Commercial Value of Satellite Imagery for Agriculture

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"RapidEye and its constellation of five Earth observation satellites can periodically inform you of what's happening in your fields throughout the upcoming growing season!"

RapidEye
Delivering the World
www.rapideye.com

"...attempts to foster the commercial development of moderate-resolution satellites have not succeeded." Plan for a U.S. National Land Imaging Program" (2007), National Science and Technology Council

Commercial Value of Satellite Imagery for Agriculture

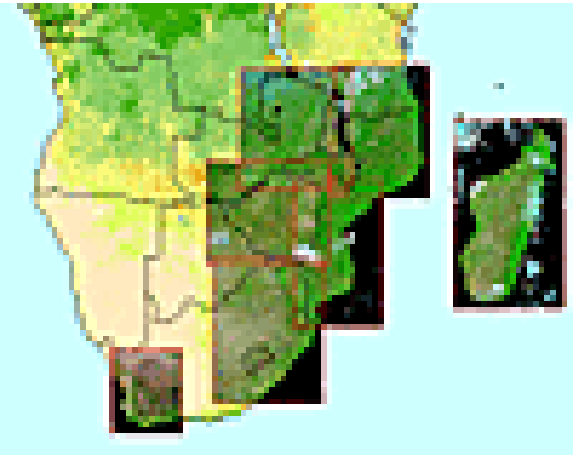
Promise of high value from commercial agricultural applications, if there is widespread adoption

- Landsat for agriculture since 1972
- Commercial satellites promote agricultural applications

Experience is a **stagnant commercial technology**, not widely adopted

Successes: **"Big Picture" public goods** applications

- Crop forecasting and famine early warning
- Clients are government agencies not farmers –
  - USDA – NASS, FAS, World Ag Outlook Board
  - FEWSnet, GIEWS

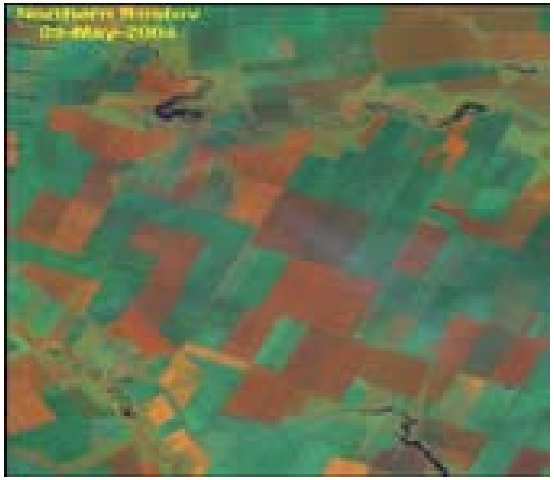


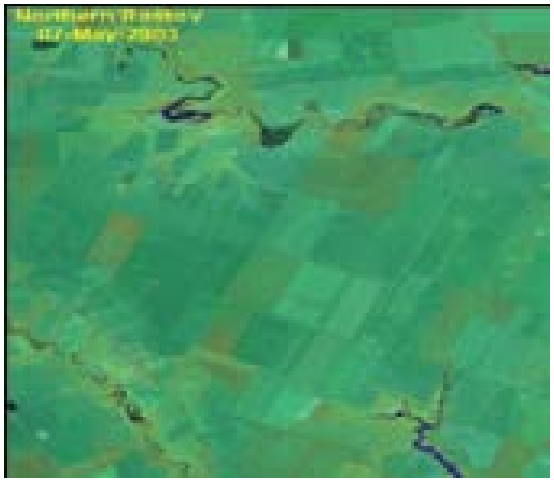
Will **newer hyper-spectral** technology change these industry dynamics?

- NASA is developing a new instrument
- What problems must the new technology solve for there to be greater commercial application?

Outline

How to value information
Taxonomy of applications to agriculture
    Public versus private information
Highlights from relevant literatures
Common recurring problems
    Interviews of practitioners
Expectations on commercial value
    Crop management, insurance,
    crop forecasting
Valuing crop forecasts (USDA WASDE)
Conclusions





How to Value Information

New information must be linked to a **revised decision**, and that decision in turn must lead to **better economic outcomes** on average

Bayesian "value of information theory" for **uncertain outcomes --**

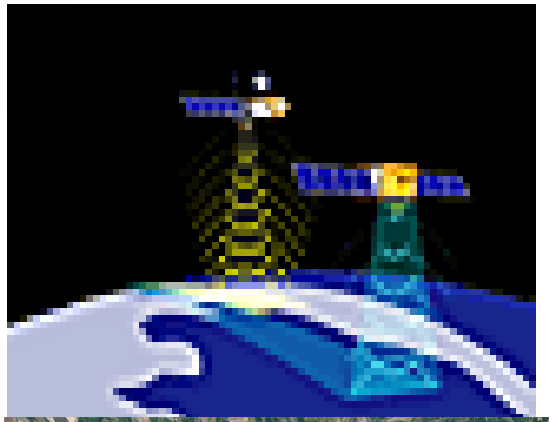
averaging over distribution of expected outcomes, updating narrowing distribution of forecast errors

Examples:

Variable rate application (VRA) of nitrogen fertilizer based on field zonation

Price driven use rates, sales, trade and stockholding following **crop forecasts**

Taxonomy of Potentially Valuable Applications in Agriculture



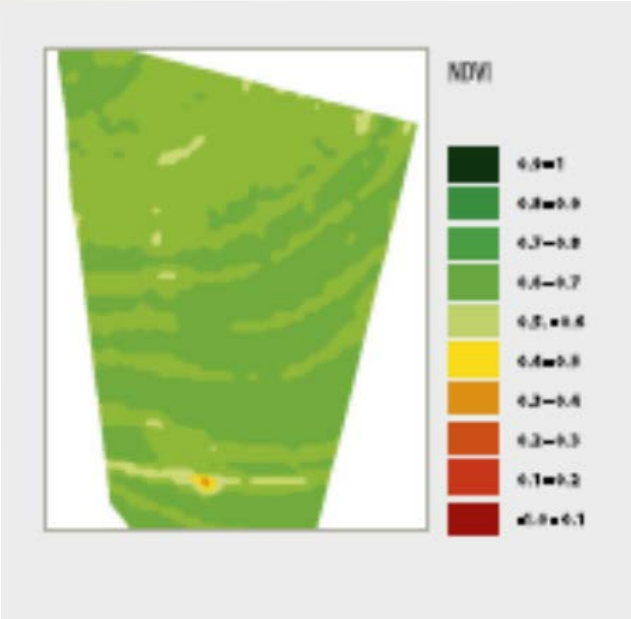
Crop management/ Precision agriculture
Real estate
Insurance
Crop forecasting / Famine early warning
Environmental monitoring

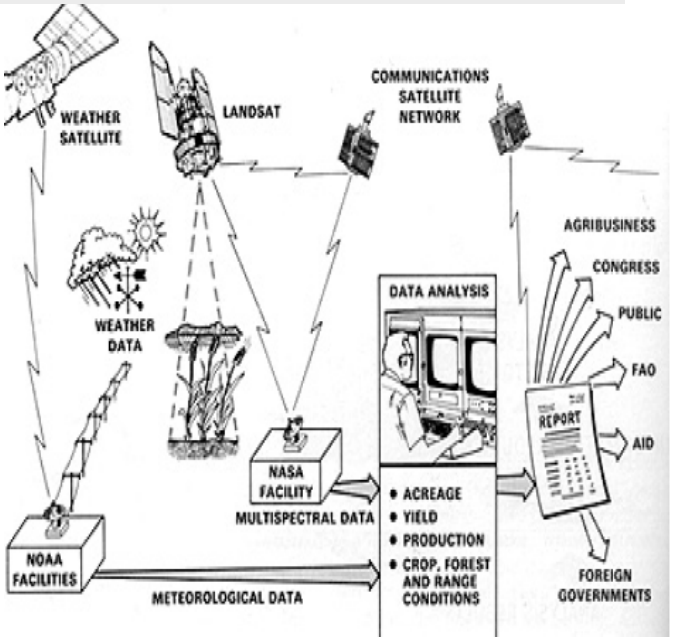
Public versus private information –
who are the clients?

What decisions are improved by remote sensing?
Examples of successes

Figure 1. Areas of Application of Remote Sensing via Satellite Images to Agriculture

Area/Public or Private?	Decisions/ actions/ effects	Specific effects on:
Crop management/ precision agriculture		
Private information	Nitrogen fertilizer application - Field zonation, in-season application	Corn, wheat, soybeans, barley, sugar beets
	Guided field scouting	
	Pesticides, growth promoters	Cotton
	Harvest date	Wine grapes in Australia, South Africa, California
	Irrigation water application	Wheat, berseem in Egypt
	Pest and disease identification	
Real estate Private information	Verifying land condition for purchases, pricing/ valuation, property taxes	Argentina
Insurance monitoring	Crop damage assessment for hail, flooding, wind, freezing, drought Replanting if information is timely	
Public & private	Fraud detection and deterrence Valuing monetary compensation	USDA
Crop forecasting Public information	Area planted, yield, production, trade forecasts Purchase/use, stocks, futures & options transactions Price formation	WASDE, FAS, NASS
	Weather forecasts and their impacts Pest and drought stresses	
	Famine early warning, food aid and imports Strategic grain reserves	FEWSnet, GIEWS
Environmental monitoring	Flooded area, external cost estimation	
Public information	Regulation monitoring, legal action Crop residues for conservation program compliance	
	Farmer decisions for regulation compliance	





Highlights from Literature

Remote sensing / image science
Precision agriculture
Crop forecasting

Massive basic science literature,
Limited "development" or management/engineering research, Even less on economic implications

Science focuses more often on "does a data product (LAI or NDVI) capture what it is intended to directly measure?" rather than "how does a new technology improve the information directly relevant to a management decision (e.g. yield)?"

Highlights from Literature

GPS guidance and related technologies are the only aspect of precision agriculture that are becoming standard practice

Classic Precision agriculture, like VRA, shows mixed profitability, has not taken off

Remote sensing applied to PA also gave mixed results,
- Suspect valuations in that literature
- Value solely from unrealistic reduced input costs

WASDE forecasts shown to move markets

Literature to put a value on that quite dated
- Advances in price stabilization literature

Science for implementation of hyper-spectral data not ready – NASA mission will remain scientific not operational

Recurring Common Issues

Data reliability -better seen as technical limitations to data availability in a number of dimensions: Timeliness, technical limitations (frequency, pointing for fee, clouds, accuracy), resolution

Large images (scale)
data processing, interpretation, pricing strategy taking humans/labor out of process

Inadequate or misdirected science
basic science not “engineering”

Competition from other information sources
Aircraft, UAVs, Equipment mounted sensors

More Lessons from Interviews

Hyper-spectral technology may not solve the problems that have limited past commercial applications

Practitioners typically wanted “more reliable” multi-spectral data:

- Timeliness and frequency key concerns
- Also data processing implications
- Need to “automate” information delivery

Scale critical – resolved to some extent by crop consultants, cooperatives, ag input dealers as “intermediaries”

Expectations on Commercial Value

Widespread adoption should yield high commercial value

Crop management - $30 per hectare fertilizer cost savings = $1.2 billion for U.S. corn crop

Insurance - Detecting and deterring fraud

Claims from US crop insurance $3 billion for 2003-10, $ 13.4 billion in 2011, $18.4 billion in 2012

Deterrence more important, hard to judge extent of fraud and whether satellite information deters it

Crop forecasting

Formal model puts WASDE value at $556 million

Long term climate forecasts $3-5 per hectare –
limited alternative farmer decisions to cope

How might satellite information improve forecasts?

Updating Commercial Value Projections from Precision Agriculture

$30 per hectare cost savings in 2000-2005 is more like $125 at today's much higher fertilizer prices

High fertilizer costs should encourage economizing on its use, but farmers in practice still "over-fertilize", and adoption of VRA is limited

Is the VRA technology not profitable? or

Is the current information from satellites inadequate to implement this technology?

Will new technology relieve this constraint?

Valuing Crop Forecasts

Logic: **Smoothed use that better matches available production** yields greater economic welfare

Surplus for consumers/ food processors, livestock producers, industrial uses; export earnings

Stocks, trade and quarterly use smoothing

Exports forecast depends on worldwide production, but also economic conditions and policy elsewhere

Monte Carlo simulations to reflect information uncertainty

Quarterly equilibriums and new WASDE reports that reduce error variance

Expected values averaged over 1000 simulations per case

Alternative cases capturing differences in information quality

Caveats: Elasticities that measure adjustments to expected prices and welfare variations uncertain; error distributions; data quality and generalizations to other markets, countries

How reliable are existing crop forecasts? Where are errors largest?

Table 1.				
Forecast Errors (coefficients of variation - %)				
	Prior to Harvest		After Harvest	
	May	August	November	February
WASDE monthly corn forecasts				
Production	10.4%	6.2%		
Exports	18.2%	15.9%	12.2%	7.6%
Naïve trend forecast				
Production	12.7%	8.2%		
Exports	18.2%			

Rows:

Quarterly Outcomes for Economic Variables – Price, Uses, Stocks, Production

Table 2. Simulation Model of US Corn Market over Crop Year 2011/12

		Base data		Forecasts				
		(Actual outcomes		May	August	November	February	Final
		modfied to fit		(quantities in million bushels, prices in $ per bushel)				
Q3Yo	Stocks	3288	Sq3	3288	3288	3288	3288	3288
Q4Yo	Price	6.31		5.84	5.84	5.84	5.84	5.84
	FSI	1554		1572	1572	1572	1572	1572
	Feed	323		331	331	331	331	331
	Exports	283		292	292	292	292	292
	Stocks	1128	Sq4	1093	1093	1093	1093	1093
Q1Y1	Price	6.01		5.51	5.73	5.73	5.73	5.73
	Area	84		84	84	84	84	84
	Yield	147.1		147.1	147.1	147.1	147.1	147.1
	Production	12358		12358	12358	12358	12358	12358
	Production error	0		307	284	0	0	0
	FSI	1613		1633	1624	1624	1624	1624
	Feed	1823		1876	1853	1853	1853	1853
	Exports	402		415	410	410	410	410
Q2Y1	Price	6.10		5.60	5.82	6.56	6.56	6.56
	FSI	1638		1658	1649	1619	1619	1619
	Feed	1543		1587	1568	1502	1502	1502
	Exports	442		457	450	429	429	429
Q3Y1	Price	6.19		5.69	5.91	6.65	6.22	6.22
	FSI	1629		1649	1640	1611	1628	1628
	Feed	798		821	811	777	797	797
	Exports	379		391	386	368	378	378
Q4Y1	Price	6.28		5.78	6.00	6.74	6.31	6.31
	FSI	1555		1574	1566	1538	1554	1554
	Feed	383		394	389	373	382	382
	Exports	293		302	298	284	292	293
Annual Export error		0		-129	33	153	1	0
	Stocks	988	Sq4 T+1	1130	1058	911	982	983
	Pq1 T+1	4.50		5.87	6.09	6.83	6.40	6.40
2011/12	roduction	12358		12665	12642	12358	12358	12358
	FSI	6435		6514	6480	6392	6425	6426
	Feed	4547		4678	4621	4505	4534	4534
	Exports	1516		1437	1577	1643	1510	1509
Excess demands								
	Yo	0.000		0.000				
	Y1	0.000		0.000	0.000	0.000	0.000	0.000

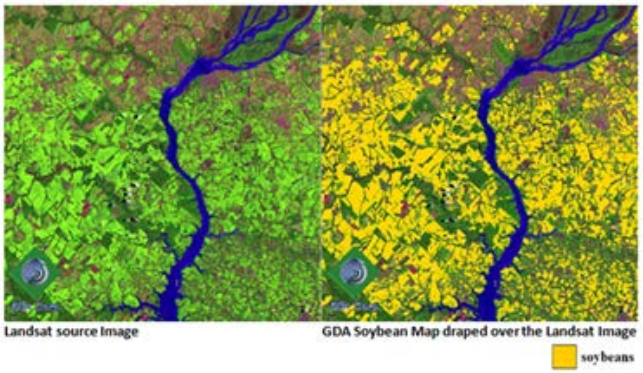
Columns:

Expected Equilibrium Predictions Following WASDE reports

History
Current price
Errors
Stocks
Equilibrium

How much have the components of USDA crop forecasts been worth?

Table 3.		
Expected Value of Information from WASDE Corn Forecasts		
(relative to naïve trend forecast)		
	Mean	Median
	($ millions per year)	
Overall WASDE	556	422
Exports	208	403
Production	346	189
Perfect information	1282	



By how much might improved remote sensed data improve area, yield and export forecasts?

Practitioners – 10%; NASA & science 20%

Table 4.					
Mean Expected Value of Improved WASDE Forecasts					
	($ millions per year)				
RMSE reductions	Overall	Exports	Production	Area	Yield
5%	60.9	8.8	50.6	5.2	47.8
10%	121.7	17.2	106.3	12.8	93.9
15%	182.5	25.1	156.4	16.8	138.2
20%	236.5	31.0	204.4	25.3	178.7

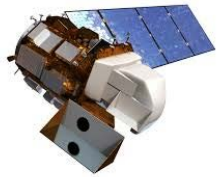
Export errors still greater, but improving export forecasts involves more than better production estimates

Conclusions

Promise from potential widespread commercial agricultural applications contradicted by limited adoption

Issues limiting private applications: profitability of precision agriculture; data reliability; scale; misdirected science; competition from aircraft, UAVs, equipment sensors

- Science needs to focus more on questions relevant to practitioners (yield not just NDVI), and on interpretation for decision-making
- Advances in this technology, such as hyper-spectral data, may not solve the problems limiting commercial application



"Big picture" public goods applications take better advantage of this technology – scale economies, public goods critical

- Greatest future value from improved crop forecasting and famine early warning; Potential in other countries where existing data collection for agriculture not so well developed – satellites may be the only way to look