Preprints of the 21st IFAC World Congress (Virtual)
Berlin, Germany, July 12-17, 2020

A Human-Centred Systems Theory of e-Agriculture Automation and Control Systems Adoption:

An Empirical Study of the Social Effects of Digital Control and Automation Systems in Agricultural Communities

Sinead O'Neill Somers* & Larry Stapleton**

*INSYTE, Waterford Institute of Technology Ireland (Tel: 353-051-302683; e-mail: sinead.oneill@ wit.ie).
** INSYTE, Waterford Institute of Technology Ireland (Tel: 353-051-302683; e-mail: lstapleton@ wit.ie).

Abstract: Climate change, biodiversity crises and other challenges impinge upon agricultural communities who must adapt to these pressures. However, in many countries agriculture lags behind other sectors in its uptake of digital automation and control systems on the farm. In spite of decades of research into technological innovation adoption factors we still do not have a good understanding as to why this sector is slower than others to adopt these new systems. This paper is based on a qualitative study of farmers in the south-east of Ireland which explored social effects in technology adoption. It draws out key themes associated with Irish farming as communities of knowledge networks, learning and innovation dynamics and cultural features, as well as tensions in relationships between farmers and institutions. From this analysis new theoretical "RooT" model is offered to reorient control and automation technology adoption theories and better support agricultural technology innovation.

Keywords**:** eAgriculture, multicultural interactions, knowledge networks.

1. INTRODUCTION

In the international socio-economic system, innovation in agriculture practices and techniques are important for food security and sustainability. Control and automation systems, digital technologies and other innovations have an important role to play in these developments (such as in such as e-Agriculture for climate-smart farming (Rutto (2020)). Despite decades of research into the processes underlying systems adoption we still do not have a good understanding of control and automation systems innovation adoption factors in agricultural communities.

Although, by its very nature, farming implies innovation and adaptation (such as adapting to changing weather conditions) the uptake of control and automation systems innovations in the Irish farming sector remains slow. This paper offers a new analytical lens for advanced technology adoption the farming communities. Unlike other studies of social factors in advanced technology adoption, this study explored the human knowledge which is embedded in farming life. Although this knowledge may not be formalised nor empirically scientific, we assert that this knowledge has an important status as a kind of "technical" knowledge, embedded in the context of use and in tune with inter-generational intelligences and shared meanings which should not be simply discarded or overlooked. This study explored how farming knowledge is cared for in rural communities and relates these processes to a trust (or distrust) of scientific methods embodied in many technological advances and institutional solutions to farming problems. We explored the extent to which these factors shaped adoption attitudes.

2. LITERATURE REVIEW

Agrarian science is generally focused on a process-oriented scientific- one-fix-for-all approach to innovation. This relies on scientific experiment to create a fix for problems farmers face (Leeuwis 2009). In Ireland a major study of e-agricultural systems adoption applied the Unified Theory of Acceptance and use of Technology (UTAUT) (Connolly 2010). This theory was technology-but revealed in its core findings that farmers believed these technologies were not useful in their everyday working lives and did not adopt them for this reason. The solutions did not match individual farm conditions (Koutsouris (2012); Gakuru *et al* (2009This technological reductionist paradigm ignores the working environments of the farmer and concentrated too much on the technical aspects of design rather than understanding the user's needs (Alter 2013). Given the difficulties and criticisms associated with the reductionist approach in technology transfer researchers need a new set of assumptions (Somers and Stapleton 2013). Perhaps a deeper understanding as to what an e-agricultural system is could improve technology transfer. To address these issues Somers and Stapleton (2014) proposed models based on the following social dimensions:

1. Tacit Knowledge in the Socio-Technical Work Environment
2. Institutionalism

3. Cultural Values

4. Community of Practices

The framework in figure one offers a human centred systems perspective that goes beyond modelling human interaction with a technical artefact: It incorporates a rich understanding of the context in which knowledge is used in everyday working life. The theoretical framework was published previously in Somers and Stapleton (2014) and the reader is directed to that publication for more detail on the development of the model and the hypotheses and assumptions which it entails. In this present paper we offer findings of research designed to validate or otherwise the framework. The study gathered qualitative data which explored the particular perspectives of farming families and their experiences of their social context.

Figure 1 Proposed Tentative Framework (Somers and Stapleton (2014)

3. RESEARCH DESIGN

The unit of analysis in this study was the family farm. Traditionally, farm research has focused on the male farmer viewing them as head of the farm. This was the unit of analysis applied in the CUITA study. In Ireland farms are mainly owned and managed by families. Whatmore (2016) argued that farm families comprise a wide variety of enterprises, size, geographical locations and family members. She argued that a farm family has many components: the farm itself and the household structure of those who live and work on the farm. It can be composed of patriarchal or matriarchal gender relationships, ties of marriage and other members of the household with economic ties to the farm. Therefore, in this research, a farm family is not based on a kinship of marriage but a farm owned and run by a family.

Document analysis allowed the researcher in a cost-efficient manner to collect data and gather insight and meaning on the language and words used by participants in their everyday lives (Creswell & Clark 2007). A desk study of national and international reports, combined with focus groups drawn from the target population, established the systems and software available for use by farming communities in Ireland.

From these a process of triangulation identified the types of farming software potentially used by the farming community and their understanding of the term e-agriculture and its use. These findings were then validated by a focus group.

The population was selected from farm families within the southeast of Ireland from counties Wexford, Kilkenny and Carlow. From the initial contact with the Irish Farmers Association (IFA) two interviews were arranged which formed the basis of the pilot study. The pilot study was conducted to test the interview schedule and to gain a feel for the study. So as not to exclude non-IFA members from the process the first two interviews were asked to suggest other farm families who might be willing to participate in the research. This exponential non-discriminative snowball sampling approach ensured a variety of farm families would yield rich data and is widely used in studies of social phenomena (Gilbert (2008)). Interviews lasted on average 40-50 minutes with each recorded and transcribed. As the volume of data gathered was large NVivo software was chosen to enable consistency in the coding of the data.

4. FINDINGS

The dataset represented farming across. Sheep, Dairy, Beef, Tillage and Mixed farming sectors. 2 samples had females registered as “the farmer” with the Department of Agriculture, all others registered male farmers. 3 interviewees engaged in farming part- time with 2 of the three-registered farmers being female. The following findings report typical respondents’ comments to indicate key themes in the data.

Farm Continuity

Somers & Stapleton (2014) postulated that shared values across farming communities would be important antecedents for technology adoption. In the theoretical model, the dimension of *cultural values* was included to represent this aspect of the theory. The findings demonstrated certain shared meanings and values in the communities studied here. The next section draws out the important themes in the data and presents some indicative qualitative data to show how these themes played out. Themes overlapped somewhat but it was possible to draw out the key value categories. Following axial coding of transcripts, these themes were present:

1. Values associated with Farm Continuity – Tradition, conservation and historicity
2. Values associated with Duty
3. Values associated with the Sustainability and Viability of the Farm
4. Values associated with Custodianship
5. Values associated with Connectedness to Nature – The Intrinsic Value of Nature and the Environment

The rest of this subsection reviews each of these in turn.

Farm Continuity: – Values of Tradition, Conservation and Historicity

Farm continuity referred to the succession mechanism in farming. In Ireland, normally the eldest son inherits the farms, unlike other businesses, which often are answerable to shareholders. All respondents inherited the farm from parents with two also inheriting the farm from an uncle. Farmers viewed themselves as keepers of the land. The following response typifies this view.

"if a farm has been handed down through generations its pride in what your predecessors done and the way I feel you know if you are farming and the herd owner you are just minding the land and keeping it going to the best you can. To keep it going to hand onto the next generation to farm if they want." (Family 11, Respondent 20)

The Value of Duty

The duty to the farm was then expressed in a powerful way by Respondent 5 who detailed leaving secondary school in first year (at 13 years of age) to come home and farm because his mother had died.

"1st year in the brothers [secondary school] and when my mother died I was brought home to farm." (Family 3 Respondent 5)

Farm Sustainability and Viability

Pivotal to farm continuity is the viability of the farm enterprise. Often, farm enterprises changed from generation. This safeguarded the family farm as illustrated by Respondent 10 below. Originally the main enterprise on their farm was sheep but his father diversified, believing he would make more money per acre from dairy farming than sheep farming and insured the sustainability of the enterprise for the next generation. When the opportunity arose, he moved into dairy farming. This move opened up another sources of income for the family and was viewed positively by his son.

" my father was very progress [oriented] and was milking when he got a chance" (Family 5 Respondent 10)

Custodians of the Land

Land management and care were described as vital for continuity and viability with farmers conscious of sustainability allowing farming to continue over generations as expressed in the following extract: "most farmers are very good custodians of the land and they have been for hundreds of years" (Family 8 Respondent 15)

Families valued the land and whilst they were dependant on it for income, they did not exhaust its value. This was reflected in the knowledge and understanding a farmer has of his land ensuring future productivity and was evident in one participant's protection of wildlife habitats on the farm.

Connectedness to Nature – The Value of Nature and the Environment

Forces of nature are seasonal and random. These farmers adapted work practices to best utilise the environment. In winter, the land was rested by housing stock indoors allowing the land to recover so when spring came it was ready to support the stock. Technology for example agfood.ie has pushed farming forward but the farmer still has to mind the land and the animals. Family 3 Respondent 5 recalled how stock numbers and calving time of animals changed on their farm from his uncle's time. He recalled how he referred to this practice as a change in technology but acknowledged his uncle was successful in farming based what was known at the time.

"He [uncle] was successful famer in his day. Now I know I would like to apply newer technologies and newer ways of having cattle. They [stock] were all out doors, where I have indoors and newer stocking rates. Well then technology has moved since then – he [uncle] died in 1992 and he was successful. Well things change and the weather patterns change in that time you had drier frostier winters nowadays we have wetter winters. " (Family 33 Respondent 5)

Institutions Context of Farming

The theoretical model postulated institutional forces as a factor in technology adoption. The following section presents findings associated with this postulate.

Institutional Policy as Coercion

The deep understanding of natural working environments created tension between farmers and the Department of Agriculture regarding farm policies. All respondents believed the Department of Agriculture set regulations and policies that were discordant with farming practice. The Department did not understand the reality of how things worked on the ground and described a 'them' and 'us' relationship. This was reflected in the following response:

"NO! It's THEM and US: we are not the same and not on the same level. If not they wouldn't be doing some of the things they're doing [setting policies]" (Family 3 Respondent 7)

All respondents described how they felt neglected by government agencies and scientific institutions alike. When science-led new practices were presented to farmers they believed it was difficult for them to implement many of these in practice. People described how farming does not following a one-fit all as regards innovative practices. T

"Teagasc [the Irish scientific agriculture agency] lads come up with new ideas. If the same blue print worked [everywhere] those lads would be out of job. (Family 4 Respondent 8)

All farmers employed the services of an agricultural Advisor which acted as a buffer between the Department of Agriculture and farmers. All respondents believed the advisor acted on their behalf and understood the implications of policy and procedures from both the farm and farmers perspective as typified in the following:

"I suppose it's that security element he's the professional he's part of the agricultural advisory group and it's a back fall if we have problems" adding "his stamp of approval means so much to the department. That's the way it is."(Family 7 Respondent 14)

The Farming Community

Somers & Stapleton (2014) theorised that the social effects of farming communities as self-organising innovation knowledge networks would shape technology adoption. The following section reviews themes found in the data associated with the community nature of farming.

Grass Roots Organisations

All farm families interviewed were paid members of their farming association (see table 5.4). Farms were satisfied with both the level of access and information from their association: "there is always someone in your locality involved in the IFA that you can approach and get them to talk up for you" (Family 13 Respondent 24). The IFA has a website with content written from the farmers perspective. This includes clear information needed for inspections by the Departmental bodies.

"Well the idea is that we [IFA] interpret into less cumbersome [language] than the department, we have it in farmer language [on the website]" (Family 9 Respondent 16)

Grass Roots Publications

Ten respondents specifically mentioned buying the Farmers Journal. The weekly publication was viewed positively from farmers typified in the response:

"yes its very practical and translated to on the ground" (Family 12 Respondent 22).

The paper presented articles written by farmers covering all aspects of farming life and enterprises.

"very good value in the week" [and] "articles will always do the pros and cons which I find good… it's more factual you mightn't agree with everything that's in it but that's fair enough like it broadens the mind". (Family 3 Respondent 5)

Farming Business as a Social Hub

When buying farm supplies all farmers went to their local Glanbia co-operative branch (Glanbia is a large multinational firm which grew out of an Irish farmer cooperative). The local branch was an important social point for farmers:

"its [co-op branch] nearly like the post office it's a bit of a rural hub" (Family 12 Respondent 22)

"A lot are on their own and they mightn't see anyone from one end of the day, and then if you weren't in someone could say I'm missing Tommy and then you could call up to their house and god knows what to expect. There is merit in those social interactions" (Family 11 Respondent 20).

Another said the co-op was "Valuable and I rate it as keeping the village alive." (Family 3 Respondent 5)

Knowledge, Learning and Innovation

The original theoretical model set out in figure 1 contended that certain important forms of knowledge and learning were being overlooked in technology adoption theory as it applies to farming communities. This section reviews findings about knowledge, learning and innovation dynamics.

Individual Learning Processes and Methods

Learning how to farm came from the parents or older generations who gathered their knowledge through practical experience of working with the land, animals and so forth. This personal way of learning was the foundations of farm knowledge and contextually rooted in the beliefs and lives of individuals typified in the response "How to educate him is to bring him along [pointing to his so]. Oh ya, that's how they learn is to bring them along. And that's always the way in farming."(Family 5 Respondent 10)

Learning by Observation

All respondents agreed that learning to farm came from parents or the wider family network such as bachelor uncles. This was a way of life in farming were children spent their lives around and out with their parents. Listening to them and learning from them. Children saw their parents work all the time making this an avenue of learning as illustrated in the following response:

"You learn swiftly or you're not in farming to much longer. I probably would have had good guidance from my uncle, I have good neighbours" (Family 9 Respondent 16)

Learning as a Social Activity (The Learning Community)

Achievement was also evident in how influential parents were in educating next generations All farmers said parents were the main source of farming knowledge and a source of guidance. Typically, respondents expressed the role of their parents in educating them in farming as follows:

"Definitely you know good husbandry skills came from my upbringing definitely"(Family 1 Respondent 1).

"No I wouldn't of been able to handle animals. Just being around animals and growing up with them you learn about their behaviour"(Family 1 Respondent 1)

Learning from Generation to Generation

All respondents described how much of their knowledge and skill came from their parents or guardians. This involved working and helping parents on the farm. One interviewee told how she learned breeding techniques from her father:

"I would of learned it [stockmanship] from sight and visually looking at my father with the herd. "(Family 1 Respondent 1)

The capacity to handle and understand an animal's temperament and behaviour was a skill that respondents felt was best gained through practical exposure. Previous generations the family setting to transfer knowledge and practical experience as expressed in the following extract:

"when you're dealing with a live animal it's different, all that knowledge comes from experience. It's hard to transfer a book to an animal."(Family 1 Respondent 1).

All respondents believed farming communities are an innovative group addressing daily challenges on the farm which forced them to adapt and problem solve in their everyday life. A wide range of skills were needed to adapt to a diversity of daily events from soldering gates to nursing sick animals. They described how devastating diseases like Foot and Mouth Disease and the Schmallenberg virus and changing weather patterns forced them to adapt working practices and find solutions to unforeseen events to sustain the enterprise.

6. DISCUSSION

A human-centred systems perspective transcends a linear predictive view often adopted by human and machine systems. These human-centred systems emphasise user-involvement in order to support human needs, purpose, skill, creativity and potential, enabling individuals and communities to lead the lives they chose for themselves. From this perspective, knowledge embedded in the working life of individuals built up over the centuries and shaped by natural environments combined with modern science in the development of agricultural solutions. Institutionalism offered a deeper analysis of the effects of social structures upon the processes, rules, routines established in farming and the importance at the micro-level social system of the family. Accompanying these social structures are the cultural values established over generations. The findings for inter-generational knowledge suggested a major revision of the Tacit Knowledge dimension. It was evident that system developers need to understand, interpret and appreciate the role of tacit knowledge, including most importantly intergenerational processes associated with that knowledge. The literature defines tacit knowledge as embedded in the best practice, experience, expertise, and innovation but has generally underemphasised the historicity of that knowledge. The original definition associated with figure 2 was felt to be too narrow to account for all the evidence associated with tacit knowledge gathered within this study. The most important learning within farming communities happened within the family context. The family is a body of knowledge residing in a natural environment. A farm is not only a commercial entity but is socially embedded in the family which itself is intertwined with the natural environment as well as the larger farming community. This created an "eco-system of knowledge" is the site of practices and values associated with the know-how and expertise exchanged between family members and across the farming community. This learning eco-system provides a solid foundation for educating farmers and is deeply valued by these communities. It is firmly rooted in the interaction of nature and nurture expressed in various ecological settings. Information exchanges occur in the most basic human relationship of parent and child. People actively engaged with this knowledge by accompanying and observing family members and completing assigned duties, often in the humblest of settings i.e. in the mucky reality of everyday farming life. By learning skills such as husbandry and land management young farmers were inculcated in the local "farming way" and, over time, respondents became initiated into the rural community of knowledge which valued these insights. The critical importance of intergenerational knowledge exchange ensures farm viability and continuity over time. Engagement in the cyclical nature of farming from animal birthing to harvesting crops also helped a farmer to learn. In these communities, family expertise and insights, often built up over generations, is treasured and built upon further in later life by farmers, each generation adding to the vast store of local, contextualised knowledge about the farm. The local co-operative or the government agency Teagasc supported discussion groups which were so important because they also facilitated this learning and knowledge transfer across families in the communities. It was also evident that more formal institutional arrangements were not so effective, and, for example, scientific advice was often treated with suspicion. This kind of knowledge was felt to be "out-of-touch" with the everyday realities of farming and the context which made each farm unique. We suggest that any proposed online education for farmers, disembodied as it is from the everyday life of the local farm, may undermine these deeply social and human learning processes and knowledge systems, and may even contribute to the demise of some family farms if it means that the tacit knowledge present in these families is lost. It was readily apparent that the most important, and most valuable, learning within farming communities happened within the family context and had deep roots both in the relationships between family members and doe to its historicity which sometimes stretched back centuries. The data revealed the farming family as a receptacle and custodian, a curator, of environmental knowledge about the local natural world.

Appreciation of the land and nature is intertwined within farm practices. The land must be nourished to future proof the farm. The resilience of the community was expressed by respondents who recalled weather events and disasters such as the spread of disease. The environment challenges them to adapt and learn from such events. Often future events were best prevented or eased by implementing old traditions learned long ago such as the use of lime to halt the spread of Foot and Mouth disease. The shared mind set amongst respondents revealed that farmers expected such challenges but learned and adapted to safeguard future impacts. Systems development needs to be cognisant of, and pay respect to, these ancient and deeply imbedded learning processes if new technology such as e-agricultural systems is to take a foothold in Ireland. In farming, knowledge is often gained when the learning trajectory is not known. It often happens in the contingencies of unplanned events and therefore involves sensemaking processes at various levels from the individual to the family to the farming community. For example, the spread of diseases with no known cures forced these communities to arrive at practical solutions which were previously unknown.

In the institutional context, coercive isomorphism appeared as a force to the farming community who felt forcedtop adopt practices and initiatives which made little sense to them, and

were experienced as dominating and were sometimes resented. To help them make sense of these pressures, respondents employed agricultural advisors so they could understand and interpret changes to farming regulation and policy. Respondents placed more trust in tried and trusted practices and solutions, that emerged long ago as a result of (for example) their interactions with their natural environment, such as changes in winter weather patterns and were passed along from one generation to the next.

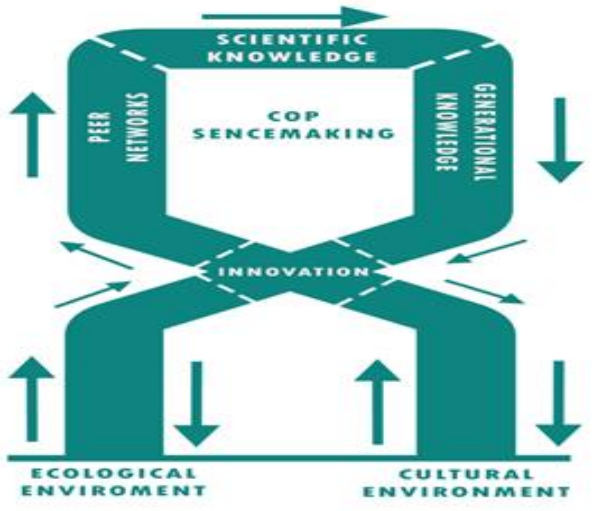

Figure 2 RooT – The Rural Technology Model (revision of figure 1)

To refine figure one in light of the evidence collected in this study, the authors prepared "The RooT framework" (figure 2) to adjust for particular aspects of the evidence gathered in this study and discussed above.

System development approaches that make assumptions about scientific, economic or functional realities of farmers may overlook important factors that are revealed in this study. System developers should take account of the behaviours associated with the conditions, values, beliefs and techniques of everyday life in farms.

7. CONCLUSIONS

The overall objective of the project was to determine factors influencing the adoption and continued usage of these control and automation systems and technologies amongst rural communities. Dynamics of agricultural knowledge in farming produces social effects which play out in the adoption of technological innovations, such as. Human centred-ness is committed to designing purposive, socially-responsible socio-technical, human machine systems. The RooT model offers a new understanding of the complex nature of the overlapping and intersecting context of social, cultural and technological realities within farming communities. It is based on rich interpretations and insights into the complicated phenomenon of innovation and knowledge in rural communities. Agricultural and Information Studies regarding technology adoption have mainly applied quantitative research methods to studies perhaps due to the lack of qualitative frameworks to guide such research (Dooley 2007). This present study offers a new way to theorize about the social effects associated with e-agricultural systems adoption, based on a qualitative analysis of everyday rural life.

REFERENCES

S. Alter (2013). "Work system theory: overview of core concepts, extensions, and challenges for the future", *Journal of the Association for Information Systems*, 14(2), pp.72-121.

R. Connolly (2010). *Examining Technology Adoption and Usage by Farmers in Ireland*. Dept. of Agriculture, Fisheries and Food, Committee for the Uptake of ICT.

K. Dooley (2007). "Viewing Agricultural Education Research through a Qualitative Lens", *Journal of Agricultural Education*, 48(4), pp.32-42.

M. Gakuru, K. Winters and F. Stepman (2009). "Inventory of innovative farmer advisory services using ICTs", *Forum for Agricultural Research in Africa (FARA)*, Accra, GH.

N. Gilbert (2008). *Researching Social Life*, CA: Sage.

A. Koutsouris (2010). "The emergence of the intra-rural digital divide: A critical review of the adoption of ICTs in rural areas and the farming community", *Proc. Of 9th European IFSA Symposium*, 4(7).

S. O'Neill Somers and L. Stapleton (2014). "e-Agricultural innovation using a human-centred systems lens, proposed conceptual framework", *AI & society*, *29*(2), pp.193-202.

S. O'Neill Somers & L. Stapleton (2015). "A Human-Centred approach to e-Agricultural systems", *IFAC-PapersOnLine*, *48*(24), pp.213-218.

V. Rutto (2020). *Shocks and coping mechanisms in Climate-Smart Villages of the Nyando Basin, Kenya Findings from a climate-smart agriculture (CSA) survey in Nyando Basin, Kenya*, CCAFS Program Management Report, Wageningen University & Research, Netherlands.

S. Whatmore (2016). *Farming Women: Gender, Work and Family Enterprise*. Springer.