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WORLD
ECONOMIC
FORUM

Space Applications in Agriculture:
Enhancing Food and Water Security, Improving Climate Action

APRIL 2023

Contents

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Introduction

Impact of space-enabled applications in agriculture

The value of space technologies in agriculture is becoming more widely recognized, and will gain greater acceptance in the near future. Adoption of space applications has been historically limited by high costs, low resolutions and limited consumer trust. These barriers are coming down, and applied at full scale, insights from space could address up to 30% of the food gap projected for 2050 by reducing waste, decreasing global freshwater use by 5-10%, lowering agricultural CO_2 emissions by up to 50 million tonnes, and shrinking grower costs by 5%.

These societal benefits will come hand-in-hand with economic returns: food waste reduction could contribute an additional $150-175 billion in economic value for producers,[1] and a 5% cost reduction for growers represents $7-8 billion from input savings alone.[2] With such value at stake, the market for space-borne insights in agriculture is projected to nearly double by 2030, reaching almost $1 billion.

Examples of satellite technology driving value for agriculture are already visible. Growers today are using aerial and satellite insights to reduce herbicide, fertilizer and water use, and governments are employing satellites to address food security, verify conditional subsidies and reduce food waste. Yet, technical and human-driven hurdles remain. Scaling will require cross-industry collaboration, training algorithms with sufficient ground-truth data, and a clearly defined value proposition for end-users with trusted, actionable insights. Put most simply, the industry still needs to bring together the right data to develop the right insights at the right time for the right people.

Will adoption accelerate, or will the hurdles persist? Informed by industry research and conversations with stakeholders across the agriculture and space industries, this report examines this question.

FIGURE 1

Satellite applications' potential to address challenges in agriculture

What's at stake?

Insights from satellite imagery can improve the food system and contribute to solutions for…

Select the tabs to discover more

Food insecurity | **Climate action** | **Water availability**

4.2bn

Tonnes of crops produced worldwide each year[1]

2.1bn

Additional production needed by 2050[2]

$0.4bn

Potential crop loss prevented via satellite identification of pests[3]

Global annual crop production for human consumption is estimated at 4.2 billion tonnes, and must increase by a minimum of 50%, or 2.1 billion tonnes, to meet projected 2050 food demand. Identification of early-stage pests, weeds and diseases via hyperspectral and optical imagery shows an ability to prevent crop loss, which today is between 20% and 40% of total production. If applied at scale, up to 0.8 billion tonnes of crops could be salvaged annually.

Notes:

1. Excluding animal protein. Source: FAO 2020.
2. M. van Dijk, T. Morley, M.L. Rau et al., "A meta-analysis of projected global food demand and population at risk of hunger for the period 2010-2050", *Nature Food*, https://www.nature.com/articles/s43016-021-00322-9.
3. Pests include weeds, animal pests and disease pathogens; E. Oerke, "Crop losses to pests", *The Journal of Agricultural Science*, Vol. 1, No. 44(1), pp. 31-43 (2006); C. Yang, G. Odvody, J. Thomasson, et al., "Site-specific management of cotton root rot using airborne and high-resolution satellite imagery and variable-rate technology", *Transactions of the ASABE*, https://elibrary.asabe.org/abstract.asp?aid=48999.

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What’s at stake?

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Food insecurity

Climate action

Water availability

3.8bn

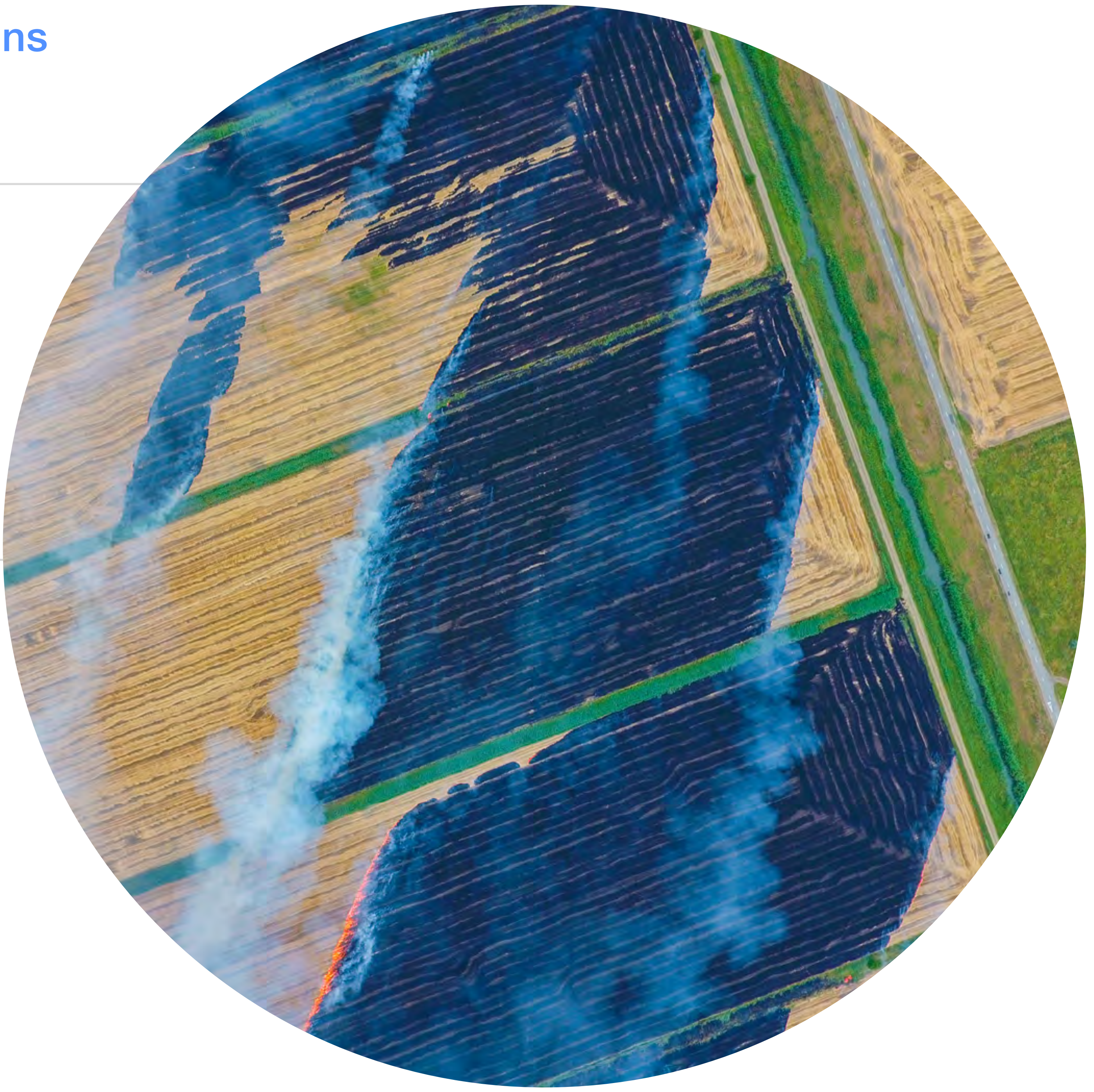
Tonnes of CO_2-equivalent emissions from croplands each year[4]

1bn

Emissions attributable to agriculture inputs[5]

0.5bn

Potential decrease in emissions when insights inform input application



Agriculture emits 1 billion tonnes of greenhouse gases from fertilizer and pesticide inputs annually. Imagery insights have shown that inputs needed can be cut by 4-6% overall, representing a reduction of up to 0.5 billion tonnes if applied at scale.

Notes:

4. Includes crop residues, rice cultivation and burning, manure applied to soils, synthetic fertilizers, drained organic soils and fertilizer manufacturing. Source: FAO.
5. Includes emissions from fertilizers and pesticides; herbicides excluded as eliminating weeds decreases emissions from decomposition.

FIGURE 1

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What's at stake?

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Food insecurity

Climate action

Water availability

40bn

Litres of freshwater withdrawn annually[6]

28bn

Freshwater withdrawals used for agriculture[7]

2.8bn

Reduction in freshwater use from satellite-informed irrigation improvements[8]

28 billion litres of freshwater are withdrawn for agricultural use annually, representing 70% of global use. Satellite-enabled analysis of soil moisture content shows that agricultural water usage can be cut by 5-10% through more efficient irrigation practices, saving 2.8 billion litres of freshwater per year if applied at scale.

Notes:

6. Source: World Bank.
7. Ibid.
8. World Bank, https://blogs.worldbank.org/digital-development/sky-not-limit-satellites-support-smallholder-farming-part-2.

1

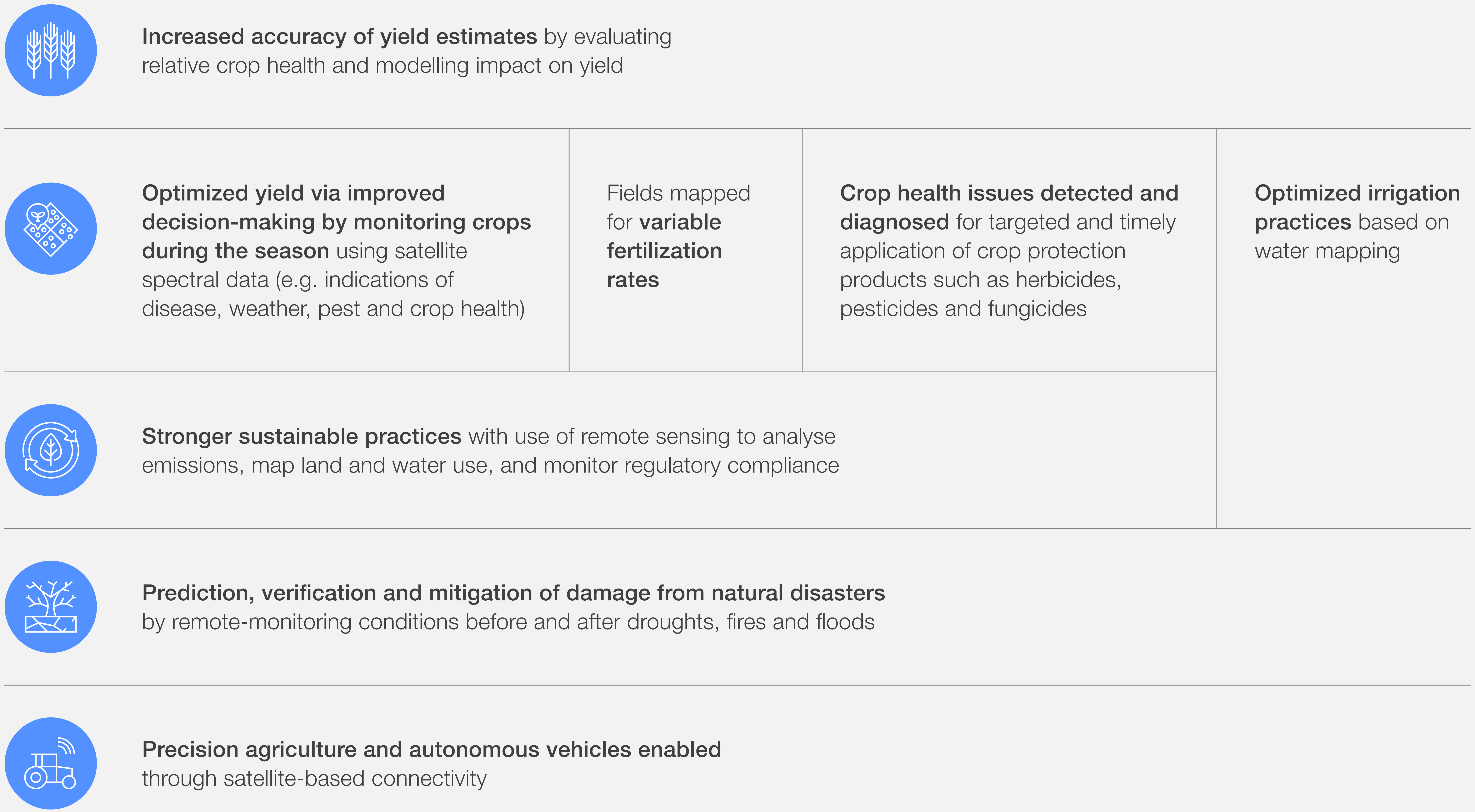
Satellite technology has multiple applications in agriculture

Space-based remote sensors collect and facilitate the exchange of a multitude of data, including weather information and imagery from visible, infrared, thermal and microwave domains, which have significant applications in agriculture. Advanced analytical methods that layer, manipulate and read satellite-collected data are providing value to stakeholders across the agriculture value chain today. Advancements in technology are rapidly expanding the satellite sector's ability to monitor and measure events and to exchange information.

These improving technologies, coupled with growing supply, will boost adoption over the next decade across five use cases (Figure 2) to generate both economic and societal value: (1) increasing the accuracy of yield estimates, (2) optimizing yield via improved decision-making, (3) bolstering sustainable practices, (4) mitigating damage from natural disasters, and (5) enabling precision agriculture.

FIGURE 2

Core use cases of space-enabled applications for agriculture



Value propositions:

Increased accuracy of yield estimates by evaluating relative crop health and modelling impact on yield

Optimized yield via improved decision-making by monitoring crops during the season using satellite spectral data (e.g. indications of disease, weather, pest and crop health)

Fields mapped for **variable fertilization rates**

Crop health issues detected and diagnosed for targeted and timely application of crop protection products such as herbicides, pesticides and fungicides

Optimized irrigation practices based on water mapping

Stronger sustainable practices with use of remote sensing to analyse emissions, map land and water use, and monitor regulatory compliance

Prediction, verification and mitigation of damage from natural disasters by remote-monitoring conditions before and after droughts, fires and floods

Precision agriculture and autonomous vehicles enabled through satellite-based connectivity

Historically, the most common use of satellite data in agriculture is for **yield estimation** – which uses satellite data and analytics to generate accurate and regionally specific estimates of expected crop production, by crop type. These insights have significant value for governments, non-governmental organizations (NGOs) and crop traders, and can be used to improve livelihoods country-wide and at larger scales. Governments and NGOs are applying yield estimation techniques to quantify and act on food demand gaps (Figure 3) and measure the impact of geopolitical crises on food yield, while crop traders and other stakeholders use the data to better predict crop prices or to align logistics in harvest areas.

In the next decade, yield estimation activities will expand in emerging markets, where advancements in technology could allow estimates even in multi-crop environments. Such improvements are demonstrating an impact already, enabling initiatives such as the "food balance sheet" of the Common Market for East and Southern Africa (COMESA) to update forecasts five times more frequently, thereby improving the utilization of foodstuff and reducing waste by up to 20%.

Select the tabs
to discover more

FIGURE 3

Tracking regional food balance sheets with digital, space-enabled tools in East and Southern Africa

Digital solutions for food security › **The need for satellite-driven insights** › **Enhanced food security and other practical outcomes**

In sub-Saharan Africa, food insecurity affects 123 million people.

In the past, national governments in food insecure regions **struggled to predict** total food availability, including expected production, stocks and trade of staple crops – a **"food balance sheet"** – with manual data compilation often resulting in **delayed or incomplete insights**.

Poor data quality resulted in ad hoc decision-making, hurting farmers, processors and consumers.

The Common Market for East and Southern Africa (COMESA) and the Alliance for a Green Revolution in Africa (AGRA), a farmer-led organization that seeks to transform African agriculture from a subsistence model to a strong industry, co-led the development of a digital food balance sheet for the region. The aim is to provide the common data and analytical infrastructure required to predict near real-time food production, stock levels and other relevant information.

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Digital solutions for food security

The need for satellite-driven insights

Enhanced food security and other practical outcomes

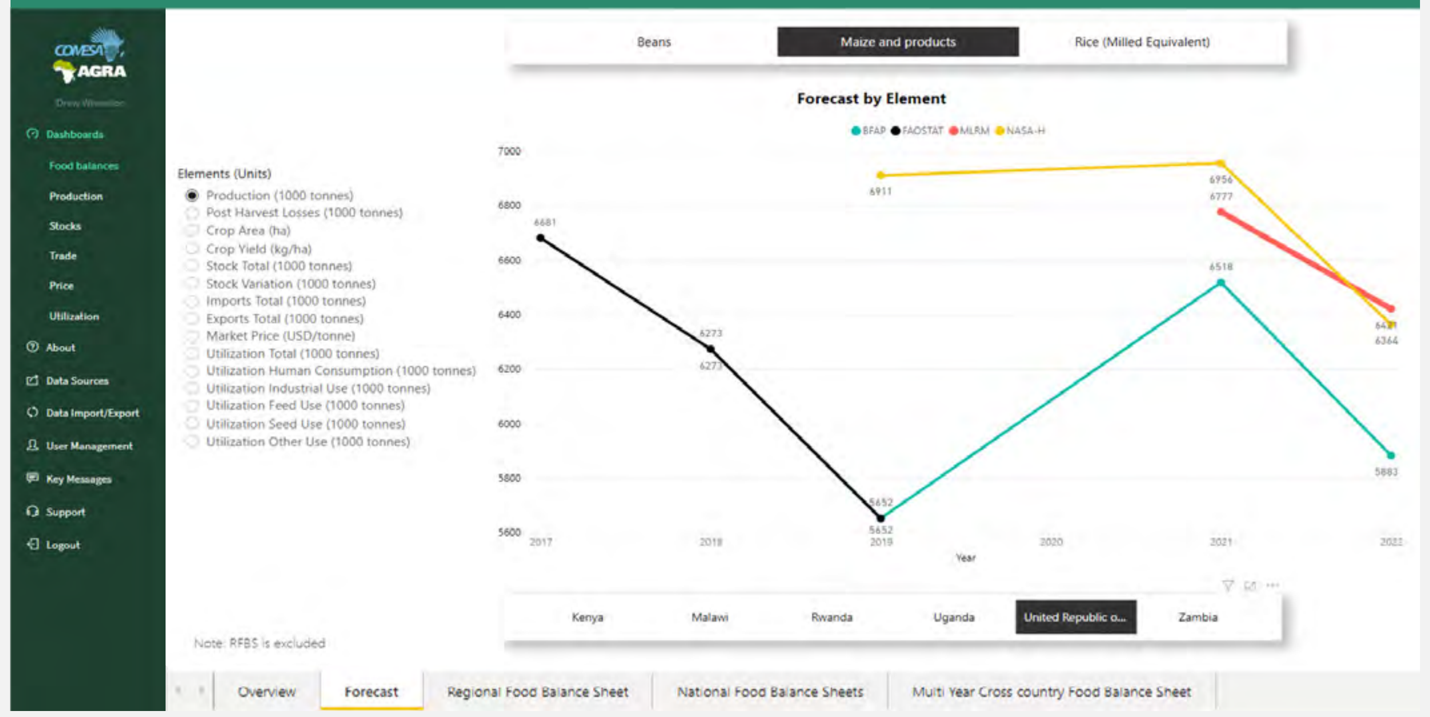
1 **Satellite imagery enables** bi-weekly, in-season estimates of crop yield and production.

2 **Remote-sensing analytics** are combined with manual surveys to validate estimates.

3 Combined survey and satellite data create **real-time, accurate crop yield forecasts** across multiple countries.

1

3 Regional Food Balance Sheet MVP



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Digital solutions for food security ›

The need for satellite-driven insights ›

Enhanced food security and other practical outcomes

Real-time information

5x

Increase in update frequency for yield estimates of staple crops

Decrease in waste

~20%

Projected reduction in food-reserve purchases over five years

Improved economics

~1-3%

Projected annual reduction in budget spent on food-reserve purchases

Looking forward, **yield optimization** will drive over 70% of the value from satellite-based insights in agriculture. Yield optimization uses advanced analytics to identify intra-field crop defects and inform operations, and its adoption is increasing as growers and agriculture input companies strive to maximize profitability and output per acre. Data from satellites can help insight providers identify areas with poor seed emergence early in the season; can identify plant-level indications of disease, weather, pests and crop health mid-season; and can map moisture content across seasons.

This data is highly actionable, and can influence operations in real time as growers decide to re-plant seeds, apply well-timed, hyper-localized inputs (e.g. herbicide, insecticide or fungicide; Figure 2), or alter irrigation plans.

Improved operations and yields improve grower profitability by doing more with less, and provide more food per acre planted for the growing population.

Use the arrows to discover more

FIGURE 4

Yield optimization in action: Eliminating yield risk and decreasing costs for a cotton farm in West Texas

Location	Crop	Annual revenue	Farm size	Field size
San Angelo, Texas	**Cotton**	**$373,000**	**500 acres**	**111 acres**

A multi-season comparison of **colour-infrared imagery identified root rot** patterns in a 111-acre cotton field

Root rot, driven by soil health, presents in similar areas year after year

● Healthy crop ● Crop with root rot

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Cotton

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Field size
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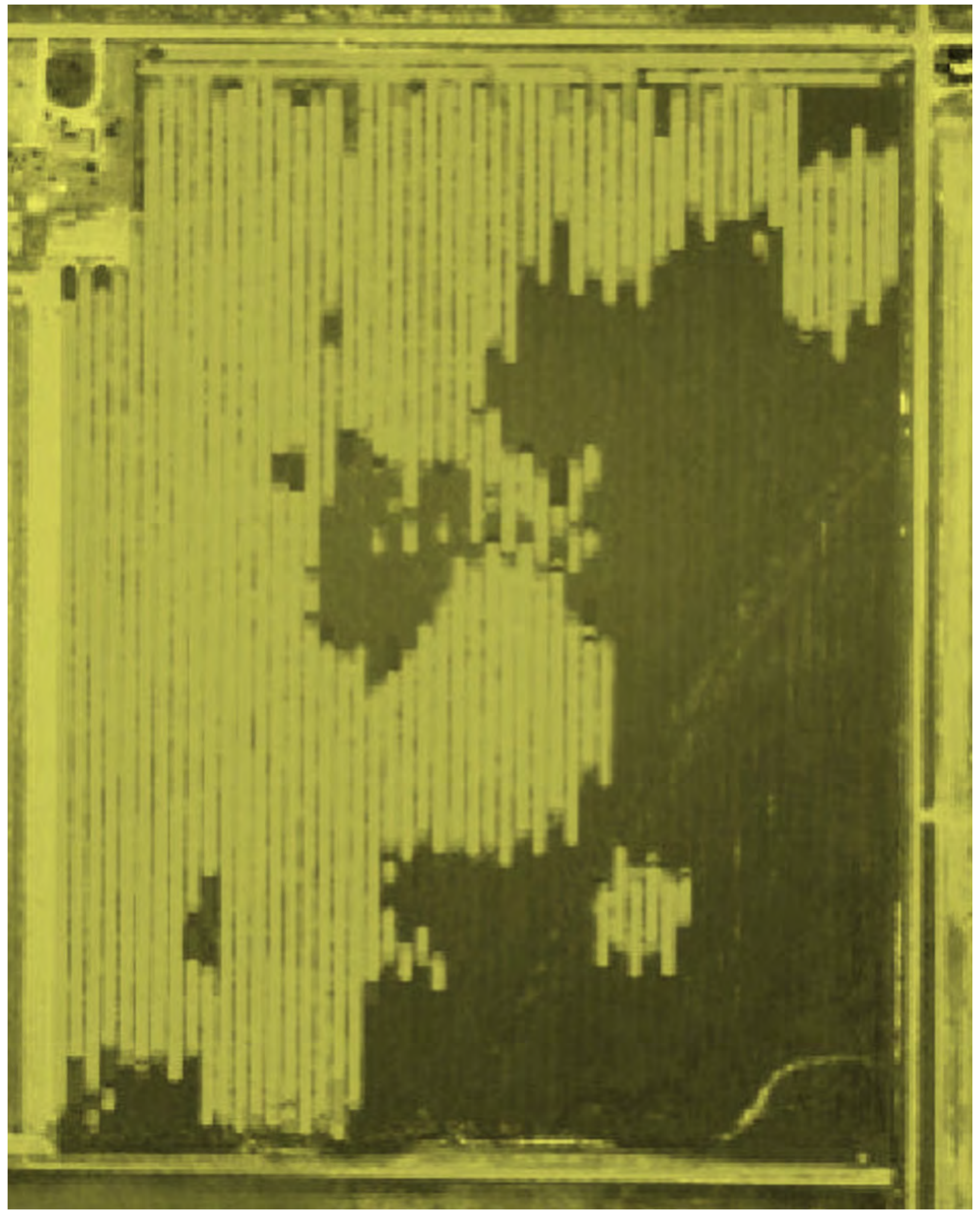

This allowed growers to **proactively spray affected areas** early in the season…

Variable-rate fungicide application on affected areas only

● Treated areas ● Untreated areas

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San Angelo, Texas	**Cotton**	**$373,000**	**500 acres**	**111 acres**

...which saved **95% of at-risk yield** using **43% less fungicide** and applying fungicide on 48 fewer acres than traditional methods

Post-application crop health

🔴 Healthy crop 🟢 Crop with root rot

Revenue protected

35 acres salvaged ×

$1.12/lb market price ×

667 lb/acre average yield =

$26,200

Cost decreased

48 acres not sprayed ×

$124/acre fungicide price =

$5,900

In tandem with the need to increase output per acre is the need to do so more sustainably, and satellite-based remote sensing can **bolster sustainable practices** to help the industry reduce emissions, use less water and encourage regenerative practices. Satellite technology has traction in the European Union (EU) today, where governments and NGOs are using satellite data to facilitate carbon markets and verify regenerative practices that qualify for subsidies.

The results are profound in their scale and potential impact: prior to the introduction of satellite technology, only 5% of sustainable agriculture subsidies could be verified due to the time-intensive nature of manual spot-checks, which occurred no more than once annually. Today, over 80% of field inspections are conducted via satellite imagery, with multiple checks across seasons.[3]

Satellites are also helping **predict, verify and mitigate damage from natural disasters**, with their unique ability to remotely monitor conditions before and after droughts, fires and floods. These capabilities are useful for insurers, and may enable parametric insurance for growers by monitoring and verifying vegetation health and soil moisture levels following storms. Parametric insurance is independent of the underlying asset, and can therefore be tied to triggering events such as extreme weather without the need for a physical audit.

Finally, **satellite-based connectivity** can make farm equipment autonomous and continuously monitor hardware in remote areas with poor mobile or broadband coverage. These capabilities help operators address field-level problems and edge cases remotely by communicating with equipment in real time, reducing the need for onsite troubleshooting. For example, satellites could help them identify an unrecognized plant as a weed and provide direction to spray. Equipment manufacturers such as John Deere are already beginning to employ this technology.[4]

2

Technology is evolving while costs decline, expanding the customer base

Expanding technology

At scale, satellites offer a distinct advantage over other sources such as unmanned aircraft systems (drones), fixed-wing aircraft, high-altitude platforms (aerostats, blimps) and internet-of-things (IoT) hardware. They eliminate the need for insight providers to operate fleets of aircraft or drones, they cover large geographical areas daily, and they do so with significantly fewer boots on the ground. This scale and frequency advantage creates an opportunity to scale agricultural insights globally and quickly, even to disparate locations and less developed regions.

This is in contrast to how the market operates today, where providers primarily operate ground-based fleets of aircraft, drones or other sensors to deliver field-level insights. Higher imagery costs and lower resolutions (spatial and temporal) have hampered satellites' ability to derive such insights, but those disadvantages are waning. Across use cases, higher resolutions, more frequent revisits and new sensor capabilities such as thermal bands and hyperspectral sensors are expected to make satellites comparable to other platforms by 2030 (Figure 5).

Yield optimization, in particular, will move from being highly reliant on localized monitoring via fixed-wing aircraft or drone, as technology improvements will allow satellite-based advanced analytics to, for instance, more reliably detect pests in the field (including weeds, insects and disease), often before they are visible to a human observer and in time for preventive action. This advancement will bring satellite image quality in line with that obtained from fixed-wing aircraft and unmanned aerial vehicles (UAVs) – it is expected to deliver comparable quality in more than 70% of identified use cases, making it viable as the primary source of imagery outside of niche needs (e.g. under-canopy data capture).

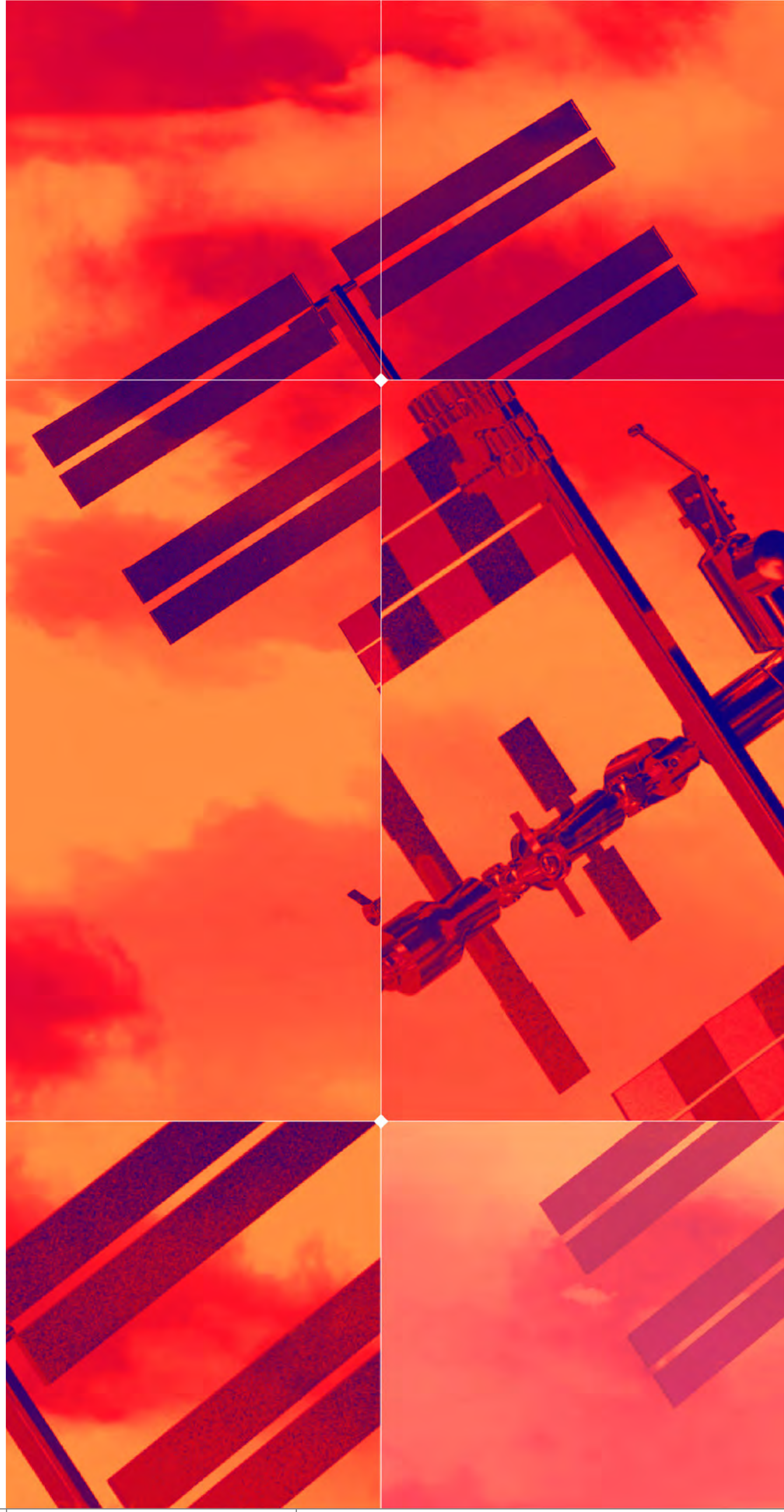

FIGURE 5

Available technology performance in core use cases

Select the available technology tabs to compare performance

Public satellite
Commercial satellite
Fixed wing
UAV

Use case		Commercial satellite <1m image resolution Prevalent 2030		>10m image resolution (prevalent 2022)	
		Quality	Status	Quality	Status
Estimate yield		●●● **High**	Majority of use cases at maximum scale	●●○ **Medium**	Limited to row crops (e.g. corn)
Optimize yield	Detect disease and prevent spread	●●○ **Medium**	Some capabilities	●○○ **Low**	Very limited
	Identify and protect from insects	●●○ **Medium**		●○○ **Low**	
	Measure and correct nutrient deficiencies	●●○ **Medium**		●◐○ **Low/Medium**	
	Spot and limit weed impact	●●◐ **Medium/High**		●○○ **Low**	
Facilitate sustainable practices	Optimize irrigation and water use[1]	●●○ **Medium**	All have MRV[2] capabilities	●○○ **Low**	Some have MRV[2] capabilities
	Monitor and verify (regenerative) practices	●●● **High**		●●○ **Medium**	
Verify and mitigate damage from natural disasters		●●● **High**		●●○ **Medium**	
Improve connectivity		●●● **High**	GPS and Internet	●○○ **Low**	GPS
Overall assessment		**Best suited if costs decline and spectral bands continue to improve**		**Lacks granularity**	

Notes: 1. Also applies to yield optimization. 2. Measurement, reporting and verification.

FIGURE 5

Available technology performance in core use cases

Select the available technology tabs to compare performance

Public satellite | **Commercial satellite** | Fixed wing | UAV

Use case		Commercial satellite <1m image resolution Prevalent 2030		>3m image resolution (prevalent 2022)	
		Quality	**Status**	**Quality**	**Status**
Estimate yield		●●● **High**	Majority of use cases at maximum scale	●●● **High**	Many use cases but lacks granularity
Optimize yield	Detect disease and prevent spread	●●○ **Medium**	Some capabilities	●○○ **Low**	Limited
	Identify and protect from insects	●●○ **Medium**		●○○ **Low**	
	Measure and correct nutrient deficiencies	●●○ **Medium**		●●○ **Medium**	
	Spot and limit weed impact	●●◐ **Medium/High**		●●○ **Medium**	
Facilitate sustainable practices	Optimize irrigation and water use[1]	●●○ **Medium**	All have MRV[2] capabilities	●○○ **Low**	Most have MRV[2] capabilities
	Monitor and verify (regenerative) practices	●●● **High**		●●◐ **Medium/High**	
Verify and mitigate damage from natural disasters		●●● **High**		●●◐ **Medium/High**	
Improve connectivity		●●● **High**	GPS and Internet	●○○ **Low**	GPS
Overall assessment		**Best suited if costs decline and spectral bands continue to improve**		**Best suited if costs decline and spectral bands continue to improve**	

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Available technology performance in core use cases

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Public satellite | Commercial satellite | **Fixed wing** | UAV

Use case		**Commercial satellite** <1m image resolution Prevalent 2030		**Fixed wing** ~10cm image resolution	
		Quality	Status	Quality	Status
Estimate yield		●●● **High**	Majority of use cases at maximum scale	●●● **High**	Majority of use cases, difficult to scale
Optimize yield	Detect disease and prevent spread	●●○ **Medium**	Some capabilities	●●○ **Medium**	Some capabilities
	Identify and protect from insects	●●○ **Medium**		●●○ **Medium**	
	Measure and correct nutrient deficiencies	●●○ **Medium**		●●○ **Medium**	
	Spot and limit weed impact	●●◐ **Medium/High**		●●● **High**	
Facilitate sustainable practices	Optimize irrigation and water use[1]	●●○ **Medium**	All have MRV[2] capabilities	●●● **High**	All have MRV[2] capabilities
	Monitor and verify (regenerative) practices	●●● **High**		●●● **High**	
Verify and mitigate damage from natural disasters		●●● **High**		●●● **High**	
Improve connectivity		●●● **High**	GPS and Internet	Lacks permanence	
Overall assessment		**Best suited if costs decline and spectral bands continue to improve**		**Lacks scale**	

Notes: 1. Also applies to yield optimization. 2. Measurement, reporting and verification.

FIGURE 5

Available technology performance in core use cases

Select the available technology tabs to compare performance

Public satellite | Commercial satellite | Fixed wing | **UAV**

Use case		**Commercial satellite** <1m image resolution Prevalent 2030		**UAV** ~3cm image resolution	
		Quality	Status	Quality	Status
Estimate yield		●●● **High**	Majority of use cases at maximum scale	●●● **High**	Most use cases, difficult to scale
Optimize yield	Detect disease and prevent spread	●●○ **Medium**	Some capabilities	●●○ **Medium**	Some capabilities
	Identify and protect from insects	●●○ **Medium**		●●● **High**	
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Better economics

In addition to technological limitations, prices for very high-resolution satellite data have historically been prohibitively high for agricultural use cases. But prices are expected to decline as an increased supply of new high-resolution providers enters the market with competitive cost structures, while UAV and fixed-wing aircraft prices remain stable due to structural labour and fuel costs that account for more than 50% of their cost structures.[5] The blended cost of high- and very high-resolution satellite imagery is expected to decline by 25% to 50% by 2030, bringing satellite imagery costs to a competitive level with that of equivalent-quality fixed-wing aircraft and UAVs.

In addition to cost, insights providers consider flexibility of imagery acquisition, operating complexity and the risks associated with the investment in each imagery source (Figure 6). Satellite imagery is the most flexible and least complex option for providers, but it has risks; for example, cloud cover can hamper image acquisition. Imagery providers may need to retain aircraft and UAV fleets to meet select customer needs or tackle inclement weather, but the scale advantages of satellite will likely reduce the size of such fleets.

FIGURE 6

Considerations for imagery acquisition

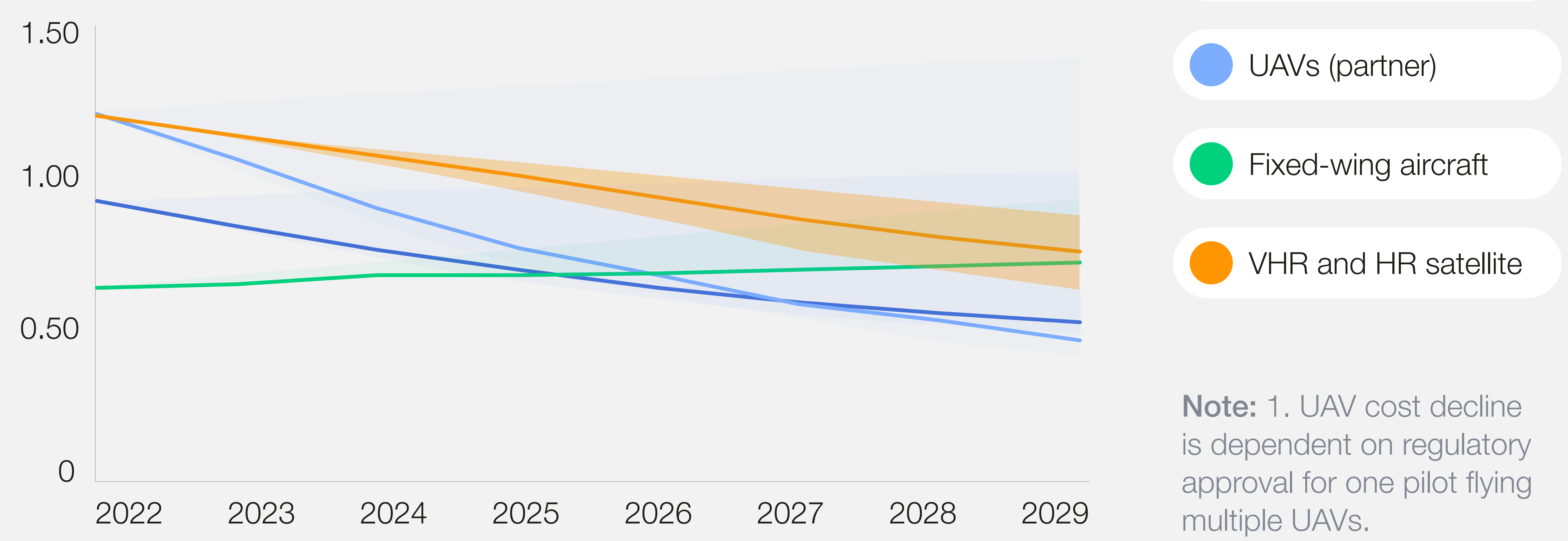
Analytics companies may use **imagery sources in combination**, but the mix will depend on relative cost, flexibility, complexity and risk

Select the tabs to discover more

Cost | Flexibility | Complexity | Risk

Satellite Blended high-resolution (HR) and very high-resolution (VHR) image acquisition	**UAVs** Grower or partner operated	**Fixed-wing aircraft**
Neutral	Advantaged	Advantaged
HR is cost competitive today. VHR costs are **expected to drop 25-50%** and become cost competitive by 2030 as supply increases, but UAVs will still be cheaper.[1]	Grower operated is **highly cost effective** Partner operated costs could decrease rapidly if pilots operate multiple drones	**Advantaged** today, but unlikely to decline given cost structure (labour, fuel)

Image acquisition cost, $/acre



Note: 1. UAV cost decline is dependent on regulatory approval for one pilot flying multiple UAVs.

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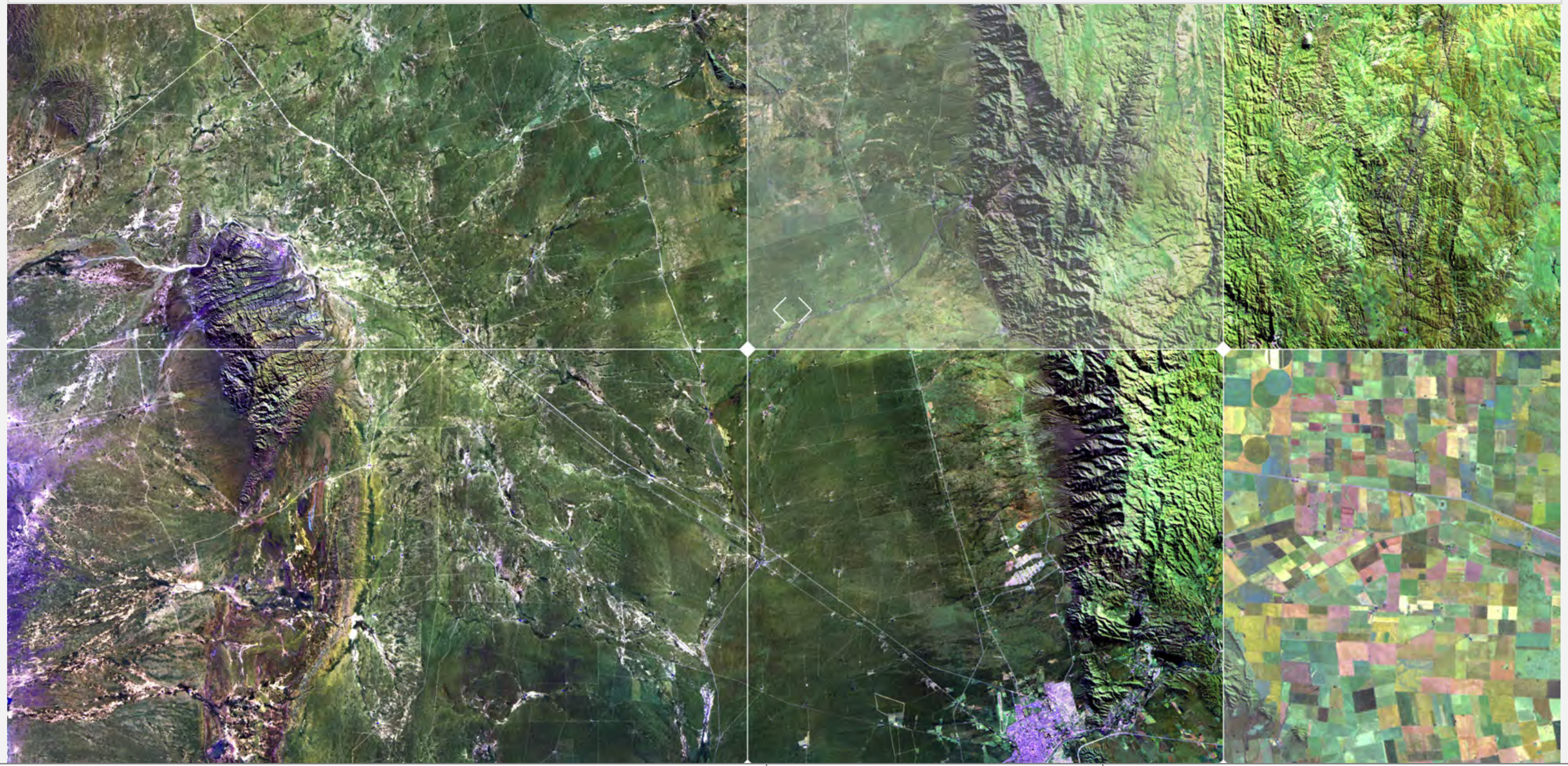
Cost | **Flexibility** | Complexity | Risk

Satellite Blended high-resolution (HR) and very high-resolution (VHR) image acquisition	**UAVs** Grower or partner operated	**Fixed-wing aircraft**
Advantaged	Disadvantaged	Disadvantaged
Highly modular, with ability to acquire images of small areas as needed	**Resource constrained** during short, high-value windows such as crop emergence, when image capture must occur within a two-week period	



Better economics

In addition to technological limitations, prices for very high-resolution satellite data have historically been prohibitively high for agricultural use cases. But prices are expected to decline as an increased supply of new high-resolution providers enters the market with competitive cost structures, while UAV and fixed-wing aircraft prices remain stable due to structural labour and fuel costs that account for more than 50% of their cost structures.[5] The blended cost of high- and very high-resolution satellite imagery is expected to decline by 25% to 50% by 2030, bringing satellite imagery costs to a competitive level with that of equivalent-quality fixed-wing aircraft and UAVs.

In addition to cost, insights providers consider flexibility of imagery acquisition, operating complexity and the risks associated with the investment in each imagery source (Figure 6). Satellite imagery is the most flexible and least complex option for providers, but it has risks; for example, cloud cover can hamper image acquisition. Imagery providers may need to retain aircraft and UAV fleets to meet select customer needs or tackle inclement weather, but the scale advantages of satellite will likely reduce the size of such fleets.

FIGURE 6

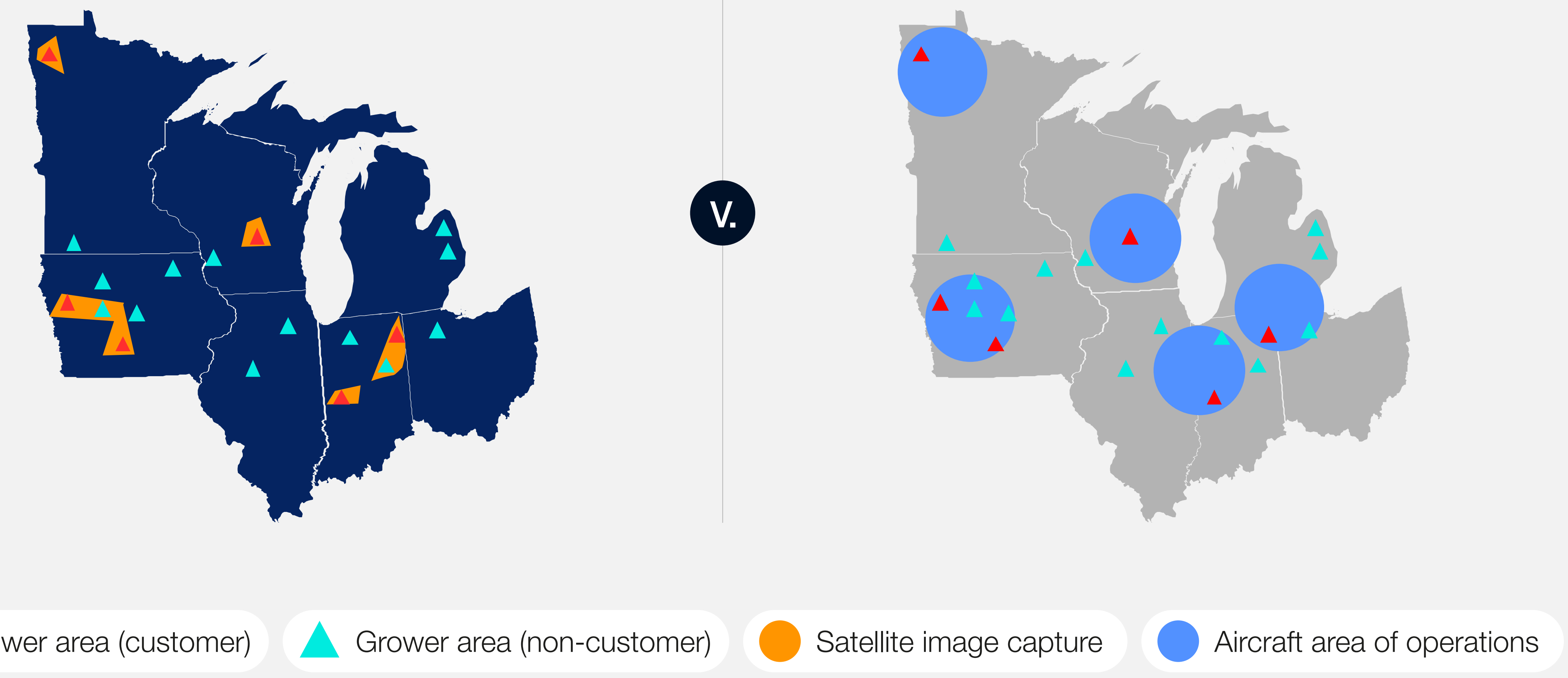
Considerations for imagery acquisition

Select the tabs to discover more

Analytics companies may use **imagery sources in combination**, but the mix will depend on relative cost, flexibility, complexity and risk

Cost | Flexibility | **Complexity** | Risk

Satellite	**UAVs**	**Fixed-wing aircraft**
Blended high-resolution (HR) and very high-resolution (VHR) image acquisition	Grower or partner operated	
Advantaged	Disadvantaged	Disadvantaged
Broad geographic reach is possible through even a single partnership	**Physical operations or partnerships are required in each market**, increasing management costs as well as logistical complexity	



A single **satellite** partner can serve multiple markets, tailoring coverage to adoption

Aircraft/UAV requires regional partnerships and increased physical presence

Better economics

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Cost | Flexibility | Complexity | **Risk**

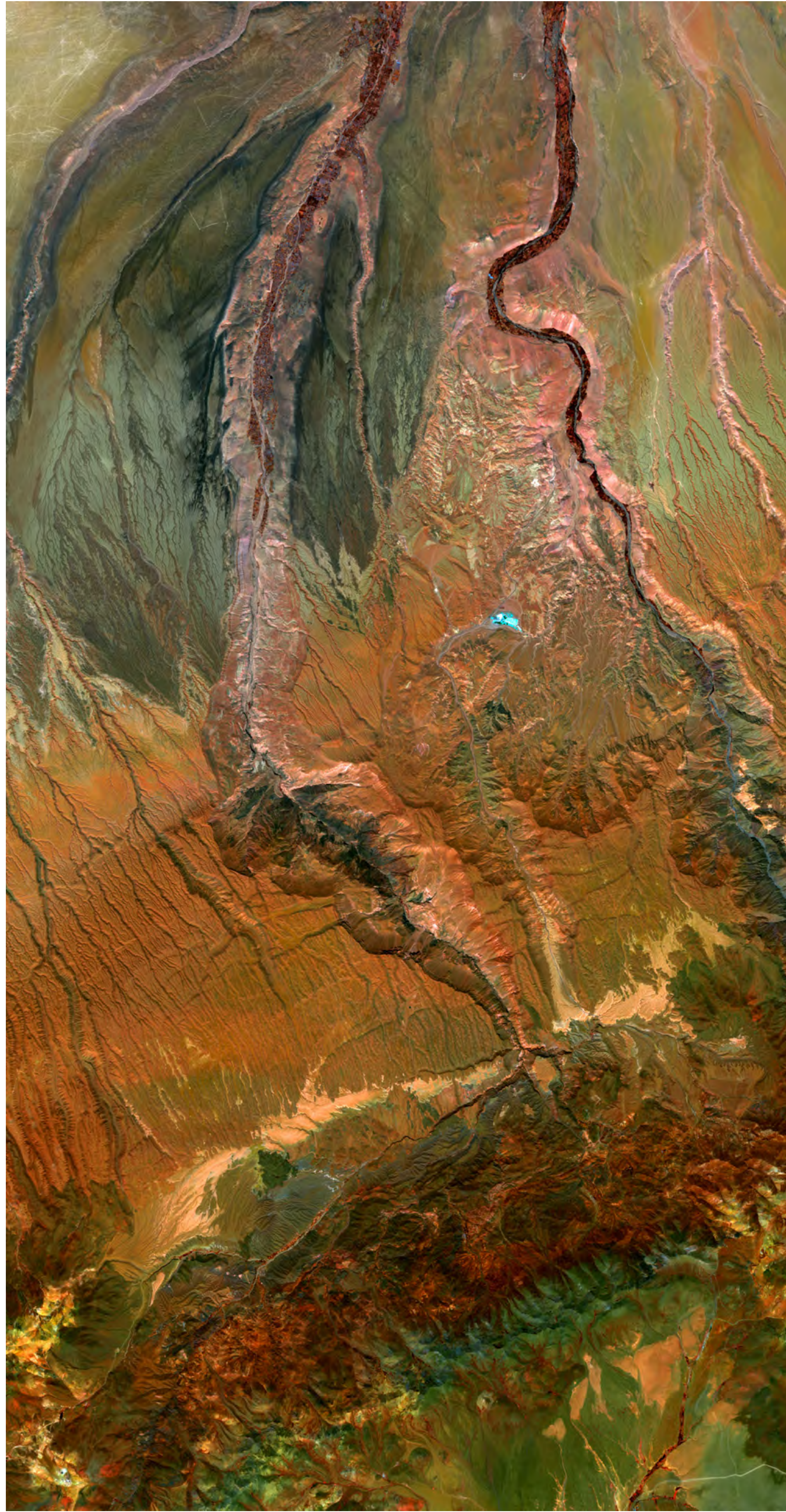
Satellite Blended high-resolution (HR) and very high-resolution (VHR) image acquisition	**UAVs** Grower or partner operated	**Fixed-wing aircraft**
Disadvantaged	Neutral	Disadvantaged
Lower certainty of image capture due to weather (cloud cover)	**Less timeliness and quality** control for owner-operated **Reliant on regulatory changes** for costs to come down	**Costs will increase moving forward**, given labour and fuel needs

Customer expansion

Improved cost and operating models will attract a multitude of customer groups, including those that operate across borders and require the scale that satellites can provide. Initiatives such as COMESA's food balance sheet garner the attention of other **governments and NGOs**, who may choose to replicate the technology or expand it to other use cases. Addressing food security is likely to remain a focus due to the cost savings and social impact – $20 billion is spent annually to combat global food insecurity – as will the compliance monitoring of climate-related regulation and other field-level verification activities made possible by satellites' scale. **Crop insurance** and **carbon credit markets** are likely to employ satellites for a similar reason – time intensive, operations heavy activities like claim validation and soil-carbon monitoring cause significant costs to owners of these businesses, who may see satellite as a singular option for expanding to data- or population-scarce environments.

Agriculture professionals, including equipment manufacturers, crop traders and growers are the largest users today, but more users and use cases are likely to emerge. Traders using satellite data have historically beaten the market by 4% to 5%, and have every reason to further invest in in-house, proprietary satellite models. Original equipment manufacturers (OEMs), which work closely with growers to provide and process immense amounts of data from the field, will be able to help growers to further optimize operations and yield.

Greater adoption of remote-sensing technologies for growers is the largest opportunity for satellite-related applications in agriculture, and their usage is already increasing. In McKinsey & Company's 2022 digital farmer adoption survey, 29% of row crop farmers and 45% of specialty crop farmers in the United States (US) said they currently employed remote sensing or planned to in the next two years. The numbers were even higher in South America (88%) and Europe (79%). With younger operators increasingly graduating into management roles, adoption will increase – already 60% of users are under 44 years of age.



③

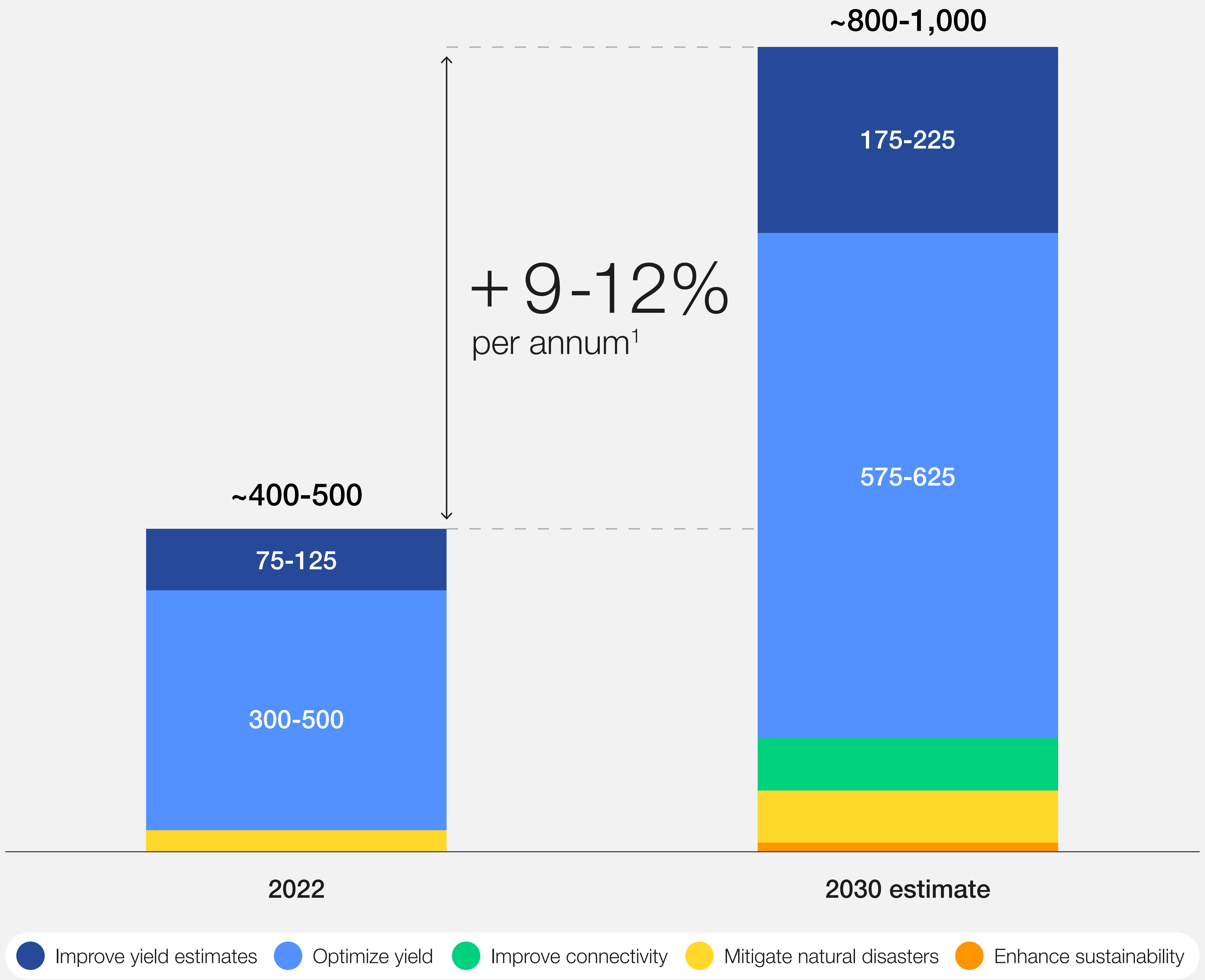
Opportunity for industry

Satellite imagery's expanding ability to serve multiple users and use cases will grow the market considerably – the amount customers spend on space-based imagery and analytics for agricultural applications is expected to increase 9-12% a year from 2022 to 2030, expanding to a serviceable market of $0.8-1 billion and creating $1.3-2 billion of value for the agriculture industry (Figure 7).[6]

This is a departure from how the market operates today, where free, publicly available data has penetrated every step of the value chain but is limited in impact by low resolution and infrequent data refreshes. Yield optimization drives the majority of the shift towards paid, high-resolution satellite imagery, as the projected 25-50% decline in cost improves the returns for growers.[7] Scale matters, though, and 70% of growth is predicted to come from larger farms with revenue of more than $1 million each, which have more to gain economically and operationally (Figure 8).

FIGURE 7

Estimated market size by use case (in million US dollars)



Note: 1. If hurdles are addressed and adoption accelerates.

Source: World Economic Forum and McKinsey analysis informed by expert interviews and industry publications (e.g. Northern Sky Research).

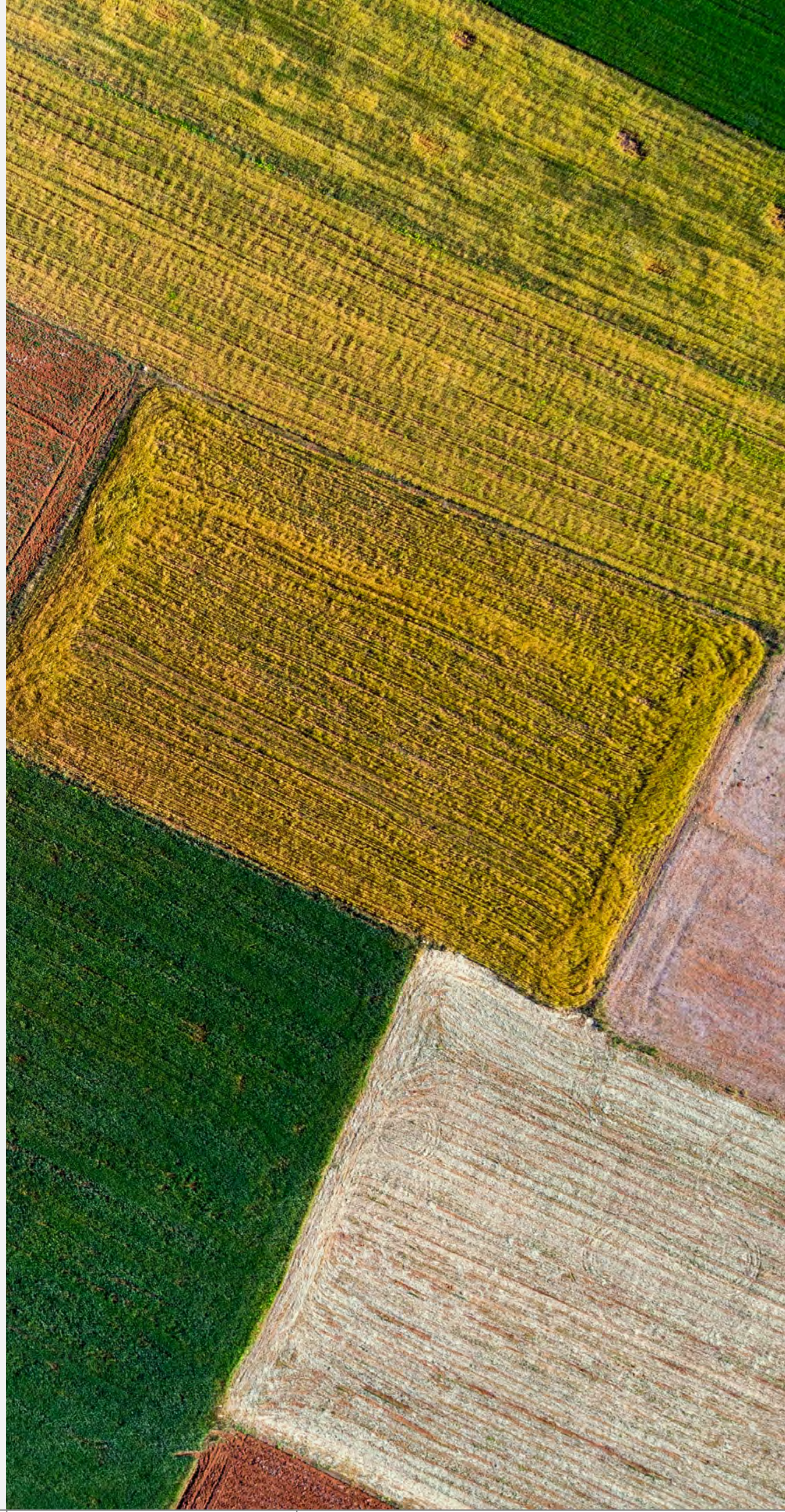
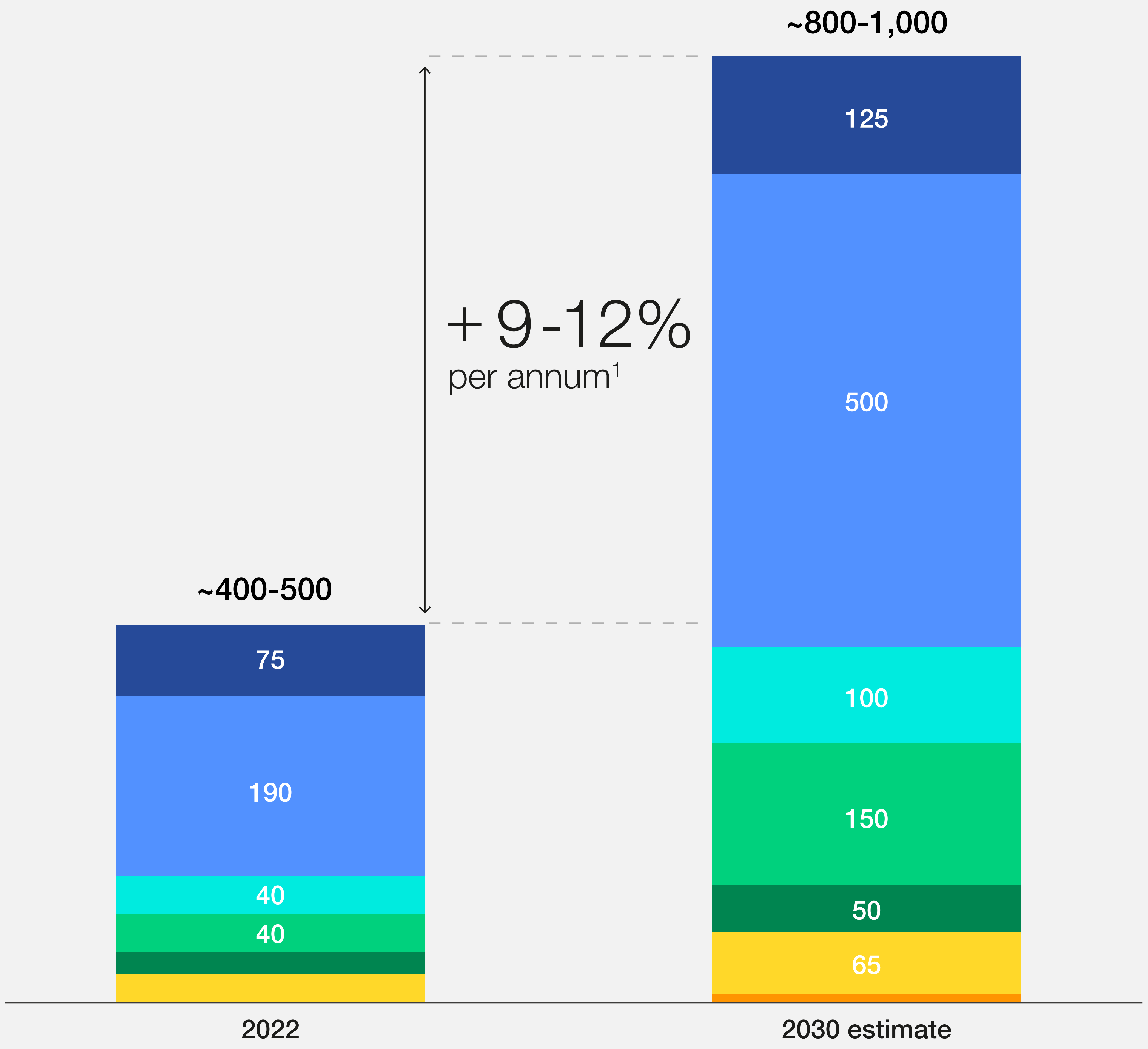


FIGURE 8

Market growth by user segment

Estimated commercial satellite-based insights market by end-customer segment, in million US dollars



	Representative end customer[2]	ROI[3]
●	**Small to medium farms** ($1m or less)	~50%
●	**Large farms** (revenue $1-5m)	~100%
●	**Very large farms** (revenue $5m+)	~200%
●	Crop traders	~100%
●	Governments	~125%
●	Insurers	~25%
●	Carbon markets	~25%

Notes:

1. If hurdles are addressed and adoption accelerates.
2. Growers may source insights from intermediaries such as agricultural distribution companies.
3. Return on investment is based on the value delivered – cost savings or revenue growth – compared to cost of insights.

Source: World Economic Forum and McKinsey analysis informed by expert interviews and industry publications (e.g. Northern Sky Research).

Applied at scale, satellite-enabled insights can improve global yields and food-management practices, as evidenced by COMESA's food balance sheet initiative. Satellite-based insights have also helped fruit farmers enrolled in the Fruitlook programme of South Africa's Western Cape Department of Agriculture to decrease water use by more than 10% through more efficient irrigation practices. Such actions could improve food security and water scarcity worldwide, driving progress towards several of the UN's Sustainable Development Goals (SDGs), including SDG 2 (zero hunger), SDG 12 (responsible consumption and production), SDG 13 (climate action) and SDG 15 (life on land).

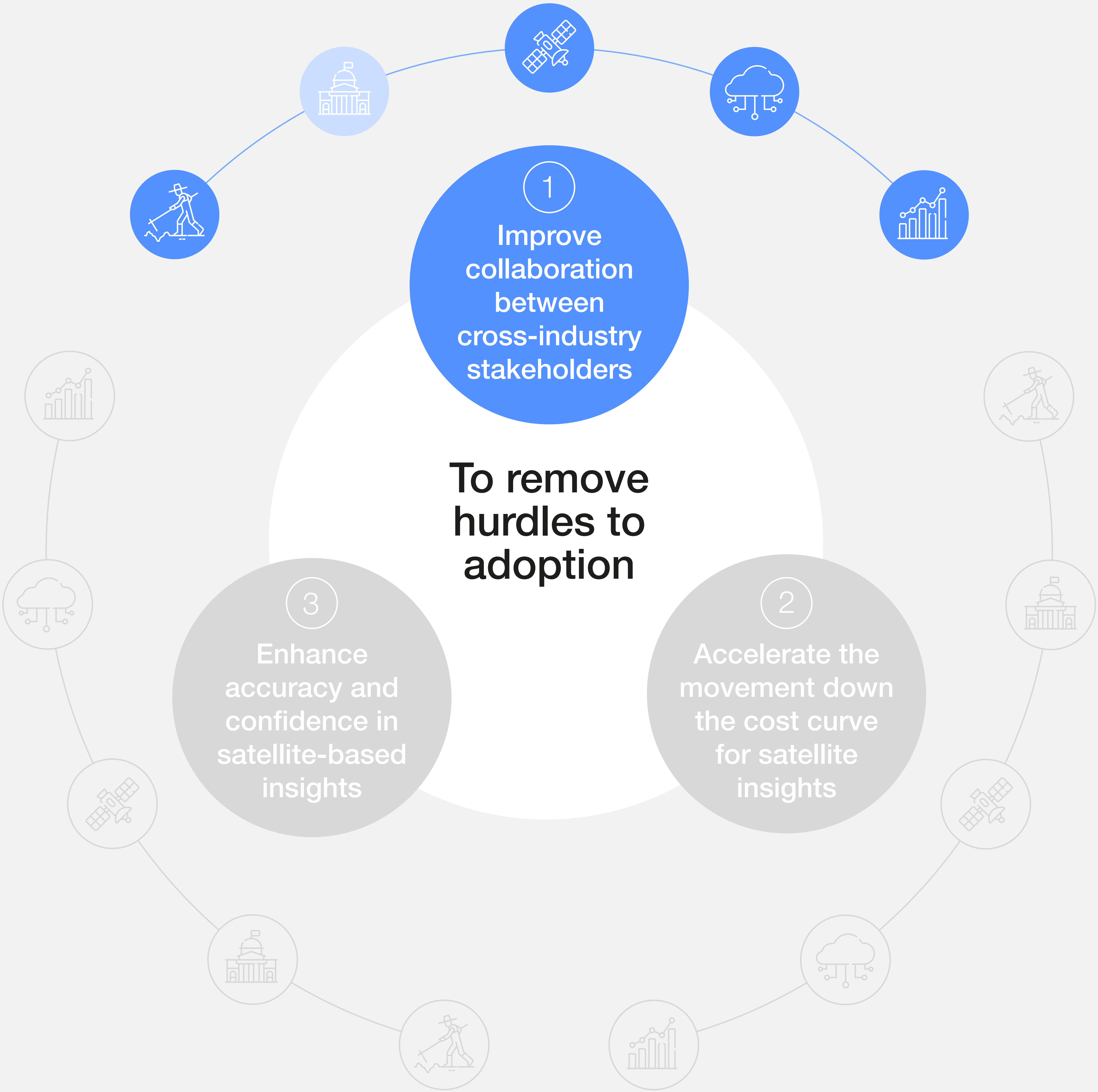
Stakeholders must collaborate

It will take coordinated efforts among disparate stakeholders to drive greater adoption of satellite applications in agriculture. Three main hurdles are evident: (1) a lack of collaboration between cross-industry stakeholders, (2) limited accuracy of, and end-user confidence in, satellite-based insights, and (3) high, slowly declining costs (Figure 11).

Select the circles to discover more

FIGURE 9

Calls to action to address hurdles



Growers

Soon: Leverage cooperatives, commodity boards and other networks for mass collaboration and sharing of relevant data

Governments

As soon as possible: Become a customer yourself

Soon: Explore collaboration models with the private sector to subsize costs and validate data

Satellite companies

Ongoing: Continue to expand volume and breadth of imagery available

Now: Provide *archival* imagery at low/ no cost

Cloud providers

Soon: Work with analytics and satellite providers to streamline processing costs

Analytics companies

Now: Create a feedback loop with satellite providers

As soon as possible: Catalyse cross-industry partnerships

Soon: Dedicate resources to develop satellite-based insights

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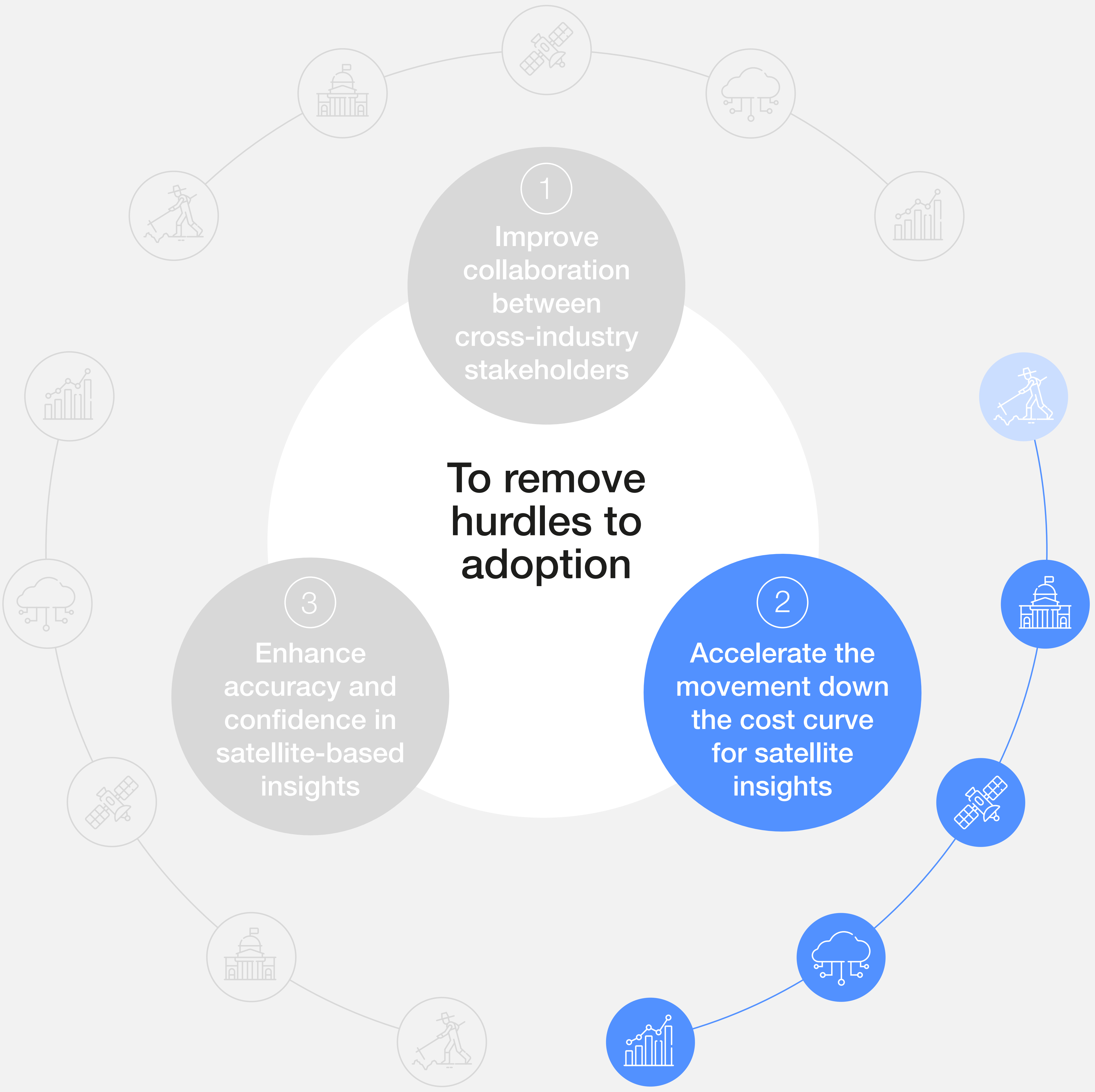

To remove hurdles to adoption

1 Improve collaboration between cross-industry stakeholders

2 Accelerate the movement down the cost curve for satellite insights

3 Enhance accuracy and confidence in satellite-based insights

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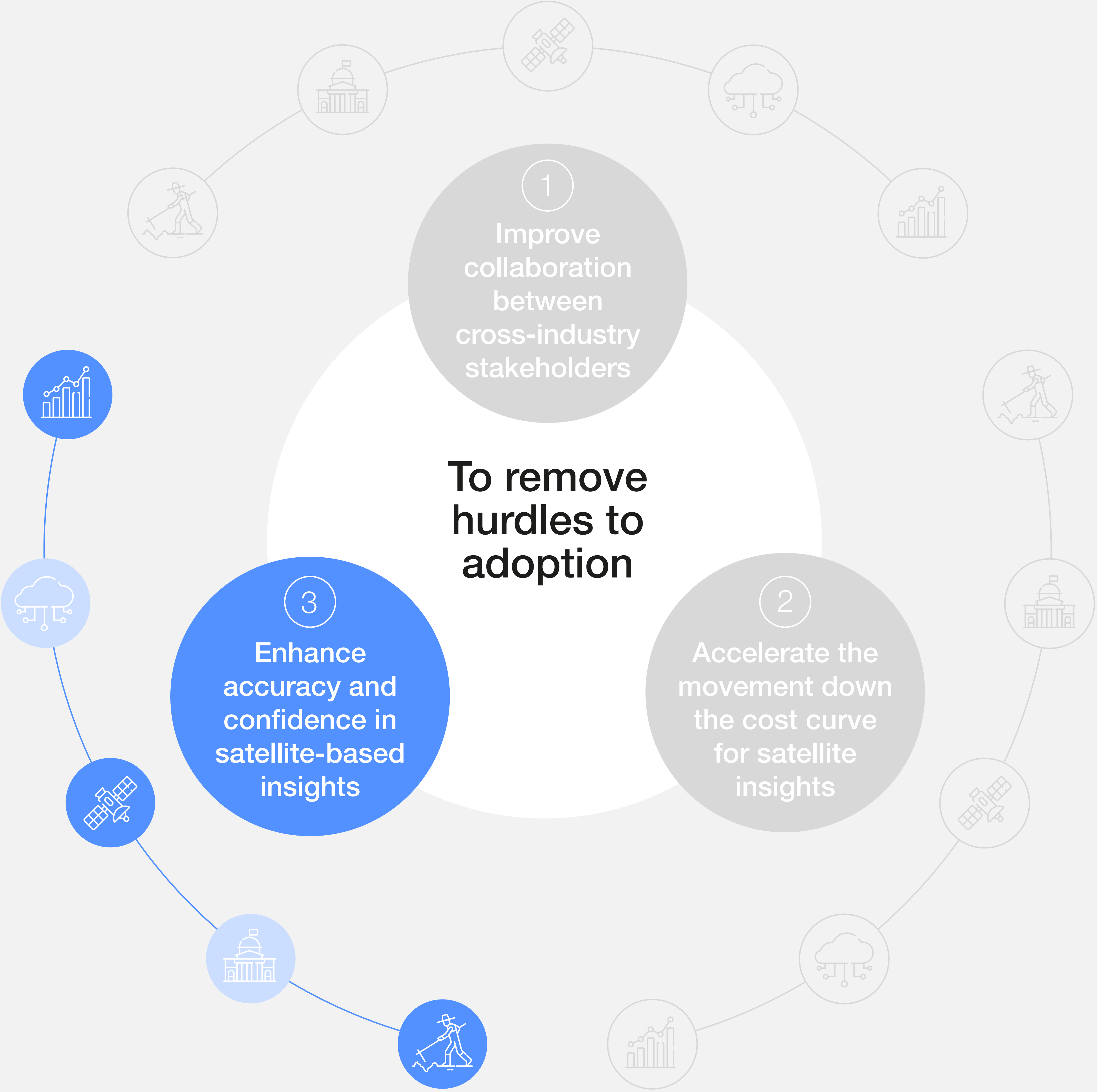

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Soon: Dedicate resources to develop satellite-based insights

Satellite and analytics providers can improve accuracy and confidence by involving users in their technology development roadmaps, ensuring a tight linkage between user needs and insights provided. Offering transparency into how insights are derived, highlighting where they are most accurate or fall short, is also critical – and will require cross-industry collaboration to clearly represent the assumptions and facts influencing results.

This is a valuable first step in gaining grower trust to act on insights – but ultimately, the true test of accuracy is testimonials and proven value creation. Ironically, getting model accuracy to reliable levels requires high investment of human resources, as data gathered manually on the ground is required to train analytics models and validate what the images predict. And not all cropland is alike – a field of maize in Kenya looks different than one in Indiana, so ground truthing data must include a comprehensive set of variables such as crop type, the observed event (e.g. planting date, weed or disease presence) and eventual yield – all tagged to the location where the observation was made and compared to imagery produced in the same period. Obviously, such data is costly to gather on a wide scale – creating the need for substantial cross-industry collaboration.

Such collaboration is not simple, involving five or more industries at varying stages of the user lifecycle. Satellite companies should be the catalyst, providing archival imagery – and often real-time imagery – at low or no cost to insight developers, who in turn must dedicate a meaningful part of their organization to satellite-based analytics. Growers, then, should ensure ground-truth data availability by bringing together cooperatives, commodity boards and other networks to collaborate and share relevant data with governments and analytics companies. This will improve insight models and decrease data validation costs. Governments, NGOs and analytics companies can make data-sharing easy, anonymous and value accretive to growers who participate. Cloud providers can aid the validation effort by working with analytics and satellite providers to avoid imagery redundancies, streamline processing costs and reduce overall data costs.

Finally, by 2030, prices for satellite imagery must decline to a level comparable with other imaging alternatives. Satellite imagery prices are already naturally declining as the market matures, and intensifying competition from multiple providers with advanced payloads could quicken the pace of price decline (Figure 10). Satellite companies should continue to work to expand the volume and breadth of imagery available to quicken market maturity, which governments can facilitate via subsidies, public-private partnerships, investments in use cases where private sector return on investment (ROI) is challenging, and other large-scale, programmatic actions.

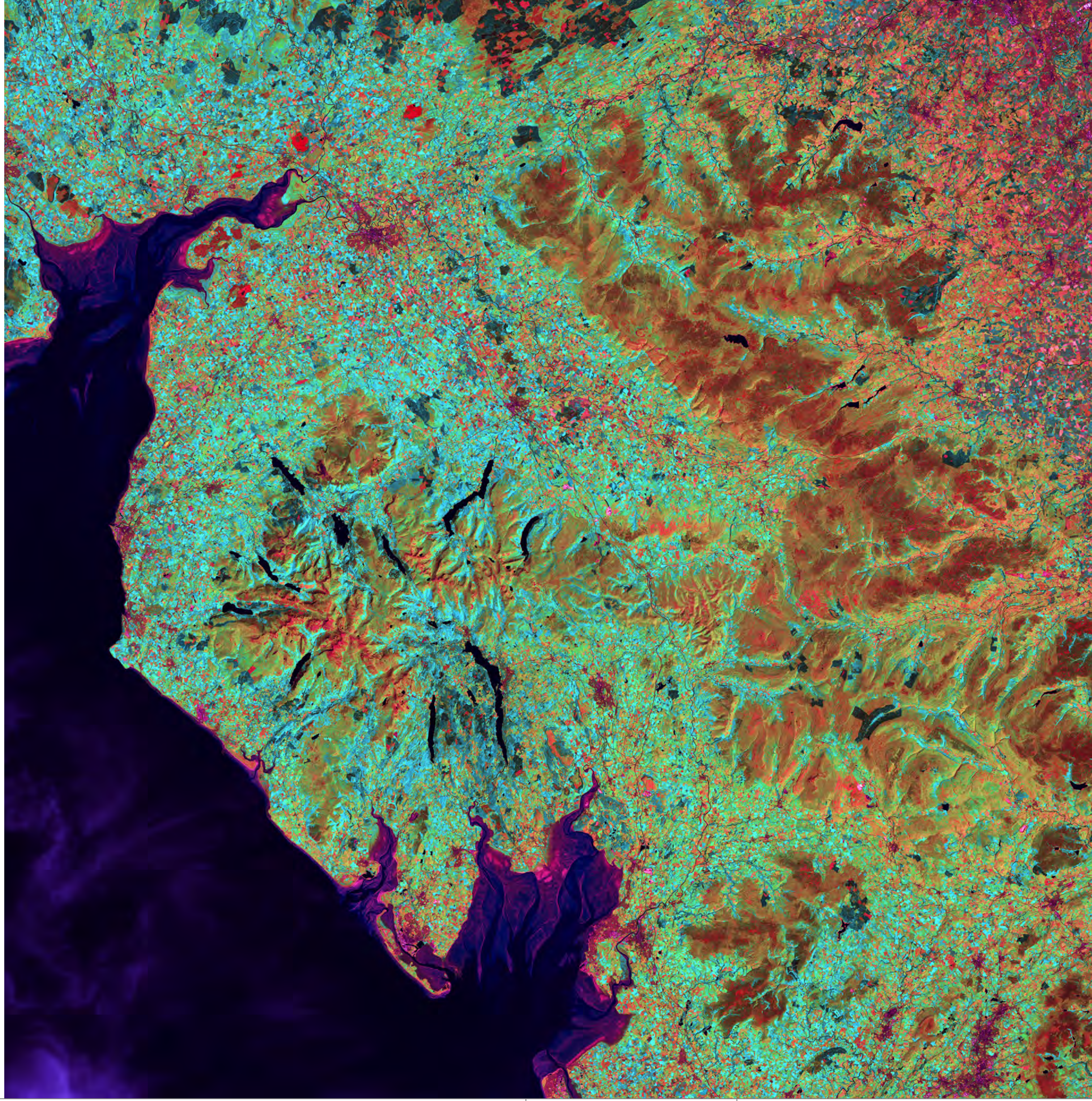

FIGURE 10

Comparison of free versus commercially available satellite data

Commercial: high resolution

Click here to switch between views

● Commercial ○ Public

Owner	Satellite	Data type	Spatial resolution (pixel width in metres)	Revisit frequency (days)	Spectral resolution (number of bands)	Base price[1] (US dollars/acre)	Area of interest – minimum area and width (acres, K)
Airbus	Pleiades Neo	Multispectral	0.3	2	6	$0.13	25
Maxar Technologies Inc.	WorldView 3	Multispectral	0.3	1	8	$0.14	25 | 0.7
Maxar Technologies Inc.	WorldView 2	Multispectral	0.4	1	8	$0.13	25
Planet	Skysat	Multispectral	0.5	7	4	$0.05	0
Airbus	Pleiades	Multispectral	0.5	2	4	$0.09	25 | 0.1
KARI	KOMPSAT-3	Multispectral	0.7	1	4	$0.06	25
BlackSky	BlackSky Global	Multispectral	0.85	0.1	3	$0.03	1
ICEYE	ICEYE	Radar	1	1	4	–	–
Satellogic	NuSat	Multispectral	1	0.25	5	$0.03	0
Airbus	SPOT6/7	Multispectral	1.5	2	4	$0.02	124
Planet	Planetscope	Multispectral	3	1	8	$0.01	62

Note: 1. Price for tasked imagery (i.e. a request that the satellite acquire an image of a new area of interest) before dedicated negotiation. Note that historical data may vary due to constellation build-up through time – that is, as new satellites are added to the constellation, they typically increase the revisit frequency and sometimes add information such as new bands, increased swath and increased spatial resolution.

FIGURE 10

Comparison of free versus commercially available satellite data

Public: low resolution

Click here to switch between views

Commercial Public

Owner	Satellite	Data type	Spatial resolution (pixel width in metres)	Revisit frequency (days)	Spectral resolution (number of bands)	Base price[1] (US dollars/acre)	Area of interest – minimum area and width (acres, K)
ESA	Sentinel-2 A/B	Multispectral	10	5	13	$0.00	0
NASA	ASTER	Hyperspectral	15	1	14	$0.00	0
ESA	Sentinel-1	Radar	20	3	4	$0.00	0
NASA	Landsat-8/9	Multispectral	30	8	11	$0.00	0
NASA	MODIS	Multispectral	500	1	36	$0.00	0

Note: 1. Price for tasked imagery (i.e. a request that the satellite acquire an image of a new area of interest) before dedicated negotiation. Note that historical data may vary due to constellation build-up through time – that is, as new satellites are added to the constellation, they typically increase the revisit frequency and sometimes add information such as new bands, increased swath and increased spatial resolution.

Conclusion

The potential of satellites to scale agricultural insights to a level operationally impossible from the ground means that even incremental improvements can make a significant impact – shifting the balance away from terrestrial-based fleets and towards space monitoring solutions. In the next decade, improving resolution and decreasing per-image prices will create the opportunity for satellite-based remote sensing to scale to a level previously considered impossible.

However, without action by most stakeholders in the industry, adoption will not reach its potential. Satellite companies, agriculture companies, insight providers, governments, NGOs and growers must act together, now.

The technology needed for satellite data-driven insights to hit S-curve growth is primed – and the right actions from growers, technologies, governments and the space and agriculture industries can help satellite applications realize their full potential rapidly in order to address some of the largest issues of today.

Contributors

The World Economic Forum would like to extend its sincere thanks to the space and agriculture leaders who contributed their valuable insights and perspectives to this briefing paper. Various individuals contributed to the two in-depth discussions as part of this workstream, to provide insights on the value and growth potential of satellite applications for the agriculture sector.

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Endnotes

1. Excluding animal protein; upper threshold assuming 50% success rate for issue identification and 80% efficacy of crop protection products. Based on estimates of costs to the global economy of annual plant disease and invasive insects by the Food and Agriculture Organization (FAO).

2. Based on composite market size for agriculture inputs (fertilizer and crop protection) from S&P Compustat, Phillips McDougal, Institute for Food and Agriculture and the World Bank.

3. European Court of Auditors, “Special Report: Using new imaging technologies to monitor the Common Agricultural Policy: steady progress overall, but slower for climate and environment monitoring,” accessed on 8 January 2020, https://www.eca.europa.eu/Lists/ECADocuments/SR20_04/SR_New_technologies_in_agri-monitoring_EN.pdf.

4. Jewett, Rachel, “John Deere releases satcom RFP for always-on, connected agricultural solution,” *Via Satellite*, accessed on 29 September 2022, https://www.satellitetoday.com/agriculture/2022/09/29/john-deere-releases-satcom-rfp-for-always-on-connected-agricultural-solution/.

5. This paper assumes drone prices could decline if regulators allow a single pilot to fly multiple drones. If this technology is not approved by regulators, satellites will be even more cost-competitive.

6. The $2 to $3 billion projection is based on expected price and adoption rates informed by McKinsey 2022 Annual Grower Survey; the $1.5 billion figure is driven by a mixture of cost reduction or revenue increase for customers by use case: 6% to 10% cost reduction for yield estimation, 4% to 6% of cost reduction for yield optimization, 2% insurance-fraud reduction and 7% uplift in carbon-market participation.

7. Projection based on McKinsey analysis of historical high-resolution and very high-resolution satellite price changes, informed by Northern Sky Research Satellite-Based Earth Observation, 10th edition.