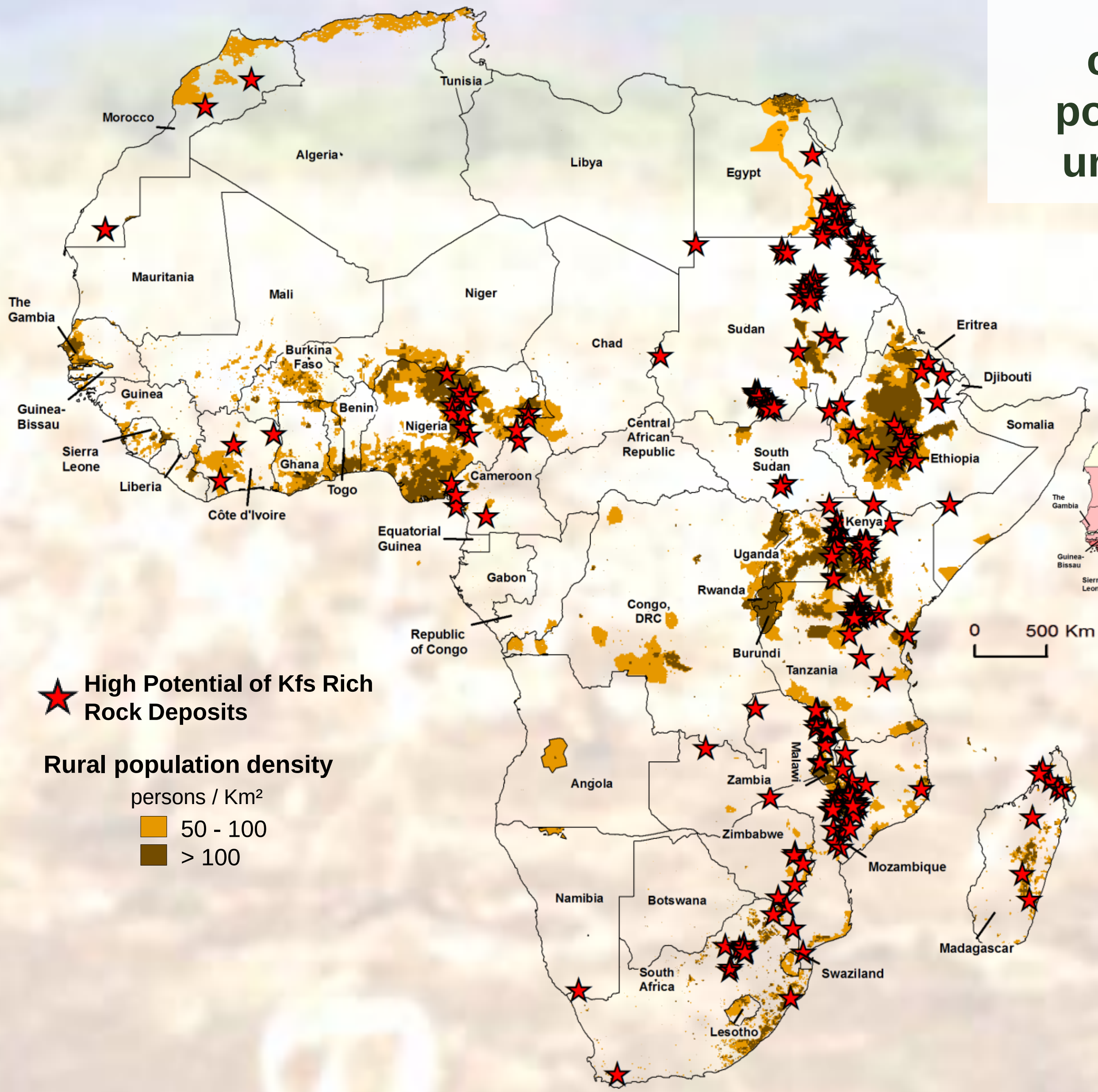


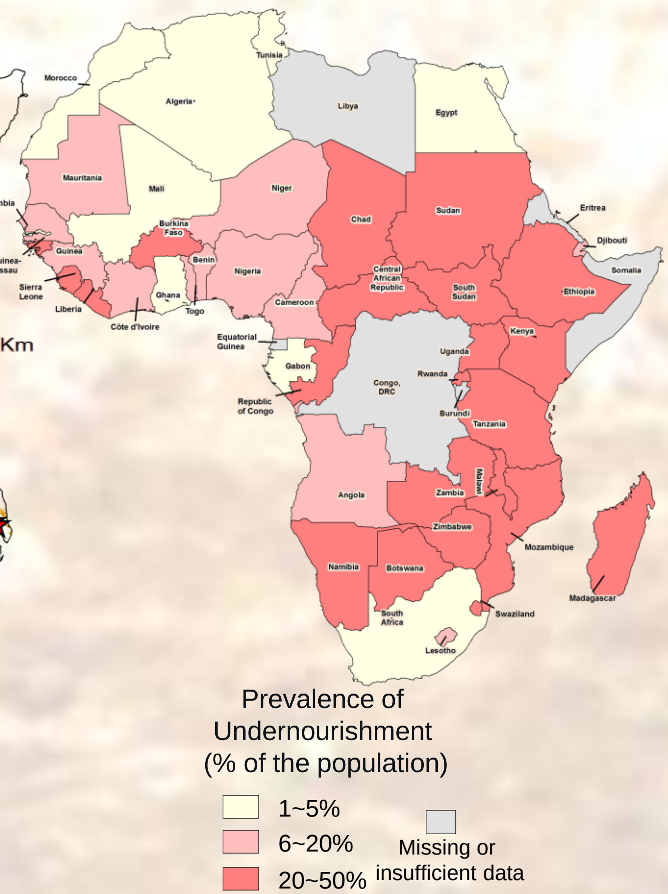
Local availability

K-Feldspar rich deposits can be found all over the world

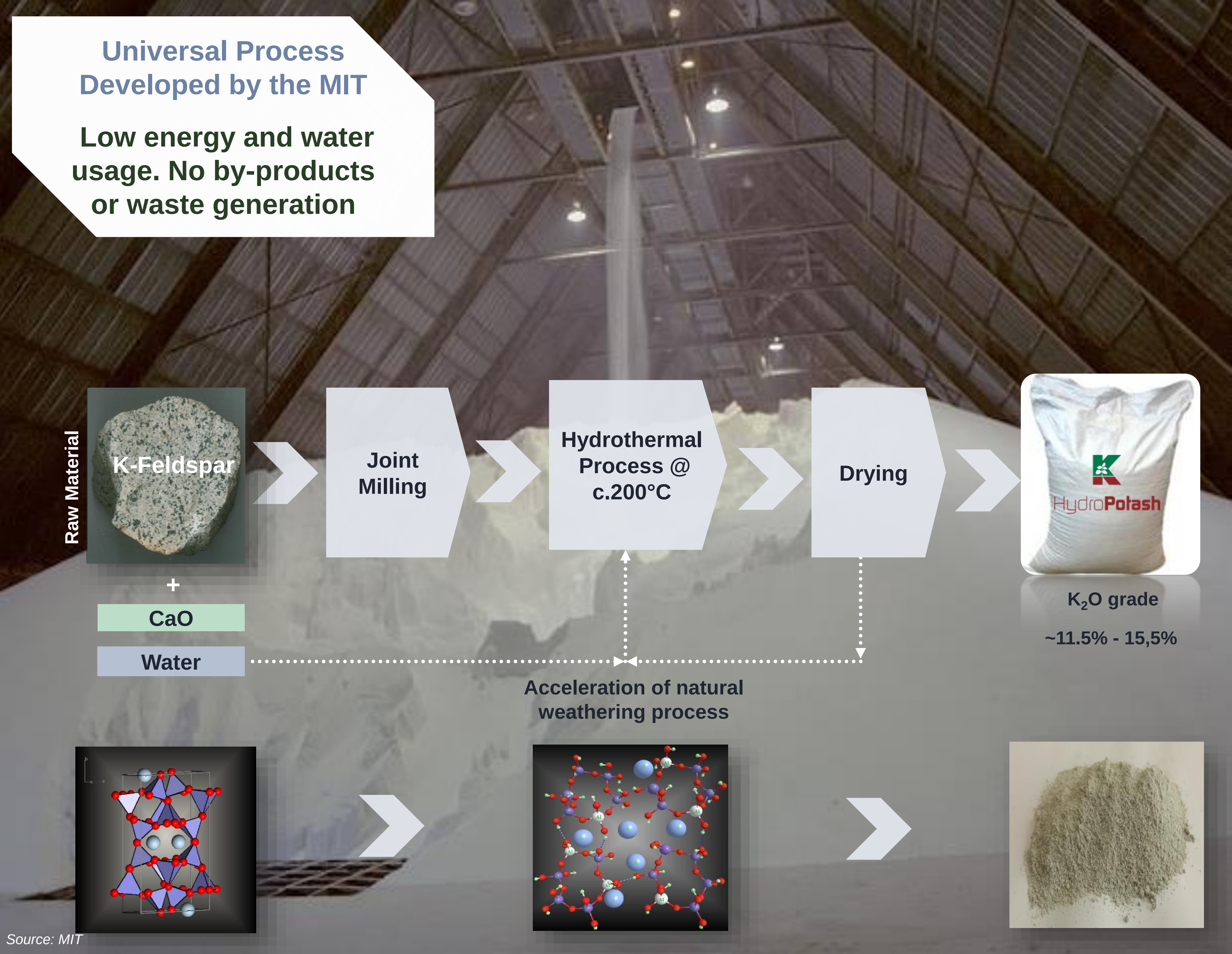
Source: Cropland Area: IIASA-IFPRI (GEOWIKI);
K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data
Research is non-exhaustive. Occurrence of K-feldspars in areas other than those researched so far is highly likely.

African continent: Kfs rich deposits close to areas with highest concentration of rural population and also high undernourishment rates





Source: rural Population: IIASA-IFPRI (GEOWIKI) and HarvestChoice; K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data

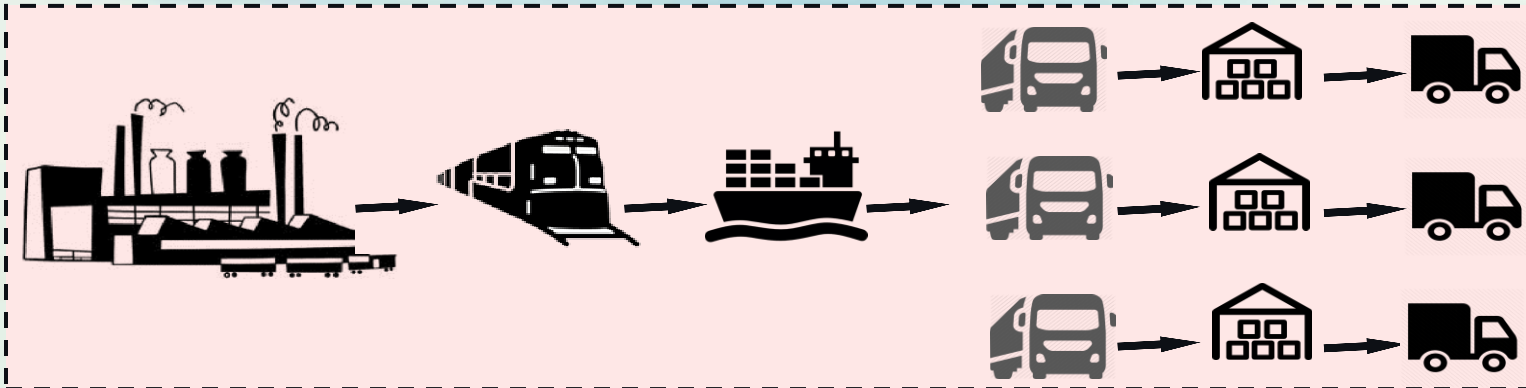

Universal Process
Developed by the MIT
Low energy and water usage. No by-products or waste generation
Raw Material
K-Feldspar
+
CaO
Water
Joint Milling
Hydrothermal Process @ c.200°C
Drying
HydroPotash
K_2O grade
~11.5% - 15,5%
Acceleration of natural weathering process
Source: MIT

Hydropotash: a far better value-proposition for end-users

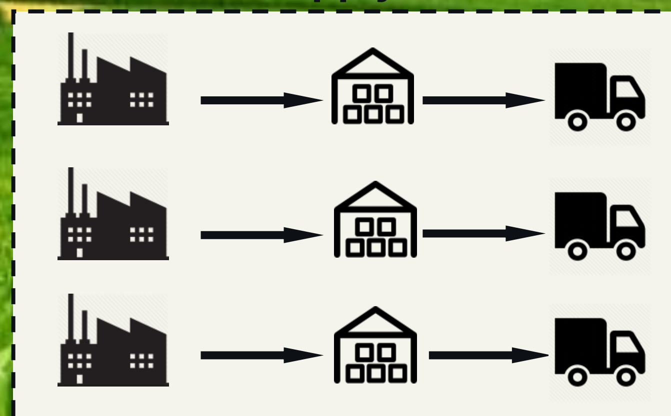
System	Characteristics	MOP	SOP	
Soil	Chloride Free		✓	✓
	High Cation Exchange Capacity			✓
	Ultra Low Salinity Index			✓
	Stimulate Fungi and Bacteria Populations		?	✓
Plant	Controlled Potassium Release			✓
	Balanced Nutrient Uptake			✓
Environment	Locally Produced, No Waste or By Product			✓
	Fit for Organic Farming		✓	✓
	No / Low Leaching and Run-off		✓	✓
Farmer	Improve Soil Quality and Residual Effect for Next Crop			✓
	High Water Retention Capacity			✓
	Best Fit for 4R Nutrient Application[1]			✓
	Can be Tailor-made to Best Suit Requirements			✓
	Higher Crop Yield with Best Value Proposition			✓

Source: Embrapa & APT
1) Right Source, Right Rate, Right Time and Right Place

Current MOP Supply Chain



HYP Supply Chain



Logistic Advantage

Source and production strategically located close to end users

Source: APT

Competitive Capex/ton per K_2O unit, significantly below other projects

	bhpbilliton	K+S	Mosaic	Acron	EuroChem	Uralkali	AdvancedPotashTechnologies		
Mine Location	**CAN**	**CAN**	**CAN**	**RUS**	**RUS**	**RUS**	**BRA**	**BRA**	**BRA**
Mine Name	*Jansen*	*Legacy*	*Esterhazy*	*Talitsky*	*Usolskyi*	*Yayvinksy*	*Brejinho (PI)*	*Serra das Araras (GO)*	*Triunfo (PE)*
Expansion / Tot. Capacity[1]	**10Mtpy**	**2.9Mtpy**	**915ktpy**	**2Mtpy**	**3.7Mtpy**	**2.5Mtpy**	**2Mtpy**	**2Mtpy**	**2Mtpy**
Project Type	*Greenfield*	*Greenfield*	*Expansion*	*Greenfield*	*Greenfield*	*Expansion*	*Greenfield*	*Greenfield*	*Greenfield*
Product Type	MOP	MOP	MOP	MOP	MOP	MOP	HydroPotash	HydroPotash	HydroPotash
% K_2O of Product	60,0%	60,0%	60,0%	60,0%	60,0%	60,0%	15,5%	12,5%	11,5%
Total Capex ($m)[2]	**15.000**	**3.315**	**1.017**	**2.000**	**2.849**	**1.353**	**223**	**225**	**230**
Capex (USD/t)	1.500	1.143	1.111	1.000	770	541	112	113	115
Capex ($/$K_2O$ Unit)	**25**	**19**	**19**	**17**	**13**	**9**	**7**	**9**	**10**

Source: APT

Global opportunity
Extensive geographic footprint through own operations and J&V or licensing

Own Operations

J&V or Licensing Agreements (Africa, India, China & SE Asia)

Source: APT

Risks and mitigating measures **carefully mapped**

Legal and Structuring

Simpson Thacher

MATTOS FILHO

Mattos Filho, Veiga Filho, Marrey Jr e Quiroga Advogados

Technology and Upscaling

POLYTECHNIQUE MONTRÉAL

MIT Massachusetts Institute of Technology

srk consulting

HAZEN

Commercial and Pricing

INFRA PARTNERS

Gestão e Investimentos em Logística

argus

Fertecon

Agribusiness intelligence

Agronomic Performance

Embrapa

Source: APT

Current Status & Next Steps

Current Status

- **Product certification and additional agronomic tests for Brazil**
- **Geological exploration program in the US and Australia**
- **Testing of worldwide Kfs samples at APT / MIT**
- **Headquarters / technical facilities set up in Boston, MA**
- **Industrial processing unit upscaling at École Polytechnique of Montreal**

Next Steps

- **Capital raising for project development**
- **Local partnerships with strategic players**

Source: APT

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info@advancedpotash.com

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Previous Attempts to Produce a Potash Fertilizer from Kfs

- **K-Feldspar** was already **considered promising** as a **Potassium source** for several authors in the **late 19th** and **early 20th century**, with **several patents** being **filed**
- However, none was successful due to **limited knowledge** of **material science** (leading inevitably to costly processes) and lack of incentive due to the discovery of US and Canadian evaporate deposits

Dry Chemistry

- KFS + CaSO4 (or $BaSO_4$ or $SrSO_4$) + $CaCO_3$, **Tilghman (1847)**
- KFS + $Ca_3(PO4)_2$ + $CaCO_3$, **Bicknell (1856)**
- KFS + soda ash (vitrification), **Vanderburgh (1864)**
- KFS + $CaCO_3$(or $Ca(OH)_2$) + CaF_2 + $Ca_3(PO_4)_2$, **Klett (1865)**
- KFS + CaCl2 + CaO**, Blackmore (1894)**
- KFS + NaCl + $CaCO_3$ Rhodin (1900a), **Rhodin (1900b)**
- KFS + $CaSO_4$ + C, **Swayze (1905)**
- KFS + T (then aqueous solution of KOH), **Swayze (1907)**
- KFS + $Ca(OH)_2$ + P, **Gibbs (1909)**
- KFS + CaO + vapor, **Pohl (1910)**
- KFS + T, **Carpenter (1910)**
- KFS + $CaCl_2$ + CaO, **Cushman (1911)**
- KFS + $BaSO_4$ + C, **Hart (1911)**
- KFS + (K) NaCl + (K)$NaHSO_4$, **Thompson (1911)**
- KFS + NaCl (or $CaCl_2$) + $CaSO_4$, **Morse&Sargent (1912)**
- KFS + $Ca_3(PO_4)_2$, **Haff (1912)**
- KFS + K_2SO_4(or $KHSO_4$) + SO_2, **Neil (1912)**
- KFS + (Na)K_2CO_3 + H_2O(g) + P, **Peacock (1912b)**
- KFS + CaO + phosphate rock, **Peacock (1912c)**
- KFS + (Na)K_2CO_3 (or (Na)KOH), **Peacock (1912b)**
- KFS + $CaCO_3$, **Peacock (1912a)**
- KFS + (Na)K_2SO_4 + C, **Hart (1913)**
- KFS + NaCl Bassett, **(1913a)**
- KFS + Na_2SO_4 + Na_2CO_3, **Bassett (1913b)**
- KFS + Ca(Mg)O (or Na(K)$_2CO_3$) + CO_2, **Gellei (1913)**
- KFS + (K) NaCl + (K)$NaHSO_4$ + C , **Bassett (1914a)**
- KFS + NaCl + Na_2CO_3 Bassett, **(1914b)**
- KFS + $CaCO_3$ (cement making), **Spencer (1915)**
- KFS + $CaCl_2$ + $CaCO_3$(or $MgCO_3$), **Brown (1915)**
- KFS + cement mixture + SO_2 (or O_2), **Schmidt (1916)**
- KFS + $CaCO_3$ + acid sludge, **Blumenberg (1918)**
- KFS + $NaNO_3$, **Blumenberg (1919)**
- KFS + NaCl + $Ca(OH)_2$, **Edwards (1919)**
- KFS + (K)Na_2O (see original), **Rody (1919)**
- KFS + $CaCO_3$, **Brenner and Scholes (1920)**
- KFS + CaF_2, **Mckirahan (1921)** KFS + $CaCl_2$(or NaCl) + Fe (or Fe_2O_3), **Glaeser (1921)**
- KFS + C + Cl_2, **Vivian and Fink (1931)**
- KFS + $CaCl_2$ + $MgCl_2$, **Dyson & Grimshaw (1979)**

Wet Chemistry

- KFS + H_2SiF_6 + H_2SO_4, **Gibbs (1904)**
- KFS + HF (electrolysis), **Cushman (1907)**
- KFS + CaF_2 + H_2SO_4 + T, **Foote and Scholes (1912)**
- KFS + HF + $CaSO_4$ + T, **Doremus (1913)**
- KFS + Na(K)OH + T, **Frazer et al. (1916)**
- KFS + (Na)K_2CO_3(or (Na)KOH) +T+P, **Gillen (1917)**
- KFS + borax + (Na)K_2CO_3(or (Na)KOH) + T + P, **Gillen (1917b)**
- KFS + $CaCO_3$ + T + P, **Andrews (1919)**
- KFS + H_3PO_4, **Robertson (1919)**
- KFS + CaO + Water, **Thomas A. Edison (1928)**

Source: Ciceri D., Manning D.A., Allanore A. (2015). Historical and technical developments of potassium resources. Science of The Total Environment, 502, 590-601

Appendix A – Kfs Rich Rocks and Deposits in Selected Countries / Regions

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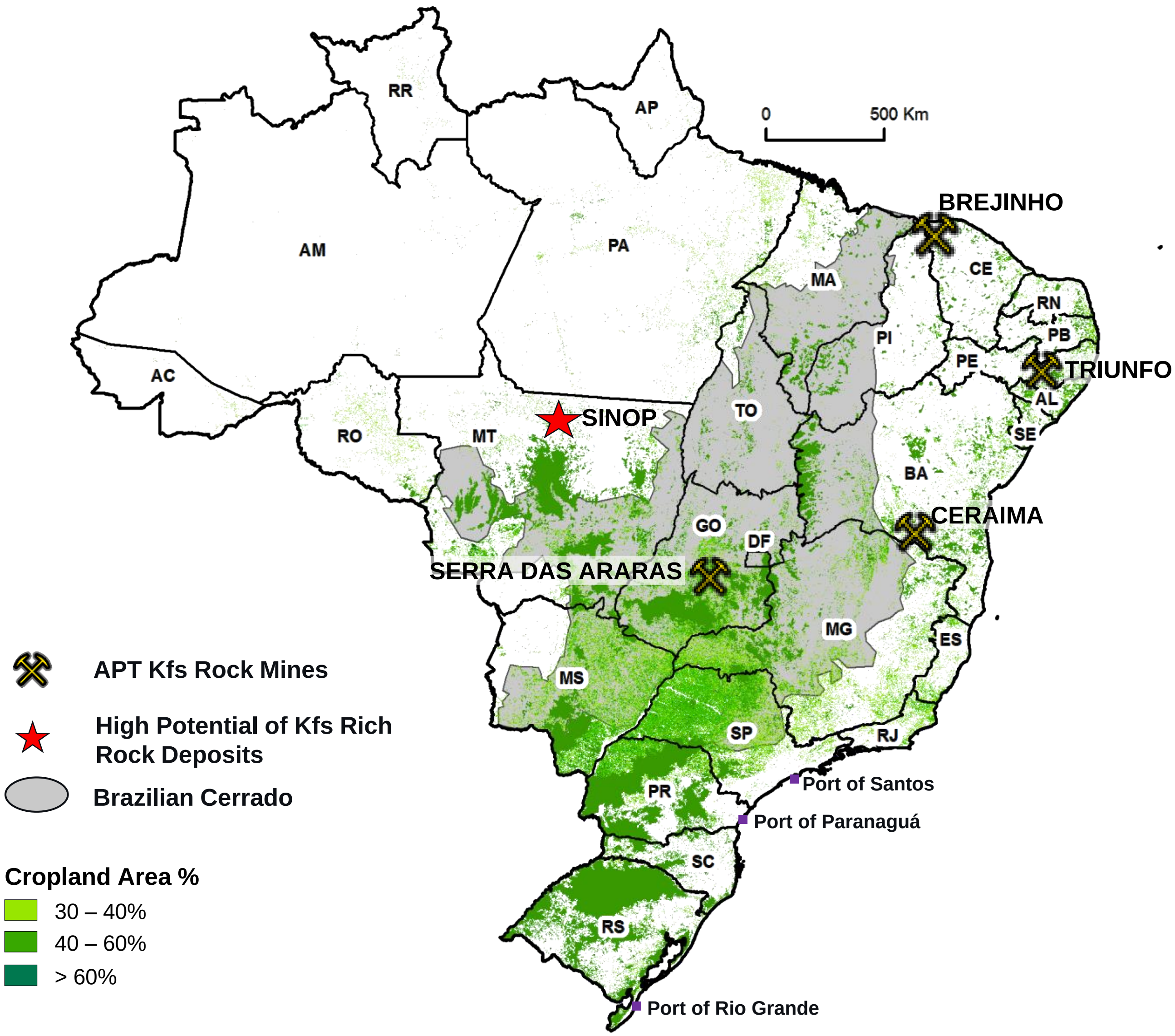
APT K-Feldspar Deposits in Brazil

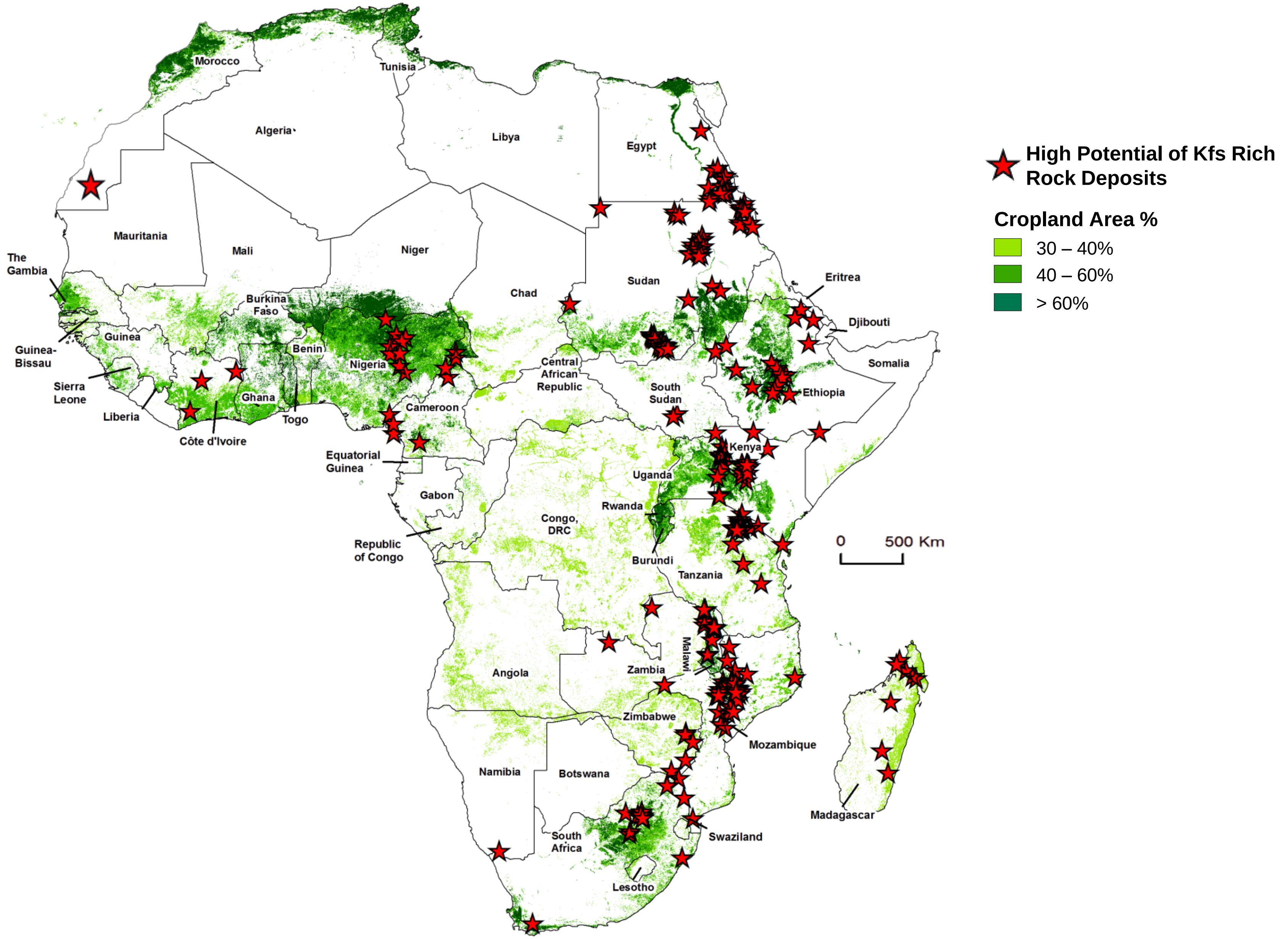


Comments

- APT developed Kfs mines close to all major agricultural areas of the Cerrado region

Source: IBGE 2007 - Census of Agriculture, 2006 collected data; Embrapa 2013 – System for Agriculture Observation and Monitoring (SOMABRASIL), 2011´s Crops; APT Analysis

African Continent – High Potential Kfs Opportunities



Source: Cropland Area: IIASA-IFPRI (GEOWIKI); K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data

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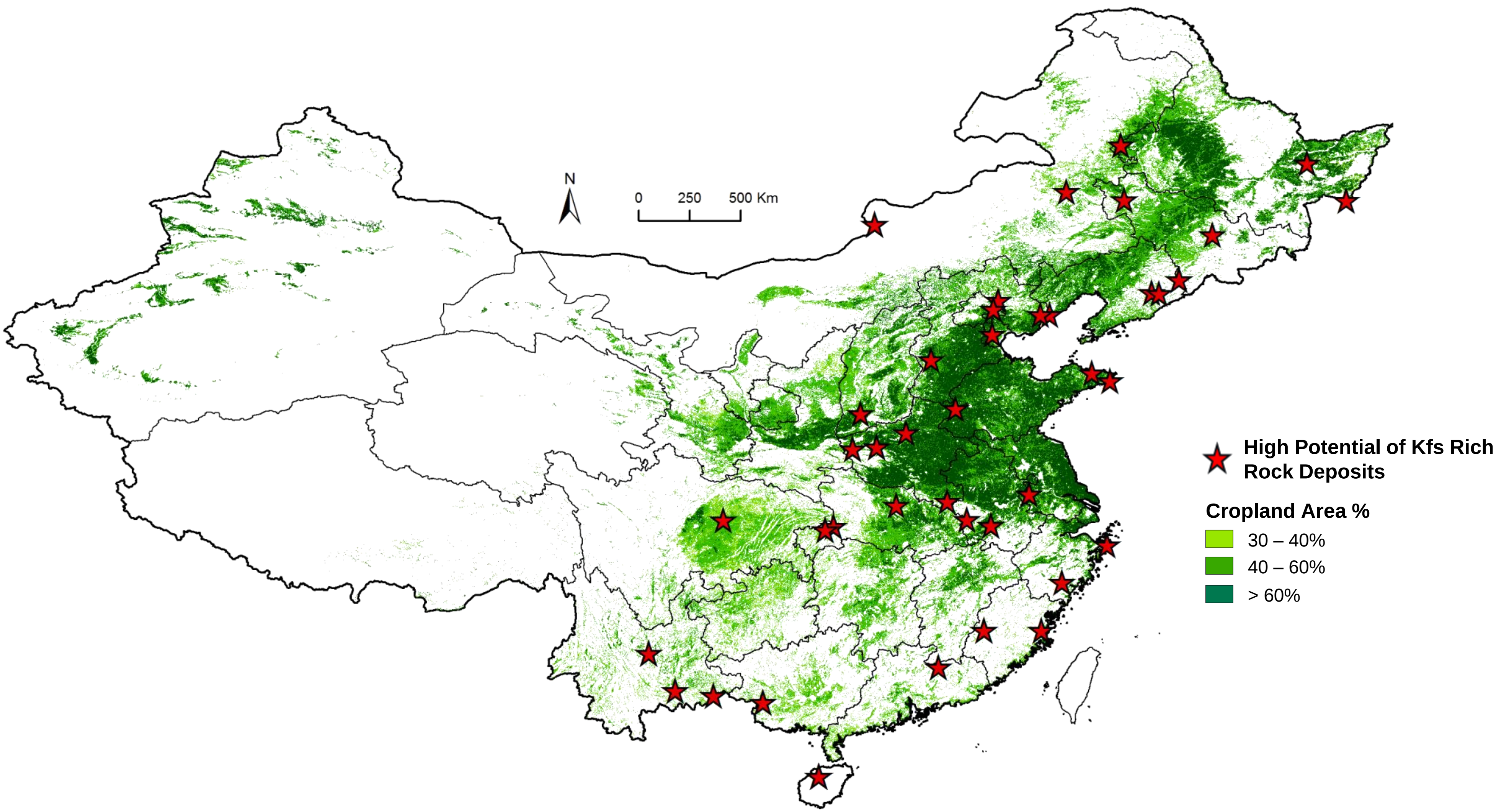
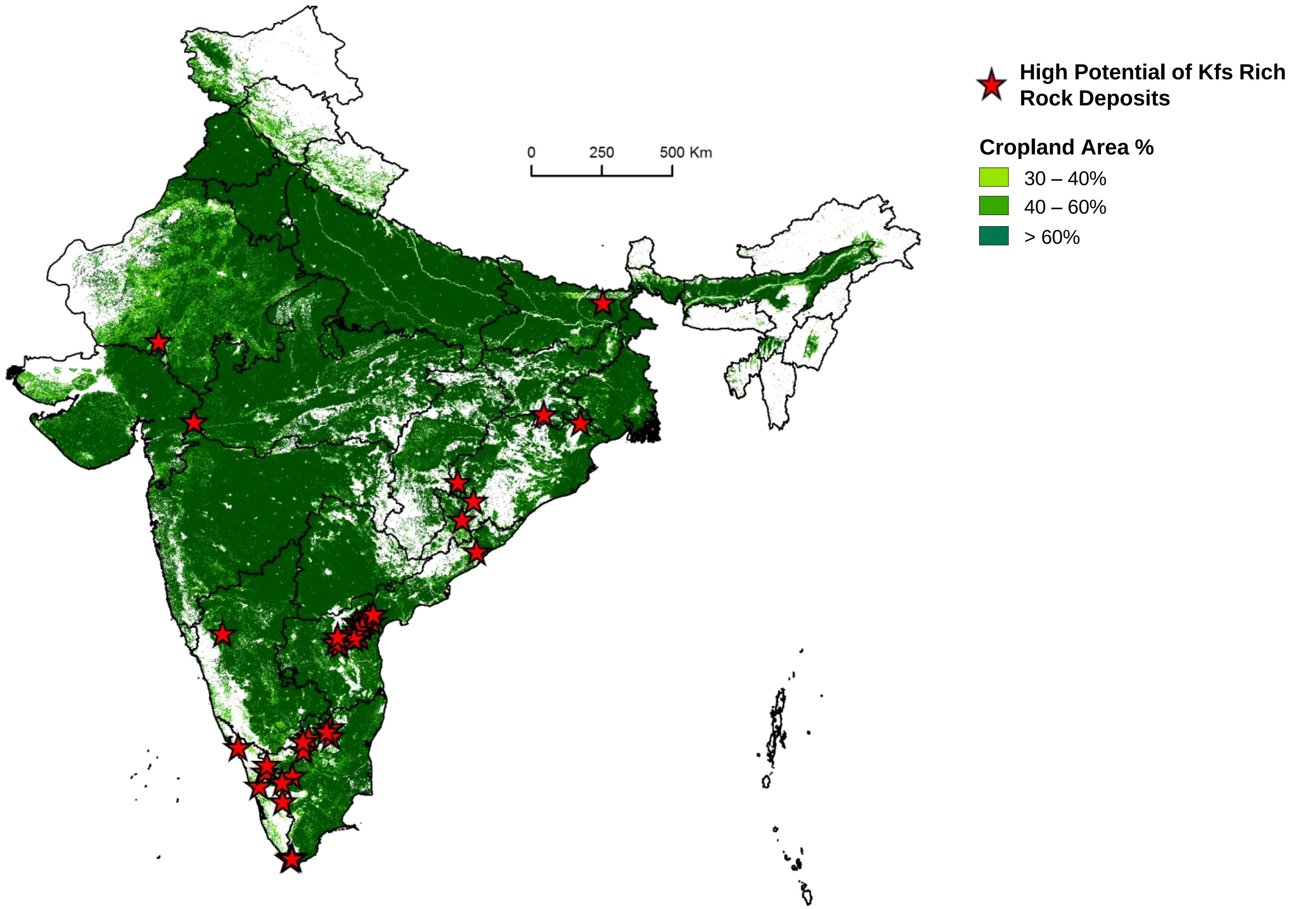
China – High Potential Kfs Opportunities



Source: Cropland Area: IIASA-IFPRI (GEOWIKI); K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data

India – High Potential Kfs Opportunities



Source: Cropland Area: IIASA-IFPRI (GEOWIKI); K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data

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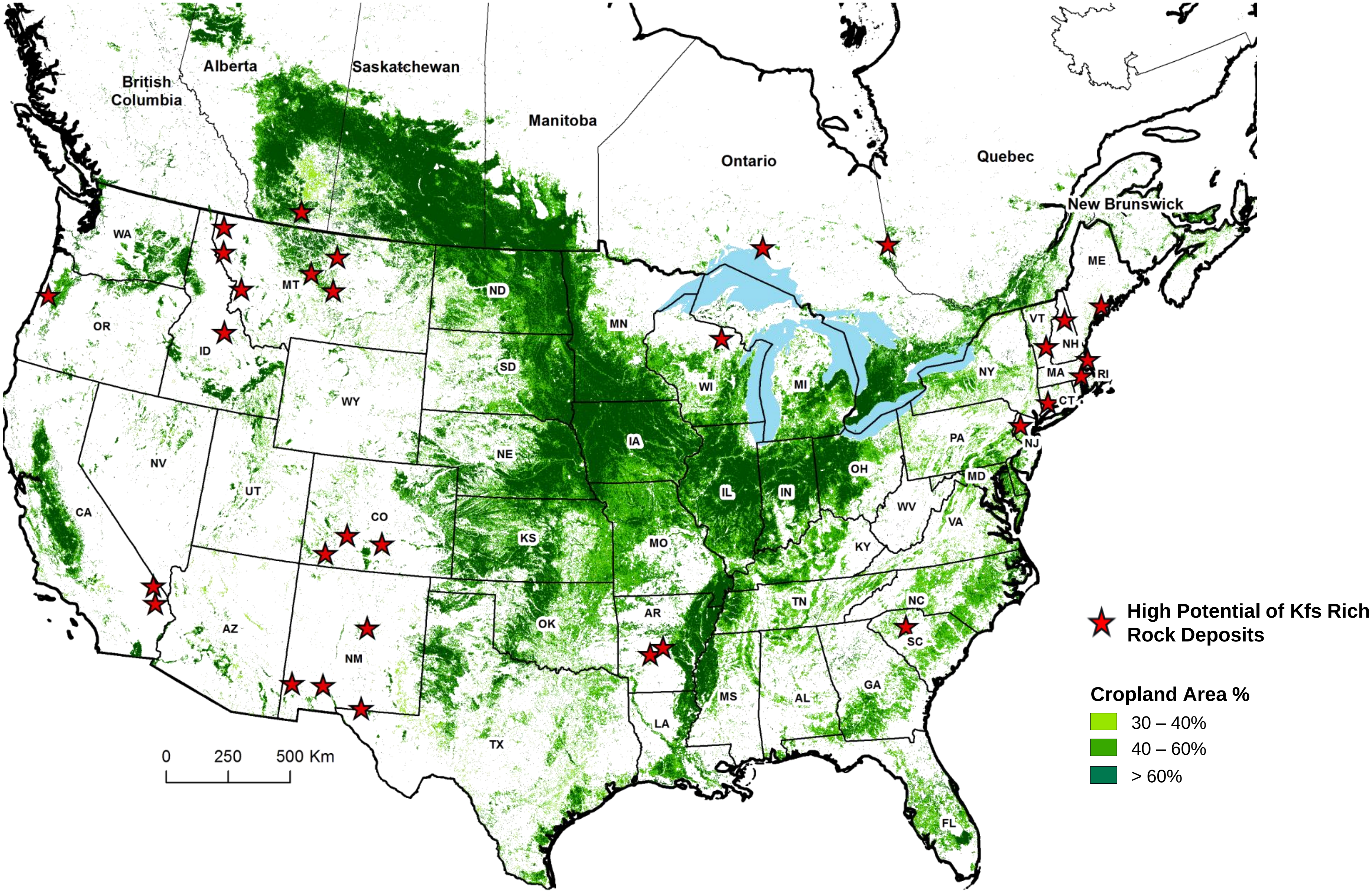
North America – High Potential Kfs Opportunities



Source: Cropland Area: IIASA-IFPRI (GEOWIKI); K-Feldspar Rich Rocks: Location of Kfs rich rock deposits based on general public information and proprietary geological data

Appendix B – Unserved Demand

Drivers of Worldwide Unserved Potassium Fertilizer Demand

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Category	Comment	Estimate of Potential Unserved Demand
Costly & Complex Logistics	▶ Due to high cost to deliver potash fertilizer to the end consumer (production + logistics), most farmers in Africa (but also many in Brazil, India and Southeast Asia) don't have access to a Potassium fertilizer ▶ This cost issue drives the unsustainable nutrient mining practice worldwide ▶ Soil degradation, low productivity and undernourishment are some of the consequences	**c.21mtpy** (Estimate for Africa, India and Brazil Only)[1]
Chloride Sensitive Crops	▶ Unserved demand of Potassium fertilizer for Chloride sensitive crops, as MOP cannot be used due to thigh Chloride content (~48wt%) ▶ Farmers planting Chloride sensitive crops either don't apply any fertilizer at all or have to rely on expensive alternatives which do not contain Chloride (SOP, NOP, etc)[5]	+ **c.2.5mtpy**[2]
Organic Crops	▶ In several countries, MOP cannot be applied on organic crops due to its Chloride content ▶ Organic farmers have to turn to alternative fertilizers, often expensive, difficult access and with low nutrient content	+ **c.2.4mtpy** (based on worldwide organic crops)[3]

=

- **c.26mtpy K_2O / 43mtpy MOP** (c.70% of 2014 global consumption)
- Potential additional market of c.USD10.5bn[4]

Source: FAO

1) Estimated by multiplying Africa's and India's arable land by the difference of 60kg/ha (Brazil's average as per FAO) and the current application of Potassium nutrients in each respective country (in K_2O units). Brazil nutrient mining estimate based on the book "Principle of Plant Nutrition" from K. Mengel and E.A. Kirkby.

2) Assuming 25% of the chloride free non-served demand of 10mtpy identified by Sirius Minerals in Jul-16.

3) Assuming application rate 60kg/ha of Potassium nutrients (in K_2O units) for the current total organic agricultural area of c.40mha (as per FAO 2013).

4) Based on MOP CFR Brazil price of $240/ton as of Jan-17.

5) Sulphate of Potash ("SOP") with 50% K_2O and Nitrate of Potash ("NOP") with 44% K_2O are expensive and therefore only represent c.10% of total potassium nutrients consumed globally.

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Worldwide Non-Served K_2O Fertilizer Demand

Limitations to Apply MOP to Chloride Sensitive Crops

Classification	Crop
Chloride Loving:	Sugar beet, fodder beet, celery, Swiss chard, coconut
Chloride Tolerant:	Cereals, maize, oilseed rape, asparagus, cabbage, beetroot, rhubarb Grassland, clover, oil palm, rubber, rice, groundnut, cassava, soybean, sugar cane, banana, cotton
Partly Chloride Tolerant:	Sunflowers, grape vines, stone fruits, blackcurrants, seed potatoes, potatoes for human consumption, tomatoes, radish, kohlrabi, peas, spinach, carrots, leek, horse-radish, chicory, pineapple, cucumber, kiwifruit, coffee, tea
Chloride Sensitive:	Starch potatoes, potatoes for processing, tobacco, redcurrants, gooseberry, raspberry, strawberry, blackberry, blueberry, mango, citrus, pepper, chilli, avocado, cashew, almond, peach, cocoa, hops, pomes and stone fruits (especially cherries), bush beans, broad beans, cucumber, melon, onion, lettuce, early vegetables, all crops under glass, conifers, flowers and ornaments as well as seedlings and transplants of most plants

Source: K+S GmbH (http://www.kali-gmbh.com/uken/fertiliser/advisory_service/chloride_tolerance.html)

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Appendix C – Overview Embrapa Testing Program

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HydroPotash Testing Program at Embrapa

Greenhouse Tests Demonstrate HydroPotash's Superior Efficiency as a Potash Fertilizer

- **Embrapa** carried out **greenhouse pot test** programs to verify efficiency of different potassium sources on maize and soybean crops. Additional test programs are underway
- Despite using the HydroPotash's first generation product, **performance** is already **significantly higher than MOP**
- Tests demonstrated substantial performance increase when comparing hydrothermally-treated Kfs with untreated Kfs rocks

Applied Fertilizer	Underwent HydroPotash Production Process?	Average Aerial Mass (g)	Efficiency[1] %	Conclusion
HydroPotash (Serra das Araras, GO)	✓	**4.0**	**154**	**Highly Efficient**
HydroPotash (Triunfo, PE)	✓	**3.2**	**122**	
Muriate of Potash (MOP)	n.m.	2.6	100	Efficient
Kfs Rich Rock (Raw material for HydroPotash GO)	✗	2.1	79	Low Efficiency
Kfs Rich Rock (Raw Material for HydroPotash PE)	✗	1.9	71	Inefficient
Control (No fertilizer added)	n.m.	1.9	71	

Source: Embrapa
Memo: Tests comparing different products were carried out by applying the same equivalent amount of Potassium nutrient (measured in K_2O Units)
Memo 2: Efficiency measured by comparing the average aerial mass of the plants treated with different nutrient sources (e.g., efficiency of 154% means that the aerial mass of the plant is 54% higher than the aerial mass of the plant treated with MOP)
1) Potassium Chloride (MOP) taken as base for efficiency calculation (i.e., 100% efficient).

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HydroPotash – Key Benefits (1/2)

Agronomic:

- **Controlled Potassium Release:** Releases nutrients over time, allowing a balanced uptake
- **No Harmful Components:** Contains no components that harm crop growth, such as Chlorine (contained in MOP)
- **Provides Other Essential Nutrients to Plants:** Releases other beneficial nutrients such as $Si(OH)_4$, important for robust growth, higher resistance of plants to fungal disease and improved phosphorus uptake
- **High Water Retention Capacity:** Beneficial to overcome longer drought periods
- **High Cation Exchange Capacity:** Increases the ability to save cationic nutrients for use on demand by plant roots

Soil and Environment:

- **Low Salinity Index:** Salinity index <10, the lowest amongst major available potassium fertilizers
- **Lowers Soil Acidity:** Allows partial reduction of liming
- **Stimulates Fungi and Bacteria Populations of the Soil:** Healthier soil
- **Recovery of Degraded Soil and Improvement of Soil Fertility Over Time:** Once decomposed, HydroPotash forms clays and other minerals, improving soil cation exchange capacity (CEC) and soil quality over time. These processes increase the negative surface of the soil and improve the use of cationic nutrients
- **Overall Lower Carbon Footprint per Unit K_2O Delivered to Farmer:** Low energy requirements in the production and lowest logistic requirements due to proximity to farmer

Source: Embrapa, MIT & APT

HydroPotash – Key Benefits (2/2)

For Society:

- **Sovereign State Independence:** Opportunity for many countries to not dependent on Potash fertilizer imports

- **Local Community Development:** HydroPotash plants will be implemented close to agricultural regions, creating jobs and further developing local communities

- **Organic Farming:** Organic crops will have a scalable potassium source to enhance their yields

- **Chloride Sensitive Crops:** Crops that are sensitive to Chloride will have a scalable potassium source to enhance their yields

Economic:

- **Production Close to Agricultural Area & Independence from Crippling Infrastructure**: Costs of long-haul are completely eliminated
- **Low Capex:** Much lower capital expenditure for production plant per unit of contained K_2O when compared to the conventional Potash fertilizer projects
- **Low Opex:** Open pit mining operation, low energy & water consumption and no generation of waste or by-products result in an overall lower OPEX at plant gate
- **No Losses from Leaching**: No K^+ is lost by leaching during heavy rains, allowing for lower application rates / less applications over the crop growth cycle
- **Residual Effect of HydroPotash:** Residual effect allows the soil/crops to benefit from a single HydroPotash application for more than one growing cycle or higher one-time application for multiple cycles
- **Increase of Soil Fertility with HydroPotash Use Over Time:** Cumulative application of HydroPotash contribute to recovery of degraded soil and higher response rate to fertilizer use, decreasing farmer's costs

Source: Embrapa, MIT & APT

HydroPotash Testing Program

- Several tests have been performed at Embrapa so far, from lab to pot tests with excellent results

Step 1

- **Extraction Solution Tests**
- **pH Test**
- **Salinity Test**
- **Cationic Exchange Capacity (CEC) Test**
- **Conductivity Test**
- **Water Retention Capacity**
- **Leaching Column Tests**
- **Bio-weathering Tests**

Step 2

- **Pot Tests in Greenhouses(2014, 2015, 2016)**
- **Larger Scale Field Experiments (In 2017/2018)**

Step 1 Characterization Tests

Step 2 Maize Pot Experiments in Greenhouse

Step 2 Soy Pot Experiments in Greenhouse

Source: Embrapa, MIT and APT

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