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Precision Agriculture in China: Exploring Awareness, Understanding, Attitudes and Perceptions of Agricultural Experts and End-Users in China.

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Abstract
Precision agriculture (PA) may improve the sustainability of Chinese agriculture. Ten experts were interviewed and 34 farm workers surveyed regarding their understanding, attitudes and perceptions towards PA. PA technologies were considered inaccessible, unsuitable and unnecessary for smaller farms. High cost, lack of perceived benefits, and skills and capability required to adopt PA represented barriers to adoption. Financial incentives/subsidies, the need for tangible benefits and tailored solutions to be demonstrated to farmers, and agronomic and peer support were desired. Future research should further explore PA with Chinese stakeholders and end-users in China, to inform future socio-technological developments.

Keywords: farmer perceptions, barriers and facilitators of adoption, China, family farms.

Introduction

The Chinese population is expected to increase to 1.3 billion by 2050 (Worldbank, 2016) placing significant pressures on the Chinese agricultural system (Jiyun & Cheng, 2002). Chinese agriculture has therefore relied heavily on fertilizers with usage increasing 4% annually, amounting to one third of global fertilizer usage (Xan *et al*., 2008). This has been shown to have significant environmental consequences (Ma *et al*., 2014). Precision agriculture (PA) is presented as a solution to reduce agro-chemical inputs whilst simultaneously facilitating reduced negative environmental impacts of agriculture in China. From a farmer's perspective, PA is has three fundamental benefits; firstly economic benefits through reductions in farm expenditure via the controlled application of agricultural inputs; secondly increased yields due to targeted management of in-field variability (Napier *et al*, 2000) and; thirdly environmental benefits through the precise application of agro-chemical applications which helps facilitate compliance with environmental legislation in China (Ma *et al.,* 2014).

Despite this, uptake in China has lagged considerably behind the US, Europe, South America and Australasia (Robert, 2002). This has in part been a symptom of the structure of the Chinese agricultural system which is characterised by small scale family run farms (known as the "family responsibility system") which are associated with different levels of mechanisation,

production scale and farmer education, and make it difficult for PA technologies to be applied (Jiyun & Cheng, 2002). Whilst research has been conducted to explore potential applications of PA in China and demonstrate the economic and environmental benefits of the technology (*inter alia* Jiyun & Cheng, 2002; Liu *et al.*, 2009), to the best of the author's knowledge no such research has been conducted in China to assess end-users' attitudes and perceptions of PA and the potential barriers to adoption, with the limited body of literature in this having focused on the adoption experiences of European and North American farmers (Kutter *et al.,* 2009; Daberkow & McBride, 2003). A number of further studies have been conducted to identify barriers to adoption at the farm level including; the cost, (Plant, 2001), end-user characteristics (Daberkow & McBride, 2003), lack of perceived benefits (Adrian *et al*, 2005), the skills required and data security fears (Reichardt &Jurgens, 2009) to name a few.

In light of the above it cannot be assumed that the same factors influencing farmer adoption in Europe and North America apply in the Chinese context. In order to increase uptake of PA in China, it is therefore essential to understand the structure of Chinese agricultural systems and explore how this may impact upon Chinese farmer's awareness, understanding, attitudes and perceptions towards PA. This will aid in understanding the relevance of PA technology for Chinese farmers, helping to inform future technological developments and provide targeted technological solutions relevant to local agronomic needs.

It is widely recognised that technological innovations, including those in the agri-food domain, can be met with societal resistance, as has been the case with genetically modified crops (Frewer *et al*, 2013). Aligning innovation with the values, needs and expectations of society is crucial to ensure the support the introduction of technologies that address socially sensitive issues (Asveld *et al*, 2015), and is the central premise of responsible research and innovation (RRI; Coles *et al*, accepted). RRI provides a framework for the identification of stakeholder, end-user, and public concerns in an open, transparent way throughout the development and introduction process, and aims to *'foster the design of inclusive and sustainable research and innovation'* (European Commission, 2015). Coles *et al* (accepted) provide a framework for understanding how RRI may be incorporated into agricultural innovations including; societal and economic impacts, equitable access to free markets and the benefits of innovation, gender inclusivity, inclusivity of potentially excluded groups (e.g. rural populations, poor, disabled, specific ethnic groups), public engagement, dissemination of scientific findings, ethics and science education.

Within the domain of PA, such an approach has also been advocated (Lamb *et al*, 2008), and it is thought that consultation with a broad cross-section of potential users and stakeholders in the design and evaluation stages of any new PA technology is necessary to ensure relevance and compatibility with the needs of the target market, especially as the introduction of new agricultural systems and practices has the potential impact upon the dynamics and socio-economic functioning of rural communities. This research therefore aimed to explore expert and end-user understandings, attitudes and perceptions towards precision agriculture technology. In particular, attention is given to the exploring the perceived barriers to adoption and the possible factors that may facilitate future using a RRI framework.

Methods

Research design
A qualitative approach was taken to provide exploratory insights into stakeholder perceptions of precision farming, and to provide the basis for future research. Interviews were conducted

with two primary stakeholders of PA technologies in China; Chinese agriculture experts (i.e. academics, researchers, and industry representatives) and Chinese farmers and farm workers in China who are the anticipated end-users of such technology.

Each expert interview lasted approximately 45 minutes and was digitally recorded to aid verbatim transcription and subsequent data analysis. Prior to the interviews, an interview discussion guide was developed The RRI framework (Coles *et al*, accepted) was used to provide a basis for the data collection protocol. This was sub-divided into 4 sections aimed at exploring; 1) penetration of PA in China, 2) perceptions of PA technologies and techniques 3) motivation and barriers to the adoption of these, 4) information, training and support for Chinese farmers (including the needs of agronomic advisers) to facilitate PA adoption and among farmers and farm advisors. The interview discussion guide was translated into Mandarin and provided to participants prior to interview. At the beginning of the interview participants were informed of the purpose of the research and asked for their informed consent to participate. Interviews were conducted in English and simultaneously translated into Mandarin.

A second discussion guide was developed for farmers and intended end-users of PA, and was informed by the results of the expert interviews and existing literature. The guide was divided into 6 sections that aimed to explore, 1) farmers land 2) potential changes to rural communities and agricultural practices which would result from application of PA, 3) current practices of PA, 4) awareness of PA agriculture techniques and technologies, 5) motivation and barriers to the adoption of PA techniques and technologies. Time was allocated at the end of the interview to summarise the discussion. The discussion guide was translated into Mandarin. Consent was gained from all participants' prior commencing the interviews; and all interviews were digitally recorded to assist with data analysis. Each interview was designed to last approximately one hour. Copies of both discussion guides can be obtained by contacting the corresponding author.

Sample

In order to gain understandings of the Chinese agricultural environment and potential facilitators of adoption of PA technologies, expert interviews were conducted at the Joint International Conference on Intelligent Agriculture in Beijing, China, in September 2015. A total of 10 expert interviews were conducted; 4 experts were working in Chinese academic institutions, 4 were working in private research institutions and organisations, 1 working for a national research centre and 1 working for an academic institution and a government ministry.

34 in-depth interviews were conducted with family farmers and potential end–users of PA technology across 3 Chinese agricultural regions between January and February 2016; Changge, Shixiang village, Changge city, Henan province, Xiaotangshan; Beijing precision agriculture research and demonstration base, Beijing city; Zhaodong farm, Zhaodong city, Heilongjiang province. The sample comprised of 25 males and 8 females, the majority of the participants were aged between 51 and 60 (38.2%) reflecting the ageing demographic of Chinese agriculture. Farm size ranged from 0.1-1,000 hectares, with very few farmers owning the land that they farmed and it was common practice to rent fields. Farmers reported to have between 1month and 20 years' experience farming their land.

Data analysis

Data collected from the expert interviews were analysed using QSR Nvivo 11 and followed a 3 stage process. First, transcripts were open coded using an inductive, grounded approach (Glaser & Strauss, 1967). Key, emerging concepts were used to develop an initial coding framework. This framework was then refined by coding a subsample of transcripts against the

framework and amending or adding codes where appropriate. Once the coding framework was finalised the full data set was coded against it. Given the structured approach to the farmer interviews, data was analysed using SPSS 21 with descriptive statistics reported in table 1.

Results

Expert interviews
Four themes emerged from the expert interviews; these related to the structure of the Chinese agricultural landscape, farmers awareness and adoption of PA technologies, barriers to adoption of PA technologies and factors to increase adoption. Experts identified the Chinese agricultural landscape as highly fragmented and characterised by small non-commercial family plots, which primarily employ traditional farming methods. Directives from the Chinese government were supporting the consolidation of family farms into small-medium sized commercial farms, and the experts considered that this amalgamation had led to increased levels of field variation with associated farm management challenges. PA technologies were considered to play an important role in supporting these emerging agronomic structures and the merger of smaller farms was considered to support the adoption of PA. From the family farm perspective, leasing land to others maintained income without having to farm the land, and allowed for engagement with additional employment outside of farming.

Although scientific research has been conducted to develop and refine PA technologies for application within the Chinese context, it was recognised that this body of knowledge had not translated well into practical solutions for adoption by farmers. Awareness of the benefits and applications of PA was confined to larger nationally owned farms, with very limited knowledge about PA technologies associated with smaller family farms. Given the traditional nature of farming practice on these smaller farms, PA technologies were considered unsuitable and unnecessary, with increased mechanisation and reducing the need for labor identified as key priorities. It was noted that the adoption of PA technologies was crop (maize, wheat, rice and cotton) and geographically restricted, with farms located in North Eastern China being primary adopters, reflecting promotion by the Chinese government within the countries agricultural heartland where large economically developed farms are located.

Farm scale was noted as the most significant barrier to PA adoption and directly influenced a range of other factors related to end-user uptake. Experts associated a number of problems with PA transfer from other global regions to China, including; the need to adapt the technology for small farms, the appreciation that PA technologies are complex for famers to learn to utilise, and that data outputs are difficult to interpret without explicit training. Simplified technology solutions are therefore necessary to increase adoption. The financial risks associated with PA technology investment were a significant barrier to adoption, with associated costs thought to be better suited to larger farms and prohibiting adoption by small farms.

Although benefits of PA technologies on small to medium sized farms were considered as unproven and difficult to quantify in the Chinese context, experts identified a number of perceived benefits including; environmental (improved fertilizers and pesticide efficiency) and economic (increased yields), improved farm management and reduced labour costs. However, as PA is considered to be in its infancy in China, immediate benefits were noted to only be of benefit to large farms, with no clear application benefits for family farms.

Significant changes to the age demographic of rural communities, as influenced by rural-urban migration trends, were thought to compound the low rates of awareness and adoption of PA,

with many small farms anecdotally noted to be managed by older farmers, with limited formal education. Such farmers were identified as too reliant on experiential knowledge of the land to guide their farming practice and did not have the requisite skills to adopt PA technologies. By comparison, mangers of larger farms were noted as younger and more highly educated (degree level) with the required skills and training to facilitate the adoption of intricate PA technologies.

In addition to tailored technologies to meet the requirements of variation across the agricultural landscape in China, a number of factors to help increase the adoption of PA technologies were identified. These included the physical demonstration of the tangible benefits of PA (both *via* demonstration farms and farmers' fields), the provision of financial incentives to farmers from the Chinese government to adopt PA, and support for farmers whilst using the technology and interpreting the data, including the need for education and training. This could be delivered through government or industry stakeholders, and the experts identified a gap in the market for independent agronomy services and agronomy extension services to ensure knowledge transfer and dissemination of research findings to farmers.

Farmer and end-user interviews

Results of the farmer and end user interviews are displayed in table 1 alongside the relevant themes from the expert interviews. The most significant change to rural communities identified was the change in population composition as a consequence of rural-urban migration, and the associated reduction in family farms as part of the government's promotion of the consolidation of these into larger management zones (identified by 62% of participants). Increased investment and support for rural communities by government was noted to have resulted in significant improvements to the infrastructure (recognised by 61.8% of participants), including improved access to schools, healthcare and transport. Significant farming challenges identified included weather unpredictability (58.8%), a shortage of skilled workers (32.4%) and the potential for disasters, including plant diseases, pests and extreme weather causing draughts and floods (32.4%). Field and yield variability were considered less significant challenges, possibly influenced by the small scale of farms and the high levels of experiential farming knowledge.

Low levels of engagement by farmers on small to medium farms with farming technology were reported, with the most frequently cited being tractors and other forms of mechanisation (88.2%) and irrigation systems (76.5%). A far lower percentage of farmers reported using computers and/or smartphones (29.4%), or GPS systems (17.6%). Participants were asked whether they were familiar with three terms; 1) PA/ farming, 2) precision nutrient management, and 3) site-specific crop management. Consistent with expert opinion, levels of awareness for each was low. For those that had reported to be familiar with PA, information had been received primarily from demonstration farms.

There was some agreement with the barriers identified by the experts. The most prominent barriers to adoption related to the financial risks and affordability of PA technologies (35.3%), the lack of skills and educational opportunities to learn new farming skills and operate complex technologies (29.4%) and the perceived uncertainty of PA benefits (29.4%). 70% of participants identified the need for financial incentives to support PA technology purchasing, and farmers also identified the need for support and advice in selecting the appropriate technology, using it within their field and interpreting data outputs. Given the lack of general awareness of PA, farmers struggled to articulate what they perceived the risks and benefits associated with PA technology adoption to be. Example benefits proposed included, reduced investment in agricultural inputs, improvements to yields and returns, reduced environmental impacts of farming practices and labour efficiencies. Whilst the majority of participants were unable to

provide any associated risks, for those that could, primary risks related to the significant upfront investment required and cost.

Discussion

PA technologies hold the potential to address pressing agricultural challenges, namely how to ensure food security for a growing Chinese population whilst simultaneously reducing the environmental impacts of agricultural production. This research sought to explore the factors influencing the adoption of PA technologies in China from the perspective of two groups of key stakeholders, agricultural experts and farmers and end-users. Guided by the principles of RRI, 10 expert and 34 farmer exploratory end-user interviews were conducted.

Whilst PA holds considerable potential to improve Chinese agriculture this research highlights limited awareness and adoption of PA technologies particularly amongst family farms in China. Consensus amongst experts indicating that PA technologies in their present form only hold relevance for larger farms (Daberkow & McBride, 2003; Adrian *et al*, 2005). The limited insights gained from farmers with respect to their knowledge and understanding of PA reflects the lack of current relevance and consideration given to this technology.

A number of factors emerged as influencing the adoption of PA technologies, with the most prominent factor being the current lack of suitability of the technology to address the challenges of small land management zones, supporting the argument that, at present, PA technologies are focused on improving agronomic production on large farms (Adrian *et al*, 2005; Reichardt & Jurgens, 2009). This further highlights the need to adapt technologies for different farming landscapes, and the difficulties of transferring technologies developed in Europe, North America and Australia to the Chinese agronomic and cultural context (Jiyun & Cheng, 2002). The suitability of PA technologies for large farms was underpinned by greater in-field variability and thus there was a need for the PA approach to adapt to this variation. Larger farms were also thought to be more likely to have the requisite capital to invest in expensive PA technologies (Plant, 2001; Kutter *et al.,* 2009). End-users within larger farms were thought to be younger with higher educational levels, and this was believed to increase willingness and ability to engage with novel and often complex PA technologies (Robert, 2002, Daberkow & McBride, 2003, Adrian *et al*, 2005). Farmers supported these arguments suggesting that they lacked the skills and motivation to learn new farming and agricultural practices.

In addition, lack of motivation to adopt PA technologies was identified as problematic in small to medium farms. The immediate benefits of PA technologies were recognised as difficult to evaluate and quantify (see also Reichardt & Jurgens, 2009, Adrian *et al*, 2005) and, although PA technologies were regarded as a significant scientific advance in farming practice, they were not perceived to be relevant to the agronomic and socio-economic conditions in small to medium farms. For farmers, one of the primary benefits of integrating farming technology was to address the labour deficiencies associated with rural-urban migration trends. However, the high capital costs of PA technologies were considered prohibitive and outweighed any perceived benefits. Farmers also recognised a need for financial incentives to accommodate high capital investment costs.

Given the above, experts recognised the fundamental need for simplified and affordable PA technologies to be developed, that were better suited to the Chinese agricultural landscape, particularly in relation to small to medium farms with greater agronomic variation over smaller areas. In addition, active demonstration of simplified PA technologies was encouraged. Experts

advocated research and engagement activities within rural communities in order to co-construct technological solutions to farming challenges and improve farmer's relational engagement with the technologies they were expected to adopt. The need for support and impartial advice was voiced from farmers, with experts identifying a gap for independent agronomy services.

Higher order risks such as the consequences of the adoption of PA technologies on rural communities and issues associated with data privacy have been noted in other cultural contexts (Daberkow & McBride, 2003; Kutter *et al.,* 2009). However, these concerns did not emerge from this study. In fact, farmers did not consider the risks of PA technology, probably attributable to very low levels of awareness of PA technologies. Experts believed that awareness was so limited risks were not yet being considered by farmers in the target population, although these perceptions of risk could arise if rates of adoption increase. Despite this result, the consideration of risks and risk perceptions is essential in developing strategies to ensure adoption of new technologies, and so should be addressed within the development process future strategic development of PA technologies within China.

This research has provided valuable insights towards perceptions of, and factors influencing, the adoption of PA technologies in China amongst farmers and end-users of this technology, in particular in the small to medium farming sector. These views will be central to the development of effective strategic implementation strategies associated with adoption and diffusion of PA. However, this research is not without limitations, as it is exploratory and conducted with a small convenience sample of experts and farmers and so is not representative of all stakeholders involved in Chinese agriculture within the relevant agronomic sector within China. It does however, provide a solid basis for future research with a more diverse range of stakeholders, and provides a useful foundation upon which to develop future PA implementation policies, including the need to develop effective educational platforms and targeted demonstration activities.

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Table 1: A summary of themes from the expert interviews

Theme	Farmers and end users	Agricultural experts
Structure of the Chinese agricultural landscape	Change in population composition Yes (67.6%) Changes in village structure Yes (44.1%) Reduction in the no. of family farms Yes (64.7%)	*"Now, only old people live in the rural area and work in the land. Young people…never. So small farm, old people, have no idea about PA. This the situation now." (P8I8)*
Awareness and adoption of PA technologies	Precision agriculture/farming t Yes (50.0%) Precision nutrient management Yes (35.3%) Site specific crop management. Yes (32.4%)	*"For example at these conferences you can see many people are working on researching or GPIs or GIs, systems and things like that but not many people really develop precision farming systems and compare to farmer's practices and demonstrate that, they are just doing research. This kind of research is still far from being practical to being applied." (P7I7)*
Barriers to adoption of PA technologies	Financial risks t Yes (35.3%) Privacy concerns Yes (8.8%) Impact on rural communities Yes (2.9%) Age, lack of skills and education Yes (29.4%) Lack of support and advice Yes (26.5%) Uncertainty as not established method Yes (29.4%) Lack of capital to make investments Yes (50.0%)	*"If PA technology can easy use like a cell phone, can treat like a cell phone, small scale farmers will use, will adopt the technology." (P4I4)* *"PA technology is not matured yet, you know, there is no good technology which has been demonstrated in farmer's fields that you can make more money or significantly reduce fertilizers; there are not enough such studies. You know so farmers haven't seen the results." (I7P7)*
Factors to increase adoption	Support/advice* Yes (67.6%) Demonstration of the technology on demonstration farms* Yes (41.2%) Provision of financial incentives to support purchase* Yes (70.6%) Seeing farmers like me apply the technology successfully* Yes (8.2%) *2 missing responses	*"Subsidize them for using high technologies, they will do so. Because right now, I know … One of the obstacles for the farmers to adopt the technologies, firstly, is the cost." (P9I9)*