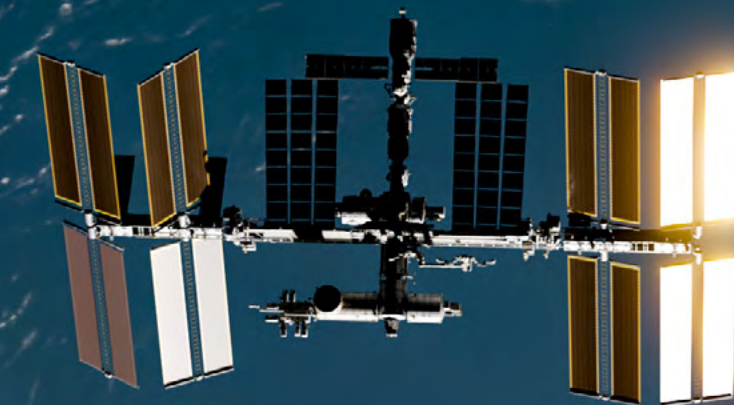


In collaboration with
McKinsey & Company



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

APRIL 2023



Contents



Introduction	3
1 Satellite technology has multiple applications in agriculture	7



2 Technology is evolving while costs decline, expanding the customer base	16
---	----



3 Opportunity for industry	27
Conclusion	36
Contributors	37
Endnotes	38

This guide is interactive

Look out for this icon for elements that can be interacted with

Disclaimer

This document is published by the World Economic Forum as a contribution to a project, insight area or interaction. The findings, interpretations and conclusions expressed herein are a result of a collaborative process facilitated and endorsed by the World Economic Forum but whose results do not necessarily represent the views of the World Economic Forum, nor the entirety of its Members, Partners or other stakeholders.

© 2023 World Economic Forum. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, including photocopying and recording, or by any information storage and retrieval system.

Images: Getty Images, Unsplash

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 CO₂ 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

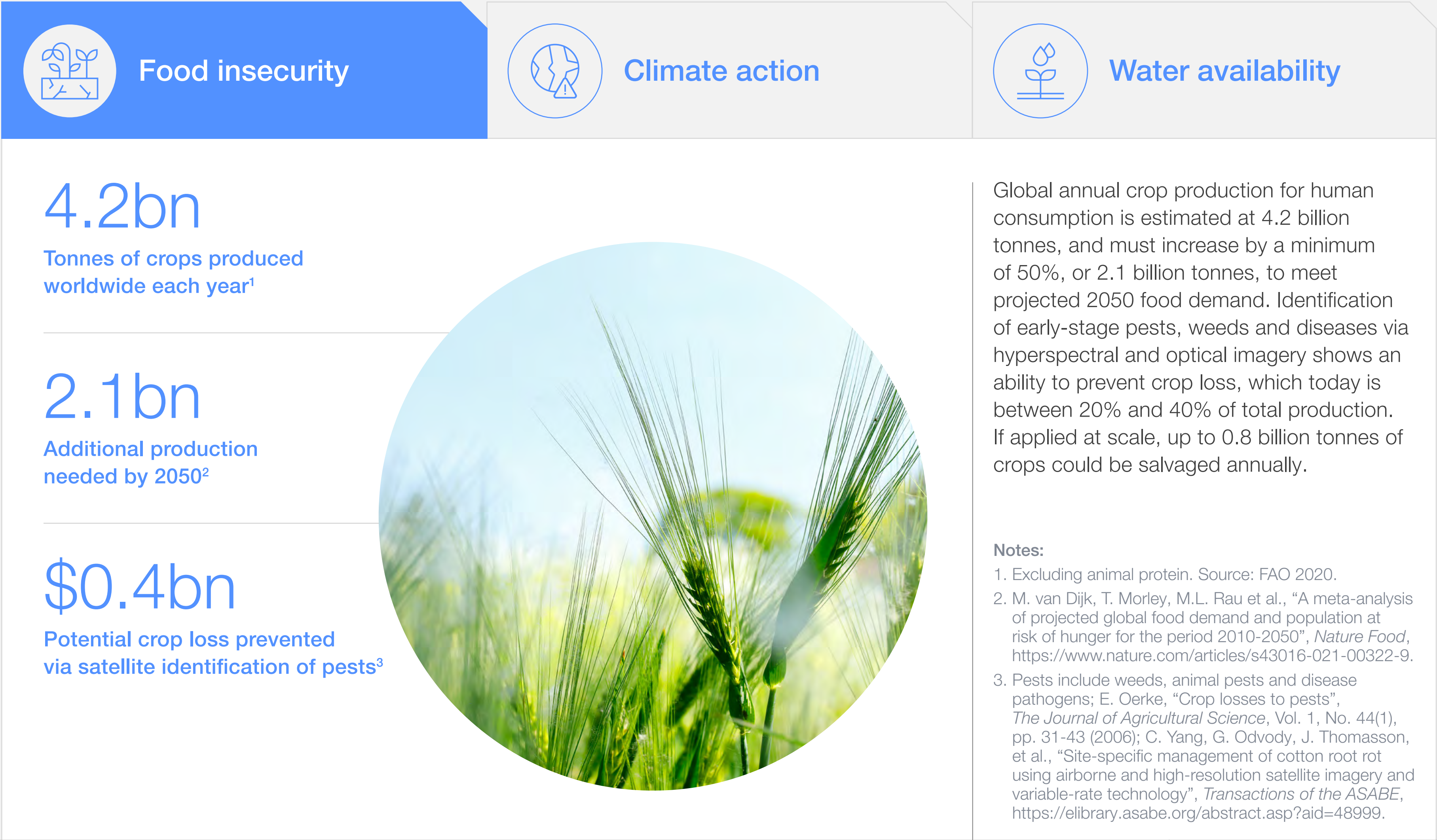


FIGURE 1
Satellite applications’ potential to address challenges in agriculture

What’s at stake?

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

Select the tabs to discover more

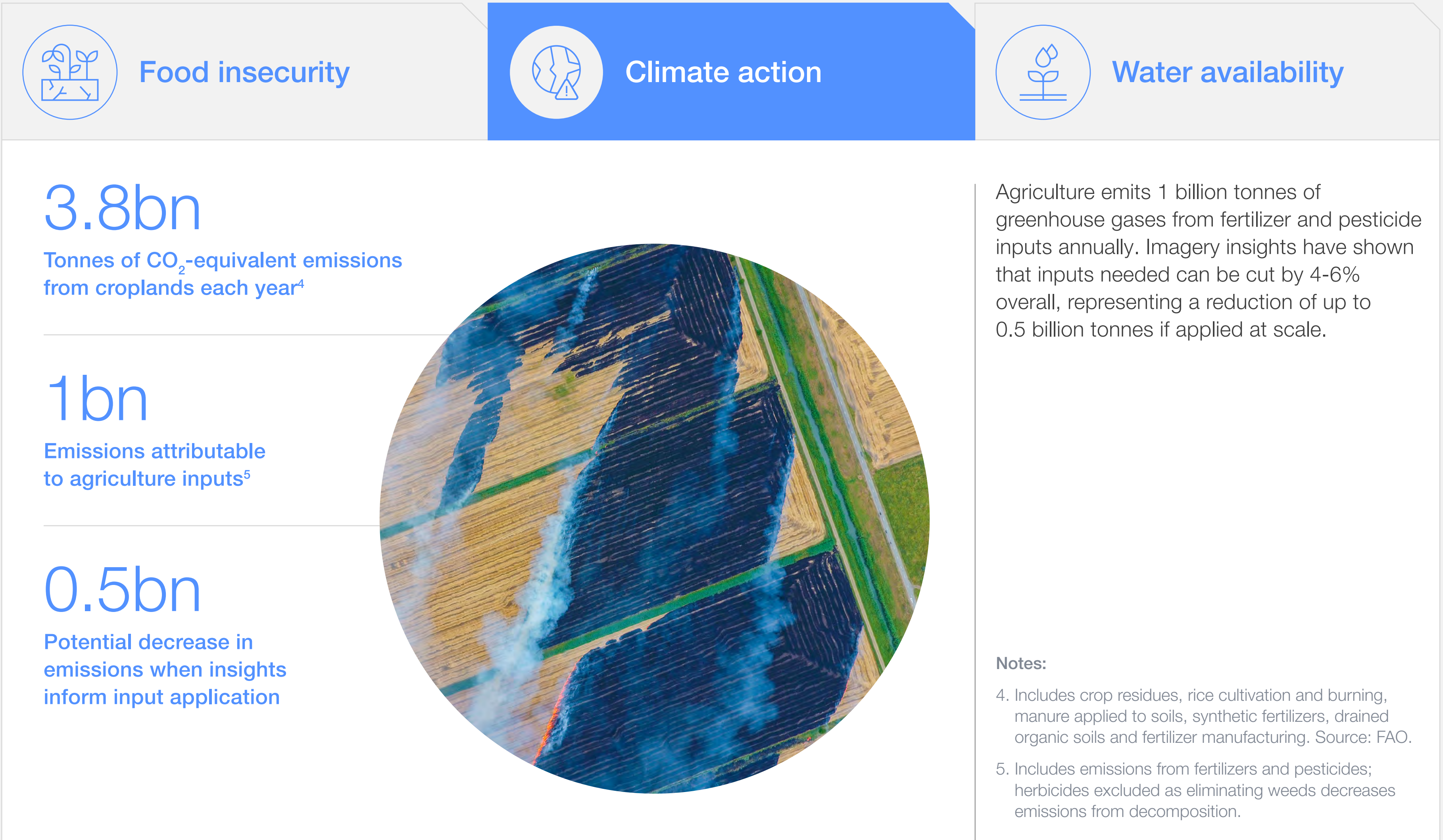


FIGURE 1

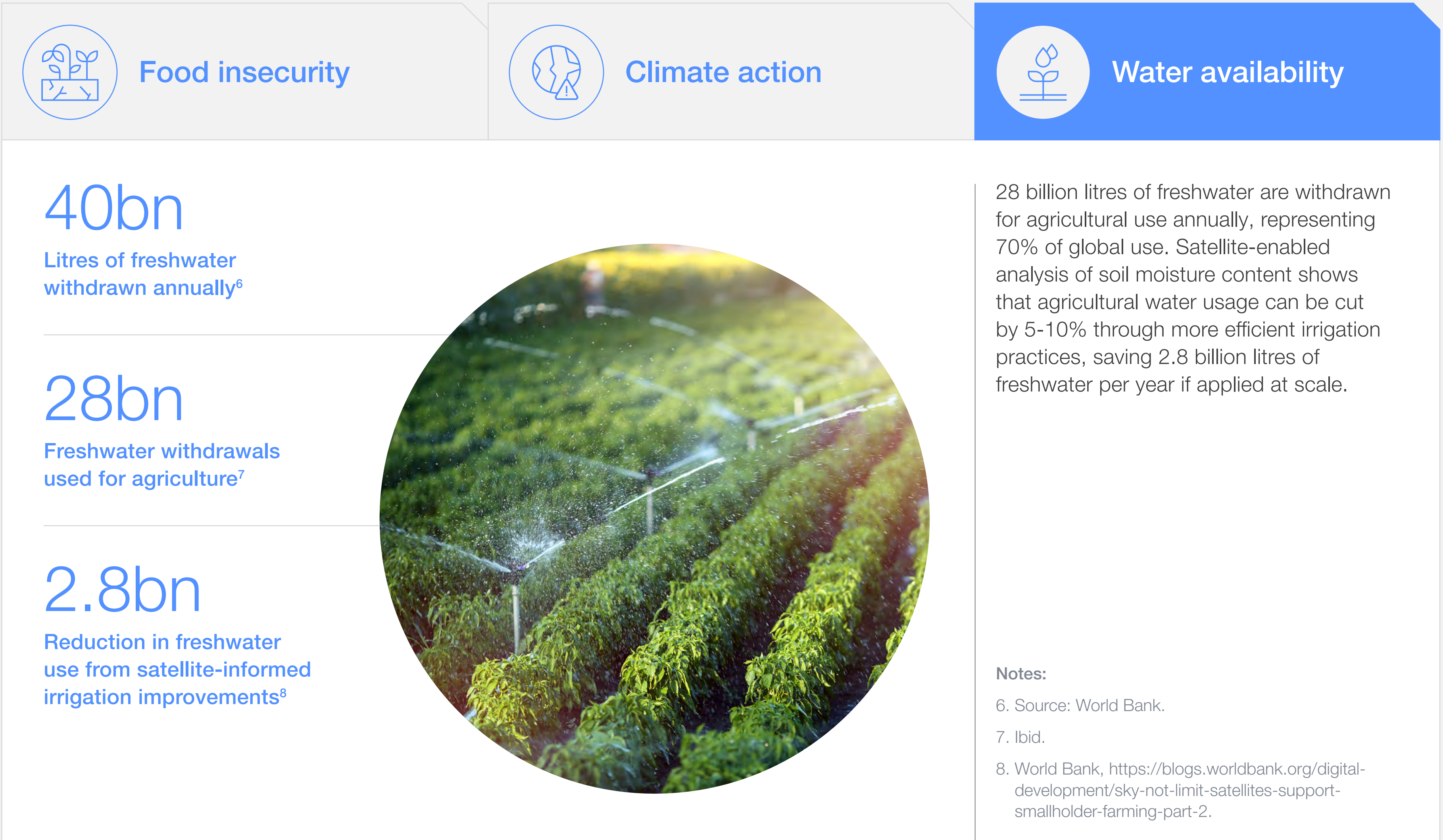
Satellite applications’ potential to address challenges in agriculture

What’s at stake?

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



Select the tabs to discover more



A satellite image of a coastal region. On the left, a river flows through a patchwork of green agricultural fields and some urban areas. The river meets the sea on the right. The sea is a deep blue-green color. Several small, dark islands are visible in the distance. A small white circle with the number '1' inside is located in the upper left quadrant of the image.

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%.

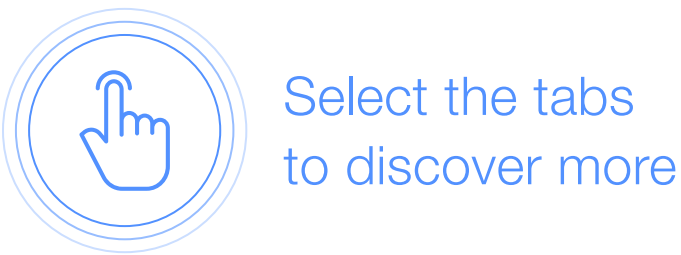
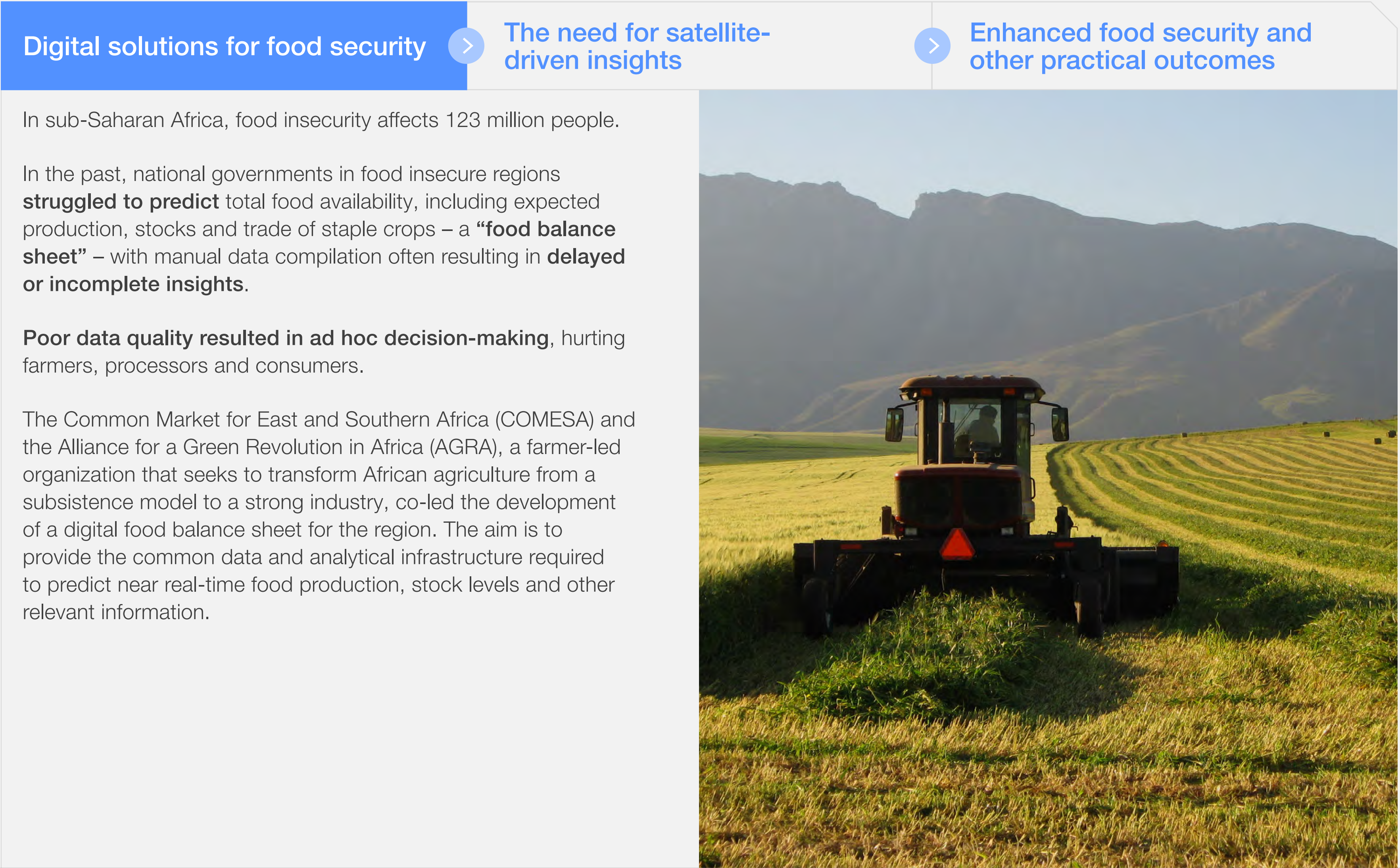


FIGURE 3
Tracking regional food balance sheets with digital, space-enabled tools in East and Southern Africa



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%.

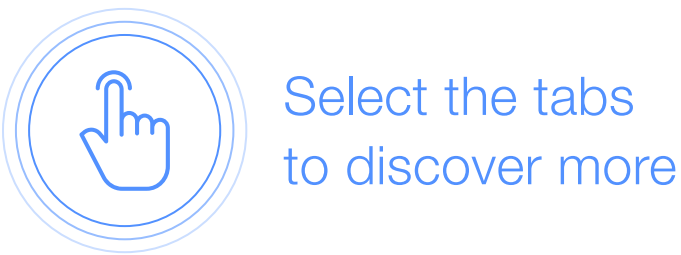


FIGURE 3
Tracking regional food balance sheets with digital, space-enabled tools in East and Southern Africa



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%.

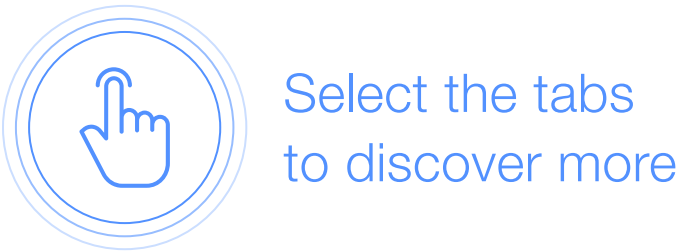


FIGURE 3
Tracking regional food balance sheets with digital, space-enabled tools in East and Southern Africa



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.

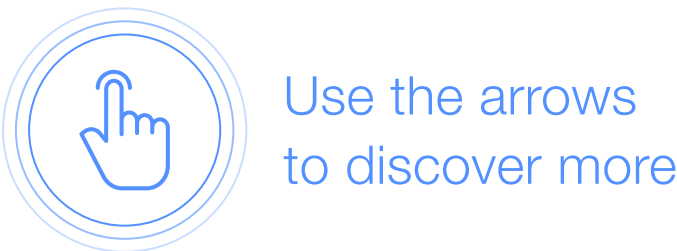
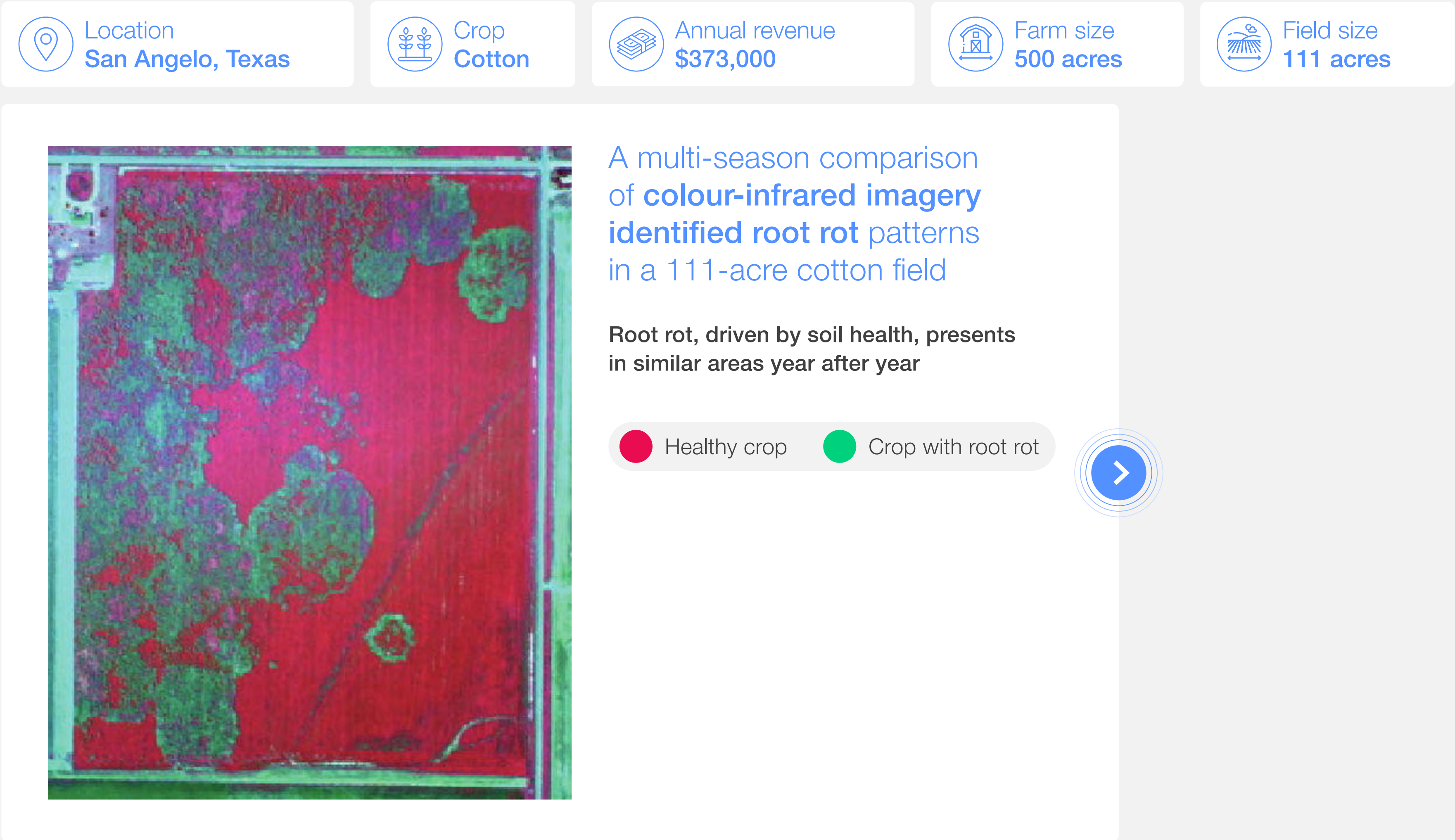


FIGURE 4

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



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.

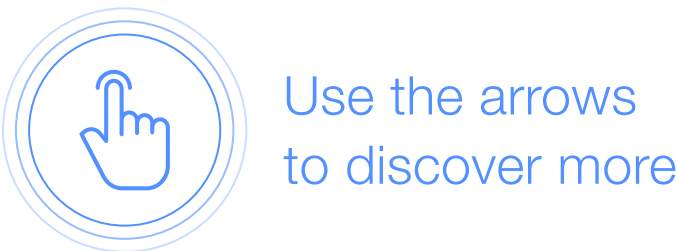
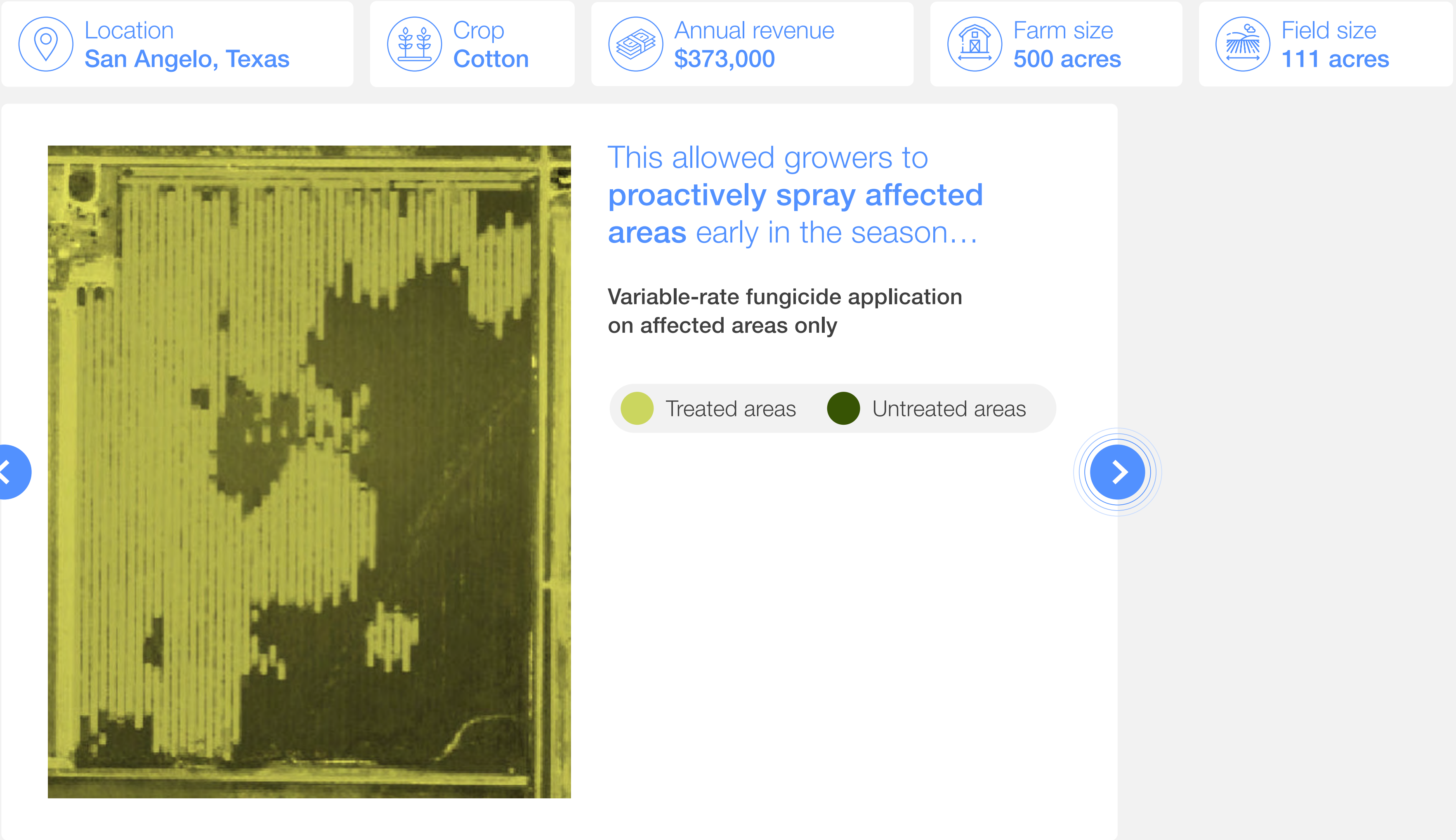


FIGURE 4
Yield optimization in action: Eliminating yield risk and decreasing costs for a cotton farm in West Texas



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.

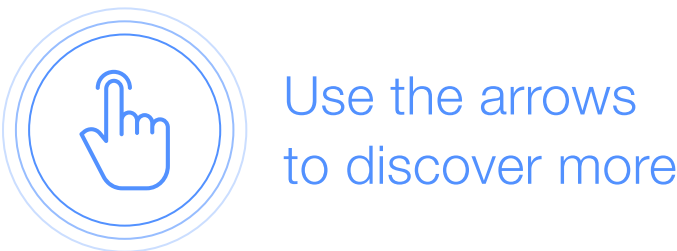
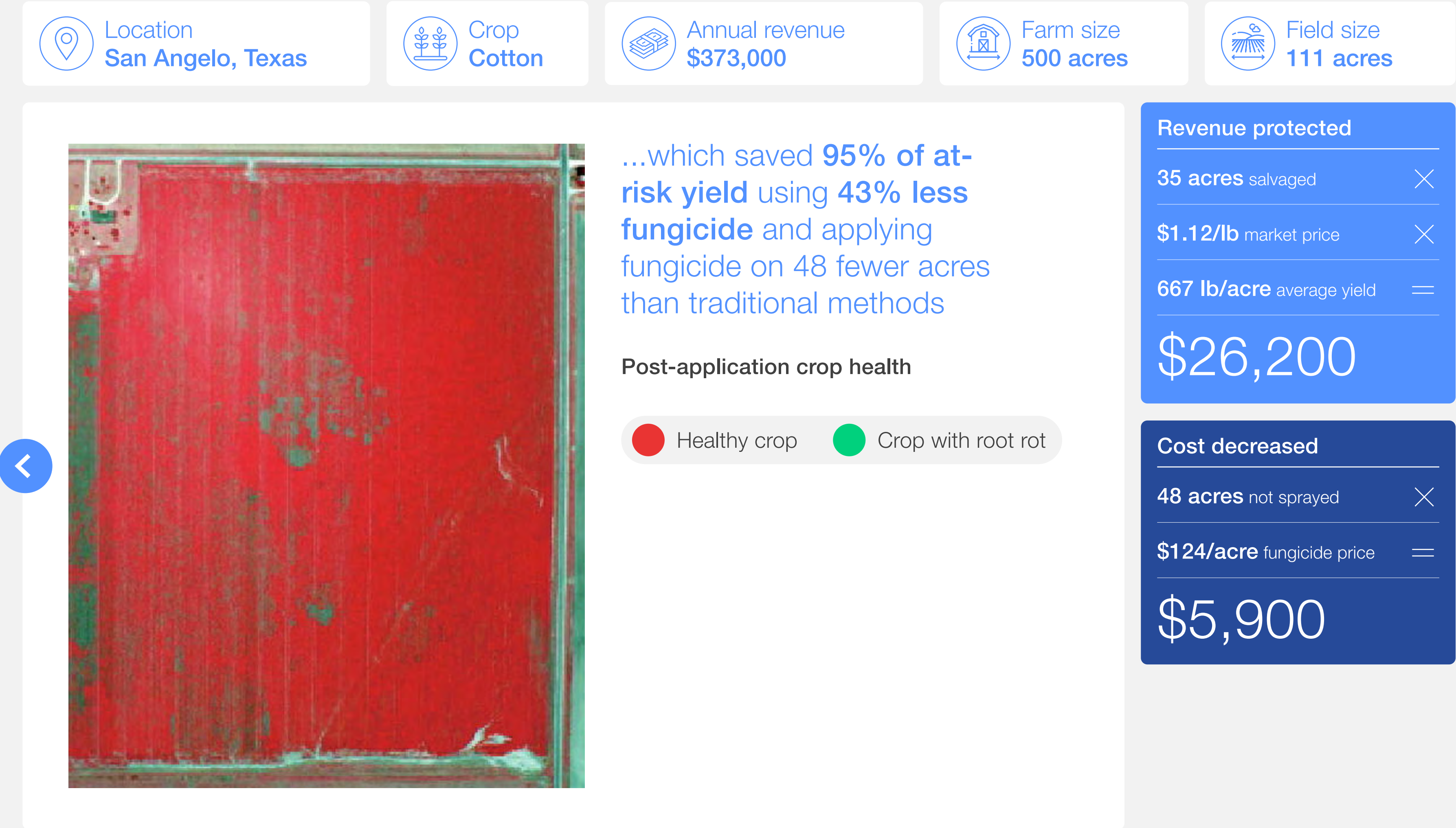


FIGURE 4
Yield optimization in action: Eliminating yield risk and decreasing costs for a cotton farm in West Texas



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).

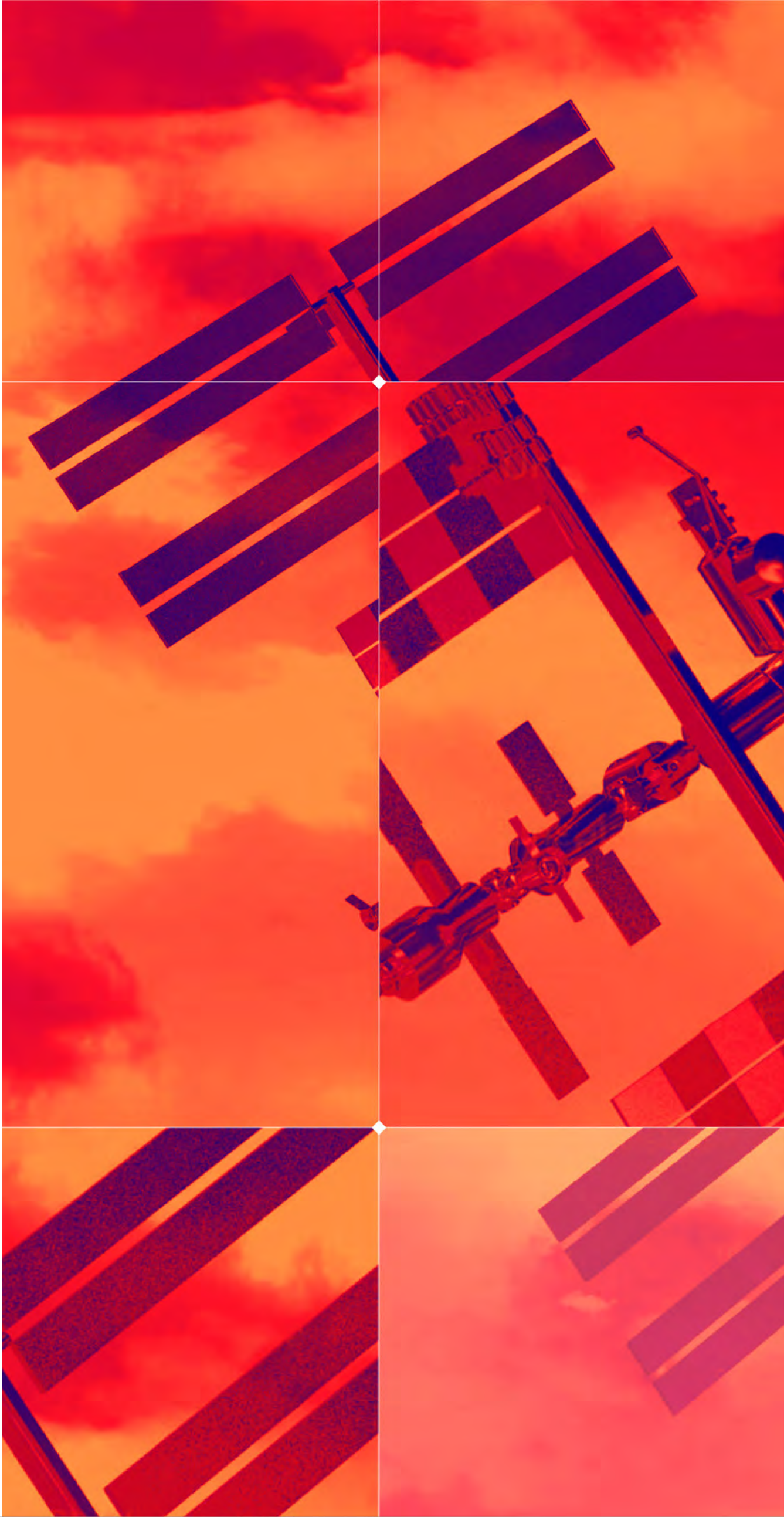


FIGURE 5

Available technology performance in core use cases

 Select the available technology tabs to compare performance

Use case		Commercial satellite <1m image resolution Prevalent 2030		Public satellite >10m image resolution (prevalent 2022)		Commercial satellite	Fixed wing	UAV
		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

Use case		Commercial satellite <1m image resolution Prevalent 2030		Public satellite	Commercial satellite	Fixed wing	UAV
		>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			

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

Use case		Commercial satellite <1m image resolution Prevalent 2030		Public satellite	Commercial satellite	Fixed wing	UAV
		~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

Use case		Commercial satellite <1m image resolution Prevalent 2030		Public satellite	Commercial satellite	Fixed wing	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			
	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.

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.

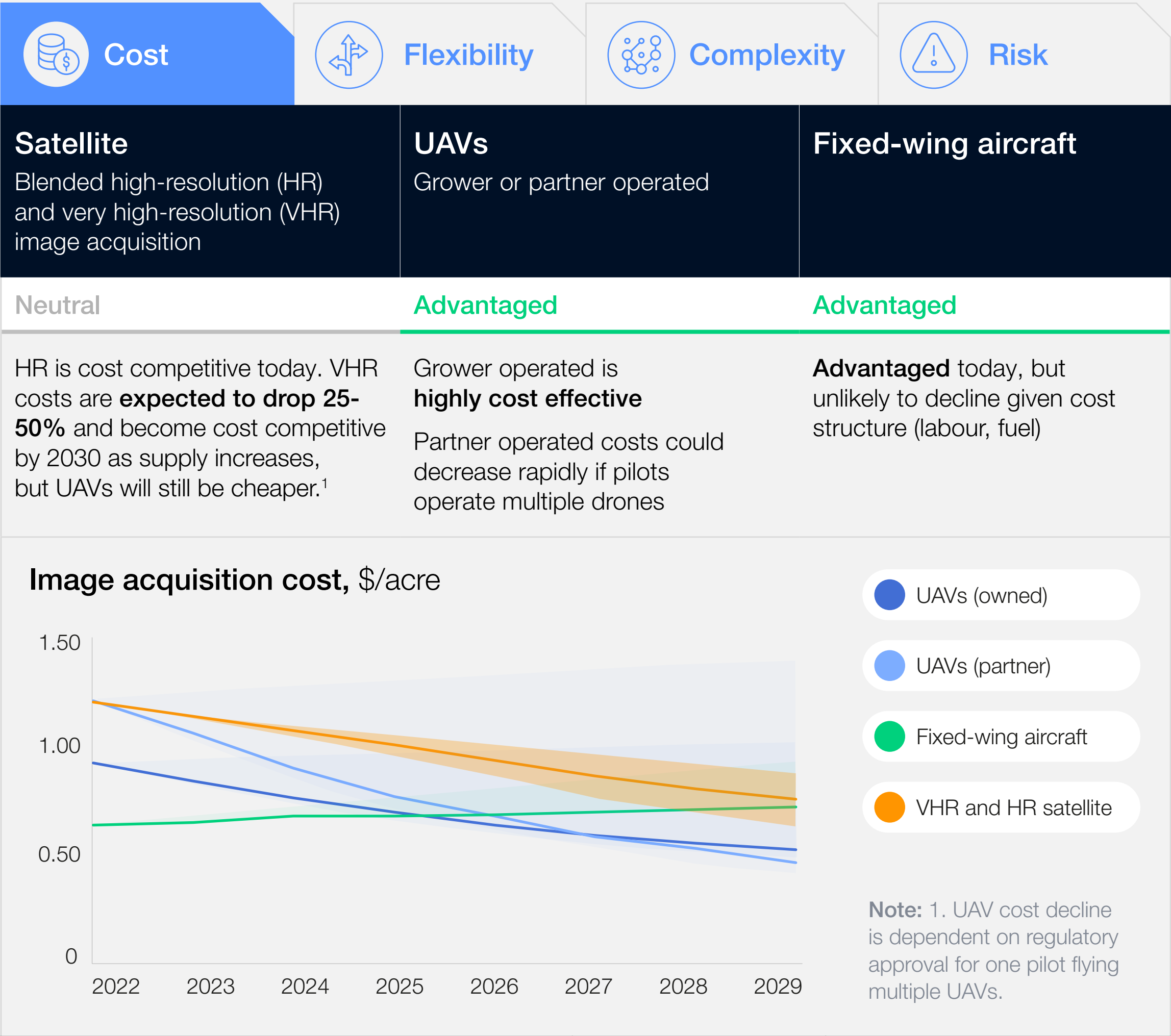
In addition to cost, insights providers consider flexibility of imagery acquisition, operating complexity and the risks associated with the investment in each imagery source (Figure 6). Satellite imagery is the most flexible and least complex option for providers, but it has risks; for example, cloud 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



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.

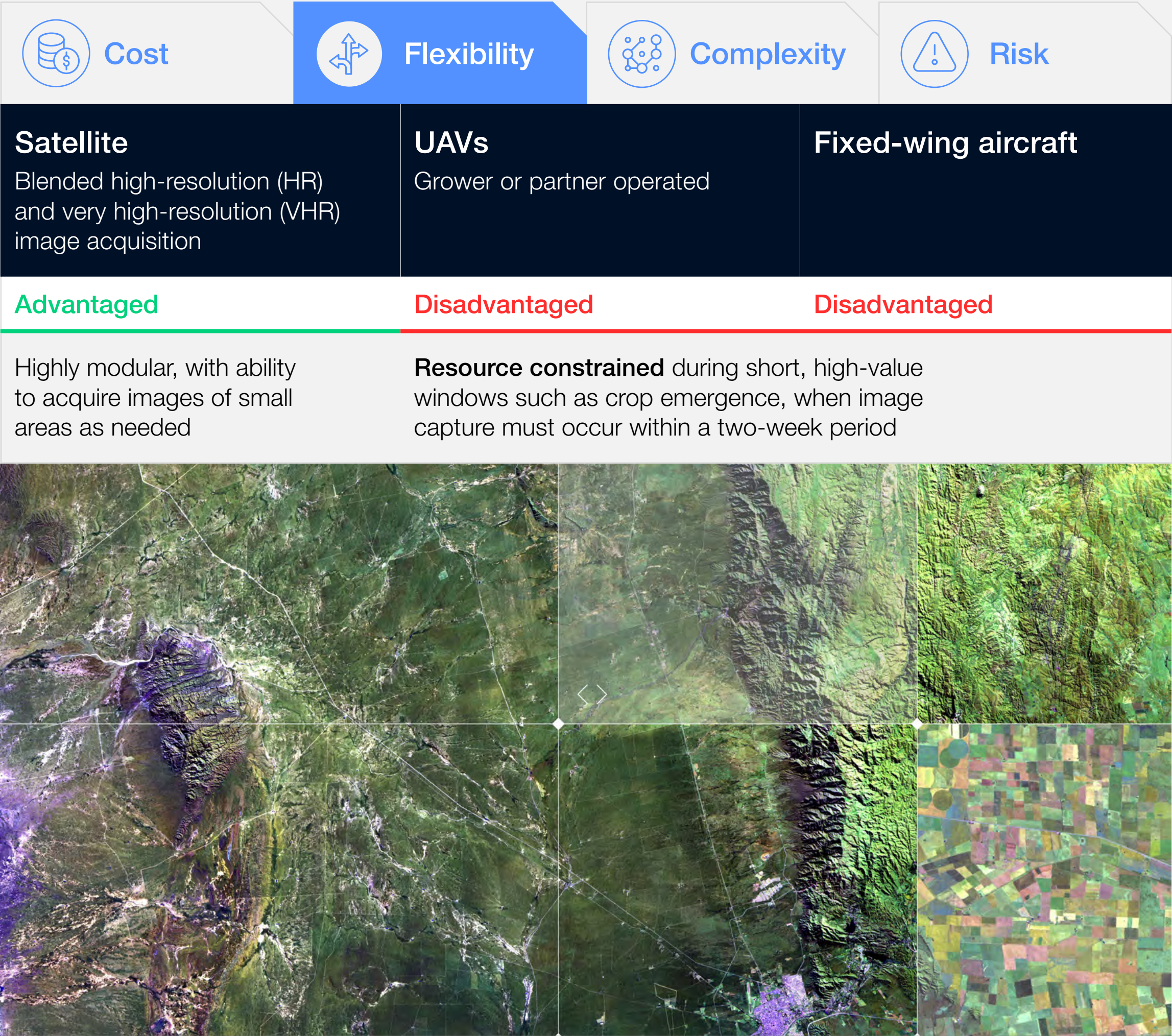
In addition to cost, insights providers consider flexibility of imagery acquisition, operating complexity and the risks associated with the investment in each imagery source (Figure 6). Satellite imagery is the most flexible and least complex option for providers, but it has risks; for example, cloud 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



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.

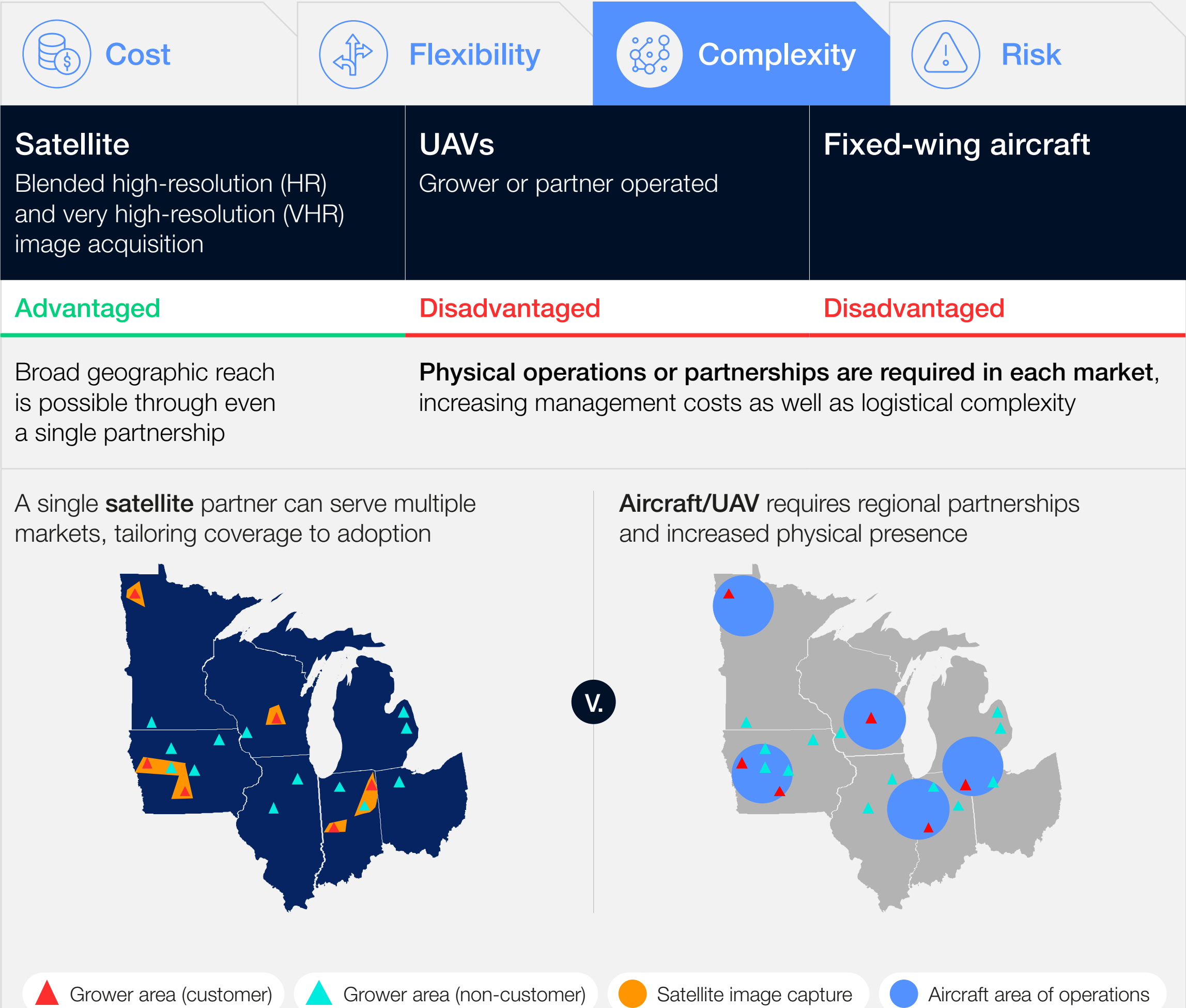
In addition to cost, insights providers consider flexibility of imagery acquisition, operating complexity and the risks associated with the investment in each imagery source (Figure 6). Satellite imagery is the most flexible and least complex option for providers, but it has risks; for example, cloud 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



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	
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	



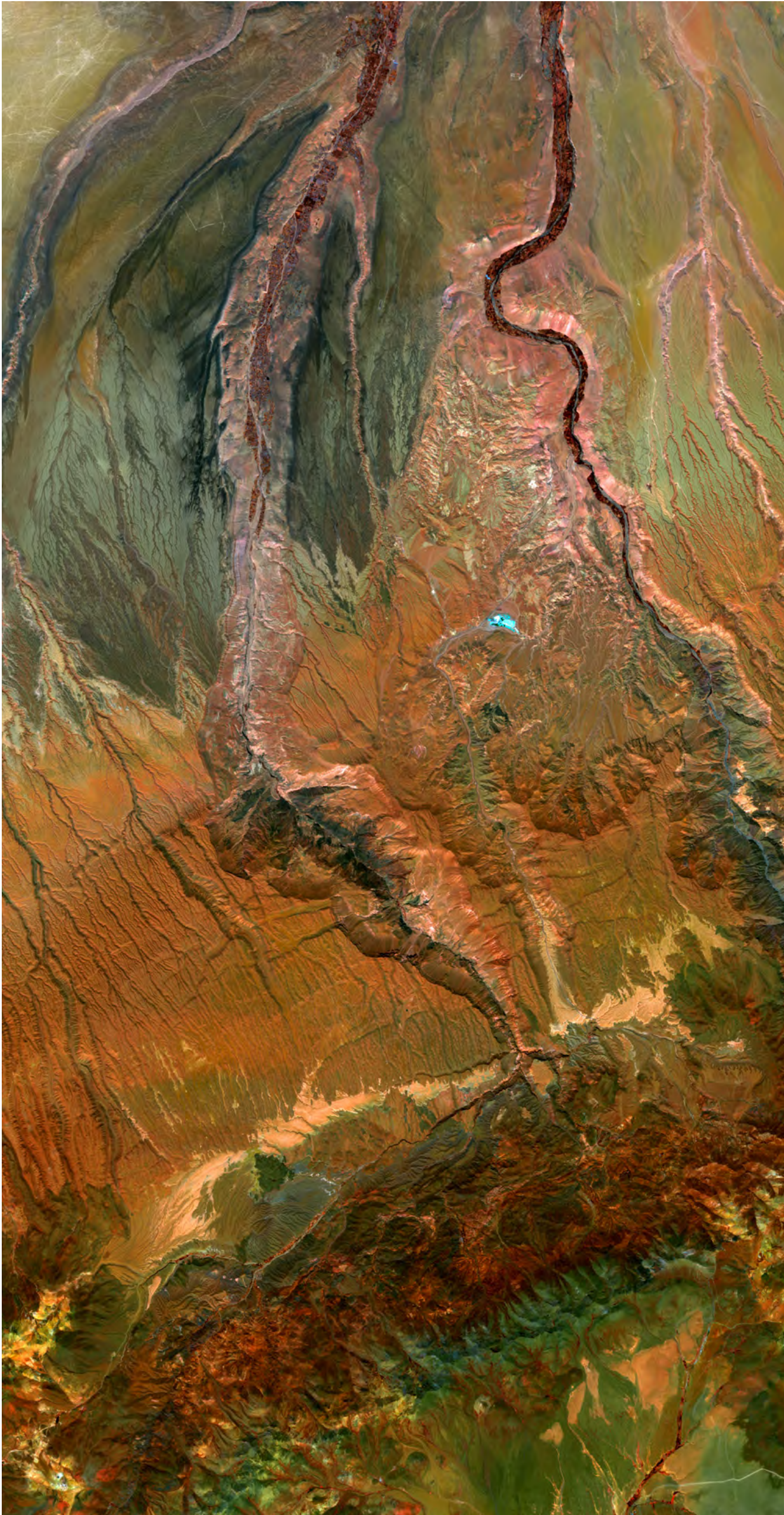
Customer expansion

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.



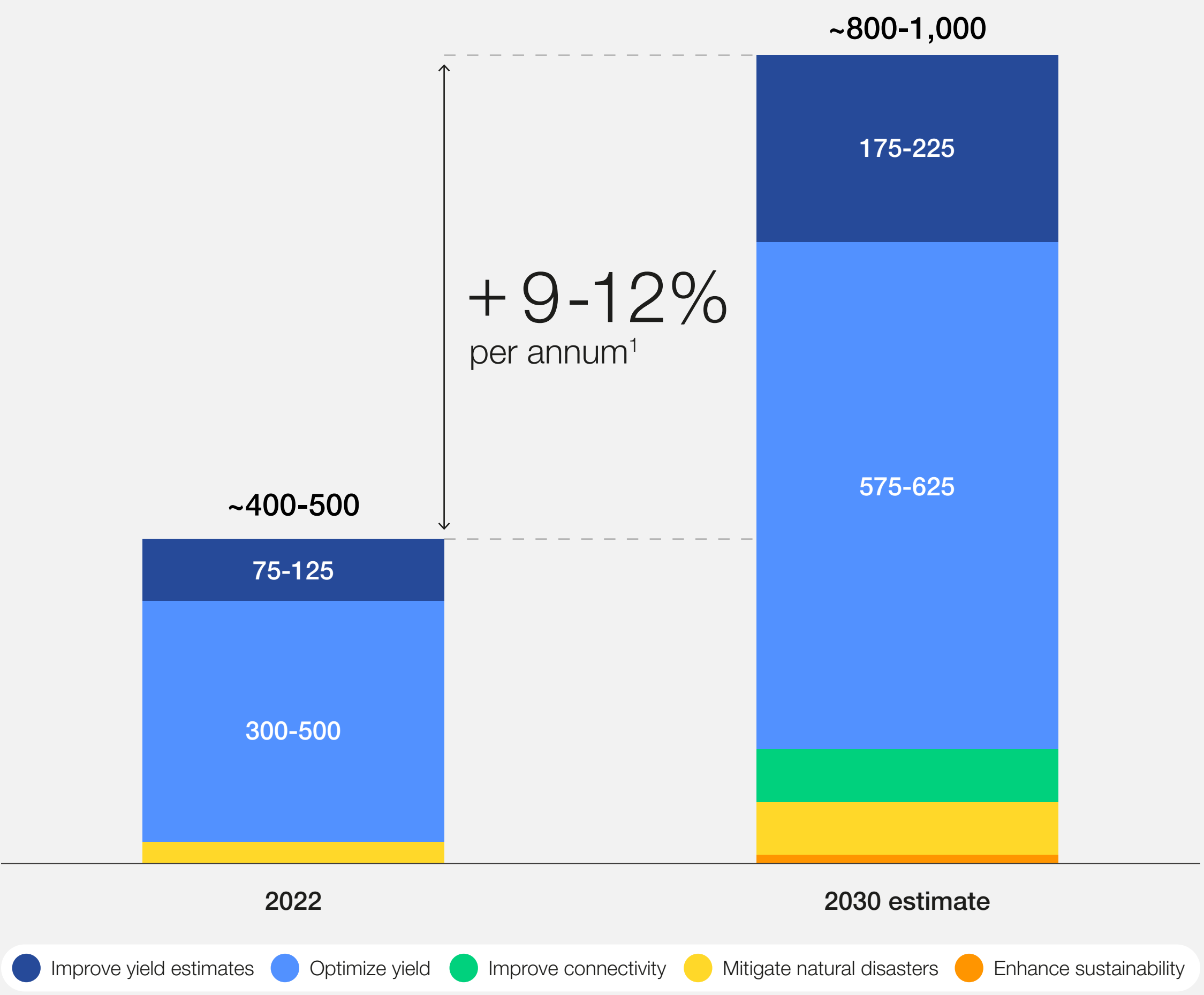
3

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)

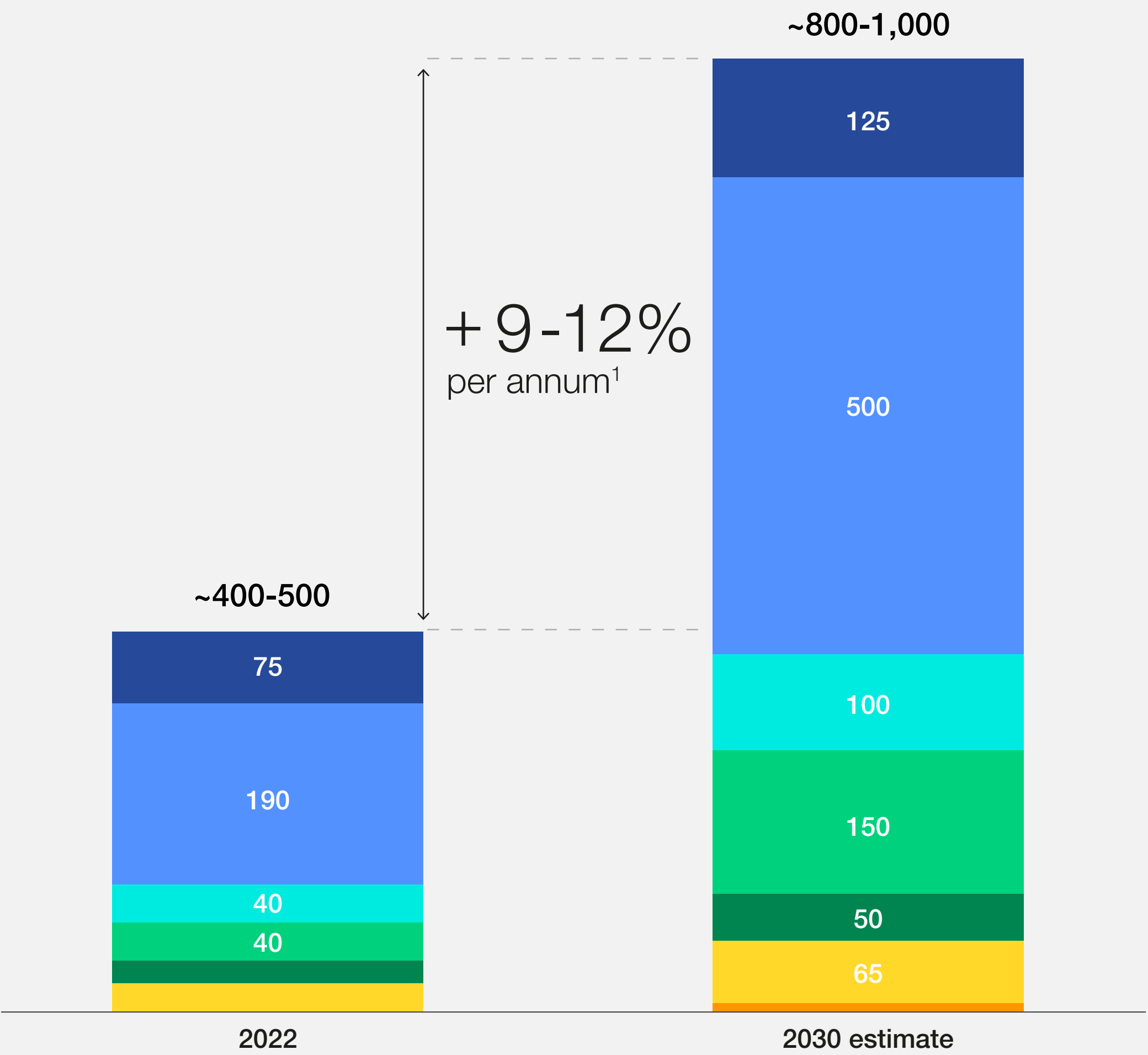


Note: 1. If hurdles are addressed and adoption accelerates.
Source: World Economic Forum and McKinsey analysis informed by expert interviews and industry publications (e.g. Northern Sky Research).

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).

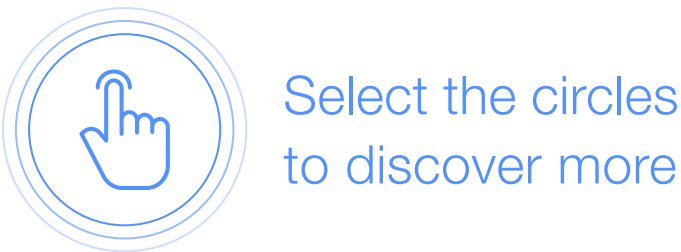
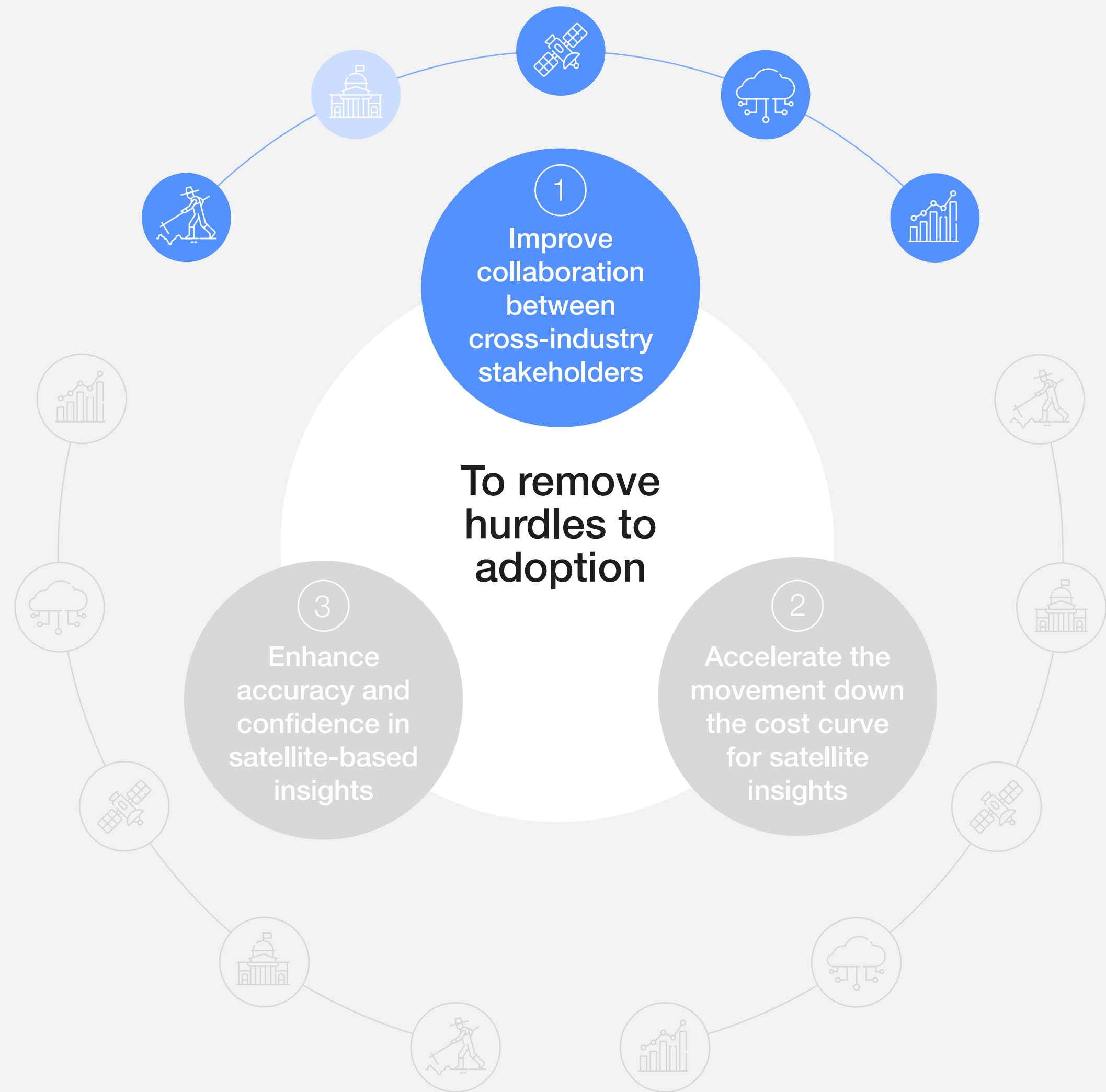


FIGURE 9
Calls to action to address hurdles



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

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).

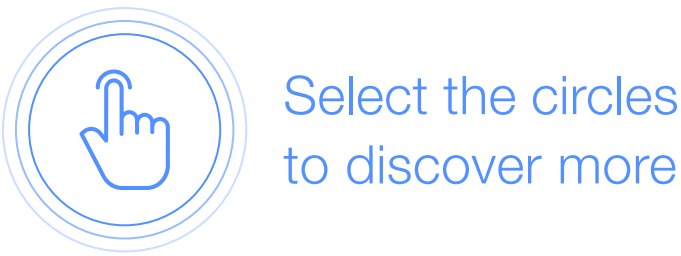


FIGURE 9
Calls to action to address hurdles



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

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).

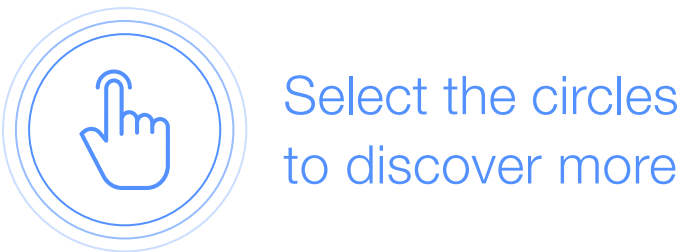
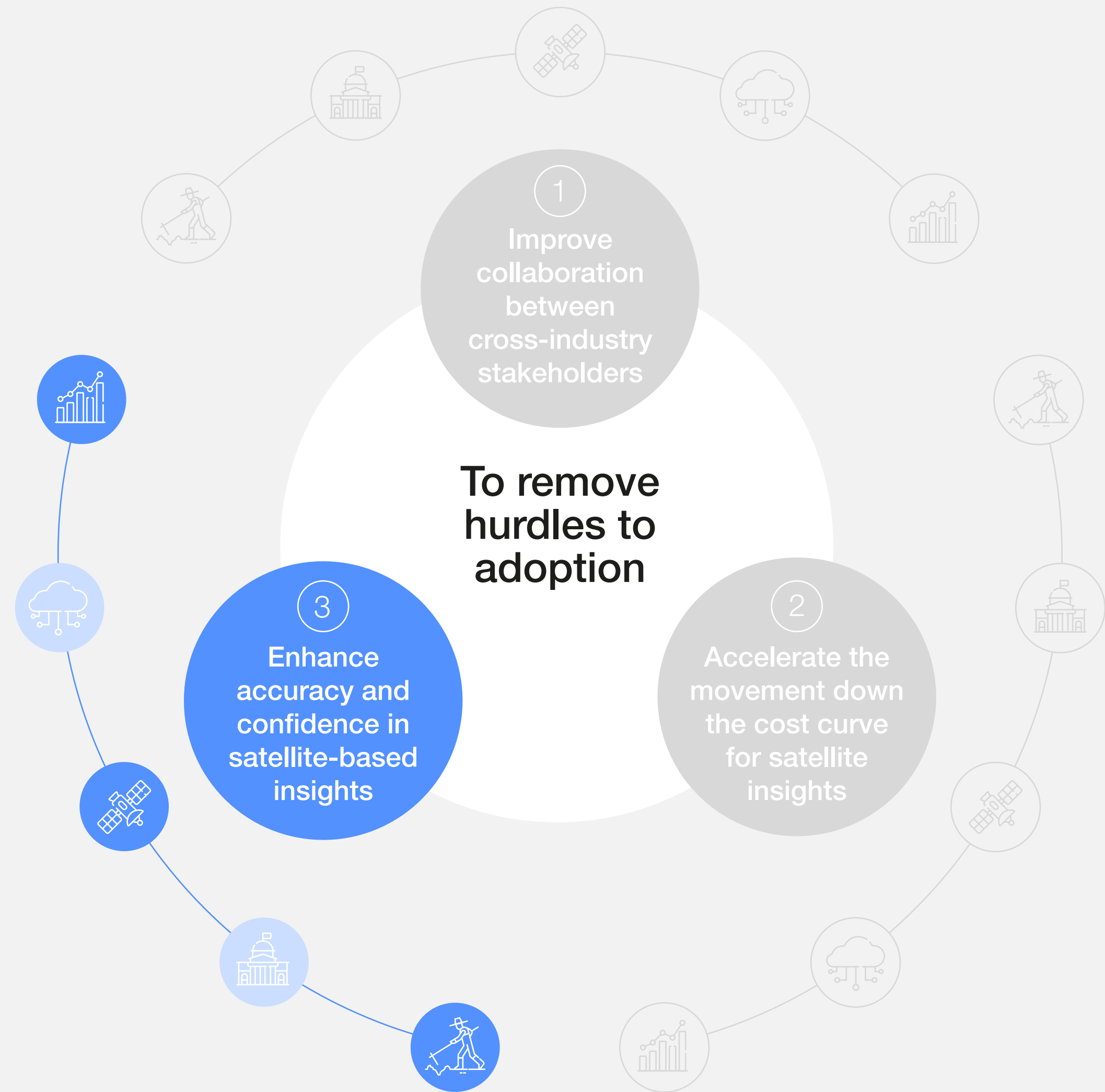


FIGURE 9
Calls to action to address hurdles



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

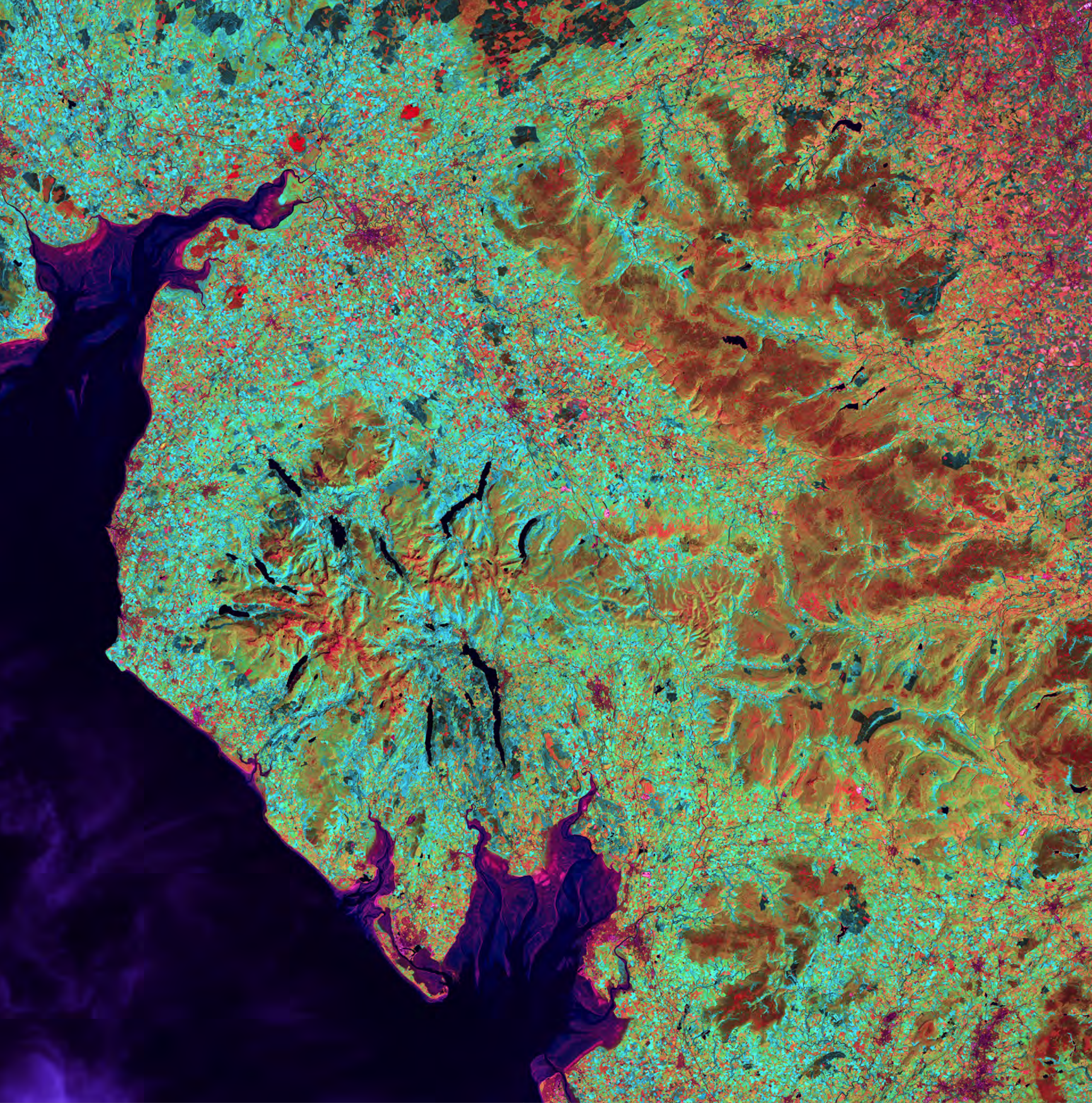
Satellite and analytics providers can improve accuracy and confidence by involving users in their technology development roadmaps, ensuring a tight linkage between user needs and insights provided. Offering transparency into how insights are derived, highlighting where they are most accurate or fall 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.

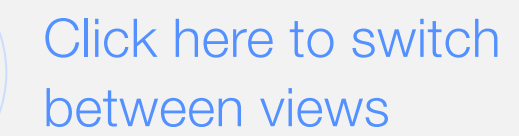
Such collaboration is not simple, involving five or more industries at varying stages of the user lifecycle. Satellite companies should

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.



Comparison of free versus commercially available satellite data



Public

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

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.

World Economic Forum

Nikolai Khlystov
Lead, Future of Space, World Economic Forum, Switzerland

Minoo Rathnasabapathy
Research Engineer, MIT Media Lab, Massachusetts Institute of Technology (MIT), USA, and Project Fellow, Future of Space, World Economic Forum, Switzerland

Federico Ronca
Community Specialist, Food Systems Initiative, World Economic Forum, Switzerland

McKinsey & Company

Nicolas Bellemans
Management Consultant, Brussels, Belgium

Ryan Brukardt
Senior Partner, Miami, USA

Sarah Catalano
Management Consultant, San Francisco, USA

Ryan Degnan
Management Consultant, Denver, USA

Ryan McCullough
Partner, Denver, USA

Production

Studio Miko

Phoebe Barker
Lead Designer

Laurence Denmark
Creative Director

Editing

Madhur Singh
Editor

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.