The Role of Emerging Technology in Forest Science, Ecosystem Stewardship & Stakeholder Engagement

Forest Ecosystem Monitoring Cooperative
2022 Annual Conference
University of Vermont, Burlington VT

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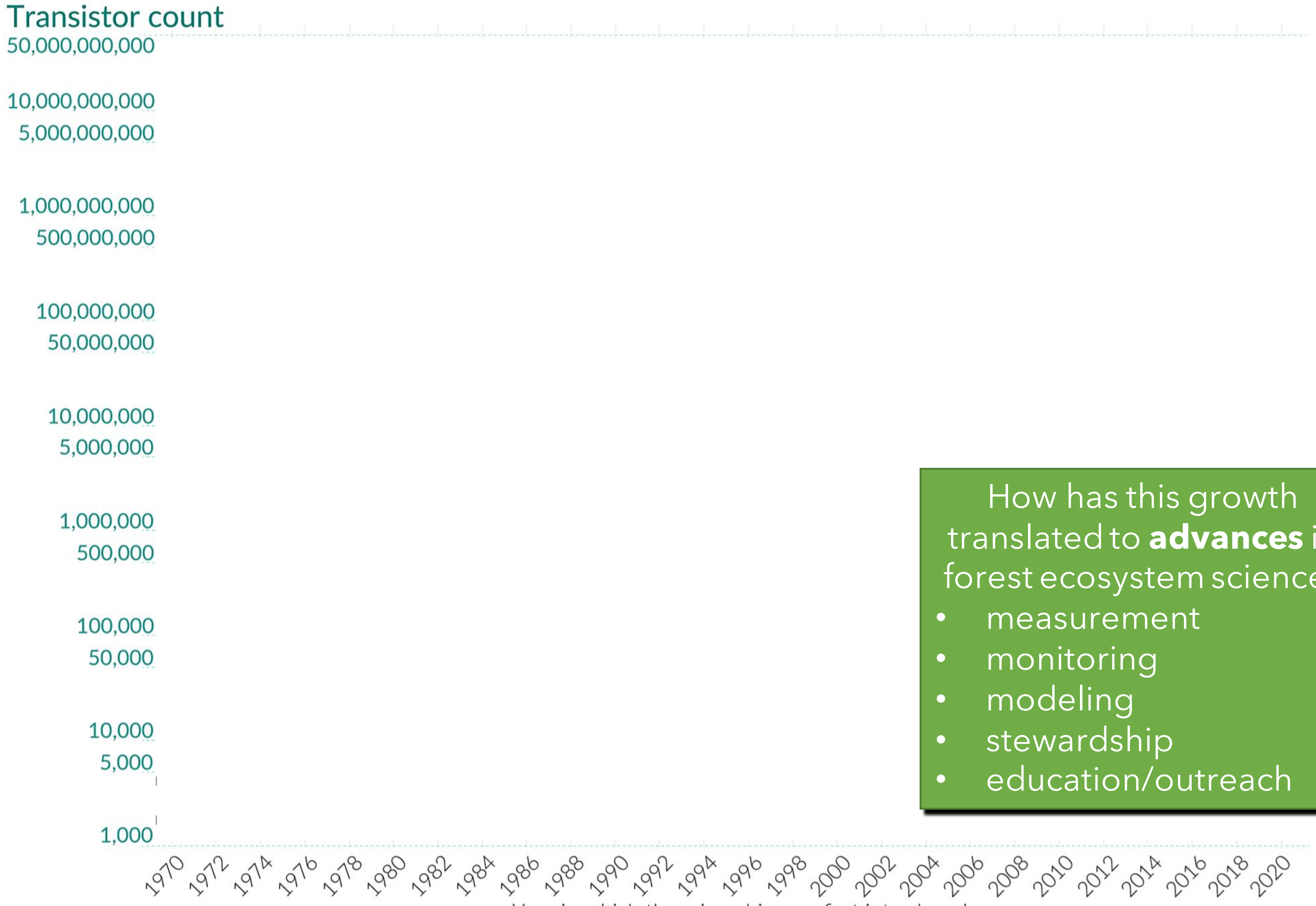
Associate Professor
SUNY ESF

Moore's Law

Microchip processing capacity doubles every 1-2 years

Five decades of exponential growth in computing power

Will Moore's Law hold for a sixth decade?



Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)

OurWorldinData.org – Research and data to make progress against the world's largest problems.

How has this growth translated to **advances** in forest ecosystem science?

- measurement
- monitoring
- modeling
- stewardship
- education/outreach

A brief history of forest measurement tech

If you cannot measure it,
you cannot improve it.
Lord Kelvin

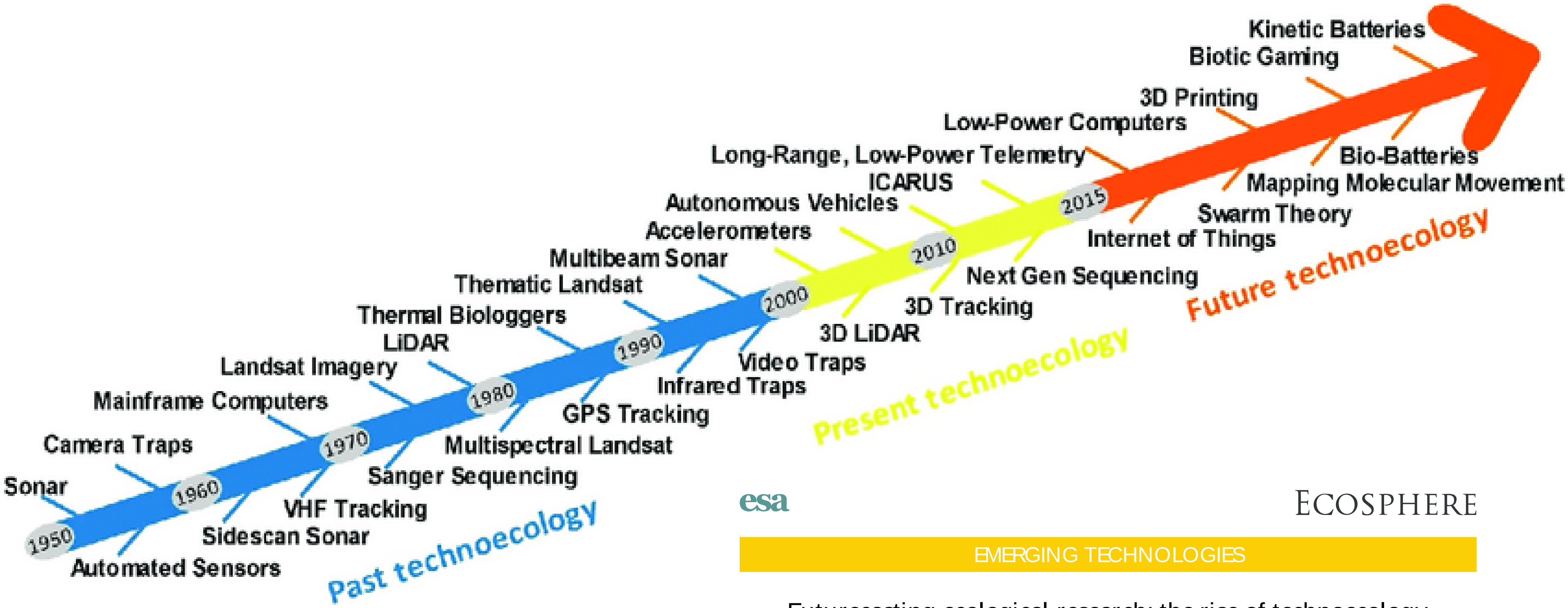
- 1889 — Increment Borer (Pressler)
- 1889 — Clinometer (Melick)
- 1890 — Biltmore Stick (Schenck)
- 1894 — Pocket Transit Compass (Brunton)
- 1920 — Aerial Photography (Fairchild)
- 1939 — Wedge Prism Angle Gauge (Bitterlich)
- 1957 — Spherical Densiometer (Lemmon)
- 1965 — Laser Rangefinder (Barr & Stroud)
- 1972 — Satellite Imagery (Landsat)
- 1993 — Global Positioning Systems (USAF)
- 1994 — Airborne LIDAR
- 1998 — Terrestrial Laser Scanning
- 2007 — UAVs for civilian use

~230 BC: $\pi = 3.14$ (Archimedes)
1821: metal tape (Chesterman)
1868: circular case with locking mechanism (Fellows)

Not tech averse but …

…"if it ain't broke, don't fix it."

A 'techno-ecological' timeline & 'futurecast'…



esa ECOSPHERE

EMERGING TECHNOLOGIES

Futurecasting ecological research: the rise of technoecology

Blake M. Allan,[1] Dale G. Nimmo,[2] Daniel Ierodiaconou,[3] Jeremy VanDerWal,[4,5]
Lian Pin Koh,[6] and Euan G. Ritchie[1,]

Allan et al. (2018). Ecosphere. 9.10.1002/ecs2.2163.

Big questions…

Does new tech yield better data than what we already have? Or is it a distraction from basic knowledge gaps and (in)ability to engage broader audiences?

How will new tech interface with existing protocols? Are new frameworks needed? Is progress worth the upheaval? How to avoid sunk cost fallacy?

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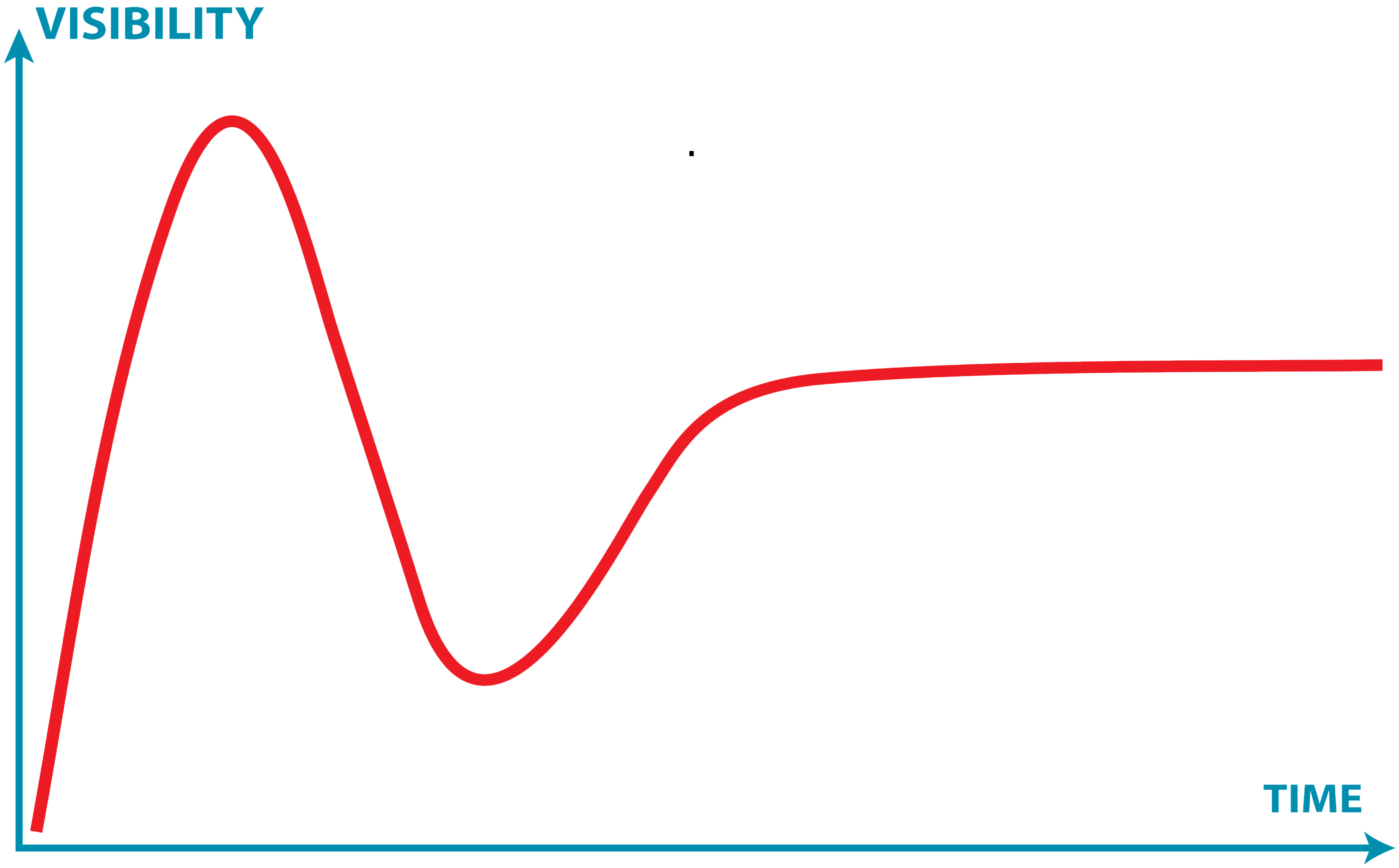
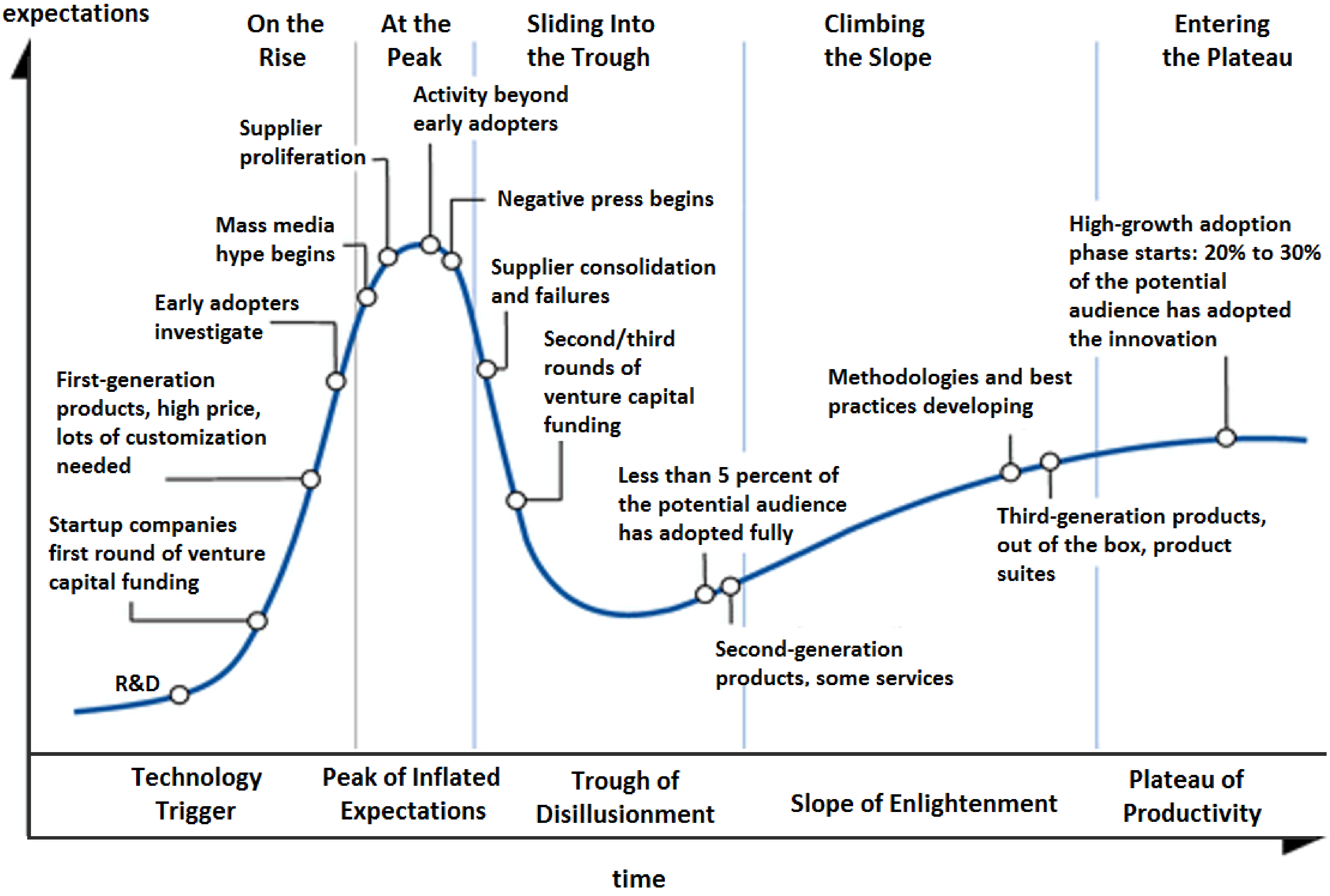
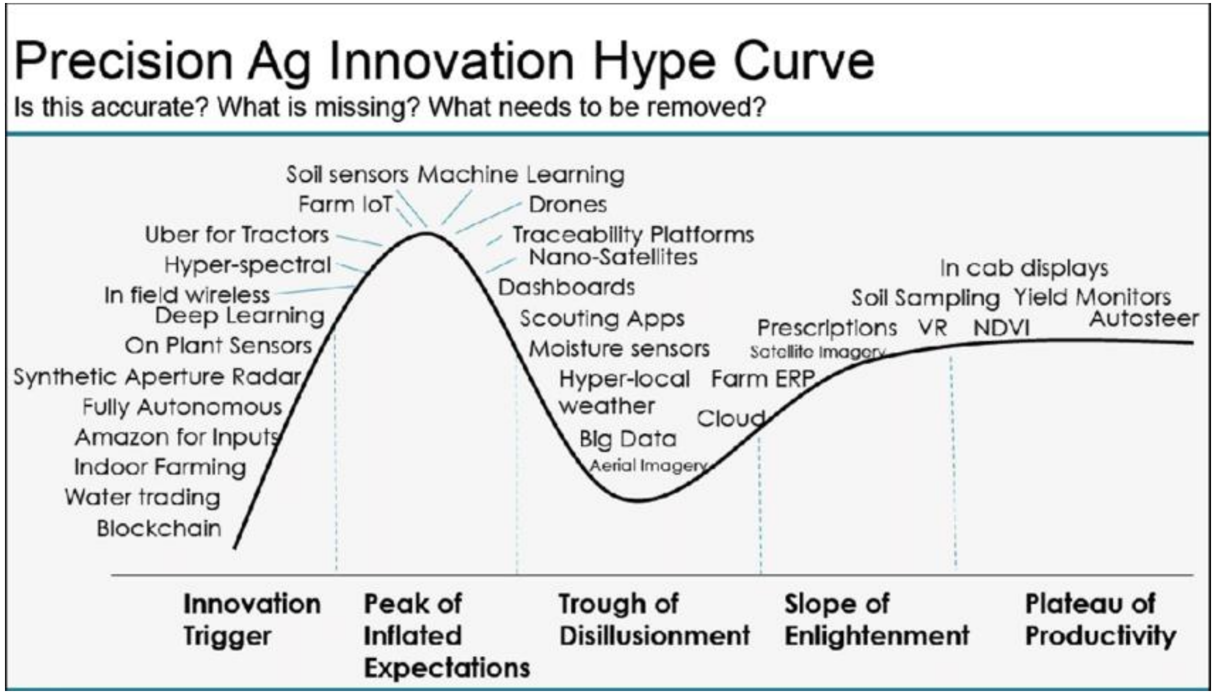
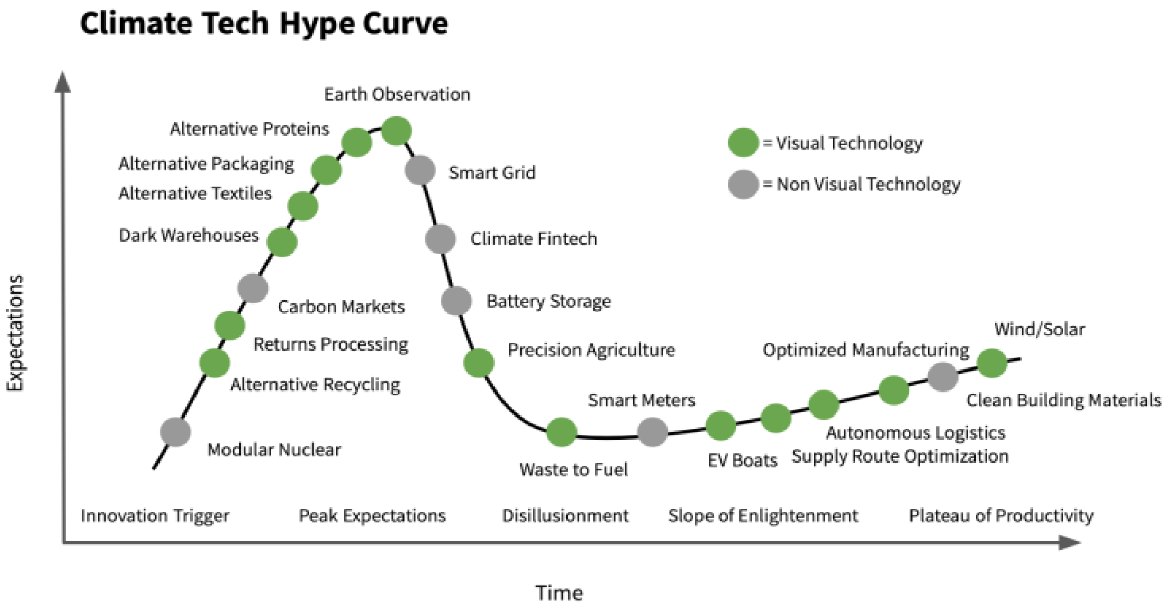
The Gartner Hype Cycle

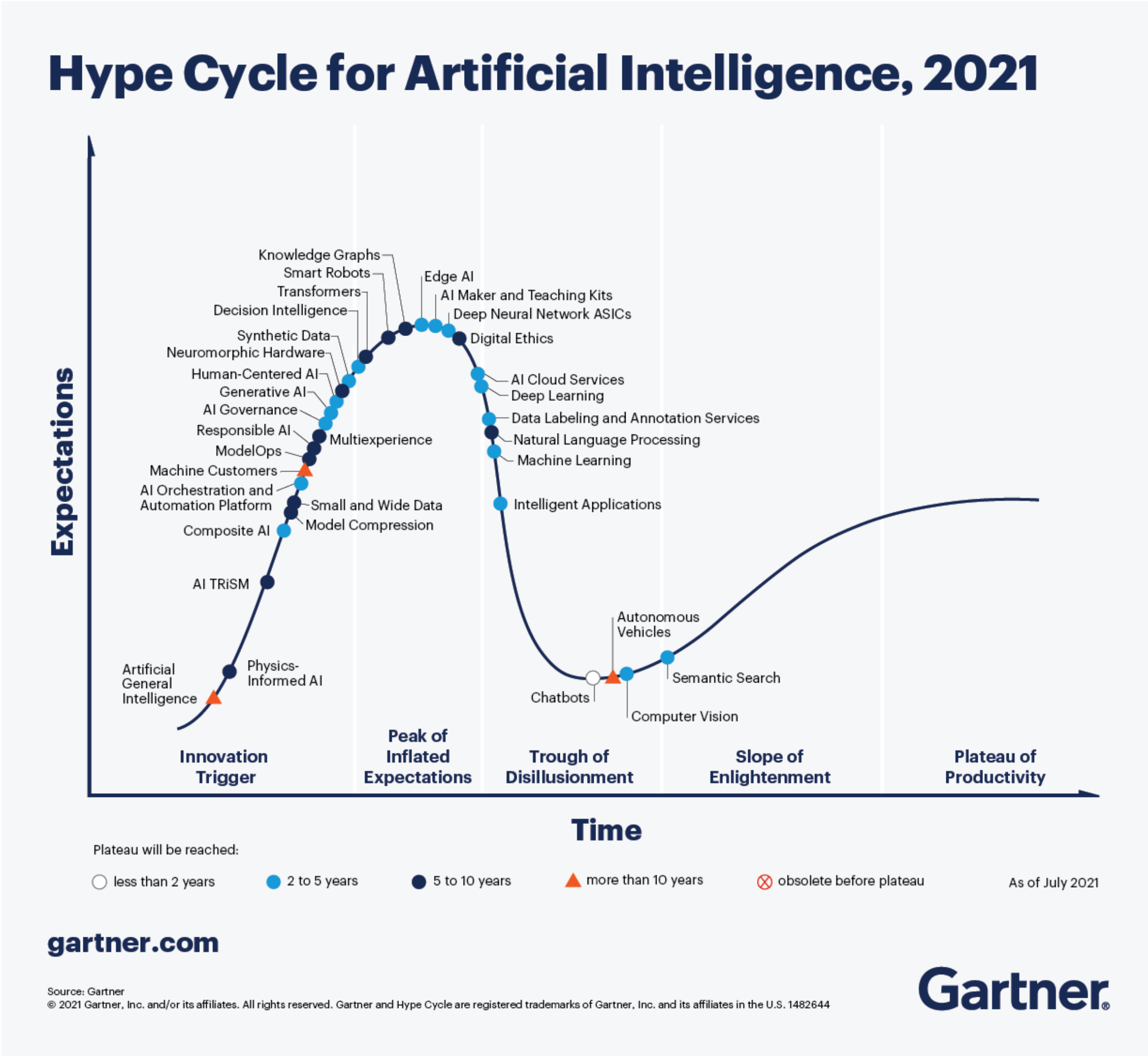


The Gartner Hype Cycle




Precision Ag Innovation Hype Curve
Is this accurate? What is missing? What needs to be removed?
Soil sensors
Machine Learning
Farm IoT
Drones
Uber for Tractors
Traceability Platforms
Nano-Satellites
Hyper-spectral
Dashboards
In field wireless
Deep Learning
Scouting Apps
On Plant Sensors
Moisture sensors
Synthetic Aperture Radar
Hyper-local weather
Farm ERP
Fully Autonomous
Cloud
Amazon for Inputs
Big Data
Aerial Imagery
Indoor Farming
Water trading
Blockchain
In cab displays
Soil Sampling
Yield Monitors
Autosteer
Prescriptions
VR
NDVI
Satellite imagery
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity


Climate Tech Hype Curve
Earth Observation
Alternative Proteins
Alternative Packaging
Alternative Textiles
Dark Warehouses
Carbon Markets
Returns Processing
Alternative Recycling
Modular Nuclear
Smart Grid
Climate Fintech
Battery Storage
Precision Agriculture
Smart Meters
Waste to Fuel
EV Boats
Supply Route Optimization
Autonomous Logistics
Optimized Manufacturing
Wind/Solar
Clean Building Materials
= Visual Technology
= Non Visual Technology
Expectations
Innovation Trigger
Peak Expectations
Disillusionment
Slope of Enlightenment
Plateau of Productivity
Time


Hype Cycle for Artificial Intelligence, 2021
Expectations
Knowledge Graphs
Smart Robots
Transformers
Decision Intelligence
Synthetic Data
Neuromorphic Hardware
Human-Centered AI
Generative AI
AI Governance
Responsible AI
ModelOps
Machine Customers
AI Orchestration and Automation Platform
Composite AI
AI TRiSM
Artificial General Intelligence
Physics-Informed AI
Edge AI
AI Maker and Teaching Kits
Deep Neural Network ASICs
Digital Ethics
AI Cloud Services
Deep Learning
Data Labeling and Annotation Services
Natural Language Processing
Machine Learning
Multiexperience
Small and Wide Data
Model Compression
Intelligent Applications
Autonomous Vehicles
Semantic Search
Chatbots
Computer Vision
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
Time
Plateau will be reached:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau
As of July 2021
gartner.com
Source: Gartner
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Gartner

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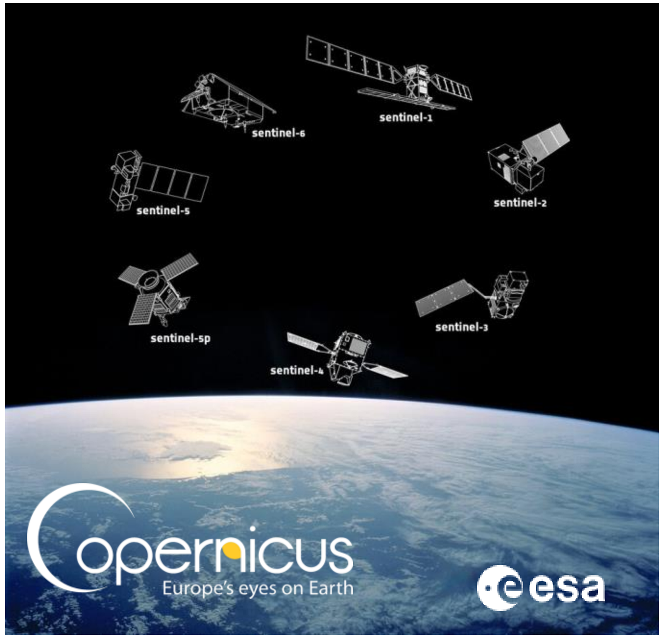
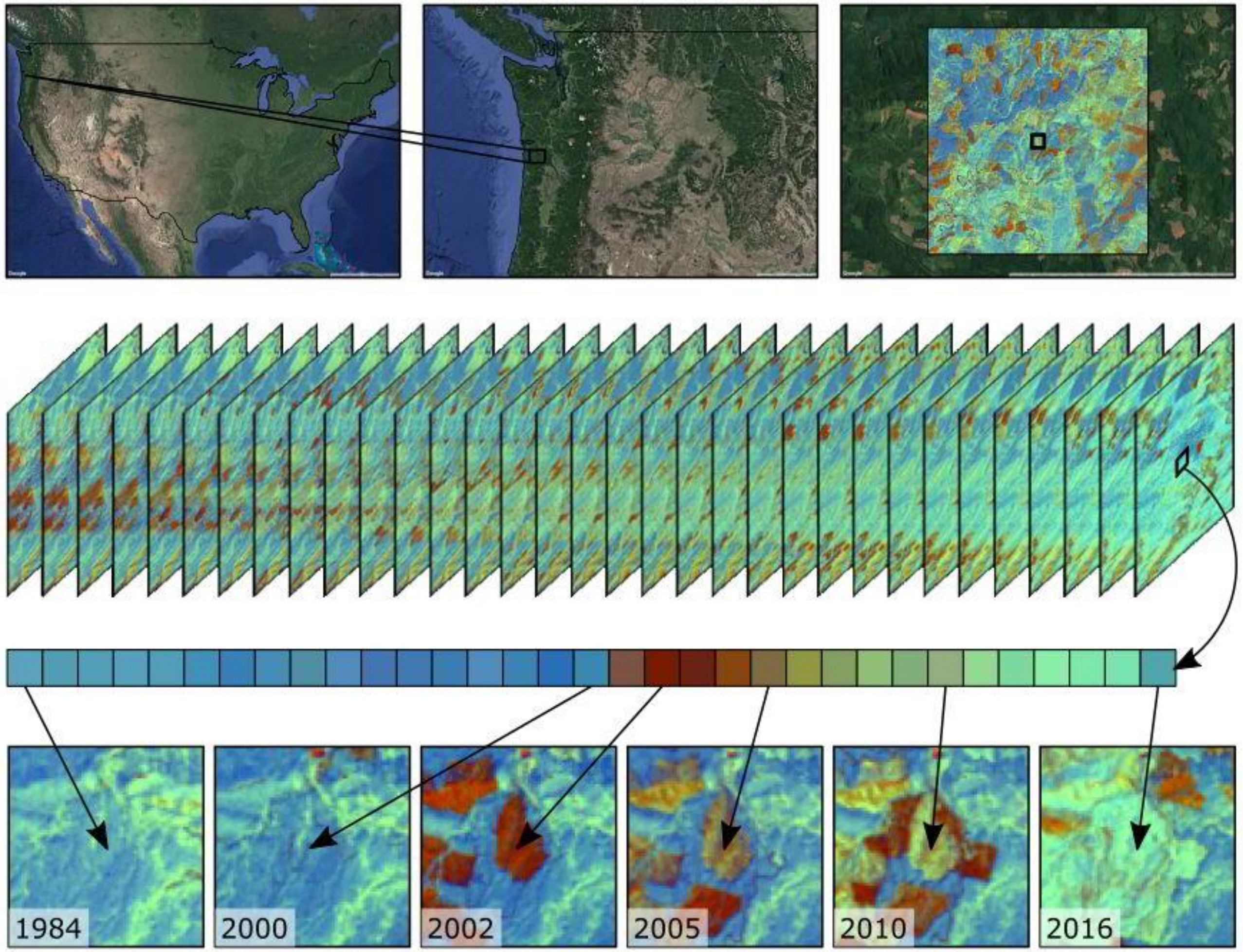
Remote sensing: monitoring forests from afar

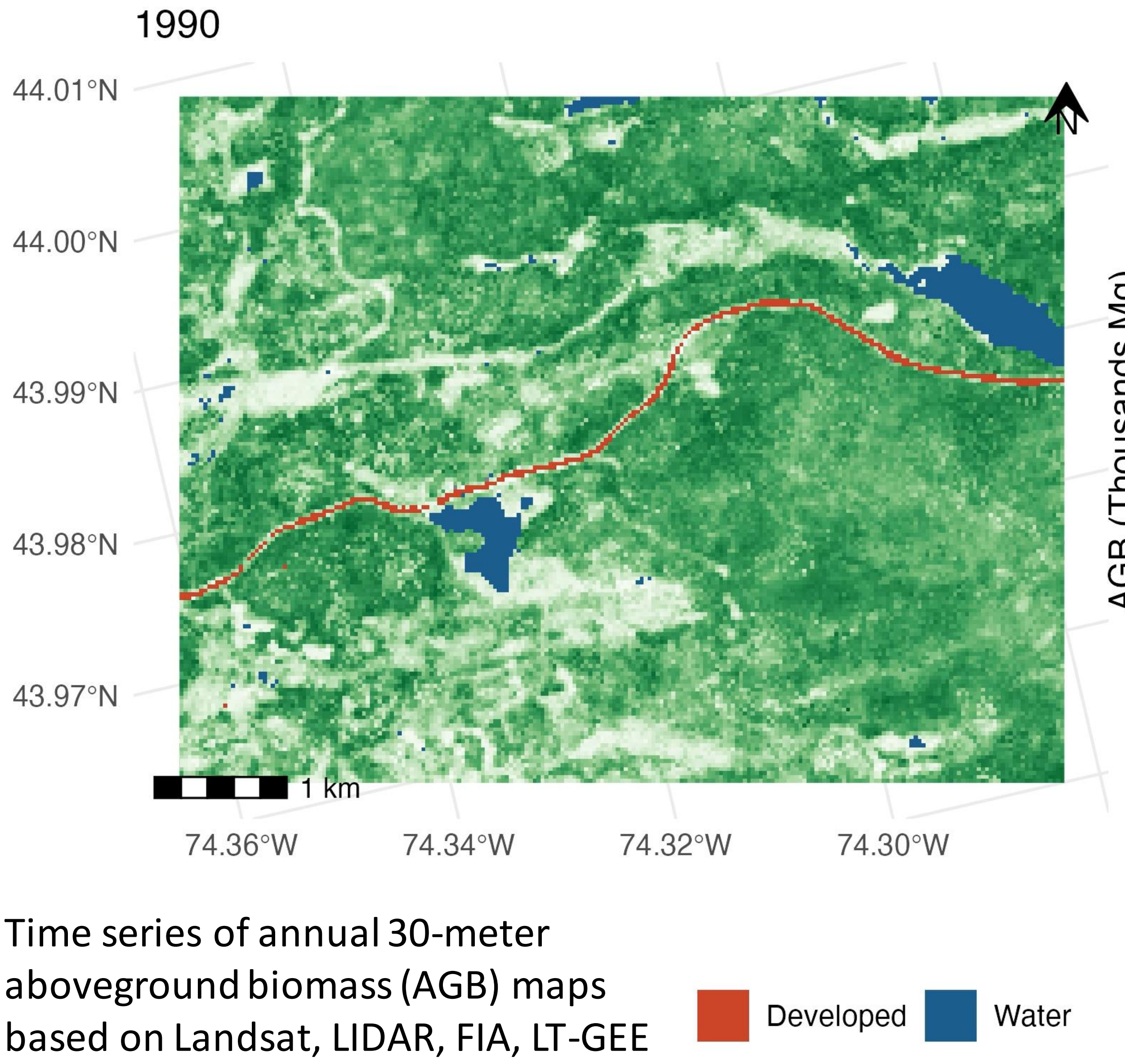


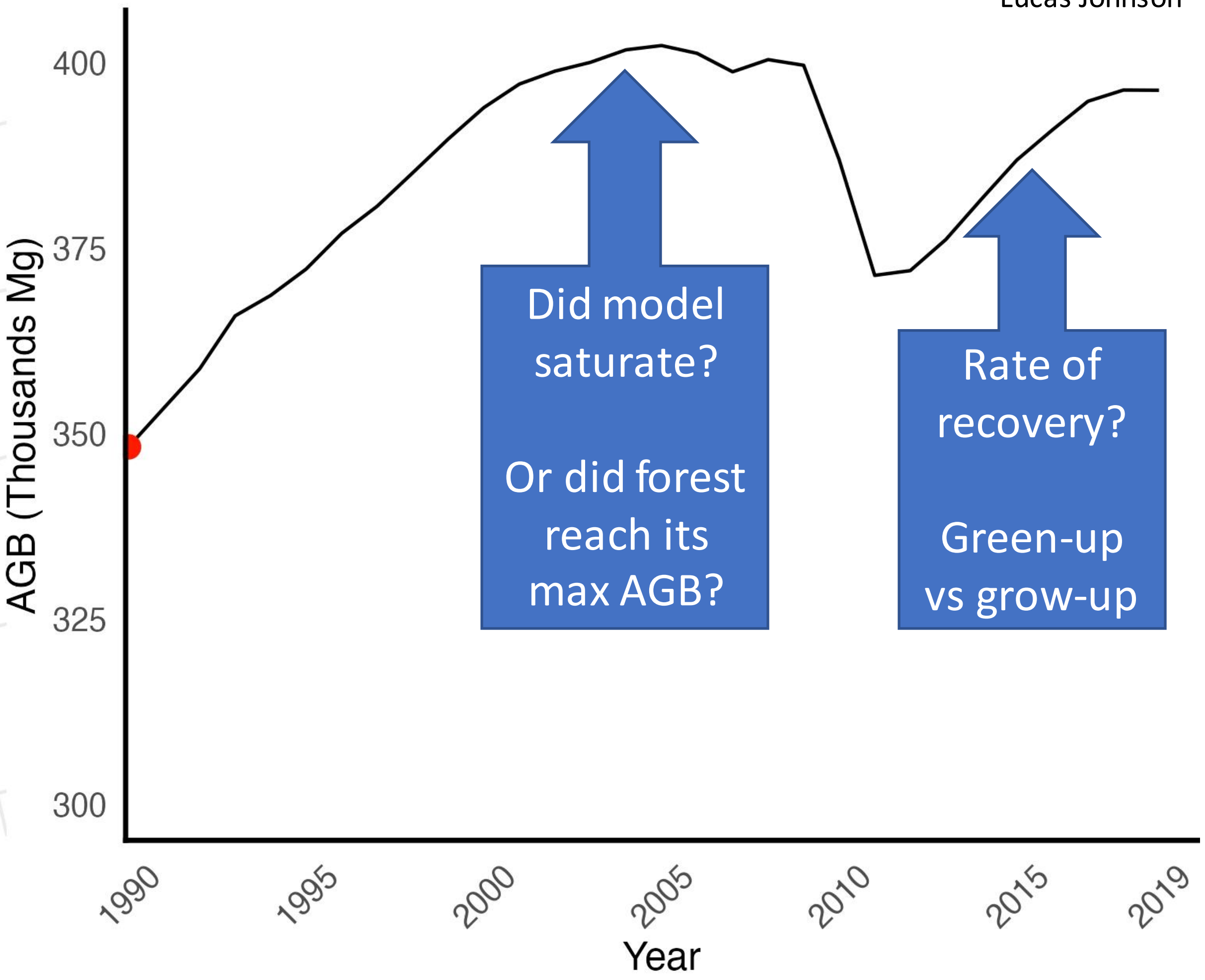


https://emapr.github.io/LT-GEE/landtrendr.html

Remote sensing: monitoring forests from afar

Lucas Johnson





Time series of annual 30-meter aboveground biomass (AGB) maps based on Landsat, LIDAR, FIA, LT-GEE

CAFRI
Climate & Applied Forest Research Institute

Remote sensing: monitoring forests from afar

Excitement

- Robust field inventory data for fusion with EO/RS via machine learning
- Long-term continuity in EO platforms (Landsat), standardized products (ARD)
- New EO platforms from NASA, ESA
- Efficient near real-time monitoring applications (carbon MRV, forest health)
- Open data & tools like Google Earth Engine lower barriers to entry

Skepticism

- Can always can have better training data!
- Signal vs noise issues, error propagation
- Model uncertainty vs application needs
- Change detection tools mostly untested across forest biomes and mgmt types**
- Maps 'hide' error / uncertainty from viewer; few groups assess map accuracy
- Engineering vs ecological mindsets in the EO/RS community

**

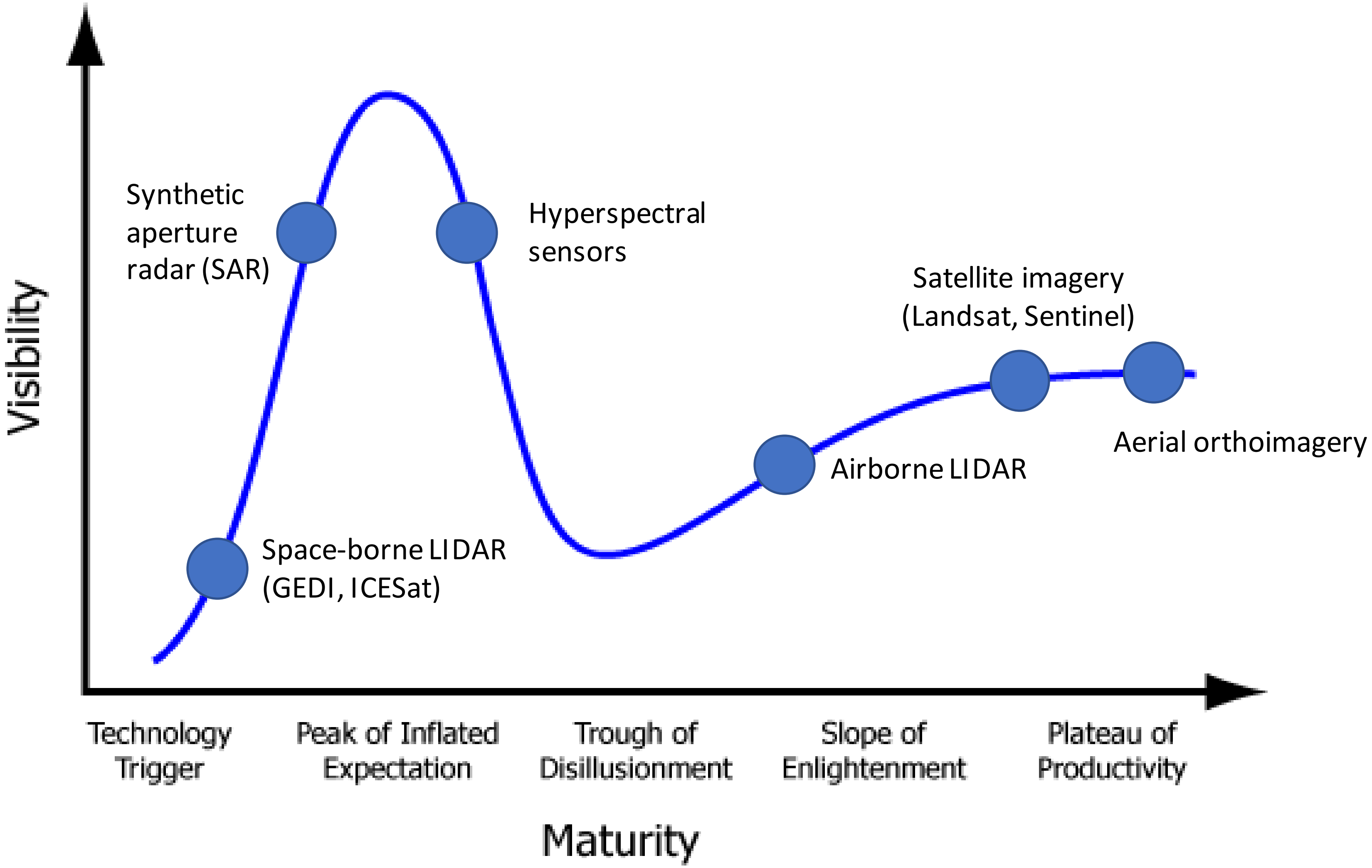
Madeleine Desrochers

Ground-Truthing Forest Change Detection Algorithms in Working Forests of the US Northeast

Journal of Forestry, 2022, 1–13

Madeleine L. Desrochers[1], Wayne Tripp[2], Stephen Logan[2], Eddie Bevilacqua[1], Lucas Johnson[3], and Colin M. Beier[1]

Remote sensing: monitoring forests from afar



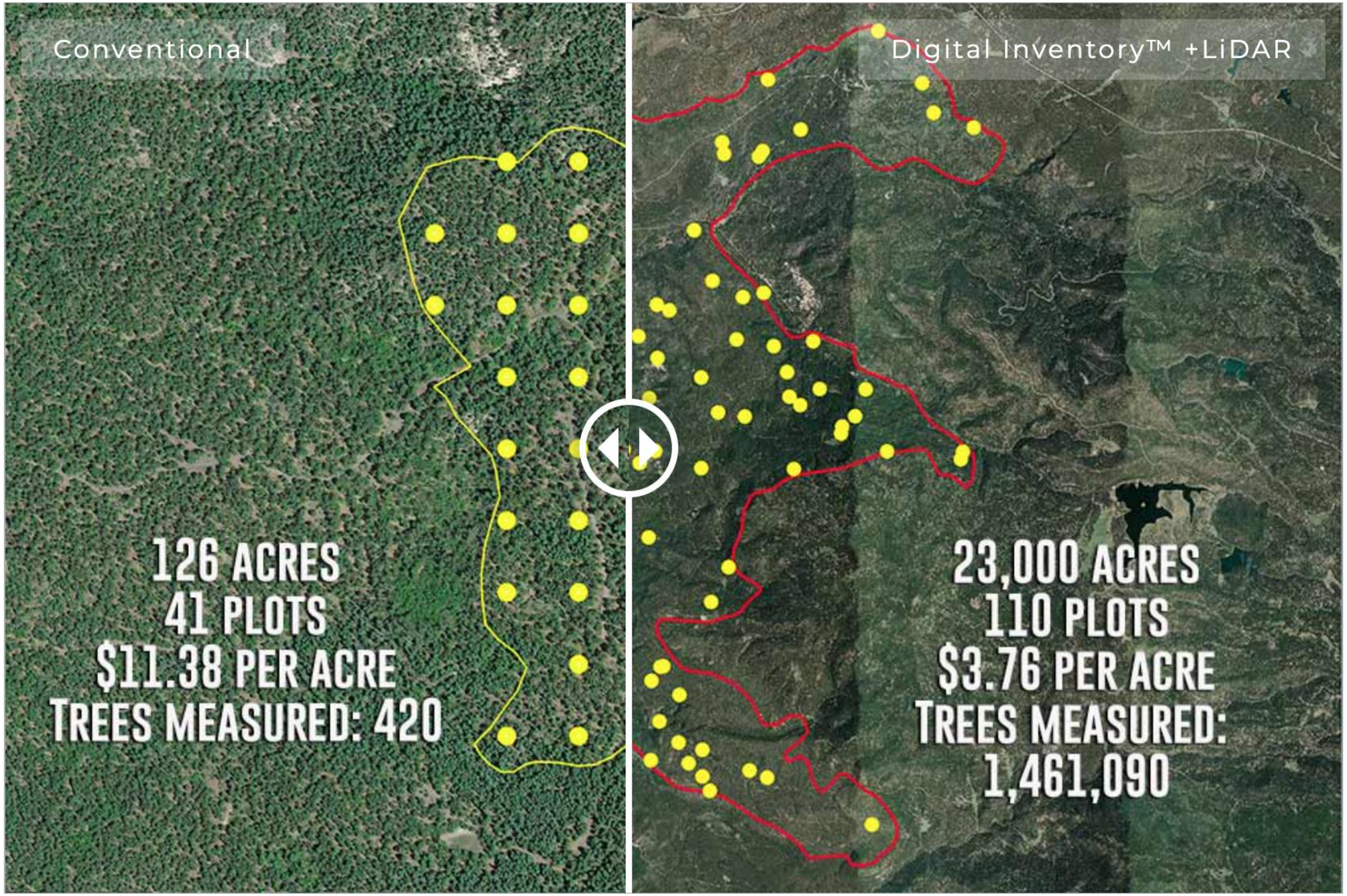
Precision forestry: a “revolution in the woods”

www.youtube.com/watch?v=wANRdliE1zQ

Precision forestry: a "revolution in the woods"

NORTHWEST
MANAGEMENT, INC.

FORESTVIEW®



https://northwestmanagement.com/services/lidar-forestview/

Precision forestry: a "revolution in the woods"

hris BY TESERA

MASON BRUCE & GIRARD Natural Resource Consultants

SWIFTGEOSPATIAL

WOODLAND SOLUTIONS GROUP

FRONTIER PRECISION

NORTHWEST MANAGEMENT, INC.

FORESTVIEW®

HEXAGON

EOS DATA ANALYTICS

FOREST monitoring

treeswift

JOHN DEERE

The building blocks of moving from traditional to precision forestry require a new approach.

From:

Traditional forestry systems involving highly manual and analog processes, "broad-brush" management prescriptions

To:

From	To
Natural regeneration of forests with seed trees of same genetic material	Selectively bred and cloned seedlings, raised in nurseries under tightly controlled conditions
Use of 2–3 standard fertilization prescriptions depending on broad soil-type classifications	Site-specific fertilization treatment based on granular assessment of soil nutrient deficiencies
Manual in-field forest inventory based on sampling to inform production planning	Digital forest inventory using drones and light detection and ranging (lidar), or in-forest scanning with smartphones
Motor-manual harvesting with no data capture	Fully mechanized harvesting, integrated with supply-chain planning
Reacting to forest fires detected only by direct observation	Satellites and drones to provide early fire detection and inform centrally planned response

McKinsey&Company mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/precision-forestry-a-revolution-in-the-woods

Precision forestry: a "revolution in the woods"

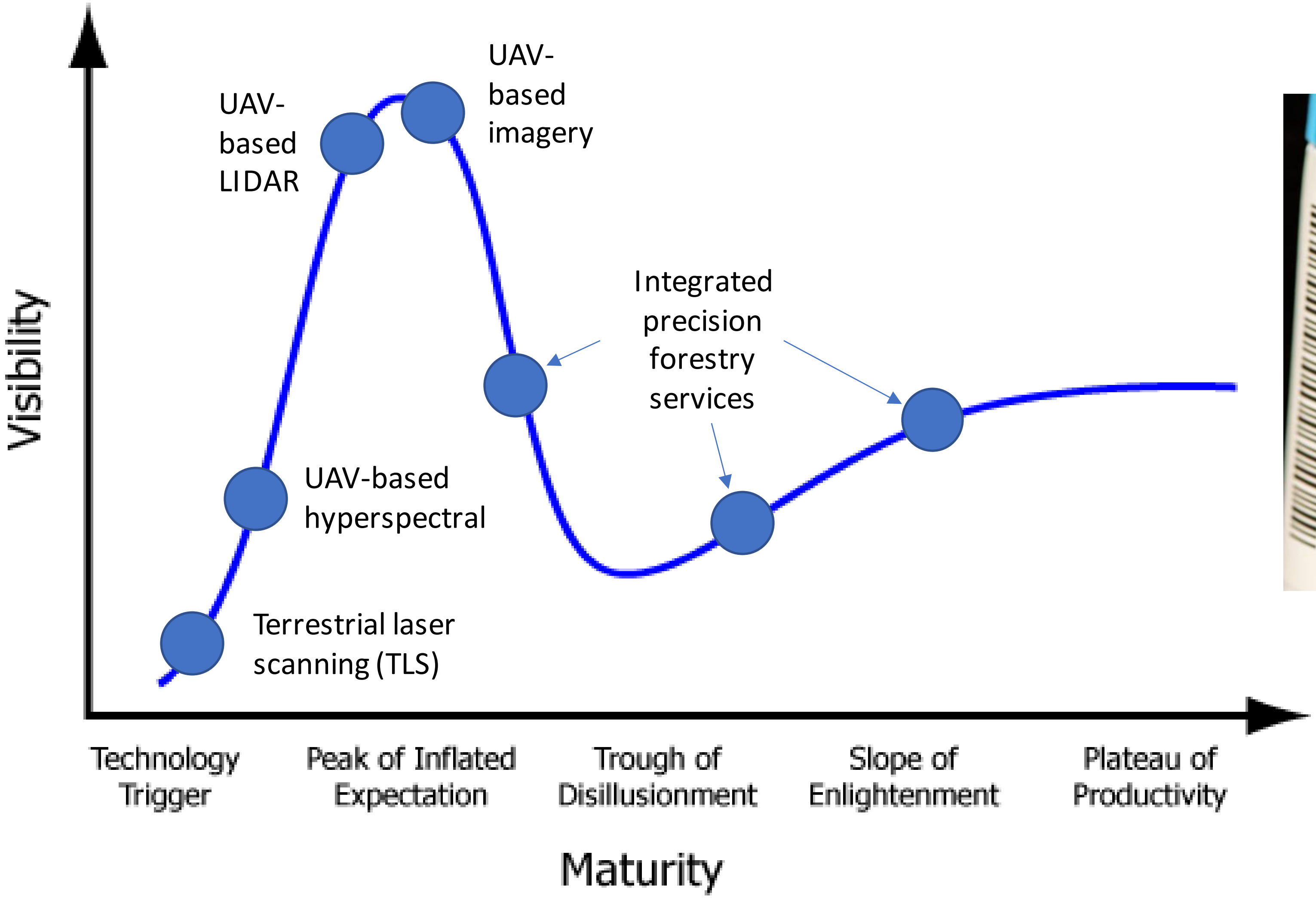
Excitement

- UAV are versatile, efficient, can be integrated with existing field protocols
- Improved forest inventory at lower cost
- UAV offer detailed maps/data for management decision-support (BMPs)
- TLS or ground-based LIDAR precisely **measures** tree volumes, forest structure
- No need for allometry (??)
- Cost of UAV / TLS devices decreasing, becoming more accessible to public

Skepticism

- For-profit firms making BIG promises: individual results vary, *caveat emptor*
- Limited scale-ability, cost-prohibitive for large landscapes
- Variability / incompatibility among UAV platforms, sensors, data procedures, etc.
- Current forest inventory frameworks (FIA) based on allometric models (CRM)
- Proprietary software needed to process / analyze self-collected data

Precision forestry: a "revolution in the woods"



Virtual worlds: visualizing forests & their benefits


Sustainable
Forest Management
Forest Carbon
Time


Sustainable
Forest Management
Forest Carbon
Time

Virtual worlds: visualizing forests & their benefits

Excitement

- Growing public awareness of forest benefits (health, climate)
- Can reach underserved audiences as 'on-ramp' to real forest experiences
- Virtual demonstration forests convey messages to broad audiences
- Game engines yield immersive first-person experiences at low cost
- Open tools being developed for data-driven viz that tell complex stories

Skepticism

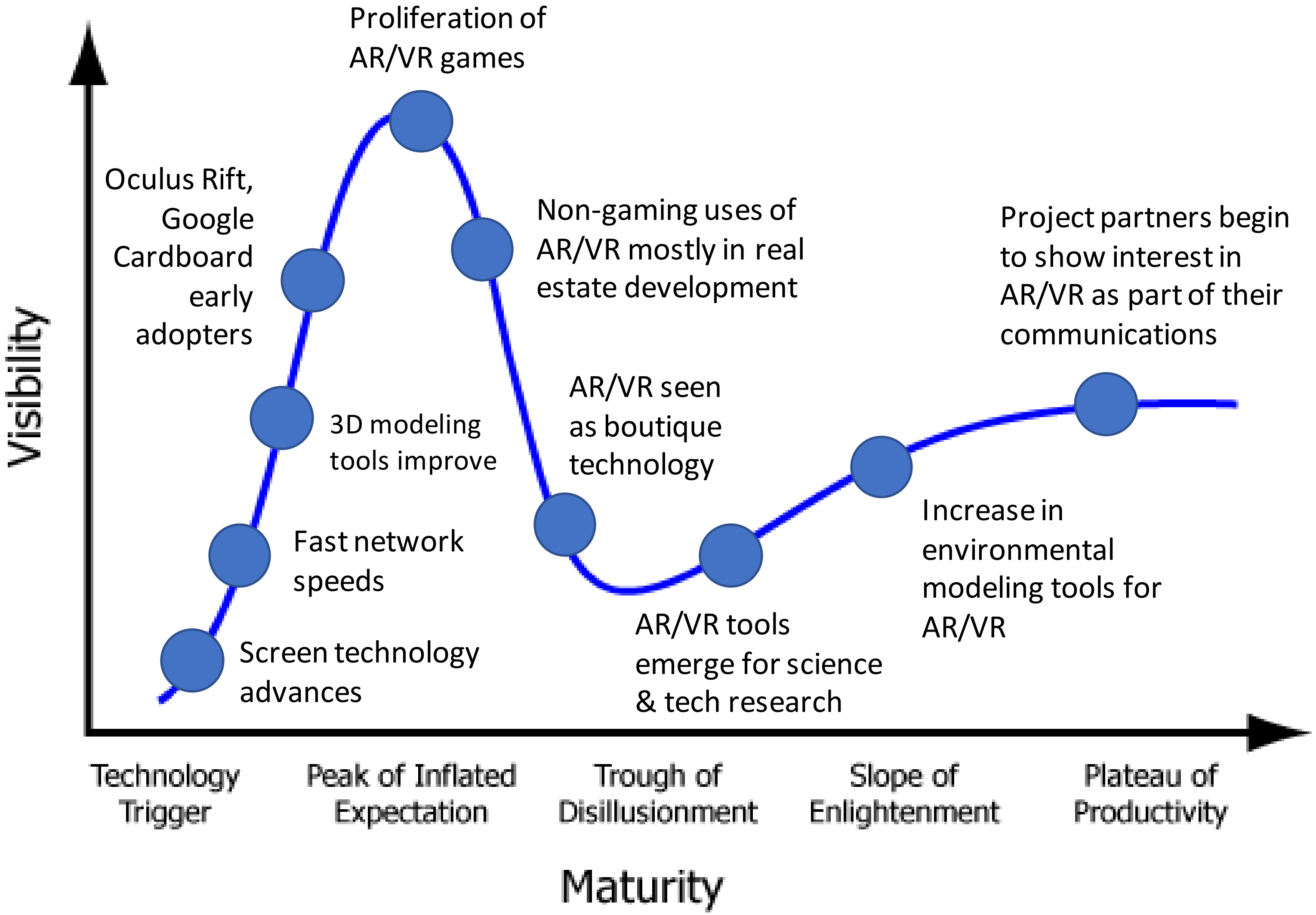
- No substitute for a walk in the woods (WITW)
- No 'silver bullet' for public misconceptions about forest ecology and management
- Two decades of unfulfilled hype around VR; will better graphics really change this?
- Could even more screen time actually exacerbate 'nature deficit disorder'?
- Significant barriers to entry remain for creating visualizations

Mike Mahoney

terrainr: An R package for creating immersive virtual environments

JOSS
The Journal of Open Source Software

Virtual worlds: visualizing forests & their benefits



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Our panel

Jarlath O'Neill-Dunne
Director, Spatial Analysis Laboratory, UVM;
US Forest Service Northern Research Stn

Spatial data science and applications, remote sensing, unmanned aerial systems, GIS landscape ecology

Dr. Sara Kuebbing
Director, Applied Science Synthesis Program,
The Forest School,
Yale University

Applied and translational ecology, conservation, invasion biology, plant community and ecosystem ecology

Aidan Ackerman
Assistant Professor,
Department of Landscape Architecture,
SUNY ESF

Data-driven environmental modeling, landscape visualization, simulation immersive VR technology, landscape design