Summary Discussion

With respect of the results of this research, below is a summary discussion of common themes, issues, and opportunities found.

- *Private vs. Public Research misaligned or disconnected*

An overarching result is that required technology and software systems that would make sweeping contributions to monitoring and measuring agriculture and environment interaction are at a level either at or approaching market level application. However, the shift of agricultural technology to the private sphere both in regard to software creation and extension services, or communication channels, has meant that there is not adequate support in delivering these services to farmers simply because it does not serve the profits of agribusiness.[1]

Wolf and Wood list in their critical paper on PA, that there have been many successful farm management methods in existence for decades which can't easily have property rights assigned to them, and don't enable information commodification, and thus have had little private industrial investment. They list integrated pest management (IPM) as an example, which is a "loosely bound set of agroecologically based practices defined largely through public sector research and extension... which include practices such as crop rotation, pest monitoring, conservation of beneficial insect populations, and chemical use when economically justified."[2] This is not to say that PA as currently practised and implemented doesn't have environmental benefits and potentially contribute to higher yields, but rather points out that if left to their own devices, agroindustry will surely leave out essential aspects of sustainability that do not fit into their profitability frameworks.

In academic research, techniques to study agrobiodiversity have been used by Karl Zimmerman and others for years. The democratization of satellite imagery and increasing affordability for these purposes allows for more access and comprehensive studies in various fields. Thus, we can assume that innovation will only continue and add new dimensions to remote sensing capabilities in agriculture.

There is also a great need for it to continue: the review on land-use applications of

1 Wolf and Wood (1997)
2 Ibid.

satellite imagery (2013) stated that the field, “lacks detailed information on the extent and pattern of agroforestry, crop rotations, shifting cultivation systems, and organic versus conventional cropping.”[3] This will most likely come from the public sector, however, as it has been found that research in the private sector is more aimed at activities that can be protected with patents or other intellectual property rights and result in the development of products or inventions that can be protected.[4]

Already, trademarks including, The Satellite Imaging Corp's service called, Agrowatch™ Soil Zone Index, which applies algorithms to satellite imagery for which the final result, “shows what the soil surface of your field looks like, including irrigation patterns, sand streaks, clay lenses, and organic matter and crop residue variations,”[5] and PurePixel™, which is a form of NDVI shown in pixels on a field map, are appearing in this field.[6] This is not necessarily an unhelpful development, but unbiased research from the public sphere will then logically need to continue to be supported to conduct research that will support the development of the field as a whole.

- *Need For More Open Data*

It was also found that many resources were not available to software companies which would help them provide additional information to users. We can look to the US as an example of a country that has strong space and geographic open-data policies. One farm management company in the US, called Farmlogs, has taken advantage of the soil maps provided by the US government and integrated them into their product, which, “leads to better nutrient management, more soil and water conservation and higher yield.”[7]

Sentinel satellite data will be made free and open access, just as Landsat data has been, which should continue to give software providers more of an incentive to include it in their products.[8] There is also the EU funded European NEtwork for Redistributing Geospatial Information to user Communities - Open Data (ENERGIC – OD) who will work toward making geographical data more accessible for citizens and businesses. This could grant more opportunities for the inclusion of more ecological and spatially

3 Kuemmerle et al. (2013): Challenges and opportunities in mapping land use intensity globally
4 National Research Council (1997): Precision Agriculture in the 21st Century
5 Satellite Imaging Corporation: Agrowatch™ Soil Zone Index website
6 Trimble (2015): PurePixel™ website
7 Bedford, L. (2014): FarmLogs Adds Free Soil Data Feature
8 Copernicus website

variable information in the products that FMS innovators create.

- *Opportunity for ecological farming to scale*

Gassner et al. point out in their analysis of PA, "while PA has not delivered the technological revolution in the agricultural sector that was predicted, it has succeeded in reintroducing the concept of locally adapted interventions to both agricultural practitioners and scientists and in highlighting the need for information about the spatial and temporal variation of factors affecting yield."[9] It is thus, that this is an opportunity to reintroduce local rather than uniform agricultural practices, as is the interest of EU-CAP.

This was also one of the main findings of this research and it is worth repeating: Even though there is an effectivity of scale factor to using satellite imagery for farm and field observation, this actually presents an opportunity for large scale farmers to practice ecological farming habits, whereas before it was more difficult due to their intrinsic distance from the land. In addition to enabling spot-specific application, satellite imagery is a tool that can depict the interacting effects of farm activities and the ecological effects thereof.

- *Inclusion of alternative farming practices*

In 2010, the percentage of agricultural holdings practising organic farming in Germany was 7.3%, and the percentage of organically farmed land went up to 5.9%.[10] This is not an insignificant market share. There are actually very simple steps that can be taken by Farm Management Software companies in Germany, such as partnering with organic seed and field input companies, which would immediately expand the potential user base and give current users more options. There is no practical difference in the way that satellite imagery could be used on organic farms vs. conventional farms, and there is in fact evidence to suggest that it could be even more helpful, especially for larger organic farms where it's extraordinarily important to catch problem areas and diseases early.[11] Thus, not only do software providers need to be more consciously inclusive of organic farmers as a user group, but also, break down the construct that there are such great differences between organic and conventional farmers with regard

9 Gassner et al. (2013): Improving food security through increasing the precision of agricultural development p. 35
10 BMEL Press Release (2011): Organic Farming in Germany still Growing
11 Cook-Anderson, G: Landsat Cultivates Fans Among Midwest Farmers

to their farm management practices.

- *Remembering that satellite imagery is a tool, not a panacea*

If satellite imagery has been enthusiastically advocated as the resource of the future for directly and indirectly investigating biodiversity from space, it is worth remembering that it should aim at sustaining, rather than replacing field-based methodologies.

To illustrate this point, one interviewed company stated, "*Time is one of the most thinly stretched resources available to a farmer, and imagery, especially imagery provided with analytics, can help a grower determine where it is most important to scout in-person. A lot of bushels can be saved if a pest or disease infestation is isolated quickly, and imagery can get you in the right spot at the right time.*"

I return to the original ideal that nature is not precise. Satellite imagery is a tool that makes nature, or agricultural fields measurable to a certain extent. The movement and trajectory of farm management is in the direction of careful measurement and exactness for the purposes of making farm activities more efficient. This is why Farm Management Software and PA have been created in the first place. It is refreshing to see that most companies that offer this software are aware of their tools and services as an accompaniment, or assistance to practical management, and in-person observations which will not be obsolete in the near future.

Recommendations

The ultimate question is how satellite imagery should be treated in the policy forum. Government support of satellite imagery in agriculture is only justified when the technological introduction has positive allocative or distributive effects for society that could not be realised otherwise. In the above research it has been demonstrated that there are specific features of satellite imagery implementation in agriculture that will not be appreciated if left to market forces alone. Namely, agrobiodiversity and inclusion of organic inputs as an additional feature of precision farming implementation.

In his 2005 paper, James Boyce states, “Rather than simply letting nature take its ostensible course, governments often seek to speed it along, promoting agricultural ‘modernization’ by means of subsidies and other policies that favor large-scale farming, purchases of farm machinery and chemical inputs, and more uniformity in the choice of crops and varieties.”[12] While we in Europe are fortunate to have shifted policy stance to actively support small farms and agrobiodiversity, we now must take the opportunity, given the outcomes of this evaluation, to address areas specifically impacted by the inclusion of satellite imagery in agriculture.

The EU-CAP stance on support of precision agriculture states that, “Since PA benefits are not universal across Europe but rather specific to local conditions and to the farming systems in place, it is felt that rural development measures are suitable to play a role in fostering the development of this technology.” Further, it is the responsibility of the Member States to define what the measures to be financed are, and thus the German agricultural governance sector has a chance to define how it supports PA, and therethrough satellite imagery.

It is with this information that I make the following recommendations:

1. *Balanced Funding:* At this point in Europe, 90% of the research funding and 80% of subsidy funds are granted to conventional farming.[13] This must change. In order for positive steps to be made with regard to reconciliation of agriculture and the environment, a fundamental shift in the information and knowledge generation needs to be made by allocating funding to those outside the

12 Boyce, J. (2004) p. 2
13 Morel, C. (2015): “Mehr Ertrage Ohne Chemie”

conventional sphere.

2. *Support of Accessible Technologies:* The EU-CAP is already taking a stance to continue the support of small farmers and rural infrastructure. Therefore, additional subsidy grant money to close the gap between large and small farmer opportunities for use and implementation is not necessary. Instead, it would be wise to support the innovation of technologies which are more accessible to all, without great cost restrictions that come along with buying expensive equipment.
3. *Open Data:* Connected to this, is opening environmental, geographic, and satellite imagery data, and making it more accessible to the public and to companies so that they can include these services as added features in their software.
4. *Research Connections:* Stronger connections need to be made between academic and government research and commercial research. This connection should at least be strong enough so that software companies working in the agricultural sector are at least aware of the capabilities in the academic and government research, because at this point they are not.
5. *Commercial Applications of Sustainability Measures:* Given that the academic literature already exists as to how biodiversity modelling systems and ecosystem service measures could be adapted to Precision Agriculture software, this should be supported and implemented by policy through research grants, subsidy money for pilot users, and subsidies for companies including these features.
6. *Compliance Links:* Strengthen the links for compliance with satellite imagery. EU-CAP is the primary source of guidelines for farmers to implement environmental practices. Satellite imagery is unbiased method of proving compliance, and if farmers were incentivised to use this method, they would become further acquainted with the technology and use it for other activities.
7. *Stronger, More Measurable Greening Measures:* Satellite imagery capabilities enable agro-ecological features to be measurable such as greenhouse gas emissions, creation of buffer zones, and use of different crop varieties, as highlighted by studies of precision conservation and Functional Agro-Biodiversity. Thus, this presents an opportunity to also make Greening Measures of the EU-CAP less vague, and more comprehensive.
8. *Support of Organic and Alternative Inclusion in PA:* More research must be

funded and carried out to evaluate and confirm that it can be just as feasible and important for organic farmers to use PA techniques. Further support of companies demonstrating the inclusion of non-conventional farms in through their products is also recommended.

9. *Farm Advisory Services:* Farm Advisory Services of the different German states have the opportunity to play an educational role in farmer adoption of satellite imagery. This needs to be exercised to maintain balanced information dissemination without bias or special interests.
10. *Privacy:* A public debate and formation of laws and regulations around ordering satellite imagery with regard to privacy is essential. This is especially important for satellite tasking where citizens, companies, and organisations alike can order an image to be taken at a specific time and location with high resolution satellites.
11. *Data Protection:* Data protection laws for farmers need to be made secure. As much as German companies have been responsible in comparison to U.S. companies, unless clear legislation is drawn, there will always be opportunities for companies to sell farmer data to third parties without their consent.

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